

TECHNICAL REPORT



Audio/video, information and communication technology equipment –
Part 2: Explanatory information related to IEC 62368-1:2014~~2018~~



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TECHNICAL REPORT



Audio/video, information and communication technology equipment –
Part 2: Explanatory information related to IEC 62368-1: ~~2014~~2018

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

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FOREWORD

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The main task of IEC technical committees is to prepare International Standards. However, a technical committee may propose the publication of a technical report when it has collected data of a different kind from that which is normally published as an International Standard, for example, "state of the art".

IEC 62368-2, which is a Technical Report, has been prepared by IEC technical committee TC 108: Safety of electronic equipment within the field of audio/video, information technology and communication technology.

This third edition updates the second edition of IEC 62368-2 published in 2014 to take into account changes made to IEC 62368-1:2014 as identified in the Foreword of IEC 62368-1:2018.

This Technical Report is informative only. In case of a conflict between IEC 62368-1 and IEC TR 62368-2, the requirements in IEC 62368-1 prevail over this Technical Report.

The text of this technical report is based on the following documents:

Enquiry draft	Report on voting
108/708/DTR	108/711/RVDTR

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

In this document, the following print types are used:

- notes/explanatory matter: in smaller roman type;
- tables and figures that are included in the rationale have linked fields (shaded in grey if "field shading" is active);
- terms that are defined in IEC 62368-1: in **bold type**.

In this document, where the term (HBSDT) is used, it stands for Hazard Based Standard Development Team, which is the Working Group of IEC TC 108 responsible for the development and maintenance of IEC 62368-1.

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

A list of all parts of the IEC 62368 series can be found, under the general title *Audio/video, information and communication technology equipment*, on the IEC website.

In this document, only those subclauses from IEC 62368-1 considered to need further background reference information or explanation to benefit the reader in applying the relevant requirements are included. Therefore, not all numbered subclauses are cited. Unless otherwise noted, all references are to clauses, subclauses, annexes, figures or tables located in IEC 62368-1:2018.

The entries in the document may have one or two of the following subheadings in addition to the Rationale statement:

Source – where the source is known and is a document that is accessible to the general public, a reference is provided.

Purpose – where there is a need and when it may prove helpful to the understanding of the Rationale, we have added a Purpose statement.

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

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INTRODUCTION

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 document is different from traditional IEC safety documents in its approach and while it is believed that IEC 62368-1 provides a number of advantages, its introduction and evolution are 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 a learning process is required and experience is needed in its application. Consequently, the committee recommends that this edition of the document be considered as an alternative to IEC 60065 or IEC 60950-1 at least over the recommended transition period.

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0 Principles of this product safety standard

Clause 0 is informational and provides a rationale for the normative clauses of the document.

0.5.1 General

ISO/IEC Guide 51:2014, 6.3.5 states:

“When reducing risks the order of priority shall be as follows:

- a) inherently safe design;*
- b) guards and protective devices;*
- c) information for end users.*

Inherently safe design measures are the first and most important step in the risk reduction process. This is because protective measures inherent to the characteristics of the product or system are likely to remain effective, whereas experience has shown that even well-designed guards and protective devices can fail or be violated and information for use might not be followed.

Guards and protective devices shall be used whenever an inherently safe design measure does not reasonably make it possible either to remove hazards or to sufficiently reduce risks. Complementary protective measures involving additional equipment (for example, emergency stop equipment) might have to be implemented.

The end user has a role to play in the risk reduction procedure by complying with the information provided by the designer/supplier. However, information for use shall not be a substitute for the correct application of inherently safe design measures, guards or complementary protective measures.”

In general, this principle is used in IEC 62368-1. The table below shows a comparison between the hierarchy required in ISO/IEC Guide 51 and the hierarchy used in IEC 62368-1:20142018:

ISO/IEC Guide 51	IEC 62368-1
a) inherently safe design	1. inherently safe design by limiting all energy hazards to class 1
b) guards and protective devices	2. equipment safeguards
	3. installation safeguards
	4. personal safeguards
c) information for end users	5. behavioral safeguards
	6. instructional safeguards

Risk assessment has been considered as part of the development of IEC 62368-1 as indicated in the following from ISO/IEC Guide 51 (Figure 1) in this document. See also the Hazard Based Safety Engineering (HBSE)

Process Flow (Figure 2) in this document that also provides additional details for the above comparison.

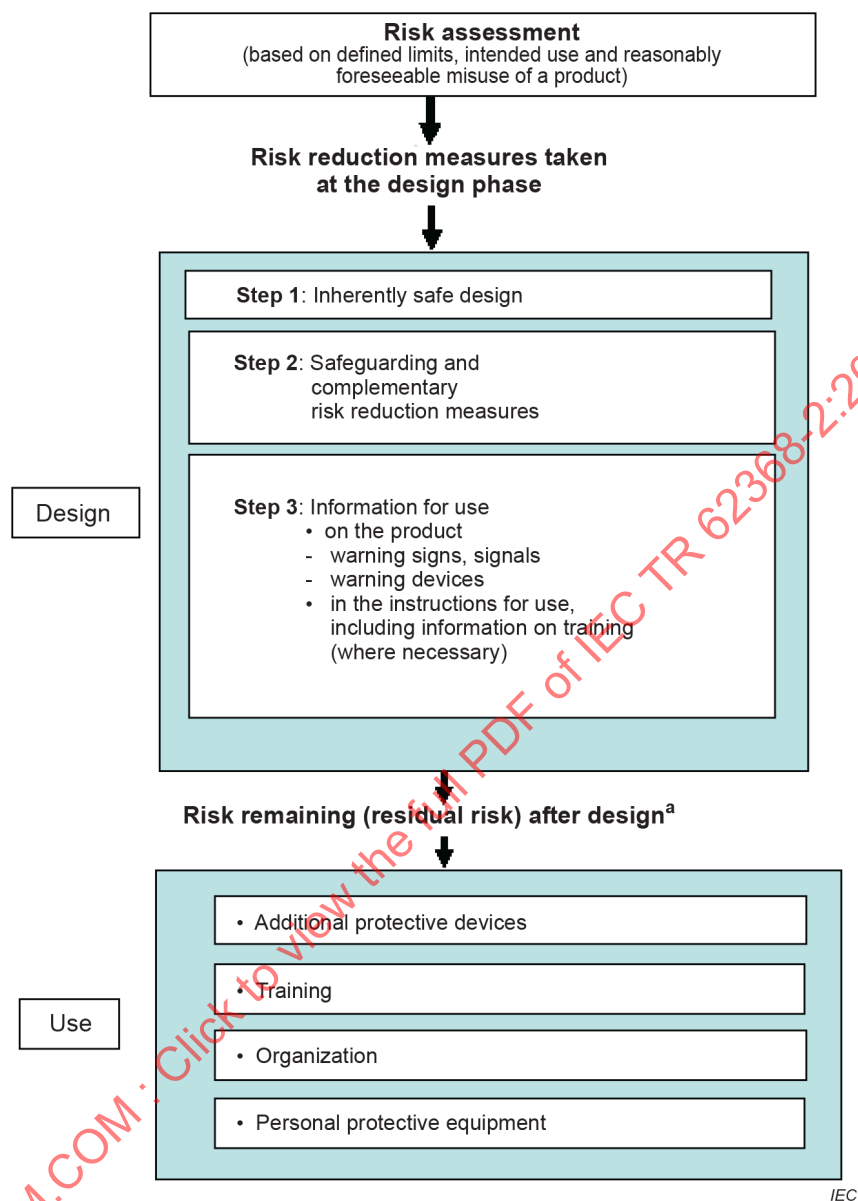


Figure 1 – Risk reduction as given in ISO/IEC Guide 51

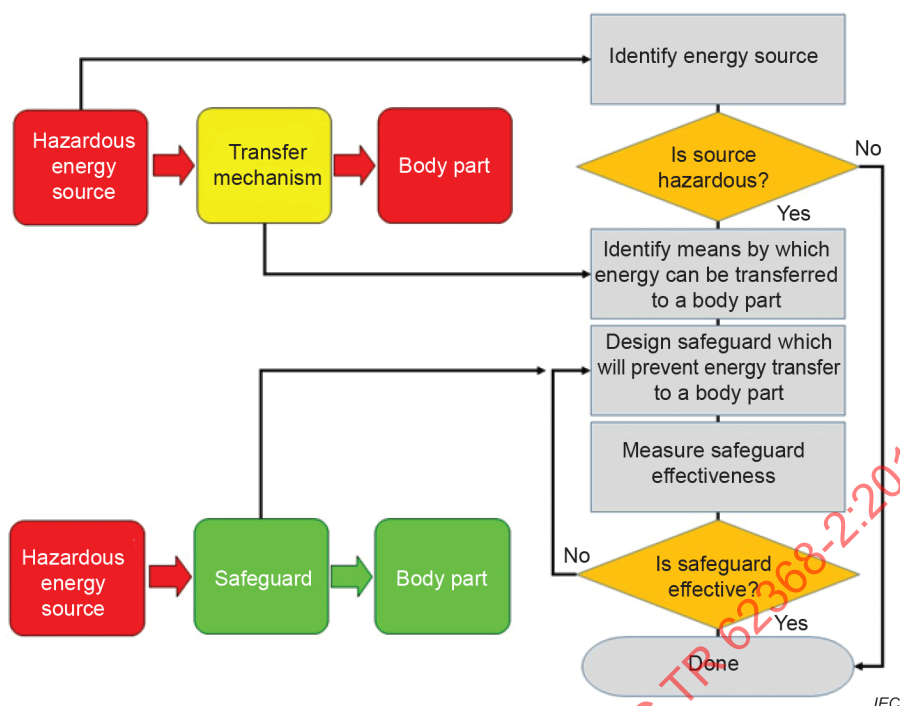


Figure 2 – HBSE Process Chart

0.5.7 Equipment safeguards during skilled person service conditions

Purpose: To explain the intent of requirements for providing **safeguards** against involuntary reaction.

Rationale: By definition, a **skilled person** has the education and experience to identify all class 3 energy sources to which he may be exposed. However, while servicing one class 3 energy source in one location, a **skilled person** may be exposed to another class 3 energy source in a different location.

In such a situation, either of two events is possible. First, something may cause an involuntary reaction of the **skilled person** with the consequences of contact with the class 3 energy source in the different location. Second, the space in which the **skilled person** is located may be small and cramped, and inadvertent contact with a class 3 energy source in the different location may be likely.

In such situations, this document may require an **equipment safeguard** solely for the protection of a **skilled person** while performing servicing activity.

1 Scope

Purpose: To identify the purpose and applicability of this document and the exclusions from the scope.

Rationale: The scope excludes requirements for functional safety. Functional safety is addressed in IEC 61508-1. Because the scope includes computers that may control safety systems, functional safety requirements would necessarily include requirements for computer processes and software.

The requirements provided in IEC 60950-23 could be modified and added to IEC 62368 as another –X document. However, because of the hazard-based nature of IEC 62368-1, the requirements from IEC 60950-23 have been incorporated into the body of IEC 62368-1 and made more generic.

The intent of the addition of the IEC 60950-23 requirements is to maintain the overall intent of the technical requirements from IEC 60950-23, incorporate them into IEC 62368-1 following the overall format of IEC 62368-1 and simplify and facilitate the application of these requirements.

Robots traditionally are covered under the scopes of ISO documents, typically maintained by ISO TC 299. ISO TC 299 has working groups for personal care robots and service robots, and produces for example, ISO 13482, *Robots and robotic devices – Safety requirements for personal care robots*.

2 Normative references

The list of normative references is a list of all documents that have a normative reference to it in the body of the document. As such, 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.

Recently, there were some issues with test houses that wanted to use the latest edition as soon as it was published. As this creates serious problems for manufacturers, since they have no chance to prepare, it was felt that a reasonable transition period should be taken into account. This is in line with earlier decisions taken by the SMB that allow transition periods to be mentioned in the foreword of the documents. Therefore IEC TC 108 decided to indicate this in the introduction of the normative references clause, to instruct test houses to take into account any transition period, effective date or date of withdrawal established for the document.

These documents are referenced, in whole, in part, or as alternative requirements to the requirements contained in this document. Their use is specified, where necessary, for the application of the requirements of this document. The fact that a standard is mentioned in the list does not mean that compliance with the document or parts of it are required.

3 Terms, definitions and abbreviations

Rationale is provided for definitions that deviate from IECV definitions or from ~~pilot standard~~ Basic or Group Safety publication definitions.

3.3.2.1 electrical enclosure

Source: IEC 60050-195:1998, 195-06-13

Purpose: To support the concept of **safeguards** as used in this document.

Rationale: The IECV definition is modified to use the term “**safeguard**” in place of the word “protection”. The word “**safeguard**” identifies a physical “thing” whereas the word “protection” identifies the act of protecting. This document sets forth requirements for use of physical **safeguards** and requirements for those **safeguards**. The **safeguards** provide “protection” against injury from the equipment.

3.3.5.1 basic insulation

Source: IEC 60050-195:1998, 195-06-06

Purpose: To support the concept of **safeguards** as used in this document.

Rationale: The **IEV** definition is modified to use the term “**safeguard**” in place of the word “protection”. The word “**safeguard**” identifies a physical “thing” whereas the word “protection” identifies the act of protecting. This document sets forth requirements for use of physical **safeguards** and requirements for those **safeguards**. The **safeguards** provide “protection” against injury from the equipment.

3.3.5.2 double insulation

Source: IEC 60050-195:1998, 195-06-08

Purpose: To support the concept of **safeguards** as used in this document.

Rationale: See 3.3.5.1, **basic insulation**.

3.3.5.56 solid insulation

Source: ~~IEC 60664-1:2007, 3.4~~ IEC 60050-212:2015, 212-11-02

~~Purpose: To support the concept that safeguards are interposed between an energy source and a body part.~~

~~Rationale: IEC 60664-1 defines insulation as material interposed between two conductive parts. The IEC 60664-1 definition is modified by adding that insulation is also “between a conductive part and a body part.” For safety purposes, solid insulation is not only used between conductors, but is also used between a conductor and a body part. For example, a Class II equipment employs solid insulation in this manner.~~

3.3.5.67 supplementary insulation

Source: IEC 60050-195:1998, 195-06-07

Purpose: To support the concept of **safeguards** as used in this document.

Rationale: See 3.3.5.1, **basic insulation**.

3.3.6.79 restricted access area

Source: IEC 60050-195:1998, 195-04-04

Purpose: To use the concept of “**instructed persons**” and “**skilled persons**” as used in this document.

Rationale: The **IEV** definition is modified to use the terms “**instructed persons**” and “**skilled persons**” rather than “electrically **instructed persons**” and “electrically **skilled persons**.”

3.3.7.87 reasonably foreseeable misuse

Source: ISO/IEC Guide 51:2014, 3.447

Rationale: Misuse depends on personal objectives, personal perception of the equipment, and the possible use of the equipment (in a manner not intended by the manufacturer) to accomplish those personal objectives. Equipment within the scope of this document ranges from small handheld equipment to large, permanently installed equipment. There is no commonality among the equipment for readily predicting human behaviour leading to misuse of the equipment and resultant injury. Where a possible **reasonably foreseeable misuse** that may lead to an injury is not covered by the requirements of the document, manufacturers are encouraged to consider **reasonably foreseeable misuse** of equipment and provide **safeguards**, as applicable, to prevent injury in the event of such misuse. (Not all **reasonably foreseeable misuse** of equipment results in injury or potential for injury.)

3.3.8.1 instructed person

Source: IEC 60050-826:2004, 826-18-02

Rationale: The IECV definition is modified to use the terms “energy sources”, “**skilled person**”, and “**precautionary safeguard**”. The definition is made stronger by using the term “instructed” rather than “advised”.

3.3.8.3 skilled person

Source: IEC 60050-826:2004, 826-18-01

Rationale: The IECV definition is modified to use the phrase “to reduce the likelihood of”. IEC 62368-1 ~~does~~, in general, tends not use the word “hazard”.

3.3.11.9 protective bonding conductor

Rationale: The **protective bonding conductor**, is not a complete **safeguard**, but a component part of the earthing system **safeguard**. The **protective bonding conductor** provides a fault current pathway from a part (insulated from ES3 by **basic insulation** only) to the equipment **protective earthing** terminal, see Figure 3 in this document.

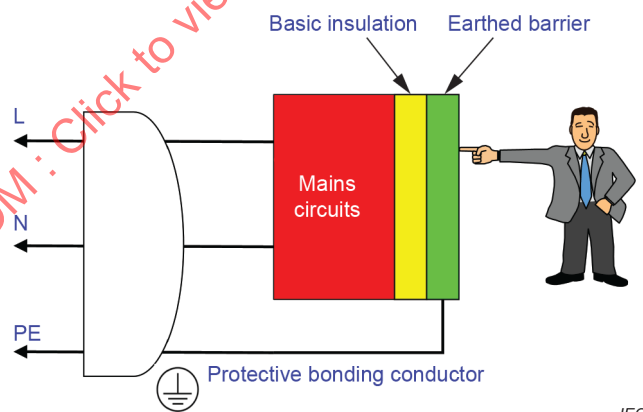


Figure 3 – Protective bonding conductor as part of a safeguard

The parts required to be earthed via a **protective bonding conductor** are those that have only **basic insulation** between the parts and ES3, and are connected to **accessible** parts.

Only the fault current pathway is required to be a **protective bonding conductor**. Other earthing connections of **accessible** conductive parts can be by means of a functional earth conductor to the equipment PE terminal or to a **protective bonding conductor**.

3.3.14.43 prospective touch voltage

Source: IEC 60050-195:1998, 195-05-09

Purpose: To properly identify electric shock energy source voltages.

Rationale: The **IEV** definition is modified to delete “animal”. The word “person” is also deleted as all of the requirements in the document are with respect to persons.

3.3.14.98 working voltage

Source: IEC 60664-1:2007, 3.5

Purpose: To distinguish between **RMS. working voltage** and the peak of the **working voltage**.

Rationale: The IEC 60664-1 definition is modified to delete “RMS”. IEC 62368-1 uses both **RMS. working voltage** and peak of the **working voltage**; each term is defined.

3.3.15.2 class II construction

Source: IEC 60335-1:2010, 3.3.11

Purpose: Although the term is not used in the document, for completeness, it was decided to retain this definition.

Rationale: The word “appliance” is changed to “equipment”.

4 General requirements

Purpose: To explain how to investigate and determine whether or not safety is involved.

Rationale: In order to establish whether or not safety is involved, the circuits and construction are investigated to determine whether the consequences of possible fault conditions would lead to an injury. Safety is involved if, as a result of a **single fault condition**, the consequences of the fault lead to a risk of injury.

If a fault condition should lead to a risk of injury, the part, material, or device whose fault was simulated may comprise a **safeguard**.

Rationale is provided for questions regarding the omission of some traditional requirements appearing in other safety documents. Rationale is also provided for further explanation of new concepts and requirements in this document.

Reasonable foreseeable misuse

Rationale: Apart from Annex M, this document does not specifically mention foreseeable misuse or **abnormal operating conditions**. Nevertheless, the requirements of the document cover many kinds of foreseeable misuse, such as covering of ventilation openings, paper jams, stalled motors, etc.

functional insulation

Rationale: This document does not include requirements for **functional insulation**. By its nature, **functional insulation** does not provide a **safeguard** function against electric shock or electrically-caused fire and therefore may be faulted. Obviously, not all **functional insulations** are faulted as this would be prohibitively time-consuming. Sites for **functional insulation** faults should be based upon physical examination of the equipment, and upon the electrical schematic.

Note that **basic insulation** and **reinforced insulation** may also serve as **functional insulation**, in which case the insulation is not faulted.

functional components

Rationale: This document does not include requirements for functional components. By their nature, individual functional components do not provide a **safeguard** function against electric shock, electrically-caused fire, thermal injury, etc., and therefore may be candidates for fault testing. Obviously, not all functional components are faulted as this would be prohibitively time-consuming. Candidate components for fault testing should be based upon physical examination of the equipment, upon the electrical schematic diagrams, and whether a fault of that component might result in conditions for electric shock, conditions for ignition and propagation of fire, conditions for thermal injury, etc.

As with all **single fault condition** testing (Clause B.4), upon faulting of a functional component, there shall not be any safety consequence (for example, a benign consequence), or a **basic safeguard**, **supplementary safeguard**, or **reinforced safeguard** shall remain effective.

In some cases, a pair of ~~functional~~ components may comprise a **safeguard**. If the fault of one of the components in the pair is mitigated by the second component, then the pair is designated as a **double safeguard**. For example, if two diodes are employed in series to protect a **battery** from reverse charge, then the pair comprises a **double safeguard** and the components should be limited to the manufacturer and part number actually tested. A second example is that of an X-capacitor and discharge resistor. If the discharge resistor should fail open, then the X-capacitor will not be discharged. Therefore, the X-capacitor value is not to exceed the ES2 limits specified for a charged capacitor. Again, the two components comprise a **double safeguard** and the values of each component are limited to values for ES1 under **normal operating conditions** and the values for ES2 under **single fault conditions**.

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

Purpose: To accept components as **safeguards**.

Rationale: This document includes requirements for **safeguard** components. A **safeguard** component is a component specifically designed and manufactured for both functional and **safeguard** parameters. Examples of **safeguard** components are capacitors complying with IEC 60384-14 and other components that comply with their related IEC component document.

Acceptance of components and component requirements from IEC 60065 and 60950-1

Purpose: To accept both components and sub-assemblies investigated to the legacy documents, IEC 60065 and IEC 60950-1, and components complying with individual component requirements within these documents during the transition period.

Rationale: To facilitate a smooth transition from the legacy documents IEC 60065 and IEC 60950-1 to IEC 62368-1, including by the component supply chain, this document allows for acceptance of both components and sub-assemblies investigated to the legacy documents. Individual component requirements within these documents may be used for compliance with IEC 62368-1 without further investigation, other than to give consideration to the appropriate use of the component or sub-assembly in the end-product.

This means, for example, if a switch mode power supply is certified to IEC 60065 or IEC 60950-1, this component can be used in equipment evaluated to IEC 62368-1 without further investigation, other than to give consideration to the appropriate use of the component, such as use within its electrical ratings.

This also means, for example, since IEC 60950-1 allows for wiring and cables insulated with PVC, TFE, PTFE, FEP, polychloroprene or polyimide to comply with material requirements for parts within a **fire enclosure** without need for the application of a flammability test, the same wire can be used to comply with the requirements in 6.5.2 for insulation on wiring used in PS2 or PS3 circuits and without the need for application of a flammability test per IEC 60332 series or IEC TS 60695-11-21 as normally is required by 6.5.1.

~~It is important to note that this will only be allowed during the transition period from the legacy standards to IEC 62368-1.~~

4.1.5 Constructions and components not specifically covered

For constructions not covered, consideration should be given for the hierarchy of safeguards in accordance with ISO/IEC Guide 51.

4.1.6 Orientation during transport and use

See also 4.1.4

In general, equipment is assumed to be installed and used in accordance with the manufacturer's instructions. However, in some cases where equipment may be installed by an **ordinary person**, it is recognized that it is common practice to mount equipment as desired if screw holes are provided, especially if they allow mounting to readily available brackets. Hence, the exception that is added to 4.1.6.

Examples of the above: a piece of equipment, such as a television set or a video projector, that has embedded screw mounting holes that allow it to be attached to a wall or other surface through the use of commercially available vertically or tilt-mountable brackets, shall also take into account that the mounting surface itself may not be vertical.

It is also recognized that **transportable equipment**, by its nature, may be transported in any and all orientations.

4.1.8 Liquids and liquid filled components (LFC)

The one-litre (1 l) restriction was placed in 4.1.8 since the origin of some of the requirements in Clause G.15 came from requirements in documents often applied to smaller systems. Nevertheless, such a limitation does not always negate the allowed application of 4.1.8 and Clause G.15 to systems with larger volumes of liquid, but it could impact direct (automatic) applicability to the larger systems.

4.2 Energy source classifications

Classification of energy sources may be done whether the source is **accessible** or not. The requirements for parts may differ on whether the part is **accessible** or not.

4.2.1 Class 1 energy source

A class 1 energy source is a source that is expected not to create any pain or injury. Therefore, a class 1 energy source may be **accessible** by any person.

Under some specific conditions of abnormal operation or **single fault conditions**, a class 1 energy source may reach class 2 limits. However, this source still remains a class 1 energy source. In this case, an **instructional safeguard** may be required.

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

A class 2 energy source is a source that may create pain, but which is unlikely to create any serious injury. Therefore, a class 2 energy source may not be **accessible** by an **ordinary person**. However, a class 2 energy source may be **accessible** by:

- an **instructed person**; and
- a **skilled person**.

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 energy source is a source that is likely to create an injury. Therefore a class 3 energy source may not be **accessible** to an **ordinary person** or an **instructed person**. A class 3 energy source may, in general, be **accessible** to a **skilled person**.

Any source may be declared a class 3 energy source without measurement, in which case all the **safeguards** applicable to class 3 are required.

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.

4.3.2 Safeguards for protection of an ordinary person

The required **safeguards** for the protection of an **ordinary person** are given in Figure 4.

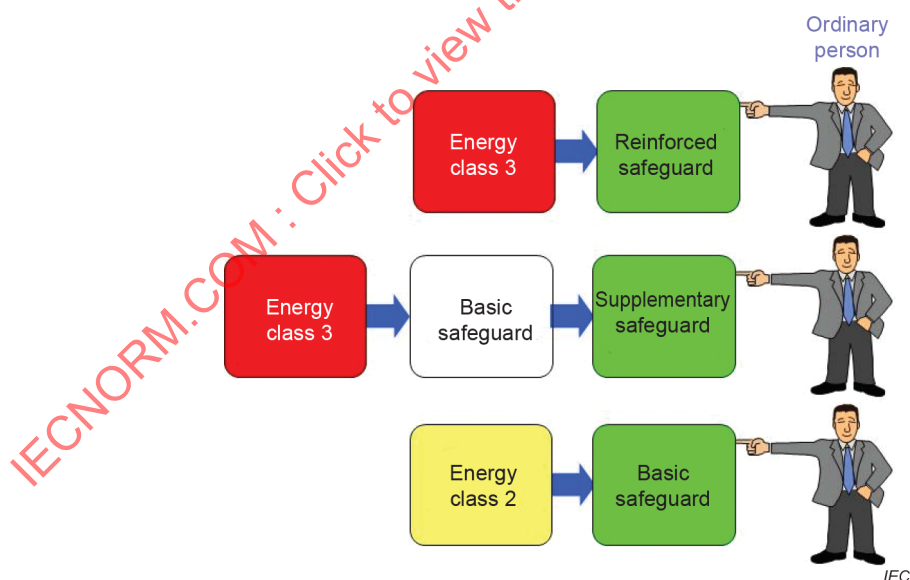


Figure 4 – Safeguards for protecting an ordinary person

4.3.3 Safeguards for protection of an instructed person

The required **safeguards** for the protection of an **instructed person** are given in Figure 5.

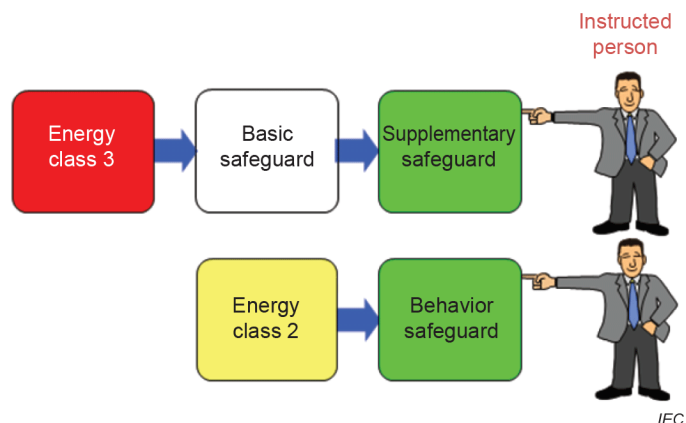


Figure 5 – Safeguards for protecting an instructed person

4.3.4 Safeguards for protection of a skilled person

The required **safeguards** for the protection of a **skilled person** are given in Figure 6.

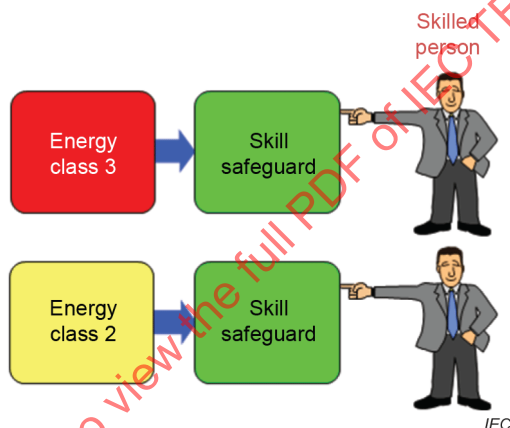


Figure 6 – Safeguards for protecting a skilled person

Table 1 in this document gives a general overview of the required number of **safeguards** depending on the energy source and the person to whom the energy source is **accessible**. The different clauses have requirements that sometimes deviate from the general principle as given above. These cases are clearly defined in the requirements sections of the document.

Table 1 – General summary of required safeguards

Person	Number of safeguards required to be interposed between an energy source and a person		
	Class 1	Class 2	Class3
Ordinary person	0	1	2
Instructed person	0	0	2
Skilled person	0	0	0 or 1

For a **skilled person**, there is normally no **safeguard** required for a class 3 energy source. However, if there are multiple class 3 energy sources **accessible** or if the energy source is not obvious, a **safeguard** may be required.

4.4.2 Composition of a safeguard

Purpose: To specify design and construction criteria for a single **safeguard** (basic, supplementary, or reinforced) comprised of more than one element, for example, a component or a device.

Rationale: **Safeguards** need not be a single, homogeneous component. Indeed, some parts of this document require a single **safeguard** be comprised of two or more elements. For example, for thin insulation, two or more layers are required to qualify as **supplementary insulation**. Another example is protective bonding and **protective earthing**, both of which are comprised of wires, terminals, screws, etc.

If a **safeguard** is comprised of two or more elements, then the function of the **safeguard** should not be compromised by a failure of any one element. For example, if a screw attaching a **protective earthing** wire should loosen, then the current-carrying capacity of the **protective earthing** circuit may be compromised, making its reliability uncertain.

4.4.43 Safeguard robustness

Rationale: **Safeguards** should be sufficiently robust to withstand the rigors of expected use throughout the equipment lifetime. Robustness requirements are specified in the various clauses.

4.4.3.4 Impact test

Rationale: **Stationary equipment** can, in some cases, be developed for a specific installation in which it is not possible for certain surfaces to be subjected to an impact when installed as intended. In those cases, the impact test is not necessary when the installation makes clear that the side cannot be impacted.

4.4.43.6 Glass impact tests

Source: IEC 60065

Purpose: Verify that any glass that breaks does not cause skin-lacerating injury, or expose class 3 hazards behind the glass.

Rationale: When it comes to glass, two hazards can be present in case the glass breaks:

- accessibility to sharp edges from the broken glass itself
- exposure of class 3 energy hazards in case the glass is used as (part of) the **enclosure**.

Should the glass break during the impact test, T.9 is applied to ensure the expelled fragments will be at MS2 level or less.

Platen glass has a long history of being exempted, because it is quite obvious for people that, if broken, the broken glass is hazardous and contact should be avoided. There is no known history of serious injuries with this application. Platen glass is the glass that is typically used in scanners, copiers, etc. Accidents are rare, probably also because they are protected by an additional cover most of the time, which limits the probability that an impact will occur on the glass.

CRTs are exempted because they have separate requirements.

The test value for floor standing equipment is higher because it is more likely to be impacted by persons or carts and dollies at a higher force while in normal use.

The exemption for glass below certain sizes is taken over from IEC 60065. There is no good rationale to keep the exemption, other than that there are no serious accidents known from the field. The HBSDT decided that they want to keep the exemption in.

The flow chart in Figure 7 in this document shows the intent for the requirements.

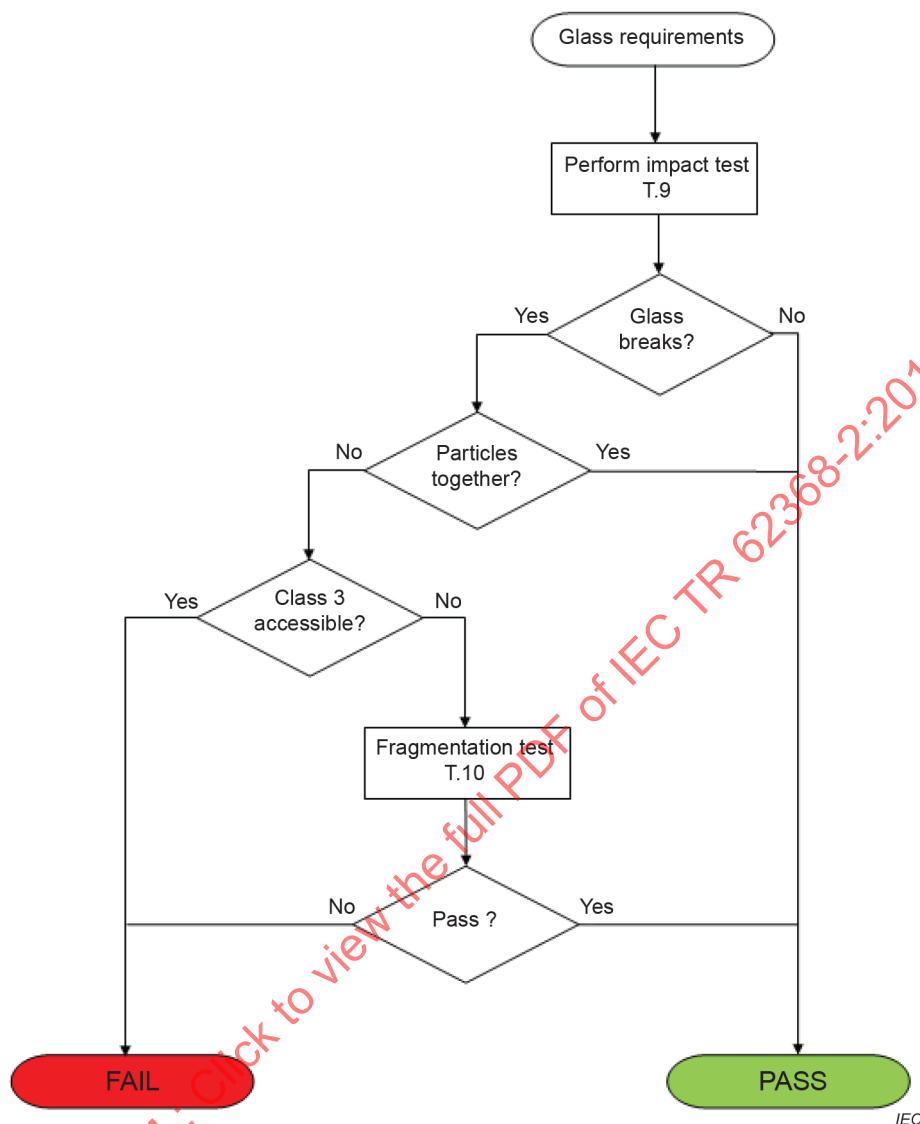


Figure 7 – Flow chart showing the intent of the glass requirements

4.4.4.93.10 Compliance criteria

The value of 30 g for the weight limit is chosen based on the maximum dimension of a side of 50 mm. A typical piece of glass with a size of 50 mm × 50 mm × 4 mm (roughly 2,80 g/cm³) would have a weight of around 30 g.

4.6 Fixing of conductors

Source: IEC 60950-1

Purpose: To reduce the likelihood that conductors could be displaced such that they reduce the **creepage distances** and **clearances**.

Rationale: These requirements have been successfully used for products in the scope of this document for many years.

4.7 Equipment for direct insertion into mains socket-outlets

Source: IEC 60065:2014, 15.5

IEC 60950-1:2005/AMD 1:2009/AMD 2:2013, 4.3.6

IEC 60335-1:2010, 22.3

IEC 60884-1:~~2002/AMD 1:2006/AMD 2~~:2013, 14.23.2

Purpose: Determine that equipment incorporating integral pins for insertion into **mains** socket-outlets does not impose undue torque on the socket-outlet due to the mass and configuration of the equipment. This type of equipment often is known as Direct Plug-in Equipment or Direct Plug-in Transformers.

Rationale: Socket outlets are required to comply with the safety requirements in IEC 60884-1:~~2002~~2013, *Plugs and socket-outlets for household and similar purposes – Part 1: General requirements*, including subclause 14.23.2. The requirements result in socket designs with certain design limitations. Equipment incorporating integral pins for insertion into **mains** socket-outlets is not allowed to exceed these design limitations.

4.9 Likelihood of fire or shock due to entry of conductive objects

Purpose: The purpose of this subclause is to establish opening requirements that would minimize the risk of foreign conductive objects falling into the equipment that could bridge parts within class 2 or class 3 circuits, or between PS circuits that could result in ignition or electric shock.

~~The 1,8 m is a height where~~ It is considered unlikely that a person would accidentally drop something that could consequently fall into the equipment at a height greater than 1,8 m.

5 Electrically-caused injury

Purpose: Clause 5 classifies electrical energy sources and provides criteria for determining the energy source class of each conductive part. The criteria for energy source class include the source current-voltage characteristics, duration, and capacitance. Each conductive part, whether current-carrying or not, or whether earthed or not, shall be classed ES1, ES2, or ES3 with respect to earth and with respect to any other simultaneously **accessible** conductive part.

240 VA limit

~~It should be noted that~~ IEC 62368-1 does not have requirements for a 240 VA energy hazard, ~~such as~~ that was previously located in 2.1.1.5 of IEC 60950-1:~~2005/AMD 1:2009/AMD 2~~:2013.

The origin/justification of the 240 VA energy hazard requirement in the legacy documents was never precisely determined, and it appears the VA limits may have come from a manufacturer's specifications originally applied to exposed bus bars in mainframe computers back in the 1960's and concerns at the time ~~with~~ service personnel inadvertently bridging them with a metal part.

However, when IEC TC 108 started the IEC 62368-1 project the intent was to take a fresh look at product safety using HBSE and only carry over a legacy requirement if the safety science and HBSE justified it. After considerable study by IEC TC 108, there was no support for carrying over the 240 VA requirement since:

- the requirements were not based on any proven science or sound technical basis;
- the 240 VA value was relatively arbitrary; and
- in practice the requirement was difficult to apply consistently (for example, on a populated printed board or inside a switch mode power supply).

In the meantime, there are energy limits for capacitors in Clause 5, which remains a more realistic concern and which were the second set of the energy hazard requirements in IEC 60950-1, the first being steady state 240 VA.

In addition, there are other requirements in IEC 62368-1 that will limit exposure to high levels of power (VA), including a VA limit for LPS outputs when those are required by Annex Q (for outputs connected to building wiring as required by 6.5.32).

Electric burn (eBurn)

Analysis of the body current generated by increasing frequency sinusoidal waveforms shows that the current continues to increase with frequency. The same analysis shows that the **touch current**, which is discounted with frequency, stabilizes.

The following paper describes the analysis fully: 'Touch Current Comparison, Looking at IEC 60990 Measurement Circuit Performance – Part 1: Electric Burn'; Peter E Perkins; IEEE PSES Product Safety Engineering Newsletter, Vol 4, No 2, Nov 2008.

The crossover frequency is different for the startle reaction circuit than for the let go-immobilization circuit because of the separate Frequency Factor body response curves related to current levels; analysis identifies the crossover frequency where the eBurn current surpasses the **touch current**. Under these conditions, a person touching the circuit will become immobilized and will not be able to let go of the circuit. This crossover frequency is determined in the analysis. The person contacting the circuit should always be able to let go.

The general conditions that apply to eBurn circuits are:

- the eBurn limit only applies to HF sinusoidal signals;
- the area of contact should be limited to a small, fingertip contact (~ 1cm²);
- the contact time should be less than 1 s; at this short contact time, it is not reasonable to define different levels for various persons;

This requirement applies to **accessible** circuits that can be contacted at both poles, including all grounded ~~secondary~~ circuits isolated from the **main**s and any isolated circuits where both contacts are easily available to touch.

A simplified application of these requirements in the documents limits the accessibility of HF sinusoidal currents above a specified frequency. The 22 kHz and 36 kHz frequency limits are where the eBurn current crosses the 5mA limit for the ES1 and ES2 measurement circuits. This will ensure that the person contacting the circuit will be able to remove themselves from the circuit under these conditions.

1 MHz limit

The effects of electric current on the human body are described in the IEC 60479 series and the requirements in IEC 62368-1 are drawn from there. The effects versus frequency are well laid out and properly accounted for in these requirements. The body effects move from conducted effects to surface radiofrequency burns at higher frequencies approaching 100 kHz. By long-term agreement, IEC safety documents are responsible for outlining the effects of current to 1 MHz, which are properly measured by the techniques given herein. Above the 1 MHz level, it becomes an EMC issue. Unless the current is provided as a principal action of the equipment operation, electric shock evaluation should not be needed above the 1 MHz level. Where it is fundamental to the equipment's operation, the high-frequency current levels shall be specially measured

using proper high-frequency techniques, including classifying the circuits and, if necessary, appropriately protected to avoid any bodily injury.

5.2.1 Electrical energy source classifications

Source: IEC TS 60479-1:2005 and IEC 61201

Purpose: To define the line between hazardous and non-hazardous electrical energy sources for **normal operating conditions** and **abnormal operating conditions**.

Rationale: The effect on persons from an electric source depends on the current through the human body. The effects are described in IEC TS 60479-1.

IEC TS 60479-1:2005 (see Figures 20 and 22, Tables 11 and 13); zone AC-1 and zone DC-1; usually no reaction (Figure 8 and Figure 9, Table 2 and Table 3 in this document) is taken as values for ES1.

IEC TS 60479-1:2005 (see Figures 20 and 22; Tables 11 and 13); zone AC-2 and zone DC-2; usually no harmful physiological effects (see Figure 8 and Figure 9, Table 2 in this document) is taken as values for ES2.

IEC TS 60479-1:2005; zone AC-3 and zone DC-3; harmful physiological effects may occur (see Figure 8 and Figure 9, Table 2 and Table 3 in this document) is the ES3 zone.

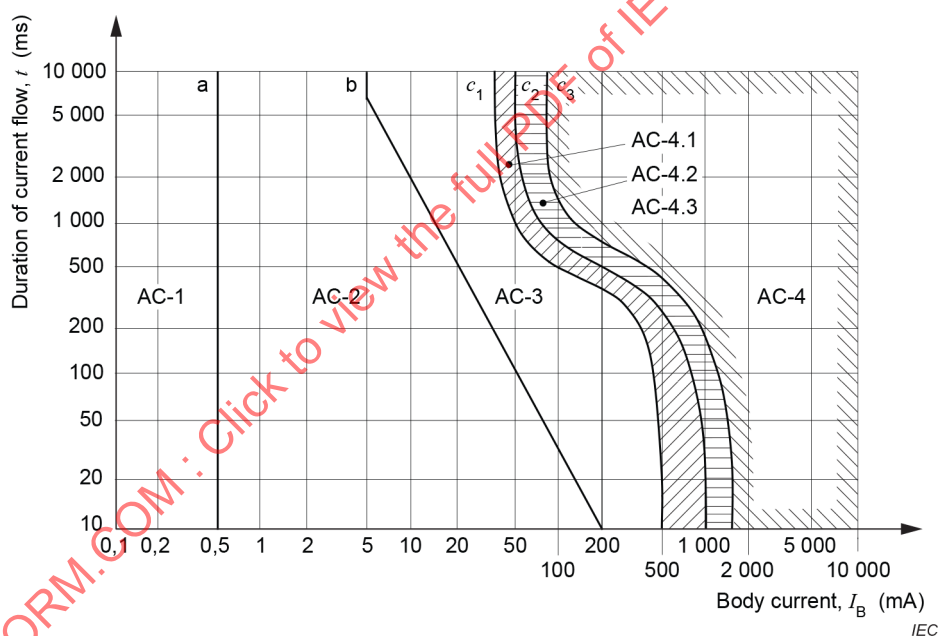


Figure 8 – Conventional time/current zones of effects of AC currents (15 Hz to 100 Hz) on persons for a current path corresponding to left hand to feet (see IEC TS 60479-1:2005, Figure 20)

**Table 2 – Time/current zones for AC 15 Hz to 100 Hz
for hand to feet pathway (see IEC TS 60479-1:2005, Table 11)**

Zones	Boundaries	Physiological effects
AC-1	up to 0,5 mA curve a	Perception possible but usually no startle reaction
AC-2	0,5 mA up to curve b	Perception and involuntary muscular contractions likely but usually no harmful electrical physiological effects
AC-3	Curve b and above	Strong involuntary muscular contractions. Difficulty in breathing. Reversible disturbances of heart function. Immobilisation may occur. Effects increasing with current magnitude. Usually no organic damage to be expected.
AC-4 ^a	Above curve c_1 $c_1 - c_2$ $c_2 - c_3$ Beyond curve c_3	Pathophysiological effects may occur such as cardiac arrest, breathing arrest, and burns or other cellular damage. Probability of ventricular fibrillation increasing with current magnitude and time. AC-4.1 Probability of ventricular fibrillation increasing up to about 5 %. AC-4.2 Probability of ventricular fibrillation up to about 50 %. AC-4.3 Probability of ventricular fibrillation above 50 %.

^a For durations of current flow below 200 ms, ventricular fibrillation is only initiated within the vulnerable period if the relevant thresholds are surpassed. As regards ventricular fibrillation, this figure relates to the effects of current that flows in the path left hand to feet. For other current paths, the heart current factor has to be considered.

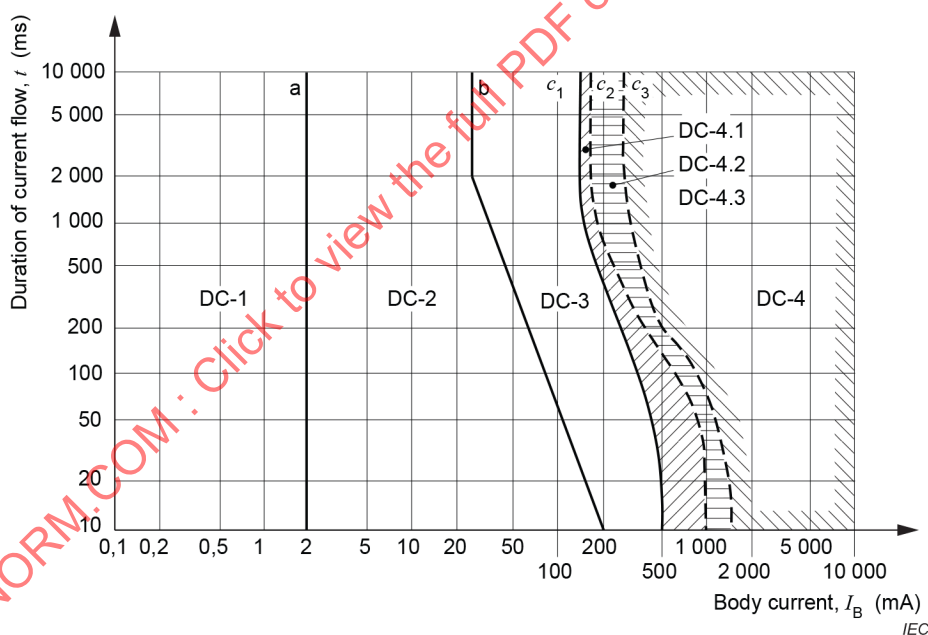
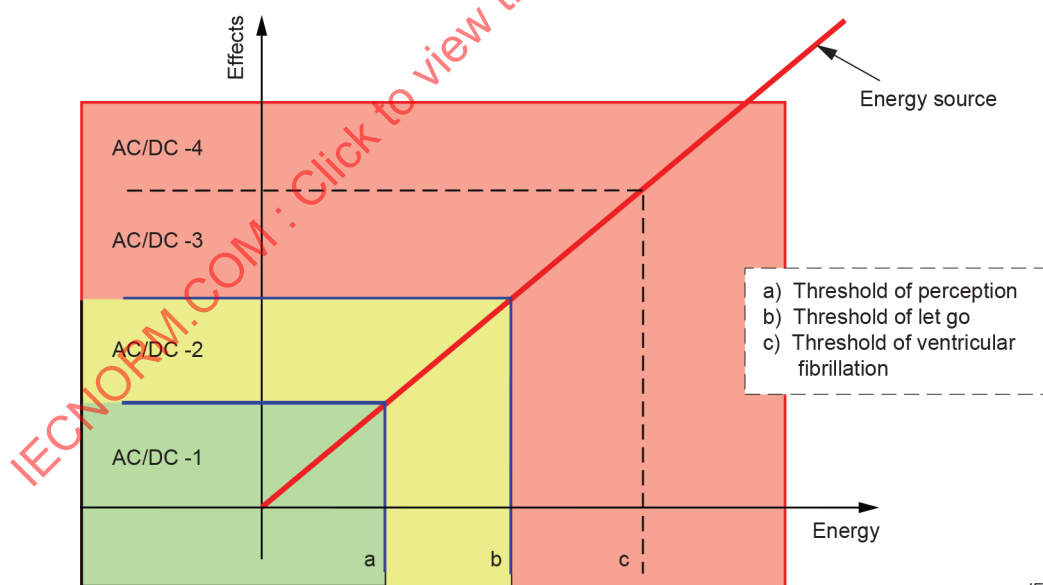


Figure 9 – Conventional time/current zones of effects of DC currents on persons for a longitudinal upward current path (see IEC TS 60479-1:2005, Figure 22)

**Table 3 – Time/current zones for DC for hand to feet pathway
(see IEC TS 60479-1:2005, Table 13)**

Zones	Boundaries	Physiological effects
DC-1	Up to 2 mA curve a	Slight pricking sensation possible when making, breaking or rapidly altering current flow.
DC-2	2 mA up to curve b	Involuntary muscular contractions likely, especially when making, breaking or rapidly altering current flow, but usually no harmful electrical physiological effects
DC-3	curve b and above	Strong involuntary muscular reactions and reversible disturbances of formation and conduction of impulses in the heart may occur, increasing with current magnitude and time. Usually no organic damage to be expected.
DC-4 ^a	Above curve c_1 $c_1 - c_2$ $c_2 - c_3$ Beyond curve c_3	Pathophysiological effects may occur such as cardiac arrest, breathing arrest, and burns or other cellular damage. Probability of ventricular fibrillation increasing with current magnitude and time. DC-4.1 Probability of ventricular fibrillation increasing up to about 5 %. DC-4.2 Probability of ventricular fibrillation up to about 50 %. DC-4.3 Probability of ventricular fibrillation above 50 %.
^a For durations of current flow below 200 ms, ventricular fibrillation is only initiated within the vulnerable period if the relevant thresholds are surpassed. As regards ventricular fibrillation, this figure relates to the effects of current which flows in the path left hand to feet and for upward current. For other current paths, the heart current factor has to be considered.		

The seriousness of an injury increases continuously with the energy transferred to the body. To demonstrate this principle Figure 8 and Figure 9 in this document (see IEC TS 60479-1:2005, Figures 20 and 22) are transferred into a graph: effects – (A) vs energy (see Figure 10 in this document).



IEC

Figure 10 – Illustration that limits depend on both voltage and current

Within the document, only the limits for Zone 1 (green) and Zone 2 (yellow) will be specified.

Curve “a” (limit of Zone 1) will be the limit for parts **accessible** by an **ordinary person** during normal use.

Curve “b” (limit of Zone 2) will be the limit for parts **accessible** by an **ordinary person** during (or after) a single fault.

IEC TC 108 regarded it not to be acceptable to go to the limits of either Zone 3 or 4.

In the document three (3) zones are described as electrical energy sources.

This classification is as follows:

- electrical energy source 1 (ES1): levels are of such a value that they do not exceed curve “a” (threshold of perception) of Figure 8 and Figure 9 in this document (see IEC TS 60479-1:2005, Figures 20 and 22).
- electrical energy source 2 (ES2): levels are of such a value that they exceed curve “a”, but do not exceed curve “b” (threshold of let go) of Figure 8 and Figure 9 in this document (see IEC TS 60479-1:2005, Figures 20 and 22).
- electrical energy source 3 (ES3): levels are of such a value that they exceed curve “b” of Figure 8 and Figure 9 in this document (see IEC TS 60479-1:2005, Figures 20 and 22).

5.2.2.1 General

When classifying a circuit or part that is not **accessible**, that circuit or part shall be regarded as being **accessible** when measuring **prospective touch voltage** and **touch current**.

5.2.2.2 Steady-state voltage and current limits

Table 4 Electrical energy source limits for steady-state ES1 and ES2

Source:	IEC TS 60479-1:2005, Dalziel, Effect of Wave Form on Let-Go Currents; AIEE Electrical Engineering Transactions, Dec 1943, Vol 62.
Rationale:	The current limits of Table 4 line 1 and 2 are derived from curve a and b, Figure 8 and Figure 9 in this document (see IEC TS 60479-1:2005, Figures 20 and 22).

The basis for setting limits for combined AC and DC **touch current** is from the work of Dalziel which provides clear data for men, women and children. In the current diagram (Figure 22), the AC current is always the peak value (per Dalziel). In the voltage diagram (Figure 23), the 30 V AC and 50 V AC points on the baseline are recognized as AC RMS values as stated in Table 4. Since IEC TC 108 is working with consumer appliances, there is a need to provide protection for children, who are generally considered the most vulnerable category of people. The formulas of IEC 62368-1:2014/2018, Table 4 address the Dalziel investigations.

Under **single fault conditions** of a relevant **basic safeguard** or **supplementary safeguard**, **touch current** is measured according to 5.1.2 of IEC 60990:1999/2016. However, this IEC 60990 subclause references both the IEC 60990 perception/reaction network (Figure 4 of IEC 60990:1999) and the let-go network (Figure 5 of IEC 60990:1999), selection of which depends on several factors, ~~one being whether the part is considered a “grippable part.” It is clear from IEC 60479 that immobilization due to electric current applies more broadly than whether or not the part is “grippable”; and.~~ Figure 5 applies to **touch currents** limits above 2 mA RMS, ~~which has been done here.~~ IEC TC 108 has decided that parts under **single fault conditions** of relevant **basic safeguards** or **supplementary safeguards** should be measured per Figure 5 of IEC 60990:1999 (let-go immobilization network). Therefore, since 5.1.2 makes reference to both Figure 4 and Figure 5 of IEC 60990:1999, for clarification Table 5 4 is mentioned directly in 5.2.2.2.

Because there is usually no reaction of the human body when touching ES1, access is permitted by any person (IEC TS 60479-1; zone AC-1 and zone DC-1).

Because there may be a reaction of the human body when touching ES2, protection is required for an **ordinary person**. One **safeguard** is sufficient because there are usually no harmful physiological effects when touching ES2 (IEC TS 60479-1:2005; zone AC-2 and zone DC-2).

Because harmful physiological effects may occur when touching ES3, (IEC TS 60479-1:2005; zone AC-3 and zone DC-3), protection is required for an **ordinary person** and an **instructed person**, including after a fault of one **safeguard**.

During the application of the electrical energy source limits for “combined AC and DC” in Table 4, if the AC component of a superimposed AC and DC energy source does not exceed 10 % of the DC energy, then the AC component can be disregarded for purposes of application of Table 4. This consideration is valid based on the definition of **DC voltage** in 3.3.14.1, which allows peak-to-peak ripple not exceeding 10 % of the average value to integrated into **DC voltage** considerations. As a result, in such cases where AC does not exceed 10 % of DC, only the DC energy source limits in Table 4 need be applied.

When measuring combined AC and DC voltages and currents, both AC and DC measurements shall be made between the same points of reference. Do not combine common-mode measurements with differential-mode measurements. They shall be assessed separately.

In using Table 4, ES1 touch current measurement specifies the startle-reaction circuit ‘a’ intended for limits less than 2 mA RMS / 2,8 mA peak and ES2 touch current specifies the let-go-immobilization circuit ‘b’ intended for limits > 2 mA RMS / 2,8 mA peak. These circuits are adopted from IEC 60990:2016, Clause 5.

Normal operating conditions of equipment for touch current testing are outlined in 5.7.2 and Clause B.2 of IEC 62368-1:2018 and includes operation of all operator controls. **Abnormal operating conditions** are specified in Clause B.3 of IEC 62368-1:2018. **Single fault conditions** (within the equipment), specified in Clause B.4 of IEC 62368-1:2018, includes faults of a relevant **basic safeguard** or a **supplementary safeguard**.

5.2.2.3 Capacitance limits

Table 5 Electrical energy source limits for a charged capacitor

Source: IEC TS 61201:2007 (Annex A)

Rationale: Where the energy source is a capacitor, the energy source class is determined from both the charge voltage and the capacitance. The capacitance limits are derived from IEC TS 61201:2007, see Table 4 in this document.

The values for ES2 are derived from Table A.2 of IEC TS 61201:2007.

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

Table 4 – Limit values of accessible capacitance (threshold of pain)

U V	C μF	U kV	C nF
70	42,4	1	8,0
78	10,0	2	4,0
80	3,8	5	1,6
90	1,2	10	0,8
100	0,58	20	0,4
150	0,17	40	0,2
200	0,091	60	0,133
250	0,061		
300	0,041		
400	0,028		
500	0,018		
700	0,012		

5.2.2.4 Single pulse limits

Table 6 Voltage limits for single pulses

Rationale: The values are based on the DC current values of Table 4, assuming 25 mA gives a voltage of 120 V DC (body resistance of 4,8 k Ω). The lowest value is taken as 120 V because, under **single fault conditions**, the voltage of ES1 ~~is permitted to go to~~ can be as high as 120 V DC without a time limit.

The table allows linear interpolation because the difference is considered to be very small. However, the following formula may be used for a more exact interpolation of the log-log based values in this table. The variable t or V is the desired unknown "in between value" and either may be determined when one is known:

$$V = \text{Antilog} \frac{\log V_2 + \log V_1 \times \frac{\log t_2 - \log t}{\log t - \log t_1}}{1 + \frac{\log t_2 - \log t}{\log t - \log t_1}}$$

and

$$t = \text{Antilog} \frac{\log t_2 + \log t_1 \times \frac{\log V_2 - \log V}{\log V - \log V_1}}{1 + \frac{\log V_2 - \log V}{\log V - \log V_1}}$$

$$V = \text{Antilog} \frac{\log V_2 + \log V_1 \times \frac{\log t_2 - \log t}{\log t - \log t_1}}{1 + \frac{\log t_2 - \log t}{\log t - \log t_1}}$$

and

$$t = \text{Antilog} \frac{\log t_2 + \log t_1 \times \frac{\log V_2 - \log V}{\log V - \log V_1}}{1 + \frac{\log V_2 - \log V}{\log V - \log V_1}}$$

where:

- t is the time duration that is required to be determined if U_{peak} voltage V is known (or t is known and V needs to be determined)
- t_1 is the time duration adjacent to t corresponding to the U_{peak} voltage V_1
- t_2 is the time duration adjacent to t corresponding to the U_{peak} voltage V_2
- V is the U_{peak} voltage value that is known if time duration t is to be determined (or V is required to be determined if time duration t is known)
- V_1 is the value of the voltage U_{peak} adjacent to V corresponding to time duration t_1
- V_2 is the value of the voltage U_{peak} adjacent to V corresponding to time duration t_2

Table 7 Current limits for single pulses

Source: IEC TS 60479-1:2005

Rationale: For ES1, the limit of single pulse should not exceed the ES1 steady-state voltage limits for **DC voltages**.

For ES2, the voltage limits have been calculated by using the DC current values of curve b Figure 9 in this document and the resistance values of Table 10 of IEC TS 60479-1:2005, column for 5 % of the population (see Table 5 in this document).

The current limits of single pulses in Table 7 for ES1 levels are from curve a and for ES2 are from curve b of Figure 9 in this document.

The table allows linear interpolation because the difference is considered to be very small. However, the following formula may be used for a more exact interpolation of the log-log based values in this table. The variable t or I is the desired unknown "in between value" and either may be determined when one is known:

$$I' = \text{Antilog} \frac{\log I_2 + \log I_1 \times \frac{\log t_2 - \log t}{\log t - \log t_1}}{1 + \frac{\log t_2 - \log t}{\log t - \log t_1}}$$

$$\text{and}$$

$$t = \text{Antilog} \frac{\log t_2 + \log t_1 \times \frac{\log I_2 - \log I}{\log I - \log I_1}}{1 + \frac{\log I_2 - \log I}{\log I - \log I_1}}$$

$$I = \text{Antilog} \frac{\log I_2 + \log I_1 \times \frac{\log t_2 - \log t}{\log t - \log t_1}}{1 + \frac{\log t_2 - \log t}{\log t - \log t_1}}$$

and

$$t = \text{Antilog} \frac{\log t_2 + \log t_1 \times \frac{\log I_2 - \log I}{\log I - \log I_1}}{1 + \frac{\log I_2 - \log I}{\log I - \log I_1}}$$

where:

- t is the time duration that is required to be determined if the electric current I is known (or t is known and I needs to be determined)
- t_1 is the time duration adjacent to t corresponding to the electric current I_1
- t_2 is the time duration adjacent to t corresponding to the electric current I_2
- I is the value of the I_{peak} current that is known if time duration t is to be determined (or I is required to be determined if time duration t is known)
- I_1 is the value of the I_{peak} adjacent to I corresponding to time duration t_1
- I_2 is the value of the I_{peak} adjacent to I corresponding to time duration t_2

Table 5 – Total body resistances R_T for a current path hand to hand, DC, for large surface areas of contact in dry condition

Touch voltage V	Values for the total body resistance R_T (Ω) that are not exceeded for		
	5 % of the population	50 % of the population	95 % of the population
25	2 100	3 875	7 275
50	1 600	2 900	5 325
75	1 275	2 275	4 100
100	1 100	1 900	3 350
125	975	1 675	2 875
150	875	1 475	2 475
175	825	1 350	2 225
200	800	1 275	2 050
225	775	1 225	1 900
400	700	950	1 275
500	625	850	1 150
700	575	775	1 050
1 000	575	775	1 050
Asymptotic value	575	775	1 050
NOTE 1 Some measurements indicate that the total body resistance R_T for the current path hand to foot is somewhat lower than for a current path hand to hand (10 % to 30 %). NOTE 2 For living persons the values of R_T correspond to a duration of current flow of about 0,1 s. For longer durations R_T values may decrease (about 10 % to 20 %) and after complete rupture of the skin R_T approaches the initial body resistance R_o. NOTE 3 Values of R_T are rounded to 25 Ω.			

5.2.2.5 Limits for repetitive pulses**Table 8 – Electrical energy source limits for repetitive pulses**

Source: IEC TS 60479-2 and IEC TS 60479-1

Rationale: For repetitive pulses with a pulse off time less than 3 s the steady state peak values of Table 4 are used.

For repetitive pulses with a pulse off time more than 3 s the limit values of single pulses from Table 6 (voltage) or Table 7 (current) are used.

In the past (IEC 60950-1) we have typically used 1 s as the normal heartbeat interval time for which we have provided protection – for example impulse protection. The reason is that 1 s (60 bpm) is the average heart rate for humans. In order to provide protection for the entire population the heart rate distribution is used and the time selected to protect the entire population. Marathon and triathlon competitors often have a rest heart rate on the order of 20 bpm. TC 64/WG 4 agrees that the protection time needs to be increased to 3 s to provide protection for the full population. We have used this value in IEC 62368-1.

5.2.2.6 Ringing signals

Source: EN 41003

Purpose: To establish limits for analogue telephone network ringing signals.

Rationale: For details see rationale for Annex H. Where the energy source is an analogue telephone network ringing signal as defined in Annex H, the energy source class is taken as ES2 (as in IEC 60950-1:2005, Annex M).

5.2.2.7 Audio signals

Source: IEC 60065:2014

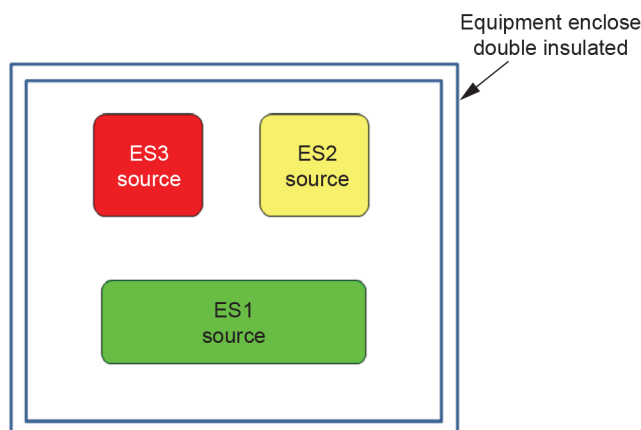
Purpose: To establish limits for touch voltages for audio signals.

Rationale: The proposed limits for touch voltages at terminals involving audio signals that may be contacted by persons have been extracted without deviation from IEC 60065. Reference: IEC 60065:2014, 9.1.1.2 a). Under **single fault conditions**, 10.2 of IEC 60065:2014 does not permit an increase in acceptable touch voltage limits.

The proposed limits are quantitatively larger than the accepted limits of Tables 5 and 6, but are not considered dangerous for the following reasons:

- the output is measured with the load disconnected (worst case load);
- defining the contact area of connectors and wiring is very difficult due to complex shapes. The area of contact is considered small due to the construction of the connectors;
- normally, it is recommended to the user, in the instruction manual provided with the equipment, that all connections be made with the equipment in the “off” condition. ~~In this case we could consider the user as an instructed person;~~
- in addition to being on, the equipment would have to be playing some program at a high output with the load disconnected to achieve the proposed limits (although possible, highly unlikely). Historically, no known cases of injury are known for amplifiers with non-clipped output less than 71 V RMS;
- the National Electrical Code (USA) permits **accessible** terminals with maximum output voltage of 120 V RMS.

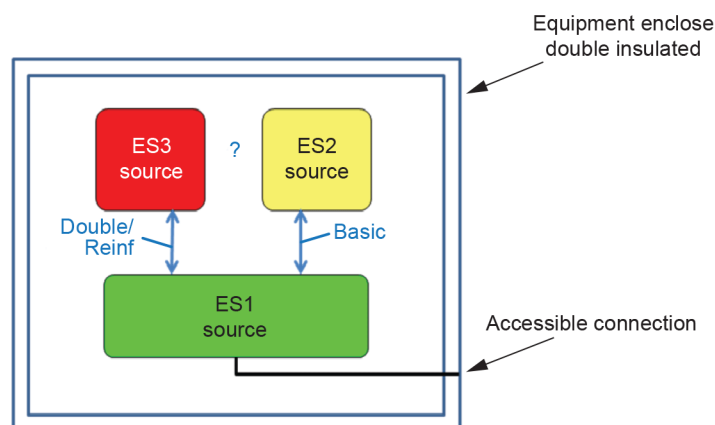
5.3.2 Accessibility to electrical energy sources and safeguards



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What are the requirements between the non-**accessible** sources?

Answer: None. As the **enclosure** is double insulated, the sources are not **accessible**.

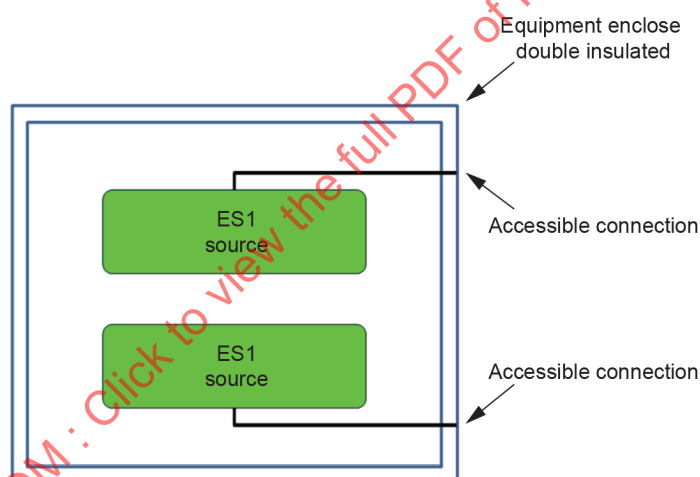


IEC

Now there is an **accessible** connection. What are the requirements between the sources in this case?

Answer:

- **Basic insulation** between ES1 and ES2
- **Double insulation** or **reinforced insulation** between ES1 and ES3
- The insulation between ES2 and ES3 depends on the insulation between the ES1 and ES2



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Now there are two **accessible** connections from independent sources. What are the requirements between the sources in this case?

Answer:

- According to Clause B.4, the insulation or any components between the sources need to be shorted
- If one of the two ES1 sources would reach ES2 levels ⇒ **basic safeguard**

~~(Note that a source that exceeds ES1 levels is not an ES1, but an ES2 source!!!)~~

- If both ES1 sources stay within ES1 limits ⇒ no **safeguard (functional insulation)**

For **outdoor equipment**, lower voltage limits apply because the body impedance is reduced to half the value when subjected to wet conditions as described in IEC TS 60479-1 and IEC TS 61201.

Where **Class III equipment** is acceptable in an indoor application, this outdoor application does not introduce additional **safeguard** requirements.

5.3.2.2 Contact requirements

- Source: IEC 61140:2001, 8.1.1
- Purpose: Determination of **accessible** parts for adults and children. Tests are in IEC 62368-1:2018, Annex V.
- Rationale: ~~For voltage below 420 V peak (300 V r.m.s.) no clearance breakdown will occur according to "Paschen-law".~~
According to Paschen's Law, air breakdown does not occur below 323 V peak or DC (at sea level). IEC 62368-1:2018 uses 420 V peak (300 V RMS) to add an additional safety margin.

5.3.2.3 Compliance criteria

The reason for accepting different requirements for components is because you cannot expect your supplier to make different components for each end application.

5.3.2.4 Terminals for connecting stripped wire

- Source: IEC 60065
- Purpose: To prevent contact of ES2 or ES3 parts.
- Rationale: Accepted constructions used in the audio/video industry for many years.

5.4 Insulation materials and requirements

- Rationale: The requirements, test methods and compliance criteria are taken from the actual outputs from IEC TC 108 MT2 (formerly WG6) as well as from IEC TC 108 MT1.
- The choice and application of components shall take into account the needs for electrical, thermal and mechanical strength, frequency of the **working voltage** and working environment (temperature, pressure, humidity and pollution).
 - Components shall have the electric strength, thermal strength, mechanical strength, dimensions, and other properties as specified in the document.
 - Depending on the grade of **safeguard (basic safeguard, supplementary safeguard, reinforced safeguard)** the requirements differ.
 - Components complying with their component documents (for example, IEC 60384-14 for capacitances) have to be verified for their application.
 - The components listed in this subclause of the new document have a separation function.

5.4.1.1 Insulation

- Source: IEC 60664-1
- Purpose: Provide a reliable **safeguard**
- Rationale: Solid **basic insulation**, **supplementary insulation**, and **reinforced insulation** shall be capable of durably withstanding electrical, mechanical, thermal, and environmental stress that may occur during the anticipated lifetime of the equipment.
- Clearances** and **creepage distances** may be divided by intervening unconnected (floating) conductive parts, such as unused contacts of a connector, provided that the sum of the individual distances meets the specified minimum requirements (see Figure O.4).

5.4.1.4 Maximum operating temperatures for materials, components and systems

Source: IEC 60085, IEC 60364-4-43, ISO 306, IEC 60695-10-2

Rationale: Temperature limits given in Table 9:

- limits for insulation materials including electrical insulation systems, including winding insulation (Classes A, E, B, F, H, N, R and 250) are taken from IEC 60085;
- limits for insulation of internal and external wiring, including power supply cords with temperature marking are those indicated by the marking or the rating assigned by the (component) manufacturer;
- limits for insulation of internal and external wiring, including power supply cords without temperature marking of 70 °C are referenced in IEC 60364-4-43 for an ambient temperature of 25 °C;
- limits for thermoplastic insulation are based on:
 - data from Vicat test B50 of ISO 306;
 - ball pressure test according to IEC 60695-10-2;
 - when it is clear from the examination of the physical characteristics of the material that it will meet the requirements of the ball pressure test;
 - experience with 125 °C value for parts in a circuit supplied from the mains.

5.4.1.4.3 Compliance criteria

Table 9 Temperature limits for materials, components and systems

Rationale Regarding condition “a”, it has been assumed by the technical committee for many years that the thermal gradient between outer surface and inner windings will be limited to 10 °C differential as an average. As a result, the temperature limits for outer surface insulation measured via thermocouple is 10 °C lower than similar measurement with a thermocouple embedded in the winding(s), with both limits at least 5 °C less than the hot-spot temperature allowed per IEC 60085 as an additional safety factor. However, some modern transformer constructions with larger power densities may have larger thermal gradients, as may some outer surface transformer insulation thermal measurements in the equipment/system be influenced by forced cooling or similar effects. Therefore, if thermal imaging, computer modeling, or actual measurement shows a thermal gradient greater than 10 °C average between transformer surface temperature and transformer winding(s), the rise of resistance temperature measurement method and limits for an embedded thermocouple should be used (for example, 100 °C maximum temperature for Class 105 (A)) for determining compliance of a transformer with Table 9 since the original assumptions do not hold true.

As an example, a material rated for 124 °C using the rise of resistance method 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 250).

5.4.1.5 Pollution degrees

Source: IEC 60664-1

Rationale: No values for PD 4 (pollution generates persistent conductivity) are included, as it is unlikely that such conditions are present when using products in the scope of the document.

5.4.1.5.2 Test for pollution degree 1 environment and for an insulating compound

The compliance check made by visual inspection applies both to single layer and multi-layer boards without the need for sectioning to check for voids, gaps, etc.

5.4.1.6 Insulation in transformers with varying dimensions

Source: IEC 60950-1

Purpose: To consider actual **working voltage** along the winding of a transformer.

Rationale: Description of a method to determine adequacy of **solid insulation** along the length of a transformer winding.

5.4.1.7 Insulation in circuits generating starting pulses

Source: IEC 60950-1, IEC 60664-1

Purpose: To avoid insulation breakdown due to starting pulses.

Rationale: This method has been successfully used for products in the scope of this document for many years.

5.4.1.8 Determination of working voltage

Source: IEC 60664-1:2007, 3.5; IEC 60950-1

Rationale: The **working voltage** does not include short duration signals, such as transients. Recurring peak voltages are **not** included. Transient overvoltages are covered in the **required withstand voltage**. Ringing signals do not carry external transients.

5.4.1.8.1 General

Rationale: **Functional insulation** is not addressed in Clause 5, as it does not provide protection against electric shock. Requirements for **functional insulation** are covered in Clause 6, which addresses protection against electrically caused fire.

~~5.4.1.8.3 Peak working voltage~~

Source: IEC 60664-1:2007, 3.8

Rationale: In ~~other product safety standards~~ IEC 62368-1, "Circuit supplied from the **mains**" is used for a "primary circuit". "Circuit isolated from the **mains**" is used for a "secondary circuit".

"**External circuit**" is defined as **external** to the equipment. ES1 can be external to the equipment.

For an **external circuit** operating at ES2 level and not exiting the building, the transient is 0 V. Therefore, in this case, ringing peak voltage needs to be taken into account.

5.4.1.8.2 RMS working voltage

Source: IEC 60664-1:2007, 3.5

Rationale: RMS **working voltage** is used when determining minimum **creepage distance**. Unless otherwise specified, **working voltage** is the **RMS value**.

5.4.1.10 Thermoplastic parts on which conductive metallic parts are directly mounted

Source: ISO 306 and IEC 60695-2 series

Rationale: The temperature of the thermoplastic parts under **normal operating conditions** shall be 15 K less than the softening temperature of a non-metallic part. Supporting parts in a circuit supplied from the **mains** shall not be less than 125 °C.

5.4.2 Clearances

5.4.2.1 General requirements

Source: IEC 60664-1:2007

Rationale: The dimension for a **clearance** is determined from the required impulse withstand voltage for that **clearance**. This concept is taken from IEC 60664-1:2007, 5.1. In addition, **clearances** are affected by the largest of the determined transients. The likelihood of simultaneous occurrence of transients is very low and is not taken into account.

Overvoltages and transients that may enter the equipment, and peak voltages that may be generated within the equipment, do not break down the **clearance** (see IEC 60664-1:2007, 5.1.5 and 5.1.6).

Minimum **clearances** of safety components shall comply with the requirements of their applicable component safety document.

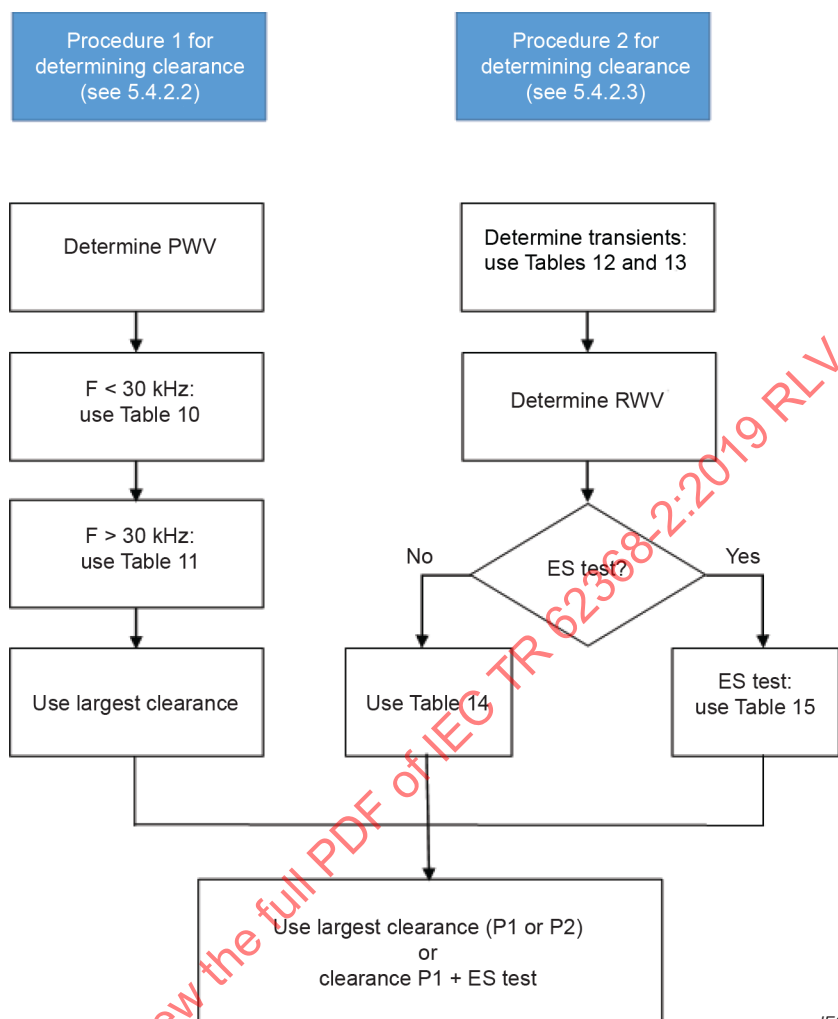
Clearances between the outer insulating surface of a connector and conductive parts at ES3 voltage level shall comply with the requirements of **basic insulation** only, if the connectors are fixed to the equipment, located internal to the outer **electrical enclosure** of the equipment, and are **accessible** only after removal of a sub-assembly that is required to be in place during normal operation.

It is assumed that the occurrence of both factors, the sub-assembly being removed and the occurrence of a transient overvoltage, have a reduced likelihood and hazard potential.

Source: IEC 60664-2 series, *Application guide*

Rationale: The method is derived from the IEC 60664-2 series, *Application guide*.

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Example:

Assuming:

- an SMPS power supply,
- connection to the AC mains,
- a peak of the working voltage (PWV) of 800 V,
- frequencies above and below 30 kHz,
- reinforced clearances required,
- temporary overvoltages: 2 000 V

Procedure 1:

Table ~~11~~ 10 requires 2,54 mm

Table ~~12~~ 11 requires 0,44 mm

Result is 2,54 mm

NOTE All PWV below 1 200 V have clearance requirements less than 3 mm for both Table ~~11~~ 10 and Table ~~12~~ 11

Final result:

- 3,0 mm or
- ES test at 4,67 KV and 2,54 mm

ATTENTION:

For a product with connection to coax cable, different values are to be used since a different transient and **required withstand voltage** is required.

Procedure 2:

Transients (OVC 2): 2 500 V

RWV = 2 500 V

Table ~~15~~ 14 requires 3,0 mm

The required ES test voltage according to Table ~~16~~ 15 is 4,67 KV

Result is 3,0 mm or ES test at 4,67 KV

5.4.2.2 Procedure 1 for determining clearance ~~using peak working voltage~~

Rationale: Related to the first dash of 5.4.2.2, it is noted that an example of a cause of determination of the peak value of steady state voltages that are below the peak voltage of the **mains** includes, for example, a determination in accordance with the 2nd and 3rd dash of 5.4.2.3.3 where filtering is in place to lower expected peak voltages.

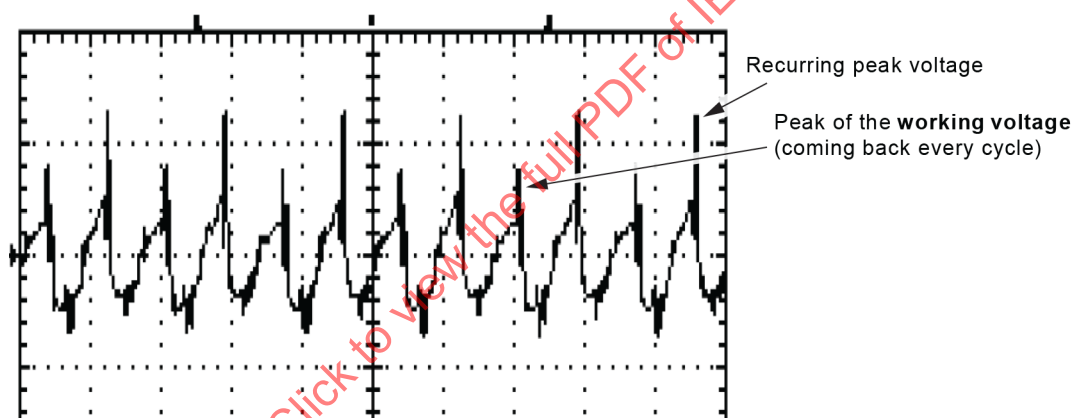
Similarly, related to the second dash of 5.4.2.2, an example of this case where the recurring peak voltage is limited to 1,1 times the **mains** voltage may be use of certain forms of surge protection devices that reduce overvoltage category.

Peak of the working voltage versus recurring peak voltage.

There has been some discussion between the two terms. The **peak of the working voltage** is the peak value of the waveform that occurs each cycle, and therefore is considered to be a part of the **working voltage**.

A recurring peak voltage is a peak that does not occur at each cycle of the waveform, but that reoccurs at a certain interval, usually at a lower frequency than the waveform frequency.

Figure 11 in this document gives an example of a waveform where the recurring peak voltage occurs every two cycles of the main waveform.



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Figure 11 – Illustration of working voltage

Table ~~11~~ 10 Minimum clearances for voltages with frequencies up to 30 kHz

Rationale: IEC TC 108 noted that, if the rules of IEC 60664-1 are followed, for reinforced **clearance**, some values were more than double the requirements for **basic insulation**. IEC TC 108 felt that this should not be the case and decided to limit the requirement for **reinforced insulation** to twice the value of **basic insulation**, thereby deviating from IEC 60664-1.

In addition, normal rounding rules were applied to the values in the table.

5.4.2.3.2.2 Determining AC mains transient voltages

Source: IEC 60664-1:2007, 4.3.3.3

Rationale: Table ~~13~~ 12 is derived from Table F.1 of IEC 60664-1:2007.

The term used in IEC 60664-1 is 'rated impulse voltage'. Products covered by IEC 62368-1 are also exposed to transients from **external circuits**, and therefore another term is needed, to show the different source.

Outdoor equipment that is part of the building installation, or that may be subject to transient overvoltages exceeding those for Overvoltage Category II, shall be designed for Overvoltage Category III or IV, unless additional protection is to be provided internally or externally to the equipment. In this case, the installation instructions shall state the need for such additional protection.

5.4.2.3.2.3 Determining DC mains transient voltages

Rationale: Transient overvoltages are attenuated by the capacitive filtering.

5.4.2.3.2.4 Determining external circuit transient voltages

Source: ITU-T K.21

Rationale: Transients have an influence on circuits and insulation, therefore transients on **external circuits** need to be taken into account. Transients are needed only for the dimensioning **safeguards**. Transients should not be used for the classification of energy sources (ES1, ES2, etc.).

It is expected that **external circuits** receive a transient voltage of 1,5 kV peak with a waveform of 10/700µs from sources outside the building.

The expected transient is independent from the application (telecom; LAN or other). Therefore, it is assumed that for all kinds of applications the same transient appears. The value 1,5 kV 10/700µs is taken from ITU-T K.21.

It is expected that **external circuits** using earthed coaxial cable receive no transients that have to be taken into account from sources outside the building.

Because of the earthed shield of the coaxial cable, a possible transient on the outside cable will be reduced at the earthed shield at the building entrance of the cable.

It is expected that for **external circuits** within the same building no transients have to be taken into account.

The transients for an interface are defined with respect to the terminals where the voltage is defined. For the majority of cases, the relevant voltages are common (U_c) and differential mode (U_d) voltages at the interface. For **hand-held** parts or other parts in extended contact with the human body, such as a telephone hand set, the voltage with respect to local earth (U_{ce}) may be relevant. Figure 12 in this document shows the definition of the various voltages for paired-conductor interface.

The transients for coaxial cable interfaces are between the centre conductor and shield (U_d) of the cable if the shield is earthed at the equipment. If the shield is isolated from earth at the equipment, then the shield-to-earth voltage (U_s) is important. Earthing of the shield can consist of connection of the shield to the **protective earthing**, functional earth inside or immediately outside the equipment. It is assumed that all earths are bonded together. Figure 13 in this document shows the definition of the various voltages for coaxial-cable interfaces.

An overview of insulation requirements is given in Table 6 in this document.

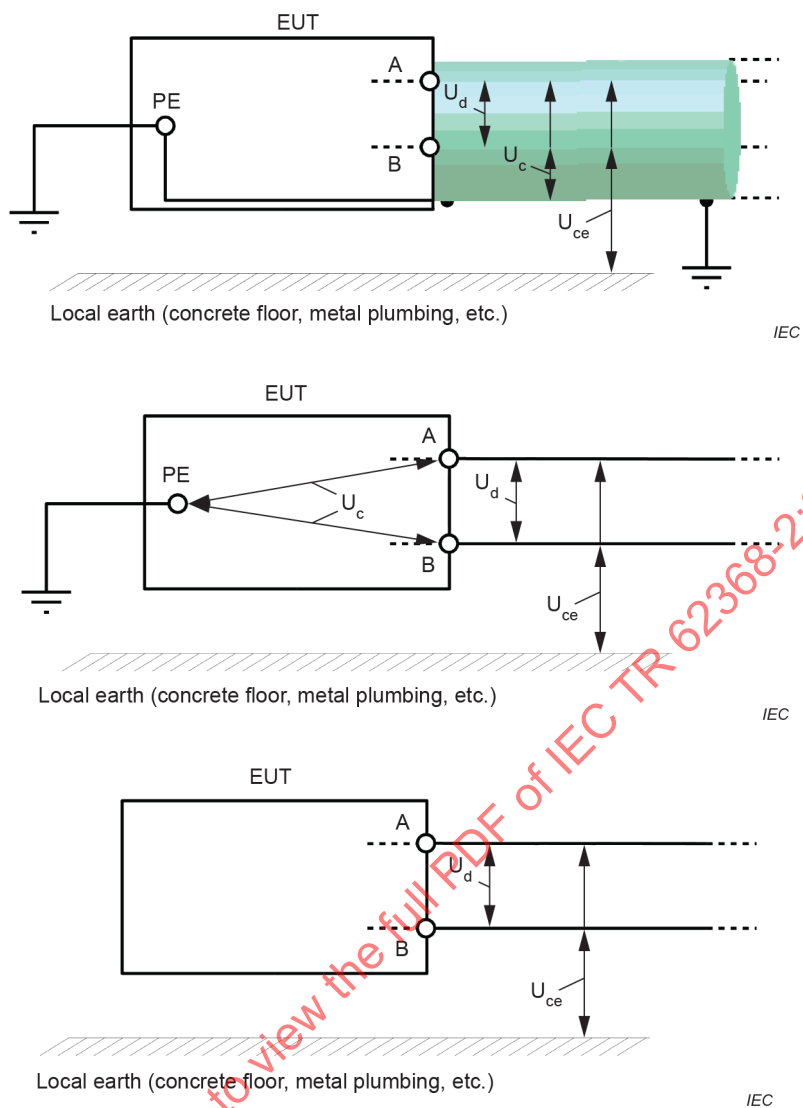


Figure 12 – Illustration of transient voltages on paired conductor external circuits

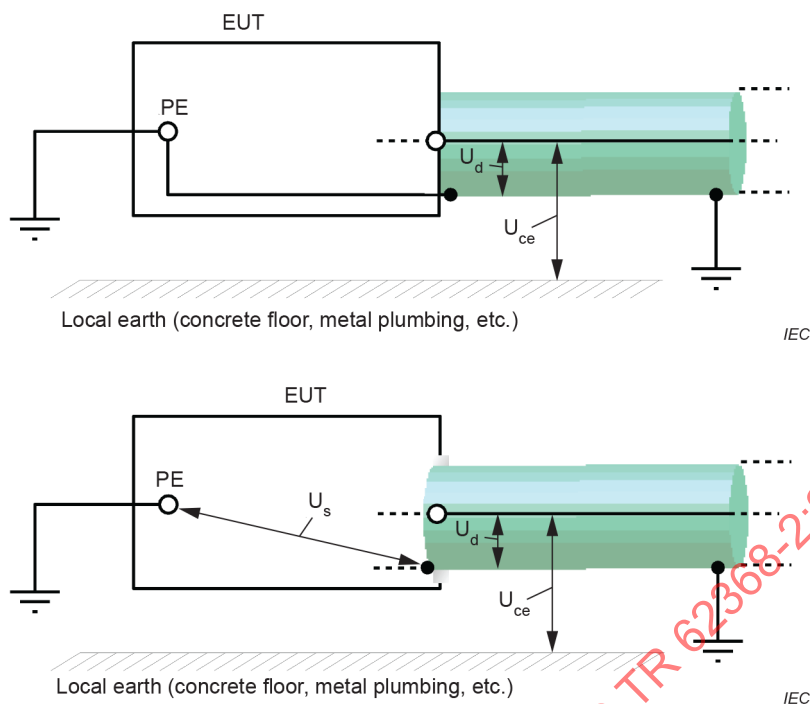


Figure 13 – Illustration of transient voltages on coaxial-cable external circuits

Table 6 – Insulation requirements for external circuits

External Circuit under consideration	Insulation	Requirement
ES1 earthed	None	None
ES1 unearthed	Separation (to floating metal parts and other floating ES1 circuits)	Electric strength test (using Table 15) between unearthed ES1 and other unearthed ES1 and floating parts
ES2	Basic insulation (to ES1 and metal parts)	Clearances; creepage distance; and solid insulation and by electric strength test (using Table 15) between ES2 and ES1 and metal parts
ES3	Double insulation or reinforced insulation (to ES1, ES2 and metal parts)	Clearances; creepage distance; and solid insulation requirements including electric strength test (using Table 15)

Table 13 External circuit transient voltages

Rationale: When the DC power distribution system is located outside the building, transient over-voltages can be expected. Transients are not present if the DC power system is connected to **protective earthing** and is located entirely within a single building.

5.4.2.3.2.3 Determining d.c. mains transient voltages

Rationale: Transient overvoltages are attenuated by the capacitive filtering.

5.4.2.3.2.5 Determining transient voltage levels by measurement

Source: Test method is taken from IEC 60950-1:2005/AMD 1:2009/AMD 2:2013, Annex G.

5.4.2.3.4 Determining clearances using required withstand voltage

Source: IEC 60664-1:2007, Table F.2 Case A (inhomogeneous field) and Case B (homogeneous field)

Rationale: Values in Table ~~15~~ 14 are taken from IEC 60664-1:2007 Table F.2 Case A (inhomogeneous field) and Case B (homogeneous field) and include explicit values for **reinforced insulation**. **Clearances** for **reinforced insulation** have been calculated in accordance with 5.1.6 of IEC 60664-1:2007. For **reinforced insulation** 5.1.6 states **clearance** shall be to the corresponding rated impulse voltage that is one step higher for voltages in the preferred series. For voltages that are not in the preferred series, the **clearance** should be based on 160 % of the **required withstand voltage** for **basic insulation**.

When determining the **required withstand voltage**, interpolation should be allowed when the internal repetitive peak voltages are higher than the **mains** peak voltages, or if the **required withstand voltage** is above the **mains** transient voltage values.

No values for PD 4 (pollution generates persistent conductivity) are included, as it is unlikely that such conditions are present when using products in the scope of the document.

Table ~~15~~ 14 Minimum clearances using required withstand voltage

Rationale: IEC 62368-1 follows the rules and requirements of IEC basic safety publications, one of which is the IEC 60664 series. IEC 60664-1 specifies **clearances** for **basic insulation** and **supplementary insulation**. **Clearances** for **reinforced insulation** are not specified. Instead, 5.1.6 ~~of IEC 60664-1:2007~~ specifies the rules for determining the reinforced **clearances**.

The reinforced **clearances** in Table ~~15~~ 14 have a varying slope, and include a "discontinuity". The values of Table ~~15~~ 14 are shown in Figure 14 in this document.

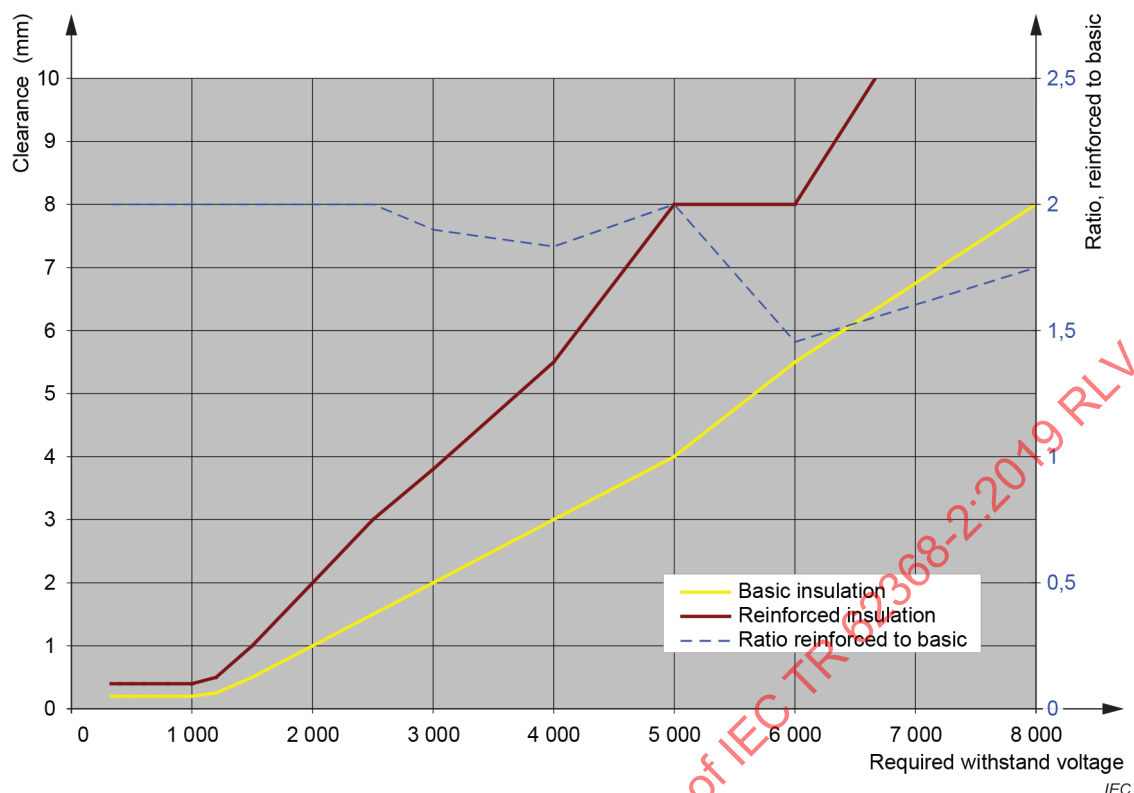


Figure 14 – Basic and reinforced insulation in Table 14 of IEC 62368-1:2014; ratio reinforced to basic

The brown line, reinforced **clearance**, is not a constant slope as is the yellow line, basic **clearance**. The ratio of reinforced to basic (blue line) varies from a maximum of 2:1 to a minimum of 1,49:1. Physically, this is not reasonable; the ratio should be nearly constant.

In IEC 60664-1:2007, the values for **basic insulation** are given in Table F.2. No values are given for **reinforced insulation**. Table F.2 refers to 5.1.6 of IEC 60664-1:2007 for **reinforced insulation**.

Rule 1, preferred series impulse withstand voltages

Subclause 5.1.6 of IEC 60664-1:2007 states:

“With respect to impulse voltages, clearances of reinforced insulation shall be dimensioned as specified in Table F.2 corresponding to the rated impulse voltage but one step higher in the preferred series of values in 4.2.3 than that specified for basic insulation.”

NOTE 1 IEC 62368-1 uses the term “**required withstand voltage**” instead of the IEC 60664-1 term “required impulse withstand voltage.”

NOTE 2 IEC 62368-1 uses the term “**mains transient voltage**” instead of the IEC 60664-1 term “rated impulse voltage.”

The preferred series of values of rated impulse voltage according to 4.2.3 of IEC 60664-1:2007 is: 330 V, 500 V, 800 V, 1 500 V, 2 500 V, 4 000 V, 6 000 V, 8 000 V, 12 000 V

Applying Rule 1, the reinforced **clearance** (inhomogeneous field, **pollution degree 2**, Table F.2 of IEC 60664-1:2007) for:

- 330 V would be the **basic insulation clearance** for 500 V: 0,2 mm
- 500 V would be the **basic insulation clearance** for 800 V: 0,2 mm
- 800 V would be the **basic insulation clearance** for 1 500 V: 0,5 mm

- 1 500 V would be the **basic insulation clearance** for 2 500 V: 1,5 mm
- 2 500 V would be the **basic insulation clearance** for 4 000 V: 3,0 mm
- 4 000 V would be the **basic insulation clearance** for 6 000 V: 5,5 mm
- 6 000 V would be the **basic insulation clearance** for 8 000 V: 8,0 mm
- 8 000 V would be the **basic insulation clearance** for 12 000 V: 14 mm
- 12 000 V is indeterminate because there is no preferred voltage above 12 000 volts.

Rule 2, 160 % of impulse withstand voltages other than the preferred series

With regard to non-mains circuits, subclause 5.1.6 of IEC 60664-1:2007 states:

“If the impulse withstand voltage required for basic insulation according to 4.3.3.4.2 is other than a value taken from the preferred series, reinforced insulation shall be dimensioned to withstand 160 % of the value required for basic insulation.”

The impulse withstand voltages other than the preferred series (in IEC 60664-1:2007, Table F.2 ~~of IEC 60664-1:2007~~) are: 400 V, 600 V, 1 200 V, 2 000 V, 3 000 V, 10 000 V, and all voltages above 12 000 V.

Applying Rule 2, the reinforced **clearance** (inhomogeneous field, **pollution degree 2**, Table F.2 ~~of IEC 60664-1:2007~~) for:

400 V $\times 1,6 = 640$ V interpolated to 0,20 mm.

Since 640 V is not in the list, the **reinforced insulation** is determined by interpolation. Interpolation yields the reinforced **clearance** as 0,2 mm.

Applying Rule 2 to the impulse withstand voltages in Table F.2 ~~of IEC 60664-1:2007~~ that are not in the preferred series:

- 400 V $\times 1,6 = 640$ V interpolated to 0,20 mm
- 600 V $\times 1,6 = 960$ V interpolated to 0,24 mm
- 1 200 V $\times 1,6 = 1 920$ V interpolated to 0,92 mm
- 2 000 V $\times 1,6 = 3 200$ V interpolated to 2,2 mm
- 3 000 V $\times 1,6 = 4 800$ V interpolated to 3,8 mm
- 10 000 V $\times 1,6 = 16 000$ V interpolated to 19,4 mm
- 15 000 V to 100 000 V $\times 1,6$ and interpolated according to the rule.

Clearance differences for Rules 1 and 2

The two rules, Rule 1 for impulse withstand voltages of the preferred series, and Rule 2 for impulse withstand voltages other than the preferred series, yield different **clearances** for the same voltages. These differences occur because the slope, mm/kV, of the two methods is slightly different. The slope for Rule 1 is not constant. The slope for Rule 2 is nearly constant. Figure 15 in this document illustrates the differences between Rule 1, Rule 2 and Table ~~15~~ 14 of IEC 62368-1:2014/2018.

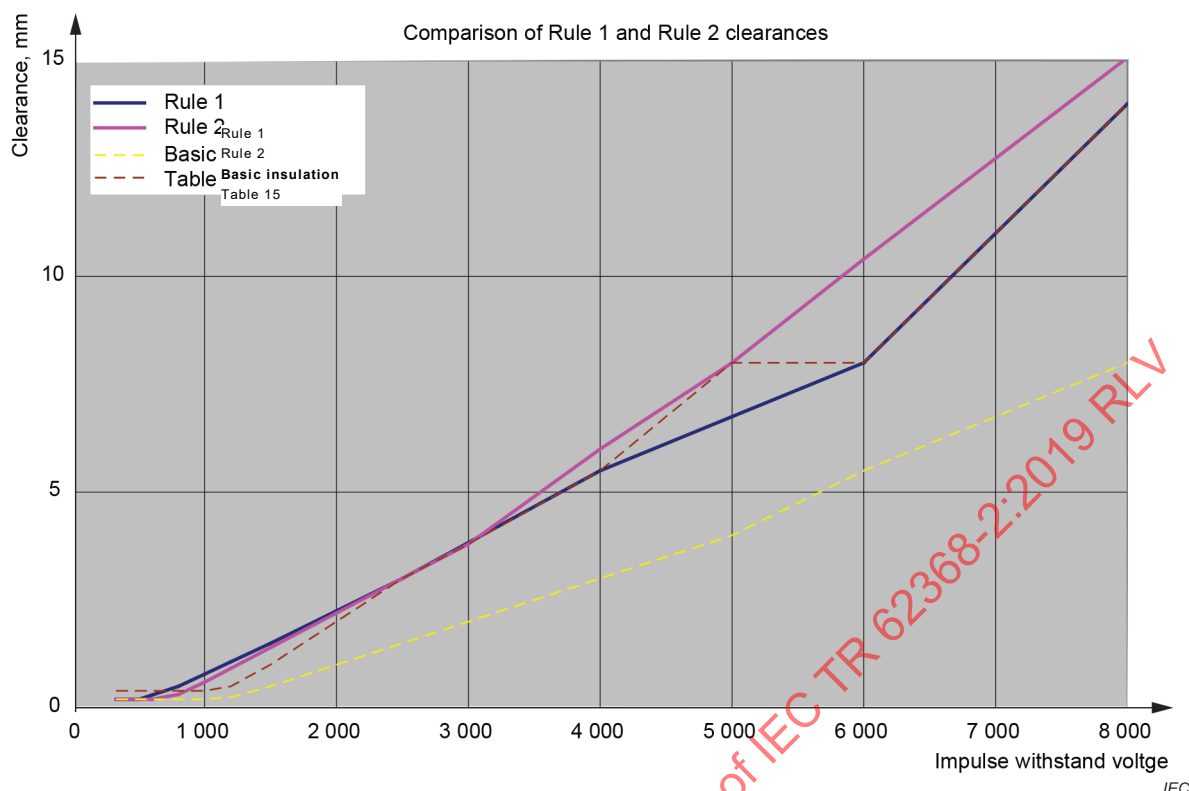


Figure 15 – Reinforced clearances according to Rule 1, Rule 2, and Table 15 14

If the two values for Rules 1 and 2 are combined into one set of values, the values are the same as in existing Table 15 14 (the brown line in Figure 14 and Figure 15 in this document). According to IEC 60664-1:2007, 5.1.6, only the impulse withstand voltages “other than a value taken from the preferred series...” are subject to the 160 % rule. Therefore, the clearances jump from Rule 1 criteria to Rule 2 criteria and back again. This yields the radical slope changes of the Table 15 14 reinforced clearances (brown) line.

Physically, the expected reinforced insulation clearances should be a constant proportion of the basic insulation clearances. However, the proportion between steps of Rule 1 (preferred series of impulse withstand voltages) are:

– 330 V to 500 V:	1,52
– 500 V to 800 V:	1,60
– 800 V to 1 500 V:	1,88
– 1 500 V to 2 500 V:	1,67
– 2 500 V to 4 000 V:	1,60
– 4 000 V to 6 000 V:	1,50
– 6 000 V to 8 000 V:	1,33
– 8 000 V to 12 000 V:	1,50

Average proportion, 330 to 12 000: 1,57

For Rule 2, all of the clearances for reinforced clearances insulation are based on exactly 1,6 times the non-preferred series impulse withstand voltage for basic insulation.

The two rules applied in accordance with 5.1.6 of IEC 60664-1:2007 result in the variable slope of the ~~reinforced clearance~~ requirements for **reinforced insulation** of IEC 62368-1.

IEC TC 108 noted that, if the rules of IEC 60664-1 are followed, for **clearances** for ~~reinforced-clearance insulation~~, some values were more than double the requirements for **basic insulation**. IEC TC 108 felt that this should not be the case and decided to limit the requirement for **reinforced insulation** to twice the value of **basic insulation**, thereby deviating from IEC 60664-1.

In addition, normal rounding rules were applied to the values in the table.

5.4.2.4 Determining the adequacy of a clearance using an electric strength test

Source: IEC 60664-1:2007, Table F.5

Purpose: Tests are carried out by either impulse voltage or AC voltage with the values of Table ~~16~~ 15.

Rationale: The impulse test voltages in Table ~~16~~ 15 are taken from IEC 60664-1:2007, Table F.5. The calculation for the AC RMS values as well as the DC values are based on the values given in Table A.1 of IEC 60664-1:2007 (see Table 7 in this document for further explanation).

This test is not suited for homogenous fields. This is for an actual design that is within the limits of the homogenous and inhomogeneous field.

Calculations for the voltage drop across an air gap during the electric strength test may be rounded up to the next higher 0,1 mm increment. In case the calculated value is higher than the value in the next row, the next row may be used.

Enamel Material: Most commonly used material is polyester resin or polyester

Dielectric constant for Polyester: 5 (can vary)

Dielectric constant for air: 1

Formula used for calculation (voltage divides inversely proportional to the dielectric constant)

Transient = 2 500 V = 2 500 (thickness of enamel / 5 + air gap / 1) = 2 500 (0,04 / 5 + 2 / 1 for 2 mm air gap) = 2 500 (0,008 + 2) = (10 V across enamel + 2 490 V across air gap)

Related to condition a of Table 15, although U is any **required withstand voltage** higher than 12,0 kV, there is an exception when using Table F.5 of IEC 60664-1:2007.

Table 7 – Voltage drop across clearance and solid insulation in series

Enamel thickness mm	Air gap mm	Transient on 240 V system	Transient voltage across air gap	Transient voltage across enamel	Peak impulse test voltage for 2 500 V peak transient from Table ~~17~~ 16	Test voltage across air gap	Test voltage across enamel
Material: Polyester, dielectric constant = 5							
0,04	2	2 500	2 490	10	2 950	12	2 938
0,04	1	2 500	2 480	20	2 950	24	2 926
0,04	0,6	2 500	2 467	33	2 950	39	2 911
For 2 500 V peak impulse (transient for 230 V system), the homogenous field distance is 0,6 mm (from Table A.1 of IEC 60664-1:2007). Our test voltage for 2 500 V peak is 2 950 V peak from Table ~~16~~ 15. This means that a minimum distance of 0,79 mm through homogenous field needs to be maintained to pass the 2 950 V impulse test. This gives us a margin of $(0,19/0,6) \times 100 = 3,2 \%$. In actual practice, the distance will be higher as it is not a true homogenous field. Therefore, we do not need to verify compliance with Table ~~15~~ 14. We are always on the ~~safe~~ conservative side.							
Material: Polyamide, dielectric constant = 2,5							
0,04	2	2 500	2 480	20	2 950	23	2 927
0,04	1	2 500	2 460	40	2 950	46	2 904
0,04	0,6	2 500	2 435	65	2 950	76	2 874
For 2 500 V peak impulse (transient for 230 V system), the homogenous field distance is 0,6 mm (from Table A.1 of IEC 60664-1:2007). Our test voltage for 2 500 V peak is 2 950 V peak from Table ~~16~~ 15. This means that a minimum distance of 0,78 mm through homogenous field needs to be maintained to pass the 2 950 V impulse test. This gives us a margin of $(0,18/0,6) \times 100 = 3,0 \%$. In actual practice, the distance will be higher, as it is not a true homogenous field. Therefore, we do not need to verify compliance with Table ~~15~~ 14. We are always on the ~~safe~~ conservative side.							

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

- Source: IEC 60664-1:2007, curve number 2 for case A using impulse test.
- Purpose: Test is carried out by either impulse voltage or AC voltage with the values of Table ~~17~~ 16 and the multiplication factors for altitudes higher than 2 000 m.
- Rationale: Table ~~17~~ 16 is developed using Figure A.1 of IEC 60664-1:2007, curve number 2 for case A using impulse test.

5.4.2.6 Compliance criteria

- Source: IEC 60664-1:2007, 5.1.1
- Rationale: IEC 62368-1:2014/2018, Annex O figures are similar/identical to figures in IEC 60664-1:2007.
- Tests of IEC 62368-1:2014/2018, Annex T simulate the occurrence of mechanical forces:
- 10 N applied to components and parts that may be touched during operation or servicing. Simulates the accidental contact with a finger or part of the hand;
 - 30 N applied to internal **enclosures** and barriers that are **accessible to ordinary persons**. Simulates accidental contact of part of the hand;
 - 100 N applied to external **enclosures of transportable equipment** and handheld equipment. Simulates expected force applied during use or movement;

- 250 N applied to external **enclosures** (except those covered in T.4). Simulates expected force applied by a body part to the surface of the equipment. It is not expected that such forces will be applied to the bottom surface of heavy equipment (> 18 kg).

During the force tests metal surfaces shall not come into contact with parts at ~~hazardous~~ ES2 or ES3 voltage.

5.4.3 Creepage distances

Source: IEC 60664-1:2007, 3.3

Purpose: To prevent flashover along a surface or breakdown of the insulation.

Rationale: Preserve **safeguard** integrity.

In IEC 60664-1:2007, Table F.4 columns 2 and 3 for printed wiring boards are deleted, as there is no rationale for the very small **creepage distances** for printed wiring in columns 2 and 3 (the only rationale is that it is in the ~~pilot standard~~ basic safety publication IEC 60664-1).

However, there is no rationale why the **creepage distances** are different for printed wiring boards and other isolation material under the same condition (same PD and same CTI).

Moreover the **creepage distances** for printed boards in columns 2 and 3 are in conflict with the requirements in G.13.3 (Coated printed boards). Consequently the values for voltages up to 455 V in Table G.13.16 were replaced.

Creepage distances between the outer insulating surface of a connector and conductive parts at ES3 voltage level shall comply with the requirements of **basic insulation** only, if the connectors are fixed to the equipment, located internal to the outer **electrical enclosure** of the equipment, and are **accessible** only after removal of a sub-assembly which is required to be in place during normal operation.

It is assumed that the occurrence of both factors, the sub-assembly being removed, and the occurrence of a transient overvoltage have a reduced likelihood and hazard potential.

5.4.3.2 Test method

Source: IEC 60664-1:2007, 3.2

Purpose: Measurement of **creepage distance**.

Rationale: To preserve **safeguard** integrity after mechanical tests.

Annex O figures are similar/identical to figures in IEC 60950-1 and IEC 60664-1.

Tests of Annex T simulate the occurrence of mechanical forces:

- 10 N applied to components and parts that are likely to be touched by a **skilled person** during servicing, where displacement of the part reduces the **creepage distance**. Simulates the accidental contact with a finger or part of the hand.
- 30 N applied to internal **enclosures** and barriers that are **accessible** to **ordinary persons**. Simulates accidental contact of part of the hand.
- 100 N applied to external **enclosures** of **transportable equipment** and **hand-held equipment**. Simulates expected force applied during use or movement.
- 250 N applied to external **enclosures** (except those covered in T.4). Simulates expected force when leaning against the equipment surface. It is not expected that such forces will be applied to the bottom surface of heavy equipment (> 18 kg).

Creepage distances are measured after performing the force tests of Annex T.

5.4.3.3 Material group and CTI

Source: IEC 60112

Rationale: Classification as given in IEC 60112.

5.4.3.4 Compliance criteria

Source: IEC 60664-1:2007, Table F.4; IEC 60664-4 for frequencies above 30 kHz

Rationale: Values in Table ~~18~~ 17 are the same as in Table F.4 of IEC 60664-1:2007.

Values in Table ~~19~~ 18 are the same as in Table 2 of IEC 60664-4:2005 and are used for frequencies up to 400 kHz.

5.4.4 Solid insulation

Source: IEC 60950-1, IEC 60664-1

Purpose: To prevent breakdown of the **solid insulation**.

Rationale: To preserve **safeguards** integrity.

Exclusion of solvent based enamel coatings for safety insulations are based on field experience. However, with the advent of newer insulation materials those materials may be acceptable in the future when passing the adequate tests.

Except for printed boards (see G.13), the **solid insulation** shall meet the requirements of 5.4.4.4 to 5.4.4.7 as applicable.

5.4.4.2 Minimum distance through insulation

Source: IEC 60950-1:2005

Purpose: Minimum distance through insulation of 0,4 mm for **supplementary insulation** and **reinforced insulation**.

Rationale: Some (very) old documents required for single insulations 2 mm dti (distance through insulation) for **reinforced insulation** and 1 mm for **supplementary insulation**. If this insulation served also as outer **enclosure** for **Class II-products equipment**, it had to be mechanically robust, which was tested with a hammer blow of 0,5 Nm.

The wire documents did not distinguish between grades of insulation, and required 0,4 mm for PVC insulation material. This value was considered adequate to protect against electric shock when touching the insulation if it was broken. This concept was also introduced in VDE 0860 (which evolved into IEC 60065), where the 0,4 mm value was discussed first. For IT products this value was first only accepted for in **accessible** insulations.

The VDE document for telecom equipment (VDE 0804) did not include any thickness requirements, but the insulation had to be adequate for the application.

The document VDE 0730 for household equipment with electric motors introduced in 1976 the requirement of an insulation thickness of 0,5 mm between input and output windings of a transformer. This was introduced by former colleagues from IBM and Siemens (against the position of the people from the transformer committee).

Also VDE 0110 (Insulation Coordination, which evolved into the IEC 60664 series) contained a minimum insulation thickness of 0,5 mm for 250 V supply voltage, to cover the effect of insulation breakage.

These 0,5 mm then evolved into 0,4 mm (in IEC 60950-1), with the reference to VDE 0860 (IEC 60065), where this value was already in use.

It is interesting to note that the 0,31 mm which is derived from Table 2A of IEC 60950-1:2005, has also a relation to the 0,4 mm. 0,31 mm is the minimum value of the average insulation thickness of 0,4 mm, according to experts from the wire manufacturers.

5.4.4.3 Insulating compound forming solid insulation

- Source: IEC 60950-1
- Purpose: Minimum distance through insulation of 0,4 mm for **supplementary insulation** and **reinforced insulation**.
- Rationale: The same distance through insulation requirements as for **solid insulation** apply (see 5.4.4.2). Insulation is subjected to thermal cycling (see 5.4.1.5.3), humidity test (see 5.4.8) and electric strength test (see 5.4.9). Insulation is inspected for cracks and voids.

5.4.4.4 Solid insulation in semiconductor devices

- Source: IEC 60950-1, UL 1577
- Purpose: No minimum thickness requirements for the **solid insulation**.
- Rationale: – **type testing** of 5.4.9.1 (electric strength testing at 160 % of the normal value after thermal cycling and humidity conditioning), and routine electric strength test of 5.4.9.2 has been used for many years, especially in North America.
- refers to G.12, which references IEC 60747-5-5.

5.4.4.5 Insulating compound forming cemented joints

- Source: IEC 60950-1
- Rationale: a) The distances along the path comply with PD 2 requirements irrespective of the joint;
- b) applies if protected to generate PD 1 environment;
- c) applies if treated like **solid insulation** environment, no **clearances** and **creepage distances** apply;
- d) is not applied to printed boards, when the board temperature is below 90 °C, as the risk for board delaminating at lower temperatures is considered low.
- Optocouplers are excluded from the requirements of this subclause, because the document requires optocouplers to comply with IEC 60747-5-5, which sufficiently covers cemented joints.

5.4.4.6.1 General requirements

- Source: IEC 60950-1, IEC 61558-1:2005
- Rationale: No dimensional or constructional requirements for insulation in thin sheet material used as **basic insulation**, is aligned to the requirements of IEC 61558-1.
- Two or more layers with no minimum thickness are required for **supplementary insulation** or **reinforced insulation**, provided they are protected against external mechanical influences.
- Each layer is qualified for the full voltage for **supplementary insulation** or **reinforced insulation**.
- The requirements are based on extensive tests performed on thin sheet material by manufacturers and test houses involved in IEC TC 74 (now IEC TC 108) work.

5.4.4.6.2 Separable thin sheet material

Source: IEC 60950-1

Rationale: For two layers, test each layer with the electric strength test of 5.4.9 for the applicable insulation grade. For three layers, test all combinations of two layers together with the electric strength test of 5.4.9 for the applicable insulation grade.

Each layer is qualified for the full voltage for **supplementary insulation** or **reinforced insulation**.

The requirements are based on extensive tests performed on thin sheet material by manufacturers and test houses involved in IEC TC 74 (now IEC TC 108) work.

5.4.4.6.3 Non-separable thin sheet material

Source: IEC 60950-1

Rationale: For testing non-separable layers, all the layers are to have the same material and thickness. If not, samples of different materials are tested as given in 5.4.4.6.2 for separable layers. When testing non-separable layers, the principle used is the same as for separable layers.

When testing two separable layers, each layer is tested for the required test voltage. Two layers get tested for two times the required test voltage as each layer is tested for the required test voltage. When testing two non-separable layers, the total test voltage remains the same, for example, two times the required test voltage. Therefore, two non-separable layers are tested at 200 % of the required test voltage.

When testing three separable layers, every combination of two layers is tested for the required test voltage. Therefore, a single layer gets tested for half the required test voltage and three layers are tested for 150 % of the required test voltage.

5.4.4.6.4 Standard test procedure for non-separable thin sheet material

Source: IEC 60950-1

Rationale: Test voltage 200 % of U_{test} if two layers are used.

Test voltage 150 % of U_{test} if three or more layers are used.

See the rationale in 5.4.4.6.3. The procedure can be applied to both separable and non-separable layers as long as the material and material thickness is same for all the layers.

5.4.4.6.5 Mandrel test

Source: IEC 61558-1:2005, 26.3.3; IEC 60950-1:2005/AMD1:2009/AMD2:2013; IEC 60065:2014/2011

Purpose: This test should detect a break of the inner layer of non-separated foils.

Rationale: This test procedure is taken from IEC 61558-1:2005, 26.3.3, and the test voltage is 150 % U_{test} , or 5 kV RMS., whatever is greater.

5.4.4.7 Solid insulation in wound components

Source: IEC 60950-1, IEC 61558-1

Purpose: To identify constructional requirements of insulation of winding wires and insulation between windings.

Rationale: Requirements have been used in IEC 60950-1 for many years and are aligned to IEC 61558-1.

Planar transformers are not considered wound components and have to comply with G.13.

5.4.4.9 Solid insulation requirements at frequencies higher than 30 kHz

Source: IEC 60664-4:2005

Purpose: To identify requirements for **solid insulation** that is exposed to voltages at frequencies above 30 kHz.

Rationale: The requirements are taken from the data presented in Annex C of IEC 60664-4:2005. Testing of **solid insulation** can be performed at line frequency as detailed in 6.2 of IEC 60664-4:2005.

In general, the breakdown electric field strength of insulation can be determined according to IEC 60243-1 (Electrical strength of insulating materials–Test methods–Part 1) as referred from 5.3.2.2.1 of IEC 60664-1:2007 (see below).

5.3.2.2.1 Frequency of the voltage

The electric strength is greatly influenced by the frequency of the applied voltage. Dielectric heating and the probability of thermal instability increase approximately in proportion to the frequency. The breakdown field strength of insulation having a thickness of 3 mm when measured at power frequency according to IEC 60243-1 is between 10 kV/mm and 40 kV/mm. Increasing the frequency will reduce the electric strength of most insulating materials.

NOTE The influence of frequencies greater than 30 kHz on the electric strength is described in IEC 60664-4.

Table 20 shows the electric field strength for some commonly used materials. These values are related to a frequency of 50/60 Hz.

Table 21, which is based on Figure 6 of IEC 60664-4:2005, shows the reduction factor for the value of breakdown electric field strength at higher frequencies. The electric field strength of materials drops differently at higher frequencies. The reduction of the insulation property is to be considered when replacing the calculation method by the alternative ES test at **mains** frequency, as shown after the sixth paragraph of 5.4.4.9. Table 21 is for materials of 0,75 mm in thickness or more. Table 22 is for materials of less than 0,75 mm in thickness.

The 1,2 times multiplier comes from IEC 60664-4:2005, subclause 7.5.1, where the partial discharge (PD) extinction voltage must include a safety margin of 1,2 times the highest peak periodic voltage.

5.4.5 Antenna terminal insulation

Source: IEC 60065

Purpose: To prevent breakdown of the insulation **safeguard**.

Rationale: The insulation shall be able to withstand surges due to overvoltages present at the antenna terminals. These overvoltages are caused by electrostatic charge build up, but not from lightning effects. A maximum voltage of 10 kV is assumed. The associated test of G.10.3.24 simulates this situation by using a 10 kV test voltage discharged over a 10 nF capacitor.

5.4.6 Insulation of internal wire as a part of a supplementary safeguard

Source: IEC 60950-1

Purpose: To specify constructional requirements of **accessible** internal wiring

Rationale: **Accessible** internal wiring isolated from ES3 by **basic insulation** only needs a **supplementary insulation**. If the wiring is reliably routed away so that it will not be subject to handling by the **ordinary person**, then smaller than 0,4 mm thick **supplementary insulation** has been accepted in IEC 60950-1. But the insulation still has to have a certain minimum thickness together with electric strength withstand capability. The given values have been successfully used in products covered by this document for many years (see Figure 16 in this document).

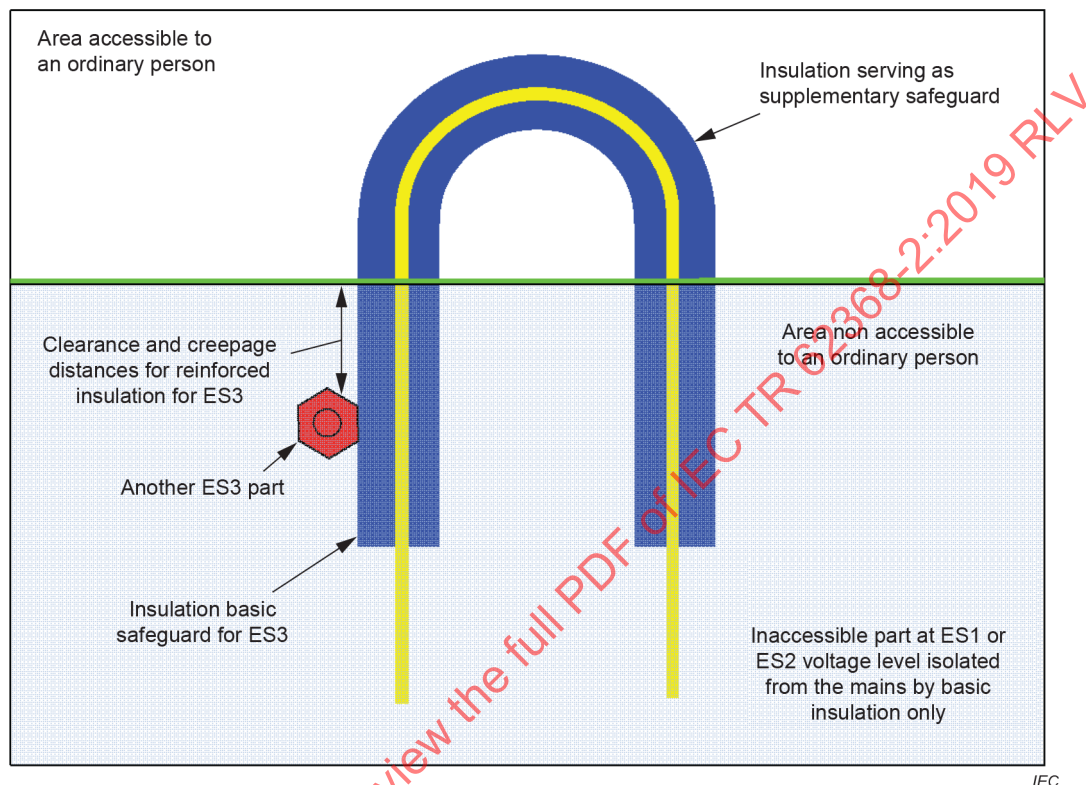


Figure 16 – Example illustrating accessible internal wiring

5.4.7 Tests for semiconductor components and for cemented joints

Source: IEC 60950-1

Purpose: To simulate lifetime stresses on adjoining materials.

To detect defects by applying elevated test voltages after sample conditioning.

To avoid voids, gaps or cracks in the insulating material and delaminating in the case of multilayer printed boards.

Rationale: This method has been successfully used for products in the scope of this document for many years.

5.4.8 Humidity conditioning

Source: IEC 60950-1 and IEC 60065. Alternative according to IEC 60664-1:2007, 6.1.3.2

Purpose: Material preparations for dielectric strength test. Prerequisite for further testing.

A tropical climate is a location where it is expected to have high temperatures and high humidity during most of the year. The document does not indicate what levels of temperature or humidity constitute a tropical climate. National authorities define whether their country requires products to comply with tropical requirements. Only a few countries, such as Singapore and China, have indicated in the CB scheme that they require such testing.

5.4.9 Electric strength test

Source: IEC 60664-1: 2007

Purpose: To test the insulation to avoid breakdown.

Rationale: Values of test voltages are derived from Table F.5 of IEC 60664-1:2007, however the test duration is 60 s.

This method has been successfully used for products in the scope of IEC 60065 and IEC 60950-1 for many years.

The **DC voltage** test with a test voltage equal to the peak value of the AC voltage is not fully equivalent to the AC voltage test due to the different withstand characteristics of **solid insulation** for these types of voltages. However in case of a pure **DC voltage** stress, the **DC voltage** test is appropriate. To address this situation the DC test is made with both polarities.

Table 26 25 Test voltages for electric strength tests based on transient voltages

Source: IEC 60664-1:2007

Rationale: To deal with withstand voltages and cover transients.

The **basic insulation** and **supplementary insulations** are to withstand a test voltage that is equal to the transient peak voltage. The test voltage for the **reinforced insulation** shall be equal to the transient in the next in the preferred series. According to 5.1.6 of IEC 60664-1:2007, the use of 160 % test value for **basic insulation** as the test value for **reinforced insulation** is only applicable if other values than the preferred series are used.

Functional insulation is not addressed, as is it presumed not to provide any protection against electric shock.

Table 27 26 Test voltages for electric strength tests based on the peak of the working voltages and recurring peak voltages

Source: IEC 60664-1:2007

Rationale: Column B covers repetitive **working voltages** and requires higher test voltages due to the greater stress to the insulation.

Recurring peak voltages (IEC 60664-1:2007, 5.3.3.2.3) need to be considered, when they are above the **temporary overvoltage** values, or in circuits separated from the **mains**.

If the recurring peak voltages are above the **temporary overvoltage** values, these voltages have to be used, multiplied by the factor given in IEC 60664-1:2007, 5.3.3.2.3 ~~($1,32 \times U_p$ for basic insulation, or $1,65 \times U_p$ for reinforced insulation).~~

Table 28 27 Test voltages for electric strength tests based on temporary overvoltages

Source: IEC 60664-1:2007

Rationale: **Temporary overvoltages** (IEC 60664-1:2007, 5.3.3.2.2) need to be considered as they may be present up to 5 s. The test voltage for **reinforced insulation** is twice the value of **basic insulation**.

5.4.10 Safeguards against transient voltages from external circuits

Source: IEC 62151:2000, Clause 6

Purpose: To protect persons against contact with **external circuits** subjected to transients (for example, telecommunication networks).

Rationale: **External circuits** are intended to connect the equipment to other equipment. Connections to remote equipment are made via communication networks, which could leave the building. Examples for such communication networks are telecommunication networks and Ethernet networks. The operating voltages of communication networks are usually within the limits of ES1 (for example, Ethernet) or within the limits of ES2 (for example, telecommunication networks).

When leaving the buildings, communication networks may be subjected to transient overvoltages due to atmospheric discharges and faults in power distribution systems. These transients are depending on the infrastructure of the cables and are independent on the operating voltage of the communication network. The expected transients on telecommunication networks are specified in ITU-T recommendations. The transient value in Table 14 ID 1 is taken from ITU-T K.21:2008 as 1,5 kV 10/700 µs (terminal equipment). This transient of 1,5 kV 10/700 µs does not cause a hazardous electric shock, but it is very uncomfortable to persons effecting by such a transient. To avoid secondary hazards a separation between an **external circuit** connected to communication networks subjected to transients is required.

Because the transient does not cause a hazardous electric shock the separation element needs not to be a **reinforced safeguard** nor a **basic safeguard** in the meaning of IEC 62368-1. It is sufficient to provide a separation complying with an electric strength test, only. Therefore for this separation no **clearance**, no **creepage distances** and no thickness requirements for **solid insulation** are required.

The separation is required between the **external circuit** subjected to transients and all parts, which may **accessible to ordinary persons** or **instructed persons**.

The likelihood a transient occurs and a body contact with an **accessible** part occurs at the same time increases with the contact time. Therefore non-conductive parts and unearthed parts of the equipment maintained in continuous contact with the body during normal use (for example, a telephone handset, head set, palm rest surfaces) the separation should withstand a higher test voltage.

Two test procedures for the electric strength test are specified in 5.4.10.2.

5.4.10.2.2 Impulse test

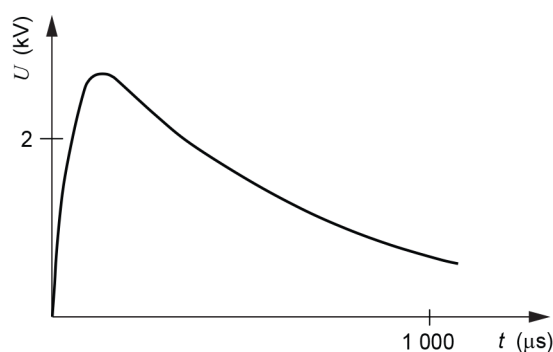
The impulse test is performing an impulse test by using the impulse generator for the 10/700 µs impulse (see test generator D.1 of Annex D). With the recorded waveforms it could be judged whether a breakdown of insulation has occurred, or if the surge suppression device has worked properly.

The examples in Figure 17, Figure 18,

- 1 – gas discharge type
- 2 – semiconductor type
- 3 – metal oxide type

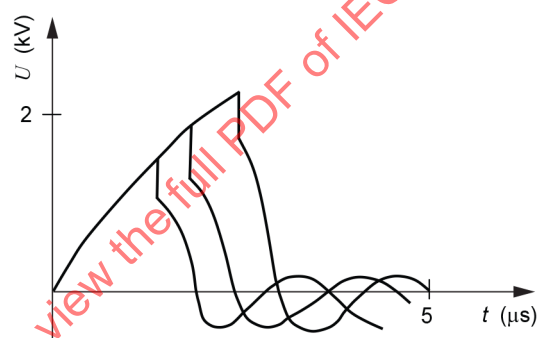
Consecutive impulses are identical in their waveforms.

Figure 19 and Figure 20 in this document could be used to assist in judging whether or not a surge suppressor has operated or insulation has broken down.



Consecutive impulses are identical in their waveforms.

Figure 17 – Waveform on insulation without surge suppressors and no breakdown



Consecutive impulses are not identical in their waveforms. The pulse shape changes from pulse to pulse until a stable resistance path through the insulation is established. Breakdown can be seen clearly on the shape of the pulse voltage oscillogram.

Figure 18 – Waveforms on insulation during breakdown without surge suppressors

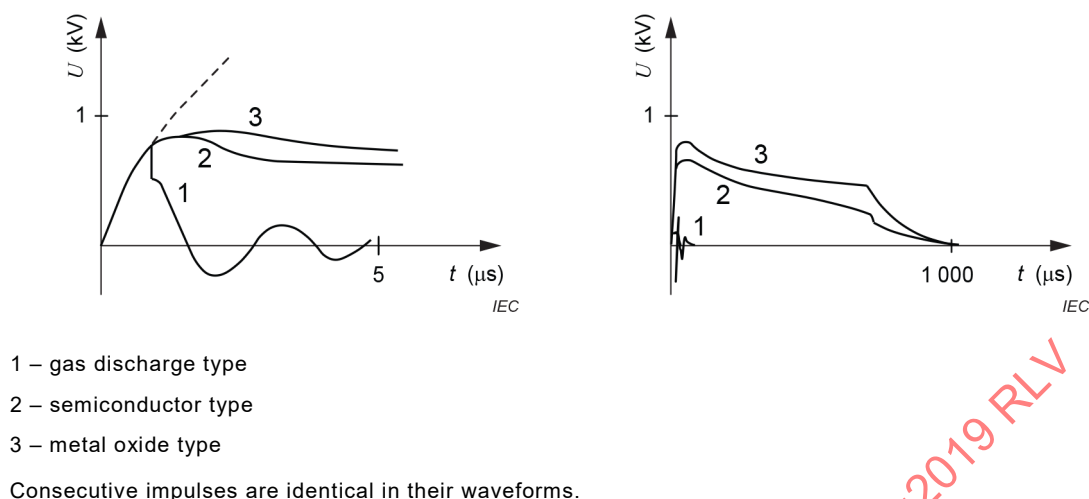


Figure 19 – Waveforms on insulation with surge suppressors in operation

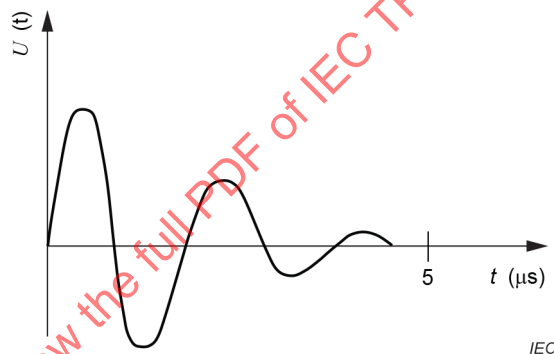


Figure 20 – Waveform on short-circuited surge suppressor and insulation

5.4.10.2.3 Steady-state test

The steady-state test is performing an electric strength test according to 5.4.9.1. This test is simple test with an RMS voltage. But if for example, surge suppressors are used to reduce the transients from the **external circuits** within the equipment this RMS test may be not adequate. In this case an impulse test is more applicable.

5.4.11 Separation between external circuits and earth

Source: IEC 62151:2000, 5.3

Purpose: To protect persons working on communication networks, and users of other equipment connected to the network from hazards in the equipment.

Rationale: Class I equipment provides **basic insulation** between **mains** and earthed conductive parts and requires the conductive parts to be connected to a PE conductor that has to be connected to the earthing terminal in the buildings installation to be safe to use. In an isolated environment such an earth terminal is not present in the building installation. Nevertheless the use of **class I equipment** in such an isolated environment is still safe to use, because in case of a breakdown of the insulation in the equipment (fault of **basic insulation**) the second barrier is provided by the isolated environment (similar to a **supplementary insulation**).

With the connection of the equipment via an **external circuit** to a communication network from outside the building installation to a remote environment the situation will change. It is unknown whether the remote environment is an isolated or non-isolated environment. During and after a fault of the **basic insulation** in a **class I equipment** (from **mains** to conductive parts) installed in an isolated installation (non-earthed installation) the conductive parts will become live (**mains** potential). If now the conductive parts are not separated from the **external circuit**, the **mains** voltage will be transferred to the remote installation via the communication network. This is a hazardous situation in the remote environment and can be dangerous for persons in that remote environment.

Also in old building installations socket outlets exist with no earth contact. This situation will not be changed in the near future.

To provide protection for those situations, a separation between an **external circuit** intended to be connected to communication networks outside the building (for example, telecommunication networks) and a separation between the **external circuit** and earthed parts is required.

For this separation, it is sufficient to comply with the requirements of 5.4.11.2 tested in accordance with 5.4.11.3. For this separation, no **clearance**, no **creepage distances** and no thickness requirements for **solid insulation** is required.

5.5 Components as safeguards

Rationale: For failure of a **safeguard** and a component or device that is not a **safeguard**:

~~**Safeguard failure:** A failure is considered to be a safeguard failure if the classification of the energy source changes. For example, all accessible parts are considered ES1, if the failure of a component or a device or an insulation provided between ES2 and accessible parts causes the accessible parts to go to ES2 levels, then it is considered a safeguard failure. If the failure of a component or a device or an insulation provided between ES2 and accessible parts causes the accessible parts to remain at ES1 levels, then it is not considered a safeguard failure. Also due to the failure of a component or a device or insulation, the ES2 voltage may collapse to ES1 levels then this is not considered a safeguard failure.~~

~~**Non-safeguard failure:** A failure is considered to be a non-safeguard failure if the classification of the energy source does not change. For example, all accessible parts are considered ES1. If the failure of a component or a device or an insulation provided between ES3 and accessible parts causes the accessible parts to remain at ES1 levels, then it is considered a non-safeguard failure and construction is considered acceptable.~~

~~Figure 13 and Figure 14 give practical examples of the requirements when ordinary components bridge insulation.~~

Safeguard failure: A failure is considered to be a **safeguard** failure if the part itself or its function, during **normal operating conditions**, contributes to change an ES class to a lower ES class. In this case, the part is assessed for its reliability by applying the applicable **safeguard** component requirements in 5.5 and the associated requirements in Annex G. When establishing ES1, ES2 limits apply during **single fault condition** of these parts. In case no requirements for the component are provided in 5.5 or Annex G, the failure is regarded as a non-**safeguard** failure.

Non-safeguard failure: A failure is considered to be a non-safeguard failure if the part itself or its function, under **normal operating conditions**, does not contribute to change an ES class to a lower ES Class. In this case, there is no need to assess the reliability of the part. When establishing ES1, ES1 limits apply for the **single fault condition** of these parts. Where applicable, 5.3.1 applies. Figure 21 and Figure 22 in this document give practical examples of the requirements when ordinary components bridge insulation.

Example 1

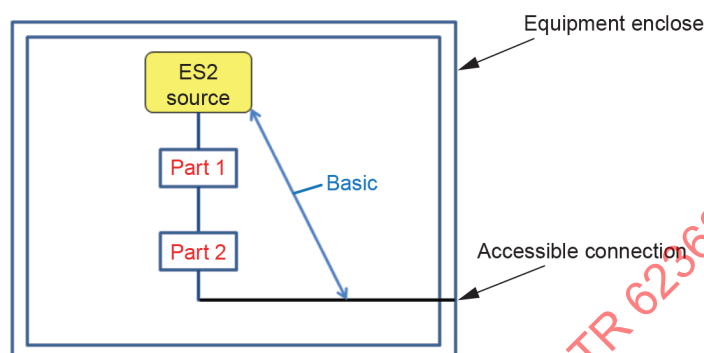


Figure 21 – Example for an ES2 source

A single fault of any component or part may not result in the **accessible** part exceeding ES1 levels, unless the part complies with the requirements for a **basic safeguard**.

The **basic safeguard** in parallel with the part(s) is to comply with:

- the **creepage distance** requirements; and
- the **clearance** requirements

for **basic insulation**.

There are no other requirements for the components or parts if the **accessible** part remains at ES1.

Example 2

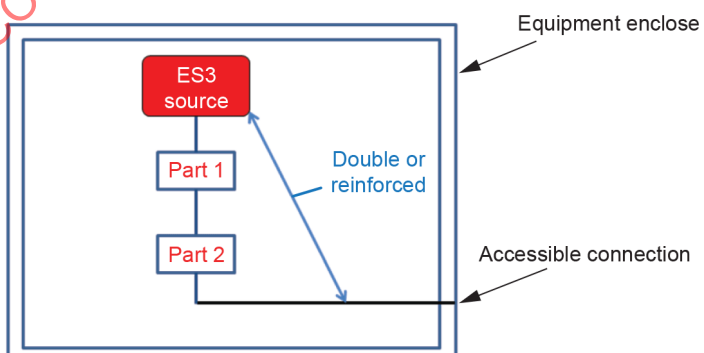


Figure 22 – Example for an ES3 source

A single fault of any component or part may not result in the **accessible** part exceeding ES1 levels, unless the parts comply with the requirements for a double or **reinforced safeguard**.

The double or reinforced safeguard in parallel with the part(s) is to comply with:

- the **creepage distance** requirements; and
- the **clearance** requirements,

for **double insulation** or **reinforced insulation**.

There are no other requirements for the components or parts if the **accessible** part remains at ES1.

5.5.2.1 General requirements

- Source: Relevant IEC component documents
- Purpose: The insulation of components has to be in compliance with the relevant insulation requirements of 5.4.1, or with the safety requirements of the relevant IEC document.
- Rationale: Safety requirements of a relevant document are accepted if they are adequate for their application, for example, Y2 capacitors of IEC 60384-14.

5.5.2.2 ~~Safeguards against~~ Capacitor discharge after disconnection of a connector

- Source: IEC TS 61201:2007, Annex A
- Rationale: The 2 s delay time represents the typical access time after disconnecting a connector ~~disconnection~~. When determining the **accessible** voltage 2 s after disconnecting a connector, the tolerance of the X capacitor is not considered.

If a capacitor is discharged by a resistor (for example, a bleeder resistor), the correct value of the resistor can be calculated using the following formula:

$$R = (2 / C) \times [1 / \ln(E / E_{\max})] \text{ M}\Omega$$

where:

C is in ~~μF~~ microfarads

E is 60 for an **ordinary person** or 120 for an **instructed person**

$E_{\max}$ is the maximum charge voltage or **mains** peak voltage

$\ln$ is the natural logarithm function

NOTE 1 When the **mains** is disconnected, the capacitance is comprised of both the X capacitors and the Y capacitors, and other possible capacitances. The circuit is analyzed to determine the total capacitance between the poles of the connector or plug.

NOTE 2 If the equipment **rated mains voltage** is 125 V, the maximum value of the discharge resistor is given by:

$$R = 1,85 / C \text{ M}\Omega$$

NOTE 3 If the equipment **rated mains voltage** is 250 V, the maximum value of the discharge resistor is given by:

$$R = 1,13 / C \text{ M}\Omega$$

NOTE 4 The absolute value of the above calculations is used for the discharge resistor value.

The test method includes a maximum time error of about 9% less than the calculated time for a capacitive discharge. This error was deemed acceptable for the sake of consistency with past practice.

For measuring the worst case, care should be taken that the discharge is measured while at the peak of the input voltage. To ensure this, an automatic control system that switches off at the peak voltage can be used.

A method used by several other documents, such as IEC 60065 and IEC 60335-1 is to repeat the measurement 10 times and record the maximum value. This assumes that one of the 10 measurements will be sufficiently close to the peak value.

Another possibility might be to use an oscilloscope during the measurement, so one can see if the measurement was done near the maximum.

~~See Attachment B for background information related to the measurement method.~~

Single fault conditions need not be considered if the component complies with the relevant component requirements of the document. For example, a resistor connected in parallel with a capacitor where a capacitor voltage becomes **accessible** upon disconnection of a connector, need not be faulted if the resistor complies with 5.5.6.

5.5.6 Resistors

Source: IEC 60950-1 and IEC 60065

Rationale: When a group of resistors is used, the resistors are in series. The whole path consists of the metal lead and helical end (metal) and resistor body. The **clearance** and **creepage distance** is across the resistor body only. The total path then consists of conductive metal paths and resistor bodies (all in series). In this case, Figure O.4 becomes relevant when you want to determine the total **clearance** and **creepage distance**.

5.5.7 SPDs

Rationale: See Attachment A for background information on the use of SPD's.

It should be noted that the issue is still under discussion in IEC TC 108. The rationale will be adapted as soon as the discussion is finalized.

5.5.8 Insulation between the mains and an external circuit consisting of a coaxial cable

Source: IEC 60065:2014, 10.2 and IEC 60950-1:2005, 1.5.6.

Rationale: The additional conditioning of G.10.2 comes from IEC 60950-1:2005, 1.5.6 Capacitors bridging insulation

5.6 Protective conductor

See Figure 23 in this document for an overview of **protective earthing** and protective bonding conductors.

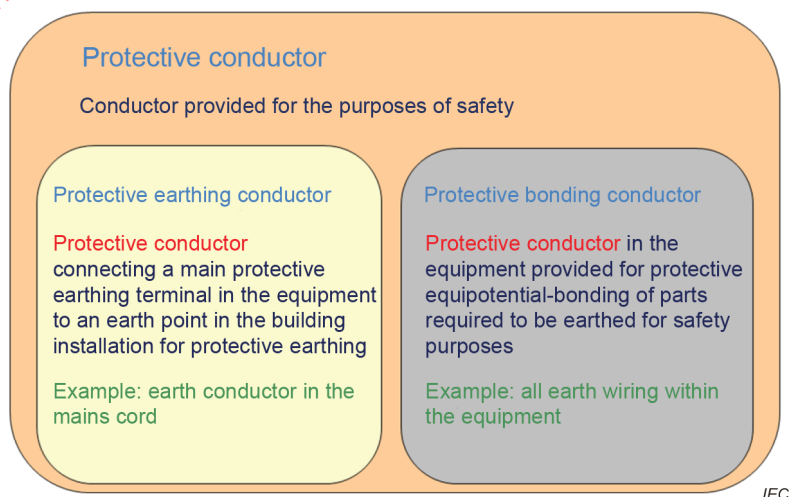


Figure 23 – Overview of protective conductors

5.6.1 General

- Source: IEC 60364-5-54, IEC 61140, IEC 60950-1
- Purpose: The **protective earthing** should have no excessive resistance, sufficient current-carrying capacity and not be interrupted in all circumstances.

5.6.2.2 Colour of insulation

- Source: IEC 60446¹
- Purpose: For clear identification of the earth connection.

An earthing braid is a conductive material, usually copper, made up of three or more interlaced strands, typically in a diagonally overlapping pattern.

It should be noted that IEC 60227-1:2007 has specific requirements for the use of the colour combination as follows:

4.1.3 Colour combination green-and-yellow

The distribution of the colours for the core coloured green-and-yellow shall comply with the following condition (which is in accordance with IEC 60173): for every 15 mm length of core, one of these colours shall cover at least 30 % and not more than 70 % of the surface of the core, the other colour covering the remainder.

NOTE Information on the use of the colours green-and-yellow and blue.

It is understood that the colours green and yellow, when they are combined as specified above, are recognized exclusively as a means of identification of the core intended for use as earth connection or similar protection, and that the colour blue is intended for the identification of the core intended to be connected to neutral. If, however, there is no neutral, blue can be used to identify any core except the earthing or protective conductor.

5.6.3 Requirements for protective earthing conductors

- Source: IEC 60950-1
- Purpose: The reinforced **protective conductor** has to be robust enough so that the interruption of the **protective conductor** is prevented in any case (interruption is not to be assumed).
- Rationale: These requirements have been successfully used for products in the scope of this document for many years.
- Where a conduit is used, if a cord or conductor exits the conduit and is not protected, then the values of Table 30 cannot be used for the conductor that exits the conduit.
- For **pluggable equipment type B** and **permanently connected equipment**, an earthing connection is always expected to be present. The earthing conductor can therefore be considered as a **reinforced safeguard**.

5.6.4 Requirements for protective bonding conductors

- Source: IEC 60950-1
- Purpose: To demonstrate the fault current capability and the capability of the termination.
- Rationale: These requirements and tests have been successfully used for products in the scope of this document for many years (see Figure 3 in this document).

¹ This publication was withdrawn.

5.6.5 Terminals for protective conductors

5.6.5.1 Requirements

- Source: IEC 60998-1, IEC 60999-1, IEC 60999-2, IEC 60950-1
- Purpose: To demonstrate the fault current capability and the capability of the termination.
- Rationale: Conductor terminations according to Table 32 have served as reliable connection means for products complying with IEC 60950-1 for many years.
- The value of 25 A is chosen to cover the minimum protective current rating in all countries of the world.

5.6.6.2 Test method

- Source: IEC 60950-1
- Rationale: This method has been successfully used for products in the scope of this document for many years.

5.6.7 Reliable connection of a protective earthing conductor

- Source: IEC 60309 (plugs and socket outlets for industrial purpose)
- Purpose: To describe reliable earthing as provided by **permanently connected equipment**, **pluggable equipment type B**, and **pluggable equipment type A**.
- Rationale: **Permanently connected equipment** is considered to provide a reliable earth connection because it is wired by an electrician.
- Pluggable equipment type B** is considered to provide a reliable earth connection because IEC 60309 type plugs are more reliable and earth is always present as it is wired by an electrician.
- For **stationary pluggable equipment type A** where a **skilled person** verifies the proper connection of the earth conductor.

5.7 Prospective touch voltage, touch current and protective conductor current

- Source: IEC 60990

5.7.3 Equipment set-up, supply connections and earth connections

- Rationale: Equipment that is designed for multiple connections to the **mains**, where more than one connection is required, shall be subjected to either of the tests below:
- have each connection tested individually while the other connections are disconnected,
 - have each connection tested while the other connections are connected, with the **protective earthing conductors** connected together.

For simultaneous multiple connections, the requirement in the document is that each connection shall be 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.

This means that if the total **touch current** with all connections tested together does not exceed the limit, the equipment complies with the requirement, if not, and each of the individual conductor touch currents don't exceed the limit, the equipment also complies with the requirement.

Coaxial external interfaces very often are connected to antennas to receive TV and sound signals. Antennas installed outside the buildings are exposed to external atmospheric discharges (for example, indirect lightning). To protect the antenna system and the equipment connected to such antennas, a path to earth needs to be provided via the screen of the coaxial network.

Each **piece of mains**-powered equipment delivers **touch current** to a coaxial **external circuit** via the stray capacitance and the capacitor (if provided) between **mains** and coaxial interface. This **touch current** is limited by the requirement for each individual equipment to comply with the **touch current** requirements (safe value) to be measured according IEC 60990. Within a building, much individual equipment (for example, TV's receivers) may be connected to a coaxial network (for example, cable distribution system). In this case, the **touch current** from each individual equipment sums up in the shield of the coaxial cable. With an earthed shield of a coaxial cable, the **touch current** has a path back to the source and the shield of the coaxial cable remains safe to touch.

5.7.67.2 Prospective touch voltage and touch current ~~to external circuits~~ associated with paired conductor cables

Source: IEC 62151

Purpose: To avoid excessive **prospective touch voltage** ~~touch~~ and excessive currents from equipment into communication networks (for example, telecommunication networks).

Rationale: All **touch current** measurements according to IEC 60990 measure the current from the **mains** to **accessible** parts. ES1 circuits are permitted to be **accessible** by an **ordinary person** and therefore it is included in the measurement according to IEC 60990. Circuits of class ES2 are not **accessible** and therefore these classes of circuits are not covered in the measurements according to IEC 60990.

Because ES2 circuits may be **accessible** to **instructed persons** and may become **accessible** during a single fault to an **ordinary person**, the **touch current** to **external circuit** has to be limited, to protect people working on networks or on other equipment, which are connected to the **external circuit** via a network.

An example for an external interface ID 1 of Table ~~14 13~~ (IEC 62368-1:2014) is the connection to a telecommunication network. It is common for service personal of telecommunication networks and telecommunication equipment to make servicing under live conditions. Therefore, the telecommunication networks are operating with a voltage not exceeding energy class ES2.

The rationale to limit the **touch current** value to 0,25 mA (lower than ES2) has a practical background. Telecommunication equipment very often have more than one **external circuit** ID 1 of Table ~~14 13~~ of IEC 62368-1:2014 (for example, connection to a telecommunication network). In such configurations a summation of the **touch current** may occur (see 5.7.7 ~~of IEC 62368-1:2014~~). With the limitation to 0,25 mA per each individual **external circuit** up to 20 **external circuits** could be connected together without any additional requirement. In 5.7.7 this value of 0,25 mA is assumed to be the **touch current** from a network to the equipment.

5.7.78 Summation of touch currents from external circuits

Source: IEC 60950-1

Purpose: To avoid excessive **touch currents** when several **external circuits** are connected.

Rationale: When limiting the **touch current** value to each individual **external circuit** (as required in 5.7.6.2), more circuits can be connected together before reaching the **touch** current limit. This allows better utilization of resources.

Detailed information about **touch currents** from **external circuits** is given in Annex W of IEC 60950-1:2005.

a) Touch current from external circuits

There are two quite different mechanisms that determine the current through a human body that touches an **external circuit**, depending on whether or not the circuit is earthed. This distinction between earthed and unearthed (floating) circuits is not the same as between class I equipment and class II equipment. Floating circuits can exist in **class I equipment** and earthed circuits in class II equipment. Floating circuits are commonly, but not exclusively, used in telecommunication equipment and earthed circuits in data processing equipment, also not exclusively.

In order to consider the worst case, it will be assumed in this annex that telecommunication networks are floating and that the AC mains supply and human bodies (**skilled persons, instructed persons or ordinary persons**) are earthed. It should be noted that a **skilled person** and an **instructed person** can touch some parts that are not **accessible** by an **ordinary person**. An "earthed" circuit means that the circuit is either directly earthed or in some way referenced to earth so that its potential with respect to earth is fixed.

a.1) Floating circuits

If the circuit is not earthed, the current (I_c) through the human body is "leakage" through stray or added capacitance (C) across the insulation in the **mains** transformer (see Figure 25 in this document).

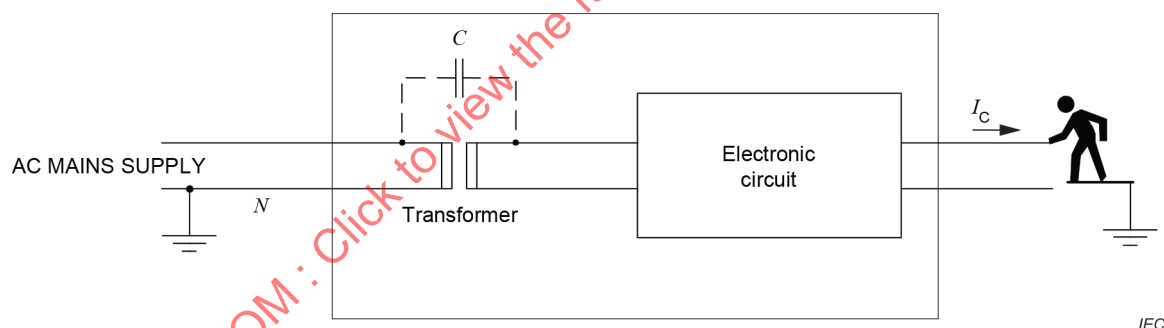


Figure 25 – Touch current from a floating circuit

This current comes from a relatively high voltage, high impedance source, and its value is largely unaffected by the operating voltage on the **external circuit**. In this document, the body current (I_c) is limited by applying a test using the measuring instrument in Annex D of IEC 60950-1:2005, which roughly simulates a human body.

a.2) Earthed circuits

If the **external circuit** is earthed, the current through the human body (I_v) is due to the operating voltage (V) of the circuit, which is a source of low impedance compared with the body (see Figure 26 in this document). Any leakage current from the **mains** transformer (see a.1), will be conducted to earth and will not pass through the body.

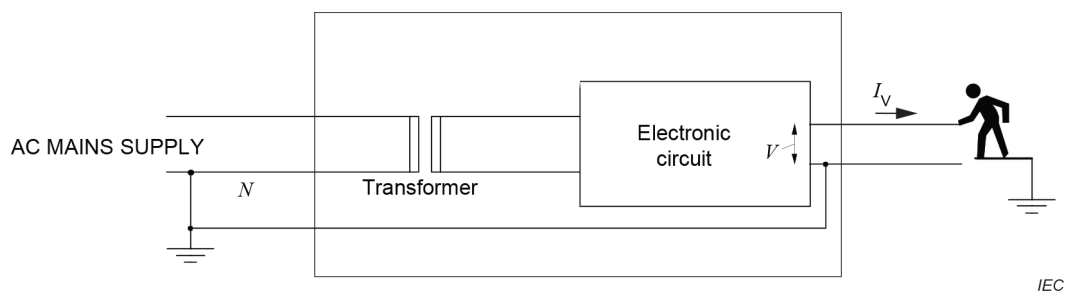


Figure 26 – Touch current from an earthed circuit

In this document, the body current (I_v) is limited by specifying maximum voltage values for the **accessible** circuit, which shall be ~~a SELV~~ an **ES1** circuit or (with restricted **accessibility**) ~~a TNV~~ an **ES2** circuit.

b) Interconnection of several equipments

It is a characteristic of information technology equipment, in particular in telecommunication applications, that many equipments may be connected to a single central equipment in a "star" topology. An example is telephone extensions or data terminals connected to a PABX, which may have tens or hundreds of ports. This example is used in the following description (see Figure 27 in this document).

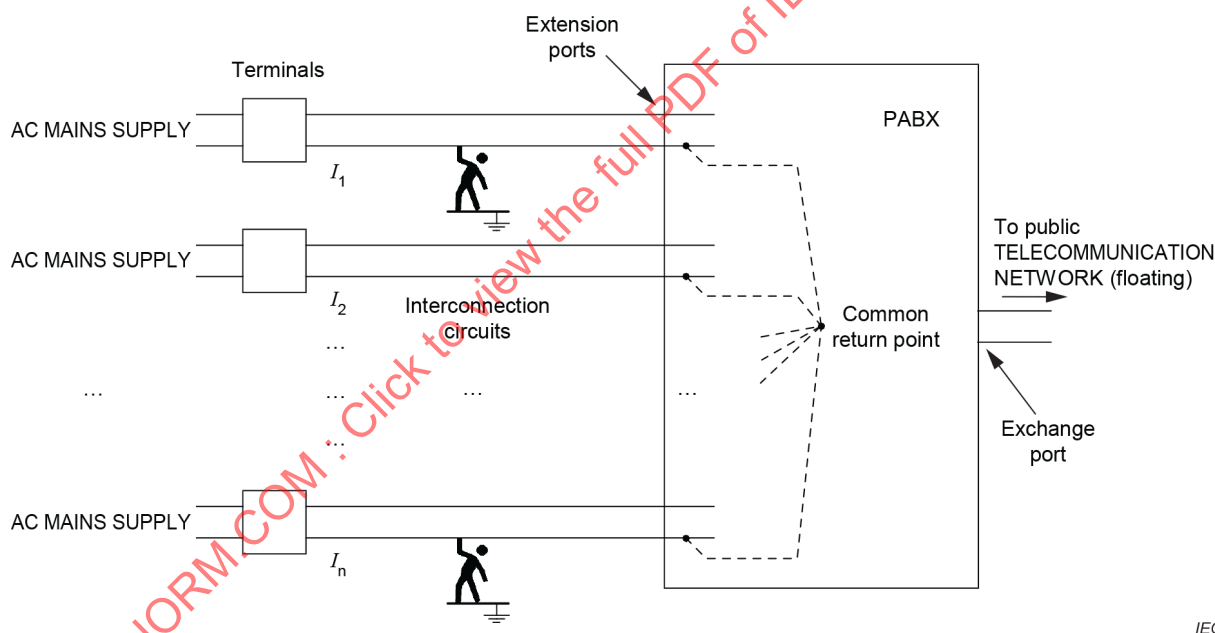


Figure 27 – Summation of touch currents in a PABX

Each terminal equipment can deliver current to a human body touching the interconnecting circuit (I_1 , I_2 , etc.), added to any current coming from the PABX port circuitry. If several circuits are connected to a common point, their individual **touch currents** will add together, and this represents a possible risk to an earthed human body that touches the interconnection circuit.

Various ways of avoiding this risk are considered in the following subclauses.

b.1) Isolation

Isolate all interconnection circuits from each other and from earth, and limit I_1 , I_2 , etc., as described in a.1. This implies either the use in the PABX of a separate power supply for each port, or the provision of an individual line (signal) transformer for each port. Such solutions may not be cost effective.

b.2) Common return, isolated from earth

Connect all interconnection circuits to a common return point that is isolated from earth. (Such connections to a common point may in any case be necessary for functional reasons.) In this case the total current from all interconnection circuits will pass through an earthed human body that touches either wire of any interconnection circuit. This current can only be limited by controlling the values I_1 , I_2 , .. I_n . In relation to the number of ports on the PABX. However, the value of the total current will probably be less than $I_1 + I_2 + \dots + I_n$ due to harmonic and other effects.

b.3) Common return, connected to protective earth

Connect all interconnection circuits to a common return point and connect that point to **protective earthing**. The situation described in a.2) applies regardless of the number of ports. Since safety depends on the presence of the earth connection, it may be necessary to use high-integrity earthing arrangements, depending on the maximum value of the total current that could flow.

5.8 Backfeed safeguard in battery backed up supplies

Source: IEC 62040-1:2017, IEC 62368-1, UL 1778 5th edition

Purpose: To establish requirements for certain **battery** backed up power supply systems that are an integral part of the equipment and that have the capability to backfeed to the **mains** of the equipment during stored energy mode. Examples include CATV network distribution supplies and any other integral supply commonly evaluated under this document with a **battery** backed option.

Rationale: Principles of **backfeed** protection

Battery backed up supplies store and generate hazardous energy. These energies may be present at the input terminals of the unit.

A **backfeed safeguard** is intended to prevent **ordinary persons**, **instructed persons** or **skilled persons** from unforeseeable or unnecessary exposure to such hazards.

A mechanical **backfeed safeguard** should meet a minimum air gap requirement. If not, the mechanical device (contacts) may be forced closed, and this will not be counted as a fault. The **backfeed safeguard** operates with any and all semiconductor devices in any single phase of the **mains** power path failed.

A **backfeed safeguard** works under any **normal operating condition**. This should include any output load or input source condition deemed normal by the manufacturer; however, it is common practice to only test at full- and no-load conditions, unless analysis of the circuitry proves other conditions would be less favourable. The circuitry that controls the **backfeed safeguard** is intended to be single-fault tolerant.

A **backfeed safeguard** can accomplish this by disconnecting the **mains** supply wiring from the internal energy source, by disabling the inverter and removing the hazardous source(s) of energy, reducing the source to a safe level, or by placing a suitable **safeguard** between the **ordinary person**, **instructed person** or **skilled person** and the hazardous energy. ES1 is defined in the body of this document. The method of measurement is as follows:

- For pluggable equipment, it is determined by opening all phases, neutral and ground.
- For **permanently connected** equipment, the neutral and ground are not removed during the **backfeed** tests.

Measurements are taken at the unit input connections across the phases, from phase to neutral and phase and neutral to ground, using the body impedance model as the measurement device.

Air gap requirements for mechanical disconnect:

An air gap is only required when the backfeed safeguard is mechanical in nature. The air gap is defined as the **clearance** distance. There are several elements to consider when determining the **clearance** requirement:

- Under normal operation, the space between poles of phases must meet the requirements for **basic insulation** (see 5.4.2).
- If the unit is operating on inverter, the source is considered to be a secondary supply, which is transient free (see 5.4.2).

For a unit with floating outputs, opening all phases and the neutral using the required **clearance** for **basic insulation** is considered acceptable. If the output is grounded to the chassis, **reinforced insulation** or equivalent is required.

Fault testing

All **backfeed safeguard** control circuits are subjected to failure analysis and testing.

Relays

Relays in the **mains** path that are required to open for mechanical protection should be normally open when not energized.

If the relay does not meet the required **clearances**, the shorting of either pole/contact may be considered as a single fault to simulate the welding of the contacts. The failure of a single relay contact may be sensed and the inverter disabled to prevent feedback.

A relay used for mechanical protection shall be horsepower-rated or pass a 50-cycle endurance test at 600 % of the normal switching current.

Electronic protection

Electronic protection for a **backfeed safeguard** is acceptable if the operation of the electronic protection device is sensed and the inverter is disabled if a fault is found. This is the same requirement as for a relay having less than the required air gap or **clearance** or is not relied upon entirely for mechanical protection.

Mechanical protection

Mechanical protection for a **backfeed safeguard** is acceptable if it prevents the user from accessing greater than ES1 and cannot be readily defeated without the use of **tool**. The voltage rating of the mechanical protection should be no less than the maximum out-of-phase voltage.

Control circuitry

The failure, open- or short-circuit, of any component of the **backfeed safeguard** circuitry may be analyzed to evaluate the effects on the proper operation of the **backfeed safeguard**. Testing may be done on all components where analysis of the results is arguable.

Components, such as resistors and inductors, are considered to fail open-circuit only. In general, capacitors may fail open or shorted. Solid-state devices typically fail short and then open.

Microprocessor controls are considered to be acceptable if the circuit operates safely with any single control line open or shorted to control logic ground, or shorted to Vcc where such fault is likely to occur. Failure of the microprocessor can also be simulated by opening the Vcc pin or shorting the Vcc pin to ground.

If the control circuitry is fully redundant, (for example, $N + 1$), failure analysis of individual components is not required if the failure of one circuit results in a fail-safe mode of operation.

6 Electrically-caused fire

Rationale: Electrically-caused fire is due to conversion of electrical energy to thermal energy, where the thermal energy heats a fuel material to pyrolyze the solid into a flammable gas in the presence of oxygen. The resulting mixture is heated further to its ignition temperature which is followed by combustion of that fuel material. The resulting combustion, if exothermic or with additional thermal energy converted from the electrical source, can be sustained and subsequently ignite adjacent fuel materials that result in the spread of fire.

The three-block model (see 0.7.2, Figure 6 of IEC 62368-1:2014) for electrically (internally) caused fire addresses the separation of a potential ignition sources from combustible materials. In addition, it can also represent an ignited fuel and the safeguards interposed between ignited fuels and adjacent fuels or to fuels located outside the equipment.

6.2 Classification of power sources (PS) and potential ignition sources (PIS)

Rationale: The first step in the application of this clause is to determine which energy sources contain **potential ignition sources** requiring a **safeguard**. The power available to each circuit can first be evaluated to determine the energy available to a circuit. Then each point or component within a circuit can be tested to determine the power that would be available to a fault at that component. With this information each part of the component energy sources within the product can be classified as either a specific ignition source or a component within a power source.

Throughout the clause, the term “reduce the likelihood of ignition” is used in place of the terms “prevent” or “eliminate”.

6.2.2 Power source circuit classifications

Source: IEC 60950-1, IEC 60065

Rationale: These power source classifications begin with the lowest available energy necessary to initiate an electronic fire (PS1) and include an intermediate level (PS2) where ignition is possible but the spread of fire can be localized with effective material control or isolation **safeguards**. The highest energy level (PS3), assumes both ignition and a potential spread of fire beyond the ignition source. Criteria for **safeguards** will vary based on the type of power source that is providing power to the circuit.

This power measurement and source classification are similar to LPS test requirements from IEC 60950-1 but are applied independently and the criteria limited to available power as opposed to in combination of criteria required in IEC 60950-1.

All circuits and devices connected or intended to be connected as a load to each measured power source are classified as being part of that power source. This test method determines the maximum power available from a power source to any circuit connected to that power source.

The identification of test points for determination of power source is at the discretion of the manufacturer. The most obvious are outputs of internal power supply circuits, connectors, ports and board to board connections. However, these measurements can be made anywhere within a circuit.

When evaluating equipment (peripherals) connected via cables to an equipment port or via cable, the impedance of any connecting cable may be taken into account in the determination of the PS classification of a connected peripheral. Therefore, it is acceptable to make the measurement at the supply connector or after the cable on the accessory side.

The location of the wattmeter is critical, as the total power available from the power source (not the power available to the fault) is measured during each fault condition. As some fault currents may be limited by a protective device, the time and current breaking characteristics of the protective device used is considered where it has an effect on the value measured.

This test method assumes a single fault in either the power source or the load circuits of the circuit being classified. It assumes both:

- a) a fault within the circuit being classified, and
- b) any fault within the power source supplying power to the circuit being classified,

each condition a) or b) being applied independently.

The higher of the power measured is considered the PS circuit classification value.

6.2.2.2 Power measurement for worst-case fault

Rationale: This test method determines the maximum power available from a power source that is operating under normal operating conditions to any circuit connected to that power source, assuming any single fault condition within the circuit being classified. This power measurement assumes normal operating conditions are established before applying the single fault to any device or insulation in the load circuit to determine the maximum power available to a circuit during a fault.

This is different for **potential ignition source** power measurements where the measured power available is that at the fault location.

A value of 125 % was chosen to have some degree of certainty that the fuse will open after a certain amount of time. As such, the measured situation will not be a continuous situation. It was impossible to use the interruption characteristics of a fuse, since different types of interrupting devices have completely different interrupting characteristics. The value of 125 % is a compromise that should cover the majority of the situations.

6.2.2.3 Power measurement for worst-case power source fault

Rationale: This test method determines the maximum power available to a normal load from a power source assuming any single fault within the power source. A power source fault could result in an increase in power drawn by a normal operating load circuit.

6.2.2.4 PS1

Source: IEC 60065, IEC 60695, IEC 60950-1

Rationale: A PS1 source is considered to have too little energy to cause ignition in electronic circuits and components.

The requirement is that the continuous available power be less than 15 W to achieve a very low possibility of ignition. The value of 15 W has been used as the lower threshold for ignition in electronic components in many documents, including IEC 60950-1 and IEC 60065. It has also routinely been demonstrated through limited power fault testing in electronic circuits.

- In order to address the ease of measurement, it was decided to make the 15 W measurement after 3 s. The value of 3 s was chosen to permit ease of measurement. Values as short as 100 ms and as high as 5 s were also considered. Quickly establishing a 15 W limit (less than 1 s) is not practical for test purposes and not considered important for typical fuel ignition. It is recognized that it normally takes as long as 10 s for thermoplastics to ignite when impinged directly by a small flame (IEC 60695 small scale material testing methods).
- In principle the measurements are to be made periodically (for example, each second) throughout the 3 s period with the expectation that after 3 s, the power would “never” exceed 15 W.
- Historically telecommunication circuits (Table ~~14~~ ~~13~~ of IEC ~~62368-1:2014~~, ID 1) are power limited by the building network to values less than 15 W and the circuits connected to them are considered PS1 (from IEC 60950-1).

It should be noted that the statement for **external circuits** is not intended to cover technologies such as USB and PoE. It is meant to relate to analogue ringing signals only.

6.2.2.5 PS2

Source: IEC 60695-11-10, IEC 60950-1

Rationale: Power Source 2 assumes a level of energy that has the possibility of ignition and subsequently requires a **safeguard**. Propagation of the ignition beyond the initially ignited component is limited by the low energy contribution to the fault and subsequently by **safeguards** to control the ignition resistance of nearby fuels.

The primary requirement is to limit power available to these circuits to no more than 100 W. This value includes both power available for normal operation and the power available for any **single fault condition**.

- This value has been used in IEC 60950-1 for a similar purpose, where ignition of internal components is possible but **fire enclosures** are not required.
- The value of 100 W is commonly used in some building or fire codes to identify where low power wiring can be used outside of a **fire containing enclosure**.
- The value is also 2×50 W, which can be related to the energy of standard flaming ignition sources (IEC 60695-11-10 test flame) on which our small-scale V-rating **material flammability classes** are based. It is recognized that the conversion of electrical energy to thermal energy is far less than 100 %, so this value is compatible with the **safeguards** prescribed for PS2 circuits, which are generally isolation and V-rated fuels.

The 5 s measurement for PS2 ensures the available power limits are both limited and practical for the purposes of measurement. The value is also used in IEC 60950 series as referenced above. No short-term limits are considered necessary, as possibility of ignition is presumed for components in these power limited circuits, recognizing that it generally takes 10 s or more for thermoplastics to pyrolyze and then ignite when impinged directly by a small 50 W flame.

Reliability of overcurrent devices (such as those found in IEC 60950 series) is not necessary as these circuits are used within or directly adjacent to the product (not widely distributed like IEC 60950-1 LPS circuits used for connection to building power). The reliability assessment for PS2 circuits that are intended to be distributed within the building wiring is addressed for **external circuits** later in this document.

6.2.2.6 PS3

Rationale: PS3 circuits are circuits that are not otherwise classified as PS1 or PS2 circuits. No classification testing is required as these circuits can have unlimited power levels. If a circuit is not measured, it can be assumed to be PS3.

6.2.3 Classification of potential ignition sources

Rationale: With each power source, points and components within a circuit can be evaluated to determine if **potential ignition sources** are further identified. These ignition sources are classified as either an **arcing PIS** for arcing sources or a **resistive PIS** for resistance heating sources. Criteria for **safeguards** will vary based on the type of **PIS** being addressed.

Ignition sources are classified on their ability to either arc or dissipate excessive heat (resistive). It is important to distinguish the type of ignition source as distances through air from arcing parts versus other resistive ignition sources vary due to a higher thermal loss in radiated energy as compared to conducted flame or resistive heat impinging directly on a **combustible fuel material**.

6.2.3.1 Arcing PIS

Source: IEC 60065

Rationale: **Arcing PIS** are considered to represent a thermal energy source that results from the conversion of electrical energy to an arc, which may impinge directly or indirectly on a fuel material.

Power levels below 15 W (PS1) are considered to be too low to initiate an electrical fire in electronic circuits. This value is used in IEC 60065 (see also 6.2.1).

The minimum voltage (50 V) required to initiate arcing is also from IEC 60065 and through experimentation.

For low-voltages, the fault that causes arc-heating is generally a result of a loose connection such as a broken solder connection, a cold-solder connection, a weakened connector contact, an improperly crimped wire, an insufficiently tightened screw connection, etc. As air does not breakdown below 300 V RMS. (Paschen's Law), most low voltage arc-heating occurs in direct contact with a fuel. For voltages greater than 300 V, arcing can occur through air.

The measurement of voltage and current necessary to establish an **arcing PIS** is related the energy that is available to the fault (as opposed to energy available from a power source). The value ($V_p \times I_{rms}$) specified is neither a W or VA but rather a calculated number reflecting a peak voltage and RMS current. It is not directly measurable.

Arcing below 300 V is generally the result of a disconnection of current-carrying connections rather than the mating or connection of potentially current-carrying connections.

Once the basic parameters of voltage and power are met, there are three conditions for which **safeguards** are required:

- those that can arc under **normal operating conditions**;
- all terminations where electrical failure resulting in heating is more likely; and
- any electrical separation that can be created during a **single fault condition** (such as the opening of a trace).

A reliable connection is a connection which is expected not to become disconnected within the lifetime of the equipment. The examples in the note give an idea as to what kinds of connections can be considered reliable.

The manufacturer may declare any location to be an **arcing PIS**.

6.2.3.2 Resistive PIS

Source: IEC 60065

Rationale: Resistive **potential ignition sources** can result from a fault that causes over-heating of any impedance in a low-resistance that does not otherwise cause an overcurrent protection to operate. This can happen in any circuit where the power to the resistive heating source is greater than 15 W (see above). A **resistive PIS** may ignite a part due to excessive power dissipation or ignite adjacent materials and components.

Under **single fault conditions**, this clause requires that two conditions exist before determining that a part can be a **resistive PIS**: The first is that there is sufficient available fault energy to the component. The second is that ignition of the part or adjacent materials can occur.

The requirement for a **resistive PIS** under **normal operating conditions** is not the available power but rather the power dissipation of the part under **normal operating conditions**.

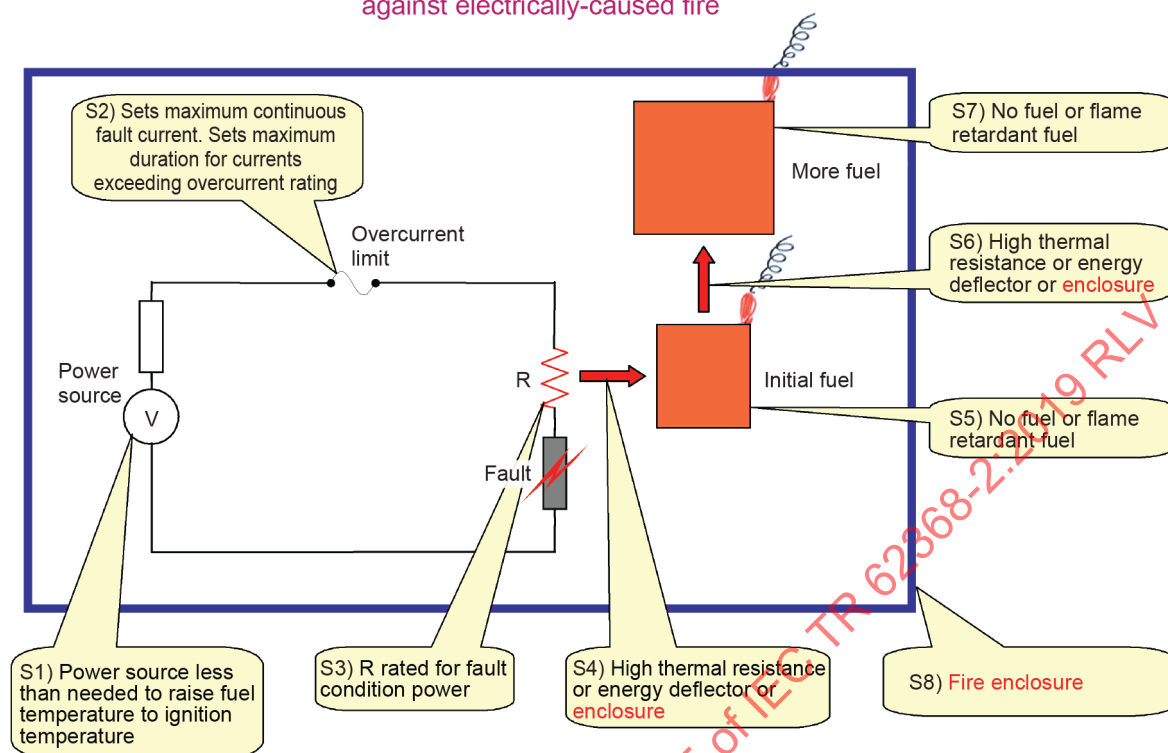
The value of 30 s was used in IEC 60065 and has historically proven to be sufficient. The value of 100 W was used in IEC 60065 and has historically proven to be adequate.

The manufacturer may declare any location to be a **resistive PIS**.

6.3 Safeguards against fire under normal operating conditions and abnormal operating conditions

Rationale: The **basic safeguard** under **normal operating conditions** and **abnormal operating conditions** is to reduce the likelihood of ignition by limiting temperature of fuels. This can be done by assuring that any available electrical energy conversion to thermal energy does not raise the temperature of any part beyond its ignition temperature.

SAFEGUARDS against electrically-caused fire



IEC

Figure 28 – Possible safeguards against electrically-caused fire

There are several **basic safeguards** and **supplementary safeguards** against electrically-caused fire under **abnormal operating conditions** and **single fault conditions** (see Figure 28, Table 8 and Table 9 in this document). These **safeguards** include, but are not limited to:

- S1) having insufficient power to raise a fuel material to ignition temperature;
- S2) limiting the maximum continuous fault current; limiting the maximum duration for fault currents exceeding the maximum continuous fault current (for example, a fuse or similar automatic-disconnecting overcurrent device);
- S3) selecting component rating based on **single fault conditions** rather than **normal operating conditions** (prevents the component from overheating);
- S4) ensuring high thermal resistance of the thermal energy transfer path from the thermal energy source to the fuel material (reduces the temperature and the rate of energy transfer to the fuel material so that the fuel material cannot attain ignition temperature); or a barrier made of non-combustible material;
- S5) using an initial fuel material located closest to an **arcing PIS** or **resistive PIS** having a temperature rating exceeding the temperature of the source (prevents fuel ignition); or a flame-retardant fuel material (prevents sustained fuel burning and spread of fire within the equipment); or a non-combustible material (for example, metal or ceramic);
- S6) ensuring high thermal resistance of the thermal energy transfer path from the initial fuel to more fuel material; or flame isolation of the burning initial fuel from more fuel material (prevents spread of fire within the equipment);
- S7) ensuring that subsequent material is either non-combustible material (for example, metal or ceramic); or is a flame-retardant material (prevents sustained fuel burning and spread of fire within the equipment);
- S8) use of a **fire-containing enclosure** (contains the fire within the equipment) or an oxygen-regulating **enclosure** (quenches a fire by suffocating it);
- S9) use of reliable electrical connections;

- S10) use of non-reversible components and **battery** connections;
- S11) use of mechanical protection (for example, barriers, mesh or the like) with limited openings;
- S12) use of clear operating instructions, **instructional safeguards**, cautions.

Methods of protection

A) Protection under normal operating conditions and abnormal operating conditions

Materials and components shall not exceed their auto-ignition temperatures.

B) Protection under single fault conditions

There are two methods of providing protection. Either method may be applied to different circuits in the same equipment:

- Prevent ignition: equipment is so designed that under **abnormal operating conditions** and **single fault conditions** no part will ignite;
- Control fire spread: selection and application of components, wiring, materials and constructional measures that reduce the spread of flame and, where necessary, by the use of a **fire enclosure**.

Thermoplastic softening values or relative thermal indices (RTI) were not considered appropriate as they do not relate specifically to ignition properties of fuel materials.

Any device that operates as a **safeguard** during normal operation (when left in the circuit) shall be assessed for reliability. If a device is taken out of the circuit during the normal operation testing then it is not considered as being a **safeguard**.

Abnormal operating conditions that do not result in a single fault are considered in much the same way as **normal operating conditions** as the condition is corrected and normal operation is presumed to be restored. However, **abnormal operating conditions** that result in a **single fault condition** are to be treated in accordance with 6.4 rather than 6.3. See Figure 29 in this document for a fire clause flow chart.

Table 8 – Examples of application of various safeguards

Cause	Prevention/protection methods	Safeguard
Start of fire under normal operating conditions	Limit temperature of combustible material	Basic
Start of fire under abnormal operating conditions and single fault conditions	Select prevent ignition or control fire spread method	Supplementary
PS1 circuit	Low available power reduces the likelihood of ignition	S1
PS2 or PS3 circuit	Reduce the likelihood of ignition Use of protection devices Sufficient distance or solid barrier interposed between any combustible material and each potential ignition source	S1, S2, S3, S5 S2 S4 (S6)
PS2 circuit	Limit the available power Sufficient distance or solid barrier interposed between any combustible material and each potential ignition source Use flame-retardant or non- combustible material	S1, S2 S4, S6 S5
PS3 circuit	Use all PS2 options and: – use fire containing enclosures – use flame-retardant or similar materials	S8 S7
Internal and external wiring	Reliable construction Limit of wire temperature and use of fire resistant insulation	S9
Fire caused by entry of foreign objects and subsequent bridging of electrical terminals in PS2 circuits and PS3 circuits	Prevent entry of foreign objects	S11
Mains supply cords	Reliable construction Limit of wire temperature and use of fire resistant insulation	S9
Fire or explosion due to abnormal operating conditions of batteries	Limit charge/discharge currents Limit short-circuit currents Prevent use of wrong polarity	S1 S2 S10

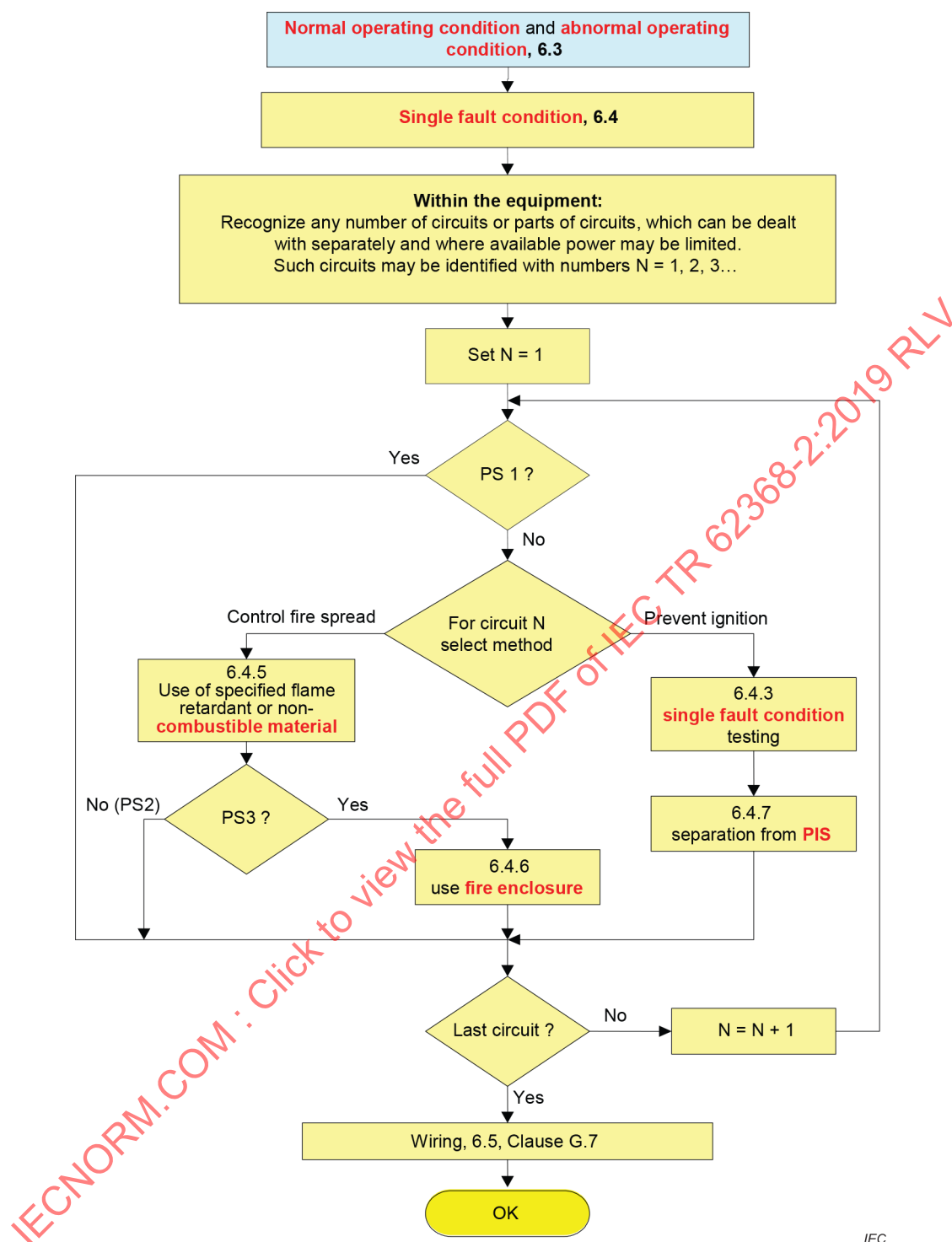


Figure 29 – Fire clause flow chart

6.3.1 Requirements

Source: IEC 60950-1, ISO 871

Rationale: Spontaneous-ignition temperature as measured by ISO 871 for materials was chosen as the ignition point of fuels. The materials specific tables were deleted in favour of a simple requirement or completely referring instead to the ASTM standard for material auto-ignition temperatures.

The 300 °C value for thermoplastics is approximately 10 % less than the lowest ignition temperature of materials commonly used in ICT and CE equipment. This value has also been used in IEC 60950-1. The designer is permitted to use material data sheets for materials that exceed this value but the auto-ignition specification has to be reduced by 10 % to accommodate measurement variations and uncertainty.

In the context of fire, **abnormal operating conditions** (blocked vents, connector overload, etc.) are to be considered just as a **normal operating condition** unless the **abnormal operating condition** results in a **single fault condition**.

As part of the compliance check, first the datasheets of the materials used have to be checked to be able to evaluate the results of the temperature rise measurements.

The glow-wire test is a fire test method of applying a heat source to the sample. The test provides a way to compare a material's tendency to resist ignition, self-extinguish flames (if ignition occurs), and to not propagate fire. Manufacturers have been using this test method to determine a plastic's flame resistance characteristics to IEC 60950-1 for many years without field issues identified with the suitability of the test. Hence, the glow-wire test should continue to be an option to the HB rating for plastics outside of the **fire enclosure** or **mechanical enclosures** and for **electrical enclosures** housing PS1 circuits. This precedence has been set in IEC 60950-1 and should be included in IEC 62368-1.

Table 9 – Basic safeguards against fire under normal operating conditions and abnormal operating conditions

Normal operating conditions and abnormal operating conditions		
The objective of this subclause is to define requirements to reduce the likelihood of ignition under normal operating conditions and abnormal operating conditions .		
PS1 PS2 PS3	6.3.1	Ignition is not allowed
		$T_{max} \leq 90\%$ auto ignition temperature according to ISO 871; or $T_{max} \leq 300\text{ °C}$
		Combustible materials for components and other parts outside fire enclosures (including electrical enclosures , mechanical enclosures and decorative parts), shall have a material flammability classification 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 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 criteria

Rationale: Steady state for temperature measurements in excess of 300 °C requires more tolerance on the rise value due to the difficulty in achieving a stable reading. However, the value in B.1.6 was considered adequate, as these values typically do not continue to rise but rather cycle. The value of 3 °C over a 15 min period was also considered for measurement of these very high temperatures but was not used in favour of harmonization with other clauses.

The use of temperature-limiting **safeguards** under **normal operating conditions** and **abnormal operating conditions** is considered acceptable only where the **safeguard** or device has been deemed a reliable temperature control device.

6.4 Safeguards against fire under single fault conditions

6.4.1 General

Source: IEC 60065, IEC 60950-1

Rationale: The consideration in the prior clause is to limit the likelihood of ignition of fuels ~~during~~ under **normal operating conditions** and **abnormal operation** **operating conditions** with a **basic safeguard**. All fuels should be used below their ignition temperatures and separated from arcing parts.

The requirements in this clause are to limit the ignition or the spread of fire under **single fault conditions** by employing **supplementary safeguards**, see Table 10 in this document. There are two approaches that can be used either jointly or independently:

- method 1 minimizes the possibility of ignition through the use of **safeguards** applied at each potential point of ignition;
- method 2 assumes the ignition of limited fuels within the product and therefore requires **safeguards** that limit the spread of fire beyond the initial ignition point or for higher energy, beyond the equipment **enclosure**.

Table 10 – Supplementary safeguards against fire under single fault conditions

Single fault conditions	
There are two methods of providing protection. Either method may be applied to different circuits of the same equipment (6.4.1)	
Method 1 Reduce the likelihood of ignition	Equipment is so designed that under single fault conditions no part shall ignite. 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.
Method 2 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.

The document's user or product designer will select a method to apply to each circuit, (either prevent ignition method or control the spread of fire method). The selection of a method can be done for a complete product, a part of a product or a circuit.

The power level of 4 000 W was chosen to ensure that products which are connected to low power **mains** (less than 240 V × 16 A), common in the office place or the home, could use the ignition protection methods, and to provide a reasonable and practical separation of product types. It is recognized that this is not representative of fault currents available but is a convenient and representative separation based on equipment connected to normal office and home **mains** circuits where experience with **potential ignition sources safeguards** is more common.

Limit values below 4 000 W create a problem for the AC **mains** of almost all equipment used in the home or office, which is not the intent. It would be much more practical to use an energy source power of 4 000 W based on **mains** voltage and overcurrent device rating which would effectively permit all **pluggable type A equipment** to use either method, and restrict very high-power energy sources to use only the method to control fire spread.

The 4 000 W value can be tested for individual circuits; however, a note has been added to clarify which types of products are considered below without test. Calculation of the product of the **mains** nominal voltage and **mains** overcurrent device rating is not a normal engineering convention but rather the product of two numbers should not exceed 4 000 (see text below).

NOTE All **pluggable equipment type A** are considered to be below the steady state value of 4 000 W. **Pluggable equipment type B** and **permanently connected equipment** are considered to be below this steady state value if the product of nominal **mains** voltage and the current rating of the installation overcurrent protective device is less than 4 000.

Prevent ignition method: Prescribes **safeguard** requirements that would prevent ignition and is predominantly based on fault testing and component selection and designs that reduce the likelihood of sustained flaming. Where a **PIS** is identified, additional **safeguards** are required to use barriers and the fire cone 'keep out' areas for non-flame rated materials (see Table 11 and Figure 30 in this document).

The prevent ignition method has been used in IEC 60065 where the predominant product connection is to low power (< 16 A) **mains** circuits. The use of this method was not considered adequate enough for larger **mains** circuits because the size of the fire cone does not adequately address large ignition sources common in higher power circuits.

This approach limits the use of prevent ignition methods to those products where the ignition sources is characterized by the fire cones and **single fault conditions** described in 6.4.7.

Table 11 – Method 1: Reduce the likelihood of ignition

Method 1: Reduce the likelihood of ignition under single fault conditions		
PS1 (≤ 15 W after 3 ~~s~~ and ~~≤ 500 W ≤ 3 s~~)	6.4.2	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.
PS2 (> PS1 and ≤ 100 W after 5 s) and PS3 (> PS2 and $\leq 4\,000$ W)	6.4.3	The objective of this subclause is to define 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. All identified supplementary safeguards need to be considered based on the equipment configuration.
		Sustained flaming > ~~5~~ 10 s is not allowed and no surrounding parts shall have ignited.
		Separation from arcing PIS and resistive PIS according to 6.4.7 – Distances have to comply with Figures 37, 38, 39a and ~~40~~ 39b; or – In case the distance between a PIS and combustible material is less than specified in Figures 37, 38, 39a and ~~40~~ 39b: • Mass of combustible material < 4 g, or • Shielded from the PIS by a fire barrier, or • Flammability requirements: ○ V-1 class material; VTM-1 class material or HF-1 class material, or needle flame in Clause S.2, or ○ Relevant component IEC document
		Using protective devices that comply with G.3.1, G.3.2, G.3.3 and G.3.4 or the relevant IEC component documents for such devices;
		Using components that comply with G.5.3, G.5.4 or the relevant IEC component document;
		Components associated with the mains shall comply with: the relevant IEC component documents; and the requirements of other clauses of IEC 62368-1

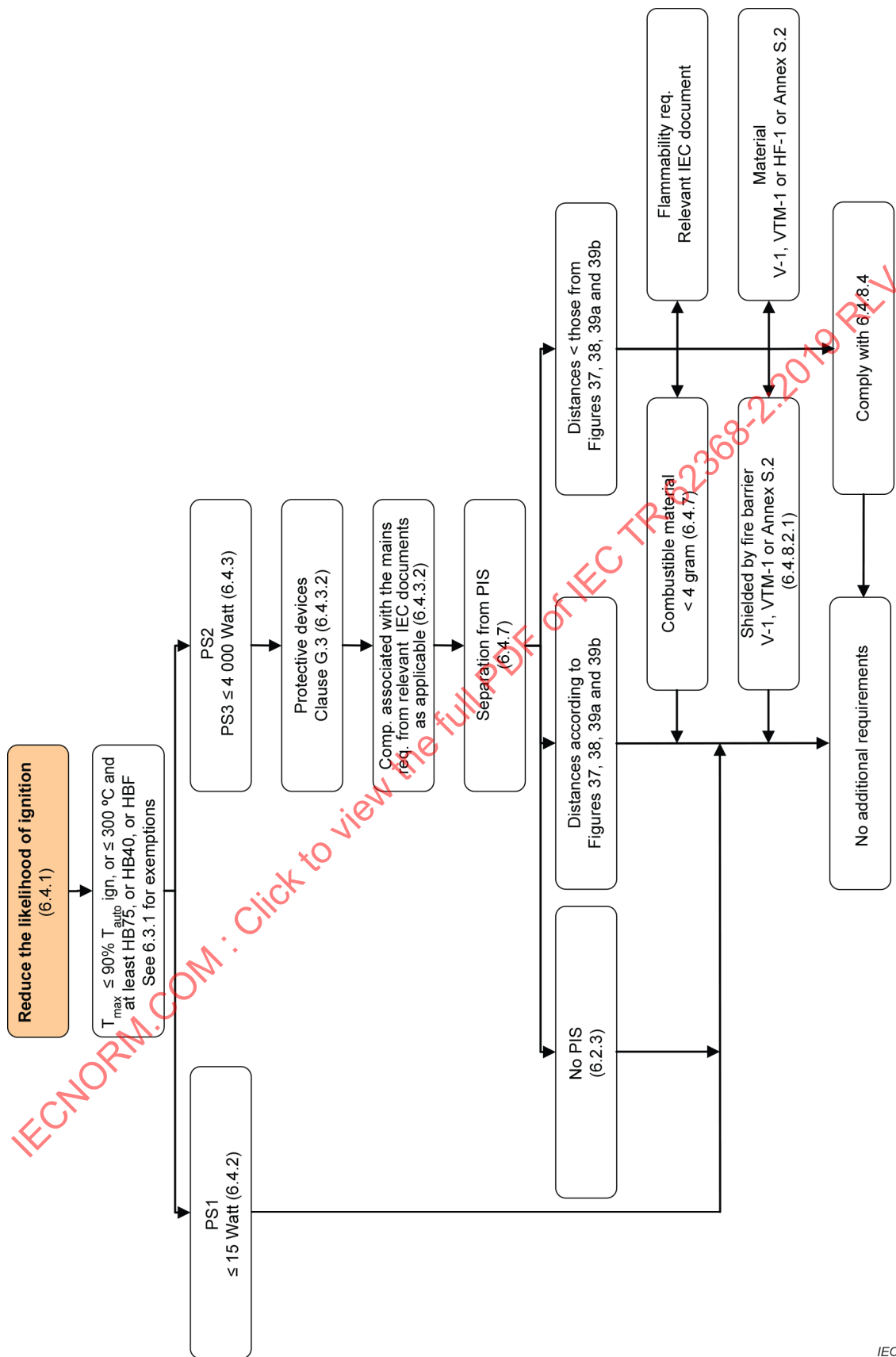
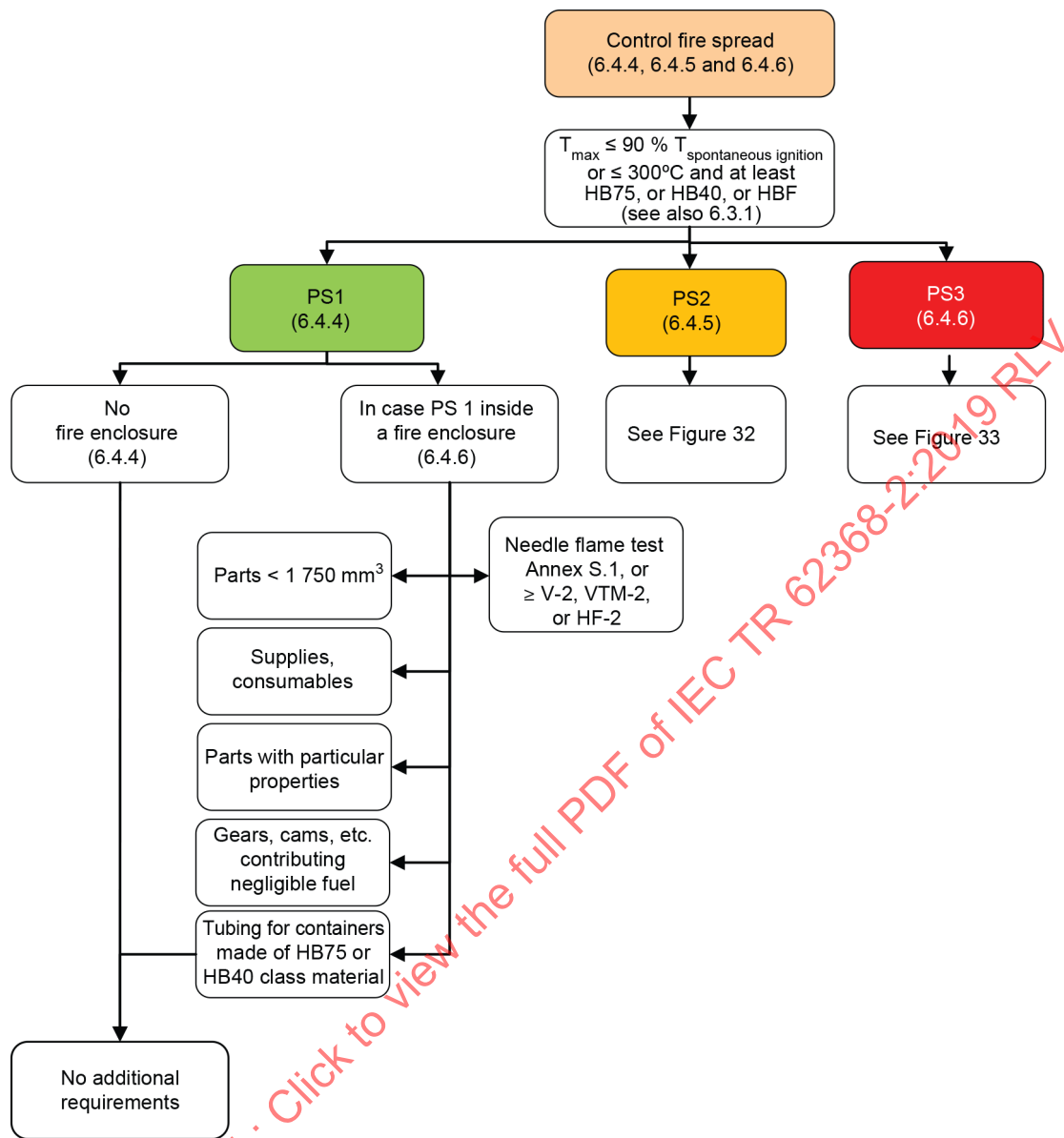


Figure 30 – Prevent ignition flow chart

Control fire spread method: Prescribes **safeguards** that are related to the spread of fire from acknowledged ignition sources. This assumes very little performance testing (no **single fault conditions**) and the **safeguards** are designed to minimize the spread of flame both within the product and beyond the **fire enclosure**. The **safeguards** described are based on power level, with higher power sources requiring more substantial **safeguards** (see Figure 31, Figure 32 and Table 12 in this document).

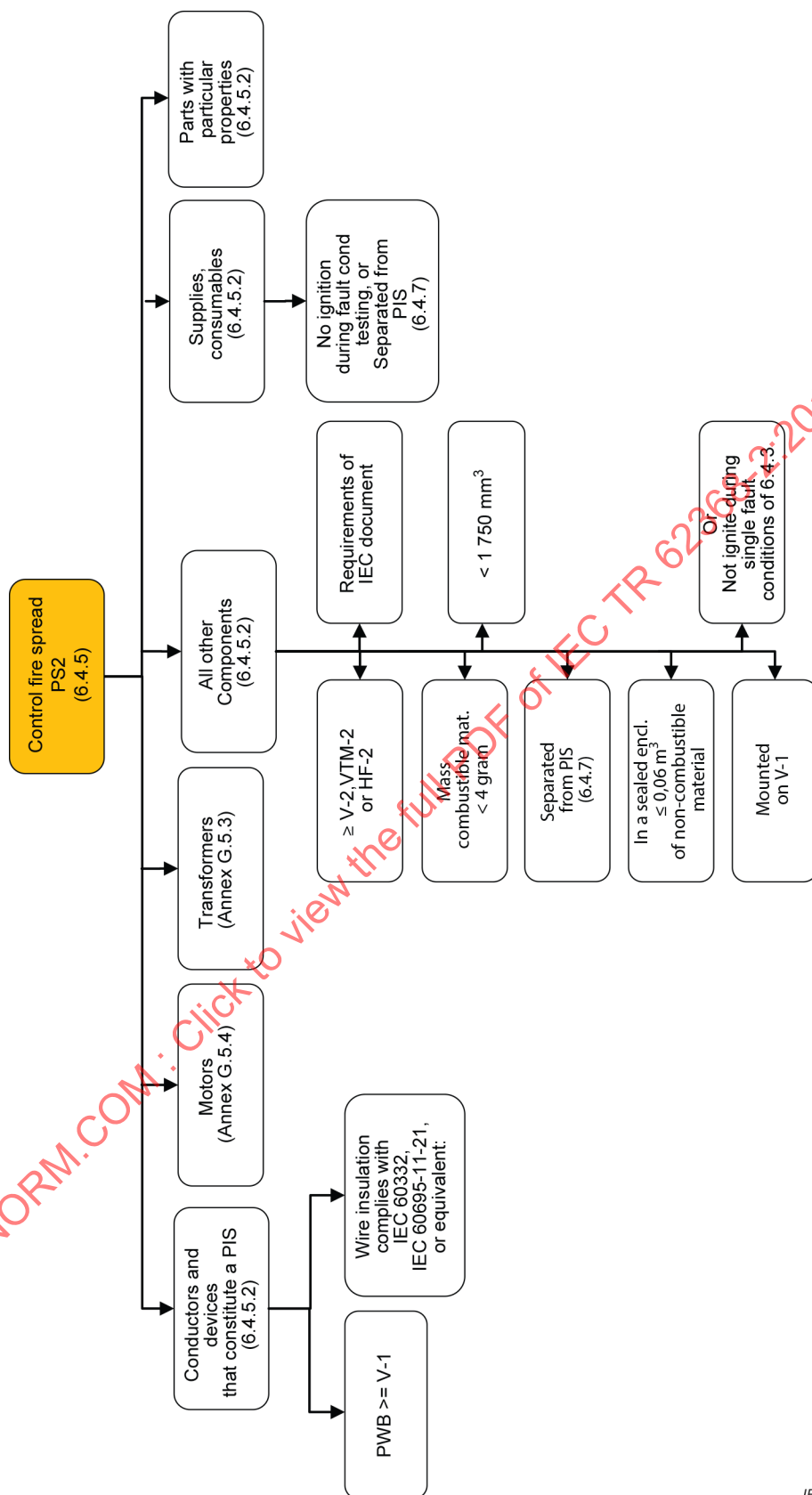
This power (4 000 W) separation is also used in the control of fire spread method to delineate **safeguard** criteria for **fire enclosure** materials (V-1 versus 5 V). IEC 60950-1 has historically used weight to define **fire enclosure** criteria and it was felt that the use of available power was more appropriate and generally reflective of current practice.

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Figure 31 – Control fire spread summary



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Figure 32 – Control fire spread PS2

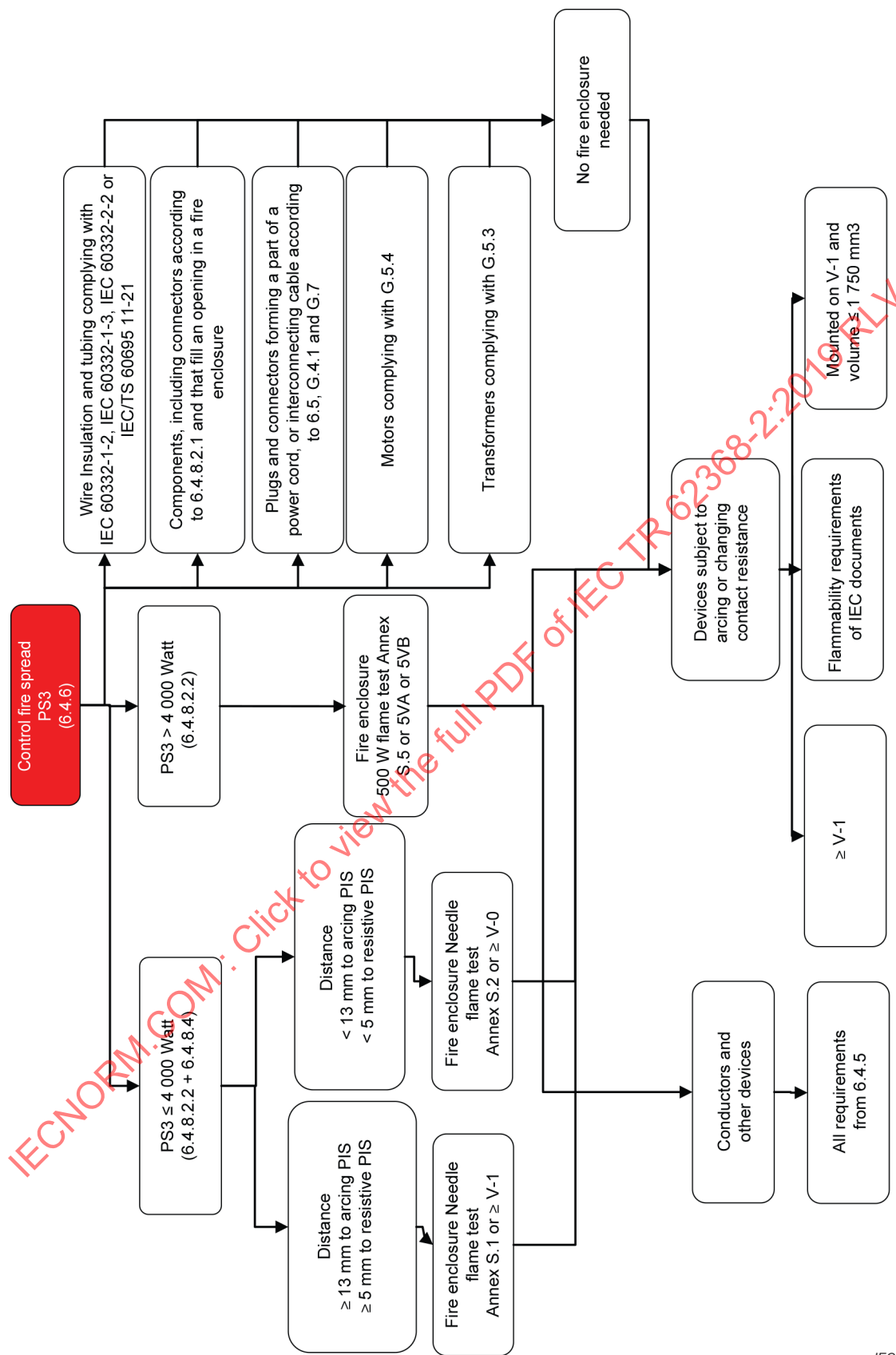


Figure 33 – Control fire spread PS3

6.4.2 Reduction of the likelihood of ignition under single fault conditions in PS1 circuits

Rationale: Low available power prevents ignition – 15 W is recognized as the lower limit of ignition for electronic products. The limiting of power is not considered the **basic safeguard** but rather the characteristic of the circuit being considered. This determination is made as part of the classification of power sources.

6.4.3 Reduction of the likelihood of ignition under single fault conditions in PS2 circuits and PS3 circuits

Rationale: To identify all **potential ignition sources**, all circuits and components within the PS2 and PS3 circuits should be evaluated for their propensity to ignite.

The ignition source derived from either PS2 or a PS3 circuit is considered equivalent. The resulting flame size and burn time is identical in all PS2 and PS3 circuits unless the power available is very large (for example, greater than 4 000 W).

For very large sources (greater than 4 000 W) the **safeguards** described for addressing **potential ignition sources** are not recognized as being adequate and the control fire spread method is used (see 6.4.1 for 4 000 W rationale).

6.4.3.21 Requirements

Source: IEC 60065, IEC 60695-2-13, IEC 60950-1

Rationale: Flaming of a fuel under **single fault conditions** is only permitted if very small and quickly extinguished (for example, a fusing resistor). A length of time is necessary during **single fault conditions** to permit the characteristic “spark” or short term “combustion flash” common when performing **single fault conditions** in electronic circuits. The value of 10 s is used, which has been used by IEC 60065 for many years. The energy of this short-term event is considered too low to ignite other parts. This value corresponds with IEC 60695-2-13 and has been used in practice by IEC TC 89 for glow wire ignition times. The time period is necessary to accommodate the expected flash/short duration flames that often result as a consequence of faults. The value of 10 s is considered to be the minimum time needed for ignition of commonly used thermoplastics by direct flame impingement. It is recognized that times as short as 2 s are used by other documents.

Protection is achieved by identifying each **PIS** and then limiting the temperature of parts below auto-ignition temperatures during **single fault conditions**, minimizing the amount of flammable material near a **PIS**, separating **combustible materials** from **PIS** by barriers, and by using reliable protection devices to limit temperature of combustible parts.

Single fault testing, while not statistically significant, has been common practice in both IEC 60065 and IEC 60950-1.

Temperatures limiting ignition are considered to be the material self-ignition points or flash temperatures for flammable liquids and vapours (this value should include a 10 % margin to take into account ambient, laboratory and equipment operating conditions). The spread to surrounding parts during and after the fault is also checked.

Providing sufficient distance or solid barrier between any **combustible material** and a **potential ignition source** should minimize the potential for the spread of fire beyond the fuels directly in contact with the **potential ignition source**. The fire cone distances developed for IEC 60065 are used and considered adequate. We prescribed the use of the cone because it is more reliable than single fault testing. Single fault testing is not representative; therefore, some material and construction requirements are necessary (fuel control area or keep out area).

Use of reliable protection devices – This includes reliability requirements for the devices that are used to prevent ignition. This permits only the use of devices that have reliability requirements included in Annex G.

Components that comply with their relevant IEC component documents are also considered to comply given these documents also have ignition protection requirements. The components included are those that are almost always part of a **potential ignition source** as they are **mains** connected.

Opening of a conductor: In general, opening of a conductor is not permitted during **single fault conditions** as it is not considered reliable protection device for limiting ignition. However for **resistive PIS**, it may be suitable provided the printed wiring board is adequately flame retardant and the opening does not create an **arcing PIS**. The V-1 printed circuit board is considered adequate to quench low voltage events and will not propagate the flame. It is not sufficient when the opening creates an **arcing PIS** (< 50 V).

As a consequence of the test, any peeling of conductor during these tests shall not result in or create other hazards associated with the movement of conductive traces during or after the test provided they do so predictably. During a single fault the peeling could bridge a **basic safeguard** but should not result in the failure of a **supplementary safeguard** or **reinforced safeguard**.

6.4.3.32 Test method

Source: IEC 60065, IEC 60127

Rationale: The available power and the classification criteria for resistive and arcing **potential ignition sources** should be used to determine which components to fault.

If the applied **single fault condition** causes another device or subsequent fault, then the consequential failure is proven reliable by repeating the **single fault condition** two more times (total of three times). This is a method used historically in IEC 60065.

Steady state determination for **single fault conditions** is related to temperature rise and the requirement is the same as the steady state requirements of Annex B, even though material ignition temperatures (> 300 °C) are much higher than required temperatures of other clauses (~25 °C – 100 °C). Shorter time periods (such as 15 min) were considered but dropped in favour of harmonization of other parts. The term steady state should take into account temperatures experienced by a material throughout the test.

Maximum attained temperature for surrounding material of heat source should be considered if further temperature increase is observed after interruption of the current.

Limit by fusing: The reliability of protection devices is ensured where they act to limit temperatures and component failures. The criteria used by the component document applying to each are considered adequate provided the parts are used as intended. The requirements included assume an IEC 60127 type fuse as the most common device.

The test methodology is established to ensure that available energy through the fuse link based on its current hold and interrupt conditions the breaking time characteristics of specified in IEC 60127. IEC 60127 permits 2,1 times the breaking current rating for 1 min.

In order to determine the impact of a fuse on the results of a **single fault condition**, if a fuse operates, it is replaced with a short circuit and the test repeated. There are three possible conditions when comparing the actual fault current through the fuse to the pre-arcing current and time data sheets provided by the fuse manufacturer.

- Where the measured current is always below the fuse manufacturer's pre-arcing characteristics (measured current is less than 2,1 times the fuse rating), the fuse cannot be relied upon as a **safeguard** and the test is continued with the fuse short circuited until steady state where the maximum temperature is measured.
- Where the measured current quickly exceeds the fuse pre-arcing characteristics (measured current is well above 2,1 times the rating current of the fuse) then the test is repeated with the open circuit in place of the fuse (assumes fuse will open quickly and be an open circuit) and then the maximum temperature recorded.
- Where the measured current does not initially exceed the fuse pre-arcing characteristics, but does at some time after introduction of the fault. The test is repeated with the short circuit in place and the temperature measured at the time where measured current exceeds the fuse pre-arcing characteristics. It is assumed the measured current through the short circuit can be graphed and compared with the fuse manufacturer's pre-arcing curves provided on the fuse datasheet to determine the test time.

6.4.4 Control of fire spread in PS1 circuits

Rationale: Low available power reduces the likelihood for ignition – 15 W is recognized as the lower limit of ignition for electronic circuits. This lower power limit is considered as a circuit characteristic of the circuit, not a **basic safeguard**.

Table 12 – Method 2: Control fire spread

Method 2: Control fire spread		
PS1 ($\leq 15\text{ W}$ ~~after 3 s~~ $\leq 500\text{ W}$ ~~$\leq 3\text{ s}$~~)	6.4.4	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.
PS2 ($\leq 100\text{ W}$ after 5 s)	6.4.5	The objective of this subclause is to describe the supplementary safeguards needed to reduce the likelihood of fire spread from a PIS in PS2 circuits to nearby combustible materials. The limiting of power available to PS2 circuits is the basic safeguard used to minimize the available energy of an ignition source. A supplementary safeguard is required to control the spread of fire from any possible PIS to other parts of the equipment
		For conductors and devices with a PIS the following apply: – Printed boards shall be at least V-1 class material – Wire insulation shall comply with IEC 60332 series or IEC 60695-11-21
		Battery cells and battery packs shall comply with Annex M.
		All other components: – Mounted on V-1 class material, or – Materials V-2 class material, VTM-2 class material, or HF-2 class material, or – Mass of combustible material $< 4\text{ g}$, provided that when the part is ignited the fire does not spread to another part, or – Separated from PIS according to 6.4.7, Distances have to comply with Figures 37; 38; 39 and 40, or In case distances do not comply with Figures 37; 38; 39 and 40 – Mass of combustible material $< 4\text{ g}$, or – Shielded from the PIS by a fire barrier, or – Flammability requirements: V-1 class material; VTM-1 class material or HF-1 class material, or comply with the needle flame test of IEC 60695-11-5 as described in Clause S.2; or – Comply with IEC component document flammability requirements, or comply with G.5.3 and G.5.4 – Insulation materials used in transformers, bobbins, V-1 class material – In a sealed enclosure $\leq 0,06\text{ m}^3$ made of non-combustible material and having no ventilation openings The following shall be separated from a PIS according to 6.4.7 or shall not ignite due to fault conditional testing – Supplies, consumables, media and recording materials – Parts which are required to have particular properties in order to perform intended functions, such as synthetic rubber rollers and ink tubes

Method 2: Control fire spread		
PS3 (> PS2)	The objective of this subclause is to describe the supplementary safeguards needed to reduce the likelihood of fire spread from a PIS in PS3 circuits to nearby combustible materials .	
	6.4.6	Fire spread in PS3 circuit shall be controlled by; – the use of a fire enclosure as specified in 6.4.8. and – applying all requirements for PS2 circuits as specified in 6.4.5 Devices subject to arcing or changing contact resistance (for example, pluggable connectors) shall comply with one of the following: – Materials V-1 class material; or – Comply with IEC component document flammability requirements; or – Mounted on V-1 class material and volume $\leq 1\,750\text{ mm}^3$ Exemptions: – Wire and tubing insulation complying with IEC 60332 series or IEC 60695-11-21 – Components, including connectors complying with 6.4.8.2.2 and that fill an opening in a fire enclosure – Plugs and connectors forming a part of a power supply cord or complying with 6.5, G.4.1 and G.7 – Transformers complying with G.5.3 – Motors complying with G.5.4
	6.4.6 For PS2 or a PS3 circuit within a fire enclosure	See all requirements for PS2 (6.4.5)
	6.4.6 For a PS1 circuit within a fire enclosure	Combustible materials: Needle flame test in Clause S.1 or V-2 class material or VTM-2 class material or HF-2 class material Exemptions: – Parts with a size less than $1\,750\text{ mm}^3$ – 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 – Gears, cams, belts, bearings and other small parts that would contribute negligible fuel to a fire, including, labels, mounting feet, key caps, knobs and the like – Tubing for air or any 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 $< 3\text{ mm}$, or HB40 class material if the thinnest significant thickness of the material is $\geq 3\text{ mm}$, or HBF class foamed material

6.4.5 Control of fire spread in PS2 circuits

Source: IEC 60950-1

Rationale: In principle, limiting the available power to the circuit (100 W) in PS2 circuits and control of adjacent fuel materials will reduce the spread of fire, assuming that ignition of components can occur. This power level limit minimizes the size of the ignition source and its impingement on adjacent fuels that are in the PS2 circuits.

The purpose of this clause is to establish control of fuels in or near circuits that have the possibility of ignition. As no fault testing is done for PS2 circuits, it is assumed that a fire ignition can occur anywhere within the circuits. These **safeguards** are to be based on component material flammability characteristics that keep the initial ignition source from spreading to surrounding internal materials.

This clause assumes only construction **safeguards** in a manner consistent with the historically effective requirements of IEC 60950-1.

Only fuels that would contribute significant fuel to a fire are considered.

Acceptance of limited power sources in Annex Q.1 to be classified as PS2 has been added to allow continued use of the long existing practice in IEC 60950-1.

6.4.5.2 Requirements

Source: IEC 60065, IEC 60950-1

Rationale: Requirements around conductors and devices subject to arcing parts and resistive heating have the most onerous requirements for sustained ignition and protection of wiring and wiring boards.

- Mounting on a flame-retardant material to limit fire growth. V-1 mounting materials are considered important as they limit fuel to reduce sustained flaming and also would not contribute to large fires or pool fire. The spread of fire from ignited small parts can be managed by the larger printed wiring board. This provision is made to allow the use of a longstanding IEC 60950-1 provision for small devices mounted directly on boards. The value 1 750 mm³ has been used in practice in IEC 60065.
- Use of flame retardant wiring is identical to the internal and external wiring requirements of Clause 6.
- Accepting existing component requirements for devices that have their own requirements (IEC or annexes of this document) are considered adequate.
- Sufficient distance or solid flame-resistant barrier between any **combustible material** and **potential ignition sources**. (KEEP OUT ZONES or RESTRICTED AREA).

All other components (those that are not directly associated with arcing or resistive heating components) have a reduced set of **safeguards** when compared to those parts more likely to ignite. Those **safeguards** include any of the following:

- For parts not directly subject to arcing or resistive heating, V-2 ratings are considered adequate. This is also a historical requirement of IEC 60950-1 for parts used in limited power circuits. Sustained ignition of **V-2 class materials** is similar to that of **V-1 class materials** in the small-scale testing. The use of **VTM-2** or **HF-2-rated class materials** were also considered adequate.
- Limiting the combustible fuel mass within the area around PS2 circuit devices. The limit of 4 g is brought from the small parts definition used with **PIS** requirements of this clause and which were originally used in IEC 60065.
- As an alternative, components and circuits can be separated from fuels per the requirements of the fire cone described for isolation of fuels from **potential ignition sources**.
- Enclosing parts in small oxygen limiting, flame proof, housing. The 0,06 m² value has been in practice in IEC 60950-1 and small enough to mitigate fire growth from a low power source.

The exceptions included are based on common constructions of material that do not routinely have flame retardants or that cannot contain flame retardants due to functional reasons. They are either isolated from any **PIS** or through **single fault condition** testing demonstrate that they will simply not ignite in their application.

Supplies are quantities of materials such as paper, ink, toner, staples etc., and that are consumed by the equipment and replaced by the user when necessary.

6.4.5.3 Compliance criteria

Rationale: Material flammability requirements are checked by the testing of Annex S, by compliance with the component document or through review of material data sheets.

6.4.6 Control of fire spread in a PS3 circuit

Source: IEC 60950-1

Rationale: There are two basic requirements to control the spread of fire from PS3 circuits:

- a) use of materials within the **fire enclosure** that limit fire spread. This includes the same requirements as for components in PS2 circuits and includes a requirement from IEC 60950-1 to address all **combustible materials** that are found within the **fire enclosure**;
- b) use **fire-containing enclosures** – Product **enclosures** will have a design capable of preventing the spread of fire from PS3 circuits. The criteria for **fire enclosures** is based on the available power.

Rationale: PS3 sourced circuits may contain a significant amount of energy. During **single fault conditions**, the available power may overwhelm the **safeguard** of material control of fuels adjacent to the fault or any consequential ignition source making a **fire enclosure** necessary as part of the **supplementary safeguard**. A **fire enclosure** and the material controls constitute the necessary **supplementary safeguard** required for a PS3 circuit.

Use adequate materials, typically permitting material pre-selection of non-**combustible** or flame-resistant **materials** for printed wiring and components in or near PS3. Only fuels that would contribute significant fuel to a fire are considered. This implies compliance with all the requirements for PS2 circuits and in addition, application of a **fire containing enclosure**.

Material flammability requirements for all materials inside a **fire enclosure** are included in this clause. This model has been used historically in IEC 60950-1 to control the amount and type of fuel that may become engaged in a significant fire. Because there is no single fault testing when applying this method, a significant ignition source may engage other fuels located inside the **fire enclosure**. PS3 circuits, particularly higher power PS3 circuits can create significant internal fires if adjacent **combustible materials**, not directly associated with a circuit, become involved in an internal fire. These fires, if unmitigated, can overwhelm the **fire enclosures** permitted in this document. Control of material flammability of fuels located within the **enclosure** should be sufficient based on historical experience with IEC 60950-1.

The exceptions provided in this clause for small parts, **consumable material**, etc. that are inside of a **fire enclosure**, mechanical components that cannot have flame retardant properties are exempt from the material flammability requirements. This is the current practice in IEC 60950-1.

Components filling openings in a **fire enclosure** that are also V-1 are considered adequate, as it is impractical to further enclose these devices. These constructions are commonly used today in IT and CE products.

Wiring already has requirements in a separate part of this clause.

Motors and transformers have their own flammability spread requirements and as such do not need a separate **enclosure** (see G.5.3 and G.5.4).

6.4.7 Separation of combustible materials from a PIS

Rationale: Where **potential ignition sources** are identified through classification and **single fault conditions**, separation from the ignition source by distance (material controls) or separation by barriers are used to limit the spread of fire from the ignition source and are necessary to ensure the ignition is not sustained.

6.4.7.2 Separation by distance

Source: IEC 60065

Rationale: The **safeguard** for materials within the fire cone includes material size control (and including prohibition on co-location of flammable parts). Otherwise the parts close to the **PIS** shall be **material flammability class V-1**, which limits sustained ignition and spread.

Small parts (less than 4 g) are considered too small to significantly propagate a fire. This value is also used for components used in PS2 and PS3 circuits. It has been used in IEC 60065 with good experience.

Where these distances are not maintained, a needle flame test option is included with 60 s needle flame application based on previous requirements in IEC 60065. This alternative to these distance requirements (the needle flame test) can be performed on the barrier to ensure that any additional holes resulting from the test flame are still compliant (openings that will limit the spread of fire through the barrier).

Redundant connections: An **arcing PIS** cannot exist where there are redundant or reliable connections as these connections are considered not to break or separate (thereby resulting in an arc).

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. Arcing is not considered to exist where the connections are redundant or otherwise deemed not likely to change contact resistance over time or through use. Some examples are given, but proof of reliable connections is left to the manufacturer and there is no specific criteria that can be given:

- Tubular rivets or eyelets that are additionally soldered – this assumes that the riveting maintains adequate contact resistance and the soldering is done to create a separate conductive path.
- Flexible terminals, such as flexible wiring or crimped device leads that remove mechanical stress (due to heating or use) from the solder joint between the lead and the printed wiring trace.
- Machine or **tool** made crimp or wire wrap connections – well-formed mechanical crimps or wraps are not considered to loosen.
- Printed boards soldered by auto-soldering machines and the auto-soldering machines have two solder baths, but they are not considered reliable without further evaluation. This means most printed boards have been subjected to a resoldering process. But there was no good connection of the lead of the component(s) and the trace of the printed board in some cases. In such cases, resoldering done by a worker by hand may be accepted.

Combustible materials, other than V-1 printed wiring boards are to be separated from each **PIS** by a distance based on the size of resulting ignition of the **PIS**. The flame cone dimensions 50 mm and 13 mm dimensions were derived from IEC 60065, where they have been used for several years with good experience. The area inside the cone is considered the area in which an open flame can exist and where material controls should be applied.

Resistive potential ignition sources are never a point object as presented in Figure 37 of IEC 62368-1:2014. They are more generally three-dimensional components, however only one dimension and two-dimension drawings are provided. The three-dimensional drawing is difficult to understand and difficult to make accurate.

Figure 34 in this document shows how to cope with **potential ignition sources** that are 3D volumes. This drawing does not include the bottom part of the fire cone. The same approach should be used for the bottom side of the part.

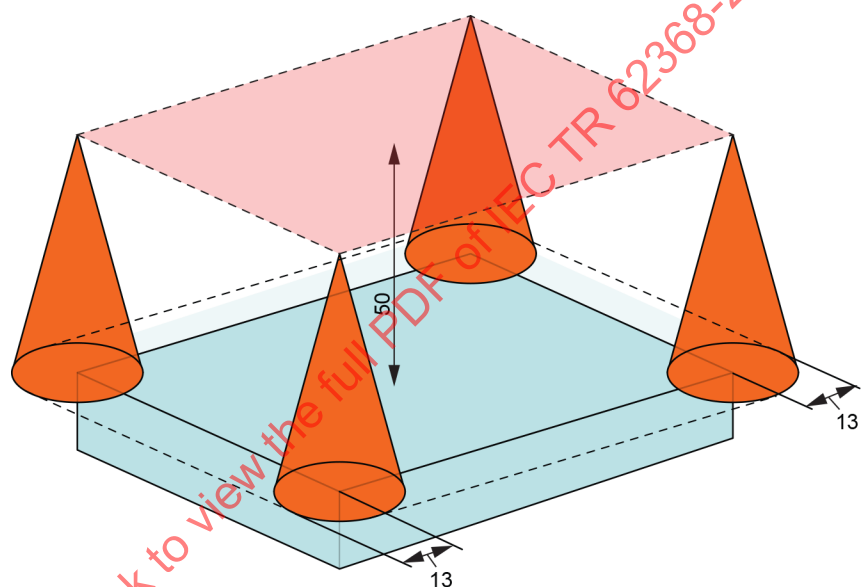


Figure 34 – Fire cone application to a large component

The fire cone is placed at each corner. The locus of the outside lines connecting each fire cone at both the top and the base defines the restricted volume.

Figure 37 Minimum separation requirements from an arcing PIS

This drawing of a flame cone and its dimensions represents the one-dimension point ignition source drawn in two dimensions. The three-dimension envelope (inverted ice cream cone) of a flame from a **potential ignition source**. This **PIS** is represented as a point source in the drawing for clarity, however these **PISs** are more often three-dimensional components that include conductors and the device packaging.

Figure 38 Extended separation requirements from a PIS

A two-dimensional representation of an ignition source intended to provide more clarity.

~~Figure 39 Rotated separation requirements due to forced air flow~~

~~This figure demonstrates the change of fire cone when in the presence of a forced air flow such as a product with a fan. This is done to compensate for the shape and movement of a potential flame caused by the forced airflow. The value of 45° was selected as adequate.~~

6.4.7.3 Separation by a fire barrier

Source: IEC 60065

Rationale: The use of flame retardant printed wiring is considered necessary as the fuel and the electrical energy source are always in direct contact. V-1 has historically been adequate for this purpose.

Printed wiring boards generally directly support **arcing PIS** and as such, cannot be used as a barrier. There is a potential that small openings or holes may develop, thus permitting the arc to cross through the board.

A printed board can act as a barrier for an **arcing PIS**, provided the **PIS** is not directly mounted on the board acting as a barrier.

For **resistive PIS**, printed wiring boards can be used provided they are of V-1 or meet the test of Clause S.1. Any V-1 and less-flammable fuels are required to minimize the possibility flammable material falling onto the supporting surface or contact with combustible fuels (resulting in pool fires). If a **PIS** ~~be mounted~~ is located on a board and supplied by a PS2 or PS3 source, there should be no other PS2 or PS3 circuits near the **PIS**, as this could create faults due to **PIS** heating that was not otherwise considered.

Figure 39 Deflected separation requirements from a PIS when a fire barrier is used

This figure demonstrates the change on the fire cone when there is a fire barrier used to separate **combustible material** from a **potential ignition source**. This drawing was retained as an example application for only two angles. Recognizing that many examples are possible, only two are kept for practical reasons. History with multiple drawings of barriers in varying angles could be difficult to resolve. The fire team decided to keep only two drawings with an angle barrier as representative.

6.4.8 Fire enclosures and fire barriers

Rationale: The **safeguard** function of the **fire enclosure** and the fire barrier is to impede the spread of fire through the **enclosure** or barrier (see Table 13 in this document).

Table 13 – Fire barrier and fire enclosure flammability requirements

Flammability requirements		
Fire barrier	6.4.8.2.1	Fire barrier requirements Non- combustible material or Needle flame test Clause S.1 or $\geq$ V-1 class material or VTM-1 class material
	6.4.8.4	Separation of a PIS to a fire barrier - Distance $\geq$ 13 mm to an arcing PIS and - Distance $\geq$ 5 mm to a resistive PIS Smaller distances are allowed provided that the part of the fire barrier complies with one of the following: - Needle flame Clause S.2; After the test no holes bigger than in 6.4.8.3.3 and 6.4.8.3.4 allowed or $\geq$ V-0 class material
Fire enclosure	6.4.8.2.2	Fire enclosure materials: - Non-combustible, or - For PS3 $\leq$ 4 000 W, needle flame test Clause S.1 or V-1 class material - For PS3 > 4 000 W, needle flame test Clause S.5 or 5VB class material
		Component materials which fill an opening in a fire enclosure or intended to be mounted in such opening - Comply with flammability requirements of relevant IEC component document; or $\geq$ V-1 class material; or - needle flame test Clause S.1
	6.4.8.4	Separation of a PIS to a fire enclosure - Distance $\geq$ 13 mm to an arcing PIS and - Distance $\geq$ 5 mm to a resistive PIS Smaller distances are allowed, provided that the part of the fire enclosure complies with one of the following: - Needle flame Clause S.2; After the test no holes bigger than in 6.4.8.3.3 and 6.4.8.3.4 allowed; or $\geq$ V-0 class material

6.4.8.2.1 Requirements for a fire barrier

Source: IEC 60065, IEC 60950-1

Rationale: Barriers used to separate **PIS** from flammable fuels reduce the ability of a resulting **PIS** flame from impinging on flammable materials. This can be achieved by using flame retardant materials that pass the performance test in Clause S.1 or the pre-selection criteria of a minimum V-1 flame class.

The test in Clause S.1 is based on the needle flame test which is currently an option for **enclosure** testing in both IEC 60950-1 and IEC 60065.

6.4.8.2.2 Requirements for a fire enclosure

Source: IEC 60065, IEC 60950-1

Rationale: The **material flammability classification of class V-1** was chosen as the minimum value based on its historical adequacy, and recent testing done during the development of the requirements for externally caused fire.

IEC 60950-1 – Prior requirements for **5 V class materials** based on product weight lacked sufficient rationale. This has been improved and related to power available to a fault in this document.

IEC 60065 – **V-2 class material** performance during large scale test reviewed by the fire team indicated inconsistencies in performance over a range of different V-2 materials. The propensity for **V-2 class materials** to create 'pool' fires is also detrimental to **fire enclosure** performance and therefore not accepted unless it passes the end-product testing.

In addition to pre-selection requirements, an end-product test (material test) is also included by reference to Clauses S.1 (for < 4 000 W) and S.5 (for > 4 000 W). This test is based on the needle flame test which is currently an option for **enclosure** testing in both IEC 60950-1 and IEC 60065.

This power (4 000 W) separation is also used in the control of fire spread method to delineate **safeguard** criteria for **fire enclosure** materials (V-1 versus 5 V). IEC 60950-1 has historically used weight to define **fire enclosure** criteria and it was felt the use of available power was more appropriate and generally reflective of current practice.

Both **5 VA** and **5 VB class materials** are considered acceptable for equipment with power above 4 000 W. This is consistent with current practice in IEC 60950-1.

6.4.8.2.3 Compliance criteria

Rationale: In each case there is a performance test, and construction (pre-selection) criteria given. For material flammability, compliance of the material is checked at the minimum thickness used as a **fire enclosure** or fire barrier.

6.4.8.3 Constructional requirements for a fire enclosure and a fire barrier

Rationale: Opening requirements for barriers and **fire enclosure** should limit the spread of flame through any existing opening. A **fire enclosure** limits the spread of fire beyond the equipment and is permitted to have holes (within established limits).

6.4.8.3.1 Fire enclosure and fire barrier openings

Rationale: These requirements are intended to reduce the spread of an internal fuel ignition through a **fire enclosure** or barrier.

Openings are restricted based on the location of each **potential ignition source** using the flame cones or in the case of control fire spread, above all PS3 circuits.

Figure 40 Determination of top, bottom and side openings

In the left figure, when the vertical surface has an inclination (angle) of less than 5° from vertical, then only the side opening requirements of 6.4.8.3.5 apply.

In the right figure, when the vertical surface has an inclination (angle) of more than 5° from the vertical, then the openings are subject to the requirements for top openings of 6.4.8.3.3 or bottom openings of 6.4.8.3.4.

6.4.8.3.2 Fire barrier dimensions

Rationale: Edges can be more easily ignited than a solid surface. Barrier dimensions shall also be sufficient to prevent ignition of the barrier edges.

Barriers made of non-combustible materials shall have edges that extend beyond the limits of the fire cone associated with each **potential ignition source**. If the barrier edge does not extend beyond the cone, then it is assumed the edges may ignite.

6.4.8.3.3 Top openings and top opening properties

Source: IEC 60065

Rationale: Top opening drawings are restricted in the areas of likely flame propagation to the side and above an ignition source.

Top openings are also considered to cover what has historically been called side opening where the opening is above the horizontal plane containing the ignition source.

The top/side openings that are subject to controls are only those within the fire cone drawing (Figure 37) plus a tolerance of 2 mm, as shown in Figure 41. The application of the fire cone dimensions has been used in IEC 60065 and proven historically adequate.

Control of openings above the flame cone is also not necessary given that the heat transfer (convection) will follow the gases moving through those openings and is not sufficient to ignite adjacent materials. If the openings are directly blocked, the convection path will be blocked which would restrict any heat transfer to an object blocking the opening.

Openings to the side of the fire cone dimensions were reviewed and ultimately not considered necessary as the radiant heat propagation through openings to the side of the ignition is very small. This radiant heat is not considered sufficient to ignite adjacent materials given the anticipated flame size and duration in AV and ICT products.

In this aspect, the virtual flame cone deflection as per Figure 39 need not be considered since the actual needle flame application will cover that.

The test method option proposed provides a test option for direct application of a needle flame ~~at a distance of 7 mm from the opening~~. The test (S.42) referred to in this clause is intended to provide a test option where holes do not comply with the prescriptive measures. ~~Work is ongoing to determine how to apply these requirements to barriers or enclosures that are oriented vertically.~~ S.2 is originally intended to test the material flammability, but in this subclause the purpose of the test is to see the potential ignition of outer material covering the openings, so application of the needle flame is considered for that aspect rather than the burning property of the **enclosure** itself.

Cheesecloth is used as a target material for the evaluation of flame spread due to its flexible nature (ease of use) and its quick propensity to ignite.

The flame cone envelope is provided as a single point source. The applicable shape and any affecting airflow are taken into account for ~~determining~~ the whole shape of the **PIS**, not just a single point. The point is applied from the top edge of the component being considered and, in practice, it is rarely a single point.

The opening dimensions for the 5 mm and 1 mm dimensions have been determined through test as being restrictive enough to cool combustible gases as they pass through the openings and those mitigate any flame from passing through the opening. Top openings properties are based on ~~tests conducted by the fire team~~ **testing** with open flames (alcohol in a Petri dish) that demonstrated these opening dimensions are adequate.

6.4.8.3.4 Bottom openings and bottom opening properties

Source: IEC 60065, IEC 60950-1

Rationale: The location of openings is restricted for barriers inside the flame cone of Figure 37 and for **enclosures**, inside the cone and directly below to protect against flammable drips from burning thermoplastic as shown in Figure 42. The application of the fire cone dimensions has been used in IEC 60065 and proven historically adequate.

There are several options for opening compliance (see Table 14 in this document). Flaming oils and varnishes are not common in ICT equipment today. The performance test based on the hot flaming oil test, in use for IEC 60950-1, have other opening options and are developed based on lower viscosity materials (when burning). They are more commonly found in ICT (that provide additional options).

Clause S.3 (hot flaming oil test) is the base performance option and provides a test option (hot flaming oil test) that historically has been adequate for tests of bottom openings.

The values ~~and tables in items b), c) and Table 34~~ in items **band c)** come directly from IEC 60950-1 where they have been historically adequate and have demonstrated compliance with the S.3 performance testing. ~~Table 34 values were developed through extensive hot flaming oil testing and have been demonstrated adequate. It is recognized that the potential flammable materials that could be liquid are far less viscous than oils used in the development of Table 34.~~ These requirements, previously from IEC 60950-1, 4.6.2 Bottoms of **fire enclosures**, have been updated in the third edition of IEC 62368-1. The IEC 60950-1 requirements are more stringent than the new IEC 62368-1 requirements and may still be used as an option without additional tests, which is likely since designs based on the IEC 60950-1 requirements have been in use for some time.

The work done to validate top openings was also considered adequate for bottom openings under materials of any properties (3 mm and 1 mm slots). This requirement is less onerous than those found in IEC 60950-1 which permitted NO openings unless they complied with the other options ~~(S.2, mesh, metal screens)~~.

Openings under **V-1 class materials** (or those that comply with Clause S.1) are controlled in the same manner as done in IEC 60950-1 which was considered adequate however an additional option to use 2 mm slots of unlimited length is also considered adequate.

The 6 mm maximum dimension relates to a maximum square opening dimension of 36 mm² and a round opening of 29 mm². In IEC 60950-1 the requirement was 40 mm², which relates to a maximum 7 mm diameter if round or 6,3 mm maximum if not round.

The only option where flammable liquids are used is to meet the requirements of the hot flaming oil test (Clause S.3).

An option for equipment that is installed in special environments where a non-combustible flooring is used (environmental **safeguard**) may obviate the need for an equipment bottom **safeguard**. This is current practice in IEC 60950-1 where equipment is used in “restricted access locations”.

Baffle plate constructions were added, as they have been used in IEC 60950-1 and have proven to be an acceptable solution.

Table 14 – Summary – Fire enclosure and fire barrier material requirements

Parameters		Fire barrier	Fire enclosure	
			Input < 4 000 W	Input > 4 000 W
Combustible material:	Separation from PIS	13 mm or more from arcing PIS 5 mm or more from resistive PIS Note: exceptions may apply		
	Dimensions	Sufficient to prevent ignition of the edges	Not applicable	
	Flammability	a) Test S.1; or b) V-1; or c) VTM-1	a) Test S.1; or b) V-1	a) Test S.5; or b) 5 VA; or c) 5 VB
Non-Combustible material:		Acceptable		
Top openings		See 6.4.8.23.3		
Bottom openings		See 6.4.8.23.4		

6.4.8.3.5 Side opening and side opening properties

Source: IEC 60950-1

Rationale: For Edition 3, IEC TC 108/WG HBSDT agreed to adopt from IEC 60950-1:2005 (4.6.1, 4.6.2 and Figure 4E) the principles and criteria for determination of suitable side openings using a five (5) degree projection. The primary rationale for adopting these principles was the demonstration of many years of a solid safety record of use for ITE with IEC 60950-1. However, one issue that had to be resolved was that in IEC 60950-1 the 5-degree projection of Figure 4E was always made from the outer surface of a combustible internal component or assembly rather than a defined potential ignition source (PIS), typically a metallic circuit inside the component. The PIS principle was not inherent to IEC 60950-1.

For example, in a component or assembly, electrical or not, made of combustible material that might ignite within a fire enclosure, the 5-degree projection was made from the surface of the component or assembly closest to the side enclosure and not from a metallic circuit inside the component or subassembly that could be a potential source of ignition. Therefore, for example, if a printed board was considered the component/subassembly likely to ignite, the 5-degree projection was made from the edge of the printed board and not the current carrying trace, which in IEC 62368-1 is the **PIS**. In some cases throughout the history of IEC 60950-1, this distance from the metallic trace to component edge could have been up to several centimetres.

However, when IEC TC 108/WG HBSDT considered the common construction of internal components and subassemblies likely to be associated with a **PIS**, including printed boards, it was determined that it was reasonable to assume that in modern AV/ICT equipment the distance between the **PIS** and the outer edge of a component or sub-assembly was likely to have negligible impact on the overall fire safety of the product, in particular in the application of the 5 degree principle. Due to general miniaturization of products, material cost optimization, and modern design techniques (including CAD/CAM), printed boards and other electronic components and assemblies associated with a **PIS** typically do not use unnecessary amounts of combustible materials – modern printed boards more typically now have metallic traces very close to the board edge rather than many millimetres away.

As a result IEC TC 108/WG HBSDT considered that the IEC 60950-1 five (5) degree projection principle for side openings remained sound even if projected from the actual **PIS** rather than the edge of combustible material associated with the **PIS**. This view also is consistent with the Note to Figure 38, Extended separation requirements from a **PIS**, which states, for a resistive **PIS** "...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 surface of the component is used."

6.4.8.3.56 Integrity of a fire enclosure

Source: IEC 60950-1

Rationale: The clause ensures that a **fire enclosure** where required, is assured to remain in place and with the product through either an equipment or behavioural **safeguard**. This requirement is a service condition **safeguard** for **ordinary persons** to ensure that a **fire enclosure** (if required) is replaced prior to placing the equipment back into use. This **safeguard** is also required in IEC 60950-1.

6.4.8.3.67 Compliance criteria

Rationale: In each case, there is a performance test, and construction (pre-selection) criteria given.

6.4.8.4 Separation of a PIS from a fire enclosure and a fire barrier

Source: IEC 60065, IEC 60950-1

Rationale: Non-metallic **fire enclosures** and fire barriers may not be sufficient to limit the spread of fire where an **enclosure** is close or in direct contact with a **potential ignition source**.

The 13 mm and 5 mm distances were used in IEC 60065 to prevent an ignition source from transferring sufficient energy to adjacent flame-retardant V-1 barriers. These distances are intended to reduce the likelihood of melting or burn-through of the barrier of **fire enclosure**.

Where these distances are not maintained, a needle flame test option is included with 60 s needle flame application based on work in IEC 60065.

Openings following the needle flame test were discussed with criteria being:

- a) no additional opening,
- b) no enlargement of existing holes,
- c) compliance with the **fire enclosure** opening requirements.

Due to test repeatability, the criteria of a) are considered most readily reproduced.

The option to use **V-0** or **5 V class materials** without distance or thickness requirements is based on historical practices in IEC 60065 and IEC 60950-1 where no distance requirements were applied.

The material thickness requirements where ignition sources are in close proximity to a barrier were not included based on discussions in IEC TC 108 and current practice for IEC 60950-1 **enclosures**. There is fire test data (barrier testing from IEC 60065) indicating that 2 mm thick (or greater) V-0 barriers and 5 VA barriers have sufficient flame resistance to minimize a risk of creating openings when used in direct contact with **PIS**'s. Good HWI or HAI tests are not available internationally to address the distance from ignition sources to **fire enclosure** and barriers. The fire team has chosen to use the needle flame test as a surrogate test (similar to that done for barriers).

6.5.21 ~~Compliance criteria~~ General requirements

Source: IEC 60332-1-2, IEC 60332-2-2

Rationale: Wiring flammability proposals have now been included for all wiring (external and internal).

Compliance with IEC 60332-1-2 for large wires and IEC 60332-2-2 for small wires has historically proven adequate for **mains** wiring. These documents include their own material flammability requirements.

The requirements of IEC TS 60695-11-21 are also considered adequate given that the flame spread requirements for vertical testing are more onerous than the IEC 60332 series of documents.

The compliance criteria are based on application of the above test methods. These are consistent with international wiring standards. National standards may have more onerous requirements.

6.5.32 Requirements for interconnection to building wiring

Source: IEC 60950-1:2005

Rationale: Externally interconnected circuits that are intended for connection to unprotected building wiring equipment can receive sufficient power from the product to cause ignition and spread of fire with the building wall, ceiling, or remotely interconnected equipment. These requirements limit the power available to connectors/circuits intended for interconnection to specific types of wiring where the product is responsible for protection of that wiring.

Where a circuit is intended for connection to equipment that is directly adjacent to the equipment, 6.6 of ~~IEC 62368-1:2014~~ prescribes the appropriate **safeguards** and limits associated for PS2 and PS3 sources.

Telecommunication wiring is designed based on the expected power from the network. The requirements of IEC 60950-1 were considered adequate and were included. Wiring in this application should be equivalent to 0,4 mm diameter wiring (26 AWG) and have a default 1,3 A current limit established. This value has been used in IEC 60950-1 for the smaller telecommunication wiring.

For some building wiring, the PS2 and PS3 **safeguards** are not considered adequate in some countries for connection to building wiring where that wiring is run outside of the conduit or other **fire protective enclosures**. The requirements for this clause come directly from requirements in IEC 60950-1:2005, 2.5 for circuits identified as limited power circuits. These requirements have proven to be historically adequate for connection of IT equipment to building wiring in these jurisdictions.

The values used and protection requirements included in IEC 60950-1 and included in Annex Q.1 came from the building and fire codes requiring this protection.

These requirements do not apply to connectors/circuits intended for interconnection of peripheral equipment used adjacent to the equipment.

This requirement is also important for the use of ICT equipment in environments subject to electrical codes such as National Fire Protection Association NFPA 70, which permit the routing of low power wiring outside of a fire containment device.

Annex Q.1 was based on requirements from IEC 60950-1 that are designed to comply with the **external circuit** power source requirements necessary for compliance with the electrical codes noted above.

6.6 Safeguards against fire due to the connection of additional equipment

Source: IEC 60950-1

Rationale: This subclause addresses potential fire hazards due to the connection of accessories or other additional equipment to unknown power source classifications. Most common low-voltage peripherals are not evaluated for connection to PS3 and therefore power sources should be identified. This is a current requirement of IEC 60950-1.

Where the interconnected devices are known (device requirements are matched to the appropriate power source), this requirement for **safeguard** is not necessary.

7 Injury caused by hazardous substances

Rationale: The majority of chemical injuries arise from inhalation or ingestion of chemical agents in the form of vapours, gases, dusts, fumes and mists, or by skin contact with these agents (see Table 15 in this document). The degree of risk of handling a given substance depends on the magnitude and duration of exposure. These injuries may be either acute or chronic.

Many resins and polymers are relatively inert and non-toxic under normal conditions of use, but when heated or machined, they may decompose to produce toxic by-products.

Toxicity is the capacity of a material to produce injury or harm when the chemical has reached a sufficient concentration at a certain site in the body.

Potentially hazardous chemicals in the equipment are either:

- as received in **consumable material** or items, such as printer cartridges, toners, paper, cleaning fluids, **batteries**;
- produced under **normal operating conditions** as a by-product of the normal function of the device (for example, dust from paper handling systems, ozone from printing and photocopying operations, and condensate from air conditioning/de-humidifier systems); or
- produced under **abnormal operating conditions** or as a result of a fault.

It is essential to:

- determine what substances are present in relative amounts in the equipment or could be generated under **normal operating conditions**; and
- minimize the likelihood of injury to a person due to interaction with these substances.

NOTE In addition to their potential toxicity, loss of containment of chemical materials ~~can~~ may cause or contribute to failure of **safeguards** against fire, electric shock, or personal injury due to spillages.

The number of different chemical materials that may be used in the wide variety of equipment covered by this document makes it impossible to identify specific hazards within the body of this document. Information needs to be sought by equipment manufacturers from the material suppliers on the hazards associated with their products and their compliance with any national and/or governmental regulations on the use and disposal of such materials.

Energy source:

The energy source for most chemically-caused injuries is ultimately the ability of a material to chemically react with human tissue, either directly or indirectly. The exception would be inert materials that can damage tissues by preventing them from functioning by limiting certain chemical reactions necessary for life. An example of this would be types of dust, which do not react with lung tissue, but prevent air from reaching the bloodstream. The reactions may be very energetic and damaging, such as acids on the skin, or can be very slow, such as the gradual build-up of substances in human tissues.

Transfer mechanism:

Transfer can only occur when chemical energy makes contact with human tissue. The routes for contact with human tissue are through the skin [or any outer membrane such as the eyes or nasal lining] (absorption), through the digestive tract (digestion), or through the lungs (inhalation). The route taken will depend largely on the physical form of the chemical: solid, liquid, or gas.

Injury:

An injury can be either acute or chronic. Acute injuries are injuries with immediate and serious consequences (for example, a strong acid in the lungs) or the injury can be mild and result in irritation or headache. Chronic injuries are injuries with long term consequences and can be as serious as acute injuries (for example, consequences of long-term exposure to cleaning solvents).

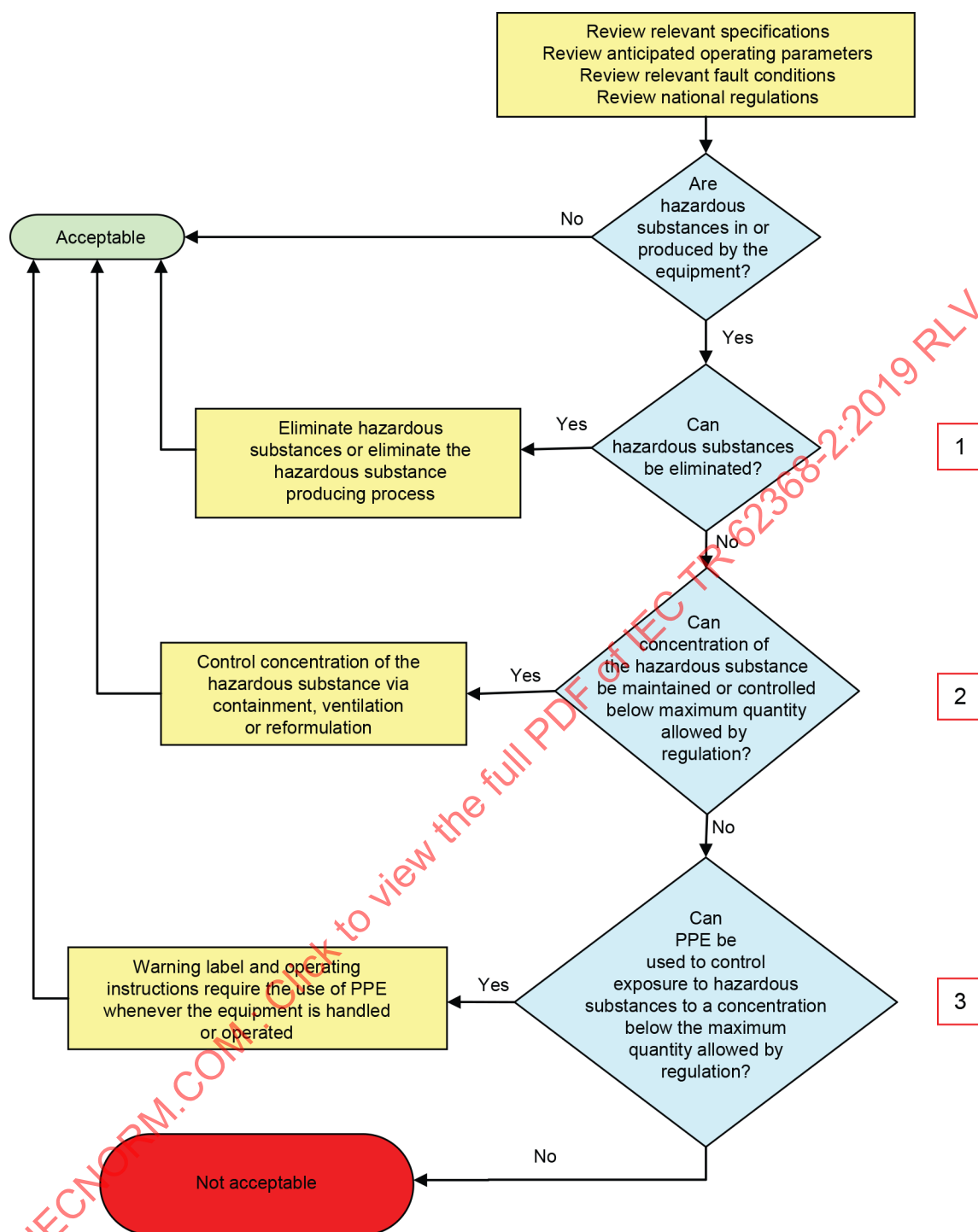
In most cases, the difference is the quantity and lethality of the toxic substance. A large amount of acetone can lead to death; a small amount may simply result in a headache. Many chemical compounds essential to life in small quantities (for example, zinc, potassium and nickel) can be lethal in larger amounts. The human body has different degrees of tolerance for different **hazardous chemical substances**. Exposure limits may be controlled by government bodies for many chemical substances. Where the use of **hazardous chemical substances** in equipment cannot be avoided, **safeguards** shall be provided to reduce the likelihood of exceeding the exposure limits.

The different types of chemical hazards are identified in Table 15 and Figure 35 in this document demonstrating the hierarchy of hazard management.

Table 15 – Control of chemical hazards

Transfer mechanism	Prevention / safeguards
Ingestion, inhalation, skin contact, or other exposure to potentially hazardous chemicals	Hierarchy of hazard management: 1. Eliminate the chemical hazard by avoiding the use of the chemical. 2. Reduce the chemical hazard by substitution of a less hazardous chemical. 3. Minimize the exposure potential of the chemical by containment, ventilation and/or reduced quantities of the chemicals. 4. Use of personal protective equipment (PPE). 5. Provide use information and instructional safeguards.
Exposure to excessive concentrations of ozone during equipment operation	Hierarchy of hazard management: 1. Where possible, minimize the use of functions that produce ozone. 2. Provide adequate room ventilation. 3. Provide filtration to remove ozone.
Explosion caused by chemical reaction during use	Hierarchy of hazard management: 1. Eliminate the explosive charge. 2. Reduce the amount of explosive charge to the least amount possible. 3. Minimize hazard by the means of vents. 4. Provide use information and instructional safeguards.

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Figure 35 – Flowchart demonstrating the hierarchy of hazard management

Chemical hazards may also degrade or destroy the **safeguards** provided for other hazards such as fire and electric shock (for example, ozone attack on electrical insulation or corrosion of metallic parts). Chemical spillages or loss of containment can also lead to other hazards such as electric shock or fire depending on the location of any spillage and proximity to electric circuits. The same methods used for chemical health exposure control should also protect against such liquid spillages.

Using a hazard-based engineering approach, Figure 36 in this document shows the main types of chemical health hazards and their transfer mechanisms.

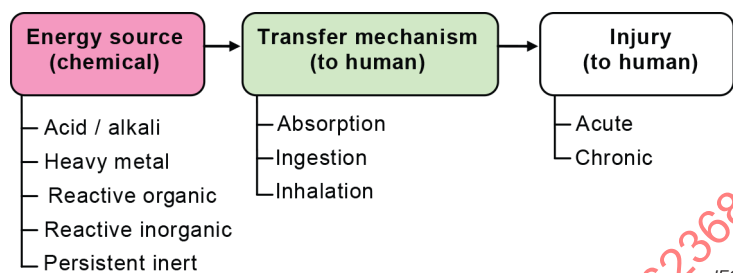


Figure 36 – Model for chemical injury

8 Mechanically-caused injury

8.1 General

Rationale: Mechanically caused injury such as cuts, bruises, broken bones, etc., may be 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.

8.2 Mechanical energy source classifications

Purpose: To differentiate between mechanical energy source levels for **normal operating conditions**, **abnormal operating conditions** and **single fault conditions** applicable to each type of person.

8.2.1 General classification

Table 35 – Classification for various categories of mechanical energy sources

Line 3 – Moving fan blades

Rationale: The acceptance criteria is based upon any number of factors such as location, but the key factor for judging acceptance is based upon the K factor, the relationship between mass (m) in kg, radius (r) in mm and speed (N) in rpm. This relationship can be used to find the K factor for the fan. Fans with a low K factor and low speeds are considered safer. See Figure 45 and Figure 46 of IEC 62368-1:2014 for MS1 values. An MS2 fan requires an **instructional safeguard** in addition to the limitation on the K factor value and the speed of the fan. The need for the relevant **safeguard** is based on the classification of fans. The K factor formula is taken from the UL standard for fans, UL 507 (which is based on a University of Waterloo study of fan motors).

Single fault condition on a fan includes, but is not limited to, inappropriate input voltage due to the fault of a voltage regulator located upstream.

As plastic fan blades are regarded less hazardous than metal fan blades, different values are used to determine separation between energy class 2 and class 3.

Typical parameters for fans used in products covered by this document are as follows:

fan mass (m) = about 25 g or 0,025 kg;

fan diameter (r) = 33 mm;

fan speed (N) = 6 000 rpm (maximum speed when the system is hottest, slower if the system is cool).

Line 4 – Loosening, exploding or imploding parts

Rationale: IEC TC 108 has tried to come up with specific requirements for solid rotating media. However, the result became too complex to be useful at this time.

Line 5 – Equipment mass

Rationale: The values chosen align with some commonly used values today. However, it is noticed that these are not completely reflecting reality and not a very good hazard-based approach. IEC TC 108 plans to work on these values in the future.

Line 6 – Wall/ceiling or other structure mount

Rationale: The values chosen align with some commonly used values today. However, it is noticed that these are not completely reflecting reality and not a very good hazard-based approach. IEC TC 108 plans to work on these values in the future.

Notes b and c

Rationale: The current values are based on experience and basic safety publications.

8.2.2 MS1

Rationale: Safe to touch. No **safeguard** necessary.

8.2.3 MS2

Rationale: Contact with this energy source may be painful, but no injury necessitating professional medical assistance occurs, for example, a small cut, abrasion or bruise that does not normally require professional medical attention. A **safeguard** is required to protect an **ordinary person**.

8.2.4 MS3

Rationale: An injury may occur that is harmful, requiring professional medical assistance. For example, a cut requiring stitches, a broken bone or permanent eye damage. A double or **reinforced safeguard** is required to protect an **ordinary person** and an **instructed person**.

8.3 Safeguards against mechanical energy sources

Purpose: To determine the number of **safeguards** needed between the type of person and the relevant energy source classification.

Rationale: An **instructional safeguard** describing hazard avoidance may be employed to circumvent the **equipment safeguard** permitting access to MS2 part locations to perform an **ordinary person** service function. The **instructional safeguard** indicates that the **equipment safeguard** be restored after the service activity and before power is reconnected. When an **instructional safeguard** is allowed, a warning is also required to identify insidious hazards.

For an **instructed person** and a **skilled person**, an **instructional safeguard**, in the form of a warning marking, is necessary to supplement the instruction they have received to remind them of the location of hazards that are not obvious.

However, for a **skilled person**, an **equipment safeguard** is required in the service area of large equipment with more than one level 3 energy sources, where the **skilled person** can insert their entire head, arm, leg or complete body. This **safeguard** is intended to protect the **skilled person** against unintentional contact with any other level 3 energy source due to an involuntary startle reaction to an event in the equipment while servicing intended parts.

The involuntary reaction may occur for a number of reasons, such as an unexpected loud noise, an arc flash or receipt of a shock, causing the person to recoil away from the energy source or part being serviced. Where more than one of the level 3 energy sources may require servicing at some time, removable **equipment safeguards** shall be designed such that any level 3 sources not being serviced can remain guarded. The **equipment safeguards** for this purpose only need to protect against larger body contact, since the potential involuntary recoil reaction will likely be full limb or body and not small body parts.

8.4 Safeguards against parts with sharp edges and corners

Rationale: Engineering judgment shall be used to class a mechanical energy source as MS1, MS2 or MS3 and an appropriate **safeguard** shall be provided. Where a MS2 or MS3 cannot be fully guarded without interfering with the intended function of the equipment, it shall be guarded as much as practical. Such an energy source shall not be **accessible** to children and be obvious to an adult. **Instructional safeguards** shall be provided to warn the person about potential contact with the energy source and what steps to take to avoid unintentional contact.

We rely on engineering judgment as there are too many variables involved to define the type of edge or corner combined with the applied force and direction of contact or to provide specific values.

8.5 Safeguards against moving parts

Rationale: **Enclosures** and barriers protect against access to hazardous moving parts. See 8.5.1 for the exception of requirements related to parts not fully guarded because of their function in the equipment.

8.5.1 Requirements

Rationale: The MS2 or MS3 energy sources need to be guarded against accidental access by a person's extremities, jewellery that may be worn, hair and clothing, etc. Access is determined by applying the appropriate **tool** from Annex V, and no further testing is necessary. We note that while it may be technically possible for some jewellery and hair to enter an opening smaller than the test finger, in such cases, the jewellery strands would have to be very thin and flexible enough to enter (as would a few strands of hair). As such while some pain may result if they happen to be caught in the mechanical device, it is deemed unlikely an injury would occur as described by this document. The residual risk can be considered a MS2 energy source at most.

~~8.5.4.1 Large data storage equipment~~

~~Rationale: Additional requirements for this type of equipment are found in IEC 60950-23. This clause provides the changes necessary to have this standard replace IEC 60950-1. The IEC 60950-23 standard may be changed to the hazard based format in a future edition.~~

8.5.4.23 Equipment having an electromechanical device for destruction of media

Source: UL/CSA 60950-1 second edition [national difference]

Rationale: Recent large scale introduction of media shredders into the home environment resulted in an increase of children being injured when inserting their fingers through the shredder openings. These incidents were studied and a new probe was developed to assess potential access by children. The new probe/wedge has been designed for both application with force when inserted into the shredder openings and assessment of access to MS3 moving parts by a population consisting of both adults and children. This design differs from the existing UL and IEC accessibility probes since the UL Articulated Accessibility Probe is not intended to be used with a force applied to it, and the current IEC probes, while having an unjointed version for application under force, do not adequately represent the population for both adults and children.

Because cross-cut shredders typically apply more force to the media than straight-cut shredders, the requirements include differentiated application forces for the two designs. The force values consider typical forces associated with straight-cut and cross-cut designs, taking into account data generated by the USA Consumer Product Safety Commission on typical pull forces associated with both strip type and crosscut type shredders.

The dimensions of the new probe/wedge are based on the data generated during the development of the UL Articulated Accessibility Probe. However, the dimensions of the UL Articulated Accessibility Probe were defined in consideration of causal handling of products. Because of this, the 95th percentile points from the data were used to define the UL Articulated Accessibility Probe. The thickness and length dimensions of the new proposed probe/wedge have been developed in consideration of all data points. Articulation points are identical to those for the UL Articulated Accessibility Probe.

8.6 Stability of equipment

Source: IEC 60950-1 and IEC 60065

Purpose: To align existing practice with the MS1, MS2 and MS3 energy.

Rationale: Equipment weighing more than 25 kg is considered MS3. Regardless of weight, equipment mounted to the wall or ceiling is considered MS3 when it is to be mounted above 2 m height.

Equipment weighing between 7 kg and not exceeding 25 kg is considered MS2. Equipment with a weight of 1 kg or more and that is mounted to the wall or ceiling to a maximum height of 2 m is also considered MS2.

Equipment with weight not exceeding 7 kg is considered MS1 if floor standing, but can be either MS2 or MS3 if mounted to the wall or ceiling. Also see carts and stands, and wall or ceiling mounted equipment.

Children are naturally attracted to moving images and may attempt to touch or hold the image by pulling or climbing up on to the equipment. The tests assess both the static stability and mounting grip when placed on a slippery surface such as glass. Children might also misuse controls that are readily available to them.

8.6.2.2 Static stability test

Rationale: Equipment is assessed for stability during expected use by applying force horizontally and downward on surfaces that could be used as a step or have other objects placed upon it.

The value of 1,5 m was chosen as the maximum height where an average person could lean on or against the product.

The 1,5 m is also used for table top equipment, since we do not know whether the product is going to be placed on a table or, if so, what the height of the table will be.

8.6.2.3 Downwards force test

Rationale: The height of 1 m represents the maximum height one could expect that people could try to use as a step to reach something.

8.6.3 Relocation stability ~~test~~

Source: IEC 60950-1 and IEC 60065

Rationale: The 10° tilt test simulates potential horizontal forces applied to the equipment either accidentally or when attempting to move the equipment. In addition it simulates moving the equipment up a ramp during transport.

The test on the horizontal support may be necessary (for example, for equipment provided with small feet, casters or the like).

8.6.4 Glass slide test

Source: IEC 60065:20142011

Purpose: To address the hazard of equipment with moving images sliding off a smooth surface when a child attempts to climb onto the equipment.

Rationale: To ensure the display does not slide too easily along a smooth surface that could result in the display falling from an elevated height on to a child.

8.6.5 Horizontal force test and compliance criteria

Purpose: To simulate the force of a child climbing up on to equipment with front mounted user controls or with moving images.

Rationale: Field data and studies in the US have shown that children 2-5 years of age were attracted to the images on the display that may result in the child climbing onto the display to touch/get close to the image. The equipment could then tip over and crush the child. Also, products with **accessible** controls or that are shorter than 1 m in height are considered likely to be handled by children.

- Data was gathered in the 1986 to 1998 for CRT TV sets ranging from 48,26 cm to 68,58 cm (19 to 27 inches). The average horizontal force was 13 % of the equipment weight.

- The 15° tilt test (an additional 5° over static stability test) provides an additional safety factor.

8.7 Equipment mounted to a wall, ceiling or other structure

Source: IEC 60065 and 60950 series

Purpose: The objective of this subclause is to minimize the likelihood of injury caused by equipment falling due to failure of the mounting means.

Rationale: Equipment intended to be mounted to a wall or ceiling should be tested to ensure adequacy for all possible mounting options and all possible failure modes. For typical equipment, such as flat panel televisions, mounting bosses are usually integrated into the equipment and used with an appropriate wall or ceiling mounting bracket to attach to a wall or ceiling. Typical mounting bosses are comprised of threaded inserts into the rear panel of the equipment.

The appropriate load is divided by the number of mounting means (for example, mounting bosses) to determine the force applied to each individual mounting means.

The horizontal force values of 50 N and 60 s have been successfully used for products in the scope of these documents for many years.

8.7.2 Test methods

Figure 37 in this document gives a graphical view of the different tests required by Test 2 and show the directions that the forces are applied.

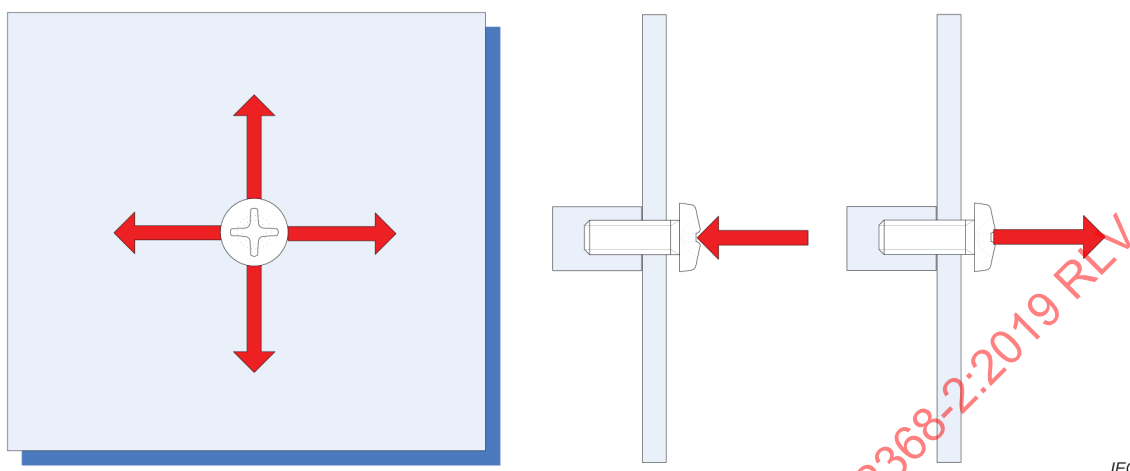


Figure 37 – Direction of forces to be applied

Table 37 Torque to be applied to screws

Source: IEC 60065

Rationale: These torque values have been successfully used for products in the scope of this document for many years.

8.8 Handle strength

Source: IEC 60065 and IEC 60950-1

Rationale: A handle is a part of the equipment that is specifically designed to carry the equipment or subassembly around. A grip which is made for easy removal or placement of a subassembly in an equipment is not considered to be a handle.

The 75 mm width simulates the hand width. The safety factors take into account the acceleration forces and additional stresses that could be applied due to extra weight on top of the equipment when being lifted. The safety factor is less at the higher weight (MS3) because the equipment would be lifted more slowly, reducing the acceleration force, and there is less probability that extra weight would be added before lifting, as this would exceed the normal weight to be lifted by one person without assistance of a **tool**. Equipment classed as MS1 with more than one handle could be used to support additional objects when being carried and should be tested.

8.8.2 Test method ~~and compliance criteria~~

Rationale: There is no test for MS1 with only one handle. Having 2 handles facilitates transporting the equipment while carrying additional objects adding stress to the handles.

8.9 Wheels or casters attachment requirements

Purpose: To verify that wheels or casters are securely fixed to the equipment.

Source: UL 1667

Purpose: For wheel size, reduce the likelihood of the equipment on the cart or stand tipping while being moved from room to room where the wheels may encounter a variety of obstacles, such as: friction of different surfaces (for example, transition from a hard surface over carpet edging), cables, and doorway sills.

Rationale: The 100 mm min wheel size was found to be adequate to enable rolling over these obstacles without abruptly stopping that could cause the cart or stand to tip, or the equipment located on the cart or stand to slide off.

8.10 Carts, stands, and similar carriers

Source: UL 60065

Rationale: To avoid tipping, the 20 N test simulates cart wheels being unintentionally blocked during movement.

8.10.1 General

Source: IEC 60065

Rationale: A wheel of at least 100 mm diameter can be expected to climb over usual obstacles such as electrical cords, door jams, etc., and not be halted suddenly.

8.10.2 Marking and instructions

Rationale: Various means of marking may apply depending on the method of associating the equipment with a particular cart, stand of similar carrier.

8.10.3 Cart, stand or carrier loading test and compliance criteria

Source: IEC 60065

Purpose: To verify that a cart or stand can withstand foreseeable overloading without creating a hazardous situation.

Rationale: The 220 N force simulates the weight of a small child approximately 5 years of age, who may attempt to climb onto the cart or stand. The 30 mm circular cylinder simulates a child's foot. The 750 mm height is the approximate access height of the 5-year-old child. The additional 440 N force test simulates potential additional materials or equipment being placed on the cart or stand. The additional 100 N simulates overloading by the user. Testing has been limited to 1 min as experience has shown that the likelihood of a test failure will occur within that time.

8.10.4 Cart, stand or carrier impact test

Purpose: To verify that a cart or stand can withstand a foreseeable impact without creating a hazardous situation.

Source: IEC 60065 and IEC 60950 series

Rationale: The 7 joules simulate intentional and accidental contact with the equipment and come from the T.6 **enclosure test**.

8.10.5 Mechanical stability

Purpose: To verify that a cart or stand remains stable under specified loading. The equipment installed on the cart may come loose, but not fall off the cart.

Rationale: The weight of the force test is reduced to 13 % should the equipment on the cart or stand move, as the equipment would then be considered separately from the cart or stand. When the equipment does not move during the force test, together they are considered a single unit.

8.10.6 Thermoplastic temperature stability

Source: IEC 60065 and IEC 60950-1

Rationale: Intended to prevent shrinkage, relaxation or warping of materials that could expose a hazard.

8.11 Mounting means for ~~rack~~ slide-rail mounted equipment (SRME)

8.11.1 General

Source: UL/CSA 60950-1:~~2005~~ second edition

Rationale: The potential hazardous energy source is a product that contains significant mass, and which is mounted on slide-rails in a rack. A joint US/Canadian Adhoc researched and developed these requirements based on hazard-based assessment and tests.

The center of gravity was chosen to apply the downward force because in general, when installing equipment in a rack, it is foreseeable that previously installed equipment of similar size/mass may be pulled out into the service position (fully extended) and used to set the new equipment on while positioning and installing the new slide/rails. In this scenario, it is not likely that the new equipment would be significantly off-centre from the installed equipment that it is being set on.

Vertically mounted SRMEs are not addressed in this document.

8.11.3 Mechanical strength test

Purpose: To simulate temporary placement of another server on top of an existing one during installation of the new one. So the test is the downward force.

Rationale: 50 % of the equipment mass is derived from the mass of the equipment, and a 50 % tolerance allowed for manufacturing differences in the rails which effectively adds a safety buffer.

The 330 N to 530 N additional force accounts for equipment that is about to be installed in a rack being placed or set on a previously installed piece of equipment where the previously installed equipment is being used as a temporary shelf or work space. It is estimated that 530 N is the maximum mass of equipment allowed to be safely lifted by two persons without the use of mechanical lifting devices. Equipment having a mass greater than 530 N will have mechanical lifting devices and it is therefore unlikely that the equipment being installed will be set on any equipment previously installed in the rack.

Taking the actual installation environment into consideration, an additional force is limited to maximum 800 N (average weight of an adult man) that is same value as the downward test force in 8.6.2.3. The 800 N value comes from IEC 60950-1:2005, 4.1 Stability.

~~8.11.4 Mechanical strength test, 250 N, including end stops~~

8.11.3.2 Lateral push force test

8.11.3.3 Integrity of slide rail end stops

Source: UL/CSA 60950-1:~~2005~~ second edition

Purpose: To simulate maintenance on the server itself, by smaller applying forces equivalent to what is expected during subassembly and card replacement, etc. So this also tests the laterally stability of the slide rails. It is not necessary to retest the downward vertical force if it is already tested for 8.11.3, but that should be common sense when preparing a test plan.

The cycling of the slide rail after the tests ensures they have not been bent in a way that could easily fly apart after the service operation.

Rationale: The 250 N force is considered a force likely to be encountered during servicing of the equipment, and normal operations around equipment. The force is partially derived from the existing IEC 60950-1:2005, 4.1, and partially from research into normally encountered module plug forces seen on various manufacturers' equipment. The application of force at the most unfavourable position takes into account the servicing of a fully extended piece of equipment, leaning on or bumping into an extended piece of equipment and other reasonably foreseen circumstances which may be encountered.

9 Thermal burn injury

9.1 General

Source: ISO 13732-1:2006 and IEC Guide 117

Rationale: **A General**

A burn injury can occur when thermal energy is conducted to a body part to cause damage to the epidermis. Depending on the thermal mass of the object, duration of contact and exposure temperature, the body response can range from perception of warmth to a burn.

The energy transfer mechanism for equipment typically covered by the document is via conduction of thermal energy through physical contact with a body part.

The likelihood of thermal injury is a function of several thermal energy parameters including:

- temperature difference between the part and the body;
- the thermal conductivity (or thermal resistance) between the hot part and the body;
- the mass of the hot part;
- the specific heat of the part material;
- the area of contact;
- the duration of contact.

B Model for a burn injury

A skin burn injury occurs when thermal energy impinges on the skin and raises its temperature to a level that causes cell damage. The occurrence of a burn will depend on several parameters. The hazard based three block model applied to the occurrence of a burn (see Figure 38 in this document) takes account of not just the temperature of the source, but its total thermal energy, which will depend on its temperature (relative to the skin), as well as its overall heat capacity. The model also takes account of the energy transfer mechanism, which will depend on the thermal conductivity between the body and the thermal source as well as the area and duration of contact. The occurrence and severity of a burn will depend on the amount of thermal energy transferred.

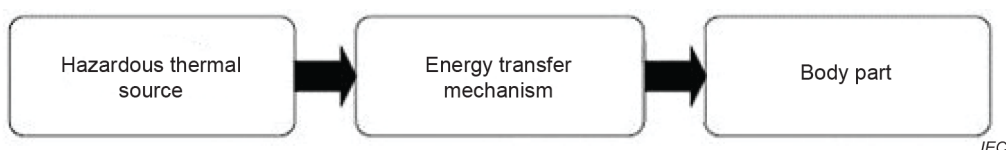


Figure 38 – Model for a burn injury

Normally, the energy transfer mechanism from the energy source to a body part is through direct contact with the body part and sufficient contact duration to allow transfer of thermal energy causing a burn. The higher the temperature of the thermal source and the more efficient the transfer mechanism, the shorter the contact time becomes before the occurrence of a burn. This is not a linear function and it is dependent on the material, the temperature and the efficiency of the thermal transfer. The following examples demonstrate the impact of this non-linear relationship to short-term/high temperature and longer term/lower temperature contact burns.

Example 1: An **accessible** metal heat sink at a temperature of 60 °C may have sufficient energy to cause a burn after contact duration of about 5 s. At a temperature of 65 °C, a burn may occur after contact duration of just 1,5 s (see IEC Guide 117:2010/2017, Figure A.1). As the temperature of the metal surface increases, the contact time necessary to cause a burn decreases rapidly.

Example 2: Consider a thermal source with low to moderate conductivity such as a plastic **enclosure**. At a temperature of 48 °C, it may take up to 10 min for the transfer of sufficient thermal energy to cause a burn. At 60 °C, a burn may occur after contact duration of just 1 min (see IEC Guide 117:2010, Table A.1). Although the temperature of the source has increased by just 25 %, the contact time necessary to cause a burn threshold has decreased by 90 %.

In practice, the actual thermal energy and duration of exposure required to cause a burn will also depend on the area of contact and condition of the skin. For simplification of the model and based upon practice in the past, it is assumed that the contact area will be ≤ 10 % of the body and applied to healthy, adult skin.

As a general rule, low temperature devices are likely to cause a heating or pain sensation before causing a significant burn to which **ordinary persons** will normally respond (see ISO 13732-1:2006/2009, Note of 5.7.3). Requirements for persons with impaired neurological systems are not considered in this document but may be considered in the future.

NOTE 1 The impact of surface area contact is not being addressed in this paper at this time and is an opportunity for future work. Use and coverage of large contact areas as might occur in medical applications of heating pads covering more than 10 % of the body surface are outside the scope of this document, as this type of application is more appropriate to medical device publications.

NOTE 2 The pressure of the contact between the thermal source and the body part can have an impact on the transfer of thermal energy. Studies have shown this effect to have appreciable impact at higher pressures. For typical pressures associated with casual contact up to a pressure of 20 N the effect has been shown to be negligible, and thus contact pressure is not considered in this document (Ref: ATSM C 1055, X1.2.3.4, ASTM C 1057, Note 10).

NOTE 3 Considerations for burns generated by infrared (IR), visible, ultra violet light radiation and RF radiation sources are outside the scope of Clause 9 dealing with thermal burn injury.

C Types of burn injuries

Burn injuries are commonly classed as first degree, second degree or third degree in order of increasing severity:

First degree burn: the reaction to an exposure where the intensity or duration is insufficient to cause complete necrosis of the epidermis. The normal response to this level of exposure is dilation of the superficial blood vessels (reddening of the skin). No blistering occurs. (Reference: ASTM C1057)

Second degree burn: the reaction to an exposure where the intensity and duration is sufficient to cause complete necrosis of the epidermis but no significant damage to the dermis. The normal response to this exposure is blistering of the epidermis. (Reference: ASTM C1057)

Third degree burn: the reaction to an exposure where significant dermal necrosis occurs. Significant dermal necrosis with 75 % destruction of the dermis is a result of the burn. The normal response to this exposure is open sores that leave permanent scar tissue upon healing. (Reference: ASTM C1057)

ISO 13732-1:2006, 3.5 classifies burns as follows:

Superficial partial thickness burn – In all but the most superficial burns, the epidermis is completely destroyed but the hair follicles and sebaceous glands as well as the sweat glands are spared.

Deep partial thickness burn: a substantial part of the dermis and all sebaceous glands are destroyed and only the deeper parts of the hair follicles or the sweat glands survive.

Whole thickness burn: when the full thickness of the skin has been destroyed and there are no surviving epithelial elements.

Although there is some overlap between the classifications in ASTM C1057 and those in IEC Guide 117, the individual classifications do not correspond exactly with each other. Further, it should be noted that the classifications of burns described here is not intended to correspond with the individual thermal source classifications (TS1, TS2, and TS3) described later in this document.

D Model for safeguards against thermal burn injury

To prevent thermally-caused injury, a **safeguard** is interposed between the body part and the energy source. More than one **safeguard** may be used to meet the requirements for thermal burn hazard protection.



Figure 39 – Model for safeguards against thermal burn injury

To prevent thermally-caused injury, a **safeguard** is interposed between the body part and the energy source (see Figure 39 in this document). More than one **safeguard** may be used to meet the requirements for thermal burn hazard protection.

Safeguards overview

This section shows examples of the different types of **safeguards** that may be applied:

a) Thermal hazard not present

The first model, in Figure 40 in this document, presumes contact to a surface by an **ordinary person** where a thermal hazard is not present. In this case, no **safeguard** is required.



Figure 40 – Model for absence of a thermal hazard

b) Thermal hazard is present with a physical safeguard in place

The second model, see Figure 41 in this document, presumes some contact with a surface by an **ordinary person**. The thermal energy source is above the threshold limit value for burns (Table 38 of IEC 62368-1:2014/2018), but there are **safeguards** interposed to reduce the rate of thermal energy transferred such that the surface temperature will not exceed the threshold limit values for the expected contact durations. Thermal insulation is an example of a physical **safeguard**.

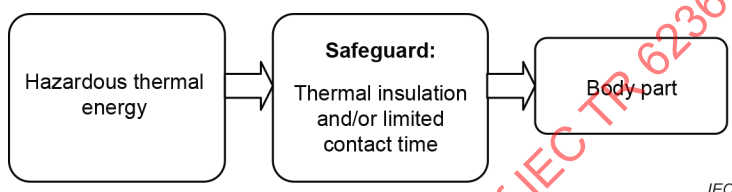


Figure 41 – Model for presence of a thermal hazard with a physical safeguard in place

c) Thermal hazard is present with a behavioural safeguard in place

The third model, see Figure 42 in this document, presumes the possibility of some contact to the thermal source or part by an **ordinary person**. The temperature is above the threshold limit value but the exposure time is limited by the expected usage conditions or through instructions to the user to avoid or limit contact to a safe exposure time. The contact time and exposure will not exceed the threshold limit value. An additional **safeguard** may not be required.



Figure 42 – Model for presence of a thermal hazard with behavioural safeguard in place

9.2 Thermal energy source classifications

Rationale: Surfaces that may be touched are classified as thermal energy sources TS1, TS2 or TS3 with TS1 representing the lowest energy level and TS3 the highest. The classification of each surface will determine the type of **safeguards** required.

The assessment of thermal burn hazards is complex and, as discussed in the model for a burn injury above, involves several factors. Important aspects include the overall heat capacity of the source, its temperature relative to the body, thermal conductivity of the contact and others. To present a simple model for assessment of a given surface, it is assumed that the overall heat capacity and the thermal conductivity will remain constant.

Thus, thermal energy sources are classified in terms of the material of the surface, its relative temperature and duration of contact only. Usually, for a given material the temperature and duration of contact are likely to be the only significant variables when assessing the risk of a burn injury.

9.2.21 TS1

Rationale: The lowest thermal energy source is TS1. TS1 represents a level of thermal energy that generally will not cause a burn injury.

9.2.32 TS2

Rationale: A TS2 thermal energy source has sufficient energy to cause a burn injury in some circumstances. The occurrence of a burn from a TS2 source will largely depend on the duration of contact. Depending on the contact time, and contact area, contact material, and other factors, a TS2 source is not likely to cause an injury requiring professional medical attention. Table 38 of IEC 62368-2:2014 defines the upper limits for TS2 surfaces.

A TS2 circuit is an example of a class 2 energy source where the **basic safeguard** may, in some cases, be replaced by an **instructional safeguard**. Details are given in Table 38, footnote e.

9.2.43 TS3

Rationale: A TS3 thermal energy source has sufficient energy to cause a burn injury immediately on contact with the surface. There is no table defining the limits for a TS3 surface because any surface that is in excess of TS2 limits is considered to be TS3. Within the specified contact time, as well as contact area, contact material and other factors, a TS3 source may cause an injury requiring professional medical attention. As TS3 surfaces require that maximum level of **safeguard** defined in the document. All surfaces may be treated as TS3 if not otherwise classified.

Source: IEC Guide 117.

Rationale: When doing the temperature measurements, an ambient temperature is used as described in 9.2.5 to measure the temperatures without taking into account the maximum ambient specified by the manufacturer.

9.2.63 Touch temperature levels limits

Table 38 Touch temperature limits for accessible parts

Source: The limits in Table 38 are primarily derived from data in IEC Guide 117.

Rationale: The temperature of the skin and the duration of raised temperature are the primary parameters in the occurrence of a skin burn injury. In practice, it is difficult to measure the temperature of the skin accurately while it is in contact with a hot surface. Thus the limits in Table 38 do not represent skin temperatures. These limits do represent the surface temperatures that are known to cause a skin burn injury when contacted for greater than the specified time limit.

The thermal energy source criterion takes account of the temperature of the source, its thermal capacity and conductivity as well as the likely duration and area of contact. As the thermal capacity and conductivity will normally remain constant for a given surface, the limits here are expressed in degrees C for typical material types and contact durations.

Contact time duration > 8 h

For devices worn on the body (in direct contact with the skin) in normal use (> 8 h), examples include portable, lightweight devices such as watches, headsets, music players and sports monitoring equipment. Since the values in the table do not represent skin temperature as indicated above, measurements should not be done while wearing the devices.

The value of 43 °C for all materials for a contact period of 8 h and longer assumes that only a minor part of the body (less than 10 % of the entire skin surface of the body) or a minor part of the head (less than 10 % of the skin surface of the head) touches the hot surface. If the touching area is not local or if the hot surface is touched by vital areas of the face (for example, the airways), severe injuries may occur even if the surface temperature does not exceed 43 °C (see IEC Guide 117).

NOTE Prolonged exposure to 43 °C may result in erythema (temporary redness of the skin causing dilation of the blood capillaries) which will typically go away within a few hours after removal of the heat source. For some users, this may be misperceived as a burn.

Contact time durations > 1 min

For very long-term contact (> 10 min), the temperature below which a burn will not occur converges towards 43 °C for most materials (see IEC Guide 117:2010, Figure A.1). Studies carried out on portable IT Equipment have shown that for long term contact, a surface temperature will drop by between 5 °C and 12 °C when in contact with the body due to the cooling effect of the blood circulation. On this basis, and taking account of the probability that long-term contact will normally be insulated by clothing or some other form of insulation, the TS1 temperature limit for contact periods greater than 1 min in Table 38 are conservatively chosen as 48 °C for all materials.

Examples of products with surfaces where expected continuous contact durations greater than 1 min include joysticks, mice, mobile telephones, and PDAs. Any handles, knobs or grips on the equipment that are likely, under normal usage, to be touched or held for greater than 1 min are also included.

Contact time durations between 10 s and 1 min

For surfaces that are touched for shorter contact durations (up to 1 min), the temperature below which a burn will not occur is influenced by the material type as well as other factors. Because the contact time is shorter, there is insufficient time for heat transfer to cause the cooling effect described above, so it is not considered in the limits. The TS1 temperature limits in Table 38 for contact durations up to 1 min are taken directly from IEC Guide 117:2010, Table A.1.

Examples of surfaces with contact durations up to 1 min include handles or grips used primarily for moving or adjusting the equipment. Also tuning dials or other controls where contact for up to 1 min may be expected.

Contact time durations up to 10 s

Even shorter-term contact may occur for surfaces such as push button/switch, volume control; computer or telephone keys. In this case, the surfaces will not normally be touched for a duration greater than 10 s. The TS1 temperature limits in Table 38 for these surfaces are based on the burn threshold limits in IEC Guide 117 for contact durations of up to 10 s.

For surfaces that are **accessible** but need not be touched to operate the equipment, contact duration of up to 1 s is assumed. For healthy adults, a minimum reaction time of 0,5 s can be assumed. For more general applications, the reaction time increases to 1 s IEC Guide 117:2010, Table 2. The TS1 temperature limits in Table 37 38 for these surfaces are based on the burn threshold limits in Guide 117 for contact durations of 1 s (see IEC Guide 117:2010, Figures A.1 – A.6). More conservative values than those in IEC Guide 117 are chosen for metal and glass to provide some margin against a reduced reaction time while in contact with a high thermal energy surface of high thermal conductivity.

Examples of such parts include general **enclosure** surfaces, **accessible** print heads of dot matrix printers or any internal surfaces that may be **accessible** during routine maintenance. Accidental contact, with no intention to hold or contact the surface is also included.

For contact durations between 1 s and 10 s, IEC Guide 117 provides temperature ranges over which a burn may occur rather than precise limits. This takes account of the uncertainty that applies to the occurrence of burn injury over shorter periods. The texture of the surface can also be a factor in the occurrence of a burn and this is not taken into account in the limits in IEC Guide 117. As most surfaces in IT equipment will have some texturing, values at the higher end of the spreads have been chosen.

Other considerations

In the event of a fault condition arising, the user is less likely to touch the equipment and any contact with **accessible** surfaces is likely to be very brief. Thus higher limits than those allowed under IEC Guide 117 are permitted. For metal, glass and plastic surfaces, the limit is 100 °C (IEC 60065:2014 2010, Table 3). For wood, a temperature of 150 °C was chosen because 100 °C would be lower than the normal temperature of 140 °C.

When contact with a TS1 surface is unlikely due to its limited size or accessibility, a temperature up to 100 °C is acceptable if an **instructional safeguard** is provided on the equipment (see IEC 60950-1:2005, Table 4C, IEC 60065:2014 2001, Table 3).

In the case where a surface is hot in order to carry out its function, the occurrence of contact with the surface or a subsequent burn injury is unlikely if the user is made aware that the surface is hot. Thus, a temperature up to 100 °C or higher is acceptable if there is an effective **instructional safeguard** on the body of the equipment indicating that the surface is hot (see IEC 60950-1:2005, Table 4C and IEC 60065:2014 2001, Table 3).

Factors for consideration in determining test conditions

For consistency with other parts of the document and to reflect typical user conditions, the ambient conditions described in B.1.6 apply.

Assessment of **safeguards** should be carried out under **normal operating conditions** of the product that will result in elevated surface temperatures. The chosen **normal operating conditions** should be typical of the manufacturer's intended use of the product while precluding deliberate misuse or unauthorized modifications to the product or its operating parameters by the user. For some simple equipment, this will be straightforward. For more complex equipment, there may be several variables to be considered including the typical usage model. The manufacturer of the equipment should perform an assessment to determine the appropriate configuration.

Example: Factors that may be considered in determining the test conditions for a notebook computer:

- Mode of operation
 - Variable CPU speed
 - LCD brightness
- Accessories installed:
 - Number of disk drives
 - USB devices
 - External HDD
- Software installed:
 - Gaming applications
 - Duration of continuous use
 - Long term contact likely?
 - Other specialist applications
- **Battery** status:
 - Fully charged/ Discharged
 - AC connected

9.3.1 Touch temperature limit requirements

Rationale: Table 38 provides touch temperature limits for **accessible** parts, assuming steady state. IEC Guide 117 provides the methodology to assess products with changing temperatures or small parts which are likely to drop in temperature upon touch. Using a thermesthesiometer for a specified time interval, the thermesthesiometer simulates the skin temperature of human finger and heating effects caused by contact with the product surface under test. Once contact is made, the thermesthesiometer and product under test will eventually reach thermal equilibrium at which point finger skin temperature can be determined.

Background: The touch limits from Table 38 for > 1 s and < 10 s may be used for small hand-held devices with localized hotspots, given a small thermal energy source and touching can be easily avoided by changing holding position of the device.

This same rationale would also apply to small multi-media peripherals which are removed from a host device (for example, USB memory stick, PCMCIA cards, SD card, Compact Flash card, ejectable media, etc.). In many cases, these peripherals may be removed from their host (for example, power source) exposing higher thermally conductive materials (for example, metals), but are in thermal decay (i.e. no longer powered).

In cases of doubt, the method in IEC Guide 117 may be used for steady-state conditions. An example of a simplified method for thermally decaying parts is provided as a reference:

Touch temperature limits in IEC Guide 117 are based on time-weighted exposure for burn (for example, thermal energy). As long as integrated thermal energy calculations (for example, area of temp vs. time) of the part at specified time intervals is less than the associated integrated thermal energy calculated limits over that duration, the measured temperatures should be acceptable.

The most significant time intervals to consider for decaying thermal energy is between 1 s to 10 min (using 10 s, 1 min, 10 min intervals).

- For exposure times < 1 s, the 1 s temperature limits of the IEC Guide 117 should be used for 2 reasons: 1) Reaction times – under general applications reaction times of < 1 s are not probable and greatest risk of burn. 2) Repeatability – temperature measurement capability < 1 s intervals is less common and more difficult to accurately calculate the part energy.
- For exposure times > 10 min, the temperature limits of IEC Guide 117 should be used: after 10 min parts should either have cooled or reach sufficient equilibrium to utilize the temperature limits without the need for assessing thermal energy.

This simplified method requires the part under test to be mounted using thermally insulating clamp. Clamp to the part's least thermally conductive material and smallest contact needed to hold the part. Measured in still-air room ambient.

NOTE Parts that are hand-held will decay faster than open-air measurements (for example, radiation and convection) owing to direct conduction of heat to skin.

9.3.2 Test method and compliance criteria

Rationale: The general intent of the requirements are to use an ambient temperature as follows without taking into account the maximum ambient specified by the manufacturer:

- The test may be performed between 20 °C and 30 °C.
- If the test is performed below 25 °C, the results are normalized to 25 °C.
- If the test is performed above 25 °C, the results are not normalized to 25 °C and the limits (Table 38) are not adjusted. In case the product fails the requirements, the test may be repeated at 25 °C.

9.3.4 Safeguards against thermal energy sources

Rationale: TS1 represents non-hazardous energy and thus, no **safeguard** is required. Because the energy is non-hazardous, and there is no possibility of an injury, it may be **accessible** by **ordinary persons** and there is no restriction on duration of contact under **normal operating conditions**.

TS2 represents hazardous energy that could cause a burn injury if the contact duration is sufficient. Therefore, a **safeguard** is required to protect an **ordinary person**. A TS2 surface will not cause a burn immediately on contact. Because the burn injury from a TS2 surface is likely to be minor and pain or discomfort is likely to precede the occurrence of a burn injury, a physical **safeguard** may not be required if there is an effective means to inform the **ordinary person** about the risks of touching the hot surface.

Thus, a TS2 **safeguard** may be one of the following:

- a physical barrier to prevent access; or
- an **instructional safeguard** to limit contact time below the threshold limit value versus time.

TS3 represents hazardous energy that is likely to cause a burn injury immediately on contact. Because a TS3 surface is always likely to cause a burn immediately or before the expected reaction time due to pain or discomfort, an **equipment safeguard** is required.

Unless otherwise specified in the document, **ordinary persons** need to be protected against all TS2 and TS3 energy sources.

Instructed persons are protected by the supervision of a **skilled person** and can effectively employ **instructional safeguards**. Thus, **equipment safeguards** are not required for TS2 energy sources. An **instructional safeguard** may be required.

TS3 energy sources can cause severe burns after very short contact duration. Thus, an **instructional safeguard** alone is not sufficient to protect an **instructed person** and an **equipment safeguard** is required.

Skilled persons are protected by their education and experience and are capable of avoiding injury from TS3 sources. Thus, an **equipment safeguard** is not required to protect against TS3 energy sources. As a pain response may cause an unintentional reflex action even in **skilled persons**, an equipment or **instructional safeguard** may be required to protect against other class 3 energy sources adjacent to the TS3 energy source.

9.45.1 Equipment safeguard

Rationale: The function of the **equipment safeguard** is to limit the transfer of hazardous thermal energy. An **equipment safeguard** may be thermal insulation or other physical barrier.

9.45.2 Instructional safeguard

Rationale: An **instructional safeguard** will inform any person of the presence of hazardous thermal energy. **Instructional safeguards** may be in a text or graphical format and may be placed on the product or in the user documentation. In determining the format and location of the **safeguard**, consideration will be given to the expected user group, the likelihood of contact and the likely nature of the injury arising.

9.6 Requirements for wireless power transmitters

Rationale: Transmitters for near-field **wireless power transfer** can warm up foreign metallic objects that may be placed close to or on such a transmitter. To avoid burn due to high temperatures of the foreign metallic objects, the transmitter is tested as specified in 9.6.3.

Far-field transmitters are generally called "power-beaming" and are not covered by these requirements.

9.6.3 Test method and compliance criteria

Rationale: While 9.6.3 specifies a maximum temperature of 70 °C, aluminum foil that reaches 80 °C is considered to comply with the requirement. The foil described in figure 49 complies with the method allowed in 9.3.1 based on the foil dimensions and low mass.

This requirement is expected to align with the current Qi standard.

10 Radiation

10.1 General

~~Rationale: UV radiation can affect the physical properties of thermoplastic materials and so it can have a consequential effect on components protecting body parts from a range of injurious energy sources (see Table 16 in this technical report).~~

Table 16 — Protection against radiation

Energy source	Prevention / safeguards
Non-ionising radiation irradiating persons	Limit exposure of persons to radiation
Ionising radiation irradiating persons	Limit exposure of persons to radiation
Ultraviolet (UV) radiation irradiating parts, the failure of which could result in an injury	Limit exposure of materials sensitive to UV radiation or require materials that are resistant to UV exposure
Acoustic radiation	Limit exposure of persons to acoustic radiation by the use of safeguards

10.2 Radiation energy source classifications

Rationale: The first step in application is determining which energy sources represent potential radiation energy sources. Each energy source within the product can be classified as a radiation source based on the available energy within a circuit that can be used to determine the type of and number of **safeguards** required. The radiation energy source classifications include electromagnetic radiation energy sources.

10.2.1 General classification

Rationale: Radiation energy source classifications for X-rays and acoustics are given in Table 39. For optical radiation ("Lasers" and "Lamps and lamp systems"), the classification is defined by the IEC 60825 series or the IEC 62471 series as applicable.

The general classification scheme specified in IEC 60825-1 is for laser products and is not a classification scheme for energy sources. It is not practical to classify laser radiation as RS. The classification according to IEC 60825-1 is used without modification.

The classification schemes given in IEC 62471 and IEC 62471-5 specify a measurement distance (200 mm other than lamps intended for general lighting service and 1m for Image projectors) for the determination of the Risk Group. The Risk Group classification is not the actual source of the light. It is not practical to classify the radiation from lamps and lamp systems as RS. The classification according to IEC 62471 is used without modification.

Abnormal operating conditions (see Clause B.3) and **single fault conditions** (see Clause B.4) need to be taken into account. If it becomes higher risk group when **abnormal operating condition** or **single fault condition** is applied, the higher risk group is applied for classification.

Laser equipment classified as Class 1C is generally not within the scope of this document as it mainly applies to medical related applications.

Source: IEC 60825-1:2014 and IEC 62471-5

Rationale: Image Projectors are evaluated using the process in Figure 43 in this document (see IEC 60825-1:2014 and IEC 62471-5).

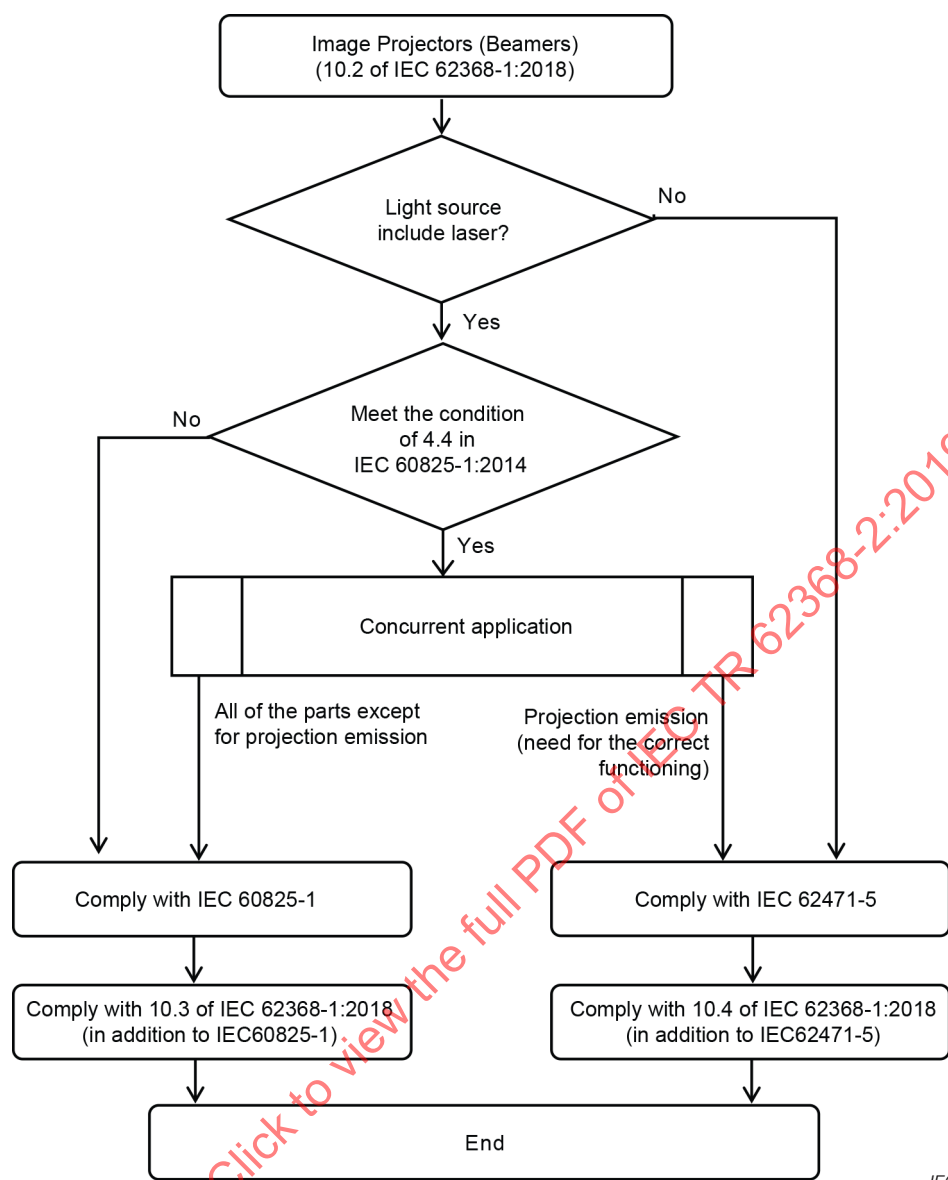


Figure 43 – Flowchart for evaluation of Image projectors (beamers)

10.2.2 & 10.2.3 RS1 and RS2

Rationale: The output circuits of personal music players are not subject to **single fault conditions**, since the outputs will not increase to a level exceeding RS2 by nature of their highly integrated hardware designs. Typically, when component faults are introduced during testing (by bypassing or shorting of the audio related ICs), the outputs are either shut down, reduced in level or muted.

~~Table 39 – Radiation energy source classifications~~

~~Line 2 – Lamps and LED's~~

~~**Rationale:** A review of IEC 62471 shows that there are only RS1 or RS3 type energy sources and therefore, there are no requirements for RS2 type energy sources in this subclause for LED's.~~

10.2.4 RS3

Rationale: RS3 energy sources are those that are not otherwise classified as RS1 or RS2. No classification testing is required as these energy sources can have unlimited levels. If an energy source is not measured, it assumed to be RS3 for application of the document. A **skilled person** uses personal protective equipment or measures to reduce the exposure to safe limits when working where RS3 may be present.

10.3 Safeguards against laser radiation

10.3.1 Requirements

~~Source: IEC 60825-1 and IEC 60825-2~~

~~Rationale: Laser radiation may cause burn hazards or could start a fire. The limits for the relevant laser classes apply. These requirements are also valid for optical communications systems (by optical fibre or free space).~~

~~Warning labels or explanatory labels are necessary for laser classes 2, 3 and 4. The labelling is defined according to the laser power levels in IEC 60825-1 and IEC 60825-2.~~

~~Laser Class 3B, class 3R and class 4 are considered to be RS3.~~

~~Laser diodes are checked according to IEC 60825-1:2007.~~

Source: IEC 60825-1:2014, Annex A

Rationale: IEC 60825-1:2014, Annex A provides an explanation of the different classes of products. **Accessible** emission limits (AELs) are generally derived from the maximum permissible exposures (MPEs). MPEs have been included in this informative annex to provide manufacturers with additional information that can assist in evaluating the safety aspects related to the intended use of their product, such as the determination of the nominal ocular hazard distance (NOHD).

10.4 Safeguards against ~~visible, infra-red, and ultra-violet~~ optical radiation from lamps and lamp systems (including LED types)

Source: IEC 62471 and IEC TR 62471-2

Rationale: Excessive optical radiation may damage the retina and cause vision impairment or blindness. The limits in the referenced documents are designed to reduce the likelihood of vision impairment due to optical radiation sources.

~~For the purpose of this standard, opaque is the term to describe a material that reduces the intensity of UV, infra-red and visible radiation to RS1 levels.~~

For the **Instructional safeguard** for lamps and lamp systems, see IEC TR 62471-2.

10.4.1 General Requirements

Source: IEC 60065

Rationale: The term 'Electronic light effect equipment' has been used in IEC 60065 (see 1.1) and is a commonly understood term for entertainment/stage effect lighting.

10.5 Safeguards against X-radiation

Source: IEC 60950-1; IEC 60065

Rationale: Exposure to X-radiation will cause injury with excessive exposure over time. The limits in this document have been selected from IEC 60950-1 and IEC 60065 in order to limit exposure to that which is below harmful levels.

10.6 Safeguards against acoustic energy sources

Source: EN 60065:2002/A11:2008

Rationale: The requirements of this subclause are made to protect against hearing loss due to long term exposure to high sound pressure levels. Therefore, the requirements are currently restricted to those kinds of products that are designed to be body-worn (of a size suitable to be carried in a clothing pocket) such that a user can take it with them all day long to listen to music (for example, on a street, in a subway, at an airport, etc.).

At this moment, the clause does not contain requirements against the hazard of short term exposure to very high sound pressure levels.

Rationale: Significance of $L_{Aeq,T}$ in EN 50332-1 and additional information

$L_{Aeq,T}$ is derived from the general formula for equivalent sound pressure:

$$L_{eq} = 10 \log \left[\frac{1}{t_2 - t_1} \int_{t_1}^{t_2} \frac{p_A^2}{p_0^2} dt \right]$$

This can be represented graphically as given in Figure 44 in this document.

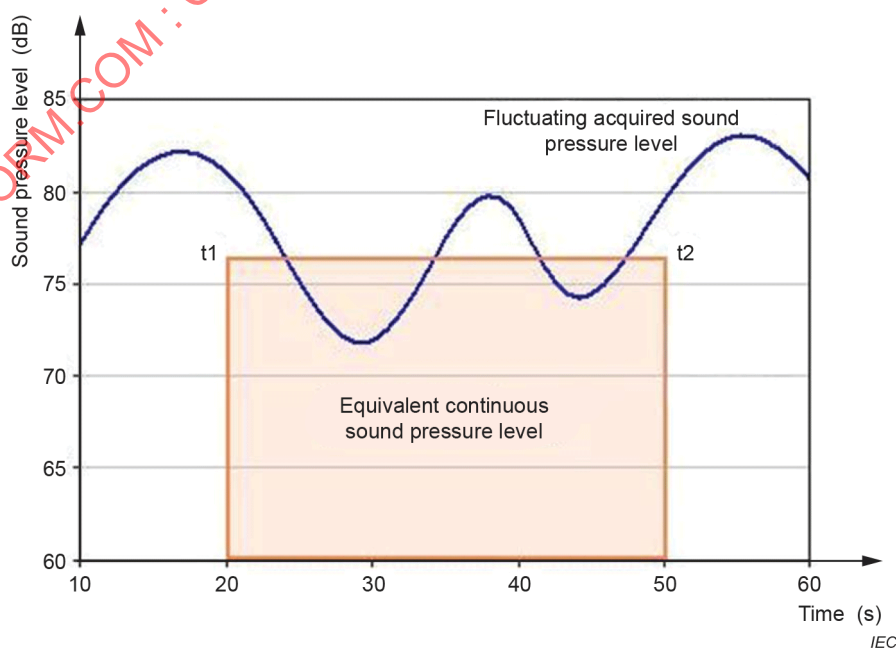


Figure 44 – Graphical representation of $L_{Aeq,T}$

In EN 50332-1 the measurement time interval ($t_2 - t_1$) is 30 s.

In practice, and for the purposes of listening to personal music player content, $L_{Aeq,T}$ has a time interval T ($t_2 - t_1$) in the order of minutes / hours and not seconds.

Subclause 6.5 (Limitation value) of EN 50332-1:2000 acknowledges this fact and states that the 100-dB limit equates to a long time average of 90 dB $L_{Aeq,T}$. By using the IEC 60268-1 "programme simulation noise" test signal, this also takes the spectral content into account.

The SCENHIR report states that 80 dB(A) is considered safe for an exposure time of 40 h/week. Most persons do not listen to 40 h/week to their personal music player. In addition, not all music tracks are at the same level of the simulated noise signal. Whilst modern music tends to be at around the same level, most of the available music is at a lower average level. Therefore, CLC TC 108/WG03 considered a value of 85 dB(A) to be safe for an overwhelming majority of the users of personal music players.

10.6.3 Requirements for dose-based systems

Rationale: The requirements on dose measurement have been developed to replace the requirements on maximum exposure as this better protects against hearing damage, which results from the combination of exposure and time (dose). For now, both systems can be used. See Table 16 in this document for a comparison.

The dose-based system mainly uses the expression CSD, meaning "calculated sound dose". The value is based on the values mentioned in the EU Commission Decision 2009/490/EC, which stipulated that sound is safe when below 80 dB(A) for a maximum of 40 h per week. Therefore, the value of 100 % CSD corresponds to 80 dB(A) for 40 h. This also means that the safe limit in the dose measurement system is chosen to be lower than the safe limit in the maximum exposure system, as this specifies the safe limit at 85 dB(A). Consequently, a user will normally receive warnings earlier with the dose measurement system compared to the maximum exposure limit. In the maximum exposure system, the warning only had to be given once every 20 h of listening when exceeding 85 dB(A). In the dose measurement system, the warning and acknowledgement has to be repeated at least at every 100 % increase of the dose. In practice, this means that the warning is repeated at a comparable level of 83 dB(A), meaning a dose that corresponds to listening to 83 dB(A) for 40 h. At each next 100 % increase of dose level, the increase in corresponding dB's is halved. Manufacturers have the freedom to give warnings earlier or ask for acknowledgement more frequently, but it has to be no later than at the next 100 % CSD increase since the last acknowledgement. For example, a device has provided the warning and acknowledgement at 100 % CSD. The manufacturer may choose to provide the next warning before 200 % CSD, for example, at 175 % CSD. If that is done, the next warning and acknowledgement may not be later than at 275 % CSD. While there are no requirements for manufacturers to warn users before the 100 % CSD is reached, it is allowed to do so. Even more, it was felt by the document writers that it would be responsible behaviour if manufacturers warn consumers about the risks before the 100 % CSD level is reached. With the maximum exposure measurement, the maximum allowable sound output is 100 dB(A). With the dosage system, only a momentary exposure limit (MEL) is required when exceeding 100 dB(A) if a visual or audible warning is provided. Where a visual or audible MEL is not provided the maximum exposure measurement of 100 dB(A) is required.

An essential element to educating the user and promoting safe listening habits is appropriate and useful guidance. This can be accomplished with informative CSD and MEL warnings that allow the user to understand the hazard, risks, and recommended action. Appropriate warnings about using the device and user instructions shall be provided. It should be noted that the CSD warning can be provided in various forms not limited to visual or audio. However, the MEL can only be provided visually or audibly. Consideration should be given to not over-message and annoy the user to the point where the message is neglected or evasive attempts (software hacks) to defeat the safe guards are taken. Extreme care should be given when implementing the MEL warning and shall be at the discretion of the manufacturer.

Manufacturers should be aware that digital sensitivity between PMP and unknown listening devices may result in excessive false positives. It is recommended industry to promote sharing of sensitivity data through a standardized means.

Table 16 – Overview of requirements for dose-based systems

	Devices with Visual or Audible MEL			EN 50332-3
	SPL before transition ³	SPL after transition ³	Dose requirements	Dose test method
Analog known ¹	> 85 dB(A) if ack, < 100 dB(A) max	< 80 dB(A) max	CSD warn at every 100 % MEL warn at > 100 dB(A)	cl 5.2
Analog unknown ²	> 27 mV r.m.s. if ack, < 150 mV r.m.s. max	< 15 mV rms max	CSD warn at every 100 % (= integrate. rms level 15 mV) MEL warn at > 150 mV r.m.s.	cl 5.3
Digital known ¹	> 85 dB(A) if ack, < 100 dB(A) max	< 80 dB(A) max	CSD warn at every 100 % MEL warn at > 100 dB(A)	cl 5.2
Digital unknown ²	> -25 dBFS if ack, < 100 dB(A) ⁴ max	< -30 dBFS max	CSD warn at every 100 % (= integrate level -30 dBFS) < 100 dB(A) max or MEL warn at > 100 dB(A) ⁴	TBD ⁵
	Devices without MEL			EN 50332-3
	SPL before transition ³	SPL after transition ³	Dose requirements	Dose test method
Analog known ¹	> 85 dB(A) if ack, < 100 dB(A) max	< 80 dB(A) max	CSD warn at every 100 % < 100 dB(A) max	cl 5.2
Analog unknown ²	> 27 mV r.m.s. if ack, < 150 mV r.m.s. max	< 15 mV r.m.s. max	CSD warn at every 100 % (= integrate rms level 15 mV) < 150 mV r.m.s. max	cl 5.3
Digital known ¹	> 85 dB(A) if ack, < 100 dB(A) max	< 80 dB(A) max	CSD warn at every 100 % < 100 dB(A) max	cl. 5.2

Digital unknown ²	> -25 dBFS if ack, < 100 dB(A) ⁴ max	< -30 dBFS max	CSD warn at every 100 % (= integrate level -30 dBFS) < 100 dB(A) ⁴ max	TBD ⁵
¹ PMP includes or can detect listening device ² PMP cannot detect listening device ³ Transition period allows migration to CSD before becoming mandatory ⁴ Defaults to 100 dB(A) gain cap from digital listening device. Need to develop industry wide protocol for digital (wired/wireless) listening device for PMPs to learn sensitivity lookup table. ⁵ Need to create test requirements with EN 50332-3. Otherwise, SPL requirements (30 dBFS gain cap) will be only feasible option.				

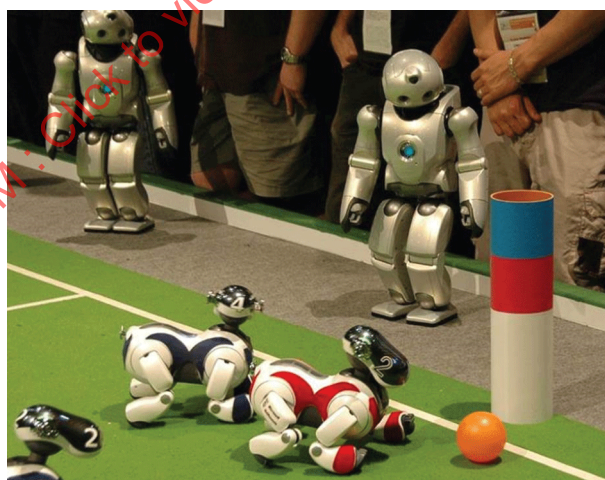
10.6.56.1 Corded ~~passive~~ listening devices with analogue input

Rationale: The value of 94 dB(A) was chosen to align with current practice in EN 50332. In addition, some equipment may already start clipping at 100 dB(A). The value used does not influence the result of the measurement.

Annex A Examples of equipment within the scope of this standard

Rationale: A variety of personal electronic entertainment products/systems can be covered by this document, including self-propelling types sometimes known as entertainment robots, which typically contain electronic components and circuits that power the device's motion, a **battery** system and charger, the electric motor(s) and control systems, together with wireless communications and audio. When no other IEC or ISO document explicitly covers these products, they can be accommodated by IEC 62368-1.

Examples of Entertainment-type Robots:



IEC

Annex B Normal operating condition tests, abnormal operating condition tests and single fault condition tests

General Equipment safeguards during various operating conditions

Purpose: To identify the various operating and use conditions of equipment that are taken into account in the document. This clause was proposed to be added to the document as a Clause 0.12, but was agreed to be added to the Rationale instead.

Rationale: Operating conditions

Normal operating condition – A **normal operating condition** is a state with intended functionality of the equipment. All equipment **basic safeguards**, **supplementary safeguards**, and **reinforced safeguards** remain effective and comply with all required **safeguard** parameters.

Abnormal operating condition – An **abnormal operating condition** is a temporary state. The equipment may have full, limited, or no functionality. The equipment generally requires operator intervention for restoration to **normal operating condition**. All equipment **basic safeguards** remain effective but may not need to comply with the required **safeguard** parameters. All equipment **supplementary safeguards** and **reinforced safeguards** remain effective and comply with the required **safeguard** parameters.

Upon restoration of **normal operating conditions**, all **basic safeguards** comply with the required parameters unless the **abnormal operating condition** leads to a **single fault condition**, in which case the requirements for **single fault condition** apply.

Reasonably foreseeable misuse condition – **Reasonably foreseeable misuse** is a form of an **abnormal operating condition** but may be either a temporary or a permanent state. The equipment may have full, limited, or no functionality. The equipment may not be capable of restoration to a **normal operating condition**. **Reasonably foreseeable misuse** may lead to a **single fault condition**, in which case equipment **basic safeguards** are not required to remain effective. All equipment **supplementary safeguards** and **reinforced safeguards** remain effective and comply with the required **safeguard** parameters.

Other misuse condition – Other misuse (unreasonable or unforeseeable) may lead to a **single or multiple fault condition**, in which **basic safeguards**, **supplementary safeguards** and **reinforced safeguards** may not remain effective. The equipment may not be repairable to a **normal operating condition**. **Safeguards** against unreasonable or unforeseeable misuse are not covered by this document.

Single fault condition – A **single fault condition** is a component or **safeguard** fault. The equipment may have full, limited or no functionality. The equipment requires repair to return to a **normal operating condition**. Equipment **basic safeguards** are not required to be functional, in this case the **supplementary safeguards** are functional and comply with the required **safeguard** parameters; or equipment **supplementary safeguards** are not required to be functional, in this case the **basic safeguards** are functional and comply with the required **safeguard** parameters.

NOTE As a **basic safeguard** and a **supplementary safeguard** may be interchangeable, the concept of which **safeguard** is not required to remain effective can be reversed.

B.1.65 Temperature measurement conditions

Source: IEC 60950-1

Purpose: To determine whether the steady state temperature of a part or material does or does not exceed the temperature limit for that part or material.

Rationale: Steady state is considered to exist if the temperature rise does not exceed 3 K in 30 min. If the measured temperature is less than the required temperature limit minus 10 %, steady state is considered to exist if the temperature rise does not exceed 1 K in 5 min.

Temperature rise follows an exponential curve and asymptotically approaches thermal equilibrium. The rate of temperature rise can be plotted as a function of time and used to guess the value at steady state. The actual steady state value needs to be accurate only to the extent to prove whether the value will exceed the limit or not.

Steady-state conditions of typical electronic devices have many different temperatures, so thermal equilibrium does not exist.

The resistance method may be used to measure temperature rises of windings unless the windings are non-uniform or if it is difficult to make the necessary connections, in which case the temperature rise is determined by other means.

When the resistance method is used, the temperature rise of a winding is calculated from the formula:

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

where:

Δt is the temperature rise of the winding;
 R_1 is the resistance at the beginning of the test;
 R_2 is the resistance at the end of the test;
 k is equal to:

- 225 for aluminium windings and copper/aluminium windings with an aluminium content ≥ 85 %;
- 229,75 for copper/aluminium windings with a copper content > 15 % to < 85 %;
- 234,5 for copper windings and copper/aluminium windings with an copper content ≥ 85 %;

t_1 is the room temperature at the beginning of the test;

t_2 is the room temperature at the end of the test.

NOTE It is recommended that the resistance of windings at the end of the test be determined by taking resistance measurements as soon as possible after switching off and then at short intervals so that a curve of resistance against time can be plotted for ascertaining the resistance at the instant of switching off.

B.2.3 Supply Voltage

Rationale: Where a test subclause does not require the most unfavourable supply voltage, the supply voltage is the value of the **rated voltage** or any value in the **rated voltage range**. This is applicable to the tests in **abnormal operation condition** and **single fault condition** as well.

B.2 – B.3 – B.4 Operating modes

See Figure 45 in this document for an overview of operating modes.

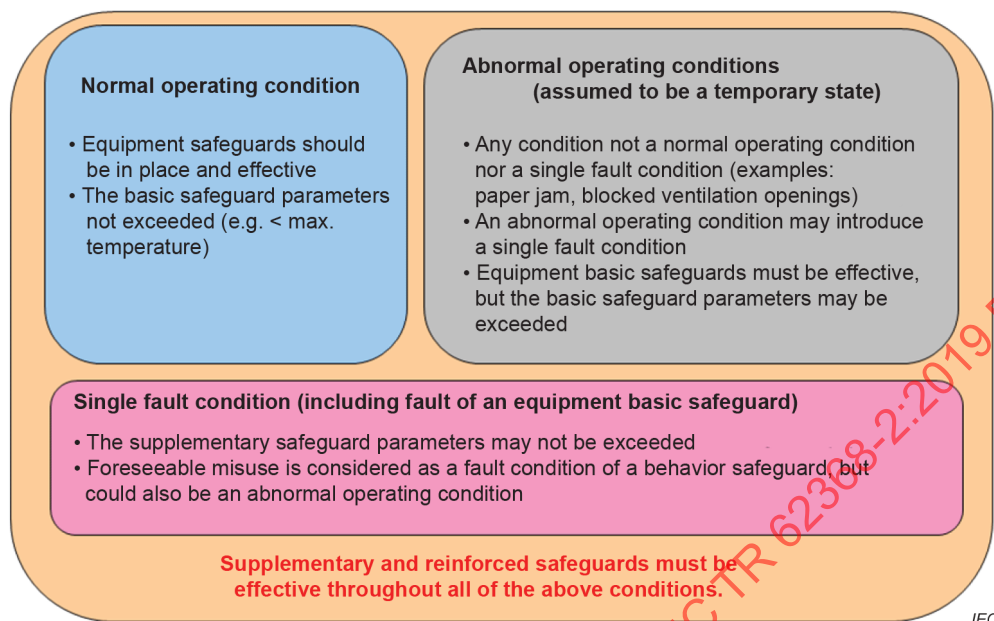


Figure 45 – Overview of operating modes

B.4.4 Functional insulation

Rationale: The use of a **functional insulation** is only acceptable when the circuit does not exceed its limits of its class under **normal operating conditions** and **abnormal operation conditions** and **single fault conditions** of a component not serving as a **safeguard** (see 5.2.1.1 and 5.2.1.2). Otherwise a **basic insulation/safeguard** would be required.

If the **functional insulation** possesses a certain quality (**clearance, creepage distances**, electric strength) comparable to a **basic safeguard**, it is acceptable to omit short-circuit.

This cannot be compared to the short-circuiting of a **basic safeguard** as required in B.4.1, because this **basic safeguard** is a required one, while the added quality of the **functional insulation** is not required.

If the short-circuiting of this **functional insulation** with added quality would lead to a changing of the class, the **functional insulation** was wrongly chosen, and a **basic safeguard** would have been required.

B.4.8 Compliance criteria during and after single fault conditions

Source: IEC 60065

Rationale: During **single fault conditions**, short term power is delivered in components which might be outside the specifications for that component. As a result, the component might interrupt. During the interruption, sometimes a small flame escapes for a short period of time. The current practice in IEC 60065 allows these short term flames for a maximum period of 10 s. This method has been successfully used for products in the scope of this document for many years.

Annex C UV Radiation

C.1.1 General

Rationale: UV radiation can affect the physical properties of thermoplastic materials and so it can have a consequential effect on components protecting body parts from a range of injurious energy sources.

Annex D Test generators

Source: ITU-T Recommendation K.44

Rationale: The circuit 1 surge in Table D.1 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.

Figure D.3 provides a circuit diagram for high energy impulse to test the high-pressure lamps.

Annex E Test conditions for equipment containing audio amplifiers

Source: IEC 60065:2014/2011

Rationale The proposed limits for touch voltages at terminals involving audio signals that may be contacted by persons have been extracted without deviation from IEC 60065:2014/2011, 9.1.1.2 a). Under **single fault conditions**, 11.1 of IEC 60065:2014/2011 does not permit an increase in acceptable touch voltage limits.

The proposed limits are quantitatively larger than the accepted limits of Table-5 and Table 6 4, but are not considered dangerous for the following reasons:

- the output is measured with the load disconnected (worst-case load);
- defining the contact area of connectors and wiring is very difficult due to complex shapes. The area of contact is considered small due to the construction of the connectors;
- normally, it is recommended to the user, in the instruction manual provided with the equipment, that all connections be made with the equipment in the “off” condition. ~~In this case we could consider the user as an instructed person.~~
- in addition to being on, the equipment would have to be playing some program at a high output with the load disconnected to achieve the proposed limits. Although possible, it is highly unlikely. Historically, no known cases of injury have been recorded for amplifiers with a non-clipped output less than 71 V RMS.
- the National Electrical Code (USA) permits **accessible** terminals with a maximum output voltage of 120 V RMS.

It seems that the current normal condition specified in IEC 60065 is appropriate and a load of 1/8 of the **non-clipped output power** should be applied to the multichannel by adjusting the individual channels.

Annex F Equipment markings, instructions, and instructional safeguards

F.3 Equipment markings

Source: EC Directives such as 98/37/EC Machinery Directive, Annex I clause 1.7.3 marking; NFPA 79:2002, clause 17.4 nameplate data; CSA C22.1 Canadian Electric Code, clause 2-100 marking of equipment give organized requirements. The requirements here are principally taken from IEC 60065 and IEC 60950 series.

F.3.3.2 Equipment without direct connection to mains

Source: IEC 60950-1

Purpose: To clarify that equipment powered by **mains** circuits, but not directly connected to the **mains** using standard plugs and connectors, need not have an electrical rating.

Rationale: Only equipment that is directly connected to the **mains** supplied from the building installation needs to have an electrical rating that takes into account the full load that may be connected to the building supply outlet. For equipment that is daisy-chained or involves a master-slave configuration, only the master unit or the first unit in the daisy chain needs to be marked.

F.3.6.2 ~~Class II equipment~~ Equipment class marking

Rationale: For compliance with EMC standards and regulations, more and more class II products are equipped with a functional earth connection. The latest version of the basic safety publication IEC 61140 allows this construction. On request of IEC TC 108, IEC SC3C has developed a new symbol, which is now used in IEC 62368-1.

Rationale: Equipment having a class II construction, but that is provided with a class I input connector with the internal earthing pin not connected is also considered to be a **class II-product equipment** with functional earth. The class I connector is used to provide a more robust connection means, which is considered to be a functional reason for the earth connection.

F.4 Instructions

Rationale: The dash requiring graphical symbols placed on the equipment and used as an **instructional safeguard** to be explained does not apply to symbols used for equipment classification (see F.3.6).

F.5 Instructional safeguards

Rationale: When a symbol is used, the triangle represents the words “Warning” or “Caution”. Therefore, when the symbol is used, there is no need to also use the words “Warning” or “Caution”. However, when only element 2 is used, the text needs to be preceded with the words.

Annex G Components

G.1 Switches

Source: IEC 61058-1

Rationale: A contact should not draw an arc that will cause pitting and damage to the contacts when switching off and should not weld when switching on if located in PS2 or PS3 energy sources. A PS1 energy source is not considered to have enough energy to cause pitting and damage to the contacts. Both these actions (pitting and damage) may result in a lot of heating that may result in fire. There should be sufficient gap between the two contact points in the off position which should be equal to the reinforced **clearance** if the circuit is ES3 and basic **clearance** if the circuit is ES2 or ES1 (we may have an **arcing PIS** or **resistive PIS** in an ES1 circuit) in order to avoid shock and fire hazards. The contacts should not show wear and tear and pitting after tests simulating lifetime endurance; and overload tests ~~should~~ and operate normally after such tests.

G.2.1 Requirements

Source: IEC 61810-1, for electromechanical relays controlling currents exceeding 0,2 A AC or DC, if the voltage across the open relay contacts exceeds 35 V peak AC or 24 V DC

Rationale: A contact should not draw an arc that will cause pitting and damage to the contacts when switching off and should not weld when switching on if located in PS2 or PS3 energy sources. A PS1 energy source is not considered to have enough energy to cause pitting and damage to the contacts. Both these actions (pitting and damage) may result in a lot of heating that may result in fire. There should be sufficient gap between the two contact points in the off position which should be equal to the reinforced **clearance** if the circuit is ES3 and basic **clearance** if the circuit is ES2 or ES1 (we may have an **arcing PIS** or **resistive PIS** in an ES1 circuit) in order to avoid shock and fire hazards. The contacts should not show wear and tear and pitting after tests simulating lifetime endurance, and overload tests and operate normally after such tests.

G.3.3 PTC thermistors

Source: IEC 60730-1:2006

Rationale: PTC thermistor for current limitation is always connected in series with the load to be protected.

In a non-tripping stage, the source voltage is shared by the load impedance and the resistance of PTC thermistor (which is close to the zero-power resistance at 25 °C). In order to define the power dissipation of the PTC thermistor in this stage, the source voltage and the load impedance are also important parameters.

In a tripping stage, the PTC thermistor heats up by itself and increases the resistance value to protect the circuit. The zero-power resistance at 25 °C is no longer related to the power dissipation of PTC thermistors in this stage. The power dissipation of PTC thermistor in this stage depends on factors such as mounting condition and ambient temperature.

In either stage, some parameters other than the rated zero-power resistance at an ambient temperature of 25 °C are required to calculate the power dissipation of PTC thermistor.

The tripping stage is more hazardous than the non-tripping stage because the temperature of the PTC thermistor in the tripping stage becomes much higher than in the non-tripping stage.

Figure 46 in this document shows “Voltage-Current Characteristics”. The blue dotted lines show the constant power dissipation line. It shows that the power at the operation point, during the tripping stage, is the highest power dissipation. This point is calculable with “ $I_{res} \times U_{max}$ ” of IEC 60738-1:2006, 3.38.

(U_{max} = maximum voltage, I_{res} = residual current, measured by the PTC manufacturers.)

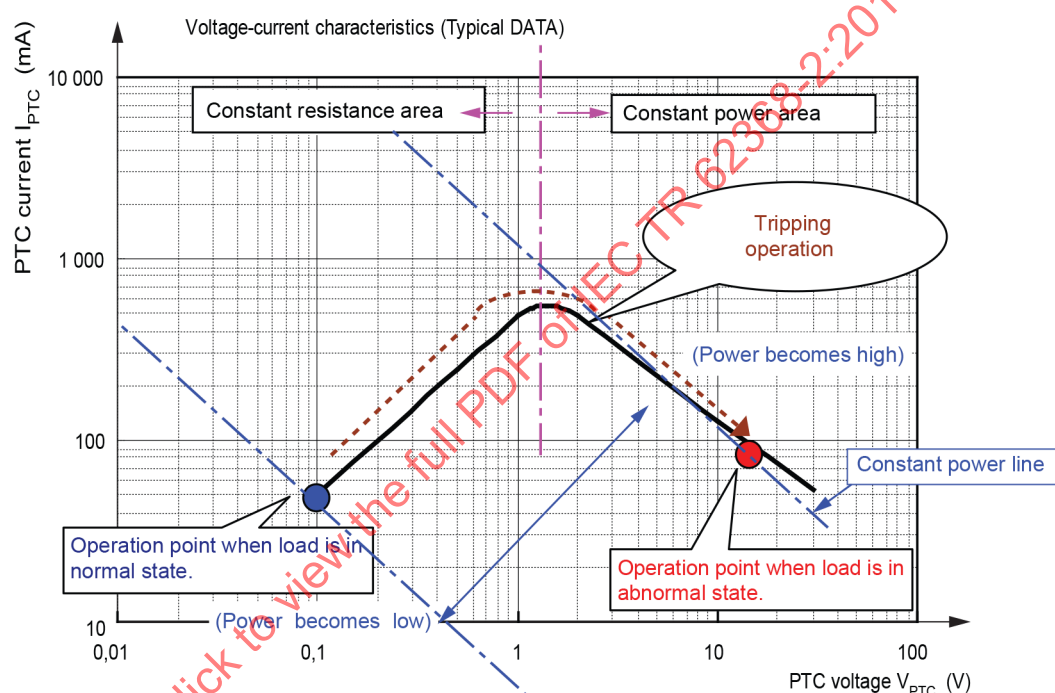
3.38

maximum power

P_{max}

maximum power is the power $U_{max} \times I_{res}$ which can be dissipated continuously by the thermistor when the maximum voltage is applied under specified conditions of ambient temperature, circuit and thermal dissipation when thermal equilibrium is obtained

NOTE If the power is supplied by an a.c. source then the voltage and current should be measured with true r.m.s. meters.



IEC

3.38

maximum power

P_{max}

maximum power is the power $U_{max} \times I_{res}$ which can be dissipated continuously by the thermistor when the maximum voltage is applied under specified conditions of ambient temperature, circuit and thermal dissipation when thermal equilibrium is obtained

NOTE If the power is supplied by an a.c. source then the voltage and current should be measured with true r.m.s. meters.

Figure 46 – Voltage-current characteristics (Typical data)

If the PTC is installed in a PS1 circuit, the power dissipation of the PTC will be 15W or less. In this state, the PTC is not considered to be a **resistive PIS**, regardless of its $I_{res} \times U_{max}$.

A PTC with a size of less than 1 750 mm³ is not considered to be a **resistive PIS**, described in 6.3.1, 6.4.5.2 and 6.4.6.

G.3.4 Overcurrent protective devices

Rationale: Just like any other safety critical component, protective devices are not allowed to be used outside their specifications, to guarantee safe and controlled interruption (no fire and **explosion** phenomena's) during **single fault conditions** (short circuits and overload conditions) in the end products. This should include having a breaking capacity capable of interrupting the maximum fault current (including short-circuit current and earth fault current) that can occur.

G.3.5 Safeguard components not mentioned in G.3.1 to G.3.4

Rationale: Protective devices shall have adequate ratings, including breaking capacity.

G.5.1 Wire insulation in wound components

Source: IEC 60317 series, IEC 60950-1

Purpose: Enamel winding wire is acceptable as **basic insulation** between **external circuit** at ES2 voltage level and an ES1.

Rationale: ES1 becomes ES2 under **single fault conditions**. The enamel winding wires have been used in telecom transformers for the past 25 years to provide **basic insulation** between TNV and SELV. The winding wire is **type tested** for electric strength for **basic insulation** in addition to compliance with IEC 60317 series of standards. Enamel is present on both input and output winding wires and therefore, the possibility of having pinholes aligned is minimized. The finished component is tested for **routine test** for the applicable electric strength test voltage.

G.5.2 Endurance test

Source: IEC 60065:2014 2011, 8.18

Rationale: This test is meant to determine if insulated winding wires without additional interleaved insulation will isolate for their expected lifetime. The endurance test comprises a heat run test, a vibration test and a humidity test. After those tests, the component still has to be able to pass the electric strength test.

G.5.2.2 Heat run test

Rationale: In Table G.2, the tolerance is ± 5 °C. It is proposed that the above tolerance be the same.

G.5.3 Transformers

Source: IEC 61558-1, IEC 60950-1

Rationale: Alternative requirements have been successfully used with products in the scope of this document for many years.

G.5.3.3 Transformer overload tests

G.5.3.3.2 Compliance criteria

Source: IEC 61558-1, IEC 60950-1

Rationale: The transformer overload test is conducted mainly to check the deterioration by thermal stress due to overload conditions, and the compliance criteria is to check whether the temperature of the windings are within the allowable limits specified in Table G.3. For that purpose, the maximum temperature of windings is measured.

However, in the actual testing condition, the windings or other current carrying parts of the transformer under testing may pose temperature higher than the measured value due to uneven temperature, such as a windings isolated from the **main**s (see third paragraph of G.5.3.3.2), so that such spot exposed to higher temperature may have thermal damage.

In order to evaluate such potential damage, electric strength test after the overload condition is considered necessary.

Both of the source documents require the electric strength test after the overload test.

Table G.3 Temperature limits for transformer windings and for motor windings (except for the motor running overload test)

Although the document does not clearly state it, the first row should also be used in cases where no protective device is used or the component is inherently protected by impedance.

For example, in the test practice of a switch mode power supply, a transformer is to be intentionally loaded to the maximum current without a protection operating. In this case, the method of protection is NOT 'inherently' or 'impedance', but other sets of limits are specified with the time of protection to operate. In reality, a switch mode transformer tested with a maximum load attempting the protection not to operate, but the limits in first row have been considered appropriate, because the thermal stress in that loading condition continues for a long time (no ending). Thus, the lowest limit should be applied. In this context, the application of the first row limit shall be chosen according to the situation of long lasting overloading rather than the type of protection.

G.5.3.4 Transformers using fully insulated winding wire (FIW)

Source: IEC 60317-56, IEC 60317-0-7

Rationale: In 2012, IEC TC 55 published IEC 60317-56 and IEC 60317-0-7, Specification for Particular Types of Winding Wires – Part 0-7: General requirements – Fully insulated (FIW) zero-defect enamelled round copper wire with nominal conductor diameter of 0,040 mm to 1,600 mm.

This wire is more robust enameled-coated wire used with minimal amounts of interleaved insulation. It is another step in the advancement of technology to allow manufacturers to design smaller products safely.

IEC TC 96 was the first TC to incorporate the use of FIW in their safety documents for switch mode power supply units, IEC 61558-2-16. Since IEC 62368-1:2018 references in G.5.3.1 IEC 61558-1-16 as one of the acceptable documents for transformers used in switch mode power supplies, FIW already is acceptable in equipment investigated to IEC 62368-1 that use an IEC 61558-1-16 compliant transformer.

FIW may not be **accessible**, whether it has **basic insulation**, **double insulation** or **reinforced insulation**. Note that this differs from other parts of the document that permit **supplementary insulation** and **reinforced insulation** to be **accessible** to an **ordinary person**. The reason is that this kind of wire is fragile and the insulation could easily be damaged when it is **accessible** to an **ordinary person**.

G.5.4 Motors

Source: IEC 60950-1

Rationale: Requirements have been successfully used with products in the scope of this document for many years.

G.7 Mains supply cords

Source: IEC 60245 (rubber insulation), IEC 60227 (PVC insulation), IEC 60364-5-54

Rationale: **Mains** connections generally have large normal and fault energy available from the **mains** circuits. It is also necessary to ensure compatibility with installation requirements.

Stress on **mains** terminal that can result in an ignition source owing to loose or broken connections shall be minimized.

Terminal size and construction requirements are necessary to ensure adequate current-carrying capacity and reliable connection such that the possibility of ignition is reduced.

Wiring flammability is necessary to reduce flame propagation potential should ignition take place.

Conductor size requirements are necessary to ensure adequate current-carrying capacity and reliable connection such that the possibility of ignition is reduced.

Alternative cords to rubber and PVC are accepted to allow for PVC free alternatives to be used. At the time of development of the document, IEC TC20 had no published documents available for these alternatives. However, several countries do have established requirements. Therefore, it was felt that these alternatives should be allowed.

G.7.3 – G.7.5 Mains supply cord anchorage, cord entry, bend protection

Source: IEC 60065:2014 and IEC 60950-1:2005/AMD 1:2009/AMD 2:2013

Purpose: Robustness requirements for cord anchorages

Rationale: The requirements for cord anchorages, cord entry, bend protection and cord replacement are primarily based on 16.5 and 16.6 of IEC 60065:2014 and 3.2.6 and 3.2.7 of IEC 60950-1:2005/2013.

Experience shows that 2 mm displacement is the requirement and if an appropriate strain relief is used there is no damage to the cord and therefore, no need to conduct an electric strength test in most cases. This method has been successfully used for products in the scope of these documents for many years.

G.8 Varistors

Source: IEC 61051-1 and IEC 61051-2

Rationale: The magnitude of external transient overvoltage (mainly attributed to lightning), to which the equipment is exposed, depends on the location of the equipment.

This idea is described in Table 14 of IEC 62368-1:2014 and also specified in IEC 60664-1.

In response to this idea, IEC 61051-2 has been revised taking into account the location of the equipment, which also influences the requirement for the varistors used in the equipment.

The combination pulse test performed according to G.8.2 of IEC 62368-1:2014 can now refer to the new IEC 61051-2:1994 with Amendment 1:2009.

G.9 Integrated circuit (IC) current limiters

Source: IEC 60730-1, IEC 60950-1

Rationale: ~~Integrated circuit chips with many components are used especially in class 1 and class 2 energy sources for providing isolation for basic safeguards and functions such as limiting current.~~

~~IEC 60335 series already has requirements for "electronic protection devices" where conditioning tests such as EMF impulses are applied to such ICs and the basic safeguard function or current limiting function evaluated after conditioning tests. In addition, clearances and creepage distances are maintained for double or reinforced insulation if the IC current limiter is in an ES2 circuit. The two pins where above is met are not shorted. Many applications such as SLIC Chips and current limiting chips (in ES2 circuits) are not shorted if qualified by the required conditioning and determining clearances and creepage distances on the outside of the IC chips.~~

~~Two test programs were used in IEC 60950-1. An additional program was developed in IEC 62368-1. It was felt that all three programs were considered adequate. Therefore the three methods were kept.~~

Integrated circuits (containing numerous integral components) are frequently used for class 1 and class 2 energy source isolation and, more frequently (for example, USB or PoE), for functions such as current limiting.

IEC 60335 series already has requirements for “electronic protection devices,” where conditioning tests such as EMF impulses are applied to such ICs, and the energy source isolation or current limiting function is evaluated after conditioning tests. When such energy isolation or current limitation has been proven reliable via performance, pins on the IC associated with this energy isolation or limitation are not shorted.

For ICs used for current limitation, two test programs were used in IEC 60950-1:2009. An additional program was developed in IEC 62368-1:2010. It was felt that all three programs were considered adequate. Therefore, the three methods were kept.

An Ad Hoc formed at the March 2015, Northbrook HBSDT meeting revised this test program with the following guiding principles:

- a) Streamline the number of tests in overall test program to concentrate on those tests and conditions that most likely will identify deficiencies in IC Current Limiter design from a safety perspective, such as allowing more current to flow than designed for. Some of the existing conditions are redundant or have questionable value identifying such deficiencies.
- b) Focus on test conditions that are applicable for semiconductor devices rather than test conditions more suited for traditional electro-mechanical devices. For example, 10 000-cycle testing has more applicability to electro-mechanical devices (in relation to parts wearing out) versus semiconductor devices (such as IC current limiters).
- c) Combine test conditions when justified to increase efficiency when conducting individual tests, also trying to make the testing more compatible with automated testing processes (e.g. combine individual temperature tests as individual sub-conditions of other required tests).

Table G.10 provides the specific performance test program for IC current limiters.

- Input loading to the device should be representative of the manufacturer’s IC specification (as typically communicated in the IC application notes for the particular device).
- Output loading is intended to represent a short circuit condition (0 Ω shunt), with parallel capacitive loading (470 μ F +/- 20 %) to better accommodate on/off cycling.

See Figure 47 in this document for additional detail.

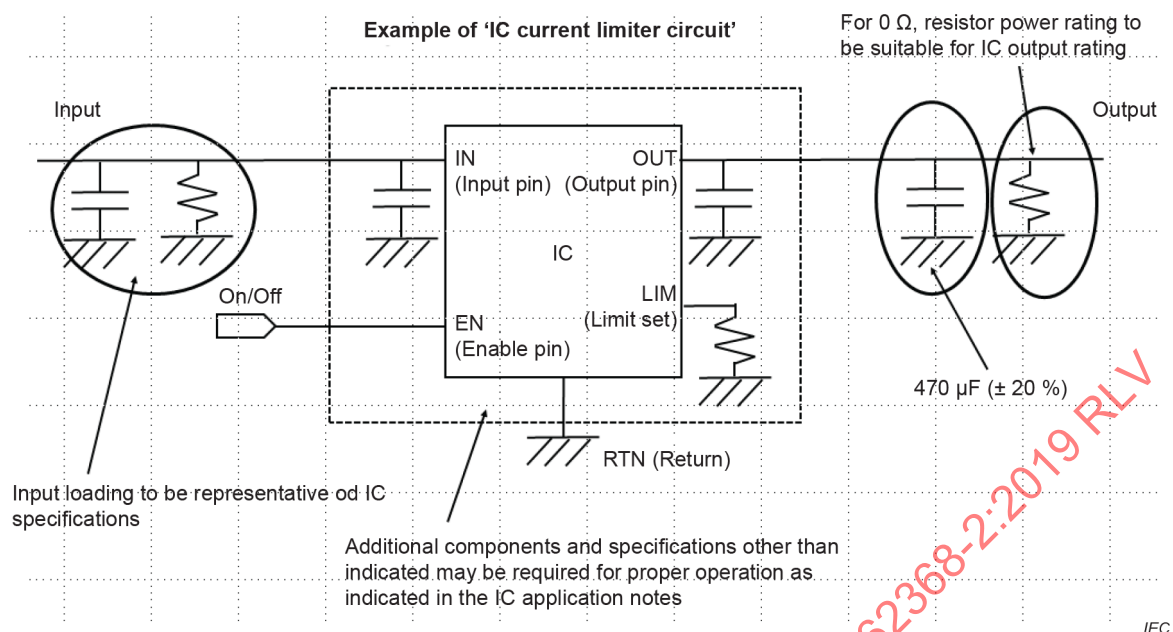


Figure 47 – Example of IC current limiter circuit

Regarding the 250 VA provision, this provision is intended to mean that the usual test power source has 250 VA capability as long as the IC is designed for installation in a system with a source of 250 VA or larger. If the power source capability is intended to be less than 250 VA, then the manufacturer must specify so, or test in the end product. Testing at 250 VA is intended to include 250 VA or larger sources because the test program is covering relatively small and low-voltage silicon devices – if these devices pass at 250 VA they likely would pass at higher VA too since they are not electro-mechanical. Also, this allows for more practical associated certification test programs.

Also, to avoid recertification of existing components, IC current limiters that met a previous legacy test program (G.9.2, G.9.3 or G.9.4) are an equivalent level of safety as the proposed rewritten Clause G.9, primarily because Clause G.9 is derivation of the legacy requirements. Therefore, IC current limiters that comply with the legacy test program should not need to be reinvestigated to the latest document that includes this revised Clause G.9. However, this is a certification consideration outside the scope of this technical committee.

G.11 Capacitors and RC units

Source: IEC 60384-14:20132005

Rationale: Table G.811: Test voltage values aligned with those used in IEC 60384-14 (Tables 1, 2 and 10 of IEC 60384-14:20132005).

Table G.912: Minimum number of Y capacitors based on **required withstand voltage** of Table-26 25 of IEC 62368-1:20142018.

Table G.1013: Maximum voltage that can appear across a Y capacitor based on the peak value of the **working voltage** of Table-27 26 of IEC 62368-1:20142018.

Table G.1114: Minimum number of Y capacitors based on the test voltages (due to **temporary overvoltages**) of Table-28 27 of IEC 62368-1:20142018.

Table G.1215: Minimum number of X capacitors (line to line or line to neutral) based on the **mains** transient withstand voltage of Table 13 of IEC 62368-1:20142018.

All of the above are aligned with the requirements of IEC 60384-14.

G.13 Printed boards

Source: IEC 60950-1 or IEC 60664-3:2003.

Purpose: To provide details for reliable construction of PCBs.

Rationale: This proposal is based on IEC 60664-3 and the work of IBM and UL in testing coatings on printed boards when using coatings to achieve insulation coordination of printed board assemblies. Breakdown voltages of more than 8 000 V for 0,025 mm were routinely achieved in this program.

These parts have multiple stresses on the materials with limited separation between conductors. This section is taken from IEC 60950-1, where these requirements have been used for many years.

G.13.6 Tests on coated printed boards

Purpose: Prevent breakdown of the insulation **safeguard**.

Rationale: Avoid pinholes or bubbles in the coating or breakthrough of conductive tracks at corners.

G.14 Coatings on component terminals

Source: IEC 60950-1 and IEC 60664-3

Purpose: The mechanical arrangement and rigidity of the terminations are adequate to ensure that, during normal handling, assembly into equipment and subsequent use, the terminations will not be subject to deformation which would crack the coating or reduce the separation distances between conductive parts.

Rationale: The terminations are treated like coated printed boards (see G.13.3) and the same separation distances apply.

This section is taken from IEC 60950-1 where these requirements have been used for many years.

G.15 Pressurized liquid filled components

Source: IEC 60950-1, IEC 61010-1, UL 2178, UL 1995

Purpose: Avoid spillage of liquids resulting in electric shock hazard

Rationale: These requirements apply to devices that contain less than 1 l of ~~the cooling~~ liquid. A leak in the system may result in a shock hazard and therefore, needs to be properly addressed. A leak is not desirable and therefore, a strict performance criterion is proposed. Requirements were developed based on the following description of a typical system using liquid filled heat sinks. If a different type of system is used, then the requirements need to be re-evaluated.

Liquid filled heat-sink system (LFHS): a typical system consists of a heat exchanger, fan, pump, tubing, fittings and cold plate or radiator type heat exchanger. The liquid filled heat sink comes from the vendor already charged, sealed; and is installed and used inside the equipment (small type, typically found in cell stations and computing devices or other types of systems). The proposed requirements are based on a LFHS being internal to a unit, used/installed adjacent/over ~~SELV~~ ES1 circuits, in proximity to an enclosed power supply (not open frame).

The liquid-filled heat components are used in desktop units or stationary equipment and in printers. These are not used in any portable equipment where orientation may change (unless the product is tested in all such orientations. If the liquid heat sink system is of a sealed type construction, then the system is orientation proof (this should not be a concern but a good engineering practice is that the pump does not become the high point in the system).

Following assumptions are used:

- The tubing is a single-layered metal (copper or aluminium) or non-metallic construction. If it is non-metallic, flammability requirements will apply.
- The fittings are metal. If it is non-metallic, flammability requirements will apply.
- Working pressure is determined under **normal operating conditions** and **abnormal operating conditions** and construction (tubing, fitting, heat exchanger, any joints, etc.) is suitable for this working pressure;
- The volume of the liquid is reasonable (less than 1 000 ml).
- The fluid does not cause corrosion and is not flammable (for example, corrosion resistant and non-flammable liquid).
- The liquid is non-toxic as specified for the fluid material.

Annex H Criteria for telephone ringing signals

H.2 Method A

Source: ~~EN 41003:2008~~ IEC 62949:2016.

Rationale: Certain voltages within telecommunication networks often exceed the steady state, safe-to-touch limits set within general safety documents. Years of practical experience by world-wide network operators have found ringing and other operating voltages to be electrically safe. Records of accident statistics indicate that electrical injuries are not caused by operating voltages.

Access to connectors carrying such signals with the standard test finger is permitted, provided that inadvertent access is unlikely. The likelihood of inadvertent access is limited by forbidding access with the test probe Figure 2C of IEC 60950-1:2005/AMD1:2009/AMD2:2013 that has a 6 mm radius tip.

This requirement ensures that:

- contact by a large part of the human body, such as the back of the hand, is impossible;
- contact is possible only by deliberately inserting a small part of the body, less than 12 mm across, such as a fingertip, which presents a high impedance;
- the possibility of being unable to let-go the part in contact does not arise.

This applies both to contact with signals arriving from the network and to signals generated internally in the equipment, for example, ringing signals for extension telephones. By normal standards, these internally generated signals would exceed the voltage limits for **accessible** parts, but the first exemption in IEC 60950-1 states that limited access should be permitted under the above conditions.

Ventricular fibrillation of the heart is considered to be the main cause of death by electric shock. The threshold of ventricular fibrillation (Curve A) is shown in Figure 48 in this document and is equivalent to curve c1 of IEC TS 60479-1:2005, Figure 14. The point 500 mA/100 ms has been found to correspond to a fibrillation probability of the order of 0,14 %. The let go limit (Curve B) is equivalent to curve 2 of IEC TS 60479-1:2005, Figure 14. Some experts consider curve A to be the appropriate limit for safe design, but use of this curve is considered as an absolute limit.

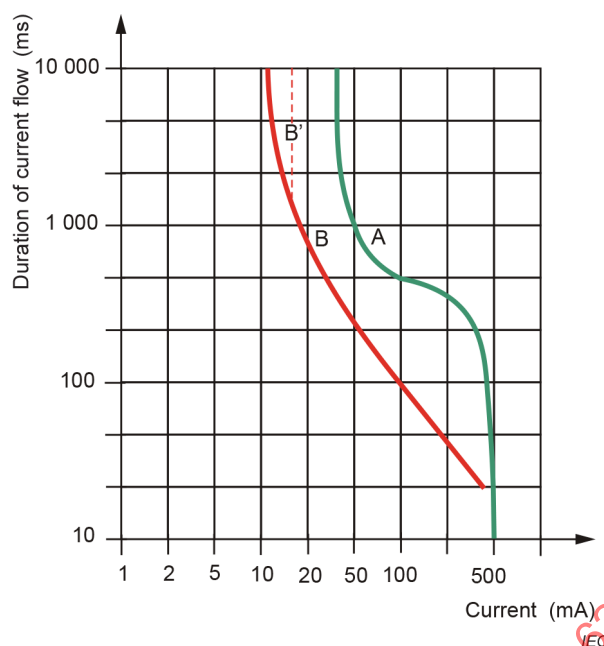


Figure 48 – Current limit curves

Contact with telecommunication operating voltages (EN 41003)

Total body impedance consists of two parts, the internal body resistance of blood and tissue and the skin impedance. Telecommunication voltages hardly reach the level where skin impedance begins to rapidly decrease due to breakdown. The skin impedance is high at low voltages, its value varying widely. The effects of skin capacitance are negligible at ringing frequencies.

IEC TS 60479-1 body impedance figures are based upon a relatively large contact area of 50 cm² to 100 cm², which is a realistic value for **mains** operated domestic appliances. Practical telecommunication contact is likely to be much less than this, typically 10 cm² to 15 cm² for uninsulated wiring pliers or similar **tools** and less than 1 cm² for finger contact with pins of a telephone wall socket. For contact with thin wires, wiring tags or contact with **tools** where fingers move beyond insulated handles, the area of contact will again be of the order of 1 cm² or less. These much smaller areas of contact with the body produce significantly higher values of body impedance than the IEC TS 60479 figures.

In IEC 60950-1, a body model value of 5 k Ω is used to provide a margin of safety compared with the higher practical values of body impedance for typical telecommunication contact areas.

The curve B' [curve C₁ of IEC TS 60479-1:2005, Figure 22 (curve A in this document)] used within the hazardous voltage definition is a version of curve B modified to cover practical situations, where the current limit is maintained constant at 16 mA above 1 667 ms. This 16 mA limit is still well within the minimum current value of curve A.

The difficulties of defining conditions that will avoid circumstances that prevent let-go have led to a very restricted contact area being allowed.

Contact with areas up to 10 cm² can be justified and means of specifying this and still ensuring let-go are for further study.

H.3 Method B

Source: This method is based on USA CFR 47 ("FCC Rules") Part 68, Sub part D, with additional requirements that apply under fault conditions.

Annex J Insulated winding wires for use without interleaved insulation

Source: IEC 60851-3:2009, IEC 60851-5:2008, IEC 60851-6:20121996

Purpose: Winding wires shall withstand mechanical, thermal and electrical stress during use and manufacturing.

Rationale: Test data indicates that there is not a major difference between rectangular wires and round wires for electric strength after the bend tests. Therefore, there is no reason to not include them.

Subclause 4.4.1 of IEC 60851-5:2008 covers only solid circular or stranded winding wires as a twisted pair can easily be formed from round wires. It is difficult to form a twisted pair from square or rectangular winding wires.

IEC 60851-5:2008, 4.7 addresses a test method that can be used for square and rectangular wires. A separate test method for square and rectangular wires has been added. The test voltage is chosen to be half of the twisted pair as a single conductor is used for the testing.

In addition, the edgewise bend test is not required by IEC 60851-5 and IEC 60851-6 for the rectangular and square winding wires.

The reference to trichloroethane is being deleted as trichloroethane is an environmentally **hazardous material substance**.

For J.2.3 (Flexibility and adherence) and J.2.4 (Heat shock), 5.1.2 in Test 8 of IEC 60851-3:2009 and 3.2.1 in Test 9 of IEC 60851-6:20121996 are not used for solid square and solid rectangular winding wires.

Annex K Safety interlocks

Source: IEC 60950-1

Purpose: To provide reliable means of **safety interlock** devices.

Rationale: **Safety interlock** constructions have been used for many years in products within the scope of this document. **Safety interlocks** should not be associated with electro-mechanical components only.

Annex L Disconnect devices

Source: IEC 60950-1

Purpose: To provide adequate protective earth connection.

Rationale: 3 mm separation distances of contacts. Can be part of building installation.

For **class I equipment**, the supply plug or appliance coupler, if used as the **disconnect device**, shall make the **protective earthing** connection earlier than the supply connections and shall break it later than the supply connections.

Clearance of 3 mm can withstand peak impulse voltages of 4 000 V, which corresponds to a transient overvoltage present in overvoltage category III environment (equipment as part of the building installation).

One **instructional safeguard** could be used for more than one disconnect device, as long as it can be visible from each disconnect point.

Annex M Equipment containing batteries and their protection circuits

M.1 General requirements

Rationale: Stand-alone **battery** chargers for general purpose **batteries** shall be evaluated using their relevant safety document, and not IEC 62368-1. If the **battery** and the charger are designed specifically for AV or ICT equipment and not to be used for other purposes, the provisions of IEC 62368-1:2018 including Annex M may be applied.

M.2 Safety of batteries and their cells

Rationale: Equipment containing **batteries** shall be designed to reduce the risk of fire, **explosion** and chemical leaks under **normal operating conditions** and after a **single fault condition** in the equipment, including a fault in circuitry within the equipment **battery** pack. For **batteries** replaceable by an **ordinary person** or an **instructed person**, the design shall provide **safeguards** against reverse polarity installation or replacement of a **battery** pack from different component manufacturers if this would otherwise defeat a **safeguard**.

Other clauses in this document address in generic terms **safeguards** associated with the use of **batteries**. This annex does not specifically address those **safeguards**, but it is expected that **batteries** and associated circuits conform to the relevant requirements in this document.

This annex addresses **safeguards** that are unique to **batteries** and that are not addressed in other parts of the document. Energy sources that arise from the use of **batteries** are addressed in this annex and include the following:

- situations where the **battery** is in a state that exceeds its specifications or ratings (for example, by overcharging, rapid-charge, rapid-discharge, overcurrent or overvoltage conditions);
- thermal runaway due to overcharge or short circuits within **battery cells**;
- reverse-charging of the **battery**;
- leakage or spillage of electrolyte;
- emission of **explosive** gases; and
- location of **safeguards** where **battery** packs may be replaceable by an **ordinary person** or an **instructed person**.

Thermal runaway in the **cell** can result in **explosion** or fire, when the temperature rise in the **cell** caused by the heat emission raises the internal **cell** pressure faster than can be released by the **cell** pressure release device. Thermal runaway can be initiated by several causes:

- defects introduced into the **cell** during **cell** construction. These defects are often not detected during the manufacturing process and may bridge an internal insulation layer or block a vent;
- over-charge and rapid-charge or rapid-discharge;
- high operational temperature or high **battery** environment temperature;
- other **cells** in a pack feeding energy to a fault in a single **cell**; and
- crushing of the **enclosure**.

NOTE **Batteries** may contain multiple **cells**.

During charging operation, gases are emitted from secondary **cells** and **batteries** excluding gastight sealed (secondary) **cells**, as the result of the electrolysis of water by electric current. Gases produced are hydrogen and oxygen.

Table 17 in this document gives an overview of the referenced **battery** documents.

IECNORM.COM : Click to view the full PDF of IEC TR 62368-2:2019 RLV

Table 17 – Safety of batteries and their cells – requirements (expanded information on documents and scope)

Document	Chemistry							Category		Movability			Scope (details)
	Alkaline; non-acid	Lead Acid	NiCd/NiMH	Lithium	Nickel; alkaline electrolyte	Various	Various, with aqueous electrolyte	Primary	Secondary	Portable	Stationary	All	
IEC 60086-4 (2014): Primary Batteries – Part 4 – Safety of Lithium Batteries				X				X				X	Specifies tests and requirements for primary lithium batteries to ensure their safe operation under intended use and reasonably foreseeable misuse (includes coin / button cell batteries).
IEC 60086-5 (2016): Primary Batteries – Part 5 – Safety of batteries with aqueous electrolyte							X	X				X	Specifies tests and requirements for primary batteries with aqueous electrolyte to ensure their safe operation under intended use and reasonably foreseeable misuse (includes coin/button cell batteries).
IEC 60896-11 (2002): Stationary Lead Acid Batteries – Part 11 – Vented type		X						X	X		X		Applicable to lead-acid cells and batteries that are designed for service in fixed locations (for example, not habitually to be moved from place to place) and which are permanently connected to the load and to the DC power supply. Batteries operating in such applications are called "stationary batteries ". Any type or construction of lead-acid battery may be used for stationary battery applications. Part 11 is applicable to vented types only.
IEC 60896-21 (2004): Stationary Lead Acid Batteries – Part 21 – Valve regulated type – method of test		X						X	X		X		Applies to all stationary lead-acid cells and monobloc batteries of the valve regulated type for float charge applications, (for example, permanently connected to a load and to a DC power supply), in a static location (for example, not generally intended to be moved from place to place) and incorporated into stationary equipment or installed in battery rooms for use in telecom, uninterruptible power supply (UPS), utility switching, emergency power or similar applications. The objective is to specify the methods of test for all types and construction of valve regulated stationary lead acid cells and monobloc batteries used in standby power applications.

Document	Chemistry							Category		Movability			Scope (details)
	Alkaline; non-acid	Lead Acid	NiCd/NiMH	Lithium	Nickel; alkaline electrolyte	Various	Various, with aqueous electrolyte	Primary	Secondary	Portable	Stationary	All	
IEC 60896-22 (2004): Stationary Lead Acid Batteries – Part 22 – Valve regulated type – requirements		X						X	X		X		Applies to all stationary lead-acid cells and monobloc batteries of the valve regulated type for float charge applications, (for example, permanently connected to a load and to a DC power supply), in a static location (for example, not generally intended to be moved from place to place) and incorporated into stationary equipment or installed in battery rooms for use in telecom, uninterruptible power supply (UPS), utility switching, emergency power or similar applications. The objective is to assist the specifier in the understanding of the purpose of each test contained within IEC 60896-21 and provide guidance on a suitable requirement that will result in the battery meeting the needs of a particular industry application and operational condition. This document is used in conjunction with the common test methods described in IEC 60896-21 and is associated with all types and construction of valve regulated stationary lead-acid cells and monobloc batteries used in standby power applications.
IEC 61056-1 (2012): General purpose lead-acid batteries (valve-regulated types) – Part 1: General requirements, functional characteristics – Methods of test		X						X	X			X	Specifies the general requirements, functional characteristics and methods of test for all general-purpose lead-acid cells and batteries of the valve-regulated type: – for either cyclic or float charge application; – in portable equipment, for instance, incorporated in tools, toys, or in static emergency, or uninterruptible power supply and general power supplies. (For stationary applications, the battery will need to meet IEC 60896-21/-22 or subject to additional evaluation).

Document	Chemistry							Category		Movability			Scope (details)
	Alkaline; non-acid	Lead Acid	NiCd/NiMH	Lithium	Nickel; alkaline electrolyte	Various	Various, with aqueous electrolyte	Primary	Secondary	Portable	Stationary	All	
IEC 61056-2 (2012): General purpose lead-acid batteries (valve-regulated types) – Part 2: Dimensions, terminals and marking		X						X	X			X	Specifies the dimensions, terminals and marking for all general-purpose lead-acid cells and batteries of the valve regulated type: – for either cyclic or float charge application; – in portable equipment, for instance, incorporated in tools, toys, or in static emergency, or uninterruptible power supply and general power supplies. (For stationary applications, the battery will need to meet IEC 60896-21/-22 or subject to additional evaluation).
IEC 61427 (all parts) (2013): Secondary cells and batteries for renewable energy storage – General requirements and methods of test – Part 1: Photovoltaic off-grid application						X			X				Part of a series that gives general information relating to the requirements for the secondary batteries used in photovoltaic energy systems (PVES) and to the typical methods of test used for the verification of battery performances. This part deals with cells and batteries used in photovoltaic off-grid applications. This document is applicable to all types of secondary batteries .
IEC TS 61430 (1997): Secondary Cells and Batteries – Test Methods for Checking the Performance of Devices Designed for Reducing Explosion Hazards – Lead-Acid Starter Batteries		X							X			X	Specification gives guidance on procedures for testing the effectiveness of devices which are used to reduce the hazards of an explosion, together with the protective measures to be taken.
IEC 61434 (1996): Secondary cells and batteries containing alkaline or other non-acid electrolytes Guide to the designation of current in alkaline secondary cell and battery standards	X								X			X	Applies to secondary cells and batteries containing alkaline or other non-acid electrolytes. It proposes a mathematically correct method of current designation which shall be used in future secondary cell and battery documents.

Document	Chemistry							Category		Movability			Scope (details)
	Alkaline; non-acid	Lead Acid	NiCd/NiMH	Lithium	Nickel; alkaline electrolyte	Various	Various, with aqueous electrolyte	Primary	Secondary	Portable	Stationary	All	
IEC 61959 (2004): Secondary cells and batteries containing alkaline or other non-acid electrolytes Mechanical tests for sealed portable secondary cells and batteries						X			X	X			Specifies tests and requirements for verifying the mechanical behavior of sealed portable secondary cells and batteries during handling and normal use.
IEC 62133 (all parts) (2012 – superseded by IEC 62133-1 and IEC 62133-2); 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	X								X	X			Specifies requirements and tests for the safe operation of portable sealed secondary cells and batteries (other than coin / button cell batteries) containing alkaline or other non-acid electrolyte, under intended use and reasonably foreseeable misuse .
IEC 62133-1 (2017): 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 – Part 1: Nickel systems					X				X	X			Specifies requirements and tests for the safe operation of portable sealed secondary nickel cells and batteries containing alkaline electrolyte, under intended use and reasonably foreseeable misuse .
IEC 62133-2 (2017): Secondary cells and batteries containing alkaline or other non-acid electrolytes – Safety requirements for portable sealed secondary lithium cells, and for batteries made from them, for use in portable applications – Part 2: lithium systems				X					X	X			Specifies requirements and tests for the safe operation of portable sealed secondary lithium cells and batteries containing non-acid electrolyte, under intended use and reasonably foreseeable misuse .

Document	Chemistry							Category		Movability			Scope (details)
	Alkaline; non-acid	Lead Acid	NiCd/NiMH	Lithium	Nickel; alkaline electrolyte	Various	Various, with aqueous electrolyte	Primary	Secondary	Portable	Stationary	All	
IEC 62281 (2016): Safety of primary and secondary lithium cells and batteries during transport				X				X	X			X	Specifies test methods and requirements for primary and secondary (rechargeable) lithium cells and batteries to ensure their safety during transport other than for recycling or disposal (similar to UN 38.3).
IEC 62485-2 (2010): Safety requirements for secondary batteries and battery installations – Part 2: Stationary batteries		X	X						X			X	Applies to stationary secondary batteries and battery installations with a maximum voltage of 1 500 V DC (nominal) and describes the principal measures for protections against hazards generated from: – electricity, – gas emission, – electrolyte. Provides requirements on safety aspects associated with the erection, use, inspection, maintenance and disposal. It covers lead-acid and NiCd/NiMH batteries (IEC 62485-2 requires the valve regulated batteries to meet safety requirements from IEC 60896).
IEC 62619 (2017): Secondary cells and batteries containing alkaline or other non-acid electrolytes – Safety requirements for secondary lithium cells and batteries, for use in industrial applications				X					X			X	Specifies requirements and tests for the safe operation of secondary lithium cells and batteries used in industrial applications including stationary applications.

M.3 Protection circuits for batteries provided within the equipment

Rationale: Equipment containing **batteries** is categorized into two types;

1. Equipment containing **batteries** which are embedded in the equipment and cannot be separated from the equipment.
2. Equipment containing **batteries** which can be separated from the equipment.

The requirements in IEC 62368-1 cover only the **battery** circuits that are not an integral part of the **battery** itself, and as such form a part of the equipment.

M.4 Additional safeguards for equipment containing a **portable secondary lithium battery**

Rationale: **Secondary lithium batteries** (often called lithium-ion or li-ion **batteries**) are expected to have high performance, such as light-weight and high energy capability. The use of li-ion **batteries** has been continuously expanding in the area of high-tech electronic equipment. However, it is said that this technology involves risks because the safety margin (distance between safe-operation zone and unsafe-operation zone) is relatively small compared to other **battery** technologies.

IEC TC 108 noted that for designing equipment containing or using li-ion **battery**, it is imperative to give careful consideration to selecting highly reliable **battery cells**, providing high performance **battery** management systems for operating **batteries** within their specified operating environment and parameter range (for example, **battery** surrounding temperature or **battery** charging/discharging voltage and current). It is also imperative to introduce **safeguards** against **abnormal operating conditions**, such as vibration during the use of devices, mechanical shock due to equipment drop, surge signals caused internally or externally, and a mechanism to reduce the likelihood of catastrophic failure such as **battery explosion** or fire.

It is suggested that suppliers of equipment and **batteries** should take into account possible **abnormal operating conditions** that may occur during use, transport, stock, and disposal, so that the equipment is well prepared for such conditions.

It is important that the key parameters (highest/lowest charging temperatures, maximum charging current, and upper limit charging voltage) during charging and discharging of the **battery** are not exceeded.

IEC TC 108 noted that, when designing **battery** compartments, the **battery** compartment dimensions should allow sufficient space for **cells** to expand normally under full operating temperature range or be flexible to prevent unnecessary compression of the **cells**. Given the wide range of **battery** constructions, corresponding **battery** compartment dimensional requirements will differ. When necessary, coordinate with the **battery** manufacturer to determine change in **battery** dimensions over full operating range during charging and discharging.

M.4.2.2 Compliance criteria

The highest temperature point in the **battery** may not always exist at the center of the **battery**. The **battery** supplier should specify the point where the highest temperature in the **battery** occurs.

To test the charging circuit, instead of using a real **battery** (which is a chemical system), an electrical circuit emulating the **battery** behavior (dummy **battery** circuit) may make the test easier by eliminating a possible **battery** defect.

An example of a dummy **battery** circuit is given in Figure 49 in this document.

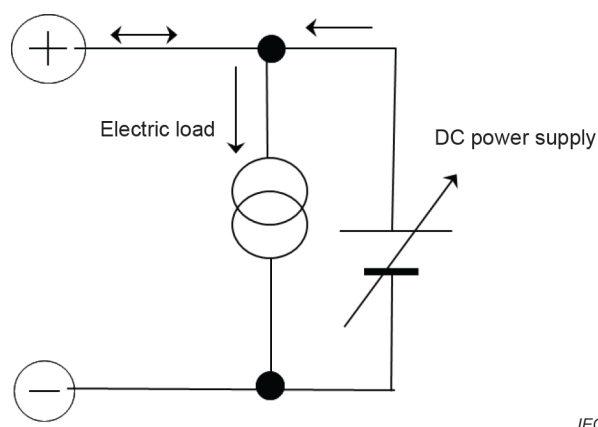


Figure 49 – Example of a dummy battery circuit

M.4.3 Fire enclosure

Lithium-ion **batteries** ~~are~~ with an energy more than PS1 (15 W) must be provided with a **fire enclosure** (either at the **battery** or at the equipment containing the **battery**) because even though measurements of output voltage and current may not necessarily show them to be a **PIS**, however they contain flammable electrolyte that can be easily ignited by the enormous amount of heat developed by internal shorts as a result of possible contaminants in the electrolyte.

M.4.4 Drop test of equipment containing a secondary lithium battery

Monitoring of lithium-ion **battery** output voltage and surface temperature during or after the drop test may not help. The concern is that if a minor dent occurs, nothing may happen to the **battery**. Temperature may go up slightly and then drop down without any significant failure. If the **battery** is damaged, the damage may only show up if the **battery** is then subjected to few charging and discharging cycles. Therefore, the surface temperature measurement was deleted and replaced with charging and discharging cycles after the drop test. The charging and discharging of the **battery** shall not result in any fire or **explosion**.

It is important that the equipment containing a **secondary lithium battery** needs to have a drop impact resistance. Equipment containing a **secondary lithium battery** should avoid further damage to the control circuit and the **batteries**.

After the drop test:

- Initially, the control functions should be checked to determine if they continue to operate and all **safeguards** are effective. A dummy **battery** or appropriate measurement tool can be used for checking the function of the equipment.
- Then, the **batteries** are checked whether or not a slight internal short circuit occurs.

Discharge and charge cycles under **normal operating conditions** test hinder detection of the slight internal short circuit because the current to discharge and charge is higher than the current caused by a slight internal short circuit.

Thus, it is very important to conduct a voltage observation of the **battery** immediately after the drop test without any discharge and charge.

To detect a slight internal short circuit of the **battery**, IEC TC 108 adopts a no-load test, which can detect a **battery** open voltage drop caused by an internal short circuit leak current in a 24 h period.

Equipment containing an embedded type of **battery** has internal power dissipation (internal consumption current). Therefore, two samples of the equipment are prepared, one for the drop test and the other for reference in a standby mode. In this way, the effect of internal power dissipation can be detected by measuring a difference between voltage drops in the 24 h period.

M.6.1.1 General Requirements

Examples: Examples of **battery** documents containing an internal short test are IEC 62133, IEC 62133-2 and IEC 62619.

Another example of compliance to internal fault requirements is a **battery** using **cells** that have passed the impact test as specified in IEC 62281.

M.7.1 Ventilation preventing an explosive gas concentration

Rationale: During charging, float charging, and overcharging operation, gases are emitted from secondary **cells** and **batteries** excluding gastight sealed (secondary) **cells**, as the result of the electrolysis of water by electric current. Gases produced are hydrogen and oxygen.

M.7.2 Test method and compliance criteria

Source: The formula comes from IEC 62485-2:2010, 7.2.

M.8.2.1 General

Source: The formula comes from IEC 60079-10-1:2008/2015, Clause B.4.

Annex O Measurement of creepage distances and clearances

Source: IEC 60664-1, IEC 60950-1.

Purpose: **Clearances** are measured from the X-points in the figure

Rationale: Figure O.13. The **clearance** determination is made from the X-points in the figure, as those are the first contact points when the test finger enters the **enclosure** opening. It is assumed that the **enclosure** is covered by conductive foil, which simulates conductive pollution.

Annex P Safeguards against conductive objects

P.1 General

Rationale: The **basic safeguard** against entry of a foreign object is that persons are not expected to insert a foreign object into the equipment. Where the equipment is used in locations where children may be present, it is expected that there will be adult supervision to address the issue of reasonable foreseeable misuse by children, such as inserting foreign objects. Therefore, the **safeguards** specified in this annex are **supplementary safeguards**.

P.2 Safeguards against entry or consequences of entry of a foreign object

Source: IEC 60950-1

Purpose: Protect against the entry of foreign objects ~~or liquids~~

Rationale: There are two alternative methods that may be used.

P.2.2 specifies maximum size limits and construction of openings. The relatively small foreign conductive objects or amounts of liquids that may pass through these openings are not likely to defeat any **equipment safeguards**. This option prevents entry of objects that may defeat a **safeguard**.

Alternatively, if the openings are larger than those specified in P.2.2, P.2.3 assumes that a foreign conductive object or liquid passing through these openings is likely to defeat an equipment **basic safeguard**, and requires that the foreign conductive object or liquid shall not defeat an equipment **supplementary safeguard** or an equipment **reinforced safeguard**.

P.2.3.1 Safeguard requirements

Rationale: Conformal coating material is applied to electronic circuitry to act as protection against moisture, dust, chemicals, and temperature extremes that, if uncoated (non-protected), could result in damage or failure of the electronics to function. When electronics are subject to harsh environments and added protection is necessary, most circuit board assembly houses coat assemblies with a layer of transparent conformal coating rather than potting.

The coating material can be applied by various methods, from brushing, spraying and dipping, or, due to the increasing complexities of the electronic boards being designed and with the 'process window' becoming smaller and smaller, by selectively coating via robot.

P.3 Safeguards against spillage of internal liquids

Source: IEC 60950-1

Rationale: If the liquid is conductive, flammable, toxic, or corrosive, then the liquid shall not be **accessible** if it spills out. The container of the liquid provides a **basic safeguard**. After the liquid spills out, then barrier, guard or **enclosure** that prevents access to the liquid acts as a **supplementary safeguard**. Another choice is to provide a container that does not leak or permit spillage for example, provide a **reinforced safeguard**.

P.4 Metalized coatings and adhesives securing parts

Source: IEC 60950-1

Rationale: Equipment having internal barriers secured by adhesive are subject to mechanical tests after an aging test. If the barrier does not dislodge as a whole or partially or fall off, securement by adhesive is considered acceptable.

The temperature for conditioning should be based on the actual temperature of the adhesive secured part.

The test program for metalized coatings is the same as for aging of adhesives. In addition, the abrasion resistance test is done to see if particles fall off from the metalized coating. Alternatively, **clearance** and **creepage distances** for PD3 shall be provided.

Annex Q Circuits intended for interconnection with building wiring

Source: IEC 60950-1:2005/AMD1:2009/AMD2:2013

Rationale: For the countries that have electrical and fire codes based on NFPA 70, this annex is applied to ports or circuits for **external circuits** that are interconnected to building wiring for limited power circuits. Annex Q was based on requirements from IEC 60950-1 that are designed to comply with the **external circuit** power source requirements necessary for compliance with the electrical codes noted above.

Q.1.2 Test method and compliance criteria

In determining if a circuit is a limited power source, all conditions of use should be considered. For example, for circuits that may be connected to a **battery** source as well as a **mains** source, determination whether the available output from the circuit is a limited power source is made with each of the sources connected independently or simultaneously (see Figure 50 in this document).

Q.2 Test for external circuits – paired conductor cable

Time/current characteristics of type gD and type gN fuses specified in IEC 60269-2-1 comply with the limit. Type gD or type gN fuses rated 1 A, would meet the 1,3 A current limit.

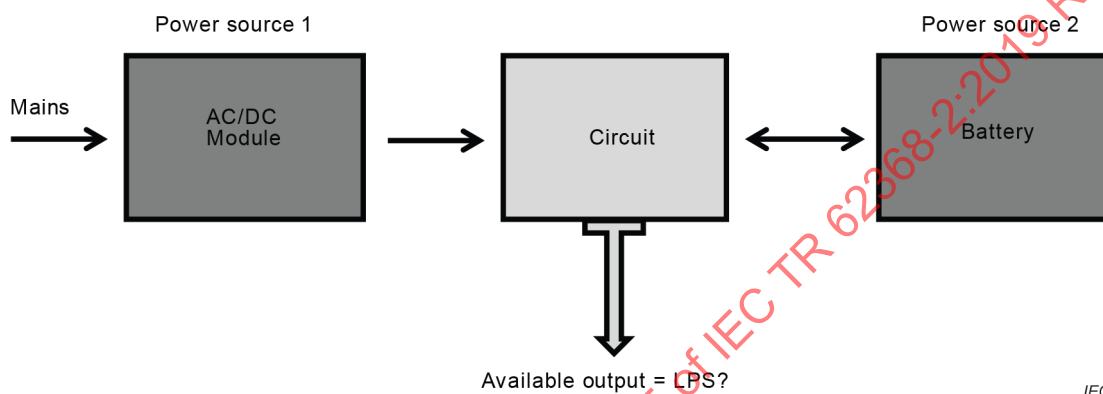


Figure 50 – Example of a circuit with two power sources

Annex R Limited short-circuit test

Source: IEC SC22E

Rationale: The value of 1 500 A is aligned with the normal breaking capacity of a high breaking fuse. In Japan the prospective short circuit current is considered less than 1 000 A.

Annex S Tests for resistance to heat and fire

S.1 Flammability test for fire enclosure and fire barrier materials of equipment where the steady-state power does not exceed 4 000 W

Rationale: This test is intended to test the ability of an end-product **enclosure** to adequately limit the spread of flame from a **potential ignition source** to the outside of the product.

- Included the text from IEC 60065 using the needle flame as the ignition source for all material testing. The reapplication of the flame after the first flaming was added to clarify that the test flame is immediately re-applied based on current practices.
- This conditioning requirement of 125 °C for printed wiring ~~comes~~ boards is derived from laminate and PCB ~~standards to accommodate~~ documents.

S.2 Flammability test for fire enclosure and fire barrier integrity

Rationale: This test method is used to test the integrity of a fire barrier or **fire enclosure** where a **potential ignition source** is in very close proximity to an **enclosure** or a barrier.

The criteria of “no additional holes” is considered important as flammable materials may be located immediately on the other side of the barrier or **fire enclosure**.

Rationale: **Application of needle flame**

The flame cone and the 50 mm distance is a new requirement that was not applied in IEC 60950 to top openings. This new requirement does impact already certified IEC 60950 ITE products, and it was found that some manufacturers' current designs were not able to comply with the 50-mm distance prescribed ventilation opening requirements and will not be able to pass the needle flame test as per IEC 60695-11. An HBSDT's fire enclosure adhoc team performed some experimental flame testing with the needle flame located at various distances from various size ventilation openings. This test approach was found to align more with hazard-based safety engineering principles and deemed to be a more realistic representation of when a thermal event may occur.

A **PIS** can be in the form of any size/shape, so it was determined not reasonable to directly apply the needle flame to top surface openings when realistically a thermal event from smaller components is unlikely to touch the top surface openings. Additionally, typically it is common for such components to be mounted on V-0 rated boards that further help reduce the spread of fire.

The test data from the fire experimental testing demonstrated clearly that, when the flame is at distances well within 50 mm, significantly larger openings can be used beyond the pre-specified sizes by 6.4.8.3.3 (for example less than 5 mm in any dimension and/or less than 1 mm regardless of length).

Therefore, for the purpose of this standard and to align more with hazard-based safety engineering principles, the needle flame is to be applied at a distance measured from the closest assessed point of a PIS to the closest surface point of the test specimen. The application of the flame is measured from the top of the needle flame burner to the closest surface point. See Figure S.1 in Clause S.2 of IEC 62368-1:2018.

S.3 Flammability tests for the bottom of a fire enclosure

Source: IEC 60950-1:2005/AMD1:2009/AMD2:2013

Rationale: This text was not changed from the original ECMA document which was originally in IEC 60950-1. This test is intended to determine the acceptability of holes or hole patterns in bottom **enclosures** to prevent flaming material from falling onto the supporting surface. It has been used principally for testing metal bottom **enclosures**.

This test is being proposed to test all bottom **enclosures**. Research is ongoing to develop a similar test based on the use of flammable (molten) thermoplastic rather than oil.

S.4 Flammability classification of materials

Rationale: The tables were considered helpful to explain the hierarchy of **material flammability class** requirements used in this document.

Whenever a certain flammability class is required, a better classification is allowed to be used.

S.5 Flammability test for fire enclosure materials of equipment with a steady state power exceeding 4 000 W

Source: IEC 60950-1:~~2005/AMD1:2009/AMD2~~:2013

Rationale: The annex for flammability test for high voltage cables was withdrawn and replaced by flammability test for fire **enclosure** materials of equipment having greater than 4 000 W faults.

Annex T Mechanical strength tests

T.2 Steady force test, 10 N

Source: IEC 60950-1

Rationale: 10 N applied to components and parts that may be touched during operation or servicing. This test simulates the accidental contact with a finger or part of a hand.

T.3 Steady force test, 30 N

Source: IEC 60065 and IEC 60950-1

Rationale: ~~30 N applied to internal enclosures and barriers that are accessible to ordinary persons.~~ This test simulates accidental contact with a part of the hand.

T.4 Steady force test, 100 N

Source: IEC 60065 and IEC 60950-1

Rationale: ~~100 N applied to external enclosures of transportable equipment and handheld equipment.~~ This test simulates an expected force applied during use or movement.

T.5 Steady force test, 250 N

Source: IEC 60065 and IEC 60950-1

Rationale: 250 N applied to external **enclosures** (except those covered in Clause T.4). This test simulates an expected force when leaning against the equipment surface to ensure **clearances** are not bridged to introduce a hazard such as shock. The 30 mm diameter surface simulates a small part of hand or foot. It is not expected that such forces will be applied to the bottom surface of heavy equipment (> 18 kg).

T.6 Enclosure impact test

Source: IEC 60065 and IEC 60950-1

Rationale: To check integrity of the **enclosure**, to ensure that no hazard is created by an impact.

The values in T.6 are taken over from existing requirements in IEC 60065 and IEC 60950-1.

The impact is applied once for each test point on the **enclosure**.

T.7 Drop test

Source: IEC 60065 and IEC 60950-1

Rationale: This test addresses potential exposure to a hazard after the impact and not impact directly on a body part. The test is applied to desk top equipment under 7 kg as it is more likely these products could be accidentally knocked off the desk. The drop height was chosen based on intended use of the product.

The term “table-top” has been used in IEC 60065, while the term “desk-top” has been used in IEC 60950-1. Both terms had been taken over in IEC 62368-1 without the intention to make the different requirements for these types of equipment. Therefore, the requirements are applicable to both type of equipment even if only either one is referred to. From edition 3 onwards, the term “table-top” has been replaced by “desk-top”.

T.8 Stress relief test

Source: IEC 60065 and IEC 60950-1

Rationale: To ensure that the mechanical integrity of moulded plastic parts is not affected by their relaxation or warping following thermal stress.

T.9 Glass impact test

Source: IEC 60065

Rationale: Test applied to test the strength of the glass.

The value of 7 J is a value that has been used for CRT in the past. Except for that, the value has also been used in commercial applications, but not in households, where the forces expected on the glass are much lower. CRT's have separate requirements in Annex W. Therefore, a value of 3,5 J is considered sufficient.

The centre of a piece of glass can be determined via the intersection of two diagonals for a rectangular piece or any other appropriate means for pieces of other geometries.

T.10 Glass fragmentation test

Source: IEC 60065

Rationale: Test applied to ensure the fragments are small enough to be considered at MS2 level or less.

Annex U Mechanical strength of CRTs and protection against the effects of implosion

U.2 Test method and compliance criteria for non-intrinsically protected CRTs

Source: IEC 61965, IEC 60065

Rationale: The 750 mm simulates the height of a typical supporting surface such as a table or counter top. Test applied to ensure any expelled fragments are small enough to be considered at MS2 level or less. The fragment size represents a grain of sand. The test distances selected ensure fragments do not travel far enough to strike a person and cause injury.

Annex V Determination of accessible parts

Figure V.3 Blunt probe

Source: This test probe is taken from Figure 2c, IEC 60950-1:2005/AMD1:2009/AMD2:2013

Annex X Alternative method for determining clearances for insulation in circuits connected to an AC mains not exceeding 420 V peak (300 V RMS)

Rationale: IEC TC 108 made a responsible decision to harmonize the requirements for **clearances** and **creepage distances** with the horizontal IEC 60664-x series documents produced by IEC TC 109. This decision is aligned with IEC harmonization directives and allows manufacturers the design benefits afforded by the IEC 60664-x series documents when minimization of spacings is a primary consideration of the product design.

However, because of the complexity of determining **clearances** as per 5.4.2, sometimes the more state-of-art theory is not practical to implement for designs not requiring minimized spacings. For example, there are a very large number of existing designs and constructions qualified to IEC 60950-1 that are associated with products, mainly switch mode power supplies, connected to AC **mains** (overvoltage category II) not exceeding 300 V RMS. These constructions have successfully used the **clearance** requirements in IEC 60950-1 without any evidence of field issues, and even at switching frequencies well above 30 kHz. In fact, almost every switch mode power supply (SMPS) used today with IT & ICT equipment intended to be connected to **mains** less than 300 V RMS, including external power supplies, direct plug-in type, and internal power supplies, have **clearances** based on the base requirements in Subclause 2.10.3.3 and Tables 2K and 2L of IEC 60950-1. Although the requirements do not incorporate the latest research on **clearances** used in circuits operating above 30 kHz, they are considered to be suitable for the application because they are a conservative implementation of IEC 60664-1 without minimization.

As a result, and in particular based on their proven history of acceptability in the broad variety of power supplies used today, IEC TC 108 should support continued limited application of a prescribed set of **clearances** as an alternative to the more state-of-art IEC 60664-based requirements in IEC 62368-1 today. However, because of the valid concern with circuits operating above 30 kHz as **clearances** are further minimized, the IEC 60950-1 option in Tables 2K and 2L for reduced **clearances** in products with manufacturing subjected to a quality control programme (values in parenthesis in Tables 2K/2L) are not included in this proposal since the reduced **clearances** associated with the quality control option has not been used frequently under IEC 60950-1, and therefore there is not the same proven track record of successful implementation in a very large number of products. Similarly, there is not the same large quantity of qualified designs/construction associated with equipment connected to **mains** voltages exceeding 300 V RMS, or for equipment connected to DC **mains**, so these constructions should comply with the existing IEC 60664-based requirements in IEC 62368-1.

Annex Y Construction requirements for outdoor enclosures

Rationale: General

In preparing the requirements for **outdoor enclosures**, it has been assumed that:

- exterior to the **outdoor equipment** there should be no hazards, just as is the case with other information technology equipment;
- protection against vandalism and other purposeful acts will be treated as a product quality issue (for example, IEC 62368-1 does not contain requirements for the security of locks, types of acceptable screw head, forced entry tests, etc.).

Electric shock

It is believed that most aspects relating to protection against the risk of electric shock are adequately covered by IEC 62368-1 including current proposals, and in some cases, quoted safety documents (in particular, the IEC 60364 series), and with the exception of the following, do not require modification. Specific requirements not already suitably addressed in IEC 60950-1 were considered as follows:

- clearing of earth faults for remotely located (exposed) information technology equipment;
- the degree of protection provided by the **enclosure** to rain, dust, etc.;
- the effect of moisture and **pollution degree** on the insulation of the enclosed parts;
- the possible consequences of ingress by plants and animals (since these could bridge or damage insulation);
- the maximum permissible touch voltage and body contact impedance for wet conditions.

It is noted that the voltage limits of user-**accessible** circuits and parts in **outdoor locations** only are applicable to circuits and parts that are actually “user-**accessible**”. If the circuits and parts are not user **accessible** (determined via application of accessibility probes) and are enclosed in **electrical enclosures**, connectors and cable suitable for the outdoor application, including being subject to all relevant **outdoor enclosure** testing, voltage limits for indoor locations may be acceptable based on the application. For example, a power-over-ethernet (PoE) surveillance camera mounted outdoors supplied by 48 V DC from PoE would be in compliance with Clause 5 if the **electrical enclosure** met the applicable requirements for **outdoor enclosures**.

Fire

It is believed that most aspects relating to protection against fire emanating from within the equipment are adequately covered by IEC 62368-1. However, certain measures that may be acceptable for equipment located inside a building would not be acceptable outdoors because they would permit the entry of rain, etc.

For certain types of **outdoor equipment**, it could be appropriate to allow the ‘no bottom **fire enclosure** required if mounted on a concrete base’ exemption that presently can be used for equipment for use within a restricted access location.

Mechanical hazards

It is believed that all aspects relating to protection against mechanical hazards emanating from the equipment are adequately covered by IEC 62368-1.

Heat-related hazards

It is believed that most aspects relating to protection against direct heat hazards are adequately covered by IEC 62368-1. However, it may be appropriate to permit higher limits for equipment that is unlikely to be touched by passersby (for example, equipment that is only intended to be pole mounted out of reach). A default nominal ambient temperature range for **outdoor equipment** has been proposed. The effects of solar heating have not been addressed.

In addition to direct thermal hazards, there is a need to consider consequential hazards. For instance, some plastics become brittle as they become cold. An **enclosure** made from such brittle plastic could expose users to other hazards (for example, electrical or mechanical) if it were to break.

Radiation

It is believed that most aspects relating to direct protection against radiation hazards are adequately covered by IEC 62368-1. However, there may be consequential hazards to consider. Just as polymeric materials can be affected by low temperatures, they can also become embrittled owing to the effect of UV radiation. An **enclosure** made from such brittle plastic could expose users to other hazards (for example, electrical or mechanical) if it were to break.

Chemical hazards

It is believed that certain types of **outdoor equipment** need to have measures relating to chemical hazards originating within, or external to, the equipment. Exposure to chemicals in the environment (for example, salt used to clear roads in the winter) can also cause problems.

Biological hazards

These are not presently addressed in IEC 62368-1. As with radiation hazards and chemical hazards, it is thought that there is not likely to be any direct biological hazard. However, plastics and some metals can be attacked by fungi or bacteria and this could result in weakening of protective **enclosures**. As stated under 'electric shock', the ingress of plants and animals could result in damage to insulation.

Explosion hazards

Outdoor equipment may need to be weather-tight, in such cases there is an increased probability that an **explosive** atmosphere can build up as a result of:

- hydrogen being produced as a result of charging lead-acid **batteries** within the equipment and;
- methane and other 'duct gasses' entering the equipment from the outdoors.

Y.3 Resistance to corrosion

Rationale: **Enclosures** made of the following materials are considered to comply with XX.1 without test:

- (a) Copper, aluminum, or stainless steel; and
- (b) Bronze or brass containing at least 80 % copper.

Y.4.6 Securing means

Rationale: Gaskets associated with doors, panels or similar parts subject to periodic opening is an example of a gasket needing either mechanical securement or adhesive testing.

Annex A (informative)

Background information related to the use of SPDs

NOTE Since there is ongoing discussion in the committee on the use of SPDs in certain situations, the content of this Annex is provided for information only. This Annex does not in any way override the requirements in the document, nor does it provide examples of universally accepted constructions.

A.1 Industry demand for incorporating SPDs in the equipment

The industry has the demand of providing protection of communication equipment from overvoltage that may be caused by lightning strike surge effect. There are reports in Japan that hundreds of products are damaged by lightening surges every year, including the risk of fire and/or electrical shock according to the damage to the equipment, especially in the regions where many thunderstorms are observed. We believe it will be the same in many other countries by the reason described in the next paragraph where the voltage of the surge is much higher than expected value for overvoltage category II equipment (1 500 V peak or 2 500 V peak). For the surge protection purpose, the manufacturers have need to introduce the surge protection devices in the equipment, not only for **class I equipment** but also for **class II equipment** or **class III equipment**, but facing to the difficulty of designing equipment because of the limited acceptance in IEC 60950-1:2005, 2nd edition and IEC 62368-1:2010, (1st edition replaced by the 2nd edition published in 2014).

If the point of bonding of electrical supply to the equipment is not adjacent to the point of bonding of telecommunication circuit that is connected to the **external circuit** of the same equipment, the surge entered from power line or from communication line causes the high potential difference on the insulation in the equipment, and cause the insulation/component breakdown which may cause product out-of-use. In some cases, the damage on the insulation or **safeguard** can cause hazardous voltage on the SELV/ES1 and **accessible** metal, or heat-up of insulation material and fire (see Figure A.1 in this document, with the example of **class II equipment**.)

The most effective way to protect equipment from a lightning surge is, as commonly understood internationally, to have an equipotential bonding system in the building/facility with a very low in-circuit impedance by the use of main-earth bar concept (see Figure A.2 in this document). This kind of high-quality earthing provision can be introduced in the building/facility in the business area, such as computer rooms, or in modern buildings. This kind of high quality earthing provision may not always be possible in the residential area, in already-existing buildings and in some countries where the reliably low impedance earth connection may not be easily obtained from technical (according to the characteristics of land) or even by practical reasons (because very expensive construction change to the building is required, or according to the lack of regulatory co-work it is difficult to get the relevant permission for cabling). We should not disregard the fact that many ICT equipment (including PCs, fax machines, TVs and printers) are brought to home, school and small business offices into the existing buildings (see Figure A.3 and Figure A.4 in this document).

If the use of surge suppressors by the means of “a varistor in series with a GDT” is allowed in the equipment to bridge **safeguards** for **class I equipment** and to bridge a **double safeguard** or a **reinforced safeguard** for **class II equipment**, means can be provided to bypass the surge current, and to avoid the possibility that the lightening surge breaks the circuit or the insulation within the equipment (see Figure A.2 in this document).

Thus, there is industry demand for using surge protecting devices (SPDs) in the equipment independent of whether the product is **class I equipment**, **class II equipment** or **class III equipment**.

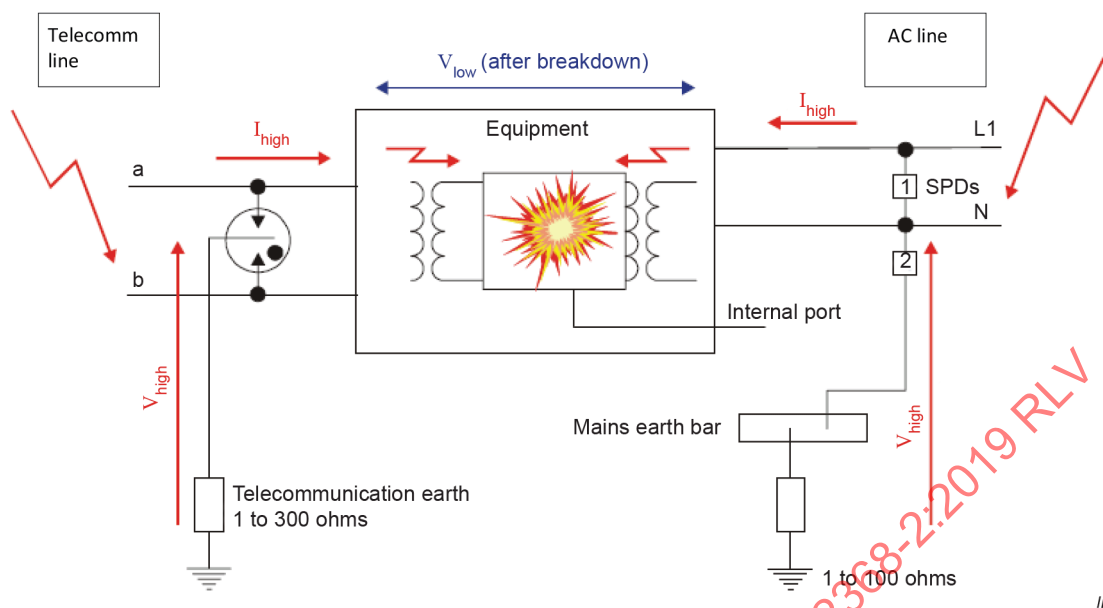


Figure A.1 – Installation has poor earthing and bonding; equipment damaged (from ITU-T K.66)

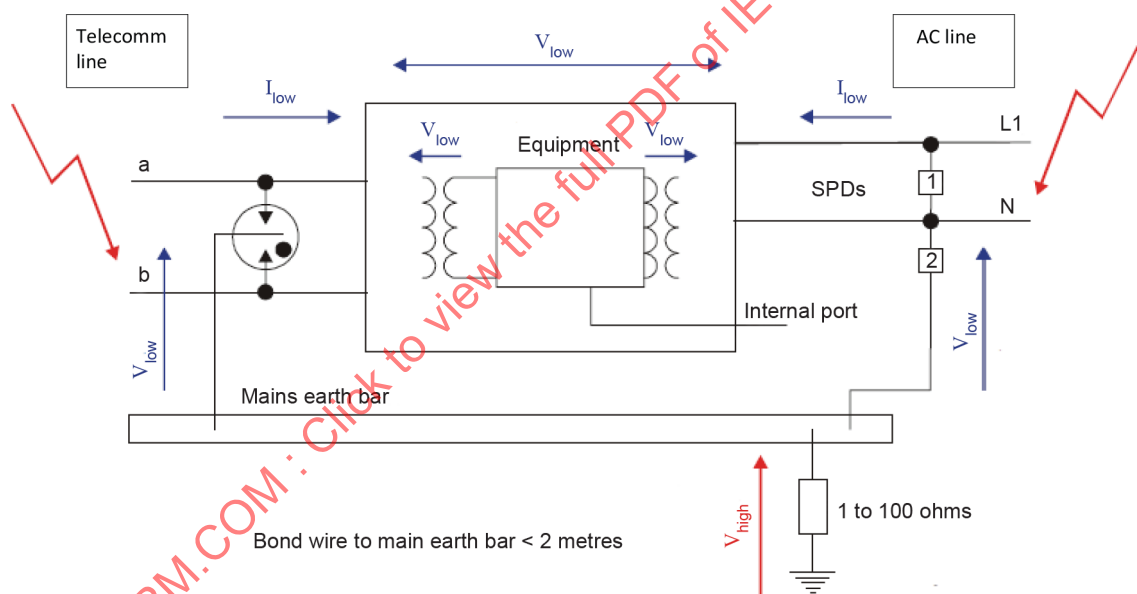


Figure A.2 – Installation has poor earthing and bonding; using main earth bar for protection against lightning strike (from ITU-T K.66)

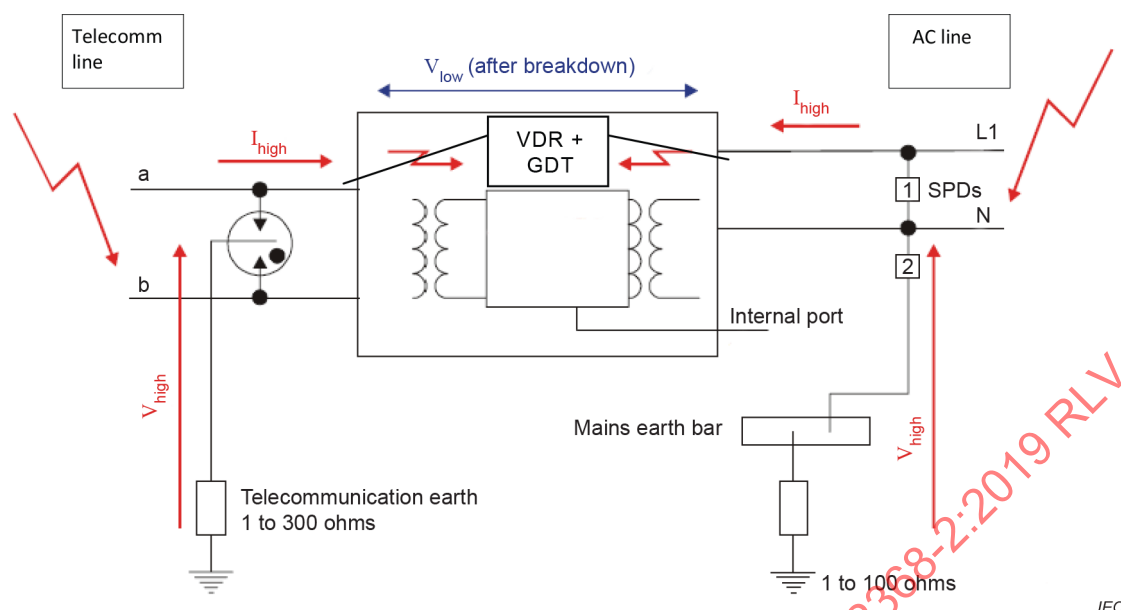


Figure A.3 – Installation with poor earthing and bonding, using a varistor and a GDT for protection against a lightning strike

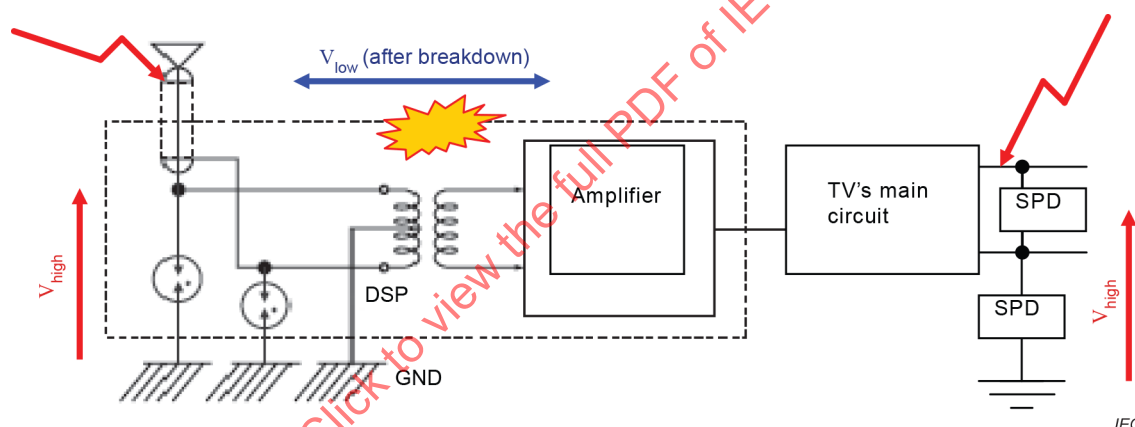


Figure A.4 – Installation with poor earthing and bonding; equipment damaged (TV set)

A.2 Technical environment of relevant component standards

Before the publication of IEC 62368-1:2010 ~~(1st edition)~~, there was no appropriate component document for a GDT deemed to be providing a sufficient level of endurance to be accepted as a **safeguard** for a primary circuit. For this reason, a GDT could not be accepted as a reliable component for use as a **safeguard** between a primary and secondary circuit.

However, recently IEC SC 37B has been developed new documents for GDTs. In these documents the spark over voltage of GDT's has been extended up to 4 500 V DC, taking the use of GDTs in the **mains** circuit in to account. We believe therefore that a GDT may be used as a **safeguard** if it complies with the following documents:

- IEC 61643-311:2013: Components for low-voltage surge protective devices – Part 311: Performance requirements and test circuits for gas discharge tubes (GDT);
- IEC 61643-312:2013: Components for low-voltage surge protective devices – Part 312: Selection and application principles for gas discharge tubes;

The sentence “does not deal with GDTs connected in series with voltage-dependent resistors in order to limit follow-on currents in electrical power systems;” in the scope of these

documents with a purpose for expressing that GDTs connected in series with varistors are a kind of SPD and this issue should be in IEC 61643-11 for SPD's standard. But this sentence may be misread as "a GDT is not allowed to be used for primary circuits", so SC37B decided to delete the sentence. This decision was made during the IEC SC 37B meeting at Phoenix, U.S.A, in Oct, 2010.

A.3 Technical discussion

A.3.1 General

For the use as surge protective devices (SPD), there are many types of components and the combined use of them. Some of them are relatively large in size and useful only in the outdoor facility or in the building circuits. Some are reliable but others may not.

For use with equipment in the scope of IEC 62368-1, varistors and GDT's are very commonly available with appropriate physical size and reliability.

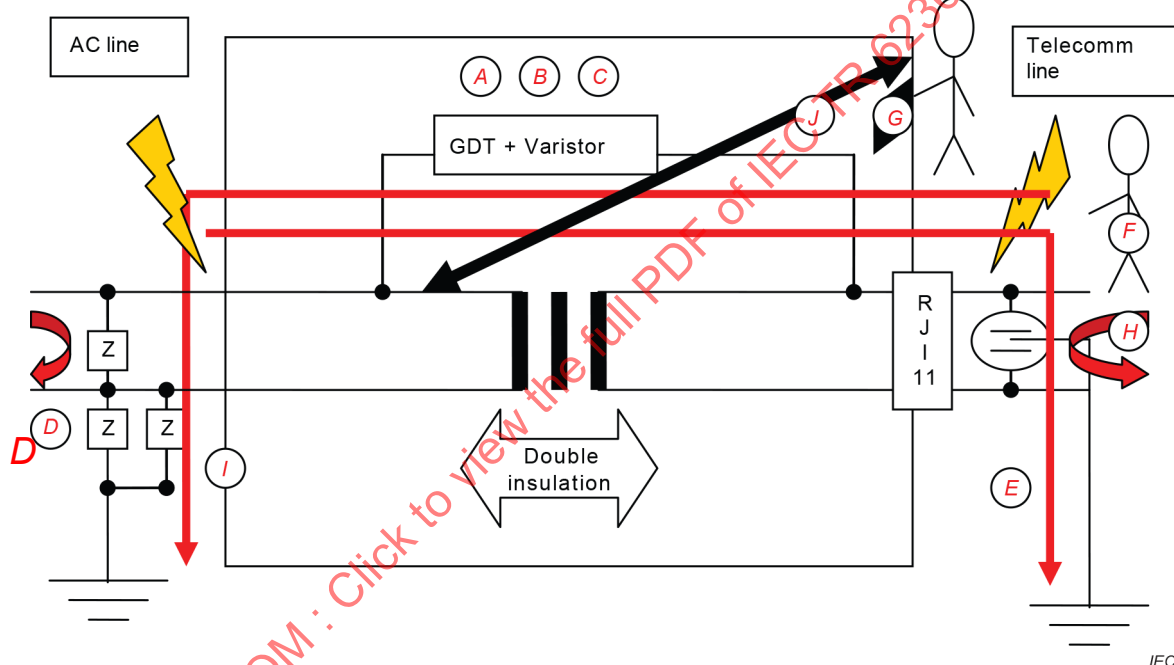


Figure A.5 – Safeguards

A.3.2 Recommended SPD and its level of sparkover voltage

The recommended construction of SPD for the purpose of protecting human and the insulations in the equipment is the combined use of a GDT and a varistor in series, by the reasons described in this subclause and A.3.3.

The level of sparkover voltage of the SPD constructed as recommended as above is important and should be selected as higher than withstand voltage level of insulation which SPD is intended to protect from damage by surge overvoltage. IEC 61643-311 and IEC 61643-312 provides the selection of GDT's up to 4 500V DC sparkover voltage series (see "A" in Figure A.5 in this document).

A.3.3 Consideration of a GDT and its follow current

If you are going to use a GDT in the primary circuit, or in the **external circuit**, you have to take the follow current in GDT into account. For more information on the GDT's follow current, see Clause A.4 in this document.

The follow current in the GDT after the surge transient voltage/current that flows ~~over~~ through it may ~~effect to~~ keep the GDT ~~staying~~ in the low impedance mode while the equipment power is on, ~~and there is~~ resulting in a risk of electric shock if somebody touches the circuit connected to the GDT. The combined use of a GDT and a varistor in series is the common method to avoid this risk. After the transient overvoltage condition is over, the varistor will stop the GDT's follow current. Complying with Clause G.8 is required for the varistor's **working voltage**. It means that $1,25 \times V_{ac}$ is required for the varistor's **working voltage**. After the transient, the varistor will stop the current from the AC line immediately.

For the reliability of the GDT, it is required that the GDT meets the requirements for electric strength and the external **clearance** and **creepage distance** requirements for **reinforced insulation** (see "**B**" in Figure A.5).

A.3.4 Consideration of varistors and its leak current

If a varistor is used in the primary circuit or in the **external circuit**, the leakage current in the varistor has to be taken into account. The continuous current caused by the leakage current may burn the varistor or other components in the circuit, and is energy inefficient. The combined use of a GDT and a varistor in series is the common method to avoid this effect, since the GDT can kill the leakage current just after the surge transient voltage passed through these components.

For the reliability of the varistor, it has to comply with Clause G.8 (see "**C**" in Figure A.5 in this document).

A.3.5 Surge voltage/current from mains

A.3.5.1 Case of transversal transient on primary circuit

A surge caused by lightning may enter in the **mains** circuit and get into the equipment as a transversal transient overvoltage. In this case, incorporating an SPD (that may be a varistor only) between the line and neutral of the primary circuit is an effective method to prevent damage in the circuit, as the surge is bypassed from line to neutral or vice versa. In this case, the reliability requirement may not be mandatory for the SPD, because the failure of the SPD can lead to an equipment fault condition (out of use) but may not lead to risk to human (see "**D**" in Figure A.5 in this document).

A.3.5.2 Case of longitudinal transient on primary circuit

A surge caused by lightning may enter in the **mains** circuit and get into the equipment as a longitudinal (common mode) transient overvoltage, which may cause high-level potential difference between the primary circuit and the **external circuits** in the equipment. In this case, providing a bypass circuit from the primary circuit to the reliable bonding, or a bypass circuit between the primary circuit and the **external circuits**, or both, incorporating an SPD (a combined use of a GDT and a varistor in series is recommended) is an effective method to prevent insulations and components in the equipment from being damaged (see "**E**" in Figure A.5 in this document).

For preventing the risk of electrical shock in this case, a bypass circuit connected to the SPD shall be either connected to the earth, or provided with a suitable **safeguard** from ES1. (A **double safeguard** or a **reinforced safeguard** between the primary side of an SPD and ES1, and a **basic safeguard** between **external circuit** side of SPD and ES1, see "**J**" and "**G**" in Figure A.5 in this document).

There may be a discussion about the safety of the telecommunication network connected to the **external circuit**, but it is presumed that the telecommunication network is appropriately bonded to the earth through the grounding system. Also, the maintenance person accessing the telecommunication for maintenance is considered to be a **skilled person**, and knows that they should not access the network lines when lightning strikes are observed in the nearby area (see "**F**" in Figure A.5 in this document).

For the risk that the connection of the **external circuit** to the telecommunication network is disconnected, the SPD cannot operate. However, in this case, the **external circuit** is left open circuit, therefore the telecom side shall have a **safeguard** to ES1. Under this condition, the SPD can be the open circuit (see “**G**” and “**F**” in Figure A.5 in this document).

A.3.6 Surge voltage/current from external circuits

A.3.6.1 Case of transversal transient on external circuits

A surge caused by lightning may enter from the **external circuit** (such as the telecommunication network) as a transversal transient overvoltage. In this case, incorporating an SPD (may be a GDT only) between the Tip and Ring of the **external circuit** is the effective method to prevent damage in the circuit, as the surge is bypassed from one wire of the **external circuit** to another wire. In this case, the reliability requirement is not mandatory for the SPD, because the failure of the SPD can only lead to an equipment fault condition (out of use) but may not lead to risk to a person (see “**H**” in Figure A.5 in this document).

A.3.6.2 Case of longitudinal transient on external circuits

A surge caused by lightning may enter the telecommunication network and get into the **external circuit** of the equipment as longitudinal (common mode) transient overvoltage, which may cause high level potential difference between a ~~primary~~ **mains** circuit and **external circuits**. In this case, providing a bypass circuit between the primary circuit and **external circuits**, or between **external circuit** and bonding, or both, incorporating an SPD (a combined use of a GDT and a varistor in series is recommended) is an effective method to protect insulations and components in the equipment (see “**I**” in Figure A.5 in this document).

For limiting the risk of electrical shock in this case, a bypass circuit connected to the SPD shall be either connected to the earth, or provided with suitable **safeguard** from ES1 (A **double safeguard** or a **reinforced safeguard** between the primary side of the SPD and ES1, and a **basic safeguard** between the **external circuit** side of the SPD and ES1, see “**J**” in Figure A.5 in this document).

About the consideration of some countries that have no polarity of the AC plug, SPDs installed between power lines in accordance with IEC 60364 will operate and the surge will go into the AC line (see “**I**” in Figure A.5 in this document).

A.3.7 Summary

As a summary of the above technical discussions, the following are proposed requirements if a varistor is connected in series with a GDT and used as **safeguard**:

- the GDT's sparkover voltage level should be selected from IEC 61643-311 and IEC 61643-312 in accordance with the bridged insulation (see A.3.2 in this document);
- the GDT shall pass the electric strength test and meet the external **clearance** and **creepage distance** requirements for **reinforced insulation** (see A.3.3 in this document);
- the varistor shall comply with Clause G.8 (see A.3.3 and A.3.4 in this document);
- the bypass circuit connected to the SPD shall be either connected to earth, or provided with a suitable **safeguard** from ES1 (a **double safeguard** or a **reinforced safeguard** between the primary side of the SPD and ES1, and a **basic safeguard** between the **external circuit** side of the SPD and ES1, see A.3.5.2 and A.3.6.2 in this document).

A.4 Information about follow current (or follow-on current)

A.4.1 General

The information was taken from “MITSUBISHI Materials home page”

A.4.2 What is follow-on-current?

Follow-on-current is literally something that will continue to flow. In this case it is the phenomenon where the current in a discharge tube continues to flow.

Normally surge absorbers are in a state of high impedance. When a surge enters the absorber it will drop to a low impedance stage, allowing the surge to bypass the electronic circuit it is protecting. After the surge has passed, the absorber should return to a high impedance condition.

However, when the absorber is in a low impedance state and if there is sufficient voltage on the line to keep the current flowing even when the surge ends, the absorber remains in a discharge state and does not return to a high impedance state. The current will then continue to flow. This is the phenomenon known as follow-on-current.

Surge absorbers that display this follow-on-current phenomenon are of the discharge type or semiconductor switching absorbers. A characteristic of these absorbers is that during surge absorption (bypass) the operating voltage (remaining voltage) is lower than the starting voltage.

The advantage of this is that during suppression the voltage is held very low, so as to reduce stress on the equipment being protected. But there can be a problem when the line current of the equipment is sufficient so that it continues to drive the absorber when the voltage is at a low state.

Below are more details about the follow-on-current mechanism. The discharge and power source characteristics for the discharge tube as well as conditions of follow-on-current will be explained.

A.4.3 What are the V-I properties of discharge tubes?

The micro-gap type surge absorber is one kind of discharge tube. The discharge characteristics where the part passes through pre-discharge, glow discharge and then arc discharge are shown in Figure A.6 in this document.

Figure A.6 in this document shows the V-I characteristics relation between voltage and current for the discharge tube. When the tube discharges, electric current flows and it moves to a glow discharge state and then an arc state all while the discharge voltage decreases. Conversely, as the discharge decreases, the voltage increases as it moves from an arc state to a glow state.

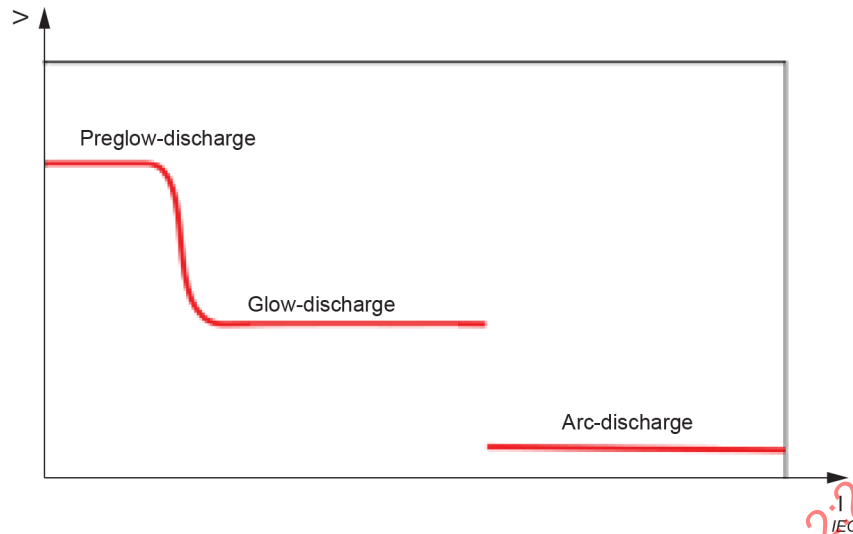


Figure A.6 – Discharge stages

Pre-glow discharge

The voltage that is maintaining this discharge is approximately equal to the DC breakdown voltage of the part. A faint light can be seen from the part at this point.

Glow discharge

There is a constant voltage rate versus the changing current. The voltage maintaining this discharge will depend on the electrode material and the gas in the tube. The discharge light now covers one of the electrodes.

Arc discharge

With this discharge, a large current flows through the part and it puts out a bright light. The maintaining voltage at this point (voltage between the discharge tube terminals) is in the 10's of volts range.

A.4.4 What is holdover?

When a discharge tube is used on a circuit that has a **DC voltage** component, there is a phenomenon where the discharge state in the tube continues to be driven by the current from the power supply even after the surge voltage has subsided. This is called holdover (see Figure A.7 in this document).

When holdover occurs, for example, in the drive circuit of a CRT, the screen darkens and discharge in the absorber continues, which can lead to the glass tube melting, smoking or burning.

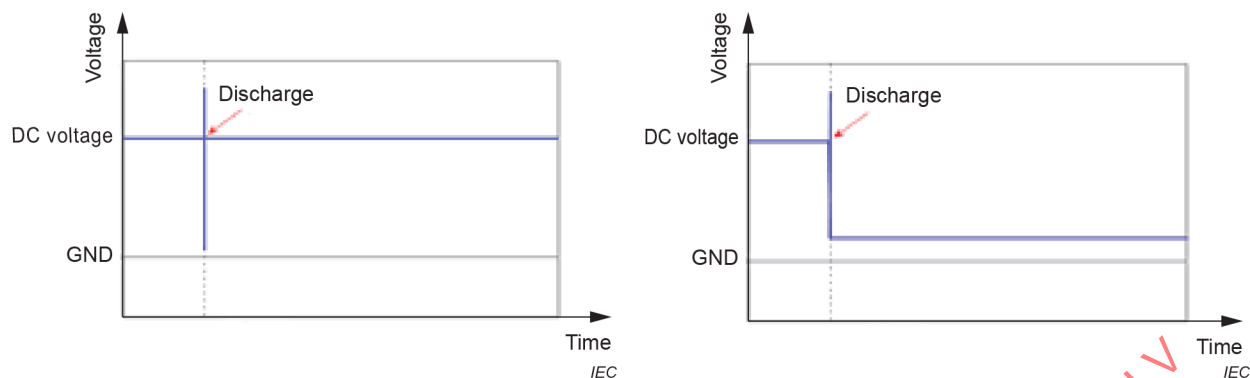


Figure A.7 – Holdover

Holdover can occur when the current can be supplied to the discharge tube due to varying conditions of output voltage and output resistance of the DC power supply. What are then the conditions that allow current to continue to flow to the discharge tube?

The relation between the power supply voltage (V_0), serial resistance (R), discharge current (I) and the terminal voltage (v) are shown in the linear relation below:

$$v = V_0 - I \times R$$

If the voltage V_0 is fixed, the slope of the power supply output characteristic line increases or decreases according to the resistance and may or may not intersect with the V-I characteristics of the discharge tube.

The characteristic linear line of a power supply shows the relation between the output voltage and current of the power supply. Likewise, the V-I curve of a discharge tube shows the relation between the voltage and current.

When static surge electricity is applied to the discharge tube, the shape of the curve shows that the surge is being absorbed during arc discharge.

As the surge ends, the discharge goes from arc discharge to glow discharge and then to the state just prior to glow discharge. At this time the relationship between the discharge tubes V-I curve and the power supply's output characteristics are very important.

As shown in the figure, with a high resistance in the power supply, the output characteristic line (pink) and the discharge tubes V-I characteristic curve (red) never intersect. Therefore, current will not flow from the power supply and follow-on-current will not occur.

However, when the output characteristic line of the power supply (pink) intersects with the V-I curve of the discharge tube (red), it is possible for current from the power supply to flow into the discharge tube. When the surge ends, the current should decrease from arc discharge to the pre-glow state, but instead the power supply will continue to drive the current where it intersects in the glow or arc discharge region. This is called holdover, and is the condition where the power supply continues to supply current to the discharge tube at the intersection on its characteristic line and the discharge tubes V-I curve.

Figure A.8 in this document shows where the power supply can continue supplying current to the discharge tube when its characteristic line intersects the discharge tubes V-I line in the glow or arc discharge sections.

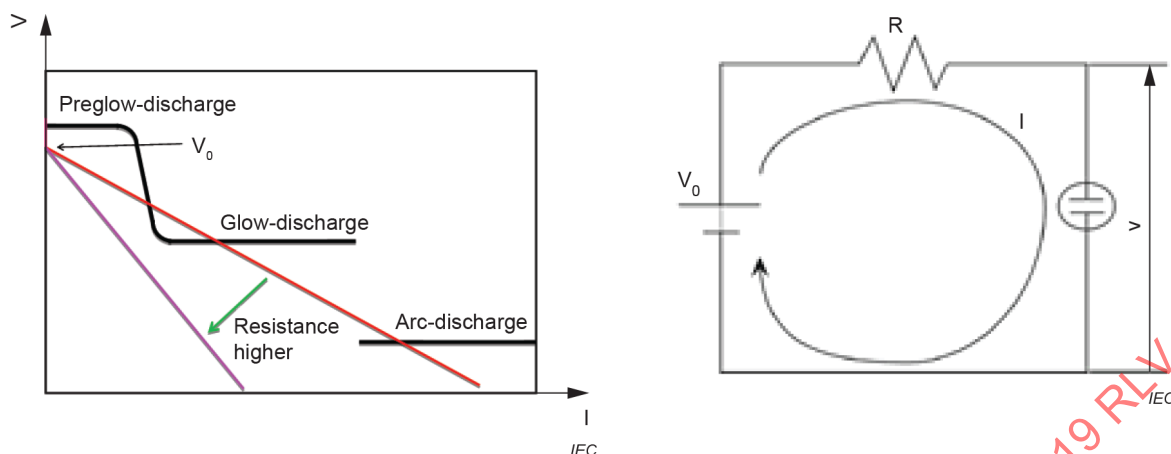


Figure A.8 – Discharge

To prevent holdover from occurring, it is important to keep the V-I characteristic line of the power supply from intersecting with the V-I curve of the discharge tube.

A.4.5 Follow-on-current from AC sources?

When using the discharge tube for AC sources, when follow-on-current occurs as per the case with DC it is easy to understand.

That is, as can be seen in the figure below, the only difference is that the power supply voltage (V_0) changes with time.

As shown on the previous page, when the power supply voltage is shown as $V_0(t)$, the output power characteristics are displayed as follows:

$$v = V_0(t) - R \times I$$

where

v is the the voltage at the power out terminal

I is the current of the circuit

$V_0(t)$ will vary with time, so when displaying the above equation on a graph, it will appear as in Figure A.9 in this document on the left. Then when $V_0(t)$ is shown as:

$$V_0(t) = V_0 \sin \omega t$$

When the power supply voltage becomes 0 (zero cross), there is a short time around this crossing where the voltage range and time range of the power supply output and discharge tube V-I curve do not intersect.

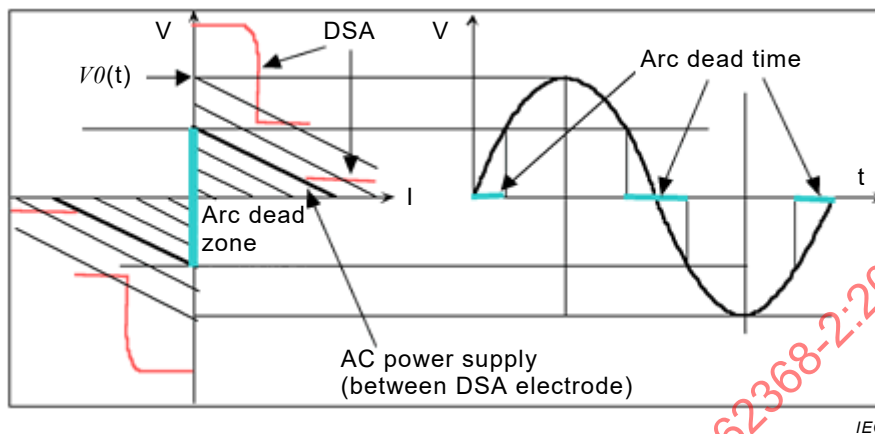
For an AC power supply, because there is always a zero crossing of the supply's voltage, more than holdover it is easier to stop the discharge. In the vicinity of the zero crossing, it is impossible to maintain the discharge since the current to the discharge is cut off. The discharge is then halted by the fact that the gas molecules, which were ionized during this time, return to their normal state.

Because the terminal voltage does not exceed the direct current break down voltage, if the discharge is halted it will not be able to start again.

However, if the gas molecules remain ionized during this period and voltage is again applied to both terminals of the discharge tube (enters the cycle of opposite voltage), this newly

applied voltage will not allow the discharge to end and it will continue in the discharge mode. This is follow-on-current for alternating current.

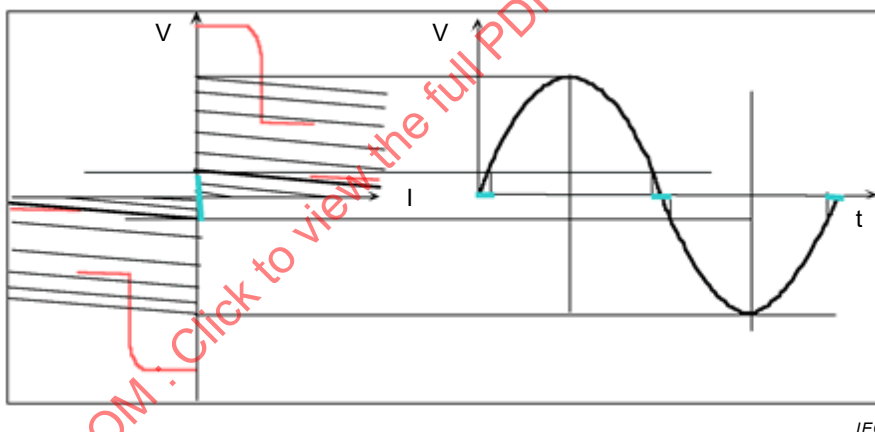
When follow-on-current occurs, the tube stays in a discharge mode and the glass of the tube will begin to smoke, melt and possibly ignite.



V-I characteristics

V-t characteristics

Illustration: When resistance is high (period where follow on current cannot occur is large)



V-I characteristics

V-t characteristics

Illustration: When resistance is low (period where follow on current cannot occur is small)

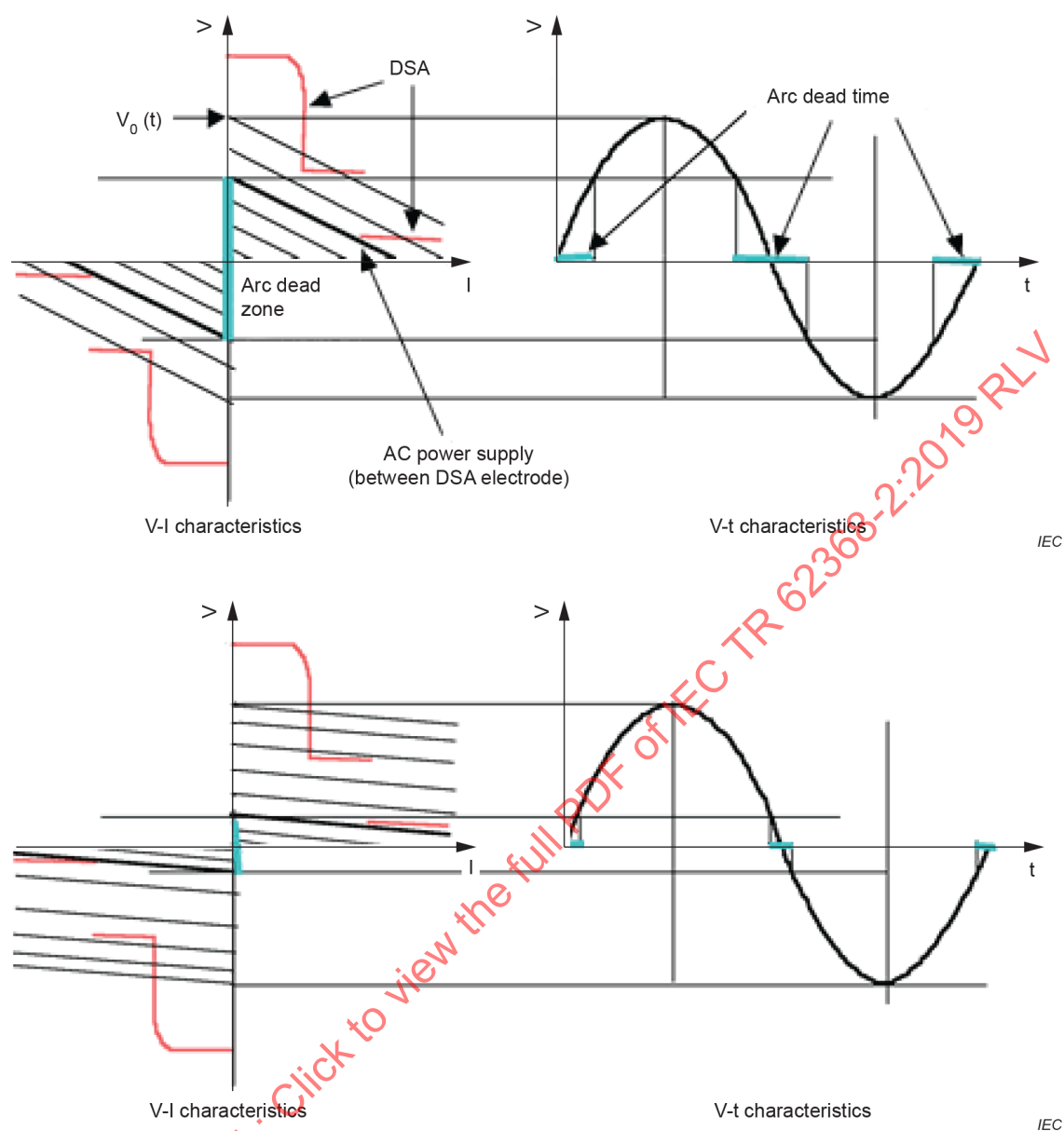
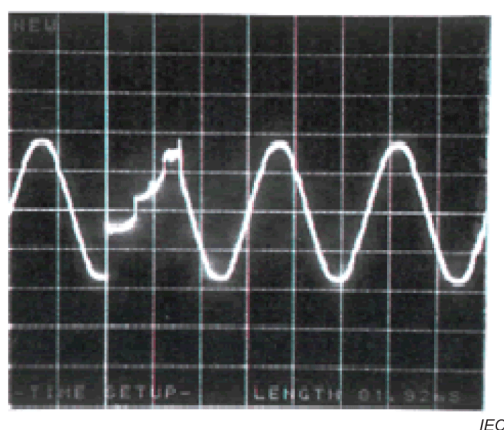


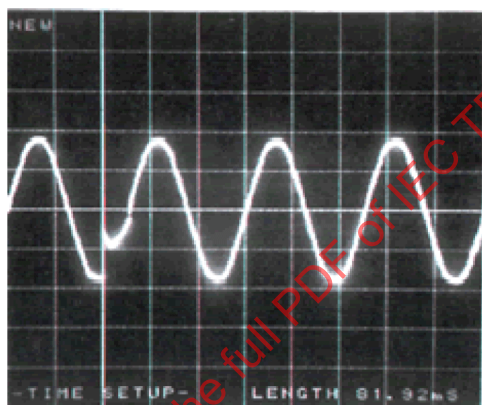
Figure A.9 – Characteristics

It is important to insert a resistance in series that is sufficiently large to prevent follow-on-current from occurring according to the conditions of the alternating current.



IEC

Picture 1: with 0 Ω
(follow-on current occurs)



IEC

Picture 2: with 0,5 Ω
(follow-on current is stopped within half a wave)

Figure A.10 – Follow on current pictures

With 1 Ω and 3 Ω resistance, results are the same as those in picture 2, follow-on-current is disrupted and discharge stops (see Figure A.10 in this document).

For AC power sources, the resistance value that is connected in series with the discharge tube is small in comparison to DC sources.

If the series resistance is 0,5 Ω or greater it should be sufficient, however for safety a value of 3 Ω (for 100 V) or greater is recommended.

In addition there is also a method to use a varistor in series that acts as a resistor. In this case the varistor should have an operating voltage greater than the AC voltage and be placed in series with the discharge tube. Unlike the resistor, discharge will be stopped without follow-on-current occurring during the first half wave.

Recommended varistor values are:

- for 100 VAC lines: a varistor voltage of 220 V minimum;
- for 200 VAC lines: a varistor voltage of 470 V minimum.

A.4.6 Applications with a high risk of follow-on-current

- 1) Holdover: CRT circuits and circuits using DC power supplies
- 2) Follow-on-current: Circuits using AC power source

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Annex B (informative)

Background information related to measurement of discharges – Determining the R-C discharge time constant for X- and Y-capacitors

B.1 General

Since the introduction of 2.1.1.7 of ~~IEC 60950-1:2005~~, “Discharge of capacitors in equipment,” in ~~IEC 60950-1:2005~~, questions continually arise as to how to measure the R-C discharge time constant. The objective of this article is to describe how to measure and determine the discharge time constant.

B.2 EMC filters

EMC filters in equipment are circuits comprised of inductors and capacitors arranged so as to limit the emission of RF energy from the equipment into the **mains** supply line. In EMC filters, capacitors connected between the supply conductors (for example, between L1 and L2) of the **mains** are designated as X capacitors. Capacitors connected between a supply conductor and the PE (**protective earthing** or grounding) conductor are designated as Y capacitors (Safety requirements for X and Y capacitors are specified in IEC 60384-14 and similar national standards). The circuit of a typical EMC filter is shown in Figure B.1. C_X is the X capacitor, and C_Y are the Y capacitors.

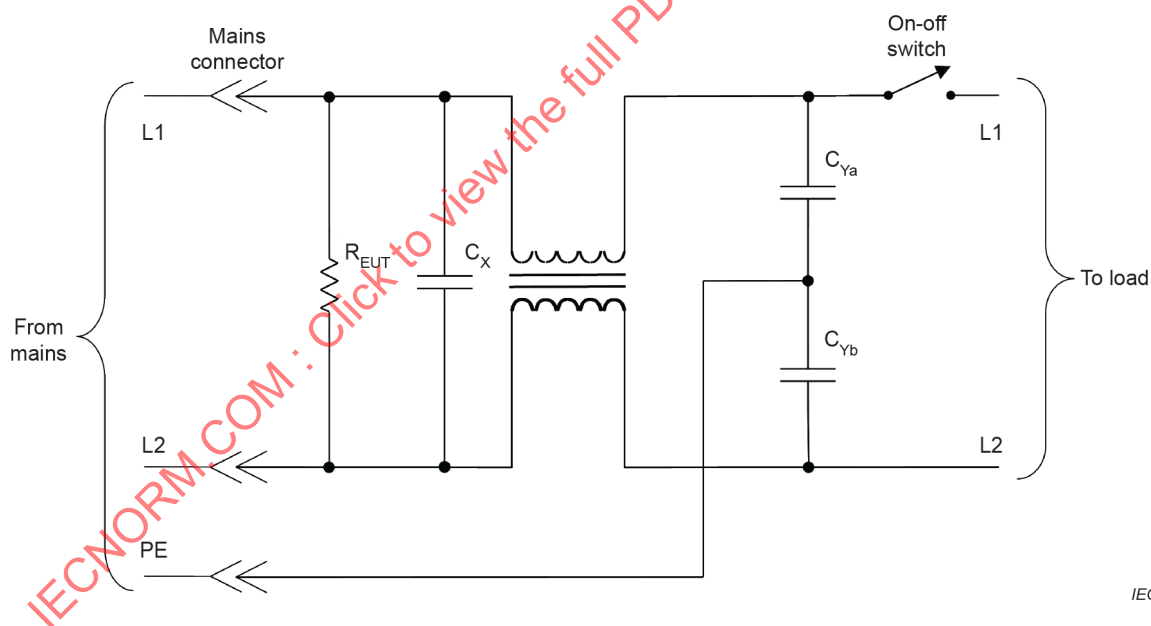


Figure B.1 – Typical EMC filter schematic

B.3 The safety issue and solution

When an EMC filter is disconnected from the **mains** supply line, both the X (C_X) and the Y (C_{Ya} and C_{Yb}) capacitors remain charged to the value of the **mains** supply voltage at the instant of disconnection.

Due to the nature of sinusoidal waveforms, more than 66 % of the time (30° to 150° and 210° to 330° of each cycle) the voltage is more than 50 % of the peak voltage. For 230 V **mains** (325 V_{peak}), the voltage is more than 162 V for more than 66 % of the time of each cycle. So, the probability of the voltage exceeding 162 V at the time of disconnection is 0,66. This

probability represents a good chance that the charge on the X and Y capacitors will exceed 162 V.

If a hand or other body part should touch both pins (L1 and L2) of the **mains** supply plug at the same time, the capacitors will discharge through that body part. If the total capacitance exceeds about 0,1 μF , the discharge will be quite painful.

To **safeguard** against such a painful experience, safety documents require that the capacitors be discharged to a non-painful voltage in a short period of time. The short period of time is taken as the time from the disconnection from the **mains** to the time when contact with both pins is likely. Usually, this time is in the range of 1 s to 10 s, depending on the documents and the type of attachment plug cap installed.

B.4 The requirement

The time constant is measured with an oscilloscope. The time constant and its parameters are defined elsewhere.

The significant parameters specified in the requirement are the capacitance exceeding 0,1 μF and the time constant of 1 s or less (for **pluggable equipment type A**) or 10 s or less (for **pluggable equipment type B**). These values bound the measurement. This attachment addresses **pluggable equipment type A** and the 1 s time constant requirement. The attachment applies to **pluggable equipment type B** ~~if~~ and the time constant is changed to 10 s.

Pluggable equipment type A is intended for connection to a **mains** supply via a non-industrial plug and socket-outlet. **Pluggable equipment type B** is intended for connection to a **mains** supply via an industrial plug and socket-outlet.

The document presumes that measurements made with an instrument having an input resistance of 95 M Ω to 105 M Ω and up to 25 pF in parallel with the ~~resistance~~ impedance and capacitance of the equipment under test (EUT) will have negligible effect on the measured time constant. The effect of probe parameters on the determination of the time constant is discussed elsewhere in this document.

The requirement specifies a time constant rather than a discharge down to a specified voltage within a specified time interval. If the document required a discharge to a specific voltage, then the start of the measurement would need to be at the peak of the voltage. This would mean that the switch (see Figure B.5) would need to be opened almost exactly at the peak of the voltage waveform. This would require special switching equipment. The time constant is specified because it can be measured from any point on the waveform (except zero), see Figure B.4b.

B.5 100 M Ω probes

Table B.1 in this document is a list of readily available oscilloscope probes with 100 M Ω input resistance and their rated input capacitances (the list is not exhaustive). Also included is a 400 M Ω input resistance probe and a 50 M Ω input resistance probe.

Table B.1 – 100 M Ω oscilloscope probes

Manufacturer	Input resistance	Input capacitance
	M Ω	pF
A	100	1
B	100	6,5
C	100	3
D	400	10 – 13
E	100	2,5
F	50	5,5

Note that the input capacitances of the 100 M Ω probe input capacitances are very much less than the maximum capacitance of 25 pFs. This attachment will discuss the effect of the probe capacitance and the maximum capacitance elsewhere.

100 M Ω probes are meant for measuring high voltages, typically 15 kV and more. These probes are quite large and are awkward to connect to the pins of a power plug.

**Figure B.2 – 100 M Ω oscilloscope probes**

General purpose oscilloscope probes have 10 M Ω input resistance and 10 pF to 15 pF input capacitance. General-purpose probes are easier to connect to the pins of the power plug. This attachment shows that a 10 M Ω , 15 pF probe can be used in place of a 100 M Ω probe.

B.6 The R-C time constant and its parameters

Capacitor charge or discharge time can be expressed by the R-C time constant parameter. One time constant is the time duration for the voltage on the capacitor to change 63 %. In five time constants, the capacitor is discharged to almost zero.

Table B.2 – Capacitor discharge

Time constant	Percent capacitor voltage (or charge)	Capacitor voltage (230 V _{rms} , 331 V _{peak})
0	100	325
1	37	120
2	14	45
3	5	16
4	2	6
5	0,7	2

The values in Table B.2 in this document are given by:

$$V_t = V_0 e^{-\left(\frac{t}{RC}\right)}$$

where:

V_t is the voltage at time t

V_0 is the voltage at time 0

R is the resistance, in Ω

C is the capacitance, in F (Farads)

t is the time, in s

The time constant is given by the formula:

$$T_{EUT} = R_{EUT} \times C_{EUT}$$

where:

T_{EUT} is the time, in seconds, for the voltage to change by 63 %

R_{EUT} is the EUT resistance, in Ω

C_{EUT} is the EUT capacitance, in F (Farads)

In the equipment under test (EUT), the EUT capacitance, C_{EUT} , in the line filter (Figure B.1) includes both the X-capacitor and the Y-capacitors.

The two Y-capacitors, C_{Ya} and C_{Yb} , are in series. The resultant value of two capacitors in series, C_Y , is:

$$C_Y = \frac{C_{Ya} \times C_{Yb}}{C_{Ya} + C_{Yb}}$$

Assuming the two Y-capacitors have the same value, their L1-L2 value is one-half of the value of one of the capacitors.

The X-capacitor is in parallel with the two Y-capacitors. The EUT capacitance is:

$$C_{EUT} = C_X + C_Y$$

The EUT resistance is the resistance, R_{EUT} , in the EUT that is used for discharging the capacitance.

The time constant, T_{EUT} , in s, is the product of the EUT capacitance in farads and the EUT resistance in Ω . More useful units are capacitance in μF and resistance in $\text{M}\Omega$.

Two parameters of the time constant formula are given by the requirement: EUT capacitance is $0,1 \mu\text{F}$ or larger and the EUT time constant does not exceed 1 s. Solving the time constant formula for EUT resistance:

$$R_{EUT} = T_{EUT} / C_{EUT}$$

Substituting the values:

$$R_{EUT} = 1\text{s} / 0,1\mu\text{F}$$

$$R_{EUT} = 10\text{M}\Omega$$

This means that the EUT resistance is no greater than $10 \text{ M}\Omega$ if the EUT capacitance is $0,1 \mu\text{F}$ or greater. The combinations of EUT resistance and EUT capacitance for EUT time constant of 1 s are shown in Figure B.3 in this document.

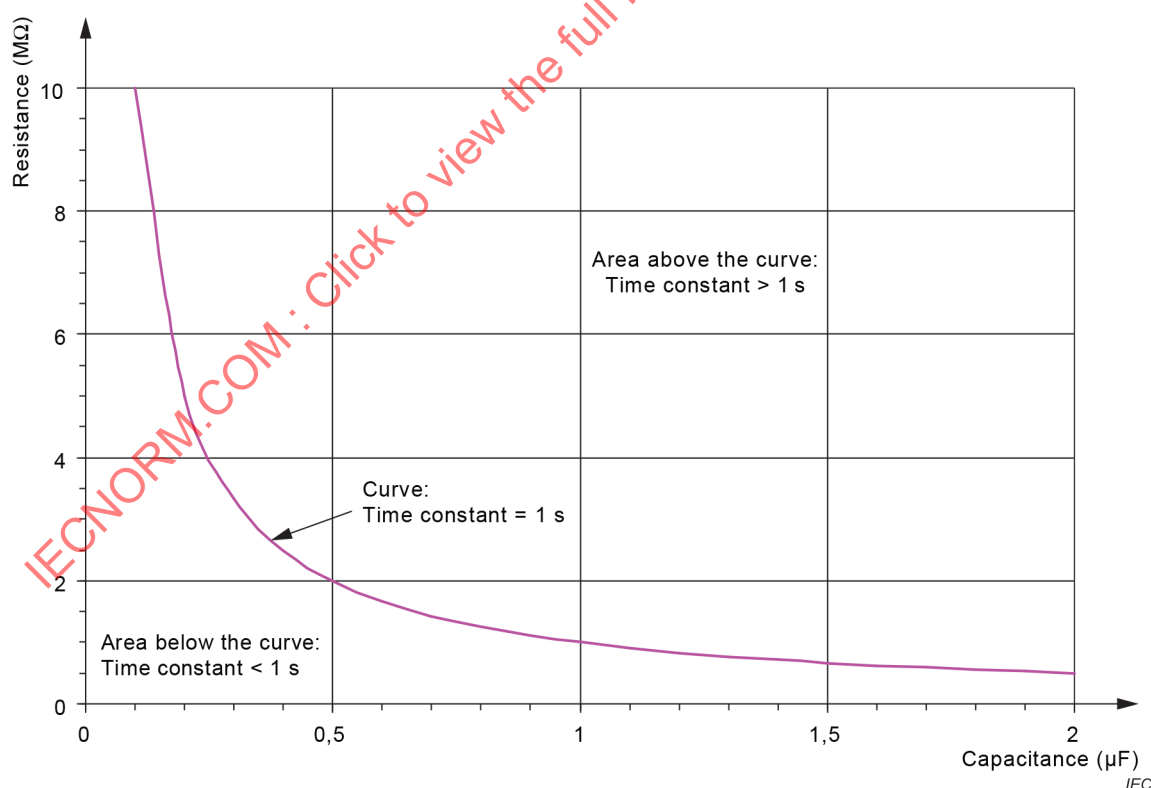
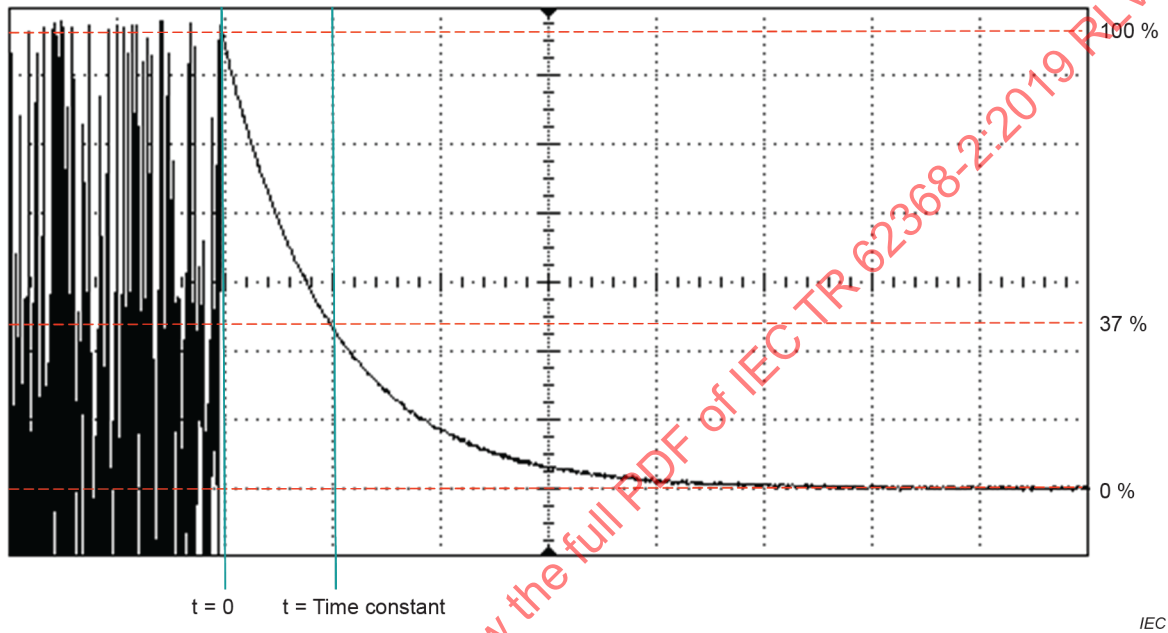


Figure B.3 – Combinations of EUT resistance and capacitance for 1 s time constant

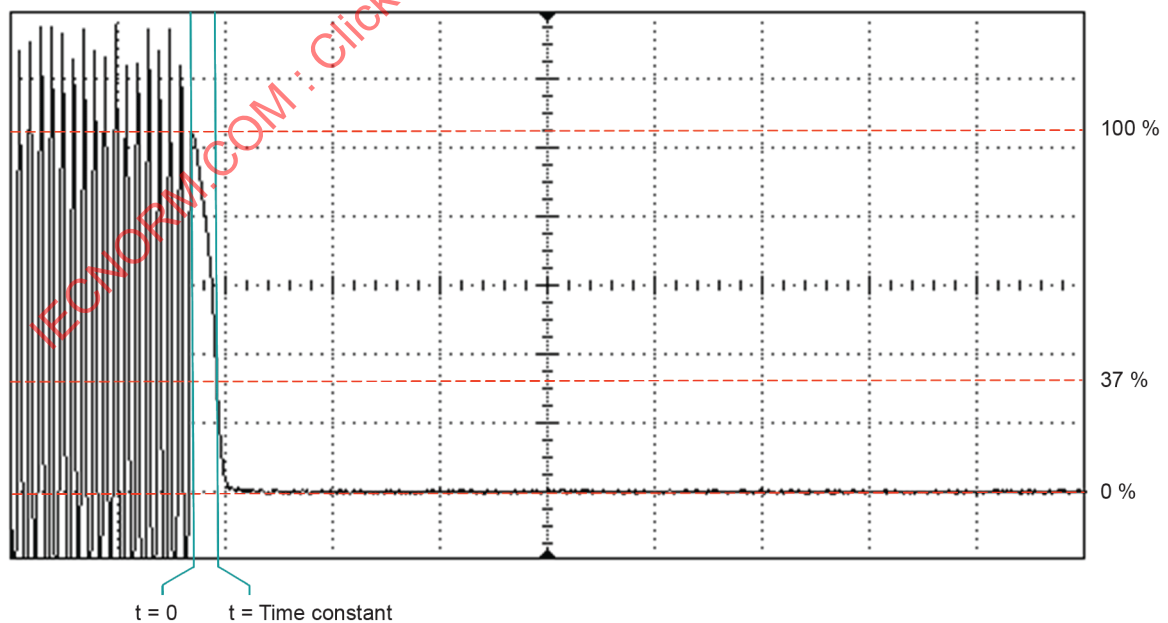
B.7 Time constant measurement.

The objective is to measure and determine the EUT time constant.

Measurement of the time constant is done with an oscilloscope connected to the **mains** input terminals of the equipment under test (EUT). **Mains** is applied to the EUT, the EUT is turned off, and then the **mains** is disconnected from the EUT. The EUT is turned off because the load circuits of the EUT may serve to discharge the EUT capacitance. The resulting oscilloscope waveform, the AC **mains** voltage followed by the discharge of the total capacitance, is shown in Figure B.4 in this document.



a) 240 V mains followed by capacitor discharge
V = 50 V/div, H = 1 s/div



b) 240 V mains followed by capacitor discharge
V = 50 V/div, H = 0,2 s/div

Figure B.4 – 240 V mains followed by capacitor discharge

The time constant is the time duration measured from the instant of disconnection to a point that is 37 % of the voltage at the instant of disconnection.

The problem is that the process of measurement affects the measured time constant. This is because the oscilloscope probe has a finite resistance and capacitance, see Figure B.5 in this document.

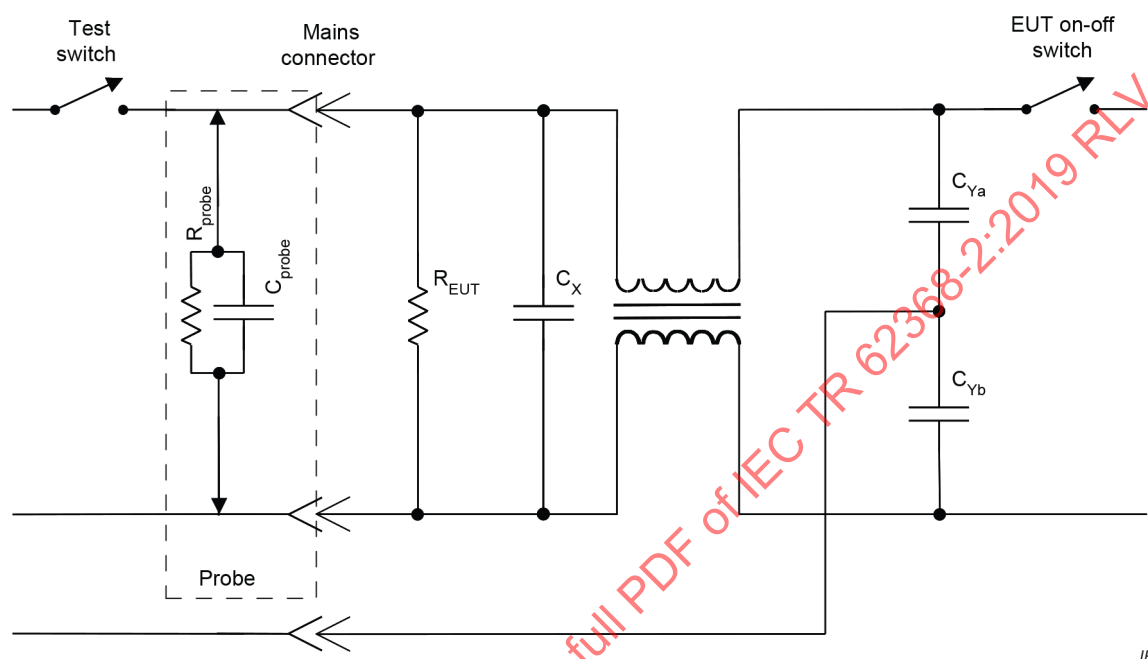


Figure B.5 – Time constant measurement schematic

The probe resistance, R_{probe} , is in parallel to the EUT resistance, R_{EUT} . And, the probe capacitance, C_{probe} , is in parallel with the EUT capacitance, C_{EUT} .

The measured time constant, $T_{measured}$, is a function of the Thevenin equivalent circuit comprised of R_{total} and C_{total} . The measured time constant is given by:

$$T_{measured} = R_{total} \times C_{total}$$

where:

$T_{measured}$ is the measured time for the voltage to change by 63 %

R_{total} is the total resistance, both the probe and the EUT

C_{total} is the total capacitance, both the probe and the EUT

R_{total} is:

$$R_{total} = \frac{R_{probe} \times R_{EUT}}{R_{probe} + R_{EUT}}$$

C_{total} is:

Combining terms, the measured time constant is:

$$T_{measured} = \left(\frac{R_{probe} \times R_{EUT}}{R_{probe} + R_{EUT}} \right) \times (C_{probe} + C_{EUT})$$

In this formula, $T_{measured}$, R_{probe} , and C_{probe} are known. $T_{measured}$ is measured with a given probe. R_{probe} and C_{probe} are determined from the probe specifications (see examples in Table B.1 in this document). Elsewhere, we shall see that C_{probe} is very small and can be ignored.

$$C_{total} = C_{EUT}$$

The measured time constant can now be expressed as:

$$T_{measured} = \left(\frac{R_{probe} \times R_{EUT}}{R_{probe} + R_{EUT}} \right) \times C_{total}$$

B.8 Effect of probe resistance

As has been shown, the EUT discharge resistance, R_{EUT} , is 10 MΩ or less in order to achieve a 1 s time constant with a 0,1 μF capacitor or larger.

R_{total} is comprised of both the EUT discharge resistance R_{EUT} , and the probe resistance, R_{probe} .

If R_{EUT} is 10 MΩ and C_{EUT} is 0,1 μF, then we know that T_{EUT} is 1 s. If we measure the time constant with a 100 MΩ probe, the parallel combination of R_{EUT} and R_{probe} is about 9,1 MΩ and the measured time constant, $T_{measured}$, will be:

$$T_{measured} = R_{total} \times C_{total}$$

$$T_{measured} = 9,1M\Omega \times 0,1\mu F$$

$$T_{measured} = 0,91s$$

So, for a C_{EUT} of 0,1 μF capacitance and a R_{EUT} of 10 MΩ, a measured time constant (using a 100 MΩ probe), $T_{measured}$, of 0,91 s would indicate a EUT time constant, T_{EUT} , of 1 s.

If we substitute a 10 MΩ probe for the same measurement, then R_{total} , the parallel combination of R_{EUT} (10 MΩ) and R_{probe} (10 MΩ), is 5 MΩ. The measured time constant, $T_{measured}$, will be:

$$T_{measured} = R_{total} \times C_{total}$$

$$T_{measured} = 5M\Omega \times 0,1\mu F$$

$$T_{measured} = 0,5s$$

So, for a C_{EUT} of 0,1 μF capacitance and a R_{EUT} of 10 $M\Omega$, the measured time constant (using a 10 $M\Omega$ probe), $T_{measured}$, is 0,5 s and would indicate a EUT time constant, T_{EUT} , of 1 s.

B.9 Effect of probe capacitance

According to the document, C_{EUT} is 0,1 μF or more. Also, according to the document, C_{probe} is 25 pF or less. Assuming the worst case for C_{probe} , the total capacitance is:

$$C_{total} = C_{probe} + C_{EUT}$$

$$C_{total} = 0,000025\mu F + 0,1\mu F$$

$$C_{total} = 0,100025\mu F$$

The worst-case probe capacitance is extremely small (0,025 %) compared to the smallest C_{EUT} capacitance (0,1 μF) and can be ignored. We can say that:

$$C_{total} = C_{EUT}$$

B.10 Determining the time constant

According to the document, T_{EUT} may not exceed 1 s.

$$T_{EUT} = 1$$

$$1 = R_{EUT} \times C_{EUT}$$

where:

R_{EUT} is 10 $M\Omega$ or less

C_{EUT} is 0,1 μF or more

The problem is to determine the values for R_{EUT} and C_{EUT} . Once these values are known, the equipment time constant, T_{EUT} , can be determined by calculation.

As shown in Figure B.1 in this document, R_{EUT} can be measured directly with an ohmmeter applied to the **mains** input terminals, i.e., between L1 and L2. Care is taken that the capacitances are fully discharged when the resistance measurement is made. Any residual charge will affect the ohmmeter and its reading. Of course, if the circuit is provided with a discharge resistor, then the capacitances will be fully discharged. If the circuit does not have a discharge resistor, then the ohmmeter will provide the discharge path, and the reading will continuously increase.

C_{EUT} can also be measured directly with a capacitance meter. Depending on the particular capacitance meter, R_{EUT} may prevent accurate measurement of C_{EUT} . For the purposes of this paper, we assume that the capacitance meter cannot measure the C_{EUT} . In this case, we measure the time constant and compensate for the probe resistance.

So, the time constant is measured, and the probe resistance is accounted for.

Since probe resistance is more or less standardized, we can calculate curves for 100 MΩ and 10 MΩ probes for all maximum values of R_{EUT} and C_{EUT} . The maximum values for combinations of R_{EUT} , C_{EUT} (C_{total}), R_{probe} , R_{total} and $T_{measured}$ are given in Table B.3 in this document. (R_{probe} and R_{total} values are rounded to 2 significant digits.)

Table B.3 – Maximum $T_{measured}$ values for combinations of R_{EUT} and C_{EUT} for T_{EUT} of 1 s

T_{EUT} s	C_{EUT} (C_{total}) μF	R_{EUT} MΩ	R_{probe} MΩ	R_{total} MΩ	$T_{measured}$ s
1	0,1	10	100	9,1	0,91
1	0,2	5	100	4,8	0,95
1	0,3	3,3	100	3,2	0,97
1	0,4	2,5	100	2,4	0,97
1	0,5	2	100	2,0	0,98
1	0,6	1,7	100	1,6	0,98
1	0,7	1,4	100	1,4	0,99
1	0,8	1,25	100	1,2	0,99
1	0,9	1,1	100	1,1	0,99
1	1,0	1	100	1,0	0,99
1	0,1	10	10	5,0	0,50
1	0,2	5	10	3,3	0,67
1	0,3	3,3	10	2,5	0,75
1	0,4	2,5	10	2,0	0,80
1	0,5	2	10	1,7	0,83
1	0,6	1,7	10	1,4	0,86
1	0,7	1,4	10	1,25	0,88
1	0,8	1,25	10	1,1	0,89
1	0,9	1,1	10	1,0	0,90
1	1,0	1	10	0,91	0,91

For each value of R_{EUT} and R_{probe} we can calculate the worst-case measured time constants, $T_{measured}$ for a T_{EUT} of 1 s. These are shown in Figure B.6 in this document.

The process is:

- With the unit disconnected from the **mains** and the power switch “off,” measure the resistance between the poles of the EUT. Repeat with the power switch “on” as the filter may be on the load side of the power switch. Select the higher value as R_{EUT} .
- Connect the oscilloscope probe between L1 and L2 as shown in Figure B.5 in this document. For safety during this test, use a 1:1 isolating transformer between the **mains** and the EUT. Set the scope sweep speed to 0,2 ms per division (2 s full screen).
- When the display is about 1 or 2 divisions from the start, turn the test switch off, and measure the time constant as shown in Figure B.4 in this document. This step may need to be repeated several times to get a suitable waveform on the oscilloscope. This step should be performed twice, once with the EUT power switch “off” and once with the EUT power switch “on.” Select the maximum value. This value is $T_{measured}$.
- Plot R_{EUT} and $T_{measured}$ on the chart, Figure B.6 in this document.

If the point is below the curve of the probe that is used to measure the time constant, then the EUT time constant, T_{EUT} , is less than 1 s.

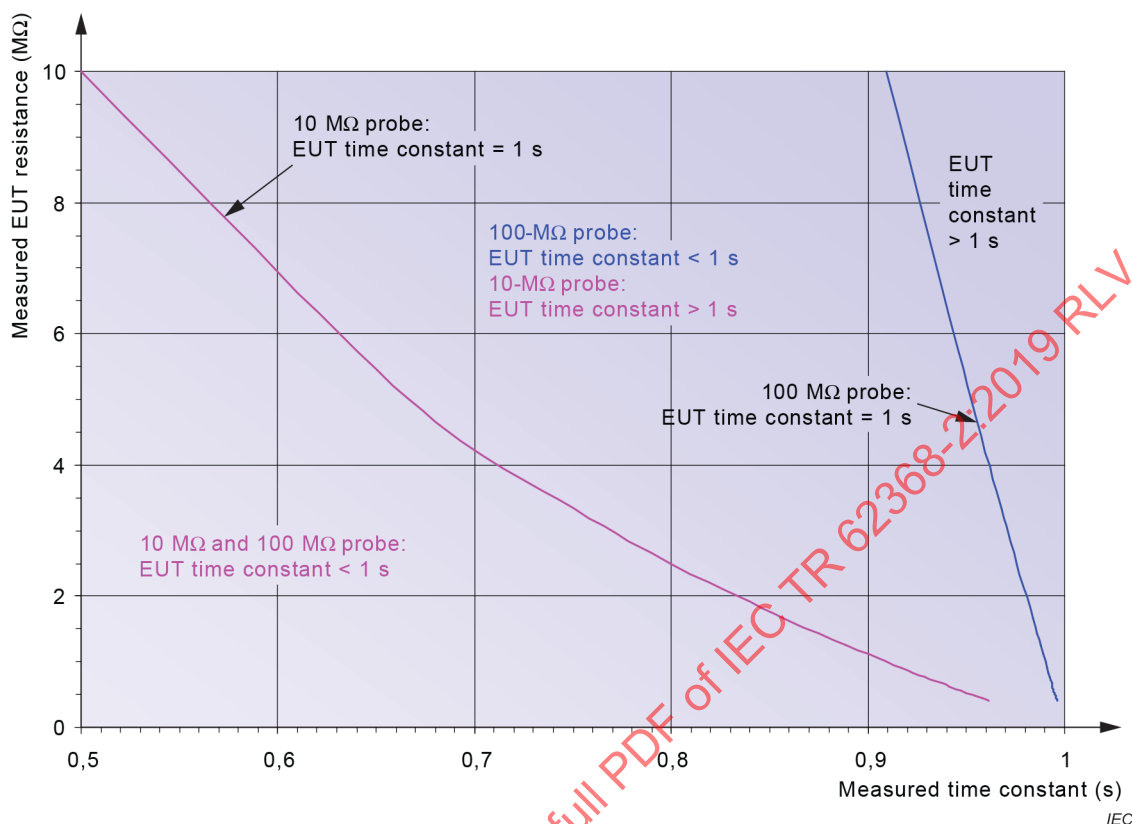


Figure B.6 – Worst-case measured time constant values for 100 MΩ and 10 MΩ probes

B.11 Conclusion

Measurement of the time constant can be made with any probe, not just a 100 MΩ probe. Ideally, the probe input resistance should be at least equal to the worst-case EUT discharge resistance (10 MΩ for **pluggable equipment type A**) or higher. The effect of the probe input resistance is given by the equation for R_{total} . 100 MΩ probes, while approaching ideal in terms of the effect on the measured time constant, are bulky and expensive and not necessary.

The document is a bit misleading by ignoring a 9 % error when a 100 MΩ probe is used to measure the time constant associated with a 10 MΩ discharge resistor (see Figure B.5 in this document).

Annex C (informative)

Background information related to resistance to candle flame ignition

In line with SMB decision 135/20, endorsing the ACOS/ACEA JTF recommendations, the former Clause 11 was added to the document up to CDV stage. However, the CDV was rejected and several national committees indicated that they wanted to have the requirements removed from the document. At the same time, several countries indicated that they wanted the requirements to stay, while others commented that they should be limited to CRT televisions only.

IEC TC 108 decided to publish the requirements as a separate document so that the different issues can be given appropriate consideration.

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² ~~This publication was withdrawn.~~

³ This publication was withdrawn.

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TECHNICAL REPORT

RAPPORT TECHNIQUE



**Audio/video, information and communication technology equipment –
Part 2: Explanatory information related to IEC 62368-1:2018**

**Équipements des technologies de l'audio/vidéo, de l'information
et de la communication –
Partie 2: Précisions relatives à l'IEC 62368-1:2018**

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

**AUDIO/VIDEO, INFORMATION AND
COMMUNICATION TECHNOLOGY EQUIPMENT –****Part 2: Explanatory information related to IEC 62368-1:2018****FOREWORD**

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IEC 62368-2, which is a Technical Report, has been prepared by IEC technical committee TC 108: Safety of electronic equipment within the field of audio/video, information technology and communication technology.

This third edition updates the second edition of IEC 62368-2 published in 2014 to take into account changes made to IEC 62368-1:2014 as identified in the Foreword of IEC 62368-1:2018.

This Technical Report is informative only. In case of a conflict between IEC 62368-1 and IEC TR 62368-2, the requirements in IEC 62368-1 prevail over this Technical Report.

The text of this technical report is based on the following documents:

Enquiry draft	Report on voting
108/708/DTR	108/711/RVDTR

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

In this document, the following print types are used:

- notes/explanatory matter: in smaller roman type;
- tables and figures that are included in the rationale have linked fields (shaded in grey if “field shading” is active);
- terms that are defined in IEC 62368-1: in **bold type**.

In this document, where the term (HBSDT) is used, it stands for Hazard Based Standard Development Team, which is the Working Group of IEC TC 108 responsible for the development and maintenance of IEC 62368-1.

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

A list of all parts of the IEC 62368 series can be found, under the general title *Audio/video, information and communication technology equipment*, on the IEC website.

In this document, only those subclauses from IEC 62368-1 considered to need further background reference information or explanation to benefit the reader in applying the relevant requirements are included. Therefore, not all numbered subclauses are cited. Unless otherwise noted, all references are to clauses, subclauses, annexes, figures or tables located in IEC 62368-1:2018.

The entries in the document may have one or two of the following subheadings in addition to the Rationale statement:

Source – where the source is known and is a document that is accessible to the general public, a reference is provided.

Purpose – where there is a need and when it may prove helpful to the understanding of the Rationale, we have added a Purpose statement.

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

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

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

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INTRODUCTION

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 document is different from traditional IEC safety documents in its approach and while it is believed that IEC 62368-1 provides a number of advantages, its introduction and evolution are 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 a learning process is required and experience is needed in its application. Consequently, the committee recommends that this edition of the document be considered as an alternative to IEC 60065 or IEC 60950-1 at least over the recommended transition period.

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AUDIO/VIDEO, INFORMATION AND COMMUNICATION TECHNOLOGY EQUIPMENT –

Part 2: Explanatory information related to IEC 62368-1:2018

0 Principles of this product safety standard

Clause 0 is informational and provides a rationale for the normative clauses of the document.

0.5.1 General

ISO/IEC Guide 51:2014, 6.3.5 states:

“When reducing risks the order of priority shall be as follows:

- a) inherently safe design;*
- b) guards and protective devices;*
- c) information for end users.*

Inherently safe design measures are the first and most important step in the risk reduction process. This is because protective measures inherent to the characteristics of the product or system are likely to remain effective, whereas experience has shown that even well-designed guards and protective devices can fail or be violated and information for use might not be followed.

Guards and protective devices shall be used whenever an inherently safe design measure does not reasonably make it possible either to remove hazards or to sufficiently reduce risks. Complementary protective measures involving additional equipment (for example, emergency stop equipment) might have to be implemented.

The end user has a role to play in the risk reduction procedure by complying with the information provided by the designer/supplier. However, information for use shall not be a substitute for the correct application of inherently safe design measures, guards or complementary protective measures.”

In general, this principle is used in IEC 62368-1. The table below shows a comparison between the hierarchy required in ISO/IEC Guide 51 and the hierarchy used in IEC 62368-1:2018:

ISO/IEC Guide 51	IEC 62368-1
a) inherently safe design	1. inherently safe design by limiting all energy hazards to class 1
b) guards and protective devices	2. equipment safeguards
	3. installation safeguards
	4. personal safeguards
c) information for end users	5. behavioral safeguards
	6. instructional safeguards

Risk assessment has been considered as part of the development of IEC 62368-1 as indicated in the following from ISO/IEC Guide 51 (Figure 1) in this document. See also the Hazard Based Safety Engineering (HBSE) Process Flow (Figure 2) in this document that also provides additional details for the above comparison.

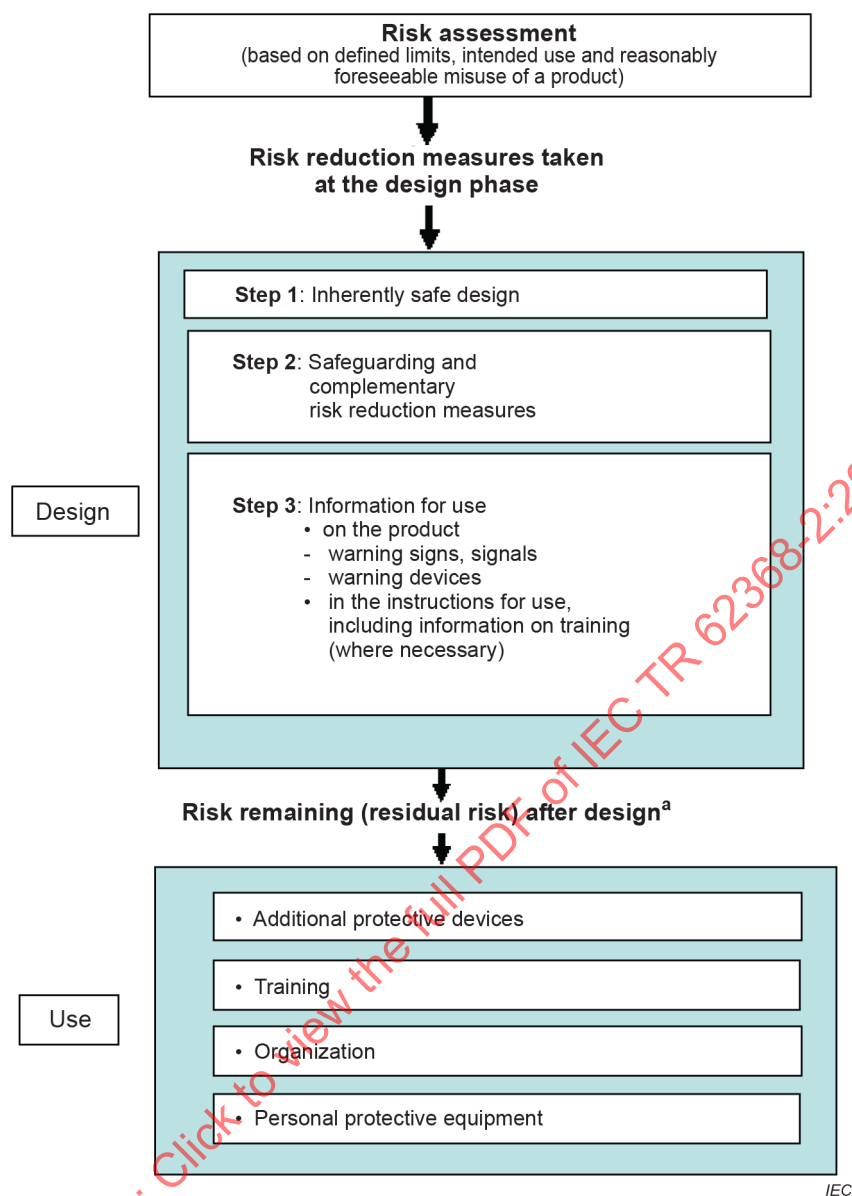


Figure 1 – Risk reduction as given in ISO/IEC Guide 51

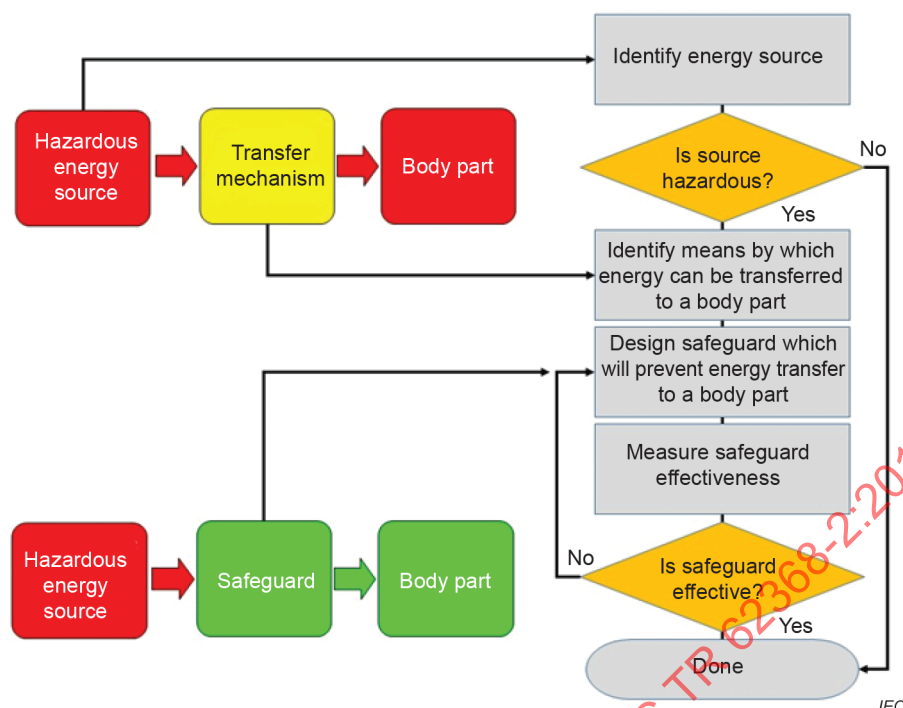


Figure 2 – HBSE Process Chart

0.5.7 Equipment safeguards during skilled person service conditions

Purpose: To explain the intent of requirements for providing **safeguards** against involuntary reaction.

Rationale: By definition, a **skilled person** has the education and experience to identify all class 3 energy sources to which he may be exposed. However, while servicing one class 3 energy source in one location, a **skilled person** may be exposed to another class 3 energy source in a different location.

In such a situation, either of two events is possible. First, something may cause an involuntary reaction of the **skilled person** with the consequences of contact with the class 3 energy source in the different location. Second, the space in which the **skilled person** is located may be small and cramped, and inadvertent contact with a class 3 energy source in the different location may be likely.

In such situations, this document may require an **equipment safeguard** solely for the protection of a **skilled person** while performing servicing activity.

1 Scope

Purpose: To identify the purpose and applicability of this document and the exclusions from the scope.

Rationale: The scope excludes requirements for functional safety. Functional safety is addressed in IEC 61508-1. Because the scope includes computers that may control safety systems, functional safety requirements would necessarily include requirements for computer processes and software.

The requirements provided in IEC 60950-23 could be modified and added to IEC 62368 as another –X document. However, because of the hazard-based nature of IEC 62368-1, the requirements from IEC 60950-23 have been incorporated into the body of IEC 62368-1 and made more generic.

The intent of the addition of the IEC 60950-23 requirements is to maintain the overall intent of the technical requirements from IEC 60950-23, incorporate them into IEC 62368-1 following the overall format of IEC 62368-1 and simplify and facilitate the application of these requirements.

Robots traditionally are covered under the scopes of ISO documents, typically maintained by ISO TC 299. ISO TC 299 has working groups for personal care robots and service robots, and produces for example, ISO 13482, *Robots and robotic devices – Safety requirements for personal care robots*.

2 Normative references

The list of normative references is a list of all documents that have a normative reference to it in the body of the document. As such, 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.

Recently, there were some issues with test houses that wanted to use the latest edition as soon as it was published. As this creates serious problems for manufacturers, since they have no chance to prepare, it was felt that a reasonable transition period should be taken into account. This is in line with earlier decisions taken by the SMB that allow transition periods to be mentioned in the foreword of the documents. Therefore IEC TC 108 decided to indicate this in the introduction of the normative references clause, to instruct test houses to take into account any transition period, effective date or date of withdrawal established for the document.

These documents are referenced, in whole, in part, or as alternative requirements to the requirements contained in this document. Their use is specified, where necessary, for the application of the requirements of this document. The fact that a standard is mentioned in the list does not mean that compliance with the document or parts of it are required.

3 Terms, definitions and abbreviations

Rationale is provided for definitions that deviate from IEC definitions or from Basic or Group Safety publication definitions.

3.3.2.1 electrical enclosure

Source: IEC 60050-195:1998, 195-06-13

Purpose: To support the concept of **safeguards** as used in this document.

Rationale: The IEC definition is modified to use the term “**safeguard**” in place of the word “protection”. The word “**safeguard**” identifies a physical “thing” whereas the word “protection” identifies the act of protecting. This document sets forth requirements for use of physical **safeguards** and requirements for those **safeguards**. The **safeguards** provide “protection” against injury from the equipment.

3.3.5.1 basic insulation

Source: IEC 60050-195:1998, 195-06-06

Purpose: To support the concept of **safeguards** as used in this document.

Rationale: The IEC definition is modified to use the term “**safeguard**” in place of the word “protection”. The word “**safeguard**” identifies a physical “thing” whereas the word “protection” identifies the act of protecting. This document sets forth requirements for use of physical **safeguards** and requirements for those **safeguards**. The **safeguards** provide “protection” against injury from the equipment.

3.3.5.2 double insulation

Source: IEC 60050-195:1998, 195-06-08

Purpose: To support the concept of **safeguards** as used in this document.

Rationale: See 3.3.5.1, **basic insulation**.

3.3.5.6 solid insulation

Source: IEC 60050-212:2015, 212-11-02

3.3.5.7 supplementary insulation

Source: IEC 60050-195:1998, 195-06-07

Purpose: To support the concept of **safeguards** as used in this document.

Rationale: See 3.3.5.1, **basic insulation**.

3.3.6.9 restricted access area

Source: IEC 60050-195:1998, 195-04-04

Purpose: To use the concept of “**instructed persons**” and “**skilled persons**” as used in this document.

Rationale: The IEC definition is modified to use the terms “**instructed persons**” and “**skilled persons**” rather than “electrically **instructed persons**” and “electrically **skilled persons**.”

3.3.7.7 reasonably foreseeable misuse

Source: ISO/IEC Guide 51:2014, 3.7

Rationale: Misuse depends on personal objectives, personal perception of the equipment, and the possible use of the equipment (in a manner not intended by the manufacturer) to accomplish those personal objectives. Equipment within the scope of this document ranges from small handheld equipment to large, permanently installed equipment. There is no commonality among the equipment for readily predicting human behaviour leading to misuse of the equipment and resultant injury. Where a possible **reasonably foreseeable misuse** that may lead to an injury is not covered by the requirements of the document, manufacturers are encouraged to consider **reasonably foreseeable misuse** of equipment and provide **safeguards**, as applicable, to prevent injury in the event of such misuse. (Not all **reasonably foreseeable misuse** of equipment results in injury or potential for injury.)

3.3.8.1 instructed person

Source: IEC 60050-826:2004, 826-18-02

Rationale: The IEC definition is modified to use the terms “energy sources”, “**skilled person**”, and “**precautionary safeguard**”. The definition is made stronger by using the term “instructed” rather than “advised”.

3.3.8.3 skilled person

Source: IEC 60050-826:2004, 826-18-01

Rationale: The IEC definition is modified to use the phrase “to reduce the likelihood of”. IEC 62368-1, in general, tends not use the word “hazard”.

3.3.11.9 protective bonding conductor

Rationale: The **protective bonding conductor**, is not a complete **safeguard**, but a component part of the earthing system **safeguard**. The **protective bonding conductor** provides a fault current pathway from a part (insulated from ES3 by **basic insulation** only) to the equipment **protective earthing** terminal, see Figure 3 in this document.

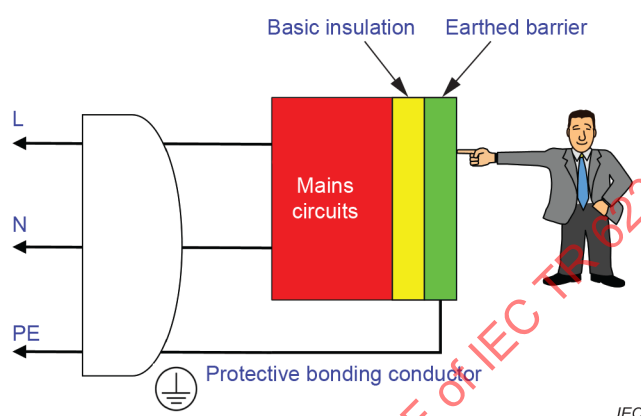


Figure 3 – Protective bonding conductor as part of a safeguard

The parts required to be earthed via a **protective bonding conductor** are those that have only **basic insulation** between the parts and ES3, and are connected to **accessible** parts.

Only the fault current pathway is required to be a **protective bonding conductor**. Other earthing connections of **accessible** conductive parts can be by means of a functional earth conductor to the equipment PE terminal or to a **protective bonding conductor**.

3.3.14.3 prospective touch voltage

Source: IEC 60050-195:1998, 195-05-09

Purpose: To properly identify electric shock energy source voltages.

Rationale: The IEC definition is modified to delete “animal”. The word “person” is also deleted as all of the requirements in the document are with respect to persons.

3.3.14.8 working voltage

Source: IEC 60664-1:2007, 3.5

Purpose: To distinguish between **RMS. working voltage** and the peak of the **working voltage**.

Rationale: The IEC 60664-1 definition is modified to delete “RMS”. IEC 62368-1 uses both **RMS. working voltage** and peak of the **working voltage**; each term is defined.

3.3.15.2 class II construction

Source: IEC 60335-1:2010, 3.3.11

Purpose: Although the term is not used in the document, for completeness, it was decided to retain this definition.

Rationale: The word “appliance” is changed to “equipment”.

4 General requirements

Purpose: To explain how to investigate and determine whether or not safety is involved.

Rationale: In order to establish whether or not safety is involved, the circuits and construction are investigated to determine whether the consequences of possible fault conditions would lead to an injury. Safety is involved if, as a result of a **single fault condition**, the consequences of the fault lead to a risk of injury.

If a fault condition should lead to a risk of injury, the part, material, or device whose fault was simulated may comprise a **safeguard**.

Rationale is provided for questions regarding the omission of some traditional requirements appearing in other safety documents. Rationale is also provided for further explanation of new concepts and requirements in this document.

Reasonable foreseeable misuse

Rationale: Apart from Annex M, this document does not specifically mention foreseeable misuse or **abnormal operating conditions**. Nevertheless, the requirements of the document cover many kinds of foreseeable misuse, such as covering of ventilation openings, paper jams, stalled motors, etc.

functional insulation

Rationale: This document does not include requirements for **functional insulation**. By its nature, **functional insulation** does not provide a **safeguard** function against electric shock or electrically-caused fire and therefore may be faulted. Obviously, not all **functional insulations** are faulted as this would be prohibitively time-consuming. Sites for **functional insulation** faults should be based upon physical examination of the equipment, and upon the electrical schematic.

Note that **basic insulation** and **reinforced insulation** may also serve as **functional insulation**, in which case the insulation is not faulted.

functional components

Rationale: This document does not include requirements for functional components. By their nature, individual functional components do not provide a **safeguard** function against electric shock, electrically-caused fire, thermal injury, etc., and therefore may be candidates for fault testing. Obviously, not all functional components are faulted as this would be prohibitively time-consuming. Candidate components for fault testing should be based upon physical examination of the equipment, upon the electrical schematic diagrams, and whether a fault of that component might result in conditions for electric shock, conditions for ignition and propagation of fire, conditions for thermal injury, etc.

As with all **single fault condition** testing (Clause B.4), upon faulting of a functional component, there shall not be any safety consequence (for example, a benign consequence), or a **basic safeguard**, **supplementary safeguard**, or **reinforced safeguard** shall remain effective.

In some cases, a pair of components may comprise a **safeguard**. If the fault of one of the components in the pair is mitigated by the second component, then the pair is designated as a **double safeguard**. For example, if two diodes are employed in series to protect a **battery** from reverse charge, then the pair comprises a **double safeguard** and the components should be limited to the manufacturer and part number actually tested. A second example is that of an X-capacitor and discharge resistor. If the discharge resistor should fail open, then the X-capacitor will not be discharged. Therefore, the X-capacitor value is not to exceed the ES2 limits specified for a charged capacitor. Again, the two components comprise a **double safeguard** and the values of each component are limited to values for ES1 under **normal operating conditions** and the values for ES2 under **single fault conditions**.

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

Purpose: To accept components as **safeguards**.

Rationale: This document includes requirements for **safeguard** components. A **safeguard** component is a component specifically designed and manufactured for both functional and **safeguard** parameters. Examples of **safeguard** components are capacitors complying with IEC 60384-14 and other components that comply with their related IEC component document.

Acceptance of components and component requirements from IEC 60065 and 60950-1

Purpose: To accept both components and sub-assemblies investigated to the legacy documents, IEC 60065 and IEC 60950-1, and components complying with individual component requirements within these documents during the transition period.

Rationale: To facilitate a smooth transition from the legacy documents IEC 60065 and IEC 60950-1 to IEC 62368-1, including by the component supply chain, this document allows for acceptance of both components and sub-assemblies investigated to the legacy documents. Individual component requirements within these documents may be used for compliance with IEC 62368-1 without further investigation, other than to give consideration to the appropriate use of the component or sub-assembly in the end-product.

This means, for example, if a switch mode power supply is certified to IEC 60065 or IEC 60950-1, this component can be used in equipment evaluated to IEC 62368-1 without further investigation, other than to give consideration to the appropriate use of the component, such as use within its electrical ratings.

This also means, for example, since IEC 60950-1 allows for wiring and cables insulated with PVC, TFE, PTFE, FEP, polychloroprene or polyimide to comply with material requirements for parts within a **fire enclosure** without need for the application of a flammability test, the same wire can be used to comply with the requirements in 6.5.2 for insulation on wiring used in PS2 or PS3 circuits and without the need for application of a flammability test per IEC 60332 series or IEC TS 60695-11-21 as normally is required by 6.5.1.

4.1.5 Constructions and components not specifically covered

For constructions not covered, consideration should be given for the hierarchy of safeguards in accordance with ISO/IEC Guide 51.

4.1.6 Orientation during transport and use

See also 4.1.4

In general, equipment is assumed to be installed and used in accordance with the manufacturer's instructions. However, in some cases where equipment may be installed by an **ordinary person**, it is recognized that it is common practice to mount equipment as desired if screw holes are provided, especially if they allow mounting to readily available brackets. Hence, the exception that is added to 4.1.6.

Examples of the above: a piece of equipment, such as a television set or a video projector, that has embedded screw mounting holes that allow it to be attached to a wall or other surface through the use of commercially available vertically or tilt-mountable brackets, shall also take into account that the mounting surface itself may not be vertical.

It is also recognized that **transportable equipment**, by its nature, may be transported in any and all orientations.

4.1.8 Liquids and liquid filled components (LFC)

The one-litre (1 l) restriction was placed in 4.1.8 since the origin of some of the requirements in Clause G.15 came from requirements in documents often applied to smaller systems. Nevertheless, such a limitation does not always negate the allowed application of 4.1.8 and Clause G.15 to systems with larger volumes of liquid, but it could impact direct (automatic) applicability to the larger systems.

4.2 Energy source classifications

Classification of energy sources may be done whether the source is **accessible** or not. The requirements for parts may differ on whether the part is **accessible** or not.

4.2.1 Class 1 energy source

A class 1 energy source is a source that is expected not to create any pain or injury. Therefore, a class 1 energy source may be **accessible** by any person.

Under some specific conditions of abnormal operation or **single fault conditions**, a class 1 energy source may reach class 2 limits. However, this source still remains a class 1 energy source. In this case, an **instructional safeguard** may be required.

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

A class 2 energy source is a source that may create pain, but which is unlikely to create any serious injury. Therefore, a class 2 energy source may not be **accessible** by an **ordinary person**. However, a class 2 energy source may be **accessible** by:

- an **instructed person**; and
- a **skilled person**.

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 energy source is a source that is likely to create an injury. Therefore a class 3 energy source may not be **accessible** to an **ordinary person** or an **instructed person**. A class 3 energy source may, in general, be **accessible** to a **skilled person**.

Any source may be declared a class 3 energy source without measurement, in which case all the **safeguards** applicable to class 3 are required.

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.

4.3.2 Safeguards for protection of an ordinary person

The required **safeguards** for the protection of an **ordinary person** are given in Figure 4.

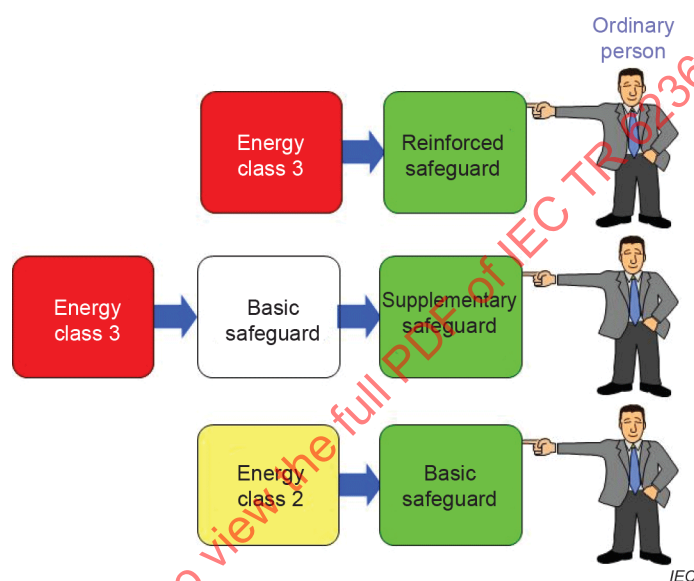


Figure 4 – Safeguards for protecting an ordinary person

4.3.3 Safeguards for protection of an instructed person

The required **safeguards** for the protection of an **instructed person** are given in Figure 5.

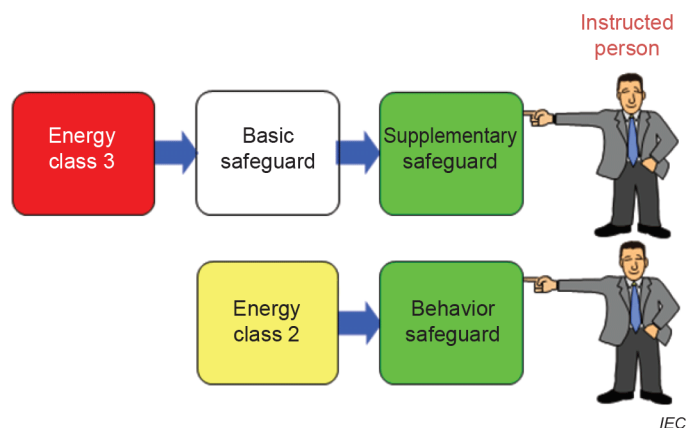


Figure 5 – Safeguards for protecting an instructed person

4.3.4 Safeguards for protection of a skilled person

The required **safeguards** for the protection of a **skilled person** are given in Figure 6.

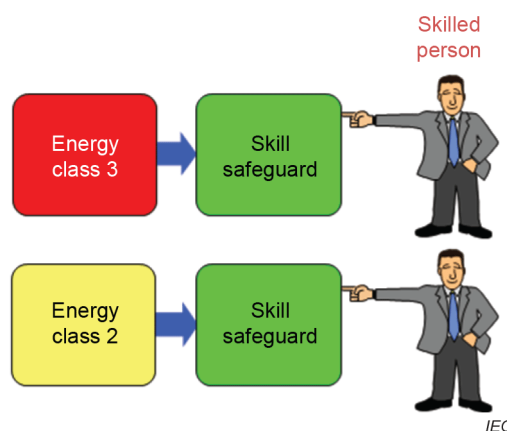


Figure 6 – Safeguards for protecting a skilled person

Table 1 in this document gives a general overview of the required number of **safeguards** depending on the energy source and the person to whom the energy source is **accessible**. The different clauses have requirements that sometimes deviate from the general principle as given above. These cases are clearly defined in the requirements sections of the document.

Table 1 – General summary of required safeguards

Person	Number of safeguards required to be interposed between an energy source and a person		
	Class 1	Class 2	Class3
Ordinary person	0	1	2
Instructed person	0	0	2
Skilled person	0	0	0 or 1

For a **skilled person**, there is normally no **safeguard** required for a class 3 energy source. However, if there are multiple class 3 energy sources **accessible** or if the energy source is not obvious, a **safeguard** may be required.

4.4.2 Composition of a safeguard

Purpose: To specify design and construction criteria for a single **safeguard** (basic, supplementary, or reinforced) comprised of more than one element, for example, a component or a device.

Rationale: **Safeguards** need not be a single, homogeneous component. Indeed, some parts of this document require a single **safeguard** be comprised of two or more elements. For example, for thin insulation, two or more layers are required to qualify as **supplementary insulation**. Another example is protective bonding and **protective earthing**, both of which are comprised of wires, terminals, screws, etc.

If a **safeguard** is comprised of two or more elements, then the function of the **safeguard** should not be compromised by a failure of any one element. For example, if a screw attaching a **protective earthing** wire should loosen, then the current-carrying capacity of the **protective earthing** circuit may be compromised, making its reliability uncertain.

4.4.3 Safeguard robustness

Rationale: **Safeguards** should be sufficiently robust to withstand the rigors of expected use throughout the equipment lifetime. Robustness requirements are specified in the various clauses.

4.4.3.4 Impact test

Rationale: **Stationary equipment** can, in some cases, be developed for a specific installation in which it is not possible for certain surfaces to be subjected to an impact when installed as intended. In those cases, the impact test is not necessary when the installation makes clear that the side cannot be impacted.

4.4.3.6 Glass impact tests

Source: IEC 60065

Purpose: Verify that any glass that breaks does not cause skin-lacerating injury, or expose class 3 hazards behind the glass.

Rationale: When it comes to glass, two hazards can be present in case the glass breaks:

- access to sharp edges from the broken glass itself
- exposure of class 3 energy hazards in case the glass is used as (part of) the **enclosure**.

Should the glass break during the impact test, T.9 is applied to ensure the expelled fragments will be at MS2 level or less.

Platen glass has a long history of being exempted, because it is quite obvious for people that, if broken, the broken glass is hazardous and contact should be avoided. There is no known history of serious injuries with this application. Platen glass is the glass that is typically used in scanners, copiers, etc. Accidents are rare, probably also because they are protected by an additional cover most of the time, which limits the probability that an impact will occur on the glass.

CRTs are exempted because they have separate requirements.

The test value for floor standing equipment is higher because it is more likely to be impacted by persons or carts and dollies at a higher force while in normal use.

The exemption for glass below certain sizes is taken over from IEC 60065. There is no good rationale to keep the exemption, other than that there are no serious accidents known from the field. The HBSDT decided that they want to keep the exemption in.

The flow chart in Figure 7 in this document shows the intent for the requirements.

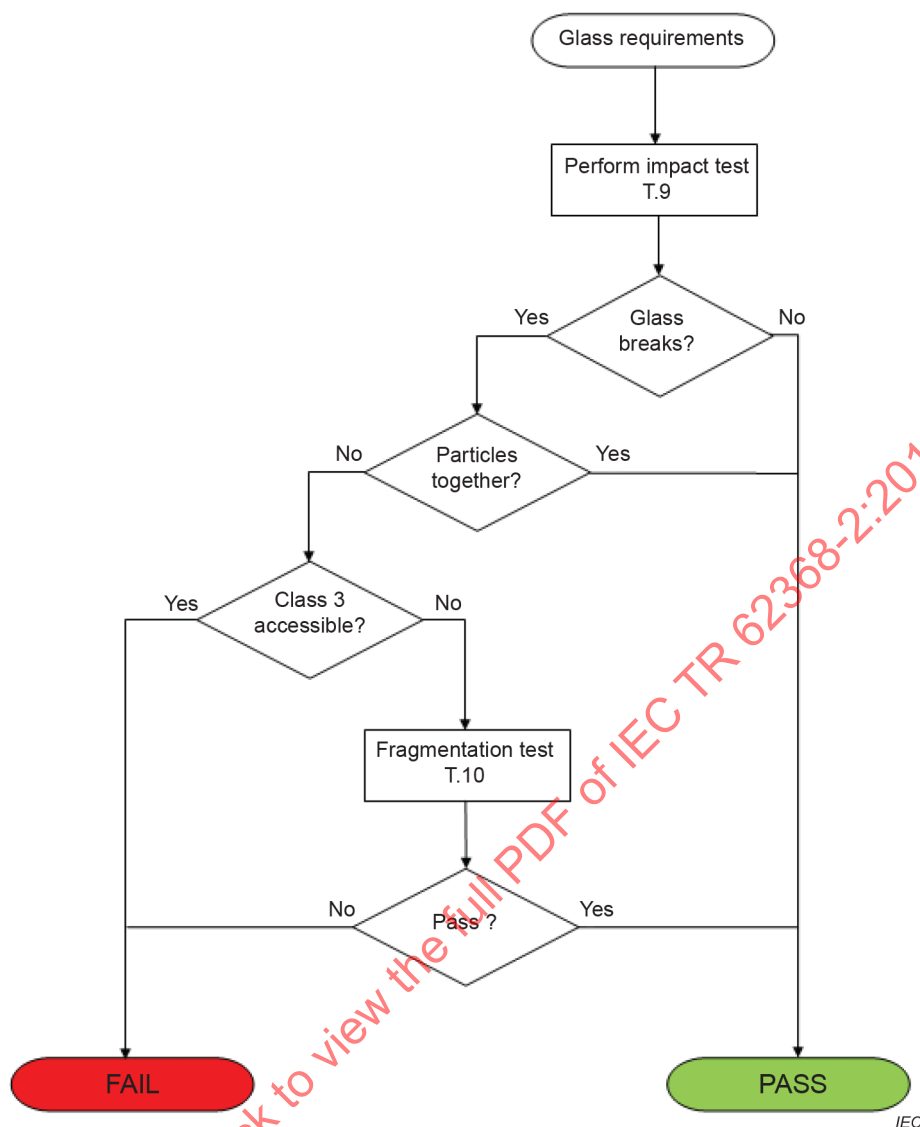


Figure 7 – Flow chart showing the intent of the glass requirements

4.4.3.10 Compliance criteria

The value of 30 g for the weight limit is chosen based on the maximum dimension of a side of 50 mm. A typical piece of glass with a size of 50 mm × 50 mm × 4 mm (roughly 2,80 g/cm³) would have a weight of around 30 g.

4.6 Fixing of conductors

Source: IEC 60950-1

Purpose: To reduce the likelihood that conductors could be displaced such that they reduce the **creepage distances** and **clearances**.

Rationale: These requirements have been successfully used for products in the scope of this document for many years.

4.7 Equipment for direct insertion into mains socket-outlets

Source: IEC 60065:2014, 15.5
 IEC 60950-1:2013, 4.3.6
 IEC 60335-1:2010, 22.3
 IEC 60884-1:2013, 14.23.2

Purpose: Determine that equipment incorporating integral pins for insertion into **mains** socket-outlets does not impose undue torque on the socket-outlet due to the mass and configuration of the equipment. This type of equipment often is known as Direct Plug-in Equipment or Direct Plug-in Transformers.

Rationale: Socket outlets are required to comply with the safety requirements in IEC 60884-1:2013, *Plugs and socket-outlets for household and similar purposes – Part 1: General requirements*, including subclause 14.23.2. The requirements result in socket designs with certain design limitations. Equipment incorporating integral pins for insertion into **mains** socket-outlets is not allowed to exceed these design limitations.

4.9 Likelihood of fire or shock due to entry of conductive objects

Purpose: The purpose of this subclause is to establish opening requirements that would minimize the risk of foreign conductive objects falling into the equipment that could bridge parts within class 2 or class 3 circuits, or between PS circuits that could result in ignition or electric shock.

It is considered unlikely that a person would accidentally drop something that could consequently fall into the equipment at a height greater than 1,8 m.

5 Electrically-caused injury

Purpose: Clause 5 classifies electrical energy sources and provides criteria for determining the energy source class of each conductive part. The criteria for energy source class include the source current-voltage characteristics, duration, and capacitance. Each conductive part, whether current-carrying or not, or whether earthed or not, shall be classed ES1, ES2, or ES3 with respect to earth and with respect to any other simultaneously **accessible** conductive part.

240 VA limit

IEC 62368-1 does not have requirements for a 240 VA energy hazard that was previously located in 2.1.1.5 of IEC 60950-1:2013.

The origin/justification of the 240 VA energy hazard requirement in the legacy documents was never precisely determined, and it appears the VA limits may have come from a manufacturer's specifications originally applied to exposed bus bars in mainframe computers back in the 1960's and concerns at the time service personnel inadvertently bridging them with a metal part.

However, when IEC TC 108 started the IEC 62368-1 project the intent was to take a fresh look at product safety using HBSE and only carry over a legacy requirement if the safety science and HBSE justified it. After considerable study by IEC TC 108, there was no support for carrying over the 240 VA requirement since:

- the requirements were not based on any proven science or sound technical basis;
- the 240 VA value was relatively arbitrary; and
- in practice the requirement was difficult to apply consistently (for example, on a populated printed board or inside a switch mode power supply).

In the meantime, there are energy limits for capacitors in Clause 5, which remains a more realistic concern and which were the second set of the energy hazard requirements in IEC 60950-1, the first being steady state 240 VA.

In addition, there are other requirements in IEC 62368-1 that will limit exposure to high levels of power (VA), including a VA limit for LPS outputs when those are required by Annex Q (for outputs connected to building wiring as required by 6.5.2).

Electric burn (eBurn)

Analysis of the body current generated by increasing frequency sinusoidal waveforms shows that the current continues to increase with frequency. The same analysis shows that the **touch current**, which is discounted with frequency, stabilizes.

The following paper describes the analysis fully: 'Touch Current Comparison, Looking at IEC 60990 Measurement Circuit Performance – Part 1: Electric Burn'; Peter E Perkins; IEEE PSES Product Safety Engineering Newsletter, Vol 4, No 2, Nov 2008.

The crossover frequency is different for the startle-reaction circuit than for the let go-immobilization circuit because of the separate Frequency Factor body response curves related to current levels; analysis identifies the crossover frequency where the eBurn current surpasses the **touch current**. Under these conditions, a person touching the circuit will become immobilized and will not be able to let go of the circuit. This crossover frequency is determined in the analysis. The person contacting the circuit should always be able to let go.

The general conditions that apply to eBurn circuits are:

- the eBurn limit only applies to HF sinusoidal signals;
- the area of contact should be limited to a small, fingertip contact (~ 1cm²);
- the contact time should be less than 1 s; at this short contact time, it is not reasonable to define different levels for various persons;

This requirement applies to **accessible** circuits that can be contacted at both poles, including all grounded circuits isolated from the **mains** and any isolated circuits where both contacts are easily available to touch.

A simplified application of these requirements in the documents limits the accessibility of HF sinusoidal currents above a specified frequency. The 22 kHz and 36 kHz frequency limits are where the eBurn current crosses the 5mA limit for the ES1 and ES2 measurement circuits. This will ensure that the person contacting the circuit will be able to remove themselves from the circuit under these conditions.

1 MHz limit

The effects of electric current on the human body are described in the IEC 60479 series and the requirements in IEC 62368-1 are drawn from there. The effects versus frequency are well laid out and properly accounted for in these requirements. The body effects move from conducted effects to surface radiofrequency burns at higher frequencies approaching 100 kHz. By long-term agreement, IEC safety documents are responsible for outlining the effects of current to 1 MHz, which are properly measured by the techniques given herein. Above the 1 MHz level, it becomes an EMC issue. Unless the current is provided as a principal action of the equipment operation, electric shock evaluation should not be needed above the 1 MHz level. Where it is fundamental to the equipment's operation, the high-frequency current levels shall be specially measured using proper high-frequency techniques, including classifying the circuits and, if necessary, appropriately protected to avoid any bodily injury.

5.2.1 Electrical energy source classifications

Source: IEC TS 60479-1:2005 and IEC 61201

Purpose: To define the line between hazardous and non-hazardous electrical energy sources for **normal operating conditions** and **abnormal operating conditions**.

Rationale: The effect on persons from an electric source depends on the current through the human body. The effects are described in IEC TS 60479-1.

IEC TS 60479-1 (see Figures 20 and 22, Tables 11 and 13); zone AC-1 and zone DC-1; usually no reaction (Figure 8 and Figure 9, Table 2 and Table 3 in this document) is taken as values for ES1.

IEC TS 60479-1 (see Figures 20 and 22; Tables 11 and 13); zone AC-2 and zone DC-2; usually no harmful physiological effects (see Figure 8 and Figure 9, Table 2 in this document) is taken as values for ES2.

IEC TS 60479-1; zone AC-3 and zone DC-3; harmful physiological effects may occur (see Figure 8 and Figure 9, Table 2 and Table 3 in this document) is the ES3 zone.

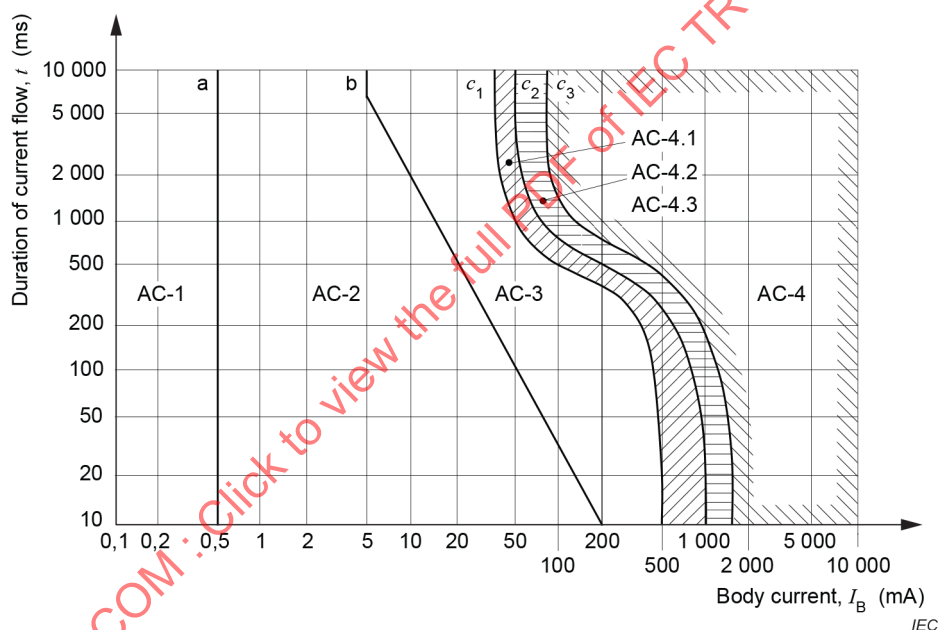


Figure 8 – Conventional time/current zones of effects of AC currents (15 Hz to 100 Hz) on persons for a current path corresponding to left hand to feet (see IEC TS 60479-1:2005, Figure 20)

**Table 2 – Time/current zones for AC 15 Hz to 100 Hz
for hand to feet pathway (see IEC TS 60479-1:2005, Table 11)**

Zones	Boundaries	Physiological effects
AC-1	up to 0,5 mA curve a	Perception possible but usually no startle reaction
AC-2	0,5 mA up to curve b	Perception and involuntary muscular contractions likely but usually no harmful electrical physiological effects
AC-3	Curve b and above	Strong involuntary muscular contractions. Difficulty in breathing. Reversible disturbances of heart function. Immobilisation may occur. Effects increasing with current magnitude. Usually no organic damage to be expected.
AC-4 ^a	Above curve c_1 $c_1 - c_2$ $c_2 - c_3$ Beyond curve c_3	Pathophysiological effects may occur such as cardiac arrest, breathing arrest, and burns or other cellular damage. Probability of ventricular fibrillation increasing with current magnitude and time. AC-4.1 Probability of ventricular fibrillation increasing up to about 5 %. AC-4.2 Probability of ventricular fibrillation up to about 50 %. AC-4.3 Probability of ventricular fibrillation above 50 %.

^a For durations of current flow below 200 ms, ventricular fibrillation is only initiated within the vulnerable period if the relevant thresholds are surpassed. As regards ventricular fibrillation, this figure relates to the effects of current that flows in the path left hand to feet. For other current paths, the heart current factor has to be considered.

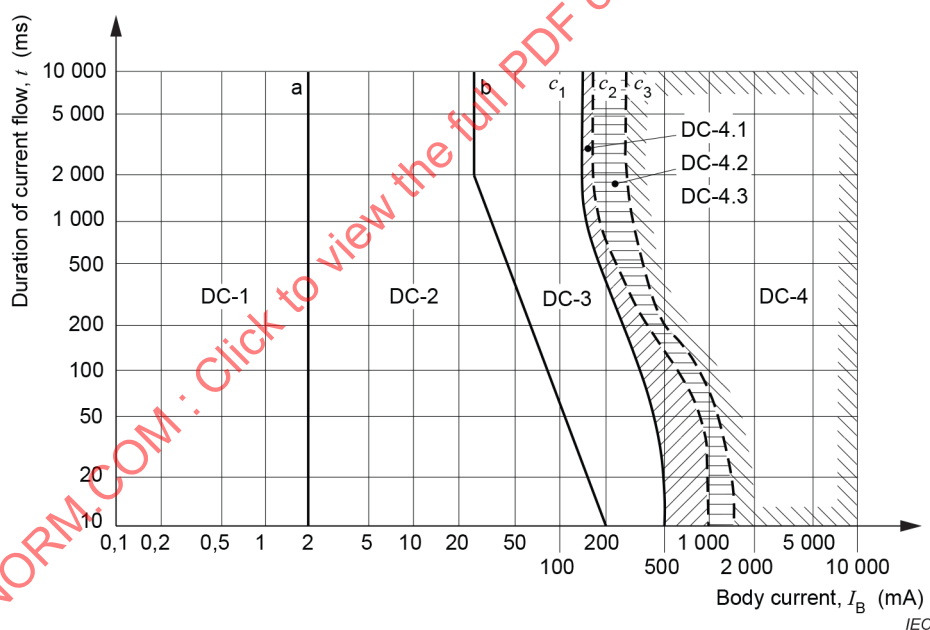


Figure 9 – Conventional time/current zones of effects of DC currents on persons for a longitudinal upward current path (see IEC TS 60479-1:2005, Figure 22)

**Table 3 – Time/current zones for DC for hand to feet pathway
(see IEC TS 60479-1:2005, Table 13)**

Zones	Boundaries	Physiological effects
DC-1	Up to 2 mA curve a	Slight pricking sensation possible when making, breaking or rapidly altering current flow.
DC-2	2 mA up to curve b	Involuntary muscular contractions likely, especially when making, breaking or rapidly altering current flow, but usually no harmful electrical physiological effects
DC-3	curve b and above	Strong involuntary muscular reactions and reversible disturbances of formation and conduction of impulses in the heart may occur, increasing with current magnitude and time. Usually no organic damage to be expected.
DC-4 ^a	Above curve c_1 $c_1 - c_2$ $c_2 - c_3$ Beyond curve c_3	Pathophysiological effects may occur such as cardiac arrest, breathing arrest, and burns or other cellular damage. Probability of ventricular fibrillation increasing with current magnitude and time. DC-4.1 Probability of ventricular fibrillation increasing up to about 5 %. DC-4.2 Probability of ventricular fibrillation up to about 50 %. DC-4.3 Probability of ventricular fibrillation above 50 %.
^a For durations of current flow below 200 ms, ventricular fibrillation is only initiated within the vulnerable period if the relevant thresholds are surpassed. As regards ventricular fibrillation, this figure relates to the effects of current which flows in the path left hand to feet and for upward current. For other current paths, the heart current factor has to be considered.		

The seriousness of an injury increases continuously with the energy transferred to the body. To demonstrate this principle Figure 8 and Figure 9 in this document (see IEC TS 60479-1, Figures 20 and 22) are transferred into a graph: effects vs energy (see Figure 10 in this document).

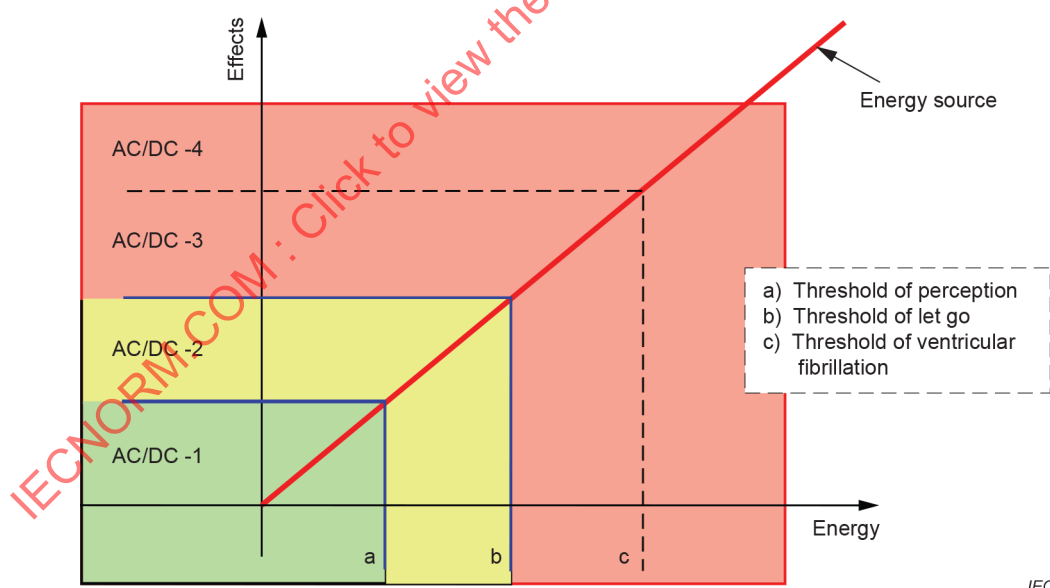


Figure 10 – Illustration that limits depend on both voltage and current

Within the document, only the limits for Zone 1 (green) and Zone 2 (yellow) will be specified.

Curve “a” (limit of Zone 1) will be the limit for parts **accessible** by an **ordinary person** during normal use.

Curve “b” (limit of Zone 2) will be the limit for parts **accessible** by an **ordinary person** during (or after) a single fault.

IEC TC 108 regarded it not to be acceptable to go to the limits of either Zone 3 or 4.

In the document three (3) zones are described as electrical energy sources.

This classification is as follows:

- electrical energy source 1 (ES1): levels are of such a value that they do not exceed curve “a” (threshold of perception) of Figure 8 and Figure 9 in this document (see IEC TS 60479-1:2005, Figures 20 and 22).
- electrical energy source 2 (ES2): levels are of such a value that they exceed curve “a”, but do not exceed curve “b” (threshold of let go) of Figure 8 and Figure 9 in this document (see IEC TS 60479-1:2005, Figures 20 and 22).
- electrical energy source 3 (ES3): levels are of such a value that they exceed curve “b” of Figure 8 and Figure 9 in this document (see IEC TS 60479-1:2005, Figures 20 and 22).

5.2.2.1 General

When classifying a circuit or part that is not **accessible**, that circuit or part shall be regarded as being **accessible** when measuring **prospective touch voltage** and **touch current**.

5.2.2.2 Steady-state voltage and current limits

Table 4 Electrical energy source limits for steady-state ES1 and ES2

Source: IEC TS 60479-1:2005, Dalziel, Effect of Wave Form on Let-Go Currents; AIEE Electrical Engineering Transactions, Dec 1943, Vol 62.

Rationale: The current limits of Table 4 line 1 and 2 are derived from curve a and b, Figure 8 and Figure 9 in this document (see IEC TS 60479-1:2005, Figures 20 and 22).

The basis for setting limits for combined AC and DC **touch current** is from the work of Dalziel which provides clear data for men, women and children. In the current diagram (Figure 22), the AC current is always the peak value (per Dalziel). In the voltage diagram (Figure 23), the 30 V AC and 50 V AC points on the baseline are recognized as AC RMS values as stated in Table 4. Since IEC TC 108 is working with consumer appliances, there is a need to provide protection for children, who are generally considered the most vulnerable category of people. The formulas of IEC 62368-1:2018, Table 4 address the Dalziel investigations.

Under **single fault conditions** of a relevant **basic safeguard** or **supplementary safeguard**, **touch current** is measured according to 5.1.2 of IEC 60990:2016. However, this IEC 60990 subclause references both the IEC 60990 perception/reaction network (Figure 4) and the let-go network (Figure 5), selection of which depends on several factors. Figure 5 applies to **touch current** limits above 2 mA RMS. IEC TC 108 has decided that parts under **single fault conditions** of relevant **basic safeguards** or **supplementary safeguards** should be measured per Figure 5 (let-go immobilization network). Therefore, since 5.1.2 makes reference to both Figure 4 and Figure 5, for clarification Table 4 is mentioned directly in 5.2.2.2.

Because there is usually no reaction of the human body when touching ES1, access is permitted by any person (IEC TS 60479-1; zone AC-1 and zone DC-1).

Because there may be a reaction of the human body when touching ES2, protection is required for an **ordinary person**. One **safeguard** is sufficient because there are usually no harmful physiological effects when touching ES2 (IEC TS 60479-1:2005; zone AC-2 and zone DC-2).

Because harmful physiological effects may occur when touching ES3, (IEC TS 60479-1:2005; zone AC-3 and zone DC-3), protection is required for an **ordinary person** and an **instructed person**, including after a fault of one **safeguard**.

During the application of the electrical energy source limits for “combined AC and DC” in Table 4, if the AC component of a superimposed AC and DC energy source does not exceed 10 % of the DC energy, then the AC component can be disregarded for purposes of application of Table 4. This consideration is valid based on the definition of **DC voltage** in 3.3.14.1, which allows peak-to-peak ripple not exceeding 10 % of the average value to be integrated into **DC voltage** considerations. As a result, in such cases where AC does not exceed 10 % of DC, only the DC energy source limits in Table 4 need be applied.

When measuring combined AC and DC voltages and currents, both AC and DC measurements shall be made between the same points of reference. Do not combine common-mode measurements with differential-mode measurements. They shall be assessed separately.

In using Table 4, ES1 touch current measurement specifies the startle-reaction circuit ‘a’ intended for limits less than 2 mA RMS / 2,8 mA peak and ES2 touch current specifies the let-go-immobilization circuit ‘b’ intended for limits > 2 mA RMS / 2,8 mA peak. These circuits are adopted from IEC 60990:2016, Clause 5.

Normal operating conditions of equipment for touch current testing are outlined in 5.7.2 and Clause B.2 of IEC 62368-1:2018 and includes operation of all operator controls. **Abnormal operating conditions** are specified in Clause B.3 of IEC 62368-1:2018. **Single fault conditions** (within the equipment), specified in Clause B.4 of IEC 62368-1:2018, includes faults of a relevant **basic safeguard** or a **supplementary safeguard**.

5.2.2.3 Capacitance limits

Table 5 Electrical energy source limits for a charged capacitor

Source:	IEC TS 61201:2007 (Annex A)
Rationale:	Where the energy source is a capacitor, the energy source class is determined from both the charge voltage and the capacitance. The capacitance limits are derived from IEC TS 61201:2007, see Table 4 in this document.
	The values for ES2 are derived from Table A.2 of IEC TS 61201:2007.
	The values for ES1 are calculated by dividing the values from Table A.2 of IEC TS 61201:2007 by two (2).

Table 4 – Limit values of accessible capacitance (threshold of pain)

U V	C μF	U kV	C nF
70	42,4	1	8,0
78	10,0	2	4,0
80	3,8	5	1,6
90	1,2	10	0,8
100	0,58	20	0,4
150	0,17	40	0,2
200	0,091	60	0,133
250	0,061		
300	0,041		
400	0,028		
500	0,018		
700	0,012		

5.2.2.4 Single pulse limits**Table 6 Voltage limits for single pulses**

Rationale: The values are based on the DC current values of Table 4, assuming 25 mA gives a voltage of 120 V DC (body resistance of 4,8 kΩ). The lowest value is taken as 120 V because, under **single fault conditions**, the voltage of ES1 can be as high as 120 V DC without a time limit.

The table allows linear interpolation because the difference is considered to be very small. However, the following formula may be used for a more exact interpolation of the log-log based values in this table. The variable t or V is the desired unknown "in between value" and either may be determined when one is known:

$$V = \text{Antilog} \frac{\log V_2 + \log V_1 \times \frac{\log t_2 - \log t}{\log t - \log t_1}}{1 + \frac{\log t_2 - \log t}{\log t - \log t_1}}$$

and

$$t = \text{Antilog} \frac{\log t_2 + \log t_1 \times \frac{\log V_2 - \log V}{\log V - \log V_1}}{1 + \frac{\log V_2 - \log V}{\log V - \log V_1}}$$

where:

t is the time duration that is required to be determined if U_{peak} voltage V is known (or t is known and V needs to be determined)

t_1 is the time duration adjacent to t corresponding to the U_{peak} voltage V_1

t_2 is the time duration adjacent to t corresponding to the U_{peak} voltage V_2

V is the U_{peak} voltage value that is known if time duration t is to be determined (or V is required to be determined if time duration t is known)

V_1 is the value of the voltage U_{peak} adjacent to V corresponding to time duration t_1

V_2 is the value of the voltage U_{peak} adjacent to V corresponding to time duration t_2

Table 7 **Current limits for single pulses**

Source: IEC TS 60479-1:2005

Rationale: For ES1, the limit of single pulse should not exceed the ES1 steady-state voltage limits for **DC voltages**.

For ES2, the voltage limits have been calculated by using the DC current values of curve b Figure 9 in this document and the resistance values of Table 10 of IEC TS 60479-1:2005, column for 5 % of the population (see Table 5 in this document).

The current limits of single pulses in Table 7 for ES1 levels are from curve a and for ES2 are from curve b of Figure 9 in this document.

The table allows linear interpolation because the difference is considered to be very small. However, the following formula may be used for a more exact interpolation of the log-log based values in this table. The variable t or I is the desired unknown "in between value" and either may be determined when one is known:

$$I = \text{Antilog} \frac{\log I_2 + \log I_1 \times \frac{\log t_2 - \log t}{\log t - \log t_1}}{1 + \frac{\log t_2 - \log t}{\log t - \log t_1}}$$

and

$$t = \text{Antilog} \frac{\log t_2 + \log t_1 \times \frac{\log I_2 - \log I}{\log I - \log I_1}}{1 + \frac{\log I_2 - \log I}{\log I - \log I_1}}$$

where:

t is the time duration that is required to be determined if the electric current I is known (or t is known and I needs to be determined)

t_1 is the time duration adjacent to t corresponding to the electric current I_1

t_2 is the time duration adjacent to t corresponding to the electric current I_2

I is the value of the I_{peak} current that is known if time duration t is to be determined (or I is required to be determined if time duration t is known)

I_1 is the value of the I_{peak} adjacent to I corresponding to time duration t_1

I_2 is the value of the I_{peak} adjacent to I corresponding to time duration t_2

Table 5 – Total body resistances R_T for a current path hand to hand, DC, for large surface areas of contact in dry condition

Touch voltage V	Values for the total body resistance R_T (Ω) that are not exceeded for		
	5 % of the population	50 % of the population	95 % of the population
25	2 100	3 875	7 275
50	1 600	2 900	5 325
75	1 275	2 275	4 100
100	1 100	1 900	3 350
125	975	1 675	2 875
150	875	1 475	2 475
175	825	1 350	2 225
200	800	1 275	2 050
225	775	1 225	1 900
400	700	950	1 275
500	625	850	1 150
700	575	775	1 050
1 000	575	775	1 050
Asymptotic value	575	775	1 050
NOTE 1 Some measurements indicate that the total body resistance R_T for the current path hand to foot is somewhat lower than for a current path hand to hand (10 % to 30 %). NOTE 2 For living persons the values of R_T correspond to a duration of current flow of about 0,1 s. For longer durations R_T values may decrease (about 10 % to 20 %) and after complete rupture of the skin R_T approaches the initial body resistance R_o. NOTE 3 Values of R_T are rounded to 25 Ω.			

5.2.2.6 Ringing signals

Source: EN 41003

Purpose: To establish limits for analogue telephone network ringing signals.

Rationale: For details see rationale for Annex H. Where the energy source is an analogue telephone network ringing signal as defined in Annex H, the energy source class is taken as ES2 (as in IEC 60950-1:2005, Annex M).

5.2.2.7 Audio signals

Source: IEC 60065:2014

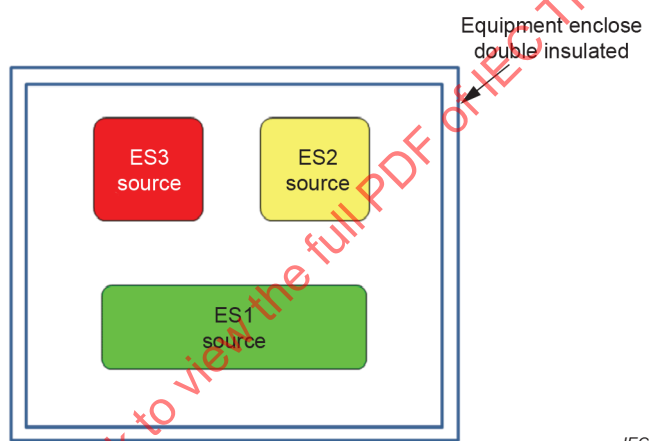
Purpose: To establish limits for touch voltages for audio signals.

Rationale: The proposed limits for touch voltages at terminals involving audio signals that may be contacted by persons have been extracted without deviation from IEC 60065. Reference: IEC 60065:2014, 9.1.1.2 a). Under **single fault conditions**, 10.2 of IEC 60065:2014 does not permit an increase in acceptable touch voltage limits.

The proposed limits are quantitatively larger than the accepted limits of Tables 5 and 6, but are not considered dangerous for the following reasons:

- the output is measured with the load disconnected (worst case load);
- defining the contact area of connectors and wiring is very difficult due to complex shapes. The area of contact is considered small due to the construction of the connectors;
- normally, it is recommended to the user, in the instruction manual provided with the equipment, that all connections be made with the equipment in the “off” condition;
- in addition to being on, the equipment would have to be playing some program at a high output with the load disconnected to achieve the proposed limits (although possible, highly unlikely). Historically, no known cases of injury are known for amplifiers with non-clipped output less than 71 V RMS;
- the National Electrical Code (USA) permits **accessible** terminals with maximum output voltage of 120 V RMS.

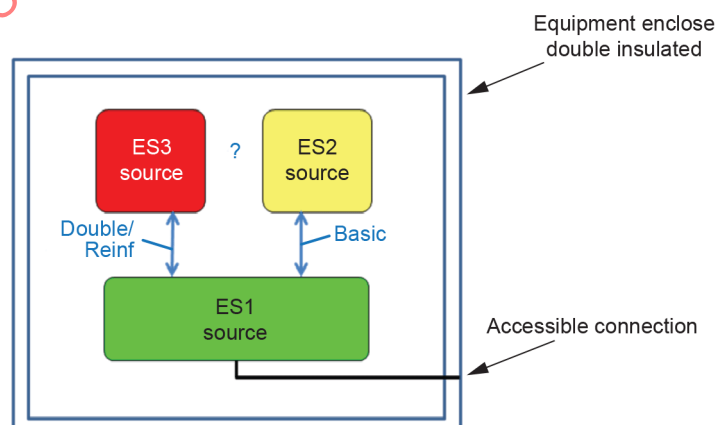
5.3.2 Accessibility to electrical energy sources and safeguards



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What are the requirements between the non-**accessible** sources?

Answer: None. As the **enclosure** is double insulated, the sources are not **accessible**.

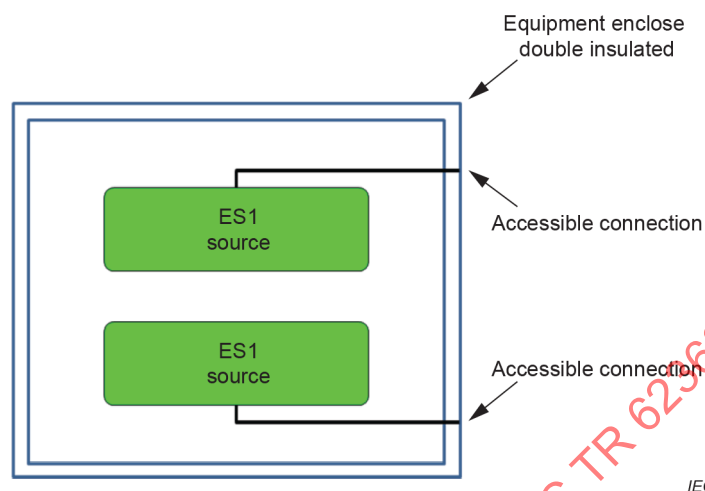


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Now there is an **accessible** connection. What are the requirements between the sources in this case?

Answer:

- **Basic insulation** between ES1 and ES2
- **Double insulation** or **reinforced insulation** between ES1 and ES3
- The insulation between ES2 and ES3 depends on the insulation between the ES1 and ES2



Now there are two **accessible** connections from independent sources. What are the requirements between the sources in this case?

Answer:

- According to Clause B.4, the insulation or any components between the sources need to be shorted
- If one of the two ES1 sources would reach ES2 levels ⇒ **basic safeguard**
- If both ES1 sources stay within ES1 limits ⇒ no **safeguard (functional insulation)**

For **outdoor equipment**, lower voltage limits apply because the body impedance is reduced to half the value when subjected to wet conditions as described in IEC TS 60479-1 and IEC TS 61201.

Where **Class III equipment** is acceptable in an indoor application, this outdoor application does not introduce additional **safeguard** requirements.

5.3.2.2 Contact requirements

Source: IEC 61140:2001, 8.1.1

Purpose: Determination of **accessible** parts for adults and children. Tests are in IEC 62368-1:2018, Annex V.

Rationale: According to Paschen's Law, air breakdown does not occur below 323 V peak or DC (at sea level). IEC 62368-1:2018 uses 420 V peak (300 V RMS) to add an additional safety margin.

5.3.2.3 Compliance criteria

The reason for accepting different requirements for components is because you cannot expect your supplier to make different components for each end application.

5.3.2.4 Terminals for connecting stripped wire

Source: IEC 60065

Purpose: To prevent contact of ES2 or ES3 parts.

Rationale: Accepted constructions used in the audio/video industry for many years.

5.4 Insulation materials and requirements

Rationale: The requirements, test methods and compliance criteria are taken from the actual outputs from IEC TC 108 MT2 (formerly WG6) as well as from IEC TC 108 MT1.

- The choice and application of components shall take into account the needs for electrical, thermal and mechanical strength, frequency of the **working voltage** and working environment (temperature, pressure, humidity and pollution).
- Components shall have the electric strength, thermal strength, mechanical strength, dimensions, and other properties as specified in the document.
- Depending on the grade of **safeguard** (**basic safeguard**, **supplementary safeguard**, **reinforced safeguard**) the requirements differ.
- Components complying with their component documents (for example, IEC 60384-14 for capacitances) have to be verified for their application.
- The components listed in this subclause of the new document have a separation function.

5.4.1.1 Insulation

Source: IEC 60664-1

Purpose: Provide a reliable **safeguard**

Rationale: Solid **basic insulation**, **supplementary insulation**, and **reinforced insulation** shall be capable of durably withstanding electrical, mechanical, thermal, and environmental stress that may occur during the anticipated lifetime of the equipment.

Clearances and **creepage distances** may be divided by intervening unconnected (floating) conductive parts, such as unused contacts of a connector, provided that the sum of the individual distances meets the specified minimum requirements (see Figure O.4).

5.4.1.4 Maximum operating temperatures for materials, components and systems

Source: IEC 60085, IEC 60364-4-43, ISO 306, IEC 60695-10-2

Rationale: Temperature limits given in Table 9:

- limits for insulation materials including electrical insulation systems, including winding insulation (Classes A, E, B, F, H, N, R and 250) are taken from IEC 60085;
- limits for insulation of internal and external wiring, including power supply cords with temperature marking are those indicated by the marking or the rating assigned by the (component) manufacturer;
- limits for insulation of internal and external wiring, including power supply cords without temperature marking of 70 °C are referenced in IEC 60364-4-43 for an ambient temperature of 25 °C;
- limits for thermoplastic insulation are based on:
 - data from Vicat test B50 of ISO 306;
 - ball pressure test according to IEC 60695-10-2;
 - when it is clear from the examination of the physical characteristics of the material that it will meet the requirements of the ball pressure test;

- experience with 125 °C value for parts in a circuit supplied from the **mains**.

5.4.1.4.3 Compliance criteria

Table 9 Temperature limits for materials, components and systems

Rationale Regarding condition “a”, it has been assumed by the technical committee for many years that the thermal gradient between outer surface and inner windings will be limited to 10 °C differential as an average. As a result, the temperature limits for outer surface insulation measured via thermocouple is 10 °C lower than similar measurement with a thermocouple embedded in the winding(s), with both limits at least 5 °C less than the hot-spot temperature allowed per IEC 60085 as an additional safety factor. However, some modern transformer constructions with larger power densities may have larger thermal gradients, as may some outer surface transformer insulation thermal measurements in the equipment/system be influenced by forced cooling or similar effects. Therefore, if thermal imaging, computer modeling, or actual measurement shows a thermal gradient greater than 10 °C average between transformer surface temperature and transformer winding(s), the rise of resistance temperature measurement method and limits for an embedded thermocouple should be used (for example, 100 °C maximum temperature for Class 105 (A)) for determining compliance of a transformer with Table 9 since the original assumptions do not hold true.

As an example, a material rated for 124 °C using the rise of resistance method 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 250).

5.4.1.5 Pollution degrees

Source: IEC 60664-1

Rationale: No values for PD 4 (pollution generates persistent conductivity) are included, as it is unlikely that such conditions are present when using products in the scope of the document.

5.4.1.5.2 Test for pollution degree 1 environment and for an insulating compound

The compliance check made by visual inspection applies both to single layer and multi-layer boards without the need for sectioning to check for voids, gaps, etc.

5.4.1.6 Insulation in transformers with varying dimensions

Source: IEC 60950-1

Purpose: To consider actual **working voltage** along the winding of a transformer.

Rationale: Description of a method to determine adequacy of **solid insulation** along the length of a transformer winding.

5.4.1.7 Insulation in circuits generating starting pulses

Source: IEC 60950-1, IEC 60664-1

Purpose: To avoid insulation breakdown due to starting pulses.

Rationale: This method has been successfully used for products in the scope of this document for many years.

5.4.1.8 Determination of working voltage

Source: IEC 60664-1:2007, 3.5; IEC 60950-1

Rationale: The **working voltage** does not include short duration signals, such as transients. Recurring peak voltages are not included. Transient overvoltages are covered in the **required withstand voltage**. Ringing signals do not carry external transients.

5.4.1.8.1 General

Rationale: **Functional insulation** is not addressed in Clause 5, as it does not provide protection against electric shock. Requirements for **functional insulation** are covered in Clause 6, which addresses protection against electrically caused fire.

Source: IEC 60664-1:2007, 3.8

Rationale: In IEC 62368-1, "Circuit supplied from the **mains**" is used for a "primary circuit". "Circuit isolated from the **mains**" is used for a "secondary circuit".

"**External circuit**" is defined as **external** to the equipment. ES1 can be external to the equipment.

For an **external circuit** operating at ES2 level and not exiting the building, the transient is 0 V. Therefore, in this case, ringing peak voltage needs to be taken into account.

5.4.1.8.2 RMS working voltage

Source: IEC 60664-1:2007, 3.5

Rationale: RMS **working voltage** is used when determining minimum **creepage distance**. Unless otherwise specified, working voltage is the RMS value.

5.4.1.10 Thermoplastic parts on which conductive metallic parts are directly mounted

Source: ISO 306 and IEC 60695-2 series

Rationale: The temperature of the thermoplastic parts under **normal operating conditions** shall be 15 K less than the softening temperature of a non-metallic part. Supporting parts in a circuit supplied from the **mains** shall not be less than 125 °C.

5.4.2 Clearances

5.4.2.1 General requirements

Source: IEC 60664-1:2007

Rationale: The dimension for a **clearance** is determined from the required impulse withstand voltage for that **clearance**. This concept is taken from IEC 60664-1:2007, 5.1. In addition, **clearances** are affected by the largest of the determined transients. The likelihood of simultaneous occurrence of transients is very low and is not taken into account.

Overvoltages and transients that may enter the equipment, and peak voltages that may be generated within the equipment, do not break down the **clearance** (see IEC 60664-1:2007, 5.1.5 and 5.1.6).

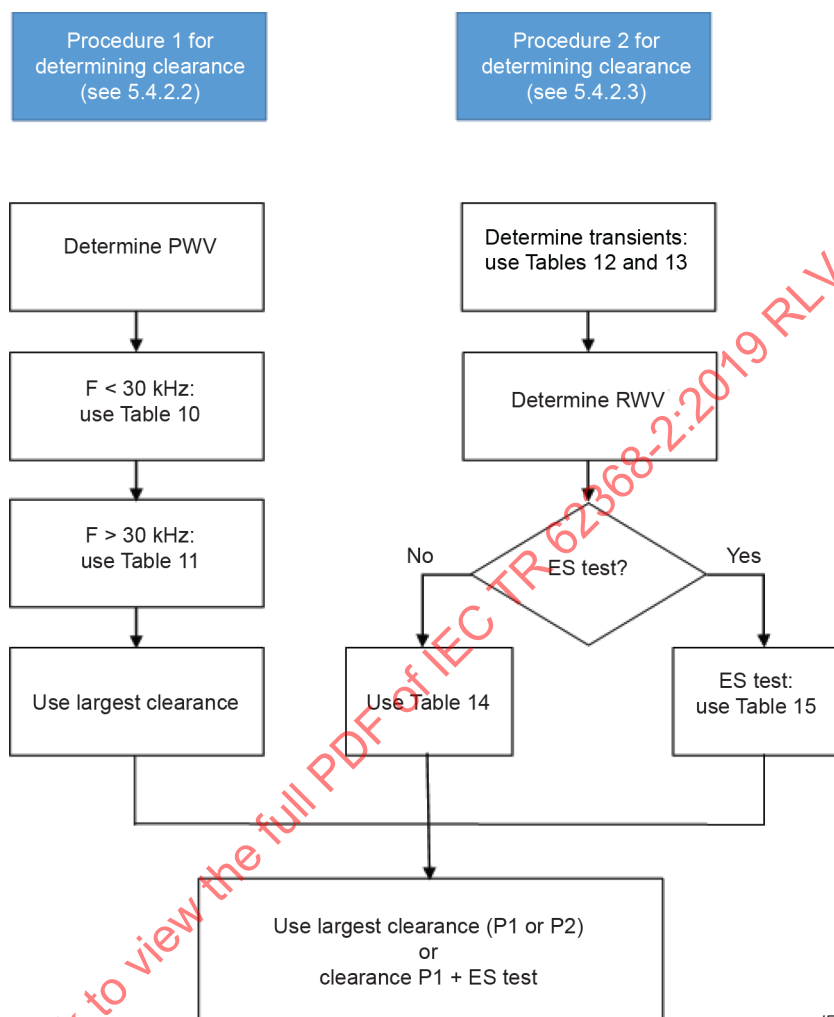
Minimum **clearances** of safety components shall comply with the requirements of their applicable component safety document.

Clearances between the outer insulating surface of a connector and conductive parts at ES3 voltage level shall comply with the requirements of **basic insulation** only, if the connectors are fixed to the equipment, located internal to the outer **electrical enclosure** of the equipment, and are **accessible** only after removal of a sub-assembly that is required to be in place during normal operation.

It is assumed that the occurrence of both factors, the sub-assembly being removed and the occurrence of a transient overvoltage, have a reduced likelihood and hazard potential.

Source: IEC 60664-2 series, *Application guide*

Rationale: The method is derived from the IEC 60664-2 series, *Application guide*.



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Example:

Assuming:

- an SMPS power supply,
- connection to the AC **mains**,
- a peak of the working voltage (PWV) of 800 V,
- frequencies above and below 30 kHz,
- reinforced **clearances** required,
- **temporary overvoltages**: 2 000 V

Procedure 1:

Table 10 requires 2,54 mm

Table 11 requires 0,44 mm

Result is 2,54 mm

NOTE All PWV below 1 200 V have **clearance** requirements less than 3 mm for both Table 10 and Table 11

Final result:

- 3,0 mm or
- ES test at 4,67 KV and 2,54 mm

Procedure 2:

Transients (OVC 2): 2 500 V

RWV = 2 500 V

Table 14 requires 3,0 mm

The required ES test voltage according to Table 15 is 4,67 KV

Result is 3,0 mm or ES test at 4,67 KV

ATTENTION:

For a product with connection to coax cable, different values are to be used since a different transient and **required withstand voltage** is required.

5.4.2.2 Procedure 1 for determining clearance

Rationale: Related to the first dash of 5.4.2.2, it is noted that an example of a cause of determination of the peak value of steady state voltages that are below the peak voltage of the **mains** includes, for example, a determination in accordance with the 2nd and 3rd dash of 5.4.2.3.3 where filtering is in place to lower expected peak voltages.

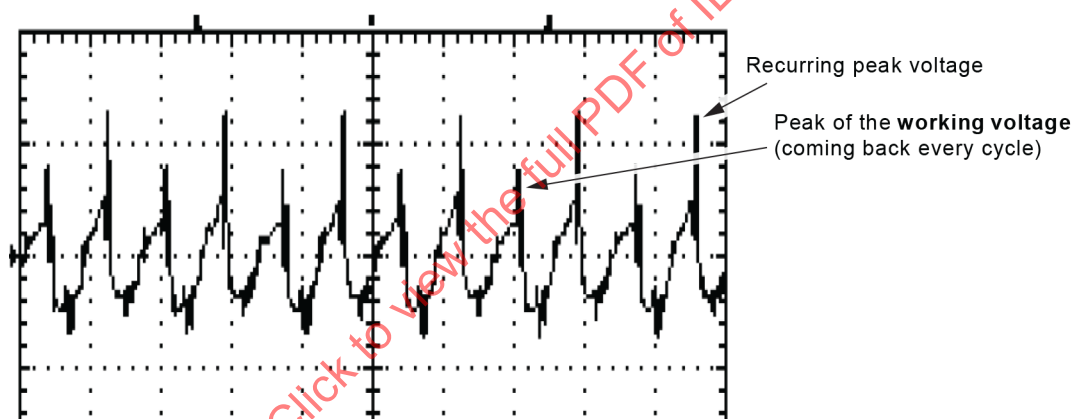
Similarly, related to the second dash of 5.4.2.2, an example of this case where the recurring peak voltage is limited to 1,1 times the **mains** voltage may be use of certain forms of surge protection devices that reduce overvoltage category.

Peak of the working voltage versus recurring peak voltage.

There has been some discussion between the two terms. The peak of the **working voltage** is the peak value of the waveform that occurs each cycle, and therefore is considered to be a part of the **working voltage**.

A recurring peak voltage is a peak that does not occur at each cycle of the waveform, but that reoccurs at a certain interval, usually at a lower frequency than the waveform frequency.

Figure 11 in this document gives an example of a waveform where the recurring peak voltage occurs every two cycles of the main waveform.



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Figure 11 – Illustration of working voltage

Table 10 Minimum clearances for voltages with frequencies up to 30 kHz

Rationale: IEC TC 108 noted that, if the rules of IEC 60664-1 are followed, for reinforced **clearance**, some values were more than double the requirements for **basic insulation**. IEC TC 108 felt that this should not be the case and decided to limit the requirement for **reinforced insulation** to twice the value of **basic insulation**, thereby deviating from IEC 60664-1.

In addition, normal rounding rules were applied to the values in the table.

5.4.2.3.2.2 Determining AC mains transient voltages

Source: IEC 60664-1:2007, 4.3.3.3

Rationale: Table 12 is derived from Table F.1 of IEC 60664-1:2007.

The term used in IEC 60664-1 is 'rated impulse voltage'. Products covered by IEC 62368-1 are also exposed to transients from **external circuits**, and therefore another term is needed, to show the different source.

Outdoor equipment that is part of the building installation, or that may be subject to transient overvoltages exceeding those for Overvoltage Category II, shall be designed for Overvoltage Category III or IV, unless additional protection is to be provided internally or externally to the equipment. In this case, the installation instructions shall state the need for such additional protection.

5.4.2.3.2.3 Determining DC mains transient voltages

Rationale: Transient overvoltages are attenuated by the capacitive filtering.

5.4.2.3.2.4 Determining external circuit transient voltages

Source: ITU-T K.21

Rationale: Transients have an influence on circuits and insulation, therefore transients on **external circuits** need to be taken into account. Transients are needed only for the dimensioning **safeguards**. Transients should not be used for the classification of energy sources (ES1, ES2, etc.).

It is expected that **external circuits** receive a transient voltage of 1,5 kV peak with a waveform of 10/700µs from sources outside the building.

The expected transient is independent from the application (telecom; LAN or other). Therefore, it is assumed that for all kinds of applications the same transient appears. The value 1,5 kV 10/700µs is taken from ITU-T K.21.

It is expected that **external circuits** using earthed coaxial cable receive no transients that have to be taken into account from sources outside the building.

Because of the earthed shield of the coaxial cable, a possible transient on the outside cable will be reduced at the earthed shield at the building entrance of the cable.

It is expected that for **external circuits** within the same building no transients have to be taken into account.

The transients for an interface are defined with respect to the terminals where the voltage is defined. For the majority of cases, the relevant voltages are common (U_c) and differential mode (U_d) voltages at the interface. For **hand-held** parts or other parts in extended contact with the human body, such as a telephone hand set, the voltage with respect to local earth (U_{ce}) may be relevant. Figure 12 in this document shows the definition of the various voltages for paired-conductor interface.

The transients for coaxial cable interfaces are between the centre conductor and shield (U_d) of the cable if the shield is earthed at the equipment. If the shield is isolated from earth at the equipment, then the shield-to-earth voltage (U_s) is important. Earthing of the shield can consist of connection of the shield to the **protective earthing**, functional earth inside or immediately outside the equipment. It is assumed that all earths are bonded together. Figure 13 in this document shows the definition of the various voltages for coaxial-cable interfaces.

An overview of insulation requirements is given in Table 6 in this document.

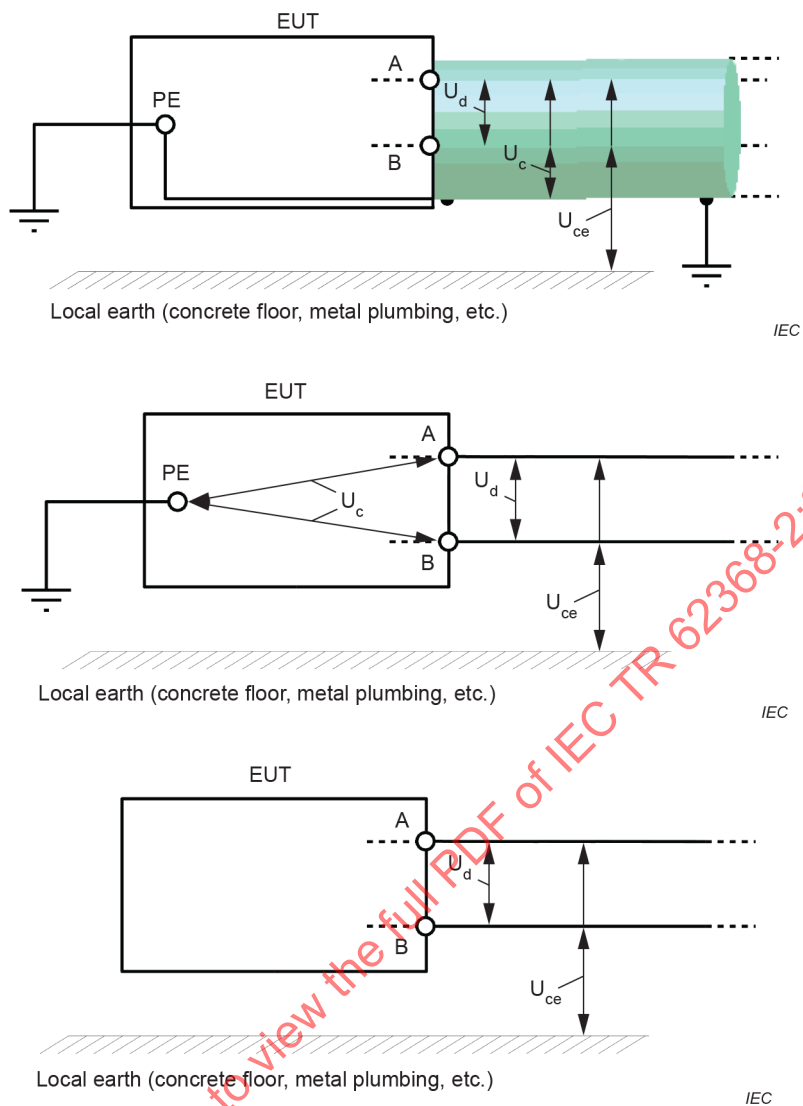


Figure 12 – Illustration of transient voltages on paired conductor external circuits

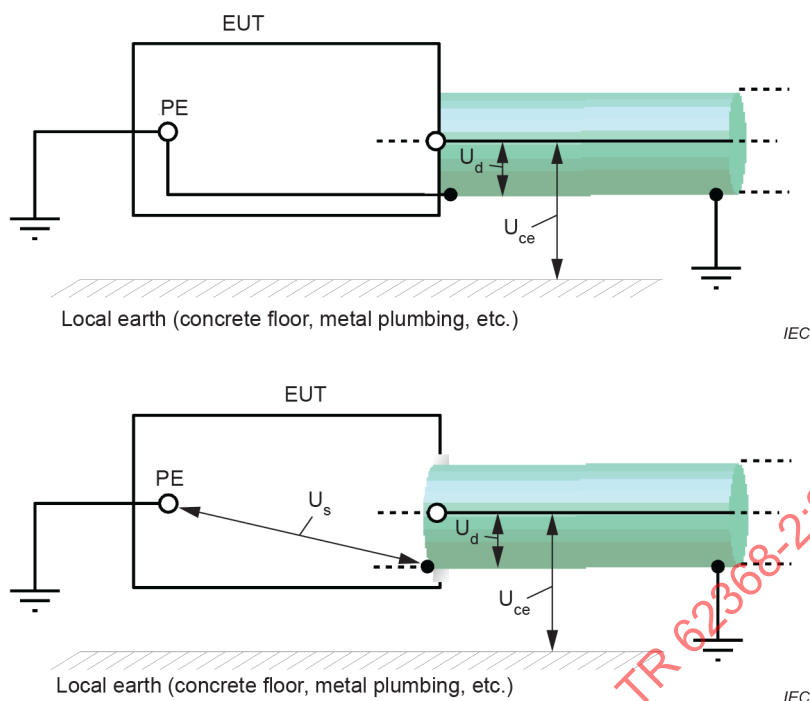


Figure 13 – Illustration of transient voltages on coaxial-cable external circuits

Table 6 – Insulation requirements for external circuits

External Circuit under consideration	Insulation	Requirement
ES1 earthed	None	None
ES1 unearthed	Separation (to floating metal parts and other floating ES1 circuits)	Electric strength test (using Table 15) between unearthed ES1 and other unearthed ES1 and floating parts
ES2	Basic insulation (to ES1 and metal parts)	Clearances; creepage distance; and solid insulation and by electric strength test (using Table 15) between ES2 and ES1 and metal parts
ES3	Double insulation or reinforced insulation (to ES1, ES2 and metal parts)	Clearances; creepage distance; and solid insulation requirements including electric strength test (using Table 15)

Table 13 External circuit transient voltages

Rationale: When the DC power distribution system is located outside the building, transient over-voltages can be expected. Transients are not present if the DC power system is connected to **protective earthing** and is located entirely within a single building.

5.4.2.3.2.5 Determining transient voltage levels by measurement

Source: Test method is taken from IEC 60950-1:2013, Annex G.

5.4.2.3.4 Determining clearances using required withstand voltage

Source: IEC 60664-1:2007, Table F.2 Case A (inhomogeneous field) and Case B (homogeneous field)

Rationale: Values in Table 14 are taken from IEC 60664-1:2007 Table F.2 Case A (inhomogeneous field) and Case B (homogeneous field) and include explicit values for **reinforced insulation**. **Clearances** for **reinforced insulation** have been calculated in accordance with 5.1.6 of IEC 60664-1:2007. For **reinforced insulation** 5.1.6 states **clearance** shall be to the corresponding rated impulse voltage that is one step higher for voltages in the preferred series. For voltages that are not in the preferred series, the **clearance** should be based on 160 % of the **required withstand voltage** for **basic insulation**.

When determining the **required withstand voltage**, interpolation should be allowed when the internal repetitive peak voltages are higher than the **mains** peak voltages, or if the **required withstand voltage** is above the **mains** transient voltage values.

No values for PD 4 (pollution generates persistent conductivity) are included, as it is unlikely that such conditions are present when using products in the scope of the document.

Table 14 Minimum clearances using required withstand voltage

Rationale: IEC 62368-1 follows the rules and requirements of IEC basic safety publications, one of which is the IEC 60664 series. IEC 60664-1 specifies **clearances** for **basic insulation** and **supplementary insulation**. **Clearances** for **reinforced insulation** are not specified. Instead, 5.1.6 specifies the rules for determining the reinforced **clearances**.

The reinforced **clearances** in Table 14 have a varying slope, and include a “discontinuity”. The values of Table 14 are shown in Figure 14 in this document.

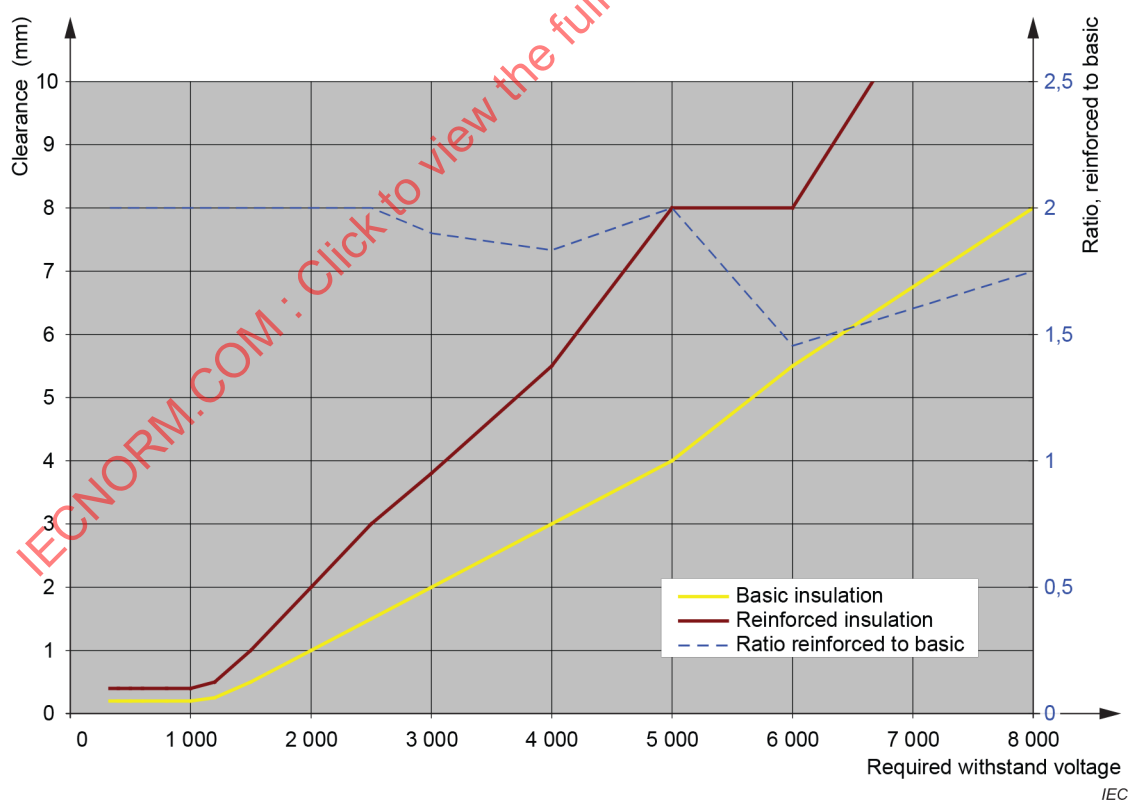


Figure 14 – Basic and reinforced insulation in Table 14 of IEC 62368-1:2018; ratio reinforced to basic

The brown line, reinforced **clearance**, is not a constant slope as is the yellow line, basic **clearance**. The ratio of reinforced to basic (blue line) varies from a maximum of 2:1 to a minimum of 1,49:1. Physically, this is not reasonable; the ratio should be nearly constant.

In IEC 60664-1:2007, the values for **basic insulation** are given in Table F.2. No values are given for **reinforced insulation**. Table F.2 refers to 5.1.6 for **reinforced insulation**.

Rule 1, preferred series impulse withstand voltages

Subclause 5.1.6 of IEC 60664-1:2007 states:

“With respect to impulse voltages, clearances of reinforced insulation shall be dimensioned as specified in Table F.2 corresponding to the rated impulse voltage but one step higher in the preferred series of values in 4.2.3 than that specified for basic insulation.”

NOTE 1 IEC 62368-1 uses the term “**required withstand voltage**” instead of the IEC 60664-1 term “required impulse withstand voltage.”

NOTE 2 IEC 62368-1 uses the term “**mains transient voltage**” instead of the IEC 60664-1 term “rated impulse voltage.”

The preferred series of values of rated impulse voltage according to 4.2.3 of IEC 60664-1:2007 is: 330 V, 500 V, 800 V, 1 500 V, 2 500 V, 4 000 V, 6 000 V, 8 000 V, 12 000 V

Applying Rule 1, the reinforced **clearance** (inhomogeneous field, **pollution degree 2**, Table F.2) for:

- 330 V would be the **basic insulation clearance** for 500 V: 0,2 mm
- 500 V would be the **basic insulation clearance** for 800 V: 0,2 mm
- 800 V would be the **basic insulation clearance** for 1 500 V: 0,5 mm
- 1 500 V would be the **basic insulation clearance** for 2 500 V: 1,5 mm
- 2 500 V would be the **basic insulation clearance** for 4 000 V: 3,0 mm
- 4 000 V would be the **basic insulation clearance** for 6 000 V: 5,5 mm
- 6 000 V would be the **basic insulation clearance** for 8 000 V: 8,0 mm
- 8 000 V would be the **basic insulation clearance** for 12 000 V: 14 mm
- 12 000 V is indeterminate because there is no preferred voltage above 12 000 volts.

Rule 2, 160 % of impulse withstand voltages other than the preferred series

With regard to non-mains circuits, subclause 5.1.6 of IEC 60664-1:2007 states:

“If the impulse withstand voltage required for basic insulation according to 4.3.3.4.2 is other than a value taken from the preferred series, reinforced insulation shall be dimensioned to withstand 160 % of the value required for basic insulation.”

The impulse withstand voltages other than the preferred series (in IEC 60664-1:2007, Table F.2) are: 400 V, 600 V, 1 200 V, 2 000 V, 3 000 V, 10 000 V, and all voltages above 12 000 V.

Applying Rule 2, the reinforced **clearance** (inhomogeneous field, **pollution degree 2**, Table F.2) for:

400 V x 1,6 = 640 V interpolated to 0,20 mm.

Since 640 V is not in the list, the **reinforced insulation** is determined by interpolation. Interpolation yields the reinforced **clearance** as 0,2 mm.

Applying Rule 2 to the impulse withstand voltages in Table F.2 that are not in the preferred series:

- $400 \text{ V} \times 1,6 = 640 \text{ V}$ interpolated to 0,20 mm
- $600 \text{ V} \times 1,6 = 960 \text{ V}$ interpolated to 0,24 mm
- $1\,200 \text{ V} \times 1,6 = 1\,920 \text{ V}$ interpolated to 0,92 mm
- $2\,000 \text{ V} \times 1,6 = 3\,200 \text{ V}$ interpolated to 2,2 mm
- $3\,000 \text{ V} \times 1,6 = 4\,800 \text{ V}$ interpolated to 3,8 mm
- $10\,000 \text{ V} \times 1,6 = 16\,000 \text{ V}$ interpolated to 19,4 mm
- $15\,000 \text{ V}$ to $100\,000 \text{ V} \times 1,6$ and interpolated according to the rule.

Clearance differences for Rules 1 and 2

The two rules, Rule 1 for impulse withstand voltages of the preferred series, and Rule 2 for impulse withstand voltages other than the preferred series, yield different **clearances** for the same voltages. These differences occur because the slope, mm/kV, of the two methods is slightly different. The slope for Rule 1 is not constant. The slope for Rule 2 is nearly constant. Figure 15 in this document illustrates the differences between Rule 1, Rule 2 and Table 14 of IEC 62368-1:2018.

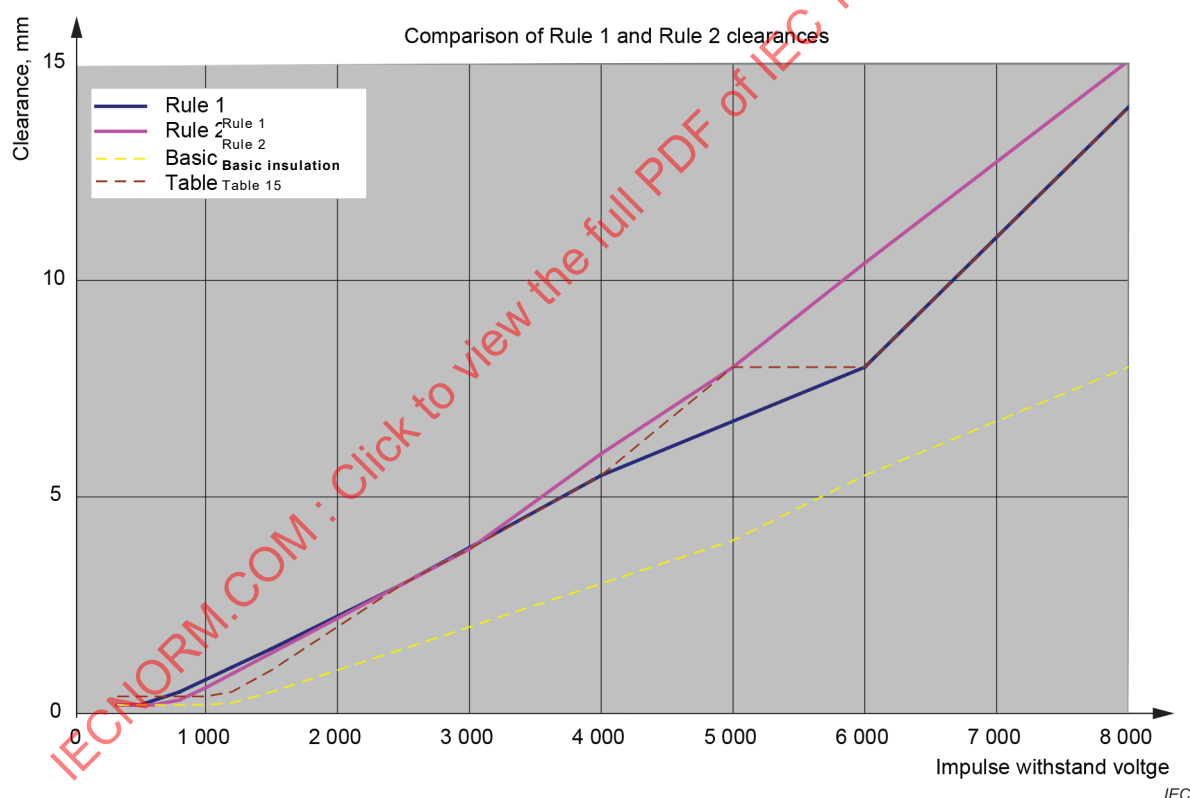


Figure 15 – Reinforced clearances according to Rule 1, Rule 2, and Table 14

If the two values for Rules 1 and 2 are combined into one set of values, the values are the same as in existing Table 14 (the brown line in Figure 14 and Figure 15 in this document). According to IEC 60664-1:2007, 5.1.6, only the impulse withstand voltages “other than a value taken from the preferred series...” are subject to the 160 % rule. Therefore, the **clearances** jump from Rule 1 criteria to Rule 2 criteria and back again. This yields the radical slope changes of the Table 14 reinforced **clearances** (brown) line.

Physically, the expected **reinforced insulation clearances** should be a constant proportion of the **basic insulation clearances**. However, the proportion between steps of Rule 1 (preferred series of impulse withstand voltages) are:

– 330 V to 500 V:	1,52
– 500 V to 800 V:	1,60
– 800 V to 1 500 V:	1,88
– 1 500 V to 2 500 V:	1,67
– 2 500 V to 4 000 V:	1,60
– 4 000 V to 6 000 V:	1,50
– 6 000 V to 8 000 V:	1,33
– 8 000 V to 12 000 V:	1,50
Average proportion, 330 to 12 000:	1,57

For Rule 2, all of the **clearances** for **reinforced insulation** are based on exactly 1,6 times the non-preferred series impulse withstand voltage for **basic insulation**.

The two rules applied in accordance with 5.1.6 of IEC 60664-1:2007 result in the variable slope of the **clearance** requirements for **reinforced insulation** of IEC 62368-1.

IEC TC 108 noted that, if the rules of IEC 60664-1 are followed, for **clearances** for **reinforced insulation**, some values were more than double the requirements for **basic insulation**. IEC TC 108 felt that this should not be the case and decided to limit the requirement for **reinforced insulation** to twice the value of **basic insulation**, thereby deviating from IEC 60664-1.

In addition, normal rounding rules were applied to the values in the table.

5.4.2.4 Determining the adequacy of a clearance using an electric strength test

Source: IEC 60664-1:2007, Table F.5

Purpose: Tests are carried out by either impulse voltage or AC voltage with the values of Table 15.

Rationale: The impulse test voltages in Table 15 are taken from IEC 60664-1:2007, Table F.5. The calculation for the AC RMS values as well as the DC values are based on the values given in Table A.1 of IEC 60664-1:2007 (see Table 7 in this document for further explanation).

This test is not suited for homogenous fields. This is for an actual design that is within the limits of the homogenous and inhomogeneous field.

Calculations for the voltage drop across an air gap during the electric strength test may be rounded up to the next higher 0,1 mm increment. In case the calculated value is higher than the value in the next row, the next row may be used.

Enamel Material: Most commonly used material is polyester resin or polyester

Dielectric constant for Polyester: 5 (can vary)

Dielectric constant for air: 1

Formula used for calculation (voltage divides inversely proportional to the dielectric constant)

Transient = 2 500 V = 2 500 (thickness of enamel / 5 + air gap / 1) = 2 500 (0,04 / 5 + 2 / 1 for 2 mm air gap) = 2 500 (0,008 + 2) = (10 V across enamel + 2 490 V across air gap)

Related to condition a of Table 15, although U is any **required withstand voltage** higher than 12,0 kV, there is an exception when using Table F.5 of IEC 60664-1:2007.

Table 7 – Voltage drop across clearance and solid insulation in series

Enamel thickness mm	Air gap mm	Transient on 240 V system	Transient voltage across air gap	Transient voltage across enamel	Peak impulse test voltage for 2 500 V peak transient from Table 16	Test voltage across air gap	Test voltage across enamel
Material: Polyester, dielectric constant = 5							
0,04	2	2 500	2 490	10	2 950	12	2 938
0,04	1	2 500	2 480	20	2 950	24	2 926
0,04	0,6	2 500	2 467	33	2 950	39	2 911
For 2 500 V peak impulse (transient for 230 V system), the homogenous field distance is 0,6 mm (from Table A.1 of IEC 60664-1:2007). Our test voltage for 2 500 V peak is 2 950 V peak from Table 15. This means that a minimum distance of 0,79 mm through homogenous field needs to be maintained to pass the 2 950 V impulse test. This gives us a margin of $(0,19/0,6) \times 100 = 3,2 \%$. In actual practice, the distance will be higher as it is not a true homogenous field. Therefore, we do not need to verify compliance with Table 14. We are always on the conservative side.							
Material: Polyamide, dielectric constant = 2,5							
0,04	2	2 500	2 480	20	2 950	23	2 927
0,04	1	2 500	2 460	40	2 950	46	2 904
0,04	0,6	2 500	2 435	65	2 950	76	2 874
For 2 500 V peak impulse (transient for 230 V system), the homogenous field distance is 0,6 mm (from Table A.1 of IEC 60664-1:2007). Our test voltage for 2 500 V peak is 2 950 V peak from Table 15. This means that a minimum distance of 0,78 mm through homogenous field needs to be maintained to pass the 2 950 V impulse test. This gives us a margin of $(0,18/0,6) \times 100 = 3,0 \%$. In actual practice, the distance will be higher, as it is not a true homogenous field. Therefore, we do not need to verify compliance with Table 14. We are always on the conservative side.							

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

Source: IEC 60664-1:2007, curve number 2 for case A using impulse test.

Purpose: Test is carried out by either impulse voltage or AC voltage with the values of Table 16 and the multiplication factors for altitudes higher than 2 000 m.

Rationale: Table 16 is developed using Figure A.1 of IEC 60664-1:2007, curve number 2 for case A using impulse test.

5.4.2.6 Compliance criteria

Source: IEC 60664-1:2007, 5.1.1

Rationale: IEC 62368-1:2018, Annex O figures are similar/identical to figures in IEC 60664-1:2007.

Tests of IEC 62368-1:2018, Annex T simulate the occurrence of mechanical forces:

- 10 N applied to components and parts that may be touched during operation or servicing. Simulates the accidental contact with a finger or part of the hand;
- 30 N applied to internal **enclosures** and barriers that are **accessible to ordinary persons**. Simulates accidental contact of part of the hand;

- 100 N applied to external **enclosures** of **transportable equipment** and handheld equipment. Simulates expected force applied during use or movement;
- 250 N applied to external **enclosures** (except those covered in T.4). Simulates expected force applied by a body part to the surface of the equipment. It is not expected that such forces will be applied to the bottom surface of heavy equipment (> 18 kg).

During the force tests metal surfaces shall not come into contact with parts at ES2 or ES3 voltage.

5.4.3 Creepage distances

Source: IEC 60664-1:2007, 3.3

Purpose: To prevent flashover along a surface or breakdown of the insulation.

Rationale: Preserve **safeguard** integrity.

In IEC 60664-1:2007, Table F.4 columns 2 and 3 for printed wiring boards are deleted, as there is no rationale for the very small **creepage distances** for printed wiring in columns 2 and 3 (the only rationale is that it is in the basic safety publication IEC 60664-1).

However, there is no rationale why the **creepage distances** are different for printed wiring boards and other isolation material under the same condition (same PD and same CTI).

Moreover the **creepage distances** for printed boards in columns 2 and 3 are in conflict with the requirements in G.13.3 (Coated printed boards). Consequently the values for voltages up to 455 V in Table G.16 were replaced.

Creepage distances between the outer insulating surface of a connector and conductive parts at ES3 voltage level shall comply with the requirements of **basic insulation** only, if the connectors are fixed to the equipment, located internal to the outer **electrical enclosure** of the equipment, and are **accessible** only after removal of a sub-assembly which is required to be in place during normal operation.

It is assumed that the occurrence of both factors, the sub-assembly being removed, and the occurrence of a transient overvoltage have a reduced likelihood and hazard potential.

5.4.3.2 Test method

Source: IEC 60664-1:2007, 3.2

Purpose: Measurement of **creepage distance**.

Rationale: To preserve **safeguard** integrity after mechanical tests.

Annex O figures are similar/identical to figures in IEC 60950-1 and IEC 60664-1.

Tests of Annex T simulate the occurrence of mechanical forces:

- 10 N applied to components and parts that are likely to be touched by a **skilled person** during servicing, where displacement of the part reduces the **creepage distance**. Simulates the accidental contact with a finger or part of the hand.
- 30 N applied to internal **enclosures** and barriers that are **accessible** to **ordinary persons**. Simulates accidental contact of part of the hand.
- 100 N applied to external **enclosures** of **transportable equipment** and **hand-held equipment**. Simulates expected force applied during use or movement.

- 250 N applied to external **enclosures** (except those covered in T.4). Simulates expected force when leaning against the equipment surface. It is not expected that such forces will be applied to the bottom surface of heavy equipment (> 18 kg).

Creepage distances are measured after performing the force tests of Annex T.

5.4.3.3 Material group and CTI

Source: IEC 60112

Rationale: Classification as given in IEC 60112.

5.4.3.4 Compliance criteria

Source: IEC 60664-1:2007, Table F.4; IEC 60664-4 for frequencies above 30 kHz

Rationale: Values in Table 17 are the same as in Table F.4 of IEC 60664-1:2007.

Values in Table 18 are the same as in Table 2 of IEC 60664-4:2005 and are used for frequencies up to 400 kHz.

5.4.4 Solid insulation

Source: IEC 60950-1, IEC 60664-1

Purpose: To prevent breakdown of the **solid insulation**.

Rationale: To preserve **safeguards** integrity.

Exclusion of solvent based enamel coatings for safety insulations are based on field experience. However, with the advent of newer insulation materials those materials may be acceptable in the future when passing the adequate tests.

Except for printed boards (see G.13), the **solid insulation** shall meet the requirements of 5.4.4.4 to 5.4.4.7 as applicable.

5.4.4.2 Minimum distance through insulation

Source: IEC 60950-1:2005

Purpose: Minimum distance through insulation of 0,4 mm for **supplementary insulation** and **reinforced insulation**.

Rationale: Some (very) old documents required for single insulations 2 mm dti (distance through insulation) for **reinforced insulation** and 1 mm for **supplementary insulation**. If this insulation served also as outer **enclosure** for **Class II equipment**, it had to be mechanically robust, which was tested with a hammer blow of 0,5 Nm.

The wire documents did not distinguish between grades of insulation, and required 0,4 mm for PVC insulation material. This value was considered adequate to protect against electric shock when touching the insulation if it was broken. This concept was also introduced in VDE 0860 (which evolved into IEC 60065), where the 0,4 mm value was discussed first. For IT products this value was first only accepted for in **accessible** insulations.

The VDE document for telecom equipment (VDE 0804) did not include any thickness requirements, but the insulation had to be adequate for the application.

The document VDE 0730 for household equipment with electric motors introduced in 1976 the requirement of an insulation thickness of 0,5 mm between input and output windings of a transformer. This was introduced by former colleagues from IBM and Siemens (against the position of the people from the transformer committee).

Also VDE 0110 (Insulation Coordination, which evolved into the IEC 60664 series) contained a minimum insulation thickness of 0,5 mm for 250 V supply voltage, to cover the effect of insulation breakage.

These 0,5 mm then evolved into 0,4 mm (in IEC 60950-1), with the reference to VDE 0860 (IEC 60065), where this value was already in use.

It is interesting to note that the 0,31 mm which is derived from Table 2A of IEC 60950-1, has also a relation to the 0,4 mm. 0,31 mm is the minimum value of the average insulation thickness of 0,4 mm, according to experts from the wire manufacturers.

5.4.4.3 Insulating compound forming solid insulation

- Source: IEC 60950-1
- Purpose: Minimum distance through insulation of 0,4 mm for **supplementary insulation** and **reinforced insulation**.
- Rationale: The same distance through insulation requirements as for **solid insulation** apply (see 5.4.4.2). Insulation is subjected to thermal cycling (see 5.4.1.5.3), humidity test (see 5.4.8) and electric strength test (see 5.4.9). Insulation is inspected for cracks and voids.

5.4.4.4 Solid insulation in semiconductor devices

- Source: IEC 60950-1, UL 1577
- Purpose: No minimum thickness requirements for the **solid insulation**.
- Rationale: – **type testing** of 5.4.9.1 (electric strength testing at 160 % of the normal value after thermal cycling and humidity conditioning), and routine electric strength test of 5.4.9.2 has been used for many years, especially in North America.
- refers to G.12, which references IEC 60747-5-5.

5.4.4.5 Insulating compound forming cemented joints

- Source: IEC 60950-1
- Rationale: a) The distances along the path comply with PD 2 requirements irrespective of the joint;
- b) applies if protected to generate PD 1 environment;
- c) applies if treated like **solid insulation** environment, no **clearances** and **creepage distances** apply;
- d) is not applied to printed boards, when the board temperature is below 90 °C, as the risk for board delaminating at lower temperatures is considered low.
- Optocouplers are excluded from the requirements of this subclause, because the document requires optocouplers to comply with IEC 60747-5-5, which sufficiently covers cemented joints.

5.4.4.6.1 General requirements

Source: IEC 60950-1, IEC 61558-1:2005

Rationale: No dimensional or constructional requirements for insulation in thin sheet material used as **basic insulation**, is aligned to the requirements of IEC 61558-1.

Two or more layers with no minimum thickness are required for **supplementary insulation** or **reinforced insulation**, provided they are protected against external mechanical influences.

Each layer is qualified for the full voltage for **supplementary insulation** or **reinforced insulation**.

The requirements are based on extensive tests performed on thin sheet material by manufacturers and test houses involved in IEC TC 74 (now IEC TC 108) work.

5.4.4.6.2 Separable thin sheet material

Source: IEC 60950-1

Rationale: For two layers, test each layer with the electric strength test of 5.4.9 for the applicable insulation grade. For three layers, test all combinations of two layers together with the electric strength test of 5.4.9 for the applicable insulation grade.

Each layer is qualified for the full voltage for **supplementary insulation** or **reinforced insulation**.

The requirements are based on extensive tests performed on thin sheet material by manufacturers and test houses involved in IEC TC 74 (now IEC TC 108) work.

5.4.4.6.3 Non-separable thin sheet material

Source: IEC 60950-1

Rationale: For testing non-separable layers, all the layers are to have the same material and thickness. If not, samples of different materials are tested as given in 5.4.4.6.2 for separable layers. When testing non-separable layers, the principle used is the same as for separable layers.

When testing two separable layers, each layer is tested for the required test voltage. Two layers get tested for two times the required test voltage as each layer is tested for the required test voltage. When testing two non-separable layers, the total test voltage remains the same, for example, two times the required test voltage. Therefore, two non-separable layers are tested at 200 % of the required test voltage.

When testing three separable layers, every combination of two layers is tested for the required test voltage. Therefore, a single layer gets tested for half the required test voltage and three layers are tested for 150 % of the required test voltage.

5.4.4.6.4 Standard test procedure for non-separable thin sheet material

Source: IEC 60950-1

Rationale: Test voltage 200 % of U_{test} if two layers are used.

Test voltage 150 % of U_{test} if three or more layers are used.

See the rationale in 5.4.4.6.3. The procedure can be applied to both separable and non-separable layers as long as the material and material thickness is same for all the layers.

5.4.4.6.5 Mandrel test

- Source: IEC 61558-1:2005, 26.3.3; IEC 60950-1:2013; IEC 60065:2011
- Purpose: This test should detect a break of the inner layer of non-separated foils.
- Rationale: This test procedure is taken from IEC 61558-1, 26.3.3, and the test voltage is 150 % U_{test} , or 5 kV RMS., whatever is greater.

5.4.4.7 Solid insulation in wound components

- Source: IEC 60950-1, IEC 61558-1
- Purpose: To identify constructional requirements of insulation of winding wires and insulation between windings.
- Rationale: Requirements have been used in IEC 60950-1 for many years and are aligned to IEC 61558-1.
- Planar transformers are not considered wound components and have to comply with G.13.

5.4.4.9 Solid insulation requirements at frequencies higher than 30 kHz

- Source: IEC 60664-4:2005
- Purpose: To identify requirements for **solid insulation** that is exposed to voltages at frequencies above 30 kHz.
- Rationale: The requirements are taken from the data presented in Annex C of IEC 60664-4:2005. Testing of **solid insulation** can be performed at line frequency as detailed in 6.2 of IEC 60664-4:2005.

In general, the breakdown electric field strength of insulation can be determined according to IEC 60243-1 (Electrical strength of insulating materials—Test methods—Part 1) as referred from 5.3.2.2.1 of IEC 60664-1:2007 (see below).

5.3.2.2.1 Frequency of the voltage

The electric strength is greatly influenced by the frequency of the applied voltage. Dielectric heating and the probability of thermal instability increase approximately in proportion to the frequency. The breakdown field strength of insulation having a thickness of 3 mm when measured at power frequency according to IEC 60243-1 is between 10 kV/mm and 40 kV/mm. Increasing the frequency will reduce the electric strength of most insulating materials.

NOTE The influence of frequencies greater than 30 kHz on the electric strength is described in IEC 60664-4.

Table 20 shows the electric field strength for some commonly used materials. These values are related to a frequency of 50/60 Hz.

Table 21, which is based on Figure 6 of IEC 60664-4:2005, shows the reduction factor for the value of breakdown electric field strength at higher frequencies. The electric field strength of materials drops differently at higher frequencies. The reduction of the insulation property is to be considered when replacing the calculation method by the alternative ES test at **mains** frequency, as shown after the sixth paragraph of 5.4.4.9. Table 21 is for materials of 0,75 mm in thickness or more. Table 22 is for materials of less than 0,75 mm in thickness.

The 1,2 times multiplier comes from IEC 60664-4:2005, subclause 7.5.1, where the partial discharge (PD) extinction voltage must include a safety margin of 1,2 times the highest peak periodic voltage.

5.4.5 Antenna terminal insulation

Source: IEC 60065

Purpose: To prevent breakdown of the insulation **safeguard**.

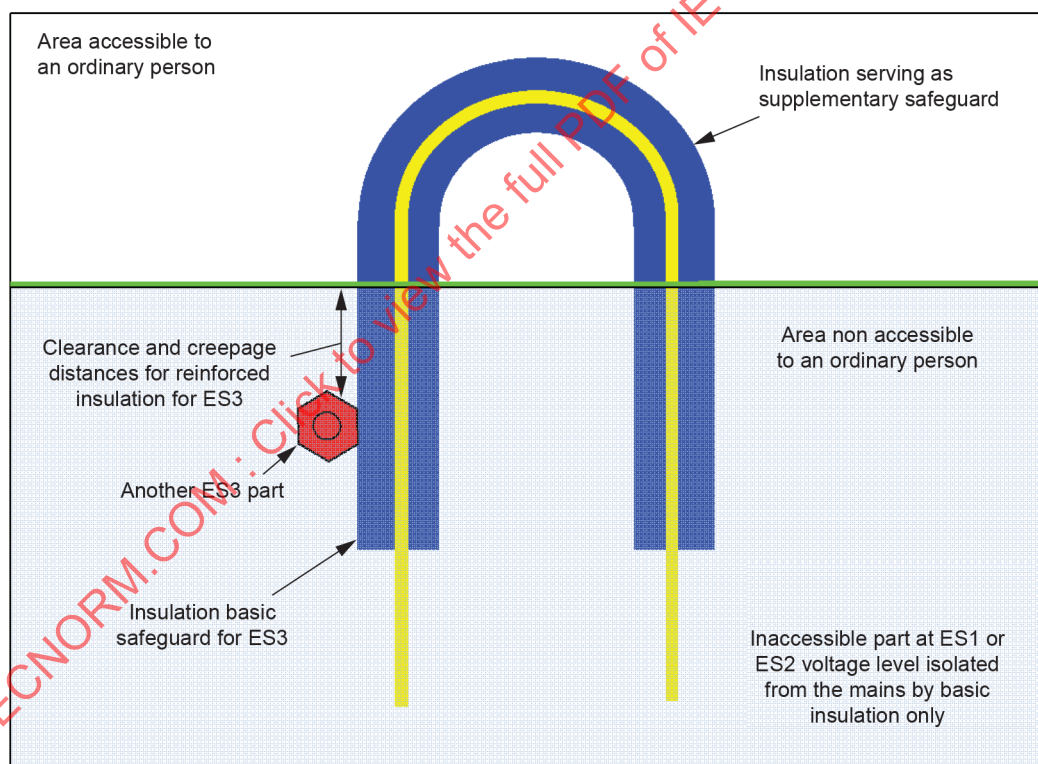
Rationale: The insulation shall be able to withstand surges due to overvoltages present at the antenna terminals. These overvoltages are caused by electrostatic charge build up, but not from lightning effects. A maximum voltage of 10 kV is assumed. The associated test of G.10.4 simulates this situation by using a 10 kV test voltage discharged over a 1 nF capacitor.

5.4.6 Insulation of internal wire as a part of a supplementary safeguard

Source: IEC 60950-1

Purpose: To specify constructional requirements of **accessible** internal wiring

Rationale: **Accessible** internal wiring isolated from ES3 by **basic insulation** only needs a **supplementary insulation**. If the wiring is reliably routed away so that it will not be subject to handling by the **ordinary person**, then smaller than 0,4 mm thick **supplementary insulation** has been accepted in IEC 60950-1. But the insulation still has to have a certain minimum thickness together with electric strength withstand capability. The given values have been successfully used in products covered by this document for many years (see Figure 16 in this document).



IEC

Figure 16 – Example illustrating accessible internal wiring

5.4.7 Tests for semiconductor components and for cemented joints

Source: IEC 60950-1

Purpose: To simulate lifetime stresses on adjoining materials.

To detect defects by applying elevated test voltages after sample conditioning.

To avoid voids, gaps or cracks in the insulating material and delaminating in the case of multilayer printed boards.

Rationale: This method has been successfully used for products in the scope of this document for many years.

5.4.8 Humidity conditioning

Source: IEC 60950-1 and IEC 60065. Alternative according to IEC 60664-1:2007, 6.1.3.2

Purpose: Material preparations for dielectric strength test. Prerequisite for further testing.

A tropical climate is a location where it is expected to have high temperatures and high humidity during most of the year. The document does not indicate what levels of temperature or humidity constitute a tropical climate. National authorities define whether their country requires products to comply with tropical requirements. Only a few countries, such as Singapore and China, have indicated in the CB scheme that they require such testing.

5.4.9 Electric strength test

Source: IEC 60664-1: 2007

Purpose: To test the insulation to avoid breakdown.

Rationale: Values of test voltages are derived from Table F.5 of IEC 60664-1:2007, however the test duration is 60 s.

This method has been successfully used for products in the scope of IEC 60065 and IEC 60950-1 for many years.

The **DC voltage** test with a test voltage equal to the peak value of the AC voltage is not fully equivalent to the AC voltage test due to the different withstand characteristics of **solid insulation** for these types of voltages. However in case of a pure **DC voltage** stress, the **DC voltage** test is appropriate. To address this situation the DC test is made with both polarities.

Table 25 Test voltages for electric strength tests based on transient voltages

Source: IEC 60664-1:2007

Rationale: To deal with withstand voltages and cover transients.

The **basic insulation** and **supplementary insulations** are to withstand a test voltage that is equal to the transient peak voltage. The test voltage for the **reinforced insulation** shall be equal to the transient in the next in the preferred series. According to 5.1.6 of IEC 60664-1:2007, the use of 160 % test value for **basic insulation** as the test value for **reinforced insulation** is only applicable if other values than the preferred series are used.

Functional insulation is not addressed, as is it presumed not to provide any protection against electric shock.

Table 26 Test voltages for electric strength tests based on the peak of the working voltages and recurring peak voltages

Source: IEC 60664-1:2007

Rationale: Column B covers repetitive **working voltages** and requires higher test voltages due to the greater stress to the insulation.

Recurring peak voltages (IEC 60664-1:2007, 5.3.3.2.3) need to be considered, when they are above the **temporary overvoltage** values, or in circuits separated from the **mains**.

If the recurring peak voltages are above the **temporary overvoltage** values, these voltages have to be used, multiplied by the factor given in IEC 60664-1:2007, 5.3.3.2.3.

Table 27 Test voltages for electric strength tests based on temporary overvoltages

Source: IEC 60664-1:2007

Rationale: **Temporary overvoltages** (IEC 60664-1:2007, 5.3.3.2.2) need to be considered as they may be present up to 5 s. The test voltage for **reinforced insulation** is twice the value of **basic insulation**.

5.4.10 Safeguards against transient voltages from external circuits

Source: IEC 62151:2000, Clause 6

Purpose: To protect persons against contact with **external circuits** subjected to transients (for example, telecommunication networks).

Rationale: **External circuits** are intended to connect the equipment to other equipment. Connections to remote equipment are made via communication networks, which could leave the building. Examples for such communication networks are telecommunication networks and Ethernet networks. The operating voltages of communication networks are usually within the limits of ES1 (for example, Ethernet) or within the limits of ES2 (for example, telecommunication networks).

When leaving the buildings, communication networks may be subjected to transient overvoltages due to atmospheric discharges and faults in power distribution systems. These transients are depending on the infrastructure of the cables and are independent on the operating voltage of the communication network. The expected transients on telecommunication networks are specified in ITU-T recommendations. The transient value in Table 13 ID 1 is taken from ITU-T K.21 as 1,5 kV 10/700 µs (terminal equipment). This transient of 1,5 kV 10/700 µs does not cause a hazardous electric shock, but it is very uncomfortable to persons effecting by such a transient. To avoid secondary hazards a separation between an **external circuit** connected to communication networks subjected transients is required.

Because the transient does not cause a hazardous electric shock the separation element needs not to be a **reinforced safeguard** nor a **basic safeguard** in the meaning of IEC 62368-1. It is sufficient to provide a separation complying with an electric strength test, only. Therefore for this separation no **clearance**, no **creepage distances** and no thickness requirements for **solid insulation** are required.

The separation is required between the **external circuit** subjected to transients and all parts, which may **accessible to ordinary persons** or **instructed persons**.

The likelihood a transient occurs and a body contact with an **accessible** part occurs at the same time increases with the contact time. Therefore non-conductive parts and unearthed parts of the equipment maintained in continuous contact with the body during normal use (for example, a telephone handset, head set, palm rest surfaces) the separation should withstand a higher test voltage.

Two test procedures for the electric strength test are specified in 5.4.10.2.

5.4.10.2.2 Impulse test

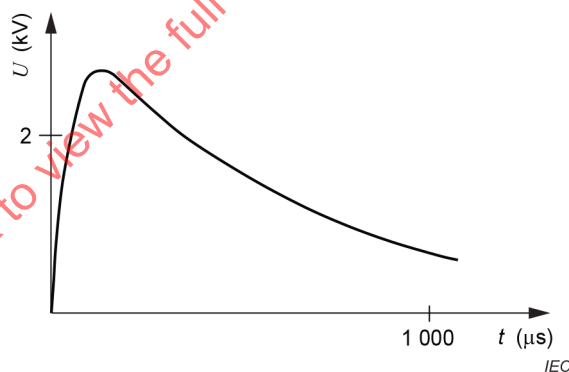
The impulse test is performing an impulse test by using the impulse generator for the 10/700 μs impulse (see test generator D.1 of Annex D). With the recorded waveforms it could be judged whether a breakdown of insulation has occurred, or if the surge suppression device has worked properly.

The examples in Figure 17, Figure 18,

- 1 – gas discharge type
- 2 – semiconductor type
- 3 – metal oxide type

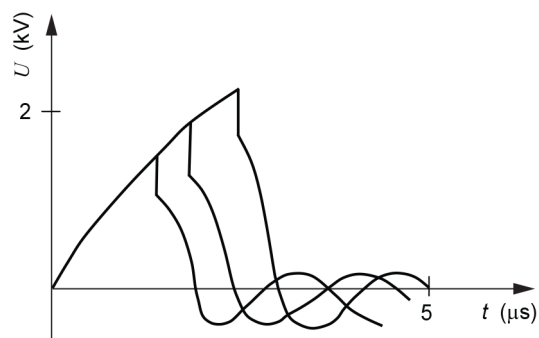
Consecutive impulses are identical in their waveforms.

Figure 19 and Figure 20 in this document could be used to assist in judging whether or not a surge suppressor has operated or insulation has broken down.



Consecutive impulses are identical in their waveforms.

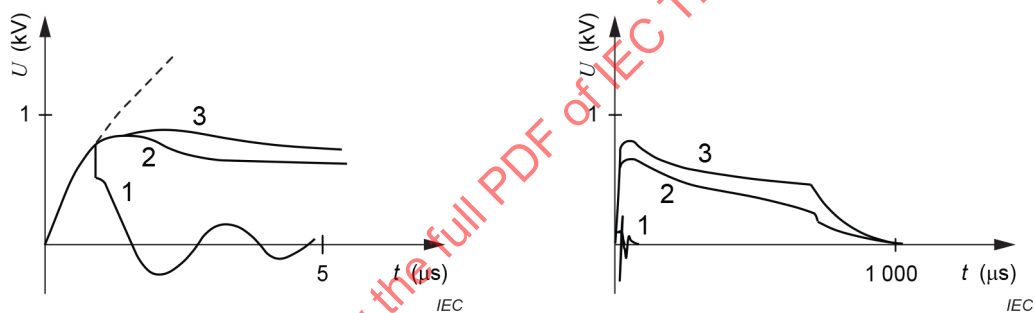
Figure 17 – Waveform on insulation without surge suppressors and no breakdown



IEC

Consecutive impulses are not identical in their waveforms. The pulse shape changes from pulse to pulse until a stable resistance path through the insulation is established. Breakdown can be seen clearly on the shape of the pulse voltage oscillogram.

Figure 18 – Waveforms on insulation during breakdown without surge suppressors



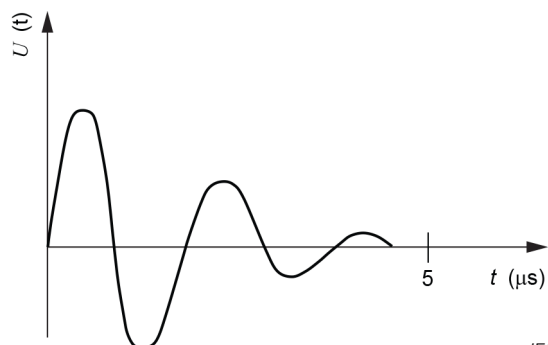
IEC

IEC

- 1 – gas discharge type
- 2 – semiconductor type
- 3 – metal oxide type

Consecutive impulses are identical in their waveforms.

Figure 19 – Waveforms on insulation with surge suppressors in operation



IEC

Figure 20 – Waveform on short-circuited surge suppressor and insulation

5.4.10.2.3 Steady-state test

The steady-state test is performing an electric strength test according to 5.4.9.1. This test is simple test with an RMS voltage. But if for example, surge suppressors are used to reduce the transients from the **external circuits** within the equipment this RMS test may be not adequate. In this case an impulse test is more applicable.

5.4.11 Separation between external circuits and earth

Source: IEC 62151:2000, 5.3

Purpose: To protect persons working on communication networks, and users of other equipment connected to the network from hazards in the equipment.

Rationale: Class I equipment provides **basic insulation** between **mains** and earthed conductive parts and requires the conductive parts to be connected to a PE conductor that has to be connected to the earthing terminal in the buildings installation to be safe to use. In an isolated environment such an earth terminal is not present in the building installation. Nevertheless the use of **class I equipment** in such an isolated environment is still safe to use, because in case of a breakdown of the insulation in the equipment (fault of **basic insulation**) the second barrier is provided by the isolated environment (similar to a **supplementary insulation**).

With the connection of the equipment via an **external circuit** to a communication network from outside the building installation to a remote environment the situation will change. It is unknown whether the remote environment is an isolated or non-isolated environment. During and after a fault of the **basic insulation** in a **class I equipment** (from **mains** to conductive parts) installed in an isolated installation (non-earthed installation) the conductive parts will become live (**mains** potential). If now the conductive parts are not separated from the **external circuit**, the **mains** voltage will be transferred to the remote installation via the communication network. This is a hazardous situation in the remote environment and can be dangerous for persons in that remote environment.

Also in old building installations socket outlets exist with no earth contact. This situation will not be changed in the near future.

To provide protection for those situations, a separation between an **external circuit** intended to be connected to communication networks outside the building (for example, telecommunication networks) and a separation between the **external circuit** and earthed parts is required.

For this separation, it is sufficient to comply with the requirements of 5.4.11.2 tested in accordance with 5.4.11.3. For this separation, no **clearance**, no **creepage distances** and no thickness requirements for **solid insulation** is required.

5.5 Components as safeguards

Rationale: For failure of a **safeguard** and a component or device that is not a **safeguard**:

Safeguard failure: A failure is considered to be a **safeguard** failure if the part itself or its function, during **normal operating conditions**, contributes to change an ES class to a lower ES class. In this case, the part is assessed for its reliability by applying the applicable **safeguard** component requirements in 5.5 and the associated requirements in Annex G. When establishing ES1, ES2 limits apply during **single fault condition** of these parts. In case no requirements for the component are provided in 5.5 or Annex G, the failure is regarded as a non-**safeguard** failure.

Non-safeguard failure: A failure is considered to be a non-safeguard failure if the part itself or its function, under **normal operating conditions**, does not contribute to change an ES class to a lower ES Class. In this case, there is no need to assess the reliability of the part. When establishing ES1, ES1 limits apply for the **single fault condition** of these parts. Where applicable, 5.3.1 applies. Figure 21 and Figure 22 in this document give practical examples of the requirements when ordinary components bridge insulation.

Example 1

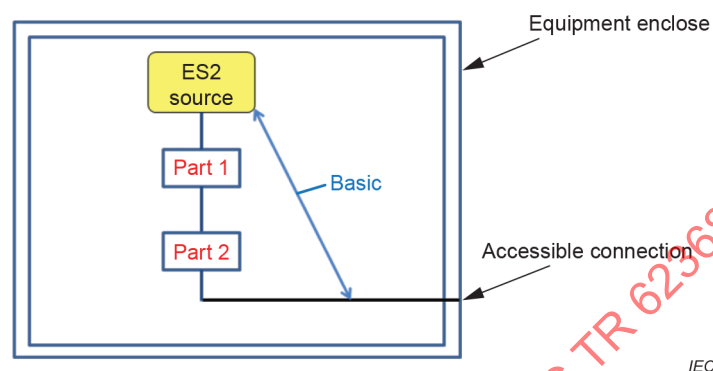


Figure 21 – Example for an ES2 source

A single fault of any component or part may not result in the **accessible** part exceeding ES1 levels, unless the part complies with the requirements for a **basic safeguard**.

The **basic safeguard** in parallel with the part(s) is to comply with:

- the **creepage distance** requirements; and
- the **clearance** requirements

for **basic insulation**.

There are no other requirements for the components or parts if the **accessible** part remains at ES1.

Example 2

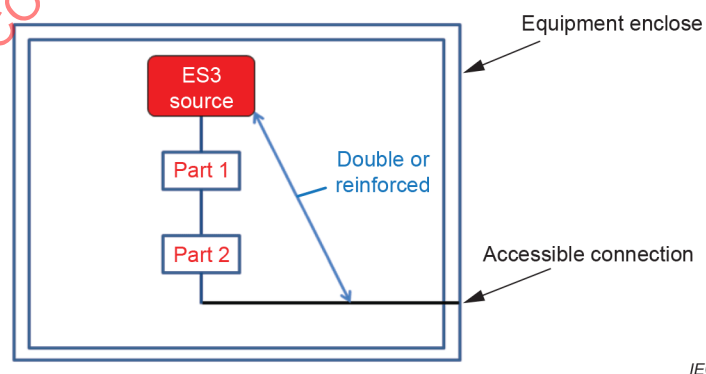


Figure 22 – Example for an ES3 source

A single fault of any component or part may not result in the **accessible** part exceeding ES1 levels, unless the parts comply with the requirements for a double or **reinforced safeguard**.

The double or reinforced safeguard in parallel with the part(s) is to comply with:

- the **creepage distance** requirements; and
- the **clearance** requirements,

for **double insulation** or **reinforced insulation**.

There are no other requirements for the components or parts if the **accessible** part remains at ES1.

5.5.2.1 General requirements

- Source: Relevant IEC component documents
- Purpose: The insulation of components has to be in compliance with the relevant insulation requirements of 5.4.1, or with the safety requirements of the relevant IEC document.
- Rationale: Safety requirements of a relevant document are accepted if they are adequate for their application, for example, Y2 capacitors of IEC 60384-14.

5.5.2.2 Capacitor discharge after disconnection of a connector

- Source: IEC TS 61201:2007, Annex A
- Rationale: The 2 s delay time represents the typical access time after disconnecting a connector. When determining the **accessible** voltage 2 s after disconnecting a connector, the tolerance of the X capacitor is not considered.

If a capacitor is discharged by a resistor (for example, a bleeder resistor), the correct value of the resistor can be calculated using the following formula:

$$R = (2 / C) \times [1 / \ln(E / E_{\max})] \text{ M}\Omega$$

where:

C is in microfarads

E is 60 for an **ordinary person** or 120 for an **instructed person**

$E_{\max}$ is the maximum charge voltage or **mains** peak voltage

$\ln$ is the natural logarithm function

NOTE 1 When the **mains** is disconnected, the capacitance is comprised of both the X capacitors and the Y capacitors, and other possible capacitances. The circuit is analyzed to determine the total capacitance between the poles of the connector or plug.

NOTE 2 If the equipment **rated mains voltage** is 125 V, the maximum value of the discharge resistor is given by:

$$R = 1,85 / C \text{ M}\Omega$$

NOTE 3 If the equipment **rated mains voltage** is 250 V, the maximum value of the discharge resistor is given by:

$$R = 1,13 / C \text{ M}\Omega$$

NOTE 4 The absolute value of the above calculations is used for the discharge resistor value.

The test method includes a maximum time error of about 9% less than the calculated time for a capacitive discharge. This error was deemed acceptable for the sake of consistency with past practice.

For measuring the worst case, care should be taken that the discharge is measured while at the peak of the input voltage. To ensure this, an automatic control system that switches off at the peak voltage can be used.

A method used by several other documents, such as IEC 60065 and IEC 60335-1 is to repeat the measurement 10 times and record the maximum value. This assumes that one of the 10 measurements will be sufficiently close to the peak value.

Another possibility might be to use an oscilloscope during the measurement, so one can see if the measurement was done near the maximum.

Single fault conditions need not be considered if the component complies with the relevant component requirements of the document. For example, a resistor connected in parallel with a capacitor where a capacitor voltage becomes **accessible** upon disconnection of a connector, need not be faulted if the resistor complies with 5.5.6.

5.5.6 Resistors

Source: IEC 60950-1 and IEC 60065

Rationale: When a group of resistors is used, the resistors are in series. The whole path consists of the metal lead and helical end (metal) and resistor body. The **clearance** and **creepage distance** is across the resistor body only. The total path then consists of conductive metal paths and resistor bodies (all in series). In this case, Figure O.4 becomes relevant when you want to determine the total **clearance** and **creepage distance**.

5.5.7 SPDs

Rationale: See Attachment A for background information on the use of SPD's.

It should be noted that the issue is still under discussion in IEC TC 108. The rationale will be adapted as soon as the discussion is finalized.

5.5.8 Insulation between the mains and an external circuit consisting of a coaxial cable

Source: IEC 60065:2014, 10.2 and IEC 60950-1:2005, 1.5.6.

Rationale: The additional conditioning of G.10.2 comes from IEC 60950-1:2005, 1.5.6 Capacitors bridging insulation

5.6 Protective conductor

See Figure 23 in this document for an overview of **protective earthing** and protective bonding conductors.

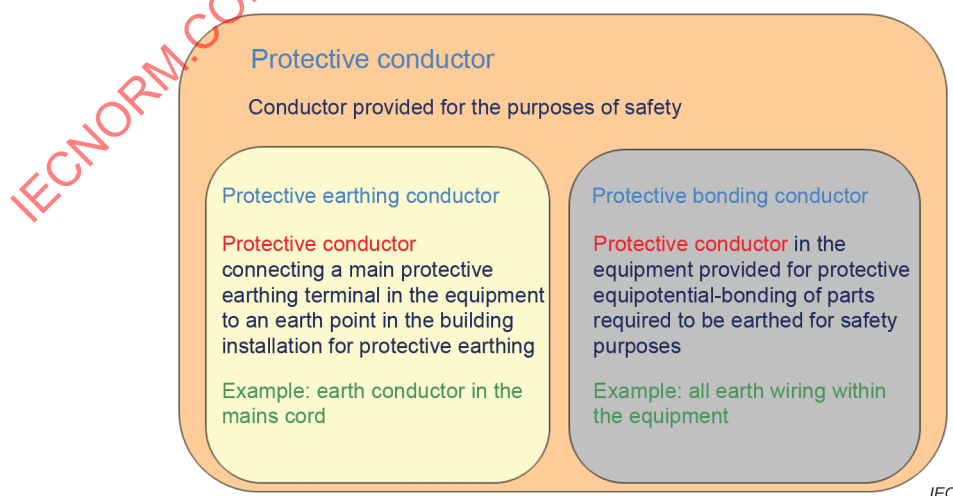


Figure 23 – Overview of protective conductors

5.6.1 General

- Source: IEC 60364-5-54, IEC 61140, IEC 60950-1
- Purpose: The **protective earthing** should have no excessive resistance, sufficient current-carrying capacity and not be interrupted in all circumstances.

5.6.2.2 Colour of insulation

- Source: IEC 60446¹
- Purpose: For clear identification of the earth connection.

An earthing braid is a conductive material, usually copper, made up of three or more interlaced strands, typically in a diagonally overlapping pattern.

It should be noted that IEC 60227-1:2007 has specific requirements for the use of the colour combination as follows:

4.1.3 Colour combination green-and-yellow

The distribution of the colours for the core coloured green-and-yellow shall comply with the following condition (which is in accordance with IEC 60173): for every 15 mm length of core, one of these colours shall cover at least 30 % and not more than 70 % of the surface of the core, the other colour covering the remainder.

NOTE Information on the use of the colours green-and-yellow and blue.

It is understood that the colours green and yellow, when they are combined as specified above, are recognized exclusively as a means of identification of the core intended for use as earth connection or similar protection, and that the colour blue is intended for the identification of the core intended to be connected to neutral. If, however, there is no neutral, blue can be used to identify any core except the earthing or protective conductor.

5.6.3 Requirements for protective earthing conductors

- Source: IEC 60950-1
- Purpose: The reinforced **protective conductor** has to be robust enough so that the interruption of the **protective conductor** is prevented in any case (interruption is not to be assumed).
- Rationale: These requirements have been successfully used for products in the scope of this document for many years.

Where a conduit is used, if a cord or conductor exits the conduit and is not protected, then the values of Table 30 cannot be used for the conductor that exits the conduit.

For **pluggable equipment type B** and **permanently connected equipment**, an earthing connection is always expected to be present. The earthing conductor can therefore be considered as a **reinforced safeguard**.

5.6.4 Requirements for protective bonding conductors

- Source: IEC 60950-1
- Purpose: To demonstrate the fault current capability and the capability of the termination.
- Rationale: These requirements and tests have been successfully used for products in the scope of this document for many years (see Figure 3 in this document).

¹ This publication was withdrawn.

5.6.5 Terminals for protective conductors

5.6.5.1 Requirements

- Source: IEC 60998-1, IEC 60999-1, IEC 60999-2, IEC 60950-1
- Purpose: To demonstrate the fault current capability and the capability of the termination.
- Rationale: Conductor terminations according to Table 32 have served as reliable connection means for products complying with IEC 60950-1 for many years.
- The value of 25 A is chosen to cover the minimum protective current rating in all countries of the world.

5.6.6.2 Test method

- Source: IEC 60950-1
- Rationale: This method has been successfully used for products in the scope of this document for many years.

5.6.7 Reliable connection of a protective earthing conductor

- Source: IEC 60309 (plugs and socket outlets for industrial purpose)
- Purpose: To describe reliable earthing as provided by **permanently connected equipment**, **pluggable equipment type B**, and **pluggable equipment type A**.
- Rationale: **Permanently connected equipment** is considered to provide a reliable earth connection because it is wired by an electrician.
- Pluggable equipment type B** is considered to provide a reliable earth connection because IEC 60309 type plugs are more reliable and earth is always present as it is wired by an electrician.
- For **stationary pluggable equipment type A** where a **skilled person** verifies the proper connection of the earth conductor.

5.7 Prospective touch voltage, touch current and protective conductor current

- Source: IEC 60990

5.7.3 Equipment set-up, supply connections and earth connections

- Rationale: Equipment that is designed for multiple connections to the **mains**, where more than one connection is required, shall be subjected to either of the tests below:
- have each connection tested individually while the other connections are disconnected,
 - have each connection tested while the other connections are connected, with the **protective earthing conductors** connected together.

For simultaneous multiple connections, the requirement in the document is that each connection shall be 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.

This means that if the total **touch current** with all connections tested together does not exceed the limit, the equipment complies with the requirement, if not, and each of the individual conductor touch currents don't exceed the limit, the equipment also complies with the requirement.

5.7.5 Earthed accessible conductive parts

Rationale: Figure 24 in this document is an example of a typical test configuration for **touch current** from single phase equipment on star TN or TT systems. Other distribution systems can be found in IEC 60990.

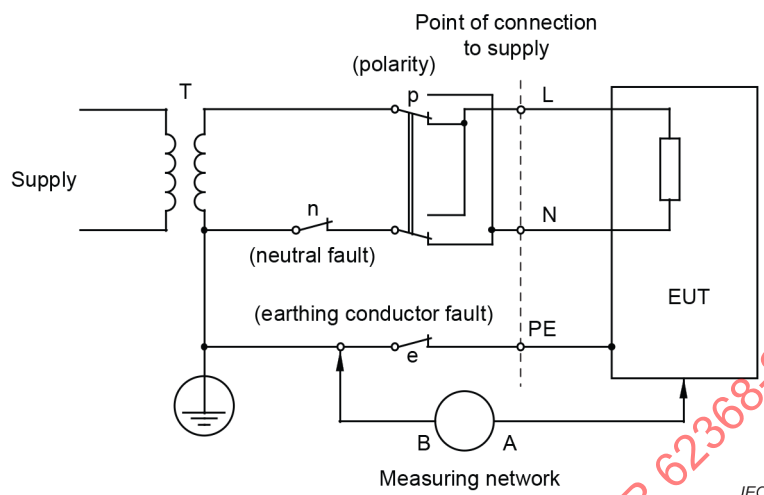


Figure 24 – Example of a typical touch current measuring network

5.7.6 Requirements when touch current exceeds ES2 limits

Source: IEC 61140:2001, IEC 60950-1

Rationale: The 5 % value has been used in IEC 60950-1 for a long time and is considered acceptable. The 5 % value is also the maximum allowed **protective conductor** current (7.5.2.2 of IEC 61140:2001).

In the case that the **protective conductor current** exceeds 10 mA, IEC 61140 requires a reinforced **protective earthing conductor** with a conductor size of 10 mm² copper or 16 mm² aluminium or a second terminal for a second **protective earthing conductor**. This paragraph of IEC 62368-1 takes that into account by requiring a reinforced or double **protective earthing conductor** as per 5.6.3.

IEC 61140:2001, 7.5.2.2 requires information about the value of the **protective conductor current** to be in the documentation and in the instruction manual, to facilitate the determination that the equipment with the high **protective conductor current** is compatible with the residual current device which may be in the building installation.

The manufacturer shall indicate the value of the **protective conductor current** in the installation instructions if the current exceeds 10 mA, this to be in line with the requirements of IEC 61140:2001, 7.6.3.5.

5.7.7 Prospective touch voltage and touch current associated with external circuits

5.7.7.1 Touch current from coaxial cables

Source: IEC 60728-11

Purpose: To avoid having an unearthed screen of a coaxial network within a building.

Rationale: An earthed screen of a coaxial network is reducing the risk to get an electric shock.

Coaxial external interfaces very often are connected to antennas to receive TV and sound signals. Antennas installed outside the buildings are exposed to external atmospheric discharges (for example, indirect lightning). To protect the antenna system and the equipment connected to such antennas, a path to earth needs to be provided via the screen of the coaxial network.

Each piece of **mains**-powered equipment delivers **touch current** to a coaxial **external circuit** via the stray capacitance and the capacitor (if provided) between **mains** and coaxial interface. This **touch current** is limited by the requirement for each individual equipment to comply with the **touch current** requirements (safe value) to be measured according IEC 60990. Within a building, much individual equipment (for example, TV's receivers) may be connected to a coaxial network (for example, cable distribution system). In this case, the **touch current** from each individual equipment sums up in the shield of the coaxial cable. With an earthed shield of a coaxial cable, the **touch current** has a path back to the source and the shield of the coaxial cable remains safe to touch.

5.7.7.2 Prospective touch voltage and touch current associated with paired conductor cables

Source: IEC 62151

Purpose: To avoid excessive **prospective touch voltage** and excessive currents from equipment into communication networks (for example, telecommunication networks).

Rationale: All **touch current** measurements according to IEC 60990 measure the current from the **mains** to **accessible** parts. ES1 circuits are permitted to be **accessible** by an **ordinary person** and therefore it is included in the measurement according to IEC 60990. Circuits of class ES2 are not **accessible** and therefore these classes of circuits are not covered in the measurements according to IEC 60990.

Because ES2 circuits may be **accessible** to **instructed persons** and may become **accessible** during a single fault to an **ordinary person**, the **touch current** to **external circuit** has to be limited, to protect people working on networks or on other equipment, which are connected to the **external circuit** via a network.

An example for an external interface ID 1 of Table 13 is the connection to a telecommunication network. It is common for service personal of telecommunication networks and telecommunication equipment to make servicing under live conditions. Therefore, the telecommunication networks are operating with a voltage not exceeding energy class ES2.

The rationale to limit the **touch current** value to 0,25 mA (lower than ES2) has a practical background. Telecommunication equipment very often have more than one **external circuit** ID 1 of Table 13 (for example, connection to a telecommunication network). In such configurations a summation of the **touch current** may occur (see 5.7.7). With the limitation to 0,25 mA per each individual **external circuit** up to 20 **external circuits** could be connected together without any additional requirement. In 5.7.7 this value of 0,25 mA is assumed to be the **touch current** from a network to the equipment.

5.7.8 Summation of touch currents from external circuits

Source: IEC 60950-1

Purpose: To avoid excessive **touch currents** when several **external circuits** are connected.

Rationale: When limiting the **touch current** value to each individual **external circuit** (as required in 5.7.6.2), more circuits can be connected together before reaching the **touch current** limit. This allows better utilization of resources.

Detailed information about **touch currents** from **external circuits** is given in Annex W of IEC 60950-1:2005.

a) Touch current from external circuits

There are two quite different mechanisms that determine the current through a human body that touches an **external circuit**, depending on whether or not the circuit is earthed. This distinction between earthed and unearthed (floating) circuits is not the same as between class I equipment and class II equipment. Floating circuits can exist in **class I equipment** and earthed circuits in class II equipment. Floating circuits are commonly, but not exclusively, used in telecommunication equipment and earthed circuits in data processing equipment, also not exclusively.

In order to consider the worst case, it will be assumed in this annex that telecommunication networks are floating and that the AC **mains** supply and human bodies (**skilled persons, instructed persons or ordinary persons**) are earthed. It should be noted that a **skilled person** and an **instructed person** can touch some parts that are not **accessible** by an **ordinary person**. An "earthed" circuit means that the circuit is either directly earthed or in some way referenced to earth so that its potential with respect to earth is fixed.

a.1) Floating circuits

If the circuit is not earthed, the current (I_c) through the human body is "leakage" through stray or added capacitance (C) across the insulation in the **mains** transformer (see Figure 25 in this document).

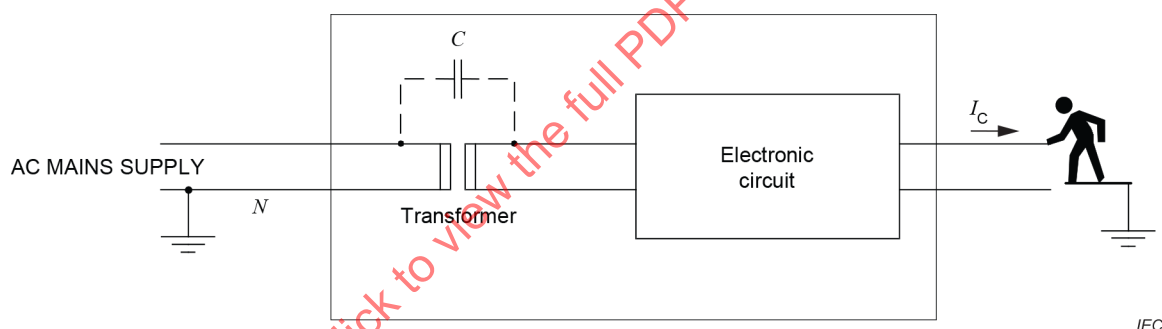


Figure 25 – Touch current from a floating circuit

This current comes from a relatively high voltage, high impedance source, and its value is largely unaffected by the operating voltage on the **external circuit**. In this document, the body current (I_c) is limited by applying a test using the measuring instrument in Annex D of IEC 60950-1:2005, which roughly simulates a human body.

a.2) Earthed circuits

If the **external circuit** is earthed, the current through the human body (I_v) is due to the operating voltage (V) of the circuit, which is a source of low impedance compared with the body (see Figure 26 in this document). Any leakage current from the **mains** transformer (see a.1), will be conducted to earth and will not pass through the body.

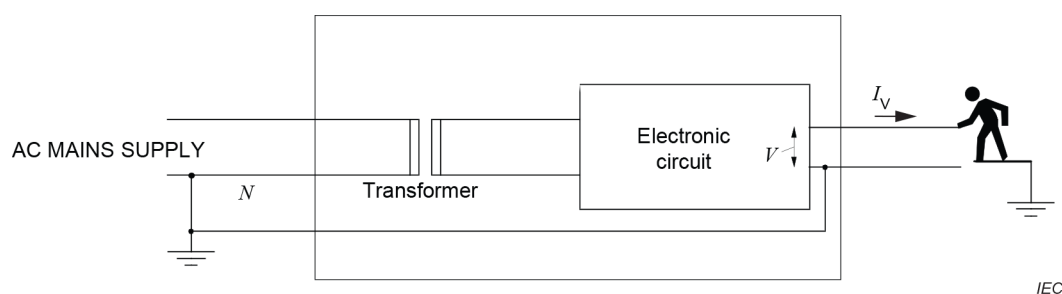


Figure 26 – Touch current from an earthed circuit

In this document, the body current (I_V) is limited by specifying maximum voltage values for the **accessible** circuit, which shall be an ES1 circuit or (with restricted **accessibility**) an ES2 circuit.

b) Interconnection of several equipments

It is a characteristic of information technology equipment, in particular in telecommunication applications, that many equipments may be connected to a single central equipment in a "star" topology. An example is telephone extensions or data terminals connected to a PABX, which may have tens or hundreds of ports. This example is used in the following description (see Figure 27 in this document).

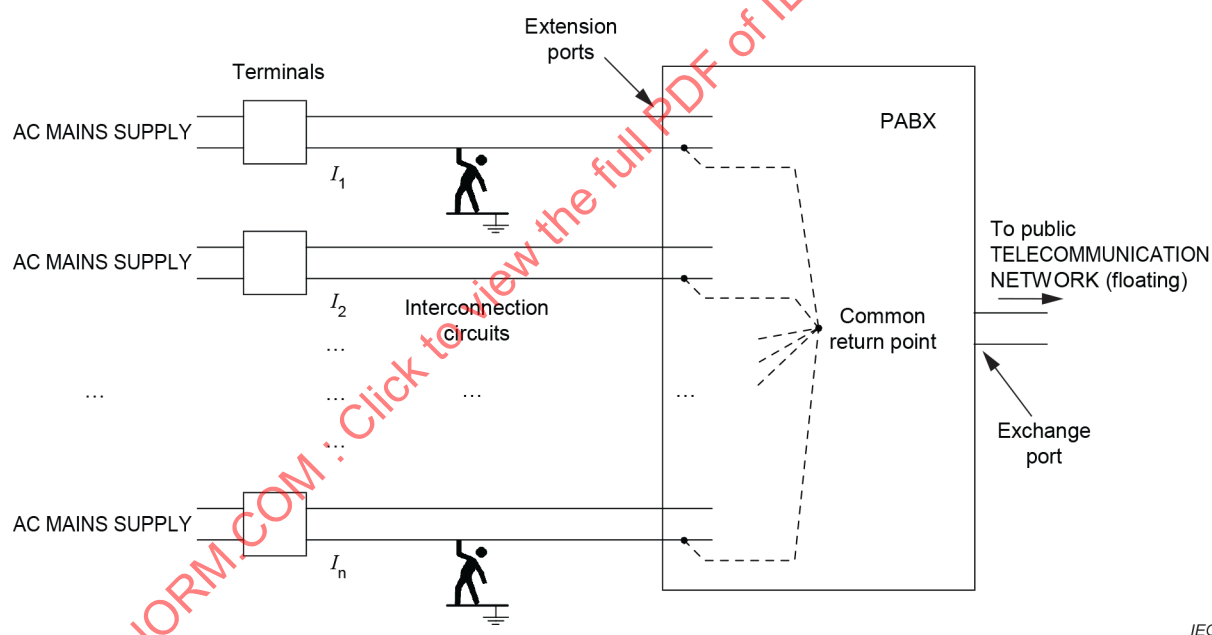


Figure 27 – Summation of touch currents in a PABX

Each terminal equipment can deliver current to a human body touching the interconnecting circuit (I_1 , I_2 , etc.), added to any current coming from the PABX port circuitry. If several circuits are connected to a common point, their individual **touch currents** will add together, and this represents a possible risk to an earthed human body that touches the interconnection circuit.

Various ways of avoiding this risk are considered in the following subclauses.

b.1) Isolation

Isolate all interconnection circuits from each other and from earth, and limit I_1 , I_2 , etc., as described in a.1. This implies either the use in the PABX of a separate power supply for each port, or the provision of an individual line (signal) transformer for each port. Such solutions may not be cost effective.

b.2) Common return, isolated from earth

Connect all interconnection circuits to a common return point that is isolated from earth. (Such connections to a common point may in any case be necessary for functional reasons.) In this case the total current from all interconnection circuits will pass through an earthed human body that touches either wire of any interconnection circuit. This current can only be limited by controlling the values I_1 , I_2 , .. I_n . In relation to the number of ports on the PABX. However, the value of the total current will probably be less than $I_1 + I_2 + \dots + I_n$ due to harmonic and other effects.

b.3) Common return, connected to protective earth

Connect all interconnection circuits to a common return point and connect that point to **protective earthing**. The situation described in a.2) applies regardless of the number of ports. Since safety depends on the presence of the earth connection, it may be necessary to use high-integrity earthing arrangements, depending on the maximum value of the total current that could flow.

5.8 Backfeed safeguard in battery backed up supplies

Source: IEC 62040-1:2017, IEC 62368-1, UL 1778 5th edition

Purpose: To establish requirements for certain **battery** backed up power supply systems that are an integral part of the equipment and that have the capability to backfeed to the **mains** of the equipment during stored energy mode. Examples include CATV network distribution supplies and any other integral supply commonly evaluated under this document with a **battery** backed option.

Rationale: Principles of **backfeed** protection

Battery backed up supplies store and generate hazardous energy. These energies may be present at the input terminals of the unit.

A **backfeed safeguard** is intended to prevent **ordinary persons**, **instructed persons** or **skilled persons** from unforeseeable or unnecessary exposure to such hazards.

A mechanical **backfeed safeguard** should meet a minimum air gap requirement. If not, the mechanical device (contacts) may be forced closed, and this will not be counted as a fault. The **backfeed safeguard** operates with any and all semiconductor devices in any single phase of the **mains** power path failed.

A **backfeed safeguard** works under any **normal operating condition**. This should include any output load or input source condition deemed normal by the manufacturer; however, it is common practice to only test at full- and no-load conditions, unless analysis of the circuitry proves other conditions would be less favourable. The circuitry that controls the **backfeed safeguard** is intended to be single-fault tolerant.

A **backfeed safeguard** can accomplish this by disconnecting the **mains** supply wiring from the internal energy source, by disabling the inverter and removing the hazardous source(s) of energy, reducing the source to a safe level, or by placing a suitable **safeguard** between the **ordinary person**, **instructed person** or **skilled person** and the hazardous energy. ES1 is defined in the body of this document. The method of measurement is as follows:

- For pluggable equipment, it is determined by opening all phases, neutral and ground.
- For **permanently connected** equipment, the neutral and ground are not removed during the **backfeed** tests.

Measurements are taken at the unit input connections across the phases, from phase to neutral and phase and neutral to ground, using the body impedance model as the measurement device.

Air gap requirements for mechanical disconnect:

An air gap is only required when the backfeed safeguard is mechanical in nature. The air gap is defined as the **clearance** distance. There are several elements to consider when determining the **clearance** requirement:

- Under normal operation, the space between poles of phases must meet the requirements for **basic insulation** (see 5.4.2).
- If the unit is operating on inverter, the source is considered to be a secondary supply, which is transient free (see 5.4.2).

For a unit with floating outputs, opening all phases and the neutral using the required **clearance** for **basic insulation** is considered acceptable. If the output is grounded to the chassis, **reinforced insulation** or equivalent is required.

Fault testing

All **backfeed safeguard** control circuits are subjected to failure analysis and testing.

Relays

Relays in the **mains** path that are required to open for mechanical protection should be normally open when not energized.

If the relay does not meet the required **clearances**, the shorting of either pole/contact may be considered as a single fault to simulate the welding of the contacts. The failure of a single relay contact may be sensed and the inverter disabled to prevent feedback.

A relay used for mechanical protection shall be horsepower-rated or pass a 50-cycle endurance test at 600 % of the normal switching current.

Electronic protection

Electronic protection for a **backfeed safeguard** is acceptable if the operation of the electronic protection device is sensed and the inverter is disabled if a fault is found. This is the same requirement as for a relay having less than the required air gap or **clearance** or is not relied upon entirely for mechanical protection.

Mechanical protection

Mechanical protection for a **backfeed safeguard** is acceptable if it prevents the user from accessing greater than ES1 and cannot be readily defeated without the use of **tool**. The voltage rating of the mechanical protection should be no less than the maximum out-of-phase voltage.

Control circuitry

The failure, open- or short-circuit, of any component of the **backfeed safeguard** circuitry may be analyzed to evaluate the effects on the proper operation of the **backfeed safeguard**. Testing may be done on all components where analysis of the results is arguable.

Components, such as resistors and inductors, are considered to fail open-circuit only. In general, capacitors may fail open or shorted. Solid-state devices typically fail short and then open.

Microprocessor controls are considered to be acceptable if the circuit operates safely with any single control line open or shorted to control logic ground, or shorted to Vcc where such fault is likely to occur. Failure of the microprocessor can also be simulated by opening the Vcc pin or shorting the Vcc pin to ground.

If the control circuitry is fully redundant, (for example, $N + 1$), failure analysis of individual components is not required if the failure of one circuit results in a fail-safe mode of operation.

6 Electrically-caused fire

Rationale: Electrically-caused fire is due to conversion of electrical energy to thermal energy, where the thermal energy heats a fuel material to pyrolyze the solid into a flammable gas in the presence of oxygen. The resulting mixture is heated further to its ignition temperature which is followed by combustion of that fuel material. The resulting combustion, if exothermic or with additional thermal energy converted from the electrical source, can be sustained and subsequently ignite adjacent fuel materials that result in the spread of fire.

The three-block model (see 0.7.2, Figure 6) for electrically (internally) caused fire addresses the separation of a potential ignition sources from combustible materials. In addition, it can also represent an ignited fuel and the safeguards interposed between ignited fuels and adjacent fuels or to fuels located outside the equipment.

6.2 Classification of power sources (PS) and potential ignition sources (PIS)

Rationale: The first step in the application of this clause is to determine which energy sources contain **potential ignition sources** requiring a **safeguard**. The power available to each circuit can first be evaluated to determine the energy available to a circuit. Then each point or component within a circuit can be tested to determine the power that would be available to a fault at that component. With this information each part of the component energy sources within the product can be classified as either a specific ignition source or a component within a power source.

Throughout the clause, the term “reduce the likelihood of ignition” is used in place of the terms “prevent” or “eliminate”.

6.2.2 Power source circuit classifications

Source: IEC 60950-1, IEC 60065

Rationale: These power source classifications begin with the lowest available energy necessary to initiate an electronic fire (PS1) and include an intermediate level (PS2) where ignition is possible but the spread of fire can be localized with effective material control or isolation **safeguards**. The highest energy level (PS3), assumes both ignition and a potential spread of fire beyond the ignition source. Criteria for **safeguards** will vary based on the type of power source that is providing power to the circuit.

This power measurement and source classification are similar to LPS test requirements from IEC 60950-1 but are applied independently and the criteria limited to available power as opposed to in combination of criteria required in IEC 60950-1.

All circuits and devices connected or intended to be connected as a load to each measured power source are classified as being part of that power source. This test method determines the maximum power available from a power source to any circuit connected to that power source.

The identification of test points for determination of power source is at the discretion of the manufacturer. The most obvious are outputs of internal power supply circuits, connectors, ports and board to board connections. However, these measurements can be made anywhere within a circuit.

When evaluating equipment (peripherals) connected via cables to an equipment port or via cable, the impedance of any connecting cable may be taken into account in the determination of the PS classification of a connected peripheral. Therefore, it is acceptable to make the measurement at the supply connector or after the cable on the accessory side.

The location of the wattmeter is critical, as the total power available from the power source (not the power available to the fault) is measured during each fault condition. As some fault currents may be limited by a protective device, the time and current breaking characteristics of the protective device used is considered where it has an effect on the value measured.

This test method assumes a single fault in either the power source or the load circuits of the circuit being classified. It assumes both:

- a) a fault within the circuit being classified, and
- b) any fault within the power source supplying power to the circuit being classified,

each condition a) or b) being applied independently.

The higher of the power measured is considered the PS circuit classification value.

6.2.2.2 Power measurement for worst-case fault

Rationale: This test method determines the maximum power available from a power source that is operating under normal operating conditions to any circuit connected to that power source, assuming any single fault condition within the circuit being classified. This power measurement assumes normal operating conditions are established before applying the single fault to any device or insulation in the load circuit to determine the maximum power available to a circuit during a fault.

This is different for **potential ignition source** power measurements where the measured power available is that at the fault location.

A value of 125 % was chosen to have some degree of certainty that the fuse will open after a certain amount of time. As such, the measured situation will not be a continuous situation. It was impossible to use the interruption characteristics of a fuse, since different types of interrupting devices have completely different interrupting characteristics. The value of 125 % is a compromise that should cover the majority of the situations.

6.2.2.3 Power measurement for worst-case power source fault

Rationale: This test method determines the maximum power available to a normal load from a power source assuming any single fault within the power source. A power source fault could result in an increase in power drawn by a normal operating load circuit.

6.2.2.4 PS1

Source: IEC 60065, IEC 60695, IEC 60950-1

Rationale: A PS1 source is considered to have too little energy to cause ignition in electronic circuits and components.

The requirement is that the continuous available power be less than 15 W to achieve a very low possibility of ignition. The value of 15 W has been used as the lower threshold for ignition in electronic components in many documents, including IEC 60950-1 and IEC 60065. It has also routinely been demonstrated through limited power fault testing in electronic circuits.

- In order to address the ease of measurement, it was decided to make the 15 W measurement after 3 s. The value of 3 s was chosen to permit ease of measurement. Values as short as 100 ms and as high as 5 s were also considered. Quickly establishing a 15 W limit (less than 1 s) is not practical for test purposes and not considered important for typical fuel ignition. It is recognized that it normally takes as long as 10 s for thermoplastics to ignite when impinged directly by a small flame (IEC 60695 small scale material testing methods).
- In principle the measurements are to be made periodically (for example, each second) throughout the 3 s period with the expectation that after 3 s, the power would “never” exceed 15 W.
- Historically telecommunication circuits (Table 13, ID 1) are power limited by the building network to values less than 15 W and the circuits connected to them are considered PS1 (from IEC 60950-1).

It should be noted that the statement for **external circuits** is not intended to cover technologies such as USB and PoE. It is meant to relate to analogue ringing signals only.

6.2.2.5 PS2

Source: IEC 60695-11-10, IEC 60950-1

Rationale: Power Source 2 assumes a level of energy that has the possibility of ignition and subsequently requires a **safeguard**. Propagation of the ignition beyond the initially ignited component is limited by the low energy contribution to the fault and subsequently by **safeguards** to control the ignition resistance of nearby fuels.

The primary requirement is to limit power available to these circuits to no more than 100 W. This value includes both power available for normal operation and the power available for any **single fault condition**.

- This value has been used in IEC 60950-1 for a similar purpose, where ignition of internal components is possible but **fire enclosures** are not required.
- The value of 100 W is commonly used in some building or fire codes to identify where low power wiring can be used outside of a **fire containing enclosure**.
- The value is also 2×50 W, which can be related to the energy of standard flaming ignition sources (IEC 60695-11-10 test flame) on which our small-scale V-rating **material flammability classes** are based. It is recognized that the conversion of electrical energy to thermal energy is far less than 100 %, so this value is compatible with the **safeguards** prescribed for PS2 circuits, which are generally isolation and V-rated fuels.

The 5 s measurement for PS2 ensures the available power limits are both limited and practical for the purposes of measurement. The value is also used in IEC 60950 series as referenced above. No short-term limits are considered necessary, as possibility of ignition is presumed for components in these power limited circuits, recognizing that it generally takes 10 s or more for thermoplastics to pyrolyze and then ignite when impinged directly by a small 50 W flame.

Reliability of overcurrent devices (such as those found in IEC 60950 series) is not necessary as these circuits are used within or directly adjacent to the product (not widely distributed like IEC 60950-1 LPS circuits used for connection to building power). The reliability assessment for PS2 circuits that are intended to be distributed within the building wiring is addressed for **external circuits** later in this document.

6.2.2.6 PS3

Rationale: PS3 circuits are circuits that are not otherwise classified as PS1 or PS2 circuits. No classification testing is required as these circuits can have unlimited power levels. If a circuit is not measured, it can be assumed to be PS3.

6.2.3 Classification of potential ignition sources

Rationale: With each power source, points and components within a circuit can be evaluated to determine if **potential ignition sources** are further identified. These ignition sources are classified as either an **arcing PIS** for arcing sources or a **resistive PIS** for resistance heating sources. Criteria for **safeguards** will vary based on the type of **PIS** being addressed.

Ignition sources are classified on their ability to either arc or dissipate excessive heat (resistive). It is important to distinguish the type of ignition source as distances through air from arcing parts versus other resistive ignition sources vary due to a higher thermal loss in radiated energy as compared to conducted flame or resistive heat impinging directly on a **combustible fuel material**.

6.2.3.1 Arcing PIS

Source: IEC 60065

Rationale: **Arcing PIS** are considered to represent a thermal energy source that results from the conversion of electrical energy to an arc, which may impinge directly or indirectly on a fuel material.

Power levels below 15 W (PS1) are considered to be too low to initiate an electrical fire in electronic circuits. This value is used in IEC 60065 (see also 6.2.1).

The minimum voltage (50 V) required to initiate arcing is also from IEC 60065 and through experimentation.

For low-voltages, the fault that causes arc-heating is generally a result of a loose connection such as a broken solder connection, a cold-solder connection, a weakened connector contact, an improperly crimped wire, an insufficiently tightened screw connection, etc. As air does not breakdown below 300 V RMS. (Paschen's Law), most low voltage arc-heating occurs in direct contact with a fuel. For voltages greater than 300 V, arcing can occur through air.

The measurement of voltage and current necessary to establish an **arcing PIS** is related the energy that is available to the fault (as opposed to energy available from a power source). The value ($V_p \times I_{rms}$) specified is neither a W or VA but rather a calculated number reflecting a peak voltage and RMS current. It is not directly measurable.

Arcing below 300 V is generally the result of a disconnection of current-carrying connections rather than the mating or connection of potentially current-carrying connections.

Once the basic parameters of voltage and power are met, there are three conditions for which **safeguards** are required:

- those that can arc under **normal operating conditions**;
- all terminations where electrical failure resulting in heating is more likely; and
- any electrical separation that can be created during a **single fault condition** (such as the opening of a trace).

A reliable connection is a connection which is expected not to become disconnected within the lifetime of the equipment. The examples in the note give an idea as to what kinds of connections can be considered reliable.

The manufacturer may declare any location to be an **arcing PIS**.

6.2.3.2 Resistive PIS

Source: IEC 60065

Rationale: Resistive **potential ignition sources** can result from a fault that causes over-heating of any impedance in a low-resistance that does not otherwise cause an overcurrent protection to operate. This can happen in any circuit where the power to the resistive heating source is greater than 15 W (see above). A **resistive PIS** may ignite a part due to excessive power dissipation or ignite adjacent materials and components.

Under **single fault conditions**, this clause requires that two conditions exist before determining that a part can be a **resistive PIS**. The first is that there is sufficient available fault energy to the component. The second is that ignition of the part or adjacent materials can occur.

The requirement for a **resistive PIS** under **normal operating conditions** is not the available power but rather the power dissipation of the part under **normal operating conditions**.

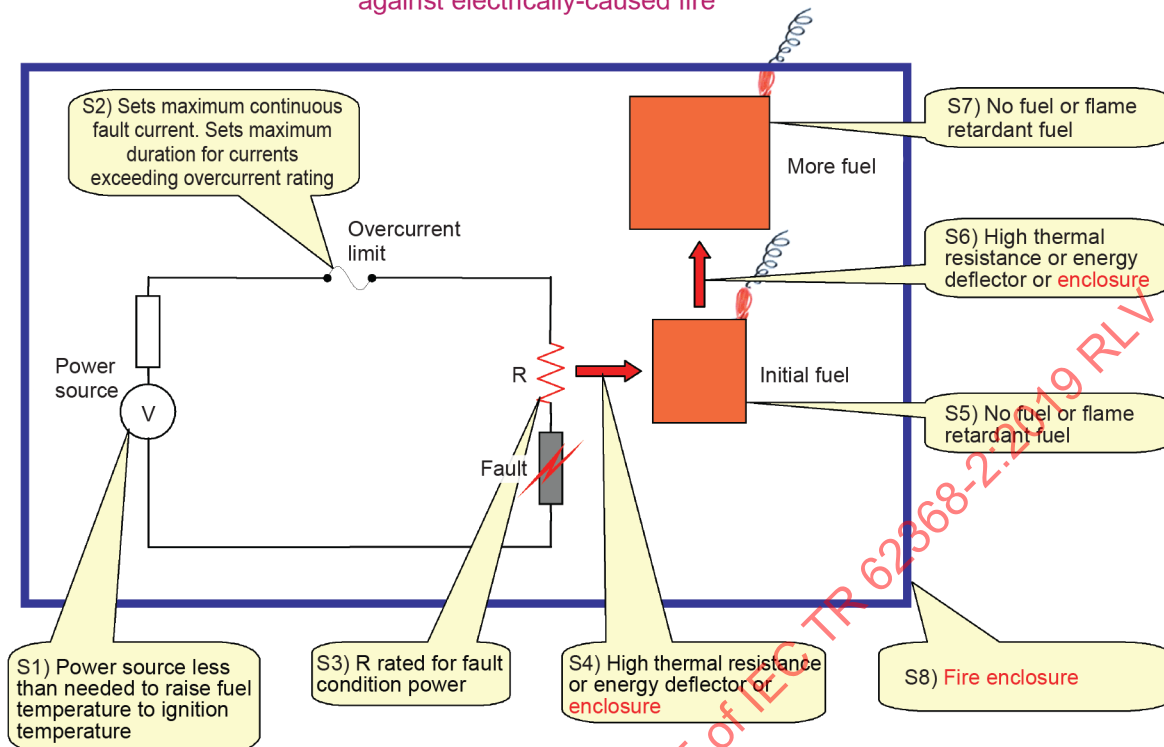
The value of 30 s was used in IEC 60065 and has historically proven to be sufficient. The value of 100 W was used in IEC 60065 and has historically proven to be adequate.

The manufacturer may declare any location to be a **resistive PIS**.

6.3 Safeguards against fire under normal operating conditions and abnormal operating conditions

Rationale: The **basic safeguard** under **normal operating conditions** and **abnormal operating conditions** is to reduce the likelihood of ignition by limiting temperature of fuels. This can be done by assuring that any available electrical energy conversion to thermal energy does not raise the temperature of any part beyond its ignition temperature.

SAFEGUARDS against electrically-caused fire



IEC

Figure 28 – Possible safeguards against electrically-caused fire

There are several **basic safeguards** and **supplementary safeguards** against electrically-caused fire under **abnormal operating conditions** and **single fault conditions** (see Figure 28, Table 8 and Table 9 in this document). These **safeguards** include, but are not limited to:

- S1) having insufficient power to raise a fuel material to ignition temperature;
- S2) limiting the maximum continuous fault current; limiting the maximum duration for fault currents exceeding the maximum continuous fault current (for example, a fuse or similar automatic-disconnecting overcurrent device);
- S3) selecting component rating based on **single fault conditions** rather than **normal operating conditions** (prevents the component from overheating);
- S4) ensuring high thermal resistance of the thermal energy transfer path from the thermal energy source to the fuel material (reduces the temperature and the rate of energy transfer to the fuel material so that the fuel material cannot attain ignition temperature); or a barrier made of non-combustible material;
- S5) using an initial fuel material located closest to an **arcing PIS** or **resistive PIS** having a temperature rating exceeding the temperature of the source (prevents fuel ignition); or a flame-retardant fuel material (prevents sustained fuel burning and spread of fire within the equipment); or a non-combustible material (for example, metal or ceramic);
- S6) ensuring high thermal resistance of the thermal energy transfer path from the initial fuel to more fuel material; or flame isolation of the burning initial fuel from more fuel material (prevents spread of fire within the equipment);
- S7) ensuring that subsequent material is either non-combustible material (for example, metal or ceramic); or is a flame-retardant material (prevents sustained fuel burning and spread of fire within the equipment);
- S8) use of a **fire-containing enclosure** (contains the fire within the equipment) or an oxygen-regulating **enclosure** (quenches a fire by suffocating it);
- S9) use of reliable electrical connections;

- S10) use of non-reversible components and **battery** connections;
- S11) use of mechanical protection (for example, barriers, mesh or the like) with limited openings;
- S12) use of clear operating instructions, **instructional safeguards**, cautions.

Methods of protection

A) Protection under normal operating conditions and abnormal operating conditions

Materials and components shall not exceed their auto-ignition temperatures.

B) Protection under single fault conditions

There are two methods of providing protection. Either method may be applied to different circuits in the same equipment:

- Prevent ignition: equipment is so designed that under **abnormal operating conditions** and **single fault conditions** no part will ignite;
- Control fire spread: selection and application of components, wiring, materials and constructional measures that reduce the spread of flame and, where necessary, by the use of a **fire enclosure**.

Thermoplastic softening values or relative thermal indices (RTI) were not considered appropriate as they do not relate specifically to ignition properties of fuel materials.

Any device that operates as a **safeguard** during normal operation (when left in the circuit) shall be assessed for reliability. If a device is taken out of the circuit during the normal operation testing then it is not considered as being a **safeguard**.

Abnormal operating conditions that do not result in a single fault are considered in much the same way as **normal operating conditions** as the condition is corrected and normal operation is presumed to be restored. However, **abnormal operating conditions** that result in a **single fault condition** are to be treated in accordance with 6.4 rather than 6.3. See Figure 29 in this document for a fire clause flow chart.

Table 8 – Examples of application of various safeguards

Cause	Prevention/protection methods	Safeguard
Start of fire under normal operating conditions	Limit temperature of combustible material	Basic
Start of fire under abnormal operating conditions and single fault conditions	Select prevent ignition or control fire spread method	Supplementary
PS1 circuit	Low available power reduces the likelihood of ignition	S1
PS2 or PS3 circuit	Reduce the likelihood of ignition Use of protection devices Sufficient distance or solid barrier interposed between any combustible material and each potential ignition source	S1, S2, S3, S5 S2 S4 (S6)
PS2 circuit	Limit the available power Sufficient distance or solid barrier interposed between any combustible material and each potential ignition source Use flame-retardant or non- combustible material	S1, S2 S4, S6 S5
PS3 circuit	Use all PS2 options and: – use fire containing enclosures – use flame-retardant or similar materials	S8 S7
Internal and external wiring	Reliable construction Limit of wire temperature and use of fire resistant insulation	S9
Fire caused by entry of foreign objects and subsequent bridging of electrical terminals in PS2 circuits and PS3 circuits	Prevent entry of foreign objects	S11
Mains supply cords	Reliable construction Limit of wire temperature and use of fire resistant insulation	S9
Fire or explosion due to abnormal operating conditions of batteries	Limit charge/discharge currents Limit short-circuit currents Prevent use of wrong polarity	S1 S2 S10

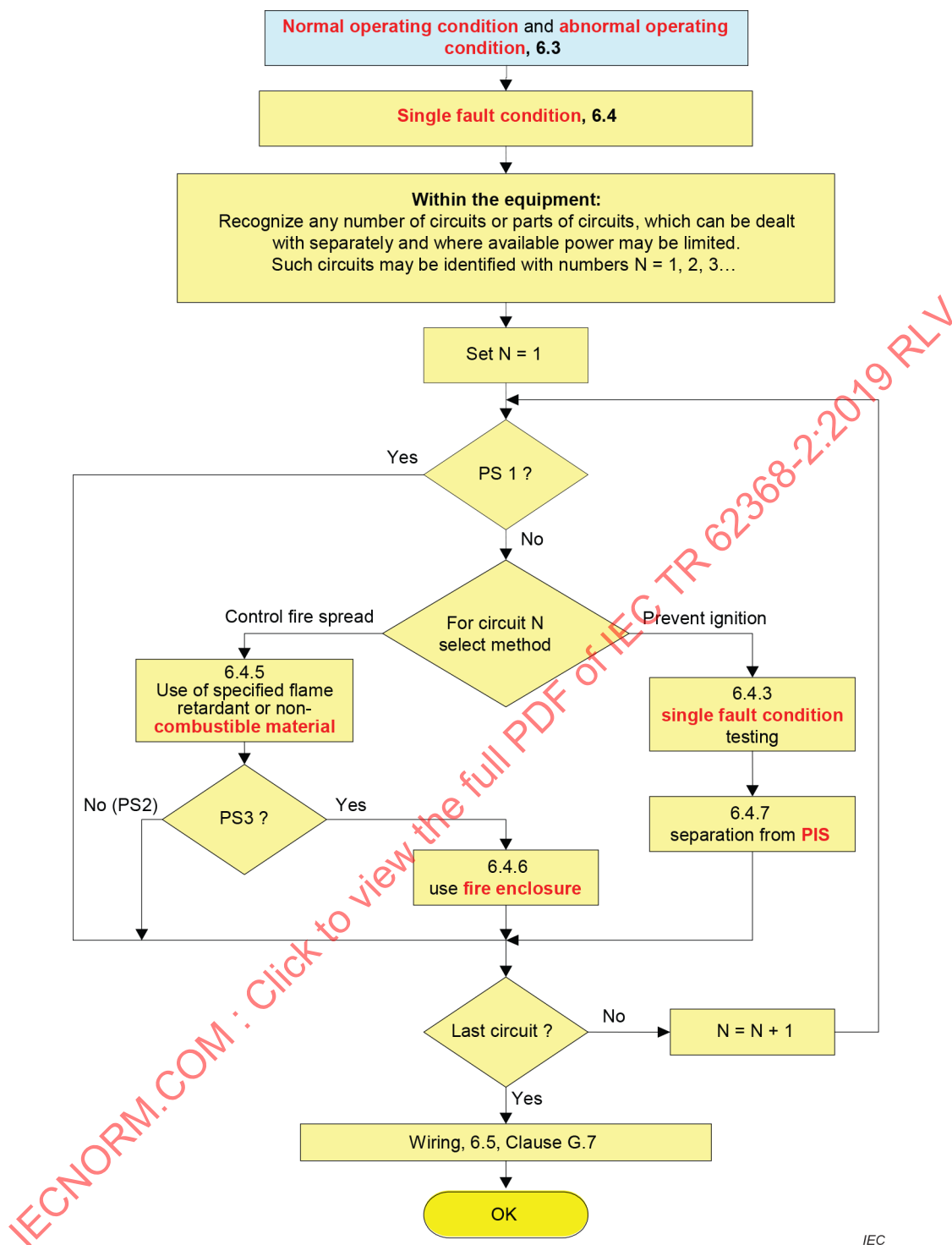


Figure 29 – Fire clause flow chart

6.3.1 Requirements

Source: IEC 60950-1, ISO 871

Rationale: Spontaneous-ignition temperature as measured by ISO 871 for materials was chosen as the ignition point of fuels. The materials specific tables were deleted in favour of a simple requirement or completely referring instead to the ASTM standard for material auto-ignition temperatures.

The 300 °C value for thermoplastics is approximately 10 % less than the lowest ignition temperature of materials commonly used in ICT and CE equipment. This value has also been used in IEC 60950-1. The designer is permitted to use material data sheets for materials that exceed this value but the auto-ignition specification has to be reduced by 10 % to accommodate measurement variations and uncertainty.

In the context of fire, **abnormal operating conditions** (blocked vents, connector overload, etc.) are to be considered just as a **normal operating condition** unless the **abnormal operating condition** results in a **single fault condition**.

As part of the compliance check, first the datasheets of the materials used have to be checked to be able to evaluate the results of the temperature rise measurements.

The glow-wire test is a fire test method of applying a heat source to the sample. The test provides a way to compare a material's tendency to resist ignition, self-extinguish flames (if ignition occurs), and to not propagate fire. Manufacturers have been using this test method to determine a plastic's flame resistance characteristics to IEC 60950-1 for many years without field issues identified with the suitability of the test. Hence, the glow-wire test should continue to be an option to the HB rating for plastics outside of the **fire enclosure** or **mechanical enclosures** and for **electrical enclosures** housing PS1 circuits. This precedence has been set in IEC 60950-1 and should be included in IEC 62368-1.

Table 9 – Basic safeguards against fire under normal operating conditions and abnormal operating conditions

Normal operating conditions and abnormal operating conditions		
The objective of this subclause is to define requirements to reduce the likelihood of ignition under normal operating conditions and abnormal operating conditions .		
PS1 PS2 PS3	6.3.1	Ignition is not allowed
		$T_{max} \leq 90\%$ auto ignition temperature according to ISO 871; or $T_{max} \leq 300\text{ °C}$
		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 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 criteria

Rationale: Steady state for temperature measurements in excess of 300 °C requires more tolerance on the rise value due to the difficulty in achieving a stable reading. However, the value in B.1.6 was considered adequate, as these values typically do not continue to rise but rather cycle. The value of 3 °C over a 15 min period was also considered for measurement of these very high temperatures but was not used in favour of harmonization with other clauses.

The use of temperature-limiting **safeguards** under **normal operating conditions** and **abnormal operating conditions** is considered acceptable only where the **safeguard** or device has been deemed a reliable temperature control device.

6.4 Safeguards against fire under single fault conditions

6.4.1 General

Source: IEC 60065, IEC 60950-1

Rationale: The consideration in the prior clause is to limit the likelihood of ignition of fuels under **normal operating conditions** and **abnormal operating conditions** with a **basic safeguard**. All fuels should be used below their ignition temperatures and separated from arcing parts.

The requirements in this clause are to limit the ignition or the spread of fire under **single fault conditions** by employing **supplementary safeguards**, see Table 10 in this document. There are two approaches that can be used either jointly or independently:

- method 1 minimizes the possibility of ignition through the use of **safeguards** applied at each potential point of ignition;
- method 2 assumes the ignition of limited fuels within the product and therefore requires **safeguards** that limit the spread of fire beyond the initial ignition point or for higher energy, beyond the equipment **enclosure**.

Table 10 – Supplementary safeguards against fire under single fault conditions

Single fault conditions	
There are two methods of providing protection. Either method may be applied to different circuits of the same equipment (6.4.1)	
Method 1 Reduce the likelihood of ignition	Equipment is so designed that under single fault conditions no part shall ignite. 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.
Method 2 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.

The document's user or product designer will select a method to apply to each circuit, (either prevent ignition method or control the spread of fire method). The selection of a method can be done for a complete product, a part of a product or a circuit.

The power level of 4 000 W was chosen to ensure that products which are connected to low power **mains** (less than 240 V × 16 A), common in the office place or the home, could use the ignition protection methods, and to provide a reasonable and practical separation of product types. It is recognized that this is not representative of fault currents available but is a convenient and representative separation based on equipment connected to normal office and home **mains** circuits where experience with **potential ignition sources safeguards** is more common.

Limit values below 4 000 W create a problem for the AC **mains** of almost all equipment used in the home or office, which is not the intent. It would be much more practical to use an energy source power of 4 000 W based on **mains** voltage and overcurrent device rating which would effectively permit all **pluggable type A equipment** to use either method, and restrict very high-power energy sources to use only the method to control fire spread.

The 4 000 W value can be tested for individual circuits; however, a note has been added to clarify which types of products are considered below without test. Calculation of the product of the **mains** nominal voltage and **mains** overcurrent device rating is not a normal engineering convention but rather the product of two numbers should not exceed 4 000 (see text below).

NOTE All **pluggable equipment type A** are considered to be below the steady state value of 4 000 W. **Pluggable equipment type B** and **permanently connected equipment** are considered to be below this steady state value if the product of nominal **mains** voltage and the current rating of the installation overcurrent protective device is less than 4 000.

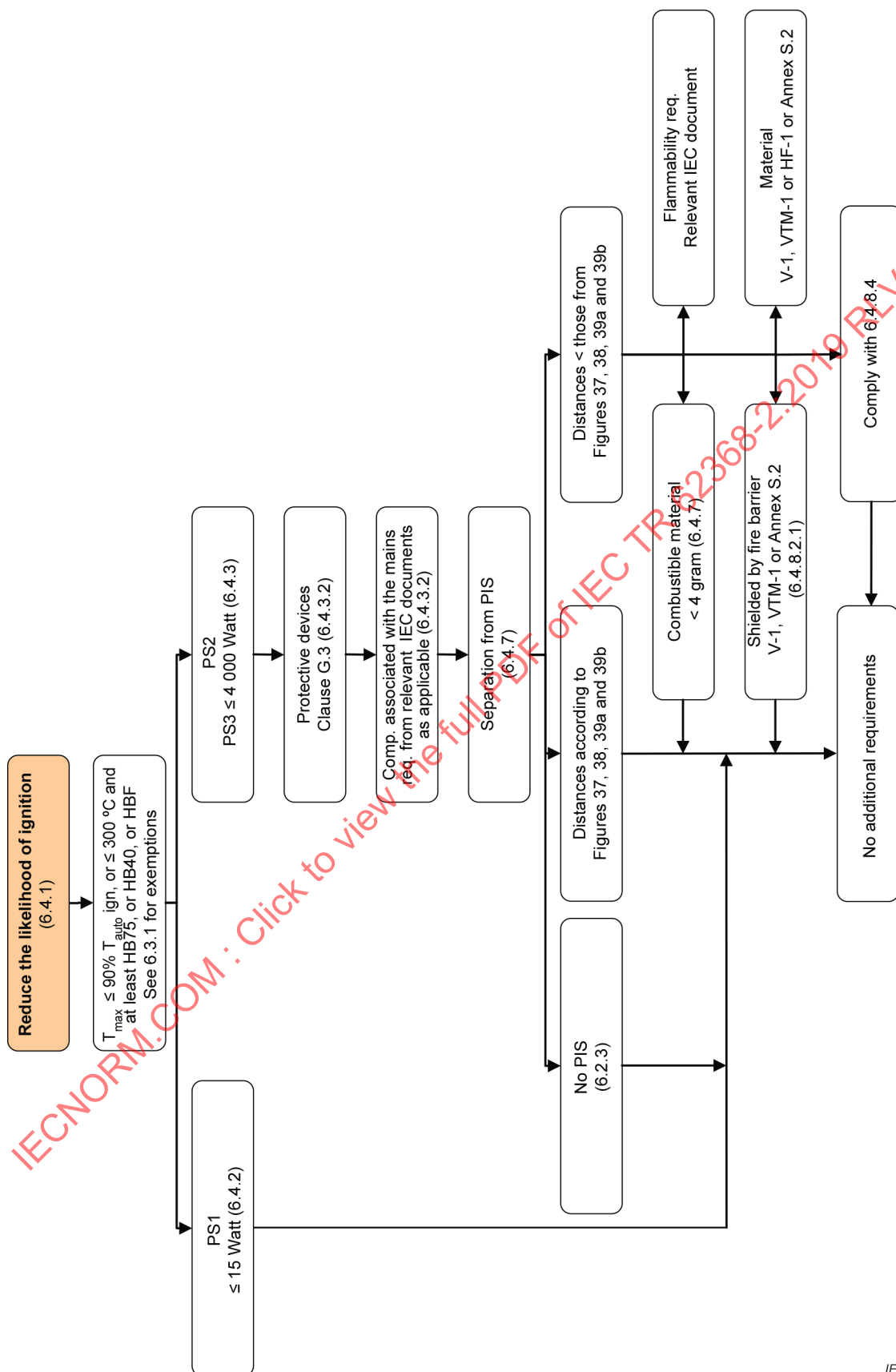
Prevent ignition method: Prescribes **safeguard** requirements that would prevent ignition and is predominantly based on fault testing and component selection and designs that reduce the likelihood of sustained flaming. Where a **PIS** is identified, additional **safeguards** are required to use barriers and the fire cone 'keep out' areas for non-flame rated materials (see Table 11 and Figure 30 in this document).

The prevent ignition method has been used in IEC 60065 where the predominant product connection is to low power (< 16 A) **mains** circuits. The use of this method was not considered adequate enough for larger **mains** circuits because the size of the fire cone does not adequately address large ignition sources common in higher power circuits.

This approach limits the use of prevent ignition methods to those products where the ignition sources is characterized by the fire cones and **single fault conditions** described in 6.4.7.

Table 11 – Method 1: Reduce the likelihood of ignition

Method 1: Reduce the likelihood of ignition under single fault conditions		
PS1 (≤ 15 W after 3)	6.4.2	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.
PS2 ($> PS1$ and ≤ 100 W after 5 s) and PS3 ($> PS2$ and $\leq 4\,000$ W)	6.4.3	The objective of this subclause is to define 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. All identified supplementary safeguards need to be considered based on the equipment configuration.
		Sustained flaming > 10 s is not allowed and no surrounding parts shall have ignited.
		Separation from arcing PIS and resistive PIS according to 6.4.7 – Distances have to comply with Figures 37, 38, 39a and 39b; or – In case the distance between a PIS and combustible material is less than specified in Figures 37, 38, 39a and 39b: • Mass of combustible material < 4 g, or • Shielded from the PIS by a fire barrier, or • Flammability requirements: ○ V-1 class material; VTM-1 class material or HF-1 class material, or needle flame in Clause S.2, or ○ Relevant component IEC document
		Using protective devices that comply with G.3.1, G.3.2, G.3.3 and G.3.4 or the relevant IEC component documents for such devices;
		Using components that comply with G.5.3, G.5.4 or the relevant IEC component document;
		Components associated with the mains shall comply with: the relevant IEC component documents; and the requirements of other clauses of IEC 62368-1



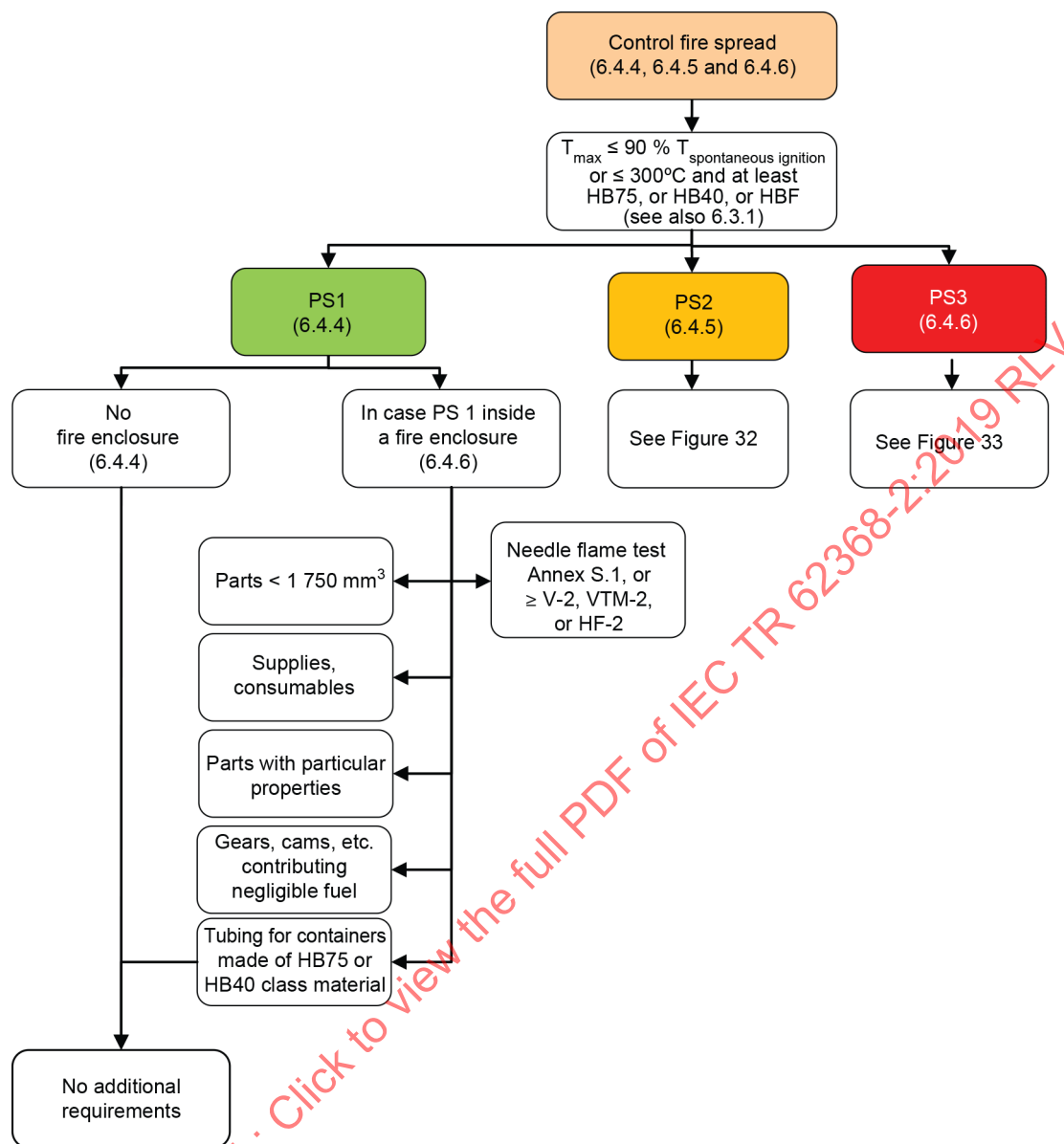
IEC

Figure 30 – Prevent ignition flow chart

Control fire spread method: Prescribes **safeguards** that are related to the spread of fire from acknowledged ignition sources. This assumes very little performance testing (no **single fault conditions**) and the **safeguards** are designed to minimize the spread of flame both within the product and beyond the **fire enclosure**. The **safeguards** described are based on power level, with higher power sources requiring more substantial **safeguards** (see Figure 31, Figure 32 and Table 12 in this document).

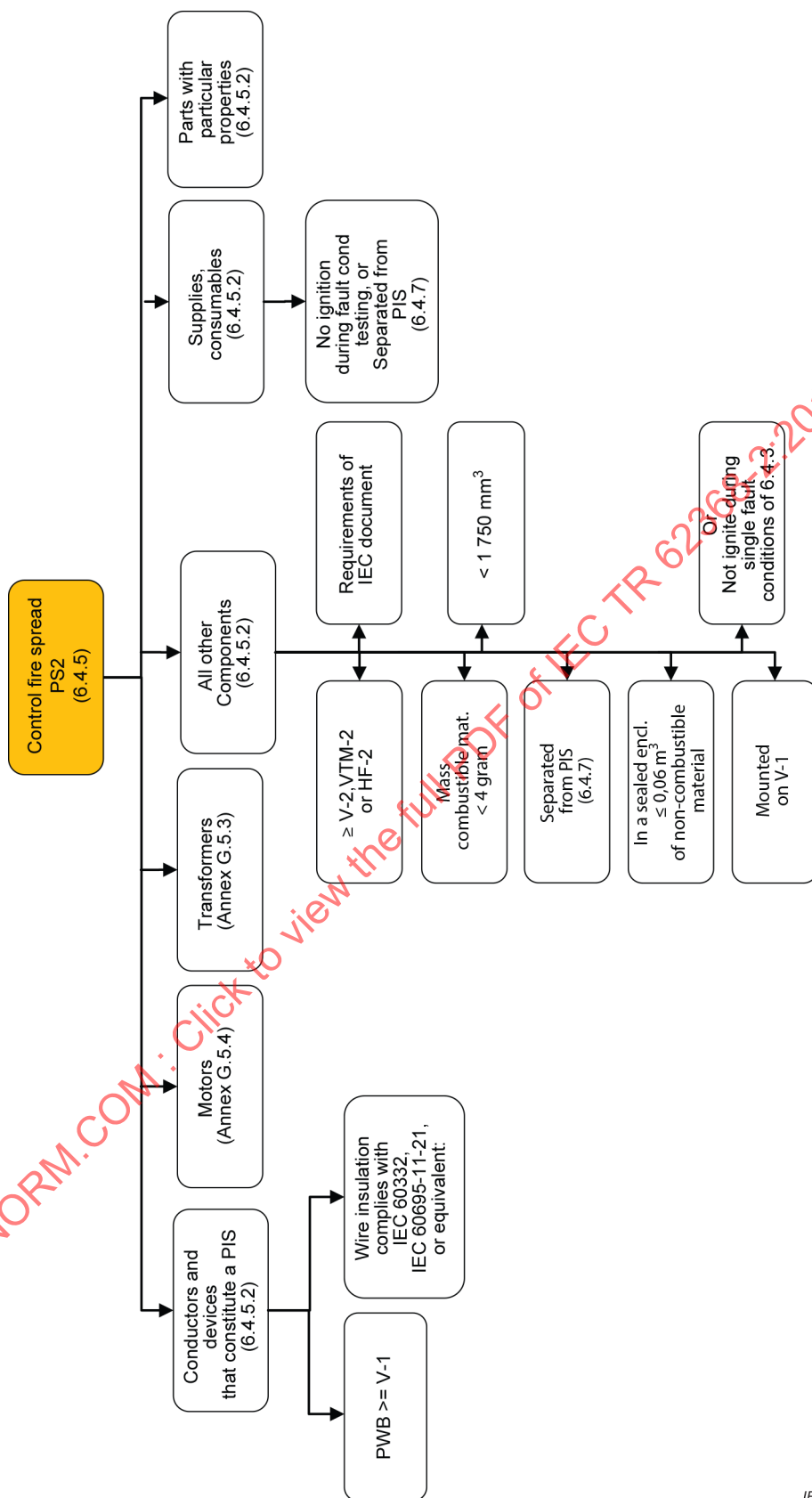
This power (4 000 W) separation is also used in the control of fire spread method to delineate **safeguard** criteria for **fire enclosure** materials (V-1 versus 5 V). IEC 60950-1 has historically used weight to define **fire enclosure** criteria and it was felt that the use of available power was more appropriate and generally reflective of current practice.

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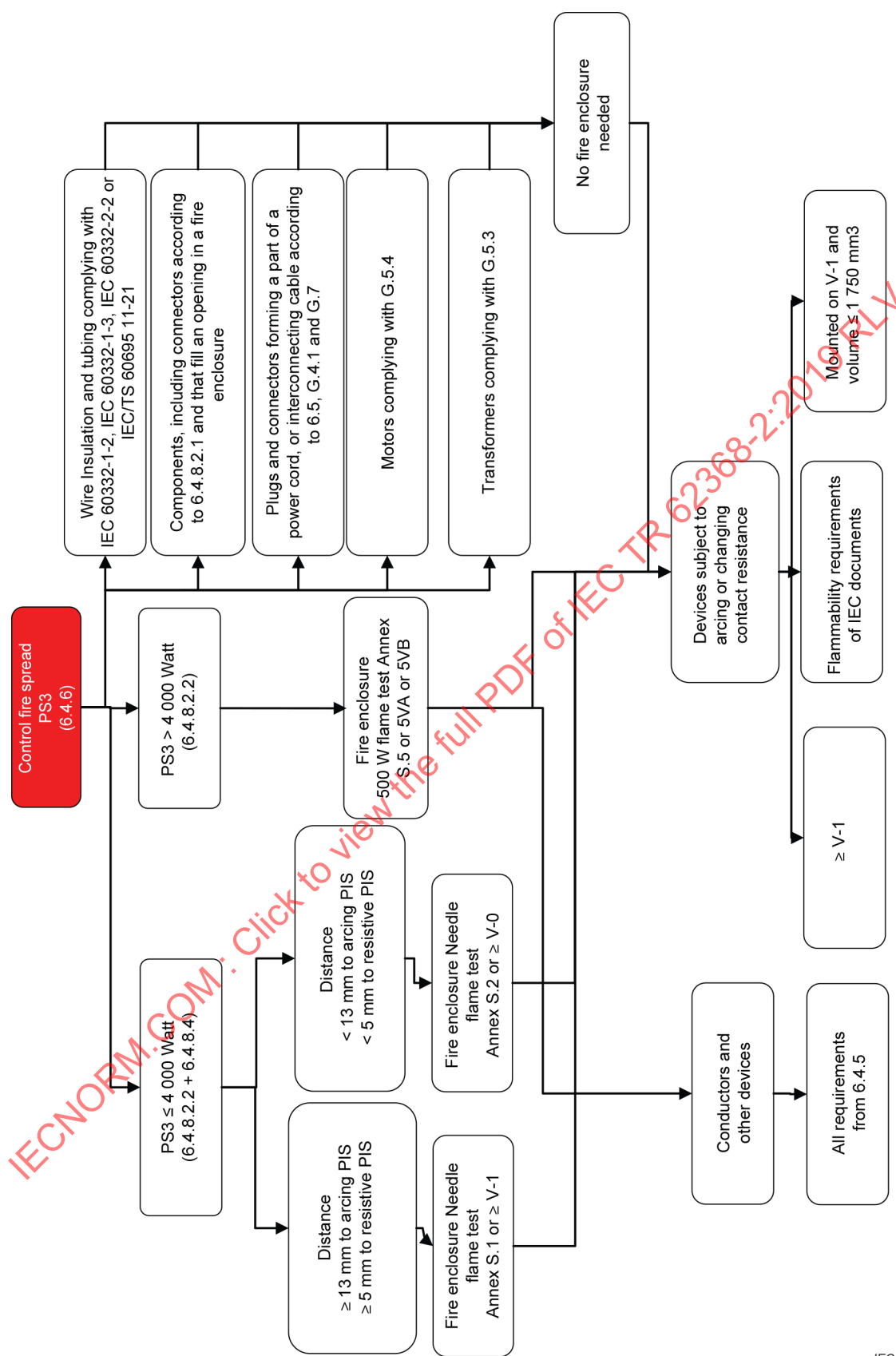
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Figure 31 – Control fire spread summary



IEC

Figure 32 – Control fire spread PS2



IEC

Figure 33 – Control fire spread PS3

6.4.2 Reduction of the likelihood of ignition under single fault conditions in PS1 circuits

Rationale: Low available power prevents ignition – 15 W is recognized as the lower limit of ignition for electronic products. The limiting of power is not considered the **basic safeguard** but rather the characteristic of the circuit being considered. This determination is made as part of the classification of power sources.

6.4.3 Reduction of the likelihood of ignition under single fault conditions in PS2 circuits and PS3 circuits

Rationale: To identify all **potential ignition sources**, all circuits and components within the PS2 and PS3 circuits should be evaluated for their propensity to ignite.

The ignition source derived from either PS2 or a PS3 circuit is considered equivalent. The resulting flame size and burn time is identical in all PS2 and PS3 circuits unless the power available is very large (for example, greater than 4 000 W).

For very large sources (greater than 4 000 W) the **safeguards** described for addressing **potential ignition sources** are not recognized as being adequate and the control fire spread method is used (see 6.4.1 for 4 000 W rationale).

6.4.3.1 Requirements

Source: IEC 60065, IEC 60695-2-13, IEC 60950-1

Rationale: Flaming of a fuel under **single fault conditions** is only permitted if very small and quickly extinguished (for example, a fusing resistor). A length of time is necessary during **single fault conditions** to permit the characteristic “spark” or short term “combustion flash” common when performing **single fault conditions** in electronic circuits. The value of 10 s is used, which has been used by IEC 60065 for many years. The energy of this short-term event is considered too low to ignite other parts. This value corresponds with IEC 60695-2-13 and has been used in practice by IEC TC 89 for glow wire ignition times. The time period is necessary to accommodate the expected flash/short duration flames that often result as a consequence of faults. The value of 10 s is considered to be the minimum time needed for ignition of commonly used thermoplastics by direct flame impingement. It is recognized that times as short as 2 s are used by other documents.

Protection is achieved by identifying each **PIS** and then limiting the temperature of parts below auto-ignition temperatures during **single fault conditions**, minimizing the amount of flammable material near a **PIS**, separating **combustible materials** from **PIS** by barriers, and by using reliable protection devices to limit temperature of combustible parts.

Single fault testing, while not statistically significant, has been common practice in both IEC 60065 and IEC 60950-1.

Temperatures limiting ignition are considered to be the material self-ignition points or flash temperatures for flammable liquids and vapours (this value should include a 10 % margin to take into account ambient, laboratory and equipment operating conditions). The spread to surrounding parts during and after the fault is also checked.

Providing sufficient distance or solid barrier between any **combustible material** and a **potential ignition source** should minimize the potential for the spread of fire beyond the fuels directly in contact with the **potential ignition source**. The fire cone distances developed for IEC 60065 are used and considered adequate. We prescribed the use of the cone because it is more reliable than single fault testing. Single fault testing is not representative; therefore, some material and construction requirements are necessary (fuel control area or keep out area).

Use of reliable protection devices – This includes reliability requirements for the devices that are used to prevent ignition. This permits only the use of devices that have reliability requirements included in Annex G.

Components that comply with their relevant IEC component documents are also considered to comply given these documents also have ignition protection requirements. The components included are those that are almost always part of a **potential ignition source** as they are **mains** connected.

Opening of a conductor: In general, opening of a conductor is not permitted during **single fault conditions** as it is not considered reliable protection device for limiting ignition. However for **resistive PIS**, it may be suitable provided the printed wiring board is adequately flame retardant and the opening does not create an **arcing PIS**. The V-1 printed circuit board is considered adequate to quench low voltage events and will not propagate the flame. It is not sufficient when the opening creates an **arcing PIS** (< 50 V).

As a consequence of the test, any peeling of conductor during these tests shall not result in or create other hazards associated with the movement of conductive traces during or after the test provided they do so predictably. During a single fault the peeling could bridge a **basic safeguard** but should not result in the failure of a **supplementary safeguard** or **reinforced safeguard**.

6.4.3.2 Test method

Source: IEC 60065, IEC 60127

Rationale: The available power and the classification criteria for resistive and arcing **potential ignition sources** should be used to determine which components to fault.

If the applied **single fault condition** causes another device or subsequent fault, then the consequential failure is proven reliable by repeating the **single fault condition** two more times (total of three times). This is a method used historically in IEC 60065.

Steady state determination for **single fault conditions** is related to temperature rise and the requirement is the same as the steady state requirements of Annex B, even though material ignition temperatures (> 300 °C) are much higher than required temperatures of other clauses (~25 °C – 100 °C). Shorter time periods (such as 15 min) were considered but dropped in favour of harmonization of other parts. The term steady state should take into account temperatures experienced by a material throughout the test.

Maximum attained temperature for surrounding material of heat source should be considered if further temperature increase is observed after interruption of the current.

Limit by fusing: The reliability of protection devices is ensured where they act to limit temperatures and component failures. The criteria used by the component document applying to each are considered adequate provided the parts are used as intended. The requirements included assume an IEC 60127 type fuse as the most common device.

The test methodology is established to ensure that available energy through the fuse link based on its current hold and interrupt conditions the breaking time characteristics of specified in IEC 60127. IEC 60127 permits 2,1 times the breaking current rating for 1 min.

In order to determine the impact of a fuse on the results of a **single fault condition**, if a fuse operates, it is replaced with a short circuit and the test repeated. There are three possible conditions when comparing the actual fault current through the fuse to the pre-arcing current and time data sheets provided by the fuse manufacturer.

- Where the measured current is always below the fuse manufacturer's pre-arcing characteristics (measured current is less than 2,1 times the fuse rating), the fuse cannot be relied upon as a **safeguard** and the test is continued with the fuse short circuited until steady state where the maximum temperature is measured.
- Where the measured current quickly exceeds the fuse pre-arcing characteristics (measured current is well above 2,1 times the rating current of the fuse) then the test is repeated with the open circuit in place of the fuse (assumes fuse will open quickly and be an open circuit) and then the maximum temperature recorded.
- Where the measured current does not initially exceed the fuse pre-arcing characteristics, but does at some time after introduction of the fault. The test is repeated with the short circuit in place and the temperature measured at the time where measured current exceeds the fuse pre-arcing characteristics. It is assumed the measured current through the short circuit can be graphed and compared with the fuse manufacturer's pre-arcing curves provided on the fuse datasheet to determine the test time.

6.4.4 Control of fire spread in PS1 circuits

Rationale: Low available power reduces the likelihood for ignition – 15 W is recognized as the lower limit of ignition for electronic circuits. This lower power limit is considered as a circuit characteristic of the circuit, not a **basic safeguard**.

Table 12 – Method 2: Control fire spread

Method 2: Control fire spread		
PS1 (≤ 15 W)	6.4.4	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.
PS2 (≤ 100 W after 5 s)	6.4.5	The objective of this subclause is to describe the supplementary safeguards needed to reduce the likelihood of fire spread from a PIS in PS2 circuits to nearby combustible materials. The limiting of power available to PS2 circuits is the basic safeguard used to minimize the available energy of an ignition source. A supplementary safeguard is required to control the spread of fire from any possible PIS to other parts of the equipment
		For conductors and devices with a PIS the following apply: – Printed boards shall be at least V-1 class material – Wire insulation shall comply with IEC 60332 series or IEC 60695-11-21
		Battery cells and battery packs shall comply with Annex M.
		All other components: – Mounted on V-1 class material, or – Materials V-2 class material, VTM-2 class material, or HF-2 class material, or – Mass of combustible material < 4 g, provided that when the part is ignited the fire does not spread to another part, or – Separated from PIS according to 6.4.7, Distances have to comply with Figures 37; 38; 39 and 40, or In case distances do not comply with Figures 37; 38; 39 and 40 – Mass of combustible material < 4 g, or – Shielded from the PIS by a fire barrier, or – Flammability requirements: V-1 class material; VTM-1 class material or HF-1 class material, or comply with the needle flame test of IEC 60695-11-5 as described in Clause S.2; or – Comply with IEC component document flammability requirements, or comply with G.5.3 and G.5.4 – Insulation materials used in transformers, bobbins, V-1 class material – In a sealed enclosure ≤ 0,06 m3 made of non-combustible material and having no ventilation openings The following shall be separated from a PIS according to 6.4.7 or shall not ignite due to fault conditional testing – Supplies, consumables, media and recording materials – Parts which are required to have particular properties in order to perform intended functions, such as synthetic rubber rollers and ink tubes

Method 2: Control fire spread		
PS3 (> PS2)	The objective of this subclause is to describe the supplementary safeguards needed to reduce the likelihood of fire spread from a PIS in PS3 circuits to nearby combustible materials .	
	6.4.6	Fire spread in PS3 circuit shall be controlled by; – the use of a fire enclosure as specified in 6.4.8. and – applying all requirements for PS2 circuits as specified in 6.4.5 Devices subject to arcing or changing contact resistance (for example, pluggable connectors) shall comply with one of the following: – Materials V-1 class material; or – Comply with IEC component document flammability requirements; or – Mounted on V-1 class material and volume $\leq 1\,750\text{ mm}^3$ Exemptions: – Wire and tubing insulation complying with IEC 60332 series or IEC 60695-11-21 – Components, including connectors complying with 6.4.8.2.2 and that fill an opening in a fire enclosure – Plugs and connectors forming a part of a power supply cord or complying with 6.5, G.4.1 and G.7 – Transformers complying with G.5.3 – Motors complying with G.5.4
	6.4.6 For PS2 or a PS3 circuit within a fire enclosure	See all requirements for PS2 (6.4.5)
	6.4.6 For a PS1 circuit within a fire enclosure	Combustible materials: Needle flame test in Clause S.1 or V-2 class material or VTM-2 class material or HF-2 class material Exemptions: – Parts with a size less than $1\,750\text{ mm}^3$ – 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 – Gears, cams, belts, bearings and other small parts that would contribute negligible fuel to a fire, including, labels, mounting feet, key caps, knobs and the like – Tubing for air or any 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 $< 3\text{ mm}$, or HB40 class material if the thinnest significant thickness of the material is $\geq 3\text{ mm}$, or HBF class foamed material

6.4.5 Control of fire spread in PS2 circuits

Source: IEC 60950-1

Rationale: In principle, limiting the available power to the circuit (100 W) in PS2 circuits and control of adjacent fuel materials will reduce the spread of fire, assuming that ignition of components can occur. This power level limit minimizes the size of the ignition source and its impingement on adjacent fuels that are in the PS2 circuits.

The purpose of this clause is to establish control of fuels in or near circuits that have the possibility of ignition. As no fault testing is done for PS2 circuits, it is assumed that a fire ignition can occur anywhere within the circuits. These **safeguards** are to be based on component material flammability characteristics that keep the initial ignition source from spreading to surrounding internal materials.

This clause assumes only construction **safeguards** in a manner consistent with the historically effective requirements of IEC 60950-1.

Only fuels that would contribute significant fuel to a fire are considered.

Acceptance of limited power sources in Annex Q.1 to be classified as PS2 has been added to allow continued use of the long existing practice in IEC 60950-1.

6.4.5.2 Requirements

Source: IEC 60065, IEC 60950-1

Rationale: Requirements around conductors and devices subject to arcing parts and resistive heating have the most onerous requirements for sustained ignition and protection of wiring and wiring boards.

- Mounting on a flame-retardant material to limit fire growth. V-1 mounting materials are considered important as they limit fuel to reduce sustained flaming and also would not contribute to large fires or pool fire. The spread of fire from ignited small parts can be managed by the larger printed wiring board. This provision is made to allow the use of a longstanding IEC 60950-1 provision for small devices mounted directly on boards. The value 1 750 mm³ has been used in practice in IEC 60065.
- Use of flame retardant wiring is identical to the internal and external wiring requirements of Clause 6.
- Accepting existing component requirements for devices that have their own requirements (IEC or annexes of this document) are considered adequate.
- Sufficient distance or solid flame-resistant barrier between any **combustible material** and **potential ignition sources**. (KEEP OUT ZONES or RESTRICTED AREA).

All other components (those that are not directly associated with arcing or resistive heating components) have a reduced set of **safeguards** when compared to those parts more likely to ignite. Those **safeguards** include any of the following:

- For parts not directly subject to arcing or resistive heating, V-2 ratings are considered adequate. This is also a historical requirement of IEC 60950-1 for parts used in limited power circuits. Sustained ignition of **V-2 class materials** is similar to that of **V-1 class materials** in the small-scale testing. The use of **VTM-2** or **HF-2 class materials** were also considered adequate.
- Limiting the combustible fuel mass within the area around PS2 circuit devices. The limit of 4 g is brought from the small parts definition used with **PIS** requirements of this clause and which were originally used in IEC 60065.
- As an alternative, components and circuits can be separated from fuels per the requirements of the fire cone described for isolation of fuels from **potential ignition sources**.
- Enclosing parts in small oxygen limiting, flame proof, housing. The 0,06 m² value has been in practice in IEC 60950-1 and small enough to mitigate fire growth from a low power source.

The exceptions included are based on common constructions of material that do not routinely have flame retardants or that cannot contain flame retardants due to functional reasons. They are either isolated from any **PIS** or through **single fault condition** testing demonstrate that they will simply not ignite in their application.

Supplies are quantities of materials such as paper, ink, toner, staples etc., and that are consumed by the equipment and replaced by the user when necessary.

6.4.5.3 Compliance criteria

Rationale: Material flammability requirements are checked by the testing of Annex S, by compliance with the component document or through review of material data sheets.

6.4.6 Control of fire spread in a PS3 circuit

Source: IEC 60950-1

Rationale: There are two basic requirements to control the spread of fire from PS3 circuits:

- a) use of materials within the **fire enclosure** that limit fire spread. This includes the same requirements as for components in PS2 circuits and includes a requirement from IEC 60950-1 to address all **combustible materials** that are found within the **fire enclosure**;
- b) use **fire-containing enclosures** – Product **enclosures** will have a design capable of preventing the spread of fire from PS3 circuits. The criteria for **fire enclosures** is based on the available power.

Rationale: PS3 sourced circuits may contain a significant amount of energy. During **single fault conditions**, the available power may overwhelm the **safeguard** of material control of fuels adjacent to the fault or any consequential ignition source making a **fire enclosure** necessary as part of the **supplementary safeguard**. A **fire enclosure** and the material controls constitute the necessary **supplementary safeguard** required for a PS3 circuit.

Use adequate materials, typically permitting material pre-selection of non-**combustible** or flame-resistant **materials** for printed wiring and components in or near PS3. Only fuels that would contribute significant fuel to a fire are considered. This implies compliance with all the requirements for PS2 circuits and in addition, application of a **fire containing enclosure**.

Material flammability requirements for all materials inside a **fire enclosure** are included in this clause. This model has been used historically in IEC 60950-1 to control the amount and type of fuel that may become engaged in a significant fire. Because there is no single fault testing when applying this method, a significant ignition source may engage other fuels located inside the **fire enclosure**. PS3 circuits, particularly higher power PS3 circuits can create significant internal fires if adjacent **combustible materials**, not directly associated with a circuit, become involved in an internal fire. These fires, if unmitigated, can overwhelm the **fire enclosures** permitted in this document. Control of material flammability of fuels located within the **enclosure** should be sufficient based on historical experience with IEC 60950-1.

The exceptions provided in this clause for small parts, **consumable material**, etc. that are inside of a **fire enclosure**, mechanical components that cannot have flame retardant properties are exempt from the material flammability requirements. This is the current practice in IEC 60950-1.

Components filling openings in a **fire enclosure** that are also V-1 are considered adequate, as it is impractical to further enclose these devices. These constructions are commonly used today in IT and CE products.

Wiring already has requirements in a separate part of this clause.

Motors and transformers have their own flammability spread requirements and as such do not need a separate **enclosure** (see G.5.3 and G.5.4).

6.4.7 Separation of combustible materials from a PIS

Rationale: Where **potential ignition sources** are identified through classification and **single fault conditions**, separation from the ignition source by distance (material controls) or separation by barriers are used to limit the spread of fire from the ignition source and are necessary to ensure the ignition is not sustained.

6.4.7.2 Separation by distance

Source: IEC 60065

Rationale: The **safeguard** for materials within the fire cone includes material size control (and including prohibition on co-location of flammable parts). Otherwise the parts close to the **PIS** shall be **material flammability class V-1**, which limits sustained ignition and spread.

Small parts (less than 4 g) are considered too small to significantly propagate a fire. This value is also used for components used in PS2 and PS3 circuits. It has been used in IEC 60065 with good experience.

Where these distances are not maintained, a needle flame test option is included with 60 s needle flame application based on previous requirements in IEC 60065. This alternative to these distance requirements (the needle flame test) can be performed on the barrier to ensure that any additional holes resulting from the test flame are still compliant (openings that will limit the spread of fire through the barrier).

Redundant connections: An **arcing PIS** cannot exist where there are redundant or reliable connections as these connections are considered not to break or separate (thereby resulting in an arc).

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. Arcing is not considered to exist where the connections are redundant or otherwise deemed not likely to change contact resistance over time or through use. Some examples are given, but proof of reliable connections is left to the manufacturer and there is no specific criteria that can be given:

- Tubular rivets or eyelets that are additionally soldered – this assumes that the riveting maintains adequate contact resistance and the soldering is done to create a separate conductive path.
- Flexible terminals, such as flexible wiring or crimped device leads that remove mechanical stress (due to heating or use) from the solder joint between the lead and the printed wiring trace.
- Machine or **tool** made crimp or wire wrap connections – well-formed mechanical crimps or wraps are not considered to loosen.
- Printed boards soldered by auto-soldering machines and the auto-soldering machines have two solder baths, but they are not considered reliable without further evaluation. This means most printed boards have been subjected to a resoldering process. But there was no good connection of the lead of the component(s) and the trace of the printed board in some cases. In such cases, resoldering done by a worker by hand may be accepted.

Combustible materials, other than V-1 printed wiring boards are to be separated from each **PIS** by a distance based on the size of resulting ignition of the **PIS**. The flame cone dimensions 50 mm and 13 mm dimensions were derived from IEC 60065, where they have been used for several years with good experience. The area inside the cone is considered the area in which an open flame can exist and where material controls should be applied.

Resistive **potential ignition sources** are never a point object as presented in Figure 37 of IEC 62368-1. They are more generally three-dimensional components, however only one dimension and two-dimension drawings are provided. The three-dimensional drawing is difficult to understand and difficult to make accurate.

Figure 34 in this document shows how to cope with **potential ignition sources** that are 3D volumes. This drawing does not include the bottom part of the fire cone. The same approach should be used for the bottom side of the part.

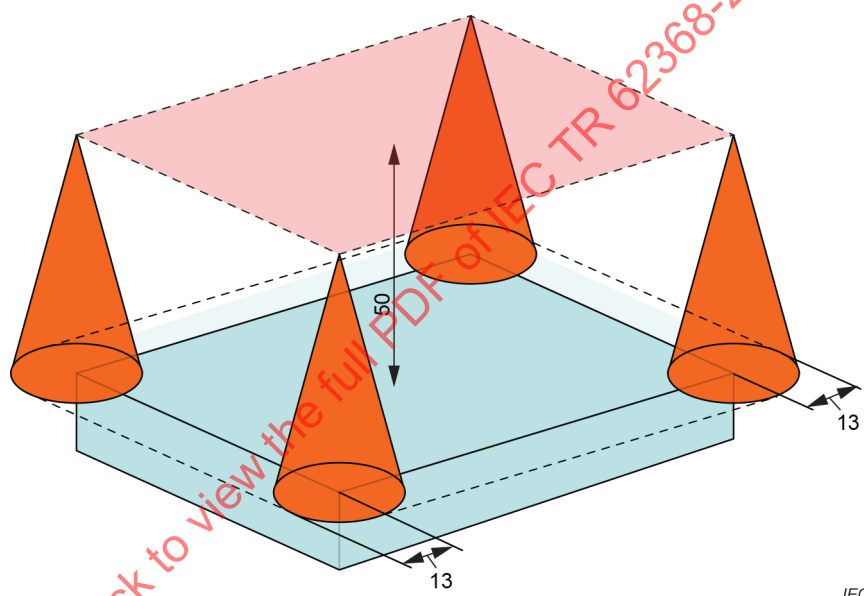


Figure 34 – Fire cone application to a large component

The fire cone is placed at each corner. The locus of the outside lines connecting each fire cone at both the top and the base defines the restricted volume.

Figure 37 Minimum separation requirements from a PIS

This drawing of a flame cone and its dimensions represents the one-dimension point ignition source drawn in two dimensions. The three-dimension envelope (inverted ice cream cone) of a flame from a **potential ignition source**. This **PIS** is represented as a point source in the drawing for clarity, however these **PISs** are more often three-dimensional components that include conductors and the device packaging.

Figure 38 Extended separation requirements from a PIS

A two-dimensional representation of an ignition source intended to provide more clarity.

6.4.7.3 Separation by a fire barrier

Source: IEC 60065

Rationale: The use of flame retardant printed wiring is considered necessary as the fuel and the electrical energy source are always in direct contact. V-1 has historically been adequate for this purpose.

Printed wiring boards generally directly support **arcing PIS** and as such, cannot be used as a barrier. There is a potential that small openings or holes may develop, thus permitting the arc to cross through the board.

A printed board can act as a barrier for an **arcing PIS**, provided the **PIS** is not directly mounted on the board acting as a barrier.

For **resistive PIS**, printed wiring boards can be used provided they are of V-1 or meet the test of Clause S.1. Any V-1 and less-flammable fuels are required to minimize the possibility flammable material falling onto the supporting surface or contact with combustible fuels (resulting in pool fires). If a **PIS** is located on a board and supplied by a PS2 or PS3 source, there should be no other PS2 or PS3 circuits near the **PIS**, as this could create faults due to **PIS** heating that was not otherwise considered.

Figure 39 Deflected separation requirements from a PIS when a fire barrier is used

This figure demonstrates the change on the fire cone when there is a fire barrier used to separate **combustible material** from a **potential ignition source**. This drawing was retained as an example application for only two angles. Recognizing that many examples are possible, only two are kept for practical reasons. History with multiple drawings of barriers in varying angles could be difficult to resolve. The fire team decided to keep only two drawings with an angle barrier as representative.

6.4.8 Fire enclosures and fire barriers

Rationale: The **safeguard** function of the **fire enclosure** and the fire barrier is to impede the spread of fire through the **enclosure** or barrier (see Table 13 in this document).

Table 13 – Fire barrier and fire enclosure flammability requirements

Flammability requirements		
Fire barrier	6.4.8.2.1	Fire barrier requirements Non- combustible material or Needle flame test Clause S.1 or $\geq$ V-1 class material or VTM-1 class material
	6.4.8.4	Separation of a PIS to a fire barrier - Distance $\geq$ 13 mm to an arcing PIS and - Distance $\geq$ 5 mm to a resistive PIS Smaller distances are allowed provided that the part of the fire barrier complies with one of the following: - Needle flame Clause S.2; After the test no holes bigger than in 6.4.8.3.3 and 6.4.8.3.4 allowed or $\geq$ V-0 class material
Fire enclosure	6.4.8.2.2	Fire enclosure materials: - Non-combustible, or - For $PS3 \leq 4\,000$ W, needle flame test Clause S.1 or V-1 class material - For $PS3 > 4\,000$ W, needle flame test Clause S.5 or 5VB class material
		Component materials which fill an opening in a fire enclosure or intended to be mounted in such opening - Comply with flammability requirements of relevant IEC component document; or $\geq$ V-1 class material; or - needle flame test Clause S.1
	6.4.8.4	Separation of a PIS to a fire enclosure - Distance $\geq$ 13 mm to an arcing PIS and - Distance $\geq$ 5 mm to a resistive PIS Smaller distances are allowed, provided that the part of the fire enclosure complies with one of the following: - Needle flame Clause S.2; After the test no holes bigger than in 6.4.8.3.3 and 6.4.8.3.4 allowed; or $\geq$ V-0 class material

6.4.8.2.1 Requirements for a fire barrier

Source: IEC 60065, IEC 60950-1

Rationale: Barriers used to separate **PIS** from flammable fuels reduce the ability of a resulting **PIS** flame from impinging on flammable materials. This can be achieved by using flame retardant materials that pass the performance test in Clause S.1 or the pre-selection criteria of a minimum V-1 flame class.

The test in Clause S.1 is based on the needle flame test which is currently an option for **enclosure** testing in both IEC 60950-1 and IEC 60065.

6.4.8.2.2 Requirements for a fire enclosure

Source: IEC 60065, IEC 60950-1

Rationale: The **material flammability class** V-1 was chosen as the minimum value based on its historical adequacy, and recent testing done during the development of the requirements for externally caused fire.

IEC 60950-1 – Prior requirements for **5 V class materials** based on product weight lacked sufficient rationale. This has been improved and related to power available to a fault in this document.

IEC 60065 – **V-2 class material** performance during large scale test reviewed by the fire team indicated inconsistencies in performance over a range of different V-2 materials. The propensity for **V-2 class materials** to create 'pool' fires is also detrimental to **fire enclosure** performance and therefore not accepted unless it passes the end-product testing.

In addition to pre-selection requirements, an end-product test (material test) is also included by reference to Clauses S.1 (for < 4 000 W) and S.5 (for > 4 000 W). This test is based on the needle flame test which is currently an option for **enclosure** testing in both IEC 60950-1 and IEC 60065.

This power (4 000 W) separation is also used in the control of fire spread method to delineate **safeguard** criteria for **fire enclosure** materials (V-1 versus 5 V). IEC 60950-1 has historically used weight to define **fire enclosure** criteria and it was felt the use of available power was more appropriate and generally reflective of current practice.

Both **5 VA** and **5 VB class materials** are considered acceptable for equipment with power above 4 000 W. This is consistent with current practice in IEC 60950-1.

6.4.8.2.3 Compliance criteria

Rationale: In each case there is a performance test, and construction (pre-selection) criteria given. For material flammability, compliance of the material is checked at the minimum thickness used as a **fire enclosure** or fire barrier.

6.4.8.3 Constructional requirements for a fire enclosure and a fire barrier

Rationale: Opening requirements for barriers and **fire enclosure** should limit the spread of flame through any existing opening. A **fire enclosure** limits the spread of fire beyond the equipment and is permitted to have holes (within established limits).

6.4.8.3.1 Fire enclosure and fire barrier openings

Rationale: These requirements are intended to reduce the spread of an internal fuel ignition through a **fire enclosure** or barrier.

Openings are restricted based on the location of each **potential ignition source** using the flame cones or in the case of control fire spread, above all PS3 circuits.

Figure 40 Determination of top, bottom and side openings

In the left figure, when the vertical surface has an inclination (angle) of less than 5° from vertical, then only the side opening requirements of 6.4.8.3.5 apply.

In the right figure, when the vertical surface has an inclination (angle) of more than 5° from the vertical, then the openings are subject to the requirements for top openings of 6.4.8.3.3 or bottom openings of 6.4.8.3.4.

6.4.8.3.2 Fire barrier dimensions

Rationale: Edges can be more easily ignited than a solid surface. Barrier dimensions shall also be sufficient to prevent ignition of the barrier edges.

Barriers made of non-combustible materials shall have edges that extend beyond the limits of the fire cone associated with each **potential ignition source**. If the barrier edge does not extend beyond the cone, then it is assumed the edges may ignite.

6.4.8.3.3 Top openings and top opening properties

Source: IEC 60065

Rationale: Top opening drawings are restricted in the areas of likely flame propagation to the side and above an ignition source.

Top openings are also considered to cover what has historically been called side opening where the opening is above the horizontal plane containing the ignition source.

The top/side openings that are subject to controls are only those within the fire cone drawing (Figure 37) plus a tolerance of 2 mm, as shown in Figure 41. The application of the fire cone dimensions has been used in IEC 60065 and proven historically adequate.

Control of openings above the flame cone is also not necessary given that the heat transfer (convection) will follow the gases moving through those openings and is not sufficient to ignite adjacent materials. If the openings are directly blocked, the convection path will be blocked which would restrict any heat transfer to an object blocking the opening.

Openings to the side of the fire cone dimensions were reviewed and ultimately not considered necessary as the radiant heat propagation through openings to the side of the ignition is very small. This radiant heat is not considered sufficient to ignite adjacent materials given the anticipated flame size and duration in AV and ICT products.

In this aspect, the virtual flame cone deflection as per Figure 39 need not be considered since the actual needle flame application will cover that.

The test method option proposed provides a test option for direct application of a needle flame. The test (S.2) referred to in this clause is intended to provide a test option where holes do not comply with the prescriptive measures. S.2 is originally intended to test the material flammability, but in this subclause the purpose of the test is to see the potential ignition of outer material covering the openings, so application of the needle flame is considered for that aspect rather than the burning property of the **enclosure** itself.

Cheesecloth is used as a target material for the evaluation of flame spread due to its flexible nature (ease of use) and its quick propensity to ignite.

The flame cone envelope is provided as a single point source. The applicable shape and any affecting airflow are taken into account for determining the whole shape of the **PIS**, not just a single point. The point is applied from the top edge of the component being considered and, in practice, it is rarely a single point.

The opening dimensions for the 5 mm and 1 mm dimensions have been determined through test as being restrictive enough to cool combustible gases as they pass through the openings and those mitigate any flame from passing through the opening. Top openings properties are based on tests conducted by the fire team with open flames (alcohol in a Petri dish) that demonstrated these opening dimensions are adequate.

6.4.8.3.4 Bottom openings and bottom opening properties

Source: IEC 60065, IEC 60950-1

Rationale: The location of openings is restricted for barriers inside the flame cone of Figure 37 and for **enclosures**, inside the cone and directly below to protect against flammable drips from burning thermoplastic as shown in Figure 42. The application of the fire cone dimensions has been used in IEC 60065 and proven historically adequate.

There are several options for opening compliance (see Table 14 in this document). Flaming oils and varnishes are not common in ICT equipment today. The performance test based on the hot flaming oil test, in use for IEC 60950-1, have other opening options and are developed based on lower viscosity materials (when burning). They are more commonly found in ICT (that provide additional options).

Clause S.3 (hot flaming oil test) is the base performance option and provides a test option (hot flaming oil test) that historically has been adequate for tests of bottom openings.

The values in items band c) come directly from IEC 60950-1 where they have been historically adequate and have demonstrated compliance with the S.3 performance testing. These requirements, previously from IEC 60950-1, 4.6.2 Bottoms of **fire enclosures**, have been updated in the third edition of IEC 62368-1. The IEC 60950-1 requirements are more stringent than the new IEC 62368-1 requirements and may still be used as an option without additional tests, which is likely since designs based on the IEC 60950-1 requirements have been in use for some time.

The work done to validate top openings was also considered adequate for bottom openings under materials of any properties (3 mm and 1 mm slots). This requirement is less onerous than those found in IEC 60950-1 which permitted NO openings unless they complied with the other options.

Openings under **V-1 class materials** (or those that comply with Clause S.1) are controlled in the same manner as done in IEC 60950-1 which was considered adequate however an additional option to use 2 mm slots of unlimited length is also considered adequate.

The 6 mm maximum dimension relates to a maximum square opening dimension of 36 mm² and a round opening of 29 mm². In IEC 60950-1 the requirement was 40 mm² which relates to a maximum 7 mm diameter if round or 6,3 mm maximum if not round.

The only option where flammable liquids are used is to meet the requirements of the hot flaming oil test (Clause S.3).

An option for equipment that is installed in special environments where a non-combustible flooring is used (environmental **safeguard**) may obviate the need for an equipment bottom **safeguard**. This is current practice in IEC 60950-1 where equipment is used in “restricted access locations”.

Baffle plate constructions were added, as they have been used in IEC 60950-1 and have proven to be an acceptable solution.

Table 14 – Summary – Fire enclosure and fire barrier material requirements

Parameters		Fire barrier	Fire enclosure	
			Input < 4 000 W	Input > 4 000 W
Combustible material:	Separation from PIS	13 mm or more from arcing PIS 5 mm or more from resistive PIS Note: exceptions may apply		
	Dimensions	Sufficient to prevent ignition of the edges	Not applicable	
	Flammability	a) Test S.1; or b) V-1; or c) VTM-1	a) Test S.1; or b) V-1	a) Test S.5; or b) 5 VA; or c) 5 VB
Non-Combustible material:		Acceptable		
Top openings		See 6.4.8.3.3		
Bottom openings		See 6.4.8.3.4		

6.4.8.3.5 Side opening and side opening properties

Source: IEC 60950-1

Rationale: For Edition 3, IEC TC 108/WG HBSDT agreed to adopt from IEC 60950-1:2005 (4.6.1, 4.6.2 and Figure 4E) the principles and criteria for determination of suitable side openings using a five (5) degree projection. The primary rationale for adopting these principles was the demonstration of many years of a solid safety record of use for ITE with IEC 60950-1. However, one issue that had to be resolved was that in IEC 60950-1 the 5-degree projection of Figure 4E was always made from the outer surface of a combustible internal component or assembly rather than a defined potential ignition source (PIS), typically a metallic circuit inside the component. The PIS principle was not inherent to IEC 60950-1.

For example, in a component or assembly, electrical or not, made of combustible material that might ignite within a fire enclosure, the 5-degree projection was made from the surface of the component or assembly closest to the side enclosure and not from a metallic circuit inside the component or subassembly that could be a potential source of ignition. Therefore, for example, if a printed board was considered the component/subassembly likely to ignite, the 5-degree projection was made from the edge of the printed board and not the current carrying trace, which in IEC 62368-1 is the **PIS**. In some cases throughout the history of IEC 60950-1, this distance from the metallic trace to component edge could have been up to several centimetres.

However, when IEC TC 108/WG HBSDT considered the common construction of internal components and subassemblies likely to be associated with a **PIS**, including printed boards, it was determined that it was reasonable to assume that in modern AV/ICT equipment the distance between the **PIS** and the outer edge of a component or sub-assembly was likely to have negligible impact on the overall fire safety of the product, in particular in the application of the 5 degree principle. Due to general miniaturization of products, material cost optimization, and modern design techniques (including CAD/CAM), printed boards and other electronic components and assemblies associated with a **PIS** typically do not use unnecessary amounts of combustible materials – modern printed boards more typically now have metallic traces very close to the board edge rather than many millimetres away.

As a result IEC TC 108/WG HBSDT considered that the IEC 60950-1 five (5) degree projection principle for side openings remained sound even if projected from the actual **PIS** rather than the edge of combustible material associated with the **PIS**. This view also is consistent with the Note to Figure 38, Extended separation requirements from a **PIS**, which states, for a resistive **PIS** “...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 surface of the component is used.”

6.4.8.3.6 Integrity of a fire enclosure

Source: IEC 60950-1

Rationale: The clause ensures that a **fire enclosure** where required, is assured to remain in place and with the product through either an equipment or behavioural **safeguard**. This requirement is a service condition **safeguard** for **ordinary persons** to ensure that a **fire enclosure** (if required) is replaced prior to placing the equipment back into use. This **safeguard** is also required in IEC 60950-1.

6.4.8.3.7 Compliance criteria

Rationale: In each case, there is a performance test, and construction (pre-selection) criteria given.

6.4.8.4 Separation of a PIS from a fire enclosure and a fire barrier

Source: IEC 60065, IEC 60950-1

Rationale: Non-metallic **fire enclosures** and fire barriers may not be sufficient to limit the spread of fire where an **enclosure** is close or in direct contact with a **potential ignition source**.

The 13 mm and 5 mm distances were used in IEC 60065 to prevent an ignition source from transferring sufficient energy to adjacent flame-retardant V-1 barriers. These distances are intended to reduce the likelihood of melting or burn-through of the barrier of **fire enclosure**.

Where these distances are not maintained, a needle flame test option is included with 60 s needle flame application based on work in IEC 60065.

Openings following the needle flame test were discussed with criteria being:

- a) no additional opening,
- b) no enlargement of existing holes,
- c) compliance with the **fire enclosure** opening requirements.

Due to test repeatability, the criteria of a) are considered most readily reproduced.

The option to use **V-0** or **5 V class materials** without distance or thickness requirements is based on historical practices in IEC 60065 and IEC 60950-1 where no distance requirements were applied.

The material thickness requirements where ignition sources are in close proximity to a barrier were not included based on discussions in IEC TC 108 and current practice for IEC 60950-1 **enclosures**. There is fire test data (barrier testing from IEC 60065) indicating that 2 mm thick (or greater) V-0 barriers and 5 VA barriers have sufficient flame resistance to minimize a risk of creating openings when used in direct contact with **PIS**'s. Good HWI or HAI tests are not available internationally to address the distance from ignition sources to **fire enclosure** and barriers. The fire team has chosen to use the needle flame test as a surrogate test (similar to that done for barriers).

6.5.1 General requirements

Source: IEC 60332-1-2, IEC 60332-2-2

Rationale: Wiring flammability proposals have now been included for all wiring (external and internal).

Compliance with IEC 60332-1-2 for large wires and IEC 60332-2-2 for small wires has historically proven adequate for **mains** wiring. These documents include their own material flammability requirements.

The requirements of IEC TS 60695-11-21 are also considered adequate given that the flame spread requirements for vertical testing are more onerous than the IEC 60332 series of documents.

The compliance criteria are based on application of the above test methods. These are consistent with international wiring standards. National standards may have more onerous requirements.

6.5.2 Requirements for interconnection to building wiring

Source: IEC 60950-1:2005

Rationale: Externally interconnected circuits that are intended for connection to unprotected building wiring equipment can receive sufficient power from the product to cause ignition and spread of fire with the building wall, ceiling, or remotely interconnected equipment. These requirements limit the power available to connectors/circuits intended for interconnection to specific types of wiring where the product is responsible for protection of that wiring.

Where a circuit is intended for connection to equipment that is directly adjacent to the equipment, 6.6 prescribes the appropriate **safeguards** and limits associated for PS2 and PS3 sources.

Telecommunication wiring is designed based on the expected power from the network. The requirements of IEC 60950-1 were considered adequate and were included. Wiring in this application should be equivalent to 0,4 mm diameter wiring (26 AWG) and have a default 1,3 A current limit established. This value has been used in IEC 60950-1 for the smaller telecommunication wiring.

For some building wiring, the PS2 and PS3 **safeguards** are not considered adequate in some countries for connection to building wiring where that wiring is run outside of the conduit or other **fire protective enclosures**. The requirements for this clause come directly from requirements in IEC 60950-1, 2.5 for circuits identified as limited power circuits. These requirements have proven to be historically adequate for connection of IT equipment to building wiring in these jurisdictions.

The values used and protection requirements included in IEC 60950-1 and included in Annex Q.1 came from the building and fire codes requiring this protection.

These requirements do not apply to connectors/circuits intended for interconnection of peripheral equipment used adjacent to the equipment.

This requirement is also important for the use of ICT equipment in environments subject to electrical codes such as National Fire Protection Association NFPA 70, which permit the routing of low power wiring outside of a fire containment device.

Annex Q.1 was based on requirements from IEC 60950-1 that are designed to comply with the **external circuit** power source requirements necessary for compliance with the electrical codes noted above.

6.6 Safeguards against fire due to the connection of additional equipment

Source: IEC 60950-1

Rationale: This subclause addresses potential fire hazards due to the connection of accessories or other additional equipment to unknown power source classifications. Most common low-voltage peripherals are not evaluated for connection to PS3 and therefore power sources should be identified. This is a current requirement of IEC 60950-1.

Where the interconnected devices are known (device requirements are matched to the appropriate power source), this requirement for **safeguard** is not necessary.

7 Injury caused by hazardous substances

Rationale: The majority of chemical injuries arise from inhalation or ingestion of chemical agents in the form of vapours, gases, dusts, fumes and mists, or by skin contact with these agents (see Table 15 in this document). The degree of risk of handling a given substance depends on the magnitude and duration of exposure. These injuries may be either acute or chronic.

Many resins and polymers are relatively inert and non-toxic under normal conditions of use, but when heated or machined, they may decompose to produce toxic by-products.

Toxicity is the capacity of a material to produce injury or harm when the chemical has reached a sufficient concentration at a certain site in the body.

Potentially hazardous chemicals in the equipment are either:

- as received in **consumable material** or items, such as printer cartridges, toners, paper, cleaning fluids, **batteries**;
- produced under **normal operating conditions** as a by-product of the normal function of the device (for example, dust from paper handling systems, ozone from printing and photocopying operations, and condensate from air conditioning/de-humidifier systems); or
- produced under **abnormal operating conditions** or as a result of a fault.

It is essential to:

- determine what substances are present in relative amounts in the equipment or could be generated under **normal operating conditions**; and
- minimize the likelihood of injury to a person due to interaction with these substances.

NOTE In addition to their potential toxicity, loss of containment of chemical materials may cause or contribute to failure of **safeguards** against fire, electric shock, or personal injury due to spillages.

The number of different chemical materials that may be used in the wide variety of equipment covered by this document makes it impossible to identify specific hazards within the body of this document. Information needs to be sought by equipment manufacturers from the material suppliers on the hazards associated with their products and their compliance with any national and/or governmental regulations on the use and disposal of such materials.

Energy source:

The energy source for most chemically-caused injuries is ultimately the ability of a material to chemically react with human tissue, either directly or indirectly. The exception would be inert materials that can damage tissues by preventing them from functioning by limiting certain chemical reactions necessary for life. An example of this would be types of dust, which do not react with lung tissue, but prevent air from reaching the bloodstream. The reactions may be very energetic and damaging, such as acids on the skin, or can be very slow, such as the gradual build-up of substances in human tissues.

Transfer mechanism:

Transfer can only occur when chemical energy makes contact with human tissue. The routes for contact with human tissue are through the skin [or any outer membrane such as the eyes or nasal lining] (absorption), through the digestive tract (digestion), or through the lungs (inhalation). The route taken will depend largely on the physical form of the chemical: solid, liquid, or gas.

Injury:

An injury can be either acute or chronic. Acute injuries are injuries with immediate and serious consequences (for example, a strong acid in the lungs) or the injury can be mild and result in irritation or headache. Chronic injuries are injuries with long term consequences and can be as serious as acute injuries (for example, consequences of long-term exposure to cleaning solvents).

In most cases, the difference is the quantity and lethality of the toxic substance. A large amount of acetone can lead to death; a small amount may simply result in a headache. Many chemical compounds essential to life in small quantities (for example, zinc, potassium and nickel) can be lethal in larger amounts. The human body has different degrees of tolerance for different **hazardous chemical substances**. Exposure limits may be controlled by government bodies for many chemical substances. Where the use of **hazardous chemical substances** in equipment cannot be avoided, **safeguards** shall be provided to reduce the likelihood of exceeding the exposure limits.

The different types of chemical hazards are identified in Table 15 and Figure 35 in this document demonstrating the hierarchy of hazard management.

Table 15 – Control of chemical hazards

Transfer mechanism	Prevention / safeguards
Ingestion, inhalation, skin contact, or other exposure to potentially hazardous chemicals	Hierarchy of hazard management: 1. Eliminate the chemical hazard by avoiding the use of the chemical. 2. Reduce the chemical hazard by substitution of a less hazardous chemical. 3. Minimize the exposure potential of the chemical by containment, ventilation and/or reduced quantities of the chemicals. 4. Use of personal protective equipment (PPE). 5. Provide use information and instructional safeguards.
Exposure to excessive concentrations of ozone during equipment operation	Hierarchy of hazard management: 1. Where possible, minimize the use of functions that produce ozone. 2. Provide adequate room ventilation. 3. Provide filtration to remove ozone.
Explosion caused by chemical reaction during use	Hierarchy of hazard management: 1. Eliminate the explosive charge. 2. Reduce the amount of explosive charge to the least amount possible. 3. Minimize hazard by the means of vents. 4. Provide use information and instructional safeguards.

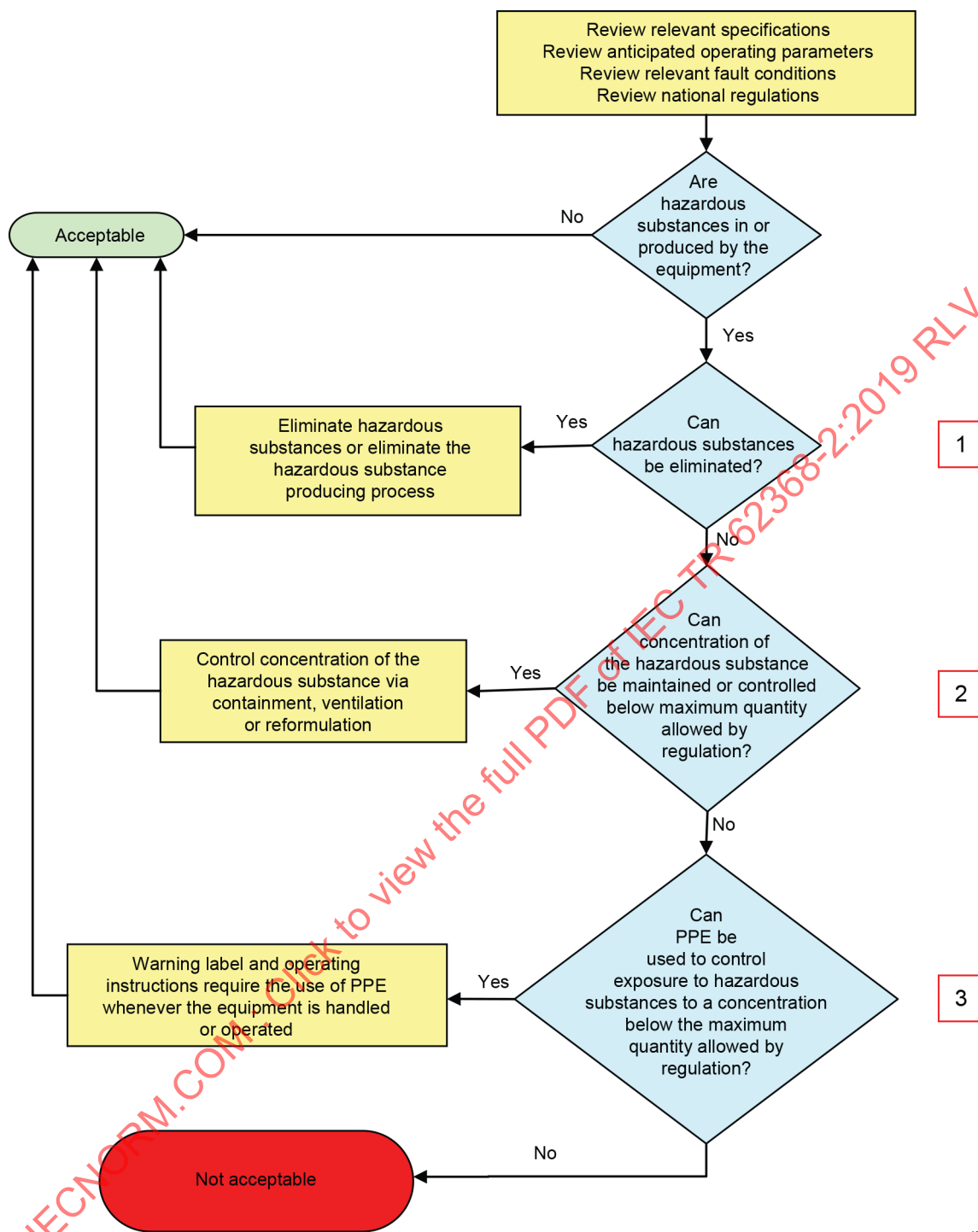


Figure 35 – Flowchart demonstrating the hierarchy of hazard management

Chemical hazards may also degrade or destroy the **safeguards** provided for other hazards such as fire and electric shock (for example, ozone attack on electrical insulation or corrosion of metallic parts). Chemical spillages or loss of containment can also lead to other hazards such as electric shock or fire depending on the location of any spillage and proximity to electric circuits. The same methods used for chemical health exposure control should also protect against such liquid spillages.

Using a hazard-based engineering approach, Figure 36 in this document shows the main types of chemical health hazards and their transfer mechanisms.

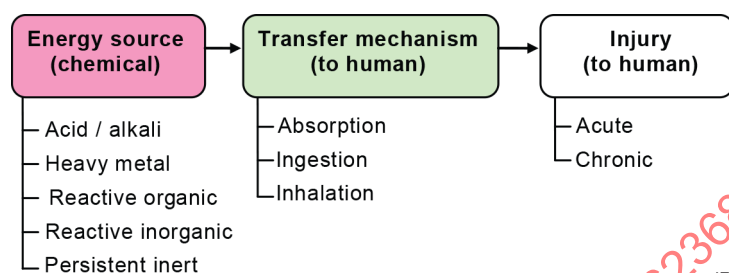


Figure 36 – Model for chemical injury

8 Mechanically-caused injury

8.1 General

Rationale: Mechanically caused injury such as cuts, bruises, broken bones, etc., may be 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.

8.2 Mechanical energy source classifications

Purpose: To differentiate between mechanical energy source levels for **normal operating conditions**, **abnormal operating conditions** and **single fault conditions** applicable to each type of person.

8.2.1 General classification

Table 35 – Classification for various categories of mechanical energy sources

Line 3 – Moving fan blades

Rationale: The acceptance criteria is based upon any number of factors such as location, but the key factor for judging acceptance is based upon the K factor, the relationship between mass (m) in kg, radius (r) in mm and speed (N) in rpm. This relationship can be used to find the K factor for the fan. Fans with a low K factor and low speeds are considered safer. See Figure 45 and Figure 46 for MS1 values. An MS2 fan requires an **instructional safeguard** in addition to the limitation on the K factor value and the speed of the fan. The need for the relevant **safeguard** is based on the classification of fans. The K factor formula is taken from the UL standard for fans, UL 507 (which is based on a University of Waterloo study of fan motors).

Single fault condition on a fan includes, but is not limited to, inappropriate input voltage due to the fault of a voltage regulator located upstream.

As plastic fan blades are regarded less hazardous than metal fan blades, different values are used to determine separation between energy class 2 and class 3.

Typical parameters for fans used in products covered by this document are as follows:

fan mass (m) = about 25 g or 0,025 kg;

fan diameter (r) = 33 mm;

fan speed (N) = 6 000 rpm (maximum speed when the system is hottest, slower if the system is cool).

Line 4 – Loosening, exploding or imploding parts

Rationale: IEC TC 108 has tried to come up with specific requirements for solid rotating media. However, the result became too complex to be useful at this time.

Line 5 – Equipment mass

Rationale: The values chosen align with some commonly used values today. However, it is noticed that these are not completely reflecting reality and not a very good hazard-based approach. IEC TC 108 plans to work on these values in the future.

Line 6 – Wall/ceiling or other structure mount

Rationale: The values chosen align with some commonly used values today. However, it is noticed that these are not completely reflecting reality and not a very good hazard-based approach. IEC TC 108 plans to work on these values in the future.

Notes b and c

Rationale: The current values are based on experience and basic safety publications.

8.2.2 MS1

Rationale: Safe to touch. No **safeguard** necessary.

8.2.3 MS2

Rationale: Contact with this energy source may be painful, but no injury necessitating professional medical assistance occurs, for example, a small cut, abrasion or bruise that does not normally require professional medical attention. A **safeguard** is required to protect an **ordinary person**.

8.2.4 MS3

Rationale: An injury may occur that is harmful, requiring professional medical assistance. For example, a cut requiring stitches, a broken bone or permanent eye damage. A double or **reinforced safeguard** is required to protect an **ordinary person** and an **instructed person**.

8.3 Safeguards against mechanical energy sources

Purpose: To determine the number of **safeguards** needed between the type of person and the relevant energy source classification.

Rationale: An **instructional safeguard** describing hazard avoidance may be employed to circumvent the **equipment safeguard** permitting access to MS2 part locations to perform an **ordinary person** service function. The **instructional safeguard** indicates that the **equipment safeguard** be restored after the service activity and before power is reconnected. When an **instructional safeguard** is allowed, a warning is also required to identify insidious hazards.

For an **instructed person** and a **skilled person**, an **instructional safeguard**, in the form of a warning marking, is necessary to supplement the instruction they have received to remind them of the location of hazards that are not obvious.

However, for a **skilled person**, an **equipment safeguard** is required in the service area of large equipment with more than one level 3 energy sources, where the **skilled person** can insert their entire head, arm, leg or complete body. This **safeguard** is intended to protect the **skilled person** against unintentional contact with any other level 3 energy source due to an involuntary startle reaction to an event in the equipment while servicing intended parts.

The involuntary reaction may occur for a number of reasons, such as an unexpected loud noise, an arc flash or receipt of a shock, causing the person to recoil away from the energy source or part being serviced. Where more than one of the level 3 energy sources may require servicing at some time, removable **equipment safeguards** shall be designed such that any level 3 sources not being serviced can remain guarded. The **equipment safeguards** for this purpose only need to protect against larger body contact, since the potential involuntary recoil reaction will likely be full limb or body and not small body parts.

8.4 Safeguards against parts with sharp edges and corners

Rationale: Engineering judgment shall be used to class a mechanical energy source as MS1, MS2 or MS3 and an appropriate **safeguard** shall be provided. Where a MS2 or MS3 cannot be fully guarded without interfering with the intended function of the equipment, it shall be guarded as much as practical. Such an energy source shall not be **accessible** to children and be obvious to an adult. **Instructional safeguards** shall be provided to warn the person about potential contact with the energy source and what steps to take to avoid unintentional contact.

We rely on engineering judgment as there are too many variables involved to define the type of edge or corner combined with the applied force and direction of contact or to provide specific values.

8.5 Safeguards against moving parts

Rationale: **Enclosures** and barriers protect against access to hazardous moving parts. See 8.5.1 for the exception of requirements related to parts not fully guarded because of their function in the equipment.

8.5.1 Requirements

Rationale: The MS2 or MS3 energy sources need to be guarded against accidental access by a person's extremities, jewellery that may be worn, hair and clothing, etc. Access is determined by applying the appropriate **tool** from Annex V, and no further testing is necessary. We note that while it may be technically possible for some jewellery and hair to enter an opening smaller than the test finger, in such cases, the jewellery strands would have to be very thin and flexible enough to enter (as would a few strands of hair). As such while some pain may result if they happen to be caught in the mechanical device, it is deemed unlikely an injury would occur as described by this document. The residual risk can be considered a MS2 energy source at most.

8.5.4.3 Equipment having an electromechanical device for destruction of media

Source: UL/CSA 60950-1 second edition [national difference]

Rationale: Recent large scale introduction of media shredders into the home environment resulted in an increase of children being injured when inserting their fingers through the shredder openings. These incidents were studied and a new probe was developed to assess potential access by children. The new probe/wedge has been designed for both application with force when inserted into the shredder openings and assessment of access to MS3 moving parts by a population consisting of both adults and children. This design differs from the existing UL and IEC accessibility probes since the UL Articulated Accessibility Probe is not intended to be used with a force applied to it, and the current IEC probes, while having an unjointed version for application under force, do not adequately represent the population for both adults and children.

Because cross-cut shredders typically apply more force to the media than straight-cut shredders, the requirements include differentiated application forces for the two designs. The force values consider typical forces associated with straight-cut and cross-cut designs, taking into account data generated by the USA Consumer Product Safety Commission on typical pull forces associated with both strip type and crosscut type shredders.

The dimensions of the new probe/wedge are based on the data generated during the development of the UL Articulated Accessibility Probe. However, the dimensions of the UL Articulated Accessibility Probe were defined in consideration of causal handling of products. Because of this, the 95th percentile points from the data were used to define the UL Articulated Accessibility Probe. The thickness and length dimensions of the new proposed probe/wedge have been developed in consideration of all data points. Articulation points are identical to those for the UL Articulated Accessibility Probe.

8.6 Stability of equipment

Source: IEC 60950-1 and IEC 60065

Purpose: To align existing practice with the MS1, MS2 and MS3 energy.

Rationale: Equipment weighing more than 25 kg is considered MS3. Regardless of weight, equipment mounted to the wall or ceiling is considered MS3 when it is to be mounted above 2 m height.

Equipment weighing between 7 kg and not exceeding 25 kg is considered MS2. Equipment with a weight of 1 kg or more and that is mounted to the wall or ceiling to a maximum height of 2 m is also considered MS2.

Equipment with weight not exceeding 7 kg is considered MS1 if floor standing, but can be either MS2 or MS3 if mounted to the wall or ceiling. Also see carts and stands, and wall or ceiling mounted equipment.

Children are naturally attracted to moving images and may attempt to touch or hold the image by pulling or climbing up on to the equipment. The tests assess both the static stability and mounting grip when placed on a slippery surface such as glass. Children might also misuse controls that are readily available to them.

8.6.2.2 Static stability test

Rationale: Equipment is assessed for stability during expected use by applying force horizontally and downward on surfaces that could be used as a step or have other objects placed upon it.

The value of 1,5 m was chosen as the maximum height where an average person could lean on or against the product.

The 1,5 m is also used for table top equipment, since we do not know whether the product is going to be placed on a table or, if so, what the height of the table will be.

8.6.2.3 Downwards force test

Rationale: The height of 1 m represents the maximum height one could expect that people could try to use as a step to reach something.

8.6.3 Relocation stability

Source: IEC 60950-1 and IEC 60065

Rationale: The 10° tilt test simulates potential horizontal forces applied to the equipment either accidentally or when attempting to move the equipment. In addition it simulates moving the equipment up a ramp during transport.

The test on the horizontal support may be necessary (for example, for equipment provided with small feet, casters or the like).

8.6.4 Glass slide test

Source: IEC 60065:2011

Purpose: To address the hazard of equipment with moving images sliding off a smooth surface when a child attempts to climb onto the equipment.

Rationale: To ensure the display does not slide too easily along a smooth surface that could result in the display falling from an elevated height on to a child.

8.6.5 Horizontal force test and compliance criteria

Purpose: To simulate the force of a child climbing up on to equipment with front mounted user controls or with moving images.

Rationale: Field data and studies in the US have shown that children 2-5 years of age were attracted to the images on the display that may result in the child climbing onto the display to touch/get close to the image. The equipment could then tip over and crush the child. Also, products with **accessible** controls or that are shorter than 1 m in height are considered likely to be handled by children.

- Data was gathered in the 1986 to 1998 for CRT TV sets ranging from 48,26 cm to 68,58 cm (19 to 27 inches). The average horizontal force was 13 % of the equipment weight.

- The 15° tilt test (an additional 5° over static stability test) provides an additional safety factor.

8.7 Equipment mounted to a wall, ceiling or other structure

Source: IEC 60065 and 60950 series

Purpose: The objective of this subclause is to minimize the likelihood of injury caused by equipment falling due to failure of the mounting means.

Rationale: Equipment intended to be mounted to a wall or ceiling should be tested to ensure adequacy for all possible mounting options and all possible failure modes. For typical equipment, such as flat panel televisions, mounting bosses are usually integrated into the equipment and used with an appropriate wall or ceiling mounting bracket to attach to a wall or ceiling. Typical mounting bosses are comprised of threaded inserts into the rear panel of the equipment.

The appropriate load is divided by the number of mounting means (for example, mounting bosses) to determine the force applied to each individual mounting means.

The horizontal force values of 50 N and 60 s have been successfully used for products in the scope of these documents for many years.

8.7.2 Test methods

Figure 37 in this document gives a graphical view of the different tests required by Test 2 and show the directions that the forces are applied.

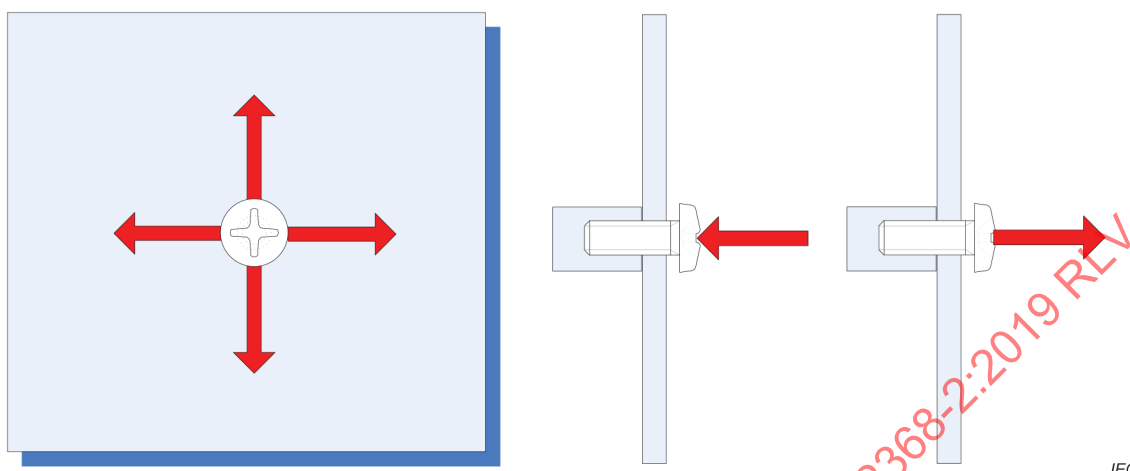


Figure 37 – Direction of forces to be applied

Table 37 Torque to be applied to screws

Source: IEC 60065

Rationale: These torque values have been successfully used for products in the scope of this document for many years.

8.8 Handle strength

Source: IEC 60065 and IEC 60950-1

Rationale: A handle is a part of the equipment that is specifically designed to carry the equipment or subassembly around. A grip which is made for easy removal or placement of a subassembly in an equipment is not considered to be a handle.

The 75 mm width simulates the hand width. The safety factors take into account the acceleration forces and additional stresses that could be applied due to extra weight on top of the equipment when being lifted. The safety factor is less at the higher weight (MS3) because the equipment would be lifted more slowly, reducing the acceleration force, and there is less probability that extra weight would be added before lifting, as this would exceed the normal weight to be lifted by one person without assistance of a **tool**. Equipment classed as MS1 with more than one handle could be used to support additional objects when being carried and should be tested.

8.8.2 Test method

Rationale: There is no test for MS1 with only one handle. Having 2 handles facilitates transporting the equipment while carrying additional objects adding stress to the handles.

8.9 Wheels or casters attachment requirements

Purpose: To verify that wheels or casters are securely fixed to the equipment.

Source: UL 1667

Purpose: For wheel size, reduce the likelihood of the equipment on the cart or stand tipping while being moved from room to room where the wheels may encounter a variety of obstacles, such as: friction of different surfaces (for example, transition from a hard surface over carpet edging), cables, and doorway sills.

Rationale: The 100 mm min wheel size was found to be adequate to enable rolling over these obstacles without abruptly stopping that could cause the cart or stand to tip, or the equipment located on the cart or stand to slide off.

8.10 Carts, stands, and similar carriers

Source: UL 60065

Rationale: To avoid tipping, the 20 N test simulates cart wheels being unintentionally blocked during movement.

8.10.1 General

Source: IEC 60065

Rationale: A wheel of at least 100 mm diameter can be expected to climb over usual obstacles such as electrical cords, door jams, etc., and not be halted suddenly.

8.10.2 Marking and instructions

Rationale: Various means of marking may apply depending on the method of associating the equipment with a particular cart, stand or similar carrier.

8.10.3 Cart, stand or carrier loading test and compliance criteria

Source: IEC 60065

Purpose: To verify that a cart or stand can withstand foreseeable overloading without creating a hazardous situation.

Rationale: The 220 N force simulates the weight of a small child approximately 5 years of age, who may attempt to climb onto the cart or stand. The 30 mm circular cylinder simulates a child's foot. The 750 mm height is the approximate access height of the 5-year-old child. The additional 440 N force test simulates potential additional materials or equipment being placed on the cart or stand. The additional 100 N simulates overloading by the user. Testing has been limited to 1 min as experience has shown that the likelihood of a test failure will occur within that time.

8.10.4 Cart, stand or carrier impact test

Purpose: To verify that a cart or stand can withstand a foreseeable impact without creating a hazardous situation.

Source: IEC 60065 and IEC 60950 series

Rationale: The 7 joules simulate intentional and accidental contact with the equipment and come from the T.6 **enclosure test**.

8.10.5 Mechanical stability

Purpose: To verify that a cart or stand remains stable under specified loading. The equipment installed on the cart may come loose, but not fall off the cart.

Rationale: The weight of the force test is reduced to 13 % should the equipment on the cart or stand move, as the equipment would then be considered separately from the cart or stand. When the equipment does not move during the force test, together they are considered a single unit.

8.10.6 Thermoplastic temperature stability

Source: IEC 60065 and IEC 60950-1

Rationale: Intended to prevent shrinkage, relaxation or warping of materials that could expose a hazard.

8.11 Mounting means for slide-rail mounted equipment (SRME)

8.11.1 General

Source: UL/CSA 60950-1 second edition

Rationale: The potential hazardous energy source is a product that contains significant mass, and which is mounted on slide-rails in a rack. A joint US/Canadian Adhoc researched and developed these requirements based on hazard-based assessment and tests.

The center of gravity was chosen to apply the downward force because in general, when installing equipment in a rack, it is foreseeable that previously installed equipment of similar size/mass may be pulled out into the service position (fully extended) and used to set the new equipment on while positioning and installing the new slide/rails. In this scenario, it is not likely that the new equipment would be significantly off-centre from the installed equipment that it is being set on.

Vertically mounted SRMEs are not addressed in this document.

8.11.3 Mechanical strength test

Purpose: To simulate temporary placement of another server on top of an existing one during installation of the new one. So the test is the downward force.

Rationale: 50 % of the equipment mass is derived from the mass of the equipment, and a 50 % tolerance allowed for manufacturing differences in the rails which effectively adds a safety buffer.

The 330 N to 530 N additional force accounts for equipment that is about to be installed in a rack being placed or set on a previously installed piece of equipment where the previously installed equipment is being used as a temporary shelf or work space. It is estimated that 530 N is the maximum mass of equipment allowed to be safely lifted by two persons without the use of mechanical lifting devices. Equipment having a mass greater than 530 N will have mechanical lifting devices and it is therefore unlikely that the equipment being installed will be set on any equipment previously installed in the rack.

Taking the actual installation environment into consideration, an additional force is limited to maximum 800 N (average weight of an adult man) that is same value as the downward test force in 8.6.2.3. The 800 N value comes from IEC 60950-1:2005, 4.1 Stability.

8.11.3.2 Lateral push force test

8.11.3.3 Integrity of slide rail end stops

Source: UL/CSA 60950-1 second edition

Purpose: To simulate maintenance on the server itself, by smaller applying forces equivalent to what is expected during subassembly and card replacement, etc. So this also tests the laterally stability of the slide rails. It is not necessary to retest the downward vertical force if it is already tested for 8.11.3, but that should be common sense when preparing a test plan.

The cycling of the slide rail after the tests ensures they have not been bent in a way that could easily fly apart after the service operation.

Rationale: The 250 N force is considered a force likely to be encountered during servicing of the equipment, and normal operations around equipment. The force is partially derived from the existing IEC 60950-1:2005, 4.1, and partially from research into normally encountered module plug forces seen on various manufacturers' equipment. The application of force at the most unfavourable position takes into account the servicing of a fully extended piece of equipment, leaning on or bumping into an extended piece of equipment and other reasonably foreseen circumstances which may be encountered.

9 Thermal burn injury

9.1 General

Source: ISO 13732-1:2006 and IEC Guide 117

Rationale: **A General**

A burn injury can occur when thermal energy is conducted to a body part to cause damage to the epidermis. Depending on the thermal mass of the object, duration of contact and exposure temperature, the body response can range from perception of warmth to a burn.

The energy transfer mechanism for equipment typically covered by the document is via conduction of thermal energy through physical contact with a body part.

The likelihood of thermal injury is a function of several thermal energy parameters including:

- temperature difference between the part and the body;
- the thermal conductivity (or thermal resistance) between the hot part and the body;
- the mass of the hot part;
- the specific heat of the part material;
- the area of contact;
- the duration of contact.

B Model for a burn injury

A skin burn injury occurs when thermal energy impinges on the skin and raises its temperature to a level that causes cell damage. The occurrence of a burn will depend on several parameters. The hazard based three block model applied to the occurrence of a burn (see Figure 38 in this document) takes account of not just the temperature of the source, but its total thermal energy, which will depend on its temperature (relative to the skin), as well as its overall heat capacity. The model also takes account of the energy transfer mechanism, which will depend on the thermal conductivity between the body and the thermal source as well as the area and duration of contact. The occurrence and severity of a burn will depend on the amount of thermal energy transferred.

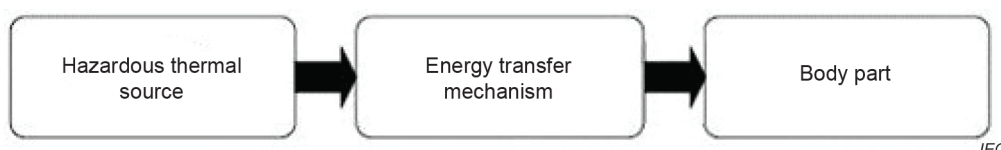


Figure 38 – Model for a burn injury

Normally, the energy transfer mechanism from the energy source to a body part is through direct contact with the body part and sufficient contact duration to allow transfer of thermal energy causing a burn. The higher the temperature of the thermal source and the more efficient the transfer mechanism, the shorter the contact time becomes before the occurrence of a burn. This is not a linear function and it is dependent on the material, the temperature and the efficiency of the thermal transfer. The following examples demonstrate the impact of this non-linear relationship to short-term/high temperature and longer term/lower temperature contact burns.

Example 1: An **accessible** metal heat sink at a temperature of 60 °C may have sufficient energy to cause a burn after contact duration of about 5 s. At a temperature of 65 °C, a burn may occur after contact duration of just 1,5 s (see IEC Guide 117:2017, Figure A.1). As the temperature of the metal surface increases, the contact time necessary to cause a burn decreases rapidly.

Example 2: Consider a thermal source with low to moderate conductivity such as a plastic **enclosure**. At a temperature of 48 °C, it may take up to 10 min for the transfer of sufficient thermal energy to cause a burn. At 60 °C, a burn may occur after contact duration of just 1 min (see IEC Guide 117:2010, Table A.1). Although the temperature of the source has increased by just 25 %, the contact time necessary to cause a burn threshold has decreased by 90 %.

In practice, the actual thermal energy and duration of exposure required to cause a burn will also depend on the area of contact and condition of the skin. For simplification of the model and based upon practice in the past, it is assumed that the contact area will be ≤ 10 % of the body and applied to healthy, adult skin.

As a general rule, low temperature devices are likely to cause a heating or pain sensation before causing a significant burn to which **ordinary persons** will normally respond (see ISO 13732-1:2009, Note of 5.7.3). Requirements for persons with impaired neurological systems are not considered in this document but may be considered in the future.

NOTE 1 The impact of surface area contact is not being addressed in this paper at this time and is an opportunity for future work. Use and coverage of large contact areas as might occur in medical applications of heating pads covering more than 10 % of the body surface are outside the scope of this document, as this type of application is more appropriate to medical device publications.

NOTE 2 The pressure of the contact between the thermal source and the body part can have an impact on the transfer of thermal energy. Studies have shown this effect to have appreciable impact at higher pressures. For typical pressures associated with casual contact up to a pressure of 20 N the effect has been shown to be negligible, and thus contact pressure is not considered in this document (Ref: ATSM C 1055, X1.2.3.4, ASTM C 1057,7, Note 10).

NOTE 3 Considerations for burns generated by infrared (IR), visible, ultra violet light radiation and RF radiation sources are outside the scope of Clause 9 dealing with thermal burn injury.

C Types of burn injuries

Burn injuries are commonly classed as first degree, second degree or third degree in order of increasing severity:

First degree burn: the reaction to an exposure where the intensity or duration is insufficient to cause complete necrosis of the epidermis. The normal response to this level of exposure is dilation of the superficial blood vessels (reddening of the skin). No blistering occurs. (Reference: ASTM C1057)

Second degree burn: the reaction to an exposure where the intensity and duration is sufficient to cause complete necrosis of the epidermis but no significant damage to the dermis. The normal response to this exposure is blistering of the epidermis. (Reference: ASTM C1057)

Third degree burn: the reaction to an exposure where significant dermal necrosis occurs. Significant dermal necrosis with 75 % destruction of the dermis is a result of the burn. The normal response to this exposure is open sores that leave permanent scar tissue upon healing. (Reference: ASTM C1057)

ISO 13732-1, 3.5 classifies burns as follows:

Superficial partial thickness burn – In all but the most superficial burns, the epidermis is completely destroyed but the hair follicles and sebaceous glands as well as the sweat glands are spared.

Deep partial thickness burn: a substantial part of the dermis and all sebaceous glands are destroyed and only the deeper parts of the hair follicles or the sweat glands survive.

Whole thickness burn: when the full thickness of the skin has been destroyed and there are no surviving epithelial elements.

Although there is some overlap between the classifications in ASTM C1057 and those in IEC Guide 117, the individual classifications do not correspond exactly with each other. Further, it should be noted that the classifications of burns described here is not intended to correspond with the individual thermal source classifications (TS1, TS2, and TS3) described later in this document.

D Model for safeguards against thermal burn injury

To prevent thermally-caused injury, a **safeguard** is interposed between the body part and the energy source. More than one **safeguard** may be used to meet the requirements for thermal burn hazard protection.



Figure 39 – Model for safeguards against thermal burn injury

To prevent thermally-caused injury, a **safeguard** is interposed between the body part and the energy source (see Figure 39 in this document). More than one **safeguard** may be used to meet the requirements for thermal burn hazard protection.

Safeguards overview

This section shows examples of the different types of **safeguards** that may be applied:

a) Thermal hazard not present

The first model, in Figure 40 in this document, presumes contact to a surface by an **ordinary person** where a thermal hazard is not present. In this case, no **safeguard** is required.



Figure 40 – Model for absence of a thermal hazard

b) Thermal hazard is present with a physical safeguard in place

The second model, see Figure 41 in this document, presumes some contact with a surface by an **ordinary person**. The thermal energy source is above the threshold limit value for burns (Table 38 of IEC 62368-1:2018), but there are **safeguards** interposed to reduce the rate of thermal energy transferred such that the surface temperature will not exceed the threshold limit values for the expected contact durations. Thermal insulation is an example of a physical **safeguard**.

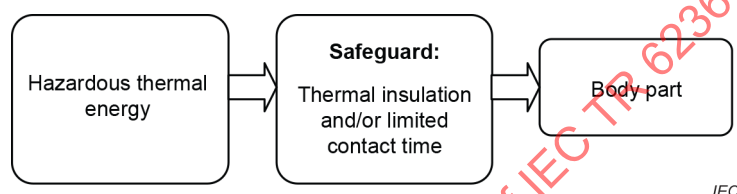


Figure 41 – Model for presence of a thermal hazard with a physical safeguard in place

c) Thermal hazard is present with a behavioural safeguard in place

The third model, see Figure 42 in this document, presumes the possibility of some contact to the thermal source or part by an **ordinary person**. The temperature is above the threshold limit value but the exposure time is limited by the expected usage conditions or through instructions to the user to avoid or limit contact to a safe exposure time. The contact time and exposure will not exceed the threshold limit value. An additional **safeguard** may not be required.



Figure 42 – Model for presence of a thermal hazard with behavioural safeguard in place

9.2 Thermal energy source classifications

Rationale: Surfaces that may be touched are classified as thermal energy sources TS1, TS2 or TS3 with TS1 representing the lowest energy level and TS3 the highest. The classification of each surface will determine the type of **safeguards** required.

The assessment of thermal burn hazards is complex and, as discussed in the model for a burn injury above, involves several factors. Important aspects include the overall heat capacity of the source, its temperature relative to the body, thermal conductivity of the contact and others. To present a simple model for assessment of a given surface, it is assumed that the overall heat capacity and the thermal conductivity will remain constant.

Thus, thermal energy sources are classified in terms of the material of the surface, its relative temperature and duration of contact only. Usually, for a given material the temperature and duration of contact are likely to be the only significant variables when assessing the risk of a burn injury.

9.2.1 TS1

Rationale: The lowest thermal energy source is TS1. TS1 represents a level of thermal energy that generally will not cause a burn injury.

9.2.2 TS2

Rationale: A TS2 thermal energy source has sufficient energy to cause a burn injury in some circumstances. The occurrence of a burn from a TS2 source will largely depend on the duration of contact. Depending on the contact time, and contact area, contact material, and other factors, a TS2 source is not likely to cause an injury requiring professional medical attention. Table 38 defines the upper limits for TS2 surfaces.

A TS2 circuit is an example of a class 2 energy source where the **basic safeguard** may, in some cases, be replaced by an **instructional safeguard**. Details are given in Table 38, footnote e.

9.2.3 TS3

Rationale: A TS3 thermal energy source has sufficient energy to cause a burn injury immediately on contact with the surface. There is no table defining the limits for a TS3 surface because any surface that is in excess of TS2 limits is considered to be TS3. Within the specified contact time, as well as contact area, contact material and other factors, a TS3 source may cause an injury requiring professional medical attention. As TS3 surfaces require that maximum level of **safeguard** defined in the document. All surfaces may be treated as TS3 if not otherwise classified.

Source: IEC Guide 117.

Rationale: When doing the temperature measurements, an ambient temperature is used as described in 9.2.5 to measure the temperatures without taking into account the maximum ambient specified by the manufacturer.

9.3 Touch temperature limits

Table 38 Touch temperature limits for accessible parts

Source: The limits in Table 38 are primarily derived from data in IEC Guide 117.

Rationale: The temperature of the skin and the duration of raised temperature are the primary parameters in the occurrence of a skin burn injury. In practice, it is difficult to measure the temperature of the skin accurately while it is in contact with a hot surface. Thus the limits in Table 38 do not represent skin temperatures. These limits do represent the surface temperatures that are known to cause a skin burn injury when contacted for greater than the specified time limit.

The thermal energy source criterion takes account of the temperature of the source, its thermal capacity and conductivity as well as the likely duration and area of contact. As the thermal capacity and conductivity will normally remain constant for a given surface, the limits here are expressed in degrees C for typical material types and contact durations.

Contact time duration > 8 h

For devices worn on the body (in direct contact with the skin) in normal use (> 8 h), examples include portable, lightweight devices such as watches, headsets, music players and sports monitoring equipment. Since the values in the table do not represent skin temperature as indicated above, measurements should not be done while wearing the devices.

The value of 43 °C for all materials for a contact period of 8 h and longer assumes that only a minor part of the body (less than 10 % of the entire skin surface of the body) or a minor part of the head (less than 10 % of the skin surface of the head) touches the hot surface. If the touching area is not local or if the hot surface is touched by vital areas of the face (for example, the airways), severe injuries may occur even if the surface temperature does not exceed 43 °C (see IEC Guide 117).

NOTE Prolonged exposure to 43 °C may result in erythema (temporary redness of the skin causing dilation of the blood capillaries) which will typically go away within a few hours after removal of the heat source. For some users, this may be misperceived as a burn.

Contact time durations > 1 min

For very long-term contact (> 10 min), the temperature below which a burn will not occur converges towards 43 °C for most materials (see IEC Guide 117:2010, Figure A.1). Studies carried out on portable IT Equipment have shown that for long term contact, a surface temperature will drop by between 5 °C and 12 °C when in contact with the body due to the cooling effect of the blood circulation. On this basis, and taking account of the probability that long-term contact will normally be insulated by clothing or some other form of insulation, the TS1 temperature limit for contact periods greater than 1 min in Table 39 are conservatively chosen as 48 °C for all materials.

Examples of products with surfaces where expected continuous contact durations greater than 1 min include joysticks, mice, mobile telephones, and PDAs. Any handles, knobs or grips on the equipment that are likely, under normal usage, to be touched or held for greater than 1 min are also included.

Contact time durations between 10 s and 1 min

For surfaces that are touched for shorter contact durations (up to 1 min), the temperature below which a burn will not occur is influenced by the material type as well as other factors. Because the contact time is shorter, there is insufficient time for heat transfer to cause the cooling effect described above, so it is not considered in the limits. The TS1 temperature limits in Table 38 for contact durations up to 1 min are taken directly from IEC Guide 117:2010, Table A.1.

Examples of surfaces with contact durations up to 1 min include handles or grips used primarily for moving or adjusting the equipment. Also tuning dials or other controls where contact for up to 1 min may be expected.

Contact time durations up to 10 s

Even shorter-term contact may occur for surfaces such as push button/switch, volume control; computer or telephone keys. In this case, the surfaces will not normally be touched for a duration greater than 10 s. The TS1 temperature limits in Table 38 for these surfaces are based on the burn threshold limits in IEC Guide 117 for contact durations of up to 10 s.

For surfaces that are **accessible** but need not be touched to operate the equipment, contact duration of up to 1 s is assumed. For healthy adults, a minimum reaction time of 0,5 s can be assumed. For more general applications, the reaction time increases to 1 s IEC Guide 117, Table 2. The TS1 temperature limits in Table 38 for these surfaces are based on the burn threshold limits in Guide 117 for contact durations of 1 s (see IEC Guide 117:2010, Figures A.1 – A.6). More conservative values than those in IEC Guide 117 are chosen for metal and glass to provide some margin against a reduced reaction time while in contact with a high thermal energy surface of high thermal conductivity.

Examples of such parts include general **enclosure** surfaces, **accessible** print heads of dot matrix printers or any internal surfaces that may be **accessible** during routine maintenance. Accidental contact, with no intention to hold or contact the surface is also included.

For contact durations between 1 s and 10 s, IEC Guide 117 provides temperature ranges over which a burn may occur rather than precise limits. This takes account of the uncertainty that applies to the occurrence of burn injury over shorter periods. The texture of the surface can also be a factor in the occurrence of a burn and this is not taken into account in the limits in IEC Guide 117. As most surfaces in IT equipment will have some texturing, values at the higher end of the spreads have been chosen.

Other considerations

In the event of a fault condition arising, the user is less likely to touch the equipment and any contact with **accessible** surfaces is likely to be very brief. Thus higher limits than those allowed under IEC Guide 117 are permitted. For metal, glass and plastic surfaces, the limit is 100 °C (IEC 60065:2010, Table 3). For wood, a temperature of 150 °C was chosen because 100 °C would be lower than the normal temperature of 140 °C.

When contact with a TS1 surface is unlikely due to its limited size or accessibility, a temperature up to 100 °C is acceptable if an **instructional safeguard** is provided on the equipment (see IEC 60950-1:2005, Table 4C, IEC 60065:2001, Table 3).

In the case where a surface is hot in order to carry out its function, the occurrence of contact with the surface or a subsequent burn injury is unlikely if the user is made aware that the surface is hot. Thus, a temperature up to 100 °C or higher is acceptable if there is an effective **instructional safeguard** on the body of the equipment indicating that the surface is hot (see IEC 60950-1:2005, Table 4C and IEC 60065:2001, Table 3).

Factors for consideration in determining test conditions

For consistency with other parts of the document and to reflect typical user conditions, the ambient conditions described in B.1.6 apply.

Assessment of **safeguards** should be carried out under **normal operating conditions** of the product that will result in elevated surface temperatures. The chosen **normal operating conditions** should be typical of the manufacturer's intended use of the product while precluding deliberate misuse or unauthorized modifications to the product or its operating parameters by the user. For some simple equipment, this will be straightforward. For more complex equipment, there may be several variables to be considered including the typical usage model. The manufacturer of the equipment should perform an assessment to determine the appropriate configuration.

Example: Factors that may be considered in determining the test conditions for a notebook computer:

- Mode of operation
 - Variable CPU speed
 - LCD brightness
- Accessories installed:
 - Number of disk drives
 - USB devices
 - External HDD
- Software installed:
 - Gaming applications
 - Duration of continuous use
 - Long term contact likely?
 - Other specialist applications
- **Battery** status:
 - Fully charged/ Discharged
 - AC connected

9.3.1 Touch temperature limit requirements

Rationale: Table 38 provides touch temperature limits for **accessible** parts, assuming steady state. IEC Guide 117 provides the methodology to assess products with changing temperatures or small parts which are likely to drop in temperature upon touch. Using a thermesthesiometer for a specified time interval, the thermesthesiometer simulates the skin temperature of human finger and heating effects caused by contact with the product surface under test. Once contact is made, the thermesthesiometer and product under test will eventually reach thermal equilibrium at which point finger skin temperature can be determined.

Background: The touch limits from Table 38 for > 1 s and < 10 s may be used for small hand-held devices with localized hotspots, given a small thermal energy source and touching can be easily avoided by changing holding position of the device.

This same rationale would also apply to small multi-media peripherals which are removed from a host device (for example, USB memory stick, PCMCIA cards, SD card, Compact Flash card, ejectable media, etc.). In many cases, these peripherals may be removed from their host (for example, power source) exposing higher thermally conductive materials (for example, metals), but are in thermal decay (i.e. no longer powered).

In cases of doubt, the method in IEC Guide 117 may be used for steady-state conditions. An example of a simplified method for thermally decaying parts is provided as a reference:

Touch temperature limits in IEC Guide 117 are based on time-weighted exposure for burn (for example, thermal energy). As long as integrated thermal energy calculations (for example, area of temp vs. time) of the part at specified time intervals is less than the associated integrated thermal energy calculated limits over that duration, the measured temperatures should be acceptable.

The most significant time intervals to consider for decaying thermal energy is between 1 s to 10 min (using 10 s, 1 min, 10 min intervals).

- For exposure times < 1 s, the 1 s temperature limits of the IEC Guide 117 should be used for 2 reasons: 1) Reaction times – under general applications reaction times of < 1 s are not probable and greatest risk of burn. 2) Repeatability – temperature measurement capability < 1 s intervals is less common and more difficult to accurately calculate the part energy.
- For exposure times > 10 min, the temperature limits of IEC Guide 117 should be used: after 10 min parts should either have cooled or reach sufficient equilibrium to utilize the temperature limits without the need for assessing thermal energy.

This simplified method requires the part under test to be mounted using thermally insulating clamp. Clamp to the part's least thermally conductive material and smallest contact needed to hold the part. Measured in still-air room ambient.

NOTE Parts that are hand-held will decay faster than open-air measurements (for example, radiation and convection) owing to direct conduction of heat to skin.

9.3.2 Test method and compliance criteria

Rationale: The general intent of the requirements are to use an ambient temperature as follows without taking into account the maximum ambient specified by the manufacturer:

- The test may be performed between 20 °C and 30 °C.
- If the test is performed below 25 °C, the results are normalized to 25 °C.
- If the test is performed above 25 °C, the results are not normalized to 25 °C and the limits (Table 38) are not adjusted. In case the product fails the requirements, the test may be repeated at 25 °C.

9.4 Safeguards against thermal energy sources

Rationale: TS1 represents non-hazardous energy and thus, no **safeguard** is required. Because the energy is non-hazardous, and there is no possibility of an injury, it may be **accessible** by **ordinary persons** and there is no restriction on duration of contact under **normal operating conditions**.

TS2 represents hazardous energy that could cause a burn injury if the contact duration is sufficient. Therefore, a **safeguard** is required to protect an **ordinary person**. A TS2 surface will not cause a burn immediately on contact. Because the burn injury from a TS2 surface is likely to be minor and pain or discomfort is likely to precede the occurrence of a burn injury, a physical **safeguard** may not be required if there is an effective means to inform the **ordinary person** about the risks of touching the hot surface.

Thus, a TS2 **safeguard** may be one of the following:

- a physical barrier to prevent access; or
- an **instructional safeguard** to limit contact time below the threshold limit value versus time.

TS3 represents hazardous energy that is likely to cause a burn injury immediately on contact. Because a TS3 surface is always likely to cause a burn immediately or before the expected reaction time due to pain or discomfort, an **equipment safeguard** is required.

Unless otherwise specified in the document, **ordinary persons** need to be protected against all TS2 and TS3 energy sources.

Instructed persons are protected by the supervision of a **skilled person** and can effectively employ **instructional safeguards**. Thus, **equipment safeguards** are not required for TS2 energy sources. An **instructional safeguard** may be required.

TS3 energy sources can cause severe burns after very short contact duration. Thus, an **instructional safeguard** alone is not sufficient to protect an **instructed person** and an **equipment safeguard** is required.

Skilled persons are protected by their education and experience and are capable of avoiding injury from TS3 sources. Thus, an **equipment safeguard** is not required to protect against TS3 energy sources. As a pain response may cause an unintentional reflex action even in **skilled persons**, an equipment or **instructional safeguard** may be required to protect against other class 3 energy sources adjacent to the TS3 energy source.

9.5.1 Equipment safeguard

Rationale: The function of the **equipment safeguard** is to limit the transfer of hazardous thermal energy. An **equipment safeguard** may be thermal insulation or other physical barrier.

9.5.2 Instructional safeguard

Rationale: An **instructional safeguard** will inform any person of the presence of hazardous thermal energy. **Instructional safeguards** may be in a text or graphical format and may be placed on the product or in the user documentation. In determining the format and location of the **safeguard**, consideration will be given to the expected user group, the likelihood of contact and the likely nature of the injury arising.

9.6 Requirements for wireless power transmitters

Rationale: Transmitters for near-field **wireless power transfer** can warm up foreign metallic objects that may be placed close to or on such a transmitter. To avoid burn due to high temperatures of the foreign metallic objects, the transmitter is tested as specified in 9.6.3.

Far-field transmitters are generally called "power-beaming" and are not covered by these requirements.

9.6.3 Test method and compliance criteria

Rationale: While 9.6.3 specifies a maximum temperature of 70 °C, aluminum foil that reaches 80 °C is considered to comply with the requirement. The foil described in figure 49 complies with the method allowed in 9.3.1 based on the foil dimensions and low mass.

This requirement is expected to align with the current Qi standard.

10 Radiation

10.2 Radiation energy source classifications

Rationale: The first step in application is determining which energy sources represent potential radiation energy sources. Each energy source within the product can be classified as a radiation source based on the available energy within a circuit that can be used to determine the type of and number of **safeguards** required. The radiation energy source classifications include electromagnetic radiation energy sources.

10.2.1 General classification

Rationale: Radiation energy source classifications for X-rays and acoustics are given in Table 39. For optical radiation ("Lasers" and "Lamps and lamp systems"), the classification is defined by the IEC 60825 series or the IEC 62471 series as applicable.

The general classification scheme specified in IEC 60825-1 is for laser products and is not a classification scheme for energy sources. It is not practical to classify laser radiation as RS. The classification according to IEC 60825-1 is used without modification.

The classification schemes given in IEC 62471 and IEC 62471-5 specify a measurement distance (200 mm other than lamps intended for general lighting service and 1m for Image projectors) for the determination of the Risk Group. The Risk Group classification is not the actual source of the light. It is not practical to classify the radiation from lamps and lamp systems as RS. The classification according to IEC 62471 is used without modification.

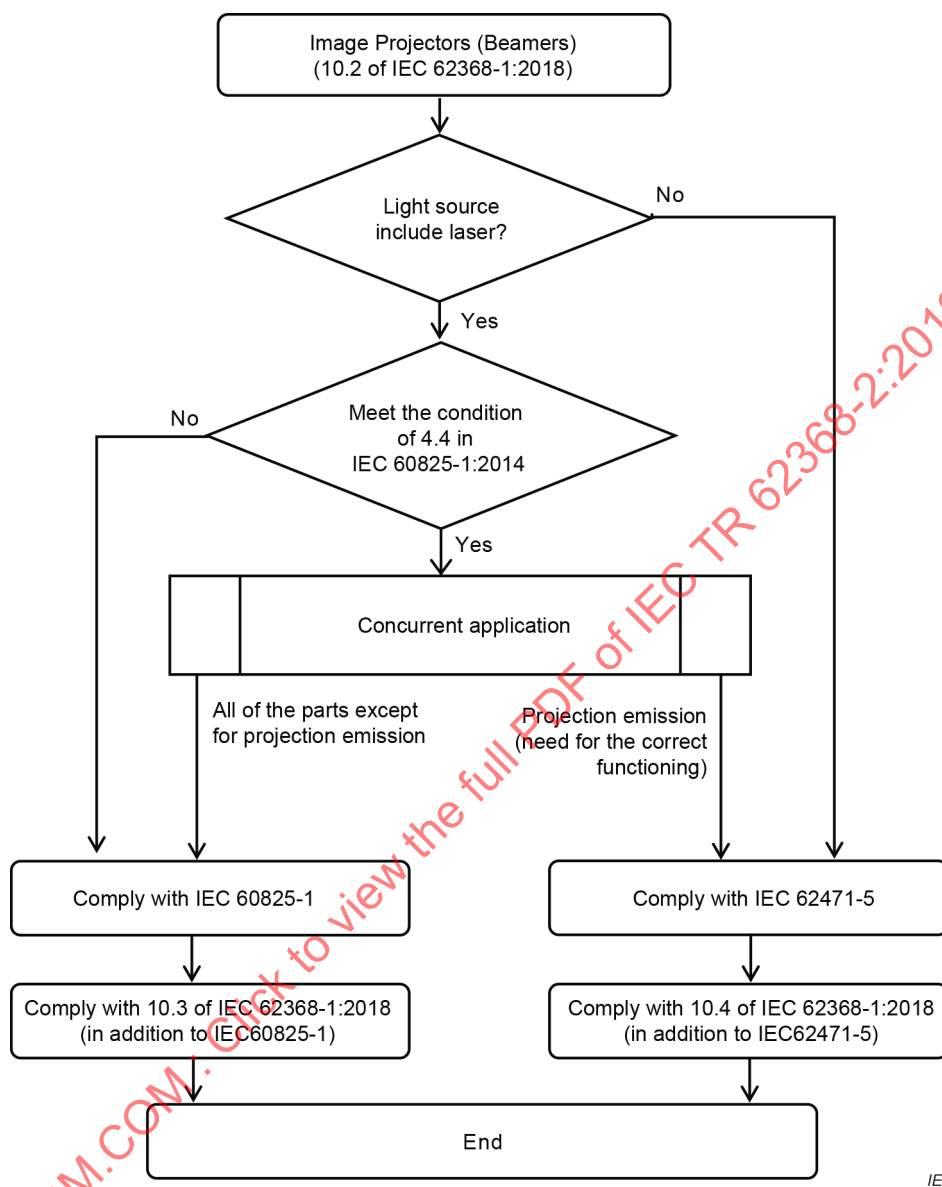
Abnormal operating conditions (see Clause B.3) and **single fault conditions** (see Clause B.4) need to be taken into account. If it becomes higher risk group when **abnormal operating condition** or **single fault condition** is applied, the higher risk group is applied for classification.

Laser equipment classified as Class 1C is generally not within the scope of this document as it mainly applies to medical related applications.

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Source: IEC 60825-1:2014 and IEC 62471-5

Rationale: Image Projectors are evaluated using the process in Figure 43 in this document (see IEC 60825-1:2014 and IEC 62471-5).



IEC

Figure 43 – Flowchart for evaluation of Image projectors (beamers)

10.2.2 & 10.2.3 RS1 and RS2

Rationale: The output circuits of personal music players are not subject to **single fault conditions**, since the outputs will not increase to a level exceeding RS2 by nature of their highly integrated hardware designs. Typically, when component faults are introduced during testing (by bypassing or shorting of the audio related ICs), the outputs are either shut down, reduced in level or muted.

10.2.4 RS3

Rationale: RS3 energy sources are those that are not otherwise classified as RS1 or RS2. No classification testing is required as these energy sources can have unlimited levels. If an energy source is not measured, it assumed to be RS3 for application of the document. A **skilled person** uses personal protective equipment or measures to reduce the exposure to safe limits when working where RS3 may be present.

10.3 Safeguards against laser radiation

Source: IEC 60825-1:2014, Annex A

Rationale: IEC 60825-1:2014, Annex A provides an explanation of the different classes of products. **Accessible** emission limits (AELs) are generally derived from the maximum permissible exposures (MPEs). MPEs have been included in this informative annex to provide manufacturers with additional information that can assist in evaluating the safety aspects related to the intended use of their product, such as the determination of the nominal ocular hazard distance (NOHD).

10.4 Safeguards against optical radiation from lamps and lamp systems (including LED types)

Source: IEC 62471 and IEC TR 62471-2

Rationale: Excessive optical radiation may damage the retina and cause vision impairment or blindness. The limits in the referenced documents are designed to reduce the likelihood of vision impairment due to optical radiation sources.

For the **Instructional safeguard** for lamps and lamp systems, see IEC TR 62471-2.

10.4.1 General Requirements

Source: IEC 60065

Rationale: The term 'Electronic light effect equipment' has been used in IEC 60065 (see 1.1) and is a commonly understood term for entertainment/stage effect lighting.

10.5 Safeguards against X-radiation

Source: IEC 60950-1; IEC 60065

Rationale: Exposure to X-radiation will cause injury with excessive exposure over time. The limits in this document have been selected from IEC 60950-1 and IEC 60065 in order to limit exposure to that which is below harmful levels.

10.6 Safeguards against acoustic energy sources

Source: EN 60065:2002/A11:2008

Rationale: The requirements of this subclause are made to protect against hearing loss due to long term exposure to high sound pressure levels. Therefore, the requirements are currently restricted to those kinds of products that are designed to be body-worn (of a size suitable to be carried in a clothing pocket) such that a user can take it with them all day long to listen to music (for example, on a street, in a subway, at an airport, etc.).

At this moment, the clause does not contain requirements against the hazard of short term exposure to very high sound pressure levels.

Rationale: Significance of $L_{Aeq,T}$ in EN 50332-1 and additional information

$L_{Aeq,T}$ is derived from the general formula for equivalent sound pressure:

$$L_{eq} = 10 \log \left[\frac{1}{t_2 - t_1} \int_{t_1}^{t_2} \frac{p_A^2}{p_0^2} dt \right]$$

This can be represented graphically as given in Figure 44 in this document.

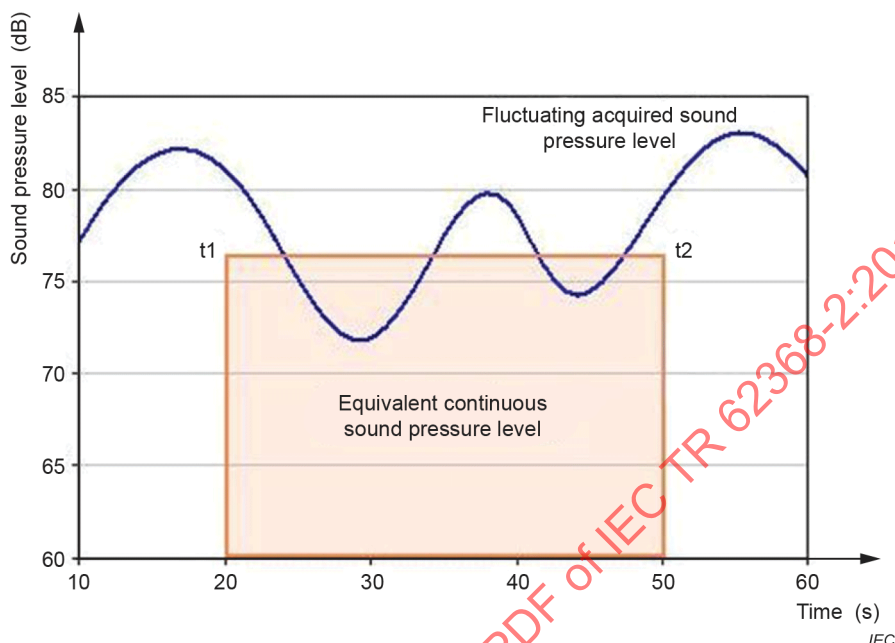


Figure 44 – Graphical representation of $L_{Aeq,T}$

In EN 50332-1 the measurement time interval ($t_2 - t_1$) is 30 s.

In practice, and for the purposes of listening to personal music player content, $L_{Aeq,T}$ has a time interval T ($t_2 - t_1$) in the order of minutes / hours and not seconds.

Subclause 6.5 (Limitation value) of EN 50332-1:2000 acknowledges this fact and states that the 100-dB limit equates to a long time average of 90 dB $L_{Aeq,T}$. By using the IEC 60268-1 “programme simulation noise” test signal, this also takes the spectral content into account.

The SCENHIR report states that 80 dB(A) is considered safe for an exposure time of 40 h/week. Most persons do not listen to 40 h/week to their personal music player. In addition, not all music tracks are at the same level of the simulated noise signal. Whilst modern music tends to be at around the same level, most of the available music is at a lower average level. Therefore, CLC TC 108/WG03 considered a value of 85 dB(A) to be safe for an overwhelming majority of the users of personal music players.

10.6.3 Requirements for dose-based systems

Rationale: The requirements on dose measurement have been developed to replace the requirements on maximum exposure as this better protects against hearing damage, which results from the combination of exposure and time (dose). For now, both systems can be used. See Table 16 in this document for a comparison.

The dose-based system mainly uses the expression CSD, meaning "calculated sound dose". The value is based on the values mentioned in the EU Commission Decision 2009/490/EC, which stipulated that sound is safe when below 80 dB(A) for a maximum of 40 h per week. Therefore, the value of 100 % CSD corresponds to 80 dB(A) for 40 h. This also means that the safe limit in the dose measurement system is chosen to be lower than the safe limit in the maximum exposure system, as this specifies the safe limit at 85 dB(A). Consequently, a user will normally receive warnings earlier with the dose measurement system compared to the maximum exposure limit. In the maximum exposure system, the warning only had to be given once every 20 h of listening when exceeding 85 dB(A). In the dose measurement system, the warning and acknowledgement has to be repeated at least at every 100 % increase of the dose. In practice, this means that the warning is repeated at a comparable level of 83 dB(A), meaning a dose that corresponds to listening to 83 dB(A) for 40 h. At each next 100 % increase of dose level, the increase in corresponding dB's is halved. Manufacturers have the freedom to give warnings earlier or ask for acknowledgement more frequently, but it has to be no later than at the next 100 % CSD increase since the last acknowledgement. For example, a device has provided the warning and acknowledgement at 100 % CSD. The manufacturer may choose to provide the next warning before 200 % CSD, for example, at 175 % CSD. If that is done, the next warning and acknowledgement may not be later than at 275 % CSD. While there are no requirements for manufacturers to warn users before the 100 % CSD is reached, it is allowed to do so. Even more, it was felt by the document writers that it would be responsible behaviour if manufacturers warn consumers about the risks before the 100 % CSD level is reached. With the maximum exposure measurement, the maximum allowable sound output is 100 dB(A). With the dosage system, only a momentary exposure limit (MEL) is required when exceeding 100 dB(A) if a visual or audible warning is provided. Where a visual or audible MEL is not provided the maximum exposure measurement of 100 dB(A) is required.

An essential element to educating the user and promoting safe listening habits is appropriate and useful guidance. This can be accomplished with informative CSD and MEL warnings that allow the user to understand the hazard, risks, and recommended action. Appropriate warnings about using the device and user instructions shall be provided. It should be noted that the CSD warning can be provided in various forms not limited to visual or audio. However, the MEL can only be provided visually or audibly. Consideration should be given to not over-message and annoy the user to the point where the message is neglected or evasive attempts (software hacks) to defeat the safe guards are taken. Extreme care should be given when implementing the MEL warning and shall be at the discretion of the manufacturer.

Manufacturers should be aware that digital sensitivity between PMP and unknown listening devices may result in excessive false positives. It is recommended industry to promote sharing of sensitivity data through a standardized means.

Table 16 – Overview of requirements for dose-based systems

	Devices with Visual or Audible MEL			EN 50332-3
	SPL before transition ³	SPL after transition ³	Dose requirements	Dose test method
Analog known ¹	> 85 dB(A) if ack, < 100 dB(A) max	<80 dB(A) max	CSD warn at every 100 % MEL warn at >100 dB(A)	cl 5.2
Analog unknown ²	> 27 mV r.m.s. if ack, < 150 mV r.m.s. max	< 15 mV rms max	CSD warn at every 100 % (= integrate. rms level 15 mV) MEL warn at > 150 mV r.m.s.	cl 5.3
Digital known ¹	> 85 dB(A) if ack, < 100 dB(A) max	< 80 dB(A) max	CSD warn at every 100 % MEL warn at > 100 dB(A)	cl 5.2
Digital unknown ²	> -25 dBFS if ack, < 100 dB(A) ⁴ max	< -30 dBFS max	CSD warn at every 100 % (= integrate level -30 dBFS) < 100 dB(A) max or MEL warn at > 100 dB(A) ⁴	TBD ⁵
	Devices without MEL			EN 50332-3
	SPL before transition ³	SPL after transition ³	Dose requirements	Dose test method
Analog known ¹	> 85 dB(A) if ack, < 100 dB(A) max	< 80 dB(A) max	CSD warn at every 100 % < 100 dB(A) max	cl 5.2
Analog unknown ²	> 27 mV r.m.s. if ack, < 150 mV r.m.s. max	< 15 mV r.m.s. max	CSD warn at every 100 % (= integrate rms level 15 mV) < 150 mV r.m.s. max	cl 5.3
Digital known ¹	> 85 dB(A) if ack, < 100 dB(A) max	< 80 dB(A) max	CSD warn at every 100 % < 100 dB(A) max	cl. 5.2
Digital unknown ²	> -25 dBFS if ack, < 100 dB(A) ⁴ max	< -30 dBFS max	CSD warn at every 100 % (= integrate level -30 dBFS) < 100 dB(A) ⁴ max	TBD ⁵
¹ PMP includes or can detect listening device ² PMP cannot detect listening device ³ Transition period allows migration to CSD before becoming mandatory ⁴ Defaults to 100 dB(A) gain cap from digital listening device. Need to develop industry wide protocol for digital (wired/wireless) listening device for PMPs to learn sensitivity lookup table. ⁵ Need to create test requirements with EN 50332-3. Otherwise, SPL requirements (30 dBFS gain cap) will be only feasible option.				

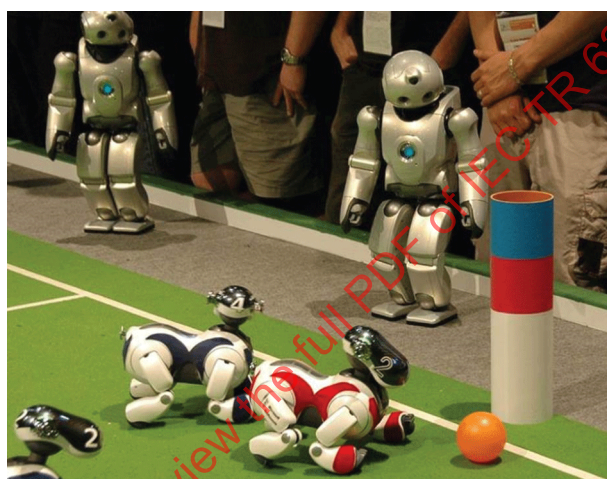
10.6.6.1 Corded listening devices with analogue input

Rationale: The value of 94 dB(A) was chosen to align with current practice in EN 50332. In addition, some equipment may already start clipping at 100 dB(A). The value used does not influence the result of the measurement.

Annex A Examples of equipment within the scope of this standard

Rationale: A variety of personal electronic entertainment products/systems can be covered by this document, including self-propelling types sometimes known as entertainment robots, which typically contain electronic components and circuits that power the device's motion, a **battery** system and charger, the electric motor(s) and control systems, together with wireless communications and audio. When no other IEC or ISO document explicitly covers these products, they can be accommodated by IEC 62368-1.

Examples of Entertainment-type Robots:



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Annex B Normal operating condition tests, abnormal operating condition tests and single fault condition tests

General Equipment safeguards during various operating conditions

Purpose: To identify the various operating and use conditions of equipment that are taken into account in the document. This clause was proposed to be added to the document as a Clause 0.12, but was agreed to be added to the Rationale instead.

Rationale: Operating conditions

Normal operating condition – A **normal operating condition** is a state with intended functionality of the equipment. All equipment **basic safeguards**, **supplementary safeguards**, and **reinforced safeguards** remain effective and comply with all required **safeguard** parameters.

Abnormal operating condition – An **abnormal operating condition** is a temporary state. The equipment may have full, limited, or no functionality. The equipment generally requires operator intervention for restoration to **normal operating condition**. All equipment **basic safeguards** remain effective but may not need to comply with the required **safeguard** parameters. All equipment **supplementary safeguards** and **reinforced safeguards** remain effective and comply with the required **safeguard** parameters.

Upon restoration of **normal operating conditions**, all **basic safeguards** comply with the required parameters unless the **abnormal operating condition** leads to a **single fault condition**, in which case the requirements for **single fault condition** apply.

Reasonably foreseeable misuse condition – **Reasonably foreseeable misuse** is a form of an **abnormal operating condition** but may be either a temporary or a permanent state. The equipment may have full, limited, or no functionality. The equipment may not be capable of restoration to a **normal operating condition**. **Reasonably foreseeable misuse** may lead to a **single fault condition**, in which case equipment **basic safeguards** are not required to remain effective. All equipment **supplementary safeguards** and **reinforced safeguards** remain effective and comply with the required **safeguard** parameters.

Other misuse condition – Other misuse (unreasonable or unforeseeable) may lead to a single or multiple fault condition, in which **basic safeguards**, **supplementary safeguards** and **reinforced safeguards** may not remain effective. The equipment may not be repairable to a **normal operating condition**. **Safeguards** against unreasonable or unforeseeable misuse are not covered by this document.

Single fault condition – A **single fault condition** is a component or **safeguard** fault. The equipment may have full, limited or no functionality. The equipment requires repair to return to a **normal operating condition**. Equipment **basic safeguards** are not required to be functional, in this case the **supplementary safeguards** are functional and comply with the required **safeguard** parameters; or equipment **supplementary safeguards** are not required to be functional, in this case the **basic safeguards** are functional and comply with the required **safeguard** parameters.

NOTE As a **basic safeguard** and a **supplementary safeguard** may be interchangeable, the concept of which **safeguard** is not required to remain effective can be reversed.

B.1.5 Temperature measurement conditions

Source: IEC 60950-1

Purpose: To determine whether the steady state temperature of a part or material does or does not exceed the temperature limit for that part or material.

Rationale: Steady state is considered to exist if the temperature rise does not exceed 3 K in 30 min. If the measured temperature is less than the required temperature limit minus 10 %, steady state is considered to exist if the temperature rise does not exceed 1 K in 5 min.

Temperature rise follows an exponential curve and asymptotically approaches thermal equilibrium. The rate of temperature rise can be plotted as a function of time and used to guess the value at steady state. The actual steady state value needs to be accurate only to the extent to prove whether the value will exceed the limit or not.

Steady-state conditions of typical electronic devices have many different temperatures, so thermal equilibrium does not exist.

The resistance method may be used to measure temperature rises of windings unless the windings are non-uniform or if it is difficult to make the necessary connections, in which case the temperature rise is determined by other means.

When the resistance method is used, the temperature rise of a winding is calculated from the formula:

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

where:

Δt is the temperature rise of the winding;

R_1 is the resistance at the beginning of the test;

R_2 is the resistance at the end of the test;

k is equal to:

- 225 for aluminium windings and copper/aluminium windings with an aluminium content ≥ 85 %,
- 229,75 for copper/aluminium windings with a copper content > 15 % to < 85 %,
- 234,5 for copper windings and copper/aluminium windings with an copper content ≥ 85 %;

t_1 is the room temperature at the beginning of the test;

t_2 is the room temperature at the end of the test.

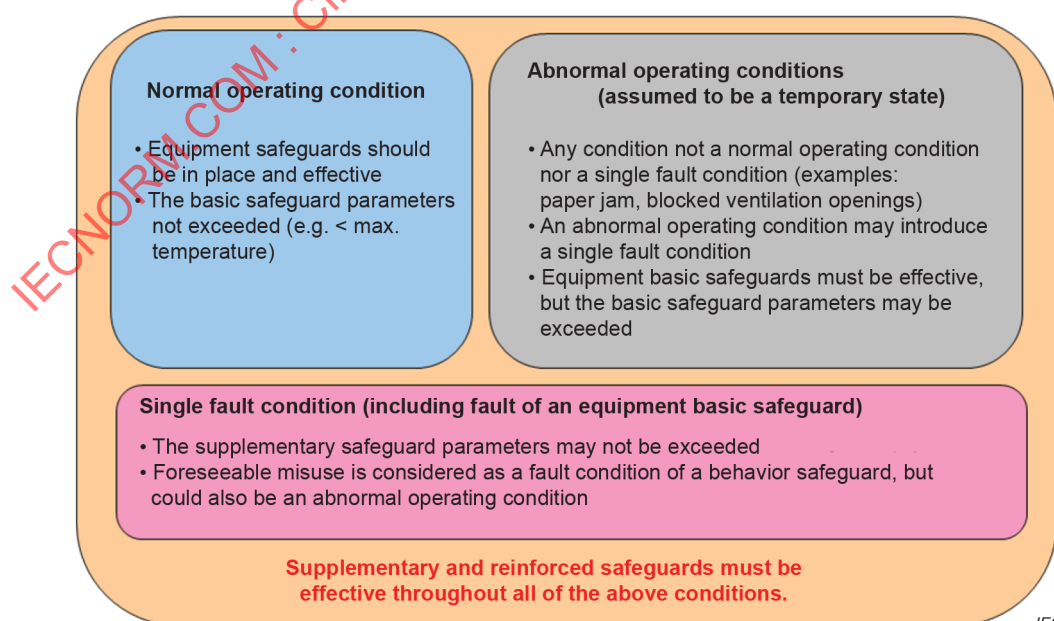
NOTE It is recommended that the resistance of windings at the end of the test be determined by taking resistance measurements as soon as possible after switching off and then at short intervals so that a curve of resistance against time can be plotted for ascertaining the resistance at the instant of switching off.

B.2.3 Supply Voltage

Rationale: Where a test subclause does not require the most unfavourable supply voltage, the supply voltage is the value of the **rated voltage** or any value in the **rated voltage range**. This is applicable to the tests in **abnormal operation condition** and **single fault condition** as well.

B.2 – B.3 – B.4 Operating modes

See Figure 45 in this document for an overview of operating modes.



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Figure 45 – Overview of operating modes

B.4.4 Functional insulation

Rationale: The use of a **functional insulation** is only acceptable when the circuit does not exceed its limits of its class under **normal operating conditions** and **abnormal operation conditions** and **single fault conditions** of a component not serving as a **safeguard** (see 5.2.1.1 and 5.2.1.2). Otherwise a **basic insulation/safeguard** would be required.

If the **functional insulation** possesses a certain quality (**clearance, creepage distances**, electric strength) comparable to a **basic safeguard**, it is acceptable to omit short-circuit.

This cannot be compared to the short-circuiting of a **basic safeguard** as required in B.4.1, because this **basic safeguard** is a required one, while the added quality of the **functional insulation** is not required.

If the short-circuiting of this **functional insulation** with added quality would lead to a changing of the class, the **functional insulation** was wrongly chosen, and a **basic safeguard** would have been required.

B.4.8 Compliance criteria during and after single fault conditions

Source: IEC 60065

Rationale: During **single fault conditions**, short term power is delivered in components which might be outside the specifications for that component. As a result, the component might interrupt. During the interruption, sometimes a small flame escapes for a short period of time. The current practice in IEC 60065 allows these short term flames for a maximum period of 10 s. This method has been successfully used for products in the scope of this document for many years.

Annex C UV Radiation

C.1.1 General

Rationale: UV radiation can affect the physical properties of thermoplastic materials and so it can have a consequential effect on components protecting body parts from a range of injurious energy sources.

Annex D Test generators

Source: ITU-T Recommendation K.44

Rationale: The circuit 1 surge in Table D.1 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.

Figure D.3 provides a circuit diagram for high energy impulse to test the high-pressure lamps.

Annex E Test conditions for equipment containing audio amplifiers

Source: IEC 60065:2011

Rationale The proposed limits for touch voltages at terminals involving audio signals that may be contacted by persons have been extracted without deviation from IEC 60065:2011, 9.1.1.2 a). Under **single fault conditions**, 11.1 of IEC 60065:2011 does not permit an increase in acceptable touch voltage limits.

The proposed limits are quantitatively larger than the accepted limits of Table 4, but are not considered dangerous for the following reasons:

- the output is measured with the load disconnected (worst-case load);
- defining the contact area of connectors and wiring is very difficult due to complex shapes. The area of contact is considered small due to the construction of the connectors;
- normally, it is recommended to the user, in the instruction manual provided with the equipment, that all connections be made with the equipment in the “off” condition.
- in addition to being on, the equipment would have to be playing some program at a high output with the load disconnected to achieve the proposed limits. Although possible, it is highly unlikely. Historically, no known cases of injury have been recorded for amplifiers with a non-clipped output less than 71 V RMS.
- the National Electrical Code (USA) permits **accessible** terminals with a maximum output voltage of 120 V RMS.

It seems that the current normal condition specified in IEC 60065 is appropriate and a load of 1/8 of the **non-clipped output power** should be applied to the multichannel by adjusting the individual channels.

Annex F Equipment markings, instructions, and instructional safeguards

F.3 Equipment markings

Source: EC Directives such as 98/37/EC Machinery Directive, Annex I clause 1.7.3 marking; NFPA 79:2002, clause 17.4 nameplate data; CSA C22.1 Canadian Electric Code, clause 2-100 marking of equipment give organized requirements. The requirements here are principally taken from IEC 60065 and IEC 60950 series.

F.3.3.2 Equipment without direct connection to mains

Source: IEC 60950-1

Purpose: To clarify that equipment powered by **mains** circuits, but not directly connected to the **mains** using standard plugs and connectors, need not have an electrical rating.

Rationale: Only equipment that is directly connected to the **mains** supplied from the building installation needs to have an electrical rating that takes into account the full load that may be connected to the building supply outlet. For equipment that is daisy-chained or involves a master-slave configuration, only the master unit or the first unit in the daisy chain needs to be marked.

F.3.6.2 Equipment class marking

Rationale: For compliance with EMC standards and regulations, more and more class II products are equipped with a functional earth connection. The latest version of the basic safety publication IEC 61140 allows this construction. On request of IEC TC 108, IEC SC3C has developed a new symbol, which is now used in IEC 62368-1.

Rationale: Equipment having a class II construction, but that is provided with a class I input connector with the internal earthing pin not connected is also considered to be a **class II equipment** with functional earth. The class I connector is used to provide a more robust connection means, which is considered to be a functional reason for the earth connection.

F.4 Instructions

Rationale: The dash requiring graphical symbols placed on the equipment and used as an **instructional safeguard** to be explained does not apply to symbols used for equipment classification (see F.3.6).

F.5 Instructional safeguards

Rationale: When a symbol is used, the triangle represents the words “Warning” or “Caution”. Therefore, when the symbol is used, there is no need to also use the words “Warning” or “Caution”. However, when only element 2 is used, the text needs to be preceded with the words.

Annex G Components

G.1 Switches

Source: IEC 61058-1

Rationale: A contact should not draw an arc that will cause pitting and damage to the contacts when switching off and should not weld when switching on if located in PS2 or PS3 energy sources. A PS1 energy source is not considered to have enough energy to cause pitting and damage to the contacts. Both these actions (pitting and damage) may result in a lot of heating that may result in fire. There should be sufficient gap between the two contact points in the off position which should be equal to the reinforced **clearance** if the circuit is ES3 and basic **clearance** if the circuit is ES2 or ES1 (we may have an **arcing PIS** or **resistive PIS** in an ES1 circuit) in order to avoid shock and fire hazards. The contacts should not show wear and tear and pitting after tests simulating lifetime endurance; and overload tests and operate normally after such tests.

G.2.1 Requirements

Source: IEC 61810-1, for electromechanical relays controlling currents exceeding 0,2 A AC or DC, if the voltage across the open relay contacts exceeds 35 V peak AC or 24 V DC

Rationale: A contact should not draw an arc that will cause pitting and damage to the contacts when switching off and should not weld when switching on if located in PS2 or PS3 energy sources. A PS1 energy source is not considered to have enough energy to cause pitting and damage to the contacts. Both these actions (pitting and damage) may result in lot of heating that may result in fire. There should be sufficient gap between the two contact points in the off position which should be equal to the reinforced **clearance** if the circuit is ES3 and basic **clearance** if the circuit is ES2 or ES1 (we may have an **arcing PIS** or **resistive PIS** in an ES1 circuit) in order to avoid shock and fire hazards. The contacts should not show wear and tear and pitting after tests simulating lifetime endurance, and overload tests and operate normally after such tests.

G.3.3 PTC thermistors

Source: IEC 60730-1:2006

Rationale: PTC thermistor for current limitation is always connected in series with the load to be protected.

In a non-tripping stage, the source voltage is shared by the load impedance and the resistance of PTC thermistor (which is close to the zero-power resistance at 25 °C). In order to define the power dissipation of the PTC thermistor in this stage, the source voltage and the load impedance are also important parameters.

In a tripping stage, the PTC thermistor heats up by itself and increases the resistance value to protect the circuit. The zero-power resistance at 25 °C is no longer related to the power dissipation of PTC thermistors in this stage. The power dissipation of PTC thermistor in this stage depends on factors such as mounting condition and ambient temperature.

In either stage, some parameters other than the rated zero-power resistance at an ambient temperature of 25 °C are required to calculate the power dissipation of PTC thermistor.

The tripping stage is more hazardous than the non-tripping stage because the temperature of the PTC thermistor in the tripping stage becomes much higher than in the non-tripping stage.

Figure 46 in this document shows “Voltage-Current Characteristics”. The blue dotted lines show the constant power dissipation line. It shows that the power at the operation point, during the tripping stage, is the highest power dissipation. This point is calculable with “ $I_{res} \times U_{max}$ ” of IEC 60738-1:2006, 3.38.

(U_{max} = maximum voltage, I_{res} = residual current, measured by the PTC manufacturers.)

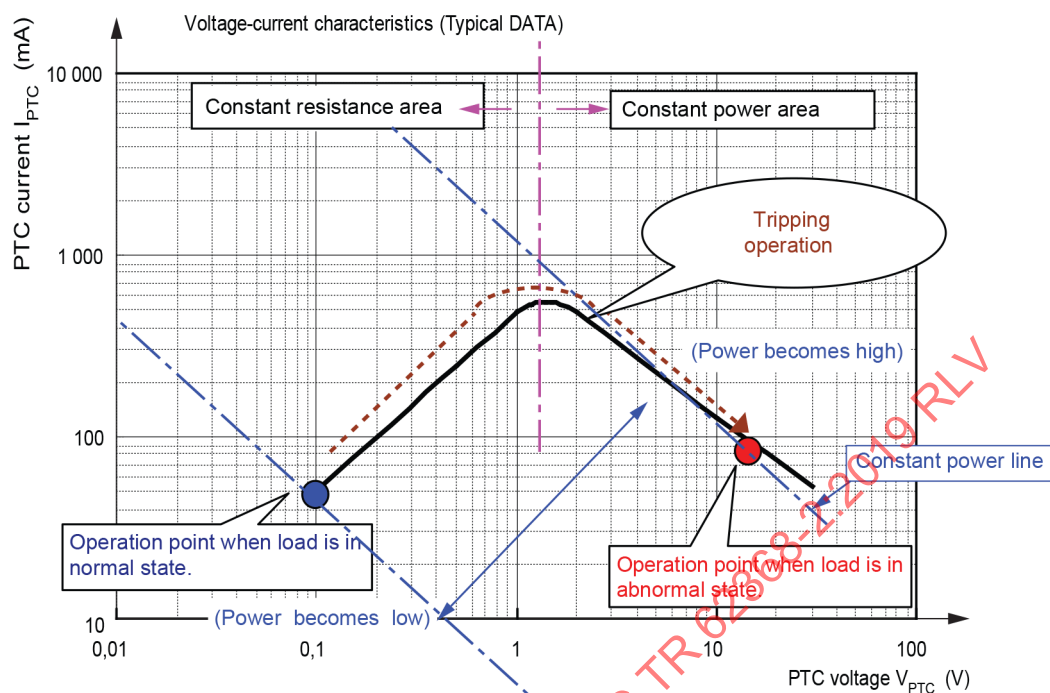
3.38

maximum power

P_{max}

maximum power is the power ($U_{max} \times I_{res}$) which can be dissipated continuously by the thermistor when the maximum voltage is applied under specified conditions of ambient temperature, circuit and thermal dissipation when thermal equilibrium is obtained

NOTE If the power is supplied by an a.c. source then the voltage and current should be measured with true r.m.s. meters.



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Figure 46 – Voltage-current characteristics (Typical data)

If the PTC is installed in a PS1 circuit, the power dissipation of the PTC will be 15W or less. In this state, the PTC is not considered to be a **resistive PIS**, regardless of its $I_{res} \times U_{max}$.

A PTC with a size of less than 1 750 mm³ is not considered to be a **resistive PIS**, described in 6.3.1, 6.4.5.2 and 6.4.6.

G.3.4 Overcurrent protective devices

Rationale: Just like any other safety critical component, protective devices are not allowed to be used outside their specifications, to guarantee safe and controlled interruption (no fire and **explosion** phenomena's) during **single fault conditions** (short circuits and overload conditions) in the end products. This should include having a breaking capacity capable of interrupting the maximum fault current (including short-circuit current and earth fault current) that can occur.

G.3.5 Safeguard components not mentioned in G.3.1 to G.3.4

Rationale: Protective devices shall have adequate ratings, including breaking capacity.

G.5.1 Wire insulation in wound components

Source: IEC 60317 series, IEC 60950-1

Purpose: Enamel winding wire is acceptable as **basic insulation** between **external circuit** at ES2 voltage level and an ES1.

Rationale: ES1 becomes ES2 under **single fault conditions**. The enamel winding wires have been used in telecom transformers for the past 25 years to provide **basic insulation** between TNV and SELV. The winding wire is **type tested** for electric strength for **basic insulation** in addition to compliance with IEC 60317 series of standards. Enamel is present on both input and output winding wires and therefore, the possibility of having pinholes aligned is minimized. The finished component is tested for **routine test** for the applicable electric strength test voltage.

G.5.2 Endurance test

Source: IEC 60065:2011, 8.18

Rationale: This test is meant to determine if insulated winding wires without additional interleaved insulation will isolate for their expected lifetime. The endurance test comprises a heat run test, a vibration test and a humidity test. After those tests, the component still has to be able to pass the electric strength test.

G.5.2.2 Heat run test

Rationale: In Table G.2, the tolerance is ± 5 °C. It is proposed that the above tolerance be the same.

G.5.3 Transformers

Source: IEC 61558-1, IEC 60950-1

Rationale: Alternative requirements have been successfully used with products in the scope of this document for many years.

G.5.3.3 Transformer overload tests

G.5.3.3.2 Compliance criteria

Source: IEC 61558-1, IEC 60950-1

Rationale: The transformer overload test is conducted mainly to check the deterioration by thermal stress due to overload conditions, and the compliance criteria is to check whether the temperature of the windings are within the allowable limits specified in Table G.3. For that purpose, the maximum temperature of windings is measured.

However, in the actual testing condition, the windings or other current carrying parts of the transformer under testing may pose temperature higher than the measured value due to uneven temperature, such as a windings isolated from the **main**s (see third paragraph of G.5.3.3.2), so that such spot exposed to higher temperature may have thermal damage.

In order to evaluate such potential damage, electric strength test after the overload condition is considered necessary.

Both of the source documents require the electric strength test after the overload test.

Table G.3 Temperature limits for transformer windings and for motor windings (except for the motor running overload test)

Although the document does not clearly state it, the first row should also be used in cases where no protective device is used or the component is inherently protected by impedance.

For example, in the test practice of a switch mode power supply, a transformer is to be intentionally loaded to the maximum current without a protection operating. In this case, the method of protection is NOT 'inherently' or 'impedance', but other sets of limits are specified with the time of protection to operate. In reality, a switch mode transformer tested with a maximum load attempting the protection not to operate, but the limits in first row have been considered appropriate, because the thermal stress in that loading condition continues for a long time (no ending). Thus, the lowest limit should be applied. In this context, the application of the first row limit shall be chosen according to the situation of long lasting overloading rather than the type of protection.

G.5.3.4 Transformers using fully insulated winding wire (FIW)

Source: IEC 60317-56, IEC 60317-0-7

Rationale: In 2012, IEC TC 55 published IEC 60317-56 and IEC 60317-0-7, Specification for Particular Types of Winding Wires – Part 0-7: General requirements – Fully insulated (FIW) zero-defect enamelled round copper wire with nominal conductor diameter of 0,040 mm to 1,600 mm.

This wire is more robust enameled-coated wire used with minimal amounts of interleaved insulation. It is another step in the advancement of technology to allow manufacturers to design smaller products safely.

IEC TC 96 was the first TC to incorporate the use of FIW in their safety documents for switch mode power supply units, IEC 61558-2-16. Since IEC 62368-1:2018 references in G.5.3.1 IEC 61558-1-16 as one of the acceptable documents for transformers used in switch mode power supplies, FIW already is acceptable in equipment investigated to IEC 62368-1 that use an IEC 61558-1-16 compliant transformer.

FIW may not be **accessible**, whether it has **basic insulation**, **double insulation** or **reinforced insulation**. Note that this differs from other parts of the document that permit **supplementary insulation** and **reinforced insulation** to be **accessible** to an **ordinary person**. The reason is that this kind of wire is fragile and the insulation could easily be damaged when it is **accessible** to an **ordinary person**.

G.5.4 Motors

Source: IEC 60950-1

Rationale: Requirements have been successfully used with products in the scope of this document for many years.

G.7 Mains supply cords

Source: IEC 60245 (rubber insulation), IEC 60227 (PVC insulation), IEC 60364-5-54

Rationale: **Mains** connections generally have large normal and fault energy available from the **mains** circuits. It is also necessary to ensure compatibility with installation requirements.

Stress on **mains** terminal that can result in an ignition source owing to loose or broken connections shall be minimized.

Terminal size and construction requirements are necessary to ensure adequate current-carrying capacity and reliable connection such that the possibility of ignition is reduced.

Wiring flammability is necessary to reduce flame propagation potential should ignition take place.

Conductor size requirements are necessary to ensure adequate current-carrying capacity and reliable connection such that the possibility of ignition is reduced.

Alternative cords to rubber and PVC are accepted to allow for PVC free alternatives to be used. At the time of development of the document, IEC TC20 had no published documents available for these alternatives. However, several countries do have established requirements. Therefore, it was felt that these alternatives should be allowed.

G.7.3 – G.7.5 Mains supply cord anchorage, cord entry, bend protection

Source: IEC 60065:2011 and IEC 60950-1:2013

Purpose: Robustness requirements for cord anchorages

Rationale: The requirements for cord anchorages, cord entry, bend protection and cord replacement are primarily based on 16.5 and 16.6 of IEC 60065:2011 and 3.2.6 and 3.2.7 of IEC 60950-1:2013.

Experience shows that 2 mm displacement is the requirement and if an appropriate strain relief is used there is no damage to the cord and therefore, no need to conduct an electric strength test in most cases. This method has been successfully used for products in the scope of these documents for many years.

G.8 Varistors

Source: IEC 61051-1 and IEC 61051-2

Rationale: The magnitude of external transient overvoltage (mainly attributed to lightning), to which the equipment is exposed, depends on the location of the equipment.

This idea is described in Table 14 of IEC 62368-1:2018 and also specified in IEC 60664-1.

In response to this idea, IEC 61051-2 has been revised taking into account the location of the equipment, which also influences the requirement for the varistors used in the equipment.

The combination pulse test performed according to G.8.2 of IEC 62368-1:2018 can now refer to the new IEC 61051-2 with Amendment 1.

G.9 Integrated circuit (IC) current limiters

Source: IEC 60730-1, IEC 60950-1

Rationale: Integrated circuits (containing numerous integral components) are frequently used for class 1 and class 2 energy source isolation and, more frequently (for example, USB or PoE), for functions such as current limiting.

IEC 60335 series already has requirements for “electronic protection devices,” where conditioning tests such as EMF impulses are applied to such ICs, and the energy source isolation or current limiting function is evaluated after conditioning tests. When such energy isolation or current limitation has been proven reliable via performance, pins on the IC associated with this energy isolation or limitation are not shorted.

For ICs used for current limitation, two test programs were used in IEC 60950-1:2009. An additional program was developed in IEC 62368-1:2010. It was felt that all three programs were considered adequate. Therefore, the three methods were kept.

An Ad Hoc formed at the March 2015, Northbrook HBSDT meeting revised this test program with the following guiding principles:

- a) Streamline the number of tests in overall test program to concentrate on those tests and conditions that most likely will identify deficiencies in IC Current Limiter design from a safety perspective, such as allowing more current to flow than designed for. Some of the existing conditions are redundant or have questionable value identifying such deficiencies.
- b) Focus on test conditions that are applicable for semiconductor devices rather than test conditions more suited for traditional electro-mechanical devices. For example, 10 000-cycle testing has more applicability to electro-mechanical devices (in relation to parts wearing out) versus semiconductor devices (such as IC current limiters).
- c) Combine test conditions when justified to increase efficiency when conducting individual tests, also trying to make the testing more compatible with automated testing processes (e.g. combine individual temperature tests as individual sub-conditions of other required tests).

Table G.10 provides the specific performance test program for IC current limiters.

- Input loading to the device should be representative of the manufacturer's IC specification (as typically communicated in the IC application notes for the particular device).
- Output loading is intended to represent a short circuit condition ($0\ \Omega$ shunt), with parallel capacitive loading ($470\ \mu\text{F} \pm 20\%$) to better accommodate on/off cycling.

See Figure 47 in this document for additional detail.

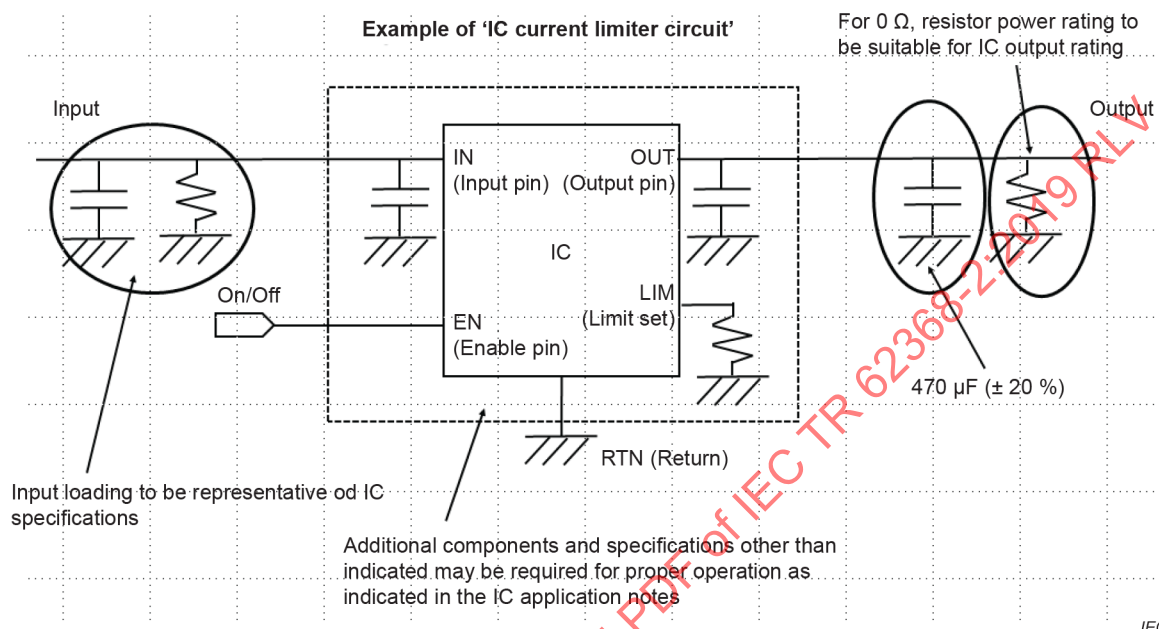


Figure 47 – Example of IC current limiter circuit

Regarding the 250 VA provision, this provision is intended to mean that the usual test power source has 250 VA capability as long as the IC is designed for installation in a system with a source of 250 VA or larger. If the power source capability is intended to be less than 250 VA, then the manufacturer must specify so, or test in the end product. Testing at 250 VA is intended to include 250 VA or larger sources because the test program is covering relatively small and low-voltage silicon devices – if these devices pass at 250 VA they likely would pass at higher VA too since they are not electro-mechanical. Also, this allows for more practical associated certification test programs.

Also, to avoid recertification of existing components, IC current limiters that met a previous legacy test program (G.9.2, G.9.3 or G.9.4) are an equivalent level of safety as the proposed rewritten Clause G.9, primarily because Clause G.9 is derivation of the legacy requirements. Therefore, IC current limiters that comply with the legacy test program should not need to be reinvestigated to the latest document that includes this revised Clause G.9. However, this is a certification consideration outside the scope of this technical committee.

G.11 Capacitors and RC units

Source: IEC 60384-14:2005

Rationale: Table G.11: Test voltage values aligned with those used in IEC 60384-14 (Tables 1, 2 and 10 of IEC 60384-14:2005).

Table G.12: Minimum number of Y capacitors based on **required withstand voltage** of Table 25 of IEC 62368-1:2018.

Table G.13: Maximum voltage that can appear across a Y capacitor based on the peak value of the **working voltage** of Table 26 of IEC 62368-1:2018.

Table G.14: Minimum number of Y capacitors based on the test voltages (due to **temporary overvoltages**) of Table 27 of IEC 62368-1:2018.

Table G.15: Minimum number of X capacitors (line to line or line to neutral) based on the **mains** transient withstand voltage of Table 13 of IEC 62368-1:2018.

All of the above are aligned with the requirements of IEC 60384-14.

G.13 Printed boards

Source: IEC 60950-1 or IEC 60664-3:2003.

Purpose: To provide details for reliable construction of PCBs.

Rationale: This proposal is based on IEC 60664-3 and the work of IBM and UL in testing coatings on printed boards when using coatings to achieve insulation coordination of printed board assemblies. Breakdown voltages of more than 8 000 V for 0,025 mm were routinely achieved in this program.

These parts have multiple stresses on the materials with limited separation between conductors. This section is taken from IEC 60950-1 where these requirements have been used for many years.

G.13.6 Tests on coated printed boards

Purpose: Prevent breakdown of the insulation **safeguard**.

Rationale: Avoid pinholes or bubbles in the coating or breakthrough of conductive tracks at corners.

G.14 Coatings on component terminals

Source: IEC 60950-1 and IEC 60664-3

Purpose: The mechanical arrangement and rigidity of the terminations are adequate to ensure that, during normal handling, assembly into equipment and subsequent use, the terminations will not be subject to deformation which would crack the coating or reduce the separation distances between conductive parts.

Rationale: The terminations are treated like coated printed boards (see G.13.3) and the same separation distances apply.

This section is taken from IEC 60950-1 where these requirements have been used for many years.

G.15 Pressurized liquid filled components

Source: IEC 60950-1, IEC 61010-1, UL 2178, UL 1995

Purpose: Avoid spillage of liquids resulting in electric shock hazard

Rationale: The requirements apply to devices that contain less than 1 l of liquid. A leak in the system may result in a shock hazard and therefore, needs to be properly addressed. A leak is not desirable and therefore, a strict performance criterion is proposed. Requirements were developed based on the following description of a typical system using liquid filled heat sinks. If a different type of system is used, then the requirements need to be re-evaluated.

Liquid filled heat-sink system (LFHS): a typical system consists of a heat exchanger, fan, pump, tubing, fittings and cold plate or radiator type heat exchanger. The liquid filled heat sink comes from the vendor already charged, sealed; and is installed and used inside the equipment (small type, typically found in cell stations and computing devices or other types of systems). The proposed requirements are based on a LFHS being internal to a unit, used/installed adjacent/over ES1 circuits, in proximity to an enclosed power supply (not open frame).

The liquid-filled heat components are used in desktop units or stationary equipment and in printers. These are not used in any portable equipment where orientation may change (unless the product is tested in all such orientations. If the liquid heat sink system is of a sealed type construction, then the system is orientation proof (this should not be a concern but a good engineering practice is that the pump does not become the high point in the system).

Following assumptions are used:

- The tubing is a single-layered metal (copper or aluminium) or non-metallic construction. If it is non-metallic, flammability requirements will apply.
- The fittings are metal. If it is non-metallic, flammability requirements will apply.
- Working pressure is determined under **normal operating conditions** and **abnormal operating conditions** and construction (tubing, fitting, heat exchanger, any joints, etc.) is suitable for this working pressure;
- The volume of the liquid is reasonable (less than 1 000 ml).
- The fluid does not cause corrosion and is not flammable (for example, corrosion resistant and non-flammable liquid).
- The liquid is non-toxic as specified for the fluid material.

Annex H Criteria for telephone ringing signals

H.2 Method A

Source: IEC 62949:2016.

Rationale: Certain voltages within telecommunication networks often exceed the steady state, safe-to-touch limits set within general safety documents. Years of practical experience by world-wide network operators have found ringing and other operating voltages to be electrically safe. Records of accident statistics indicate that electrical injuries are not caused by operating voltages.

Access to connectors carrying such signals with the standard test finger is permitted, provided that inadvertent access is unlikely. The likelihood of inadvertent access is limited by forbidding access with the test probe Figure 2C of IEC 60950-1:2013 that has a 6 mm radius tip.

This requirement ensures that:

- contact by a large part of the human body, such as the back of the hand, is impossible;
- contact is possible only by deliberately inserting a small part of the body, less than 12 mm across, such as a fingertip, which presents a high impedance;
- the possibility of being unable to let-go the part in contact does not arise.

This applies both to contact with signals arriving from the network and to signals generated internally in the equipment, for example, ringing signals for extension telephones. By normal standards, these internally generated signals would exceed the voltage limits for **accessible** parts, but the first exemption in IEC 60950-1 states that limited access should be permitted under the above conditions.

Ventricular fibrillation of the heart is considered to be the main cause of death by electric shock. The threshold of ventricular fibrillation (Curve A) is shown in Figure 48 in this document and is equivalent to curve c1 of IEC TS 60479-1:2005, Figure 14. The point 500 mA/100 ms has been found to correspond to a fibrillation probability of the order of 0,14 %. The let go limit

(Curve B) is equivalent to curve 2 of IEC TS 60479-1:2005, Figure 14. Some experts consider curve A to be the appropriate limit for safe design, but use of this curve is considered as an absolute limit.

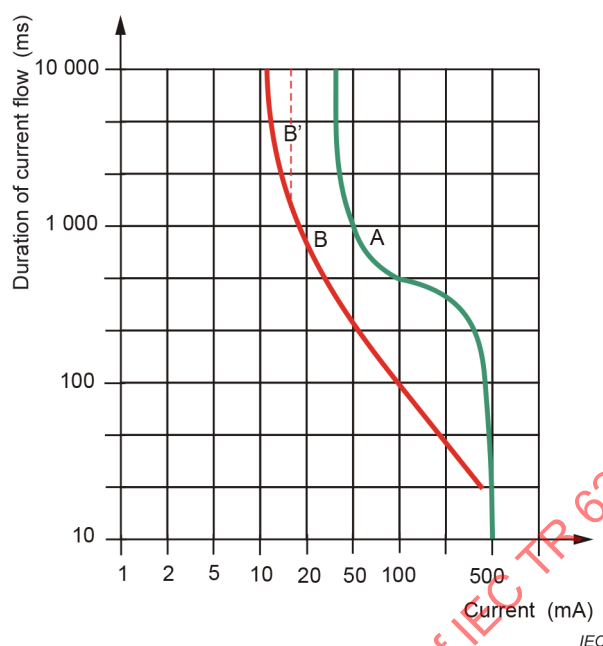


Figure 48 – Current limit curves

Contact with telecommunication operating voltages (EN 41003)

Total body impedance consists of two parts, the internal body resistance of blood and tissue and the skin impedance. Telecommunication voltages hardly reach the level where skin impedance begins to rapidly decrease due to breakdown. The skin impedance is high at low voltages, its value varying widely. The effects of skin capacitance are negligible at ringing frequencies.

IEC TS 60479-1 body impedance figures are based upon a relatively large contact area of 50 cm² to 100 cm², which is a realistic value for **mains** operated domestic appliances. Practical telecommunication contact is likely to be much less than this, typically 10 cm² to 15 cm² for uninsulated wiring pliers or similar **tools** and less than 1 cm² for finger contact with pins of a telephone wall socket. For contact with thin wires, wiring tags or contact with **tools** where fingers move beyond insulated handles, the area of contact will again be of the order of 1 cm² or less. These much smaller areas of contact with the body produce significantly higher values of body impedance than the IEC TS 60479 figures.

In IEC 60950-1, a body model value of 5 k Ω is used to provide a margin of safety compared with the higher practical values of body impedance for typical telecommunication contact areas.

The curve B' [curve C₁ of IEC TS 60479-1:2005, Figure 22 (curve A in this document)] used within the hazardous voltage definition is a version of curve B modified to cover practical situations, where the current limit is maintained constant at 16 mA above 1 667 ms. This 16 mA limit is still well within the minimum current value of curve A.

The difficulties of defining conditions that will avoid circumstances that prevent let-go have led to a very restricted contact area being allowed.

Contact with areas up to 10 cm² can be justified and means of specifying this and still ensuring let-go are for further study.

H.3 Method B

Source: This method is based on USA CFR 47 ("FCC Rules") Part 68, Sub part D, with additional requirements that apply under fault conditions.

Annex J Insulated winding wires for use without interleaved insulation

Source: IEC 60851-3:2009, IEC 60851-5:2008, IEC 60851-6:1996

Purpose: Winding wires shall withstand mechanical, thermal and electrical stress during use and manufacturing.

Rationale: Test data indicates that there is not a major difference between rectangular wires and round wires for electric strength after the bend tests. Therefore, there is no reason to not include them.

Subclause 4.4.1 of IEC 60851-5:2008 covers only solid circular or stranded winding wires as a twisted pair can easily be formed from round wires. It is difficult to form a twisted pair from square or rectangular winding wires.

IEC 60851-5:2008, 4.7 addresses a test method that can be used for square and rectangular wires. A separate test method for square and rectangular wires has been added. The test voltage is chosen to be half of the twisted pair as a single conductor is used for the testing.

In addition, the edgewise bend test is not required by IEC 60851-5 and IEC 60851-6 for the rectangular and square winding wires.

The reference to trichloroethane is being deleted as trichloroethane is an environmentally **hazardous substance**.

For J.2.3 (Flexibility and adherence) and J.2.4 (Heat shock), 5.1.2 in Test 8 of IEC 60851-3:2009 and 3.2.1 of IEC 60851-6:1996 are not used for solid square and solid rectangular winding wires.

Annex K Safety interlocks

Source: IEC 60950-1

Purpose: To provide reliable means of **safety interlock** devices.

Rationale: **Safety interlock** constructions have been used for many years in products within the scope of this document. **Safety interlocks** should not be associated with electro-mechanical components only.

Annex L Disconnect devices

Source: IEC 60950-1

Purpose: To provide adequate protective earth connection.

Rationale: 3 mm separation distances of contacts. Can be part of building installation.

For **class I equipment**, the supply plug or appliance coupler, if used as the **disconnect device**, shall make the **protective earthing** connection earlier than the supply connections and shall break it later than the supply connections.

Clearance of 3 mm can withstand peak impulse voltages of 4 000 V, which corresponds to a transient overvoltage present in overvoltage category III environment (equipment as part of the building installation).

One **instructional safeguard** could be used for more than one disconnect device, as long as it can be visible from each disconnect point.

Annex M Equipment containing batteries and their protection circuits

M.1 General requirements

Rationale: Stand-alone **battery** chargers for general purpose **batteries** shall be evaluated using their relevant safety document, and not IEC 62368-1. If the **battery** and the charger are designed specifically for AV or ICT equipment and not to be used for other purposes, the provisions of IEC 62368-1:2018 including Annex M may be applied.

M.2 Safety of batteries and their cells

Rationale: Equipment containing **batteries** shall be designed to reduce the risk of fire, **explosion** and chemical leaks under **normal operating conditions** and after a **single fault condition** in the equipment, including a fault in circuitry within the equipment **battery** pack. For **batteries** replaceable by an **ordinary person** or an **instructed person**, the design shall provide **safeguards** against reverse polarity installation or replacement of a **battery** pack from different component manufacturers if this would otherwise defeat a **safeguard**.

Other clauses in this document address in generic terms **safeguards** associated with the use of **batteries**. This annex does not specifically address those **safeguards**, but it is expected that **batteries** and associated circuits conform to the relevant requirements in this document.

This annex addresses **safeguards** that are unique to **batteries** and that are not addressed in other parts of the document. Energy sources that arise from the use of **batteries** are addressed in this annex and include the following:

- situations where the **battery** is in a state that exceeds its specifications or ratings (for example, by overcharging, rapid-charge, rapid-discharge, overcurrent or overvoltage conditions);
- thermal runaway due to overcharge or short circuits within **battery cells**;
- reverse-charging of the **battery**;
- leakage or spillage of electrolyte;
- emission of **explosive** gases; and
- location of **safeguards** where **battery** packs may be replaceable by an **ordinary person** or an **instructed person**.

Thermal runaway in the **cell** can result in **explosion** or fire, when the temperature rise in the **cell** caused by the heat emission raises the internal **cell** pressure faster than can be released by the **cell** pressure release device. Thermal runaway can be initiated by several causes:

- defects introduced into the **cell** during **cell** construction. These defects are often not detected during the manufacturing process and may bridge an internal insulation layer or block a vent;
- over-charge and rapid-charge or rapid-discharge;
- high operational temperature or high **battery** environment temperature;
- other **cells** in a pack feeding energy to a fault in a single **cell**; and
- crushing of the **enclosure**.

NOTE **Batteries** may contain multiple **cells**.

During charging operation, gases are emitted from secondary **cells** and **batteries** excluding gastight sealed (secondary) **cells**, as the result of the electrolysis of water by electric current. Gases produced are hydrogen and oxygen.

Table 17 in this document gives an overview of the referenced **battery** documents.

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Table 17 – Safety of batteries and their cells – requirements (expanded information on documents and scope)

Document	Chemistry							Category		Movability			Scope (details)
	Alkaline; non-acid	Lead Acid	NiCd/NiMH	Lithium	Nickel; alkaline electrolyte	Various	Various, with aqueous electrolyte	Primary	Secondary	Portable	Stationary	All	
IEC 60086-4 (2014): Primary Batteries – Part 4 – Safety of Lithium Batteries				X				X				X	Specifies tests and requirements for primary lithium batteries to ensure their safe operation under intended use and reasonably foreseeable misuse (includes coin / button cell batteries).
IEC 60086-5 (2016): Primary Batteries – Part 5 – Safety of batteries with aqueous electrolyte							X	X				X	Specifies tests and requirements for primary batteries with aqueous electrolyte to ensure their safe operation under intended use and reasonably foreseeable misuse (includes coin/button cell batteries).
IEC 60896-11 (2002): Stationary Lead Acid Batteries – Part 11 – Vented type		X						X	X		X		Applicable to lead-acid cells and batteries that are designed for service in fixed locations (for example, not habitually to be moved from place to place) and which are permanently connected to the load and to the DC power supply. Batteries operating in such applications are called "stationary batteries ". Any type or construction of lead-acid battery may be used for stationary battery applications. Part 11 is applicable to vented types only.
IEC 60896-21 (2004): Stationary Lead Acid Batteries – Part 21 – Valve regulated type – method of test		X						X	X		X		Applies to all stationary lead-acid cells and monobloc batteries of the valve regulated type for float charge applications, (for example, permanently connected to a load and to a DC power supply), in a static location (for example, not generally intended to be moved from place to place) and incorporated into stationary equipment or installed in battery rooms for use in telecom, uninterruptible power supply (UPS), utility switching, emergency power or similar applications. The objective is to specify the methods of test for all types and construction of valve regulated stationary lead acid cells and monobloc batteries used in standby power applications.

Document	Chemistry						Category		Movability			Scope (details)	
	Alkaline; non-acid	Lead Acid	NiCd/NiMH	Lithium	Nickel; alkaline electrolyte	Various	Various, with aqueous electrolyte	Primary	Secondary	Portable	Stationary		All
IEC 60896-22 (2004): Stationary Lead Acid Batteries – Part 22 – Valve regulated type – requirements		X						X	X		X		Applies to all stationary lead-acid cells and monobloc batteries of the valve regulated type for float charge applications, (for example, permanently connected to a load and to a DC power supply), in a static location (for example, not generally intended to be moved from place to place) and incorporated into stationary equipment or installed in battery rooms for use in telecom, uninterruptible power supply (UPS), utility switching, emergency power or similar applications. The objective is to assist the specifier in the understanding of the purpose of each test contained within IEC 60896-21 and provide guidance on a suitable requirement that will result in the battery meeting the needs of a particular industry application and operational condition. This document is used in conjunction with the common test methods described in IEC 60896-21 and is associated with all types and construction of valve regulated stationary lead-acid cells and monobloc batteries used in standby power applications.
IEC 61056-1 (2012): General purpose lead-acid batteries (valve-regulated types) – Part 1: General requirements, functional characteristics – Methods of test		X						X	X			X	Specifies the general requirements, functional characteristics and methods of test for all general-purpose lead-acid cells and batteries of the valve-regulated type: – for either cyclic or float charge application; – in portable equipment, for instance, incorporated in tools, toys, or in static emergency, or uninterruptible power supply and general power supplies. (For stationary applications, the battery will need to meet IEC 60896-21/-22 or subject to additional evaluation).

Document	Chemistry							Category		Movability			Scope (details)
	Alkaline; non-acid	Lead Acid	NiCd/NiMH	Lithium	Nickel; alkaline electrolyte	Various	Various, with aqueous electrolyte	Primary	Secondary	Portable	Stationary	All	
IEC 61056-2 (2012): General purpose lead-acid batteries (valve-regulated types) – Part 2: Dimensions, terminals and marking		X						X	X			X	Specifies the dimensions, terminals and marking for all general-purpose lead-acid cells and batteries of the valve regulated type: – for either cyclic or float charge application; – in portable equipment, for instance, incorporated in tools, toys, or in static emergency, or uninterruptible power supply and general power supplies. (For stationary applications, the battery will need to meet IEC 60896-21/-22 or subject to additional evaluation).
IEC 61427 (all parts) (2013): Secondary cells and batteries for renewable energy storage – General requirements and methods of test – Part 1: Photovoltaic off-grid application						X			X		X		Part of a series that gives general information relating to the requirements for the secondary batteries used in photovoltaic energy systems (PVES) and to the typical methods of test used for the verification of battery performances. This part deals with cells and batteries used in photovoltaic off-grid applications. This document is applicable to all types of secondary batteries .
IEC TS 61430 (1997): Secondary Cells and Batteries – Test Methods for Checking the Performance of Devices Designed for Reducing Explosion Hazards – Lead-Acid Starter Batteries		X							X			X	Specification gives guidance on procedures for testing the effectiveness of devices which are used to reduce the hazards of an explosion, together with the protective measures to be taken.
IEC 61434 (1996): Secondary cells and batteries containing alkaline or other non-acid electrolytes Guide to the designation of current in alkaline secondary cell and battery standards	X								X			X	Applies to secondary cells and batteries containing alkaline or other non-acid electrolytes. It proposes a mathematically correct method of current designation which shall be used in future secondary cell and battery documents.

Document	Chemistry							Category		Movability			Scope (details)
	Alkaline; non-acid	Lead Acid	NiCd/NiMH	Lithium	Nickel; alkaline electrolyte	Various	Various, with aqueous electrolyte	Primary	Secondary	Portable	Stationary	All	
IEC 61959 (2004): Secondary cells and batteries containing alkaline or other non-acid electrolytes Mechanical tests for sealed portable secondary cells and batteries						X		X	X	X			Specifies tests and requirements for verifying the mechanical behavior of sealed portable secondary cells and batteries during handling and normal use.
IEC 62133 (all parts) (2012 – superseded by IEC 62133-1 and IEC 62133-2); 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	X								X	X			Specifies requirements and tests for the safe operation of portable sealed secondary cells and batteries (other than coin / button cell batteries) containing alkaline or other non-acid electrolyte, under intended use and reasonably foreseeable misuse .
IEC 62133-1 (2017): 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 – Part 1: Nickel systems					X			X	X	X			Specifies requirements and tests for the safe operation of portable sealed secondary nickel cells and batteries containing alkaline electrolyte, under intended use and reasonably foreseeable misuse .
IEC 62133-2 (2017): Secondary cells and batteries containing alkaline or other non-acid electrolytes – Safety requirements for portable sealed secondary lithium cells, and for batteries made from them, for use in portable applications – Part 2: Lithium systems		X						X	X	X			Specifies requirements and tests for the safe operation of portable sealed secondary lithium cells and batteries containing non-acid electrolyte, under intended use and reasonably foreseeable misuse .

Document	Chemistry							Category		Movability			Scope (details)
	Alkaline; non-acid	Lead Acid	NiCd/NiMH	Lithium	Nickel; alkaline electrolyte	Various	Various, with aqueous electrolyte	Primary	Secondary	Portable	Stationary	All	
IEC 62281 (2016): Safety of primary and secondary lithium cells and batteries during transport				X				X	X			X	Specifies test methods and requirements for primary and secondary (rechargeable) lithium cells and batteries to ensure their safety during transport other than for recycling or disposal (similar to UN 38.3).
IEC 62485-2 (2010): Safety requirements for secondary batteries and battery installations – Part 2: Stationary batteries		X	X						X			X	Applies to stationary secondary batteries and battery installations with a maximum voltage of 1 500 V DC (nominal) and describes the principal measures for protections against hazards generated from: – electricity, – gas emission, – electrolyte. Provides requirements on safety aspects associated with the erection, use, inspection, maintenance and disposal. It covers lead-acid and NiCd/NiMH batteries (IEC 62485-2 requires the valve regulated batteries to meet safety requirements from IEC 60896).
IEC 62619 (2017): Secondary cells and batteries containing alkaline or other non-acid electrolytes – Safety requirements for secondary lithium cells and batteries, for use in industrial applications				X					X			X	Specifies requirements and tests for the safe operation of secondary lithium cells and batteries used in industrial applications including stationary applications.

M.3 Protection circuits for batteries provided within the equipment

Rationale: Equipment containing **batteries** is categorized into two types;

1. Equipment containing **batteries** which are embedded in the equipment and cannot be separated from the equipment.
2. Equipment containing **batteries** which can be separated from the equipment.

The requirements in IEC 62368-1 cover only the **battery** circuits that are not an integral part of the **battery** itself, and as such form a part of the equipment.

M.4 Additional safeguards for equipment containing a portable secondary lithium battery

Rationale: **Secondary lithium batteries** (often called lithium-ion or li-ion **batteries**) are expected to have high performance, such as light-weight and high energy capability. The use of li-ion **batteries** has been continuously expanding in the area of high-tech electronic equipment. However, it is said that this technology involves risks because the safety margin (distance between safe-operation zone and unsafe-operation zone) is relatively small compared to other **battery** technologies.

IEC TC 108 noted that for designing equipment containing or using li-ion **battery**, it is imperative to give careful consideration to selecting highly reliable **battery cells**, providing high performance **battery** management systems for operating **batteries** within their specified operating environment and parameter range (for example, **battery** surrounding temperature or **battery** charging/discharging voltage and current). It is also imperative to introduce **safeguards** against **abnormal operating conditions**, such as vibration during the use of devices, mechanical shock due to equipment drop, surge signals caused internally or externally, and a mechanism to reduce the likelihood of catastrophic failure such as **battery explosion** or fire.

It is suggested that suppliers of equipment and **batteries** should take into account possible **abnormal operating conditions** that may occur during use, transport, stock, and disposal, so that the equipment is well prepared for such conditions.

It is important that the key parameters (highest/lowest charging temperatures, maximum charging current, and upper limit charging voltage) during charging and discharging of the **battery** are not exceeded.

IEC TC 108 noted that, when designing **battery** compartments, the **battery** compartment dimensions should allow sufficient space for **cells** to expand normally under full operating temperature range or be flexible to prevent unnecessary compression of the **cells**. Given the wide range of **battery** constructions, corresponding **battery** compartment dimensional requirements will differ. When necessary, coordinate with the **battery** manufacturer to determine change in **battery** dimensions over full operating range during charging and discharging.

M.4.2.2 Compliance criteria

The highest temperature point in the **battery** may not always exist at the center of the **battery**. The **battery** supplier should specify the point where the highest temperature in the **battery** occurs.

To test the charging circuit, instead of using a real **battery** (which is a chemical system), an electrical circuit emulating the **battery** behavior (dummy **battery** circuit) may make the test easier by eliminating a possible **battery** defect.

An example of a dummy **battery** circuit is given in Figure 49 in this document.

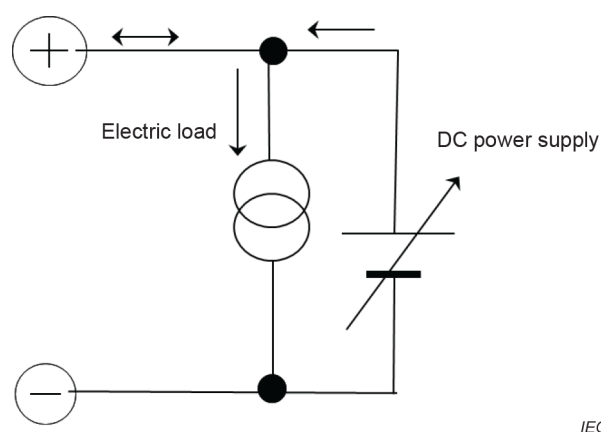


Figure 49 – Example of a dummy battery circuit

M.4.3 Fire enclosure

Lithium-ion **batteries** with an energy more than PS1 (15 W) must be provided with a **fire enclosure** (either at the **battery** or at the equipment containing the **battery**) because even though measurements of output voltage and current may not necessarily show them to be a **PIS**, however they contain flammable electrolyte that can be easily ignited by the enormous amount of heat developed by internal shorts as a result of possible contaminants in the electrolyte.

M.4.4 Drop test of equipment containing a secondary lithium battery

Monitoring of lithium-ion **battery** output voltage and surface temperature during or after the drop test may not help. The concern is that if a minor dent occurs, nothing may happen to the **battery**. Temperature may go up slightly and then drop down without any significant failure. If the **battery** is damaged, the damage may only show up if the **battery** is then subjected to few charging and discharging cycles. Therefore, the surface temperature measurement was deleted and replaced with charging and discharging cycles after the drop test. The charging and discharging of the **battery** shall not result in any fire or **explosion**.

It is important that the equipment containing a **secondary lithium battery** needs to have a drop impact resistance. Equipment containing a **secondary lithium battery** should avoid further damage to the control circuit and the **batteries**.

After the drop test:

- Initially, the control functions should be checked to determine if they continue to operate and all **safeguards** are effective. A dummy **battery** or appropriate measurement tool can be used for checking the function of the equipment.
- Then, the **batteries** are checked whether or not a slight internal short circuit occurs.

Discharge and charge cycles under **normal operating conditions** test hinder detection of the slight internal short circuit because the current to discharge and charge is higher than the current caused by a slight internal short circuit.

Thus, it is very important to conduct a voltage observation of the **battery** immediately after the drop test without any discharge and charge.

To detect a slight internal short circuit of the **battery**, IEC TC 108 adopts a no-load test, which can detect a **battery** open voltage drop caused by an internal short circuit leak current in a 24 h period.

Equipment containing an embedded type of **battery** has internal power dissipation (internal consumption current). Therefore, two samples of the equipment are prepared, one for the drop test and the other for reference in a standby mode. In this way, the effect of internal power dissipation can be detected by measuring a difference between voltage drops in the 24 h period.

M.6.1 Requirements

Examples: Examples of **battery** documents containing an internal short test are IEC 62133, IEC 62133-2 and IEC 62619.

Another example of compliance to internal fault requirements is a **battery** using **cells** that have passed the impact test as specified in IEC 62281.

M.7.1 Ventilation preventing an explosive gas concentration

Rationale: During charging, float charging, and overcharging operation, gases are emitted from secondary **cells** and **batteries** excluding gastight sealed (secondary) **cells**, as the result of the electrolysis of water by electric current. Gases produced are hydrogen and oxygen.

M.7.2 Test method and compliance criteria

Source: The formula comes from IEC 62485-2:2010, 7.2.

M.8.2.1 General

Source: The formula comes from IEC 60079-10-1:2015, Clause B.4.

Annex O Measurement of creepage distances and clearances

Source: IEC 60664-1, IEC 60950-1.

Purpose: **Clearances** are measured from the X-points in the figure

Rationale: Figure O.13. The **clearance** determination is made from the X-points in the figure, as those are the first contact points when the test finger enters the **enclosure** opening. It is assumed that the **enclosure** is covered by conductive foil, which simulates conductive pollution.

Annex P Safeguards against conductive objects

P.1 General

Rationale: The **basic safeguard** against entry of a foreign object is that persons are not expected to insert a foreign object into the equipment. Where the equipment is used in locations where children may be present, it is expected that there will be adult supervision to address the issue of reasonable foreseeable misuse by children, such as inserting foreign objects. Therefore, the **safeguards** specified in this annex are **supplementary safeguards**.

P.2 Safeguards against entry or consequences of entry of a foreign object

Source: IEC 60950-1

Purpose: Protect against the entry of foreign objects

Rationale: There are two alternative methods that may be used.

P.2.2 specifies maximum size limits and construction of openings. The relatively small foreign conductive objects or amounts of liquids that may pass through these openings are not likely to defeat any **equipment safeguards**. This option prevents entry of objects that may defeat a **safeguard**.

Alternatively, if the openings are larger than those specified in P.2.2, P.2.3 assumes that a foreign conductive object or liquid passing through these openings is likely to defeat an equipment **basic safeguard**, and requires that the foreign conductive object or liquid shall not defeat an equipment **supplementary safeguard** or an equipment **reinforced safeguard**.

P.2.3.1 Safeguard requirements

Rationale: Conformal coating material is applied to electronic circuitry to act as protection against moisture, dust, chemicals, and temperature extremes that, if uncoated (non-protected), could result in damage or failure of the electronics to function. When electronics are subject to harsh environments and added protection is necessary, most circuit board assembly houses coat assemblies with a layer of transparent conformal coating rather than potting.

The coating material can be applied by various methods, from brushing, spraying and dipping, or, due to the increasing complexities of the electronic boards being designed and with the 'process window' becoming smaller and smaller, by selectively coating via robot.

P.3 Safeguards against spillage of internal liquids

Source: IEC 60950-1

Rationale: If the liquid is conductive, flammable, toxic, or corrosive, then the liquid shall not be **accessible** if it spills out. The container of the liquid provides a **basic safeguard**. After the liquid spills out, then barrier, guard or **enclosure** that prevents access to the liquid acts as a **supplementary safeguard**. Another choice is to provide a container that does not leak or permit spillage for example, provide a **reinforced safeguard**.

P.4 Metalized coatings and adhesives securing parts

Source: IEC 60950-1

Rationale: Equipment having internal barriers secured by adhesive are subject to mechanical tests after an aging test. If the barrier does not dislodge as a whole or partially or fall off, securement by adhesive is considered acceptable.

The temperature for conditioning should be based on the actual temperature of the adhesive secured part.

The test program for metalized coatings is the same as for aging of adhesives. In addition, the abrasion resistance test is done to see if particles fall off from the metalized coating. Alternatively, **clearance** and **creepage distances** for PD3 shall be provided.

Annex Q Circuits intended for interconnection with building wiring

Source: IEC 60950-1:2013

Rationale: For the countries that have electrical and fire codes based on NFPA 70, this annex is applied to ports or circuits for **external circuits** that are interconnected to building wiring for limited power circuits. Annex Q was based on requirements from IEC 60950-1 that are designed to comply with the **external circuit** power source requirements necessary for compliance with the electrical codes noted above.

Q.1.2 Test method and compliance criteria

In determining if a circuit is a limited power source, all conditions of use should be considered. For example, for circuits that may be connected to a **battery** source as well as a **mains** source, determination whether the available output from the circuit is a limited power source is made with each of the sources connected independently or simultaneously (see Figure 50 in this document).

Q.2 Test for external circuits – paired conductor cable

Time/current characteristics of type gD and type gN fuses specified in IEC 60269-2-1 comply with the limit. Type gD or type gN fuses rated 1 A, would meet the 1,3 A current limit.

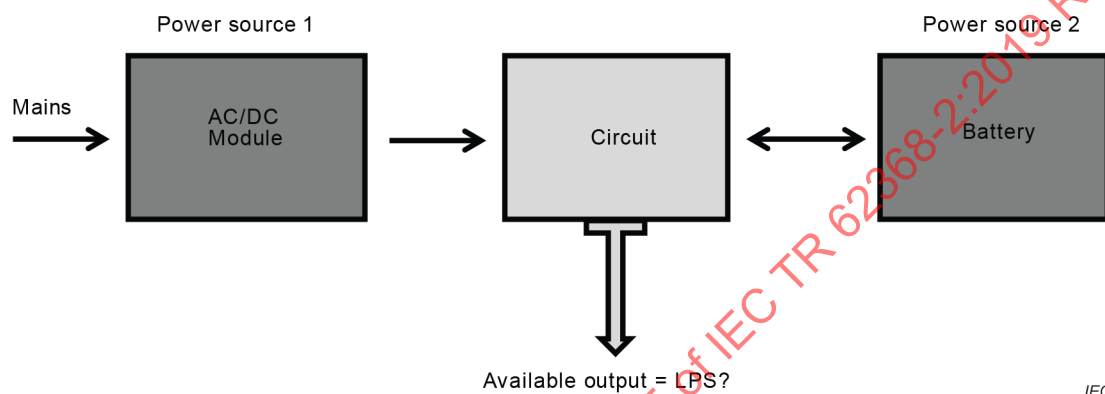


Figure 50 – Example of a circuit with two power sources

Annex R Limited short-circuit test

Source: IEC SC22E

Rationale: The value of 1 500 A is aligned with the normal breaking capacity of a high breaking fuse. In Japan the prospective short circuit current is considered less than 1 000 A.

Annex S Tests for resistance to heat and fire

S.1 Flammability test for fire enclosure and fire barrier materials of equipment where the steady-state power does not exceed 4 000 W

Rationale: This test is intended to test the ability of an end-product **enclosure** to adequately limit the spread of flame from a **potential ignition source** to the outside of the product.

- Included the text from IEC 60065 using the needle flame as the ignition source for all material testing. The reapplication of the flame after the first flaming was added to clarify that the test flame is immediately re-applied based on current practices.
- This conditioning requirement of 125 °C for printed wiring boards is derived from laminate and PCB documents.

S.2 Flammability test for fire enclosure and fire barrier integrity

Rationale: This test method is used to test the integrity of a fire barrier or **fire enclosure** where a **potential ignition source** is in very close proximity to an **enclosure** or a barrier.

The criteria of “no additional holes” is considered important as flammable materials may be located immediately on the other side of the barrier or **fire enclosure**.

Rationale: **Application of needle flame**

The flame cone and the 50 mm distance is a new requirement that was not applied in IEC 60950 to top openings. This new requirement does impact already certified IEC 60950 ITE products, and it was found that some manufacturers' current designs were not able to comply with the 50-mm distance prescribed ventilation opening requirements and will not be able to pass the needle flame test as per IEC 60695-11. An HBSDT's fire enclosure adhoc team performed some experimental flame testing with the needle flame located at various distances from various size ventilation openings. This test approach was found to align more with hazard-based safety engineering principles and deemed to be a more realistic representation of when a thermal event may occur.

A **PIS** can be in the form of any size/shape, so it was determined not reasonable to directly apply the needle flame to top surface openings when realistically a thermal event from smaller components is unlikely to touch the top surface openings. Additionally, typically it is common for such components to be mounted on V-0 rated boards that further help reduce the spread of fire.

The test data from the fire experimental testing demonstrated clearly that, when the flame is at distances well within 50 mm, significantly larger openings can be used beyond the pre-specified sizes by 6.4.8.3.3 (for example less than 5 mm in any dimension and/or less than 1 mm regardless of length).

Therefore, for the purpose of this standard and to align more with hazard-based safety engineering principles, the needle flame is to be applied at a distance measured from the closest assessed point of a PIS to the closest surface point of the test specimen. The application of the flame is measured from the top of the needle flame burner to the closest surface point. See Figure S.1 in Clause S.2 of IEC 62368-1:2018.

S.3 Flammability tests for the bottom of a fire enclosure

Source: IEC 60950-1:2013

Rationale: This text was not changed from the original ECMA document which was originally in IEC 60950-1. This test is intended to determine the acceptability of holes or hole patterns in bottom **enclosures** to prevent flaming material from falling onto the supporting surface. It has been used principally for testing metal bottom **enclosures**.

This test is being proposed to test all bottom **enclosures**. Research is ongoing to develop a similar test based on the use of flammable (molten) thermoplastic rather than oil.

S.4 Flammability classification of materials

Rationale: The tables were considered helpful to explain the hierarchy of **material flammability class** requirements used in this document.

Whenever a certain flammability class is required, a better classification is allowed to be used.

S.5 Flammability test for fire enclosure materials of equipment with a steady state power exceeding 4 000 W

Source: IEC 60950-1:2013

Rationale: The annex for flammability test for high voltage cables was withdrawn and replaced by flammability test for fire **enclosure** materials of equipment having greater than 4 000 W faults.

Annex T Mechanical strength tests

T.2 Steady force test, 10 N

Source: IEC 60950-1

Rationale: 10 N applied to components and parts that may be touched during operation or servicing. This test simulates the accidental contact with a finger or part of a hand.

T.3 Steady force test, 30 N

Source: IEC 60065 and IEC 60950-1

Rationale: This test simulates accidental contact with a part of the hand.

T.4 Steady force test, 100 N

Source: IEC 60065 and IEC 60950-1

Rationale: This test simulates an expected force applied during use or movement.

T.5 Steady force test, 250 N

Source: IEC 60065 and IEC 60950-1

Rationale: 250 N applied to external **enclosures** (except those covered in Clause T.4). This test simulates an expected force when leaning against the equipment surface to ensure **clearances** are not bridged to introduce a hazard such as shock. The 30 mm diameter surface simulates a small part of hand or foot. It is not expected that such forces will be applied to the bottom surface of heavy equipment (> 18 kg).

T.6 Enclosure impact test

Source: IEC 60065 and IEC 60950-1

Rationale: To check integrity of the **enclosure**, to ensure that no hazard is created by an impact.

The values in T.6 are taken over from existing requirements in IEC 60065 and IEC 60950-1.

The impact is applied once for each test point on the **enclosure**.

T.7 Drop test

Source: IEC 60065 and IEC 60950-1

Rationale: This test addresses potential exposure to a hazard after the impact and not impact directly on a body part. The test is applied to desk top equipment under 7 kg as it is more likely these products could be accidentally knocked off the desk. The drop height was chosen based on intended use of the product.

The term “table-top” has been used in IEC 60065, while the term “desk-top” has been used in IEC 60950-1. Both terms had been taken over in IEC 62368-1 without the intention to make the different requirements for these types of equipment. Therefore, the requirements are applicable to both type of equipment even if only either one is referred to. From edition 3 onwards, the term “table-top” has been replaced by “desk-top”.

T.8 Stress relief test

Source: IEC 60065 and IEC 60950-1

Rationale: To ensure that the mechanical integrity of moulded plastic parts is not affected by their relaxation or warping following thermal stress.

T.9 Glass impact test

Source: IEC 60065

Rationale: Test applied to test the strength of the glass.

The value of 7 J is a value that has been used for CRT in the past. Except for that, the value has also been used in commercial applications, but not in households, where the forces expected on the glass are much lower. CRT's have separate requirements in Annex W. Therefore, a value of 3,5 J is considered sufficient.

The centre of a piece of glass can be determined via the intersection of two diagonals for a rectangular piece or any other appropriate means for pieces of other geometries.

T.10 Glass fragmentation test

Source: IEC 60065

Rationale: Test applied to ensure the fragments are small enough to be considered at MS2 level or less.

Annex U Mechanical strength of CRTs and protection against the effects of implosion

U.2 Test method and compliance criteria for non-intrinsically protected CRTs

Source: IEC 61965, IEC 60065

Rationale: The 750 mm simulates the height of a typical supporting surface such as a table or counter top. Test applied to ensure any expelled fragments are small enough to be considered at MS2 level or less. The fragment size represents a grain of sand. The test distances selected ensure fragments do not travel far enough to strike a person and cause injury.

Annex V Determination of accessible parts

Figure V.3 Blunt probe

Source: This test probe is taken from Figure 2c, IEC 60950-1:2013

Annex X Alternative method for determining clearances for insulation in circuits connected to an AC mains not exceeding 420 V peak (300 V RMS)

Rationale: IEC TC 108 made a responsible decision to harmonize the requirements for **clearances** and **creepage distances** with the horizontal IEC 60664-x series documents produced by IEC TC 109. This decision is aligned with IEC harmonization directives and allows manufacturers the design benefits afforded by the IEC 60664-x series documents when minimization of spacings is a primary consideration of the product design.

However, because of the complexity of determining **clearances** as per 5.4.2, sometimes the more state-of-art theory is not practical to implement for designs not requiring minimized spacings. For example, there are a very large number of existing designs and constructions qualified to IEC 60950-1 that are associated with products, mainly switch mode power supplies, connected to AC **mains** (overvoltage category II) not exceeding 300 V RMS. These constructions have successfully used the **clearance** requirements in IEC 60950-1 without any evidence of field issues, and even at switching frequencies well above 30 kHz. In fact, almost every switch mode power supply (SMPS) used today with IT & ICT equipment intended to be connected to **mains** less than 300 V RMS, including external power supplies, direct plug-in type, and internal power supplies, have **clearances** based on the base requirements in Subclause 2.10.3.3 and Tables 2K and 2L of IEC 60950-1. Although the requirements do not incorporate the latest research on **clearances** used in circuits operating above 30 kHz, they are considered to be suitable for the application because they are a conservative implementation of IEC 60664-1 without minimization.

As a result, and in particular based on their proven history of acceptability in the broad variety of power supplies used today, IEC TC 108 should support continued limited application of a prescribed set of **clearances** as an alternative to the more state-of-art IEC 60664-based requirements in IEC 62368-1 today. However, because of the valid concern with circuits operating above 30 kHz as **clearances** are further minimized, the IEC 60950-1 option in Tables 2K and 2L for reduced **clearances** in products with manufacturing subjected to a quality control programme (values in parenthesis in Tables 2K/2L) are not included in this proposal since the reduced **clearances** associated with the quality control option has not been used frequently under IEC 60950-1, and therefore there is not the same proven track record of successful implementation in a very large number of products. Similarly, there is not the same large quantity of qualified designs/construction associated with equipment connected to **mains** voltages exceeding 300 V RMS, or for equipment connected to DC **mains**, so these constructions should comply with the existing IEC 60664-based requirements in IEC 62368-1.

Annex Y Construction requirements for outdoor enclosures

Rationale: General

In preparing the requirements for **outdoor enclosures**, it has been assumed that:

- exterior to the **outdoor equipment** there should be no hazards, just as is the case with other information technology equipment;
- protection against vandalism and other purposeful acts will be treated as a product quality issue (for example, IEC 62368-1 does not contain requirements for the security of locks, types of acceptable screw head, forced entry tests, etc.).

Electric shock

It is believed that most aspects relating to protection against the risk of electric shock are adequately covered by IEC 62368-1 including current proposals, and in some cases, quoted safety documents (in particular, the IEC 60364 series), and with the exception of the following, do not require modification. Specific requirements not already suitably addressed in IEC 60950-1 were considered as follows:

- clearing of earth faults for remotely located (exposed) information technology equipment;
- the degree of protection provided by the **enclosure** to rain, dust, etc.;
- the effect of moisture and **pollution degree** on the insulation of the enclosed parts;
- the possible consequences of ingress by plants and animals (since these could bridge or damage insulation);
- the maximum permissible touch voltage and body contact impedance for wet conditions.

It is noted that the voltage limits of user-**accessible** circuits and parts in **outdoor locations** only are applicable to circuits and parts that are actually “user-**accessible**”. If the circuits and parts are not user **accessible** (determined via application of accessibility probes) and are enclosed in **electrical enclosures**, connectors and cable suitable for the outdoor application, including being subject to all relevant **outdoor enclosure** testing, voltage limits for indoor locations may be acceptable based on the application. For example, a power-over-ethernet (PoE) surveillance camera mounted outdoors supplied by 48 V DC from PoE would be in compliance with Clause 5 if the **electrical enclosure** met the applicable requirements for **outdoor enclosures**.

Fire

It is believed that most aspects relating to protection against fire emanating from within the equipment are adequately covered by IEC 62368-1. However, certain measures that may be acceptable for equipment located inside a building would not be acceptable outdoors because they would permit the entry of rain, etc.

For certain types of **outdoor equipment**, it could be appropriate to allow the ‘no bottom **fire enclosure** required if mounted on a concrete base’ exemption that presently can be used for equipment for use within a restricted access location.

Mechanical hazards

It is believed that all aspects relating to protection against mechanical hazards emanating from the equipment are adequately covered by IEC 62368-1.

Heat-related hazards

It is believed that most aspects relating to protection against direct heat hazards are adequately covered by IEC 62368-1. However, it may be appropriate to permit higher limits for equipment that is unlikely to be touched by passersby (for example, equipment that is only intended to be pole mounted out of reach). A default nominal ambient temperature range for **outdoor equipment** has been proposed. The effects of solar heating have not been addressed.

In addition to direct thermal hazards, there is a need to consider consequential hazards. For instance, some plastics become brittle as they become cold. An **enclosure** made from such brittle plastic could expose users to other hazards (for example, electrical or mechanical) if it were to break.

Radiation

It is believed that most aspects relating to direct protection against radiation hazards are adequately covered by IEC 62368-1. However, there may be consequential hazards to consider. Just as polymeric materials can be affected by low temperatures, they can also become embrittled owing to the effect of UV radiation. An **enclosure** made from such brittle plastic could expose users to other hazards (for example, electrical or mechanical) if it were to break.

Chemical hazards

It is believed that certain types of **outdoor equipment** need to have measures relating to chemical hazards originating within, or external to, the equipment. Exposure to chemicals in the environment (for example, salt used to clear roads in the winter) can also cause problems.

Biological hazards

These are not presently addressed in IEC 62368-1. As with radiation hazards and chemical hazards, it is thought that there is not likely to be any direct biological hazard. However, plastics and some metals can be attacked by fungi or bacteria and this could result in weakening of protective **enclosures**. As stated under 'electric shock', the ingress of plants and animals could result in damage to insulation.

Explosion hazards

Outdoor equipment may need to be weather-tight, in such cases there is an increased probability that an **explosive** atmosphere can build up as a result of:

- hydrogen being produced as a result of charging lead-acid **batteries** within the equipment and;
- methane and other 'duct gasses' entering the equipment from the outdoors.

Y.3 Resistance to corrosion

Rationale: **Enclosures** made of the following materials are considered to comply with XX.1 without test:

- (a) Copper, aluminum, or stainless steel; and
- (b) Bronze or brass containing at least 80 % copper.

Y.4.6 Securing means

Rationale: Gaskets associated with doors, panels or similar parts subject to periodic opening is an example of a gasket needing either mechanical securement or adhesive testing.

Annex A (informative)

Background information related to the use of SPDs

NOTE Since there is ongoing discussion in the committee on the use of SPDs in certain situations, the content of this Annex is provided for information only. This Annex does not in any way override the requirements in the document, nor does it provide examples of universally accepted constructions.

A.1 Industry demand for incorporating SPDs in the equipment

The industry has the demand of providing protection of communication equipment from overvoltage that may be caused by lightning strike surge effect. There are reports in Japan that hundreds of products are damaged by lightening surges every year, including the risk of fire and/or electrical shock according to the damage to the equipment, especially in the regions where many thunderstorms are observed. We believe it will be the same in many other countries by the reason described in the next paragraph where the voltage of the surge is much higher than expected value for overvoltage category II equipment (1 500 V peak or 2 500 V peak). For the surge protection purpose, the manufacturers have need to introduce the surge protection devices in the equipment, not only for **class I equipment** but also for **class II equipment** or **class III equipment**, but facing to the difficulty of designing equipment because of the limited acceptance in IEC 60950-1, 2nd edition and IEC 62368-1, 1st edition.

If the point of bonding of electrical supply to the equipment is not adjacent to the point of bonding of telecommunication circuit that is connected to the **external circuit** of the same equipment, the surge entered from power line or from communication line causes the high potential difference on the insulation in the equipment, and cause the insulation/component breakdown which may cause product out-of-use. In some cases, the damage on the insulation or **safeguard** can cause hazardous voltage on the SELV/ES1 and **accessible** metal, or heat-up of insulation material and fire (see Figure A.1 in this document, with the example of **class II equipment**.)

The most effective way to protect equipment from a lightning surge is, as commonly understood internationally, to have an equipotential bonding system in the building/facility with a very low in-circuit impedance by the use of main-earth bar concept (see Figure A.2 in this document). This kind of high-quality earthing provision can be introduced in the building/facility in the business area, such as computer rooms, or in modern buildings. This kind of high quality earthing provision may not always be possible in the residential area, in already-existing buildings and in some countries where the reliably low impedance earth connection may not be easily obtained from technical (according to the characteristics of land) or even by practical reasons (because very expensive construction change to the building is required, or according to the lack of regulatory co-work it is difficult to get the relevant permission for cabling). We should not disregard the fact that many ICT equipment (including PCs, fax machines, TVs and printers) are brought to home, school and small business offices into the existing buildings (see Figure A.3 and Figure A.4 in this document).

If the use of surge suppressors by the means of “a varistor in series with a GDT” is allowed in the equipment to bridge **safeguards** for **class I equipment** and to bridge a **double safeguard** or a **reinforced safeguard** for **class II equipment**, means can be provided to bypass the surge current, and to avoid the possibility that the lightening surge breaks the circuit or the insulation within the equipment (see Figure A.2 in this document).

Thus, there is industry demand for using surge protecting devices (SPDs) in the equipment independent of whether the product is **class I equipment**, **class II equipment** or **class III equipment**.

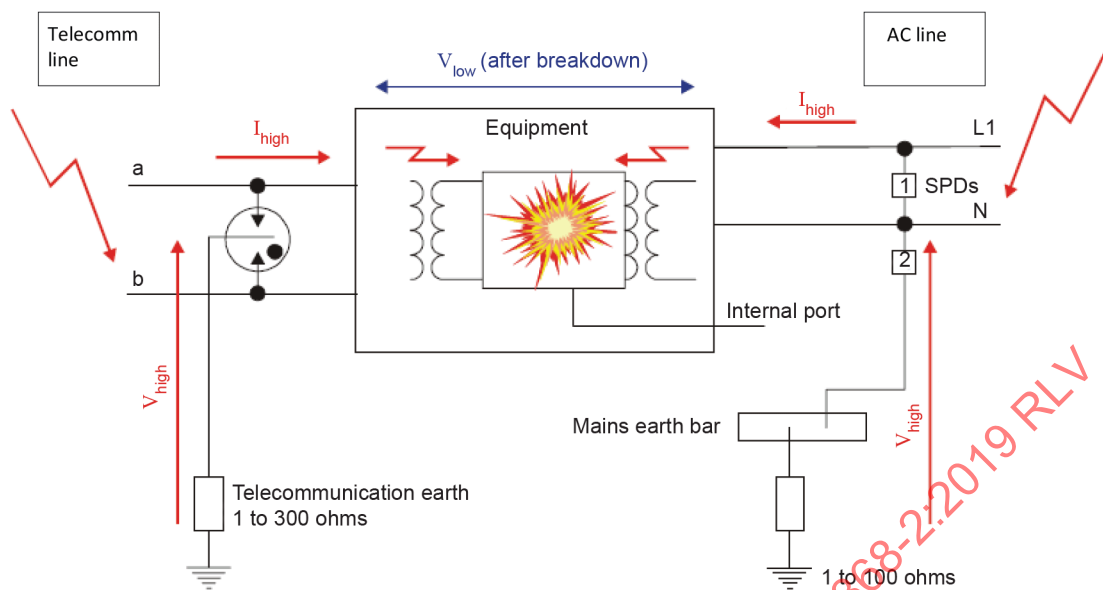


Figure A.1 – Installation has poor earthing and bonding; equipment damaged (from ITU-T K.66)

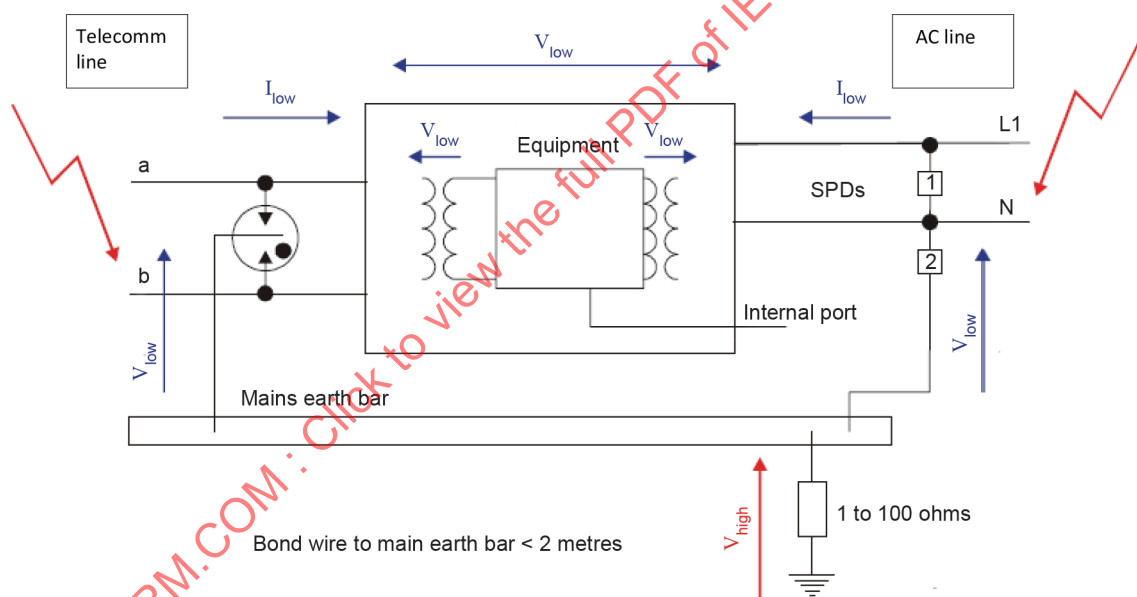


Figure A.2 – Installation has poor earthing and bonding; using main earth bar for protection against lightning strike (from ITU-T K.66)

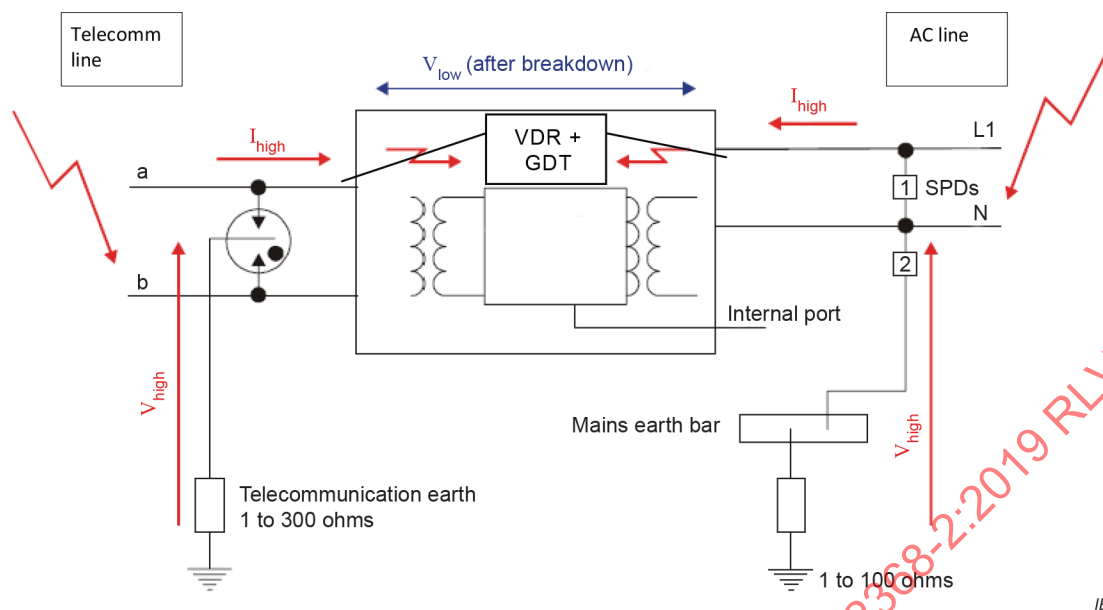


Figure A.3 – Installation with poor earthing and bonding, using a varistor and a GDT for protection against a lightning strike

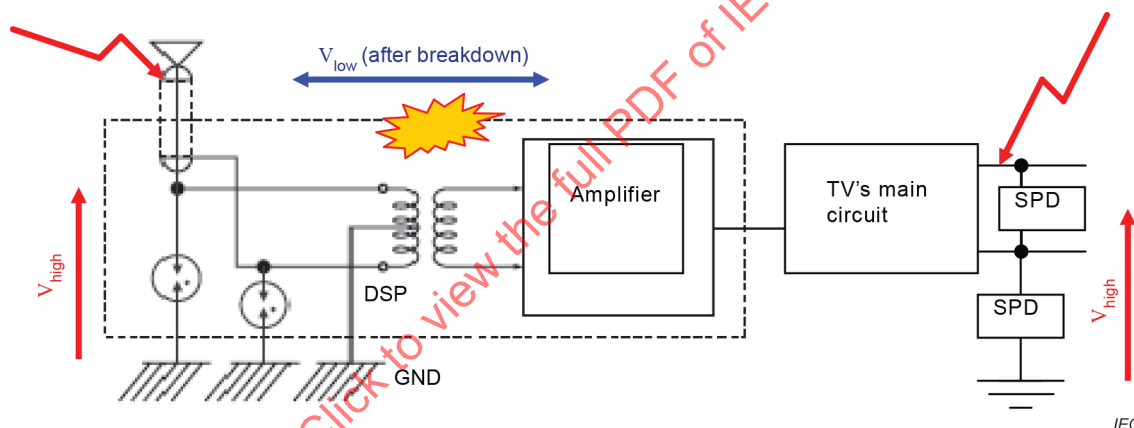


Figure A.4 – Installation with poor earthing and bonding; equipment damaged (TV set)

A.2 Technical environment of relevant component standards

Before the publication of IEC 62368-1:2010, there was no appropriate component document for a GDT deemed to be providing a sufficient level of endurance to be accepted as a **safeguard** for a primary circuit. For this reason, a GDT could not be accepted as a reliable component for use as a **safeguard** between a primary and secondary circuit.

However, recently IEC SC 37B has been developed new documents for GDTs. In these documents the spark over voltage of GDT's has been extended up to 4 500 V DC, taking the use of GDTs in the **mains** circuit in to account. We believe therefore that a GDT may be used as a **safeguard** if it complies with the following documents:

- IEC 61643-311:2013: Components for low-voltage surge protective devices – Part 311: Performance requirements and test circuits for gas discharge tubes (GDT);
- IEC 61643-312:2013: Components for low-voltage surge protective devices – Part 312: Selection and application principles for gas discharge tubes;

The sentence “does not deal with GDTs connected in series with voltage-dependent resistors in order to limit follow-on currents in electrical power systems;” in the scope of these

documents with a purpose for expressing that GDTs connected in series with varistors are a kind of SPD and this issue should be in IEC 61643-11 for SPD's standard. But this sentence may be misread as "a GDT is not allowed to be used for primary circuits", so SC37B decided to delete the sentence. This decision was made during the IEC SC 37B meeting at Phoenix, U.S.A, in Oct, 2010.

A.3 Technical discussion

A.3.1 General

For the use as surge protective devices (SPD), there are many types of components and the combined use of them. Some of them are relatively large in size and useful only in the outdoor facility or in the building circuits. Some are reliable but others may not.

For use with equipment in the scope of IEC 62368-1, varistors and GDT's are very commonly available with appropriate physical size and reliability.

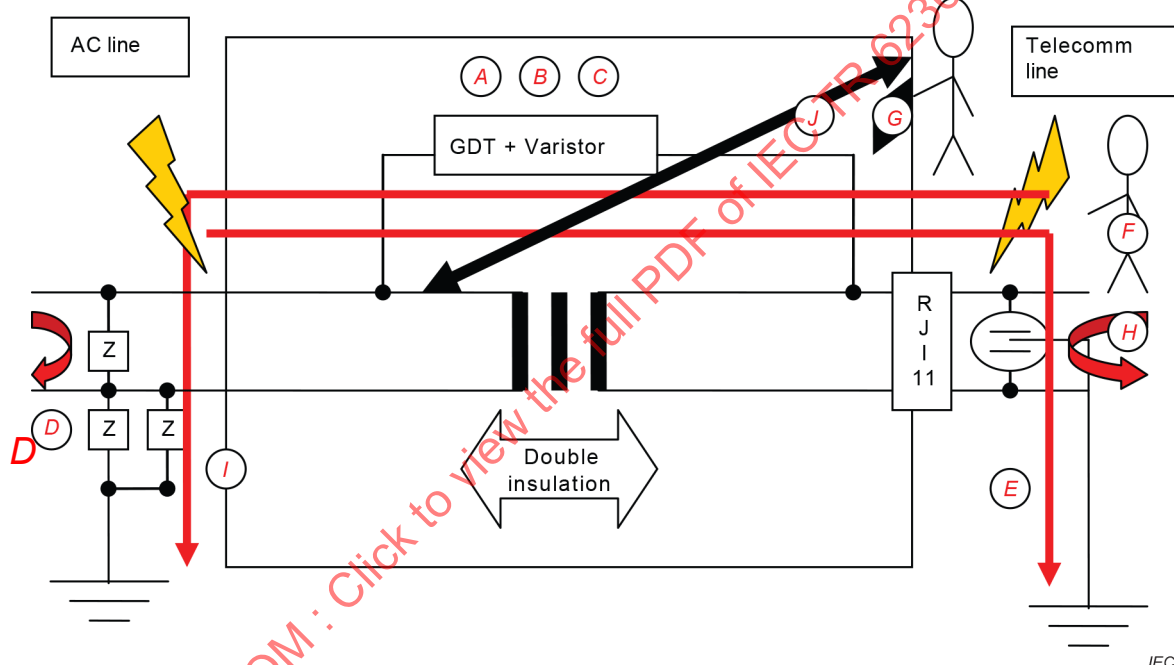


Figure A.5 – Safeguards

A.3.2 Recommended SPD and its level of sparkover voltage

The recommended construction of SPD for the purpose of protecting human and the insulations in the equipment is the combined use of a GDT and a varistor in series, by the reasons described in this subclause and A.3.3.

The level of sparkover voltage of the SPD constructed as recommended as above is important and should be selected as higher than withstand voltage level of insulation which SPD is intended to protect from damage by surge overvoltage. IEC 61643-311 and IEC 61643-312 provides the selection of GDT's up to 4 500V DC sparkover voltage series (see "A" in Figure A.5 in this document).

A.3.3 Consideration of a GDT and its follow current

If you are going to use a GDT in the primary circuit, or in the **external circuit**, you have to take the follow current in GDT into account. For more information on the GDT's follow current, see Clause A.4 in this document.

The follow current in the GDT after the surge transient voltage/current that flows through it may keep the GDT in the low impedance mode while the equipment power is on, resulting in a risk of electric shock if somebody touches the circuit connected to the GDT. The combined use of a GDT and a varistor in series is the common method to avoid this risk. After the transient overvoltage condition is over, the varistor will stop the GDT's follow current. Complying with Clause G.8 is required for the varistor's **working voltage**. It means that $1,25 \times V_{ac}$ is required for the varistor's **working voltage**. After the transient, the varistor will stop the current from the AC line immediately.

For the reliability of the GDT, it is required that the GDT meets the requirements for electric strength and the external **clearance** and **creepage distance** requirements for **reinforced insulation** (see "**B**" in Figure A.5).

A.3.4 Consideration of varistors and its leak current

If a varistor is used in the primary circuit or in the **external circuit**, the leakage current in the varistor has to be taken into account. The continuous current caused by the leakage current may burn the varistor or other components in the circuit, and is energy inefficient. The combined use of a GDT and a varistor in series is the common method to avoid this effect, since the GDT can kill the leakage current just after the surge transient voltage passed through these components.

For the reliability of the varistor, it has to comply with Clause G.8 (see "**C**" in Figure A.5 in this document).

A.3.5 Surge voltage/current from mains

A.3.5.1 Case of transversal transient on primary circuit

A surge caused by lightning may enter in the **mains** circuit and get into the equipment as a transversal transient overvoltage. In this case, incorporating an SPD (that may be a varistor only) between the line and neutral of the primary circuit is an effective method to prevent damage in the circuit, as the surge is bypassed from line to neutral or vice versa. In this case, the reliability requirement may not be mandatory for the SPD, because the failure of the SPD can lead to an equipment fault condition (out of use) but may not lead to risk to human (see "**D**" in Figure A.5 in this document).

A.3.5.2 Case of longitudinal transient on primary circuit

A surge caused by lightning may enter in the **mains** circuit and get into the equipment as a longitudinal (common mode) transient overvoltage, which may cause high-level potential difference between the primary circuit and the **external circuits** in the equipment. In this case, providing a bypass circuit from the primary circuit to the reliable bonding, or a bypass circuit between the primary circuit and the **external circuits**, or both, incorporating an SPD (a combined use of a GDT and a varistor in series is recommended) is an effective method to prevent insulations and components in the equipment from being damaged (see "**E**" in Figure A.5 in this document).

For preventing the risk of electrical shock in this case, a bypass circuit connected to the SPD shall be either connected to the earth, or provided with a suitable **safeguard** from ES1. (A **double safeguard** or a **reinforced safeguard** between the primary side of an SPD and ES1, and a **basic safeguard** between **external circuit** side of SPD and ES1, see "**J**" and "**G**" in Figure A.5 in this document).

There may be a discussion about the safety of the telecommunication network connected to the **external circuit**, but it is presumed that the telecommunication network is appropriately bonded to the earth through the grounding system. Also, the maintenance person accessing the telecommunication for maintenance is considered to be a **skilled person**, and knows that they should not access the network lines when lightning strikes are observed in the nearby area (see "**F**" in Figure A.5 in this document).

For the risk that the connection of the **external circuit** to the telecommunication network is disconnected, the SPD cannot operate. However, in this case, the **external circuit** is left open circuit, therefore the telecom side shall have a **safeguard** to ES1. Under this condition, the SPD can be the open circuit (see “**G**” and “**F**” in Figure A.5 in this document).

A.3.6 Surge voltage/current from external circuits

A.3.6.1 Case of transversal transient on external circuits

A surge caused by lightning may enter from the **external circuit** (such as the telecommunication network) as a transversal transient overvoltage. In this case, incorporating an SPD (may be a GDT only) between the Tip and Ring of the **external circuit** is the effective method to prevent damage in the circuit, as the surge is bypassed from one wire of the **external circuit** to another wire. In this case, the reliability requirement is not mandatory for the SPD, because the failure of the SPD can only lead to an equipment fault condition (out of use) but may not lead to risk to a person (see “**H**” in Figure A.5 in this document).

A.3.6.2 Case of longitudinal transient on external circuits

A surge caused by lightning may enter the telecommunication network and get into the **external circuit** of the equipment as longitudinal (common mode) transient overvoltage, which may cause high level potential difference between a **mains** circuit and **external circuits**. In this case, providing a bypass circuit between the primary circuit and **external circuits**, or between **external circuit** and bonding, or both, incorporating an SPD (a combined use of a GDT and a varistor in series is recommended) is an effective method to protect insulations and components in the equipment (see “**I**” in Figure A.5 in this document).

For limiting the risk of electrical shock in this case, a bypass circuit connected to the SPD shall be either connected to the earth, or provided with suitable **safeguard** from ES1 (A **double safeguard** or a **reinforced safeguard** between the primary side of the SPD and ES1, and a **basic safeguard** between the **external circuit** side of the SPD and ES1, see “**J**” in Figure A.5 in this document).

About the consideration of some countries that have no polarity of the AC plug, SPDs installed between power lines in accordance with IEC 60364 will operate and the surge will go into the AC line (see “**I**” in Figure A.5 in this document).

A.3.7 Summary

As a summary of the above technical discussions, the following are proposed requirements if a varistor is connected in series with a GDT and used as **safeguard**:

- the GDT's sparkover voltage level should be selected from IEC 61643-311 and IEC 61643-312 in accordance with the bridged insulation (see A.3.2 in this document);
- the GDT shall pass the electric strength test and meet the external **clearance** and **creepage distance** requirements for **reinforced insulation** (see A.3.3 in this document);
- the varistor shall comply with Clause G.8 (see A.3.3 and A.3.4 in this document);
- the bypass circuit connected to the SPD shall be either connected to earth, or provided with a suitable **safeguard** from ES1 (a **double safeguard** or a **reinforced safeguard** between the primary side of the SPD and ES1, and a **basic safeguard** between the **external circuit** side of the SPD and ES1, see A.3.5.2 and A.3.6.2 in this document).

A.4 Information about follow current (or follow-on current)

A.4.1 General

The information was taken from “MITSUBISHI Materials home page”

A.4.2 What is follow-on-current?

Follow-on-current is literally something that will continue to flow. In this case it is the phenomenon where the current in a discharge tube continues to flow.

Normally surge absorbers are in a state of high impedance. When a surge enters the absorber it will drop to a low impedance stage, allowing the surge to bypass the electronic circuit it is protecting. After the surge has passed, the absorber should return to a high impedance condition.

However, when the absorber is in a low impedance state and if there is sufficient voltage on the line to keep the current flowing even when the surge ends, the absorber remains in a discharge state and does not return to a high impedance state. The current will then continue to flow. This is the phenomenon known as follow-on-current.

Surge absorbers that display this follow-on-current phenomenon are of the discharge type or semiconductor switching absorbers. A characteristic of these absorbers is that during surge absorption (bypass) the operating voltage (remaining voltage) is lower than the starting voltage.

The advantage of this is that during suppression the voltage is held very low, so as to reduce stress on the equipment being protected. But there can be a problem when the line current of the equipment is sufficient so that it continues to drive the absorber when the voltage is at a low state.

Below are more details about the follow-on-current mechanism. The discharge and power source characteristics for the discharge tube as well as conditions of follow-on-current will be explained.

A.4.3 What are the V-I properties of discharge tubes?

The micro-gap type surge absorber is one kind of discharge tube. The discharge characteristics where the part passes through pre-discharge, glow discharge and then arc discharge are shown in Figure A.6 in this document.

Figure A.6 in this document shows the V-I characteristics relation between voltage and current for the discharge tube. When the tube discharges, electric current flows and if moves to a glow discharge state and then an arc state all while the discharge voltage decreases. Conversely, as the discharge decreases, the voltage increases as it moves from an arc state to a glow state.

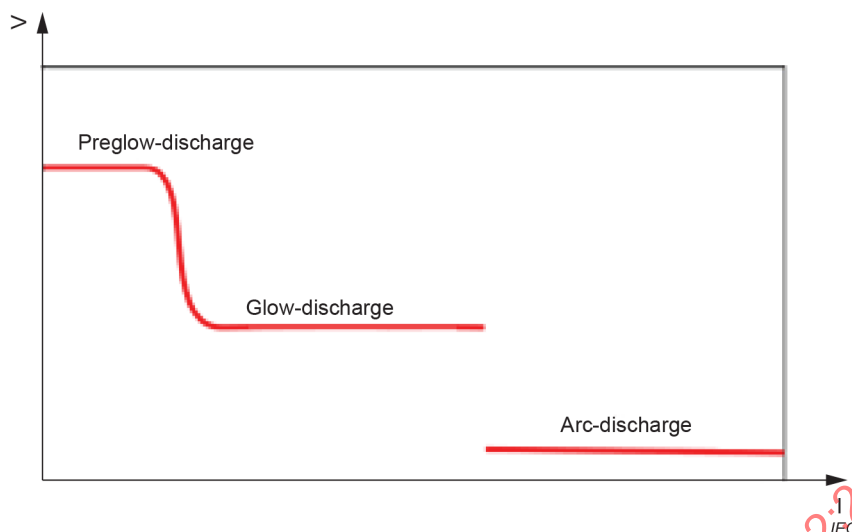


Figure A.6 – Discharge stages

Pre-glow discharge

The voltage that is maintaining this discharge is approximately equal to the DC breakdown voltage of the part. A faint light can be seen from the part at this point.

Glow discharge

There is a constant voltage rate versus the changing current. The voltage maintaining this discharge will depend on the electrode material and the gas in the tube. The discharge light now covers one of the electrodes.

Arc discharge

With this discharge, a large current flows through the part and it puts out a bright light. The maintaining voltage at this point (voltage between the discharge tube terminals) is in the 10's of volts range.

A.4.4 What is holdover?

When a discharge tube is used on a circuit that has a **DC voltage** component, there is a phenomenon where the discharge state in the tube continues to be driven by the current from the power supply even after the surge voltage has subsided. This is called holdover (see Figure A.7 in this document).

When holdover occurs, for example, in the drive circuit of a CRT, the screen darkens and discharge in the absorber continues, which can lead to the glass tube melting, smoking or burning.

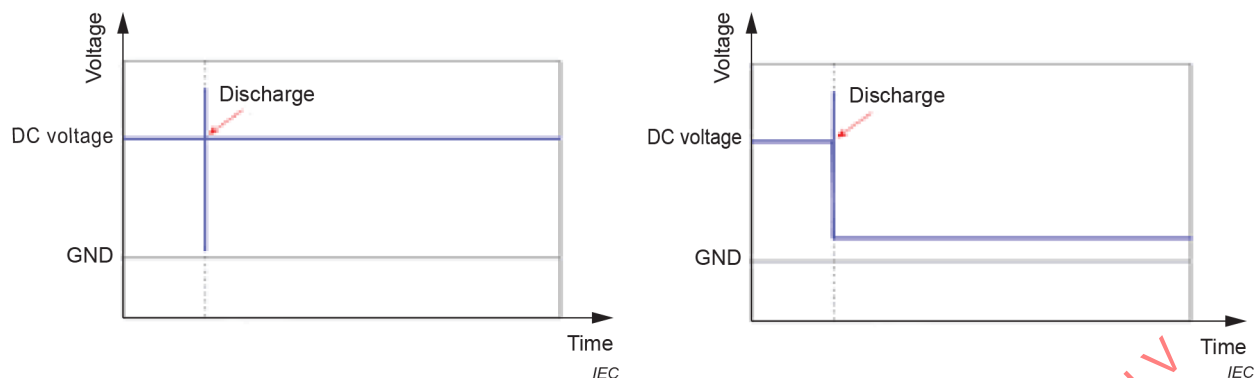


Figure A.7 – Holdover

Holdover can occur when the current can be supplied to the discharge tube due to varying conditions of output voltage and output resistance of the DC power supply. What are then the conditions that allow current to continue to flow to the discharge tube?

The relation between the power supply voltage (V_0), serial resistance (R), discharge current (I) and the terminal voltage (v) are shown in the linear relation below:

$$v = V_0 - I \times R$$

If the voltage V_0 is fixed, the slope of the power supply output characteristic line increases or decreases according to the resistance and may or may not intersect with the V-I characteristics of the discharge tube.

The characteristic linear line of a power supply shows the relation between the output voltage and current of the power supply. Likewise, the V-I curve of a discharge tube shows the relation between the voltage and current.

When static surge electricity is applied to the discharge tube, the shape of the curve shows that the surge is being absorbed during arc discharge.

As the surge ends, the discharge goes from arc discharge to glow discharge and then to the state just prior to glow discharge. At this time the relationship between the discharge tubes V-I curve and the power supply's output characteristics are very important.

As shown in the figure, with a high resistance in the power supply, the output characteristic line (pink) and the discharge tubes V-I characteristic curve (red) never intersect. Therefore, current will not flow from the power supply and follow-on-current will not occur.

However, when the output characteristic line of the power supply (pink) intersects with the V-I curve of the discharge tube (red), it is possible for current from the power supply to flow into the discharge tube. When the surge ends, the current should decrease from arc discharge to the pre-glow state, but instead the power supply will continue to drive the current where it intersects in the glow or arc discharge region. This is called holdover, and is the condition where the power supply continues to supply current to the discharge tube at the intersection on its characteristic line and the discharge tubes V-I curve.

Figure A.8 in this document shows where the power supply can continue supplying current to the discharge tube when its characteristic line intersects the discharge tubes V-I line in the glow or arc discharge sections.

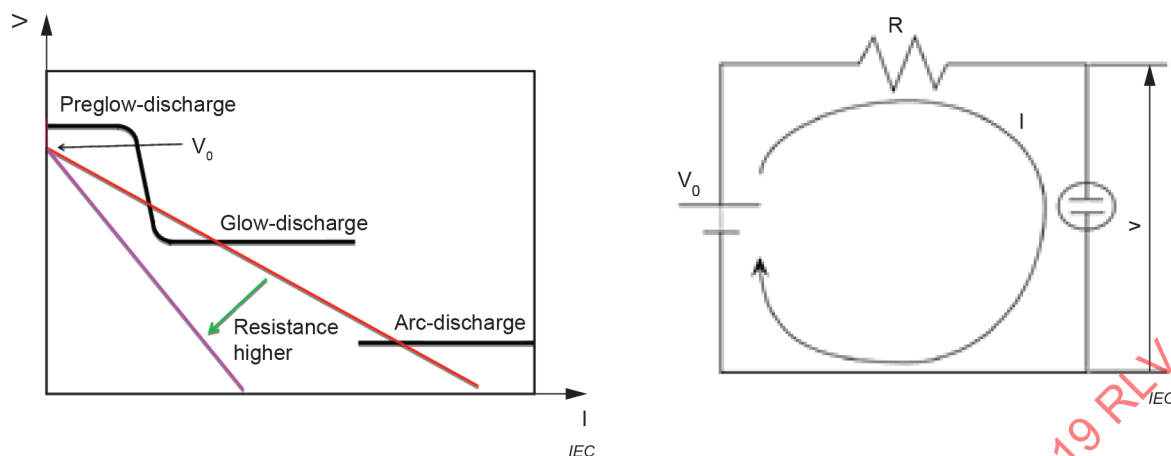


Figure A.8 – Discharge

To prevent holdover from occurring, it is important to keep the V-I characteristic line of the power supply from intersecting with the V-I curve of the discharge tube.

A.4.5 Follow-on-current from AC sources?

When using the discharge tube for AC sources, when follow-on-current occurs as per the case with DC it is easy to understand.

That is, as can be seen in the figure below, the only difference is that the power supply voltage (V_0) changes with time.

As shown on the previous page, when the power supply voltage is shown as $V_0(t)$, the output power characteristics are displayed as follows:

$$v = V_0(t) - R \times I$$

where

v is the the voltage at the power out terminal

I is the current of the circuit

$V_0(t)$ will vary with time, so when displaying the above equation on a graph, it will appear as in Figure A.9 in this document on the left. Then when $V_0(t)$ is shown as:

$$V_0(t) = V_0 \sin \omega t$$

When the power supply voltage becomes 0 (zero cross), there is a short time around this crossing where the voltage range and time range of the power supply output and discharge tube V-I curve do not intersect.

For an AC power supply, because there is always a zero crossing of the supply's voltage, more than holdover it is easier to stop the discharge. In the vicinity of the zero crossing, it is impossible to maintain the discharge since the current to the discharge is cut off. The discharge is then halted by the fact that the gas molecules, which were ionized during this time, return to their normal state.

Because the terminal voltage does not exceed the direct current break down voltage, if the discharge is halted it will not be able to start again.

However, if the gas molecules remain ionized during this period and voltage is again applied to both terminals of the discharge tube (enters the cycle of opposite voltage), this newly

applied voltage will not allow the discharge to end and it will continue in the discharge mode. This is follow-on-current for alternating current.

When follow-on-current occurs, the tube stays in a discharge mode and the glass of the tube will begin to smoke, melt and possibly ignite.

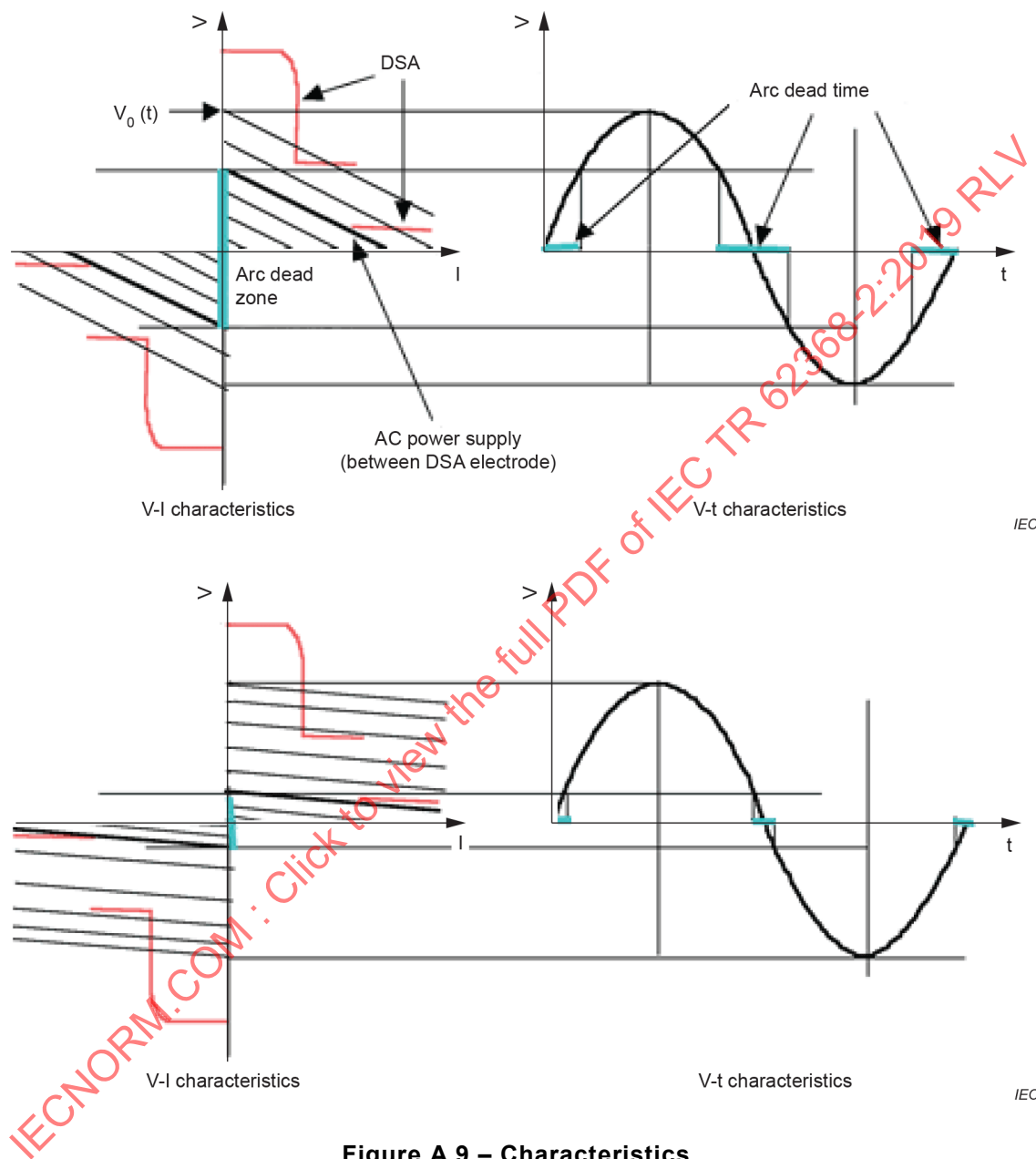
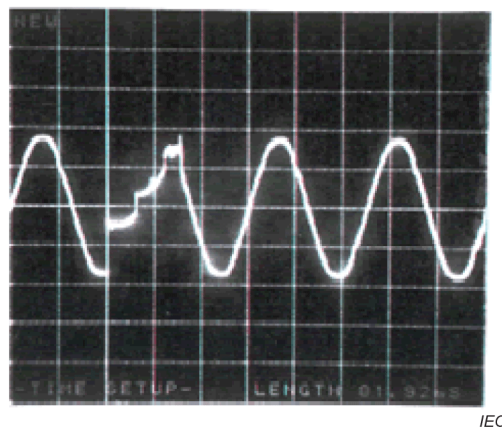
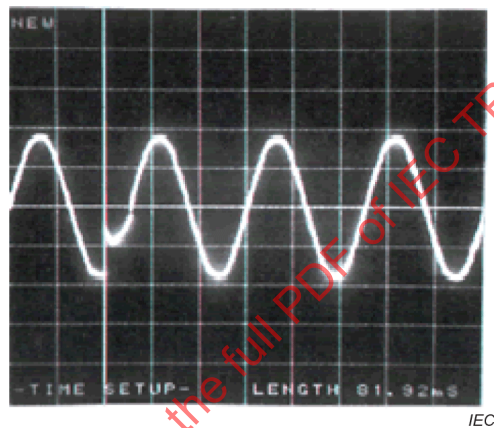


Figure A.9 – Characteristics

It is important to insert a resistance in series that is sufficiently large to prevent follow-on-current from occurring according to the conditions of the alternating current.



**Picture 1: with 0 Ω
(follow-on current occurs)**



**Picture 2: with 0,5 Ω
(follow-on current is stopped within half a wave)**

Figure A.10 – Follow on current pictures

With 1 Ω and 3 Ω resistance, results are the same as those in picture 2, follow-on-current is disrupted and discharge stops (see Figure A.10 in this document).

For AC power sources, the resistance value that is connected in series with the discharge tube is small in comparison to DC sources.

If the series resistance is 0,5 Ω or greater it should be sufficient, however for safety a value of 3 Ω (for 100 V) or greater is recommended.

In addition there is also a method to use a varistor in series that acts as a resistor. In this case the varistor should have an operating voltage greater than the AC voltage and be placed in series with the discharge tube. Unlike the resistor, discharge will be stopped without follow-on-current occurring during the first half wave.

Recommended varistor values are:

- for 100 VAC lines: a varistor voltage of 220 V minimum;
- for 200 VAC lines: a varistor voltage of 470 V minimum.

A.4.6 Applications with a high risk of follow-on-current

- 1) Holdover: CRT circuits and circuits using DC power supplies
- 2) Follow-on-current: Circuits using AC power source

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Annex B (informative)

Background information related to measurement of discharges – Determining the R-C discharge time constant for X- and Y-capacitors

B.1 General

Since the introduction of 2.1.1.7, "Discharge of capacitors in equipment," in IEC 60950-1:2013, questions continually arise as to how to measure the R-C discharge time constant. The objective of this article is to describe how to measure and determine the discharge time constant.

B.2 EMC filters

EMC filters in equipment are circuits comprised of inductors and capacitors arranged so as to limit the emission of RF energy from the equipment into the **mains** supply line. In EMC filters, capacitors connected between the supply conductors (for example, between L1 and L2) of the **mains** are designated as X capacitors. Capacitors connected between a supply conductor and the PE (**protective earthing** or grounding) conductor are designated as Y capacitors (Safety requirements for X and Y capacitors are specified in IEC 60384-14 and similar national standards). The circuit of a typical EMC filter is shown in Figure B.1. C_X is the X capacitor, and C_Y are the Y capacitors.

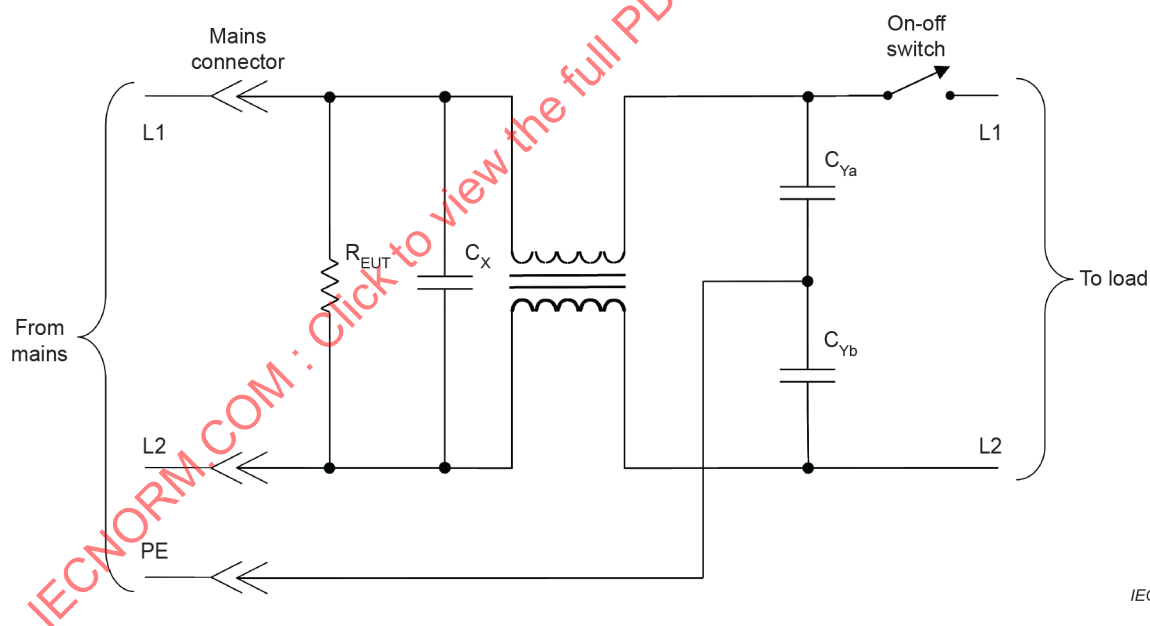


Figure B.1 – Typical EMC filter schematic

B.3 The safety issue and solution

When an EMC filter is disconnected from the **mains** supply line, both the X (C_X) and the Y (C_{Ya} and C_{Yb}) capacitors remain charged to the value of the **mains** supply voltage at the instant of disconnection.

Due to the nature of sinusoidal waveforms, more than 66 % of the time (30° to 150° and 210° to 330° of each cycle) the voltage is more than 50 % of the peak voltage. For 230 V **mains** ($325 V_{peak}$), the voltage is more than 162 V for more than 66 % of the time of each cycle. So, the probability of the voltage exceeding 162 V at the time of disconnection is 0,66. This

probability represents a good chance that the charge on the X and Y capacitors will exceed 162 V.

If a hand or other body part should touch both pins (L1 and L2) of the **mains** supply plug at the same time, the capacitors will discharge through that body part. If the total capacitance exceeds about 0,1 μF , the discharge will be quite painful.

To **safeguard** against such a painful experience, safety documents require that the capacitors be discharged to a non-painful voltage in a short period of time. The short period of time is taken as the time from the disconnection from the **mains** to the time when contact with both pins is likely. Usually, this time is in the range of 1 s to 10 s, depending on the documents and the type of attachment plug cap installed.

B.4 The requirement

The time constant is measured with an oscilloscope. The time constant and its parameters are defined elsewhere.

The significant parameters specified in the requirement are the capacitance exceeding 0,1 μF and the time constant of 1 s or less (for **pluggable equipment type A**) or 10 s or less (for **pluggable equipment type B**). These values bound the measurement. This attachment addresses **pluggable equipment type A** and the 1 s time constant requirement. The attachment applies to **pluggable equipment type B** and the time constant is changed to 10 s.

Pluggable equipment type A is intended for connection to a **mains** supply via a non-industrial plug and socket-outlet. **Pluggable equipment type B** is intended for connection to a **mains** supply via an industrial plug and socket-outlet.

The document presumes that measurements made with an instrument having an input resistance of 95 $\text{M}\Omega$ to 105 $\text{M}\Omega$ and up to 25 pF in parallel with the impedance and capacitance of the equipment under test (EUT) will have negligible effect on the measured time constant. The effect of probe parameters on the determination of the time constant is discussed elsewhere in this document.

The requirement specifies a time constant rather than a discharge down to a specified voltage within a specified time interval. If the document required a discharge to a specific voltage, then the start of the measurement would need to be at the peak of the voltage. This would mean that the switch (see Figure B.5) would need to be opened almost exactly at the peak of the voltage waveform. This would require special switching equipment. The time constant is specified because it can be measured from any point on the waveform (except zero), see Figure B.4b.

B.5 100 $\text{M}\Omega$ probes

Table B.1 in this document is a list of readily available oscilloscope probes with 100 $\text{M}\Omega$ input resistance and their rated input capacitances (the list is not exhaustive). Also included is a 400 $\text{M}\Omega$ input resistance probe and a 50 $\text{M}\Omega$ input resistance probe.

Table B.1 – 100 M Ω oscilloscope probes

Manufacturer	Input resistance	Input capacitance
	M Ω	pF
A	100	1
B	100	6,5
C	100	3
D	400	10 – 13
E	100	2,5
F	50	5,5

Note that the input capacitances of the 100 M Ω probe input capacitances are very much less than the maximum capacitance of 25 pFs. This attachment will discuss the effect of the probe capacitance and the maximum capacitance elsewhere.

100 M Ω probes are meant for measuring high voltages, typically 15 kV and more. These probes are quite large and are awkward to connect to the pins of a power plug.



Figure B.2 – 100 M Ω oscilloscope probes

General purpose oscilloscope probes have 10 M Ω input resistance and 10 pF to 15 pF input capacitance. General-purpose probes are easier to connect to the pins of the power plug. This attachment shows that a 10 M Ω , 15 pF probe can be used in place of a 100 M Ω probe.

B.6 The R-C time constant and its parameters

Capacitor charge or discharge time can be expressed by the R-C time constant parameter. One time constant is the time duration for the voltage on the capacitor to change 63 %. In five time constants, the capacitor is discharged to almost zero.

Table B.2 – Capacitor discharge

Time constant	Percent capacitor voltage (or charge)	Capacitor voltage (230 V _{rms} , 331 V _{peak})
0	100	325
1	37	120
2	14	45
3	5	16
4	2	6
5	0,7	2

The values in Table B.2 in this document are given by:

$$V_t = V_0 e^{-\left(\frac{t}{RC}\right)}$$

where:

V_t is the voltage at time t

V_0 is the voltage at time 0

R is the resistance, in Ω

C is the capacitance, in F (Farads)

t is the time, in s

The time constant is given by the formula:

$$T_{EUT} = R_{EUT} \times C_{EUT}$$

where:

T_{EUT} is the time, in seconds, for the voltage to change by 63 %

R_{EUT} is the EUT resistance, in Ω

C_{EUT} is the EUT capacitance, in F (Farads)

In the equipment under test (EUT), the EUT capacitance, C_{EUT} , in the line filter (Figure B.1) includes both the X-capacitor and the Y-capacitors.

The two Y-capacitors, C_{Ya} and C_{Yb} , are in series. The resultant value of two capacitors in series, C_Y , is:

$$C_Y = \frac{C_{Ya} \times C_{Yb}}{C_{Ya} + C_{Yb}}$$

Assuming the two Y-capacitors have the same value, their L1-L2 value is one-half of the value of one of the capacitors.

The X-capacitor is in parallel with the two Y-capacitors. The EUT capacitance is:

$$C_{EUT} = C_X + C_Y$$

The EUT resistance is the resistance, R_{EUT} , in the EUT that is used for discharging the capacitance.

The time constant, T_{EUT} , in s, is the product of the EUT capacitance in farads and the EUT resistance in Ω . More useful units are capacitance in μF and resistance in $\text{M}\Omega$.

Two parameters of the time constant formula are given by the requirement: EUT capacitance is 0,1 μF or larger and the EUT time constant does not exceed 1 s. Solving the time constant formula for EUT resistance:

$$R_{EUT} = T_{EUT} / C_{EUT}$$

Substituting the values:

$$R_{EUT} = 1\text{s} / 0,1\mu\text{F}$$

$$R_{EUT} = 10\text{M}\Omega$$

This means that the EUT resistance is no greater than 10 $\text{M}\Omega$ if the EUT capacitance is 0,1 μF or greater. The combinations of EUT resistance and EUT capacitance for EUT time constant of 1 s are shown in Figure B.3 in this document.

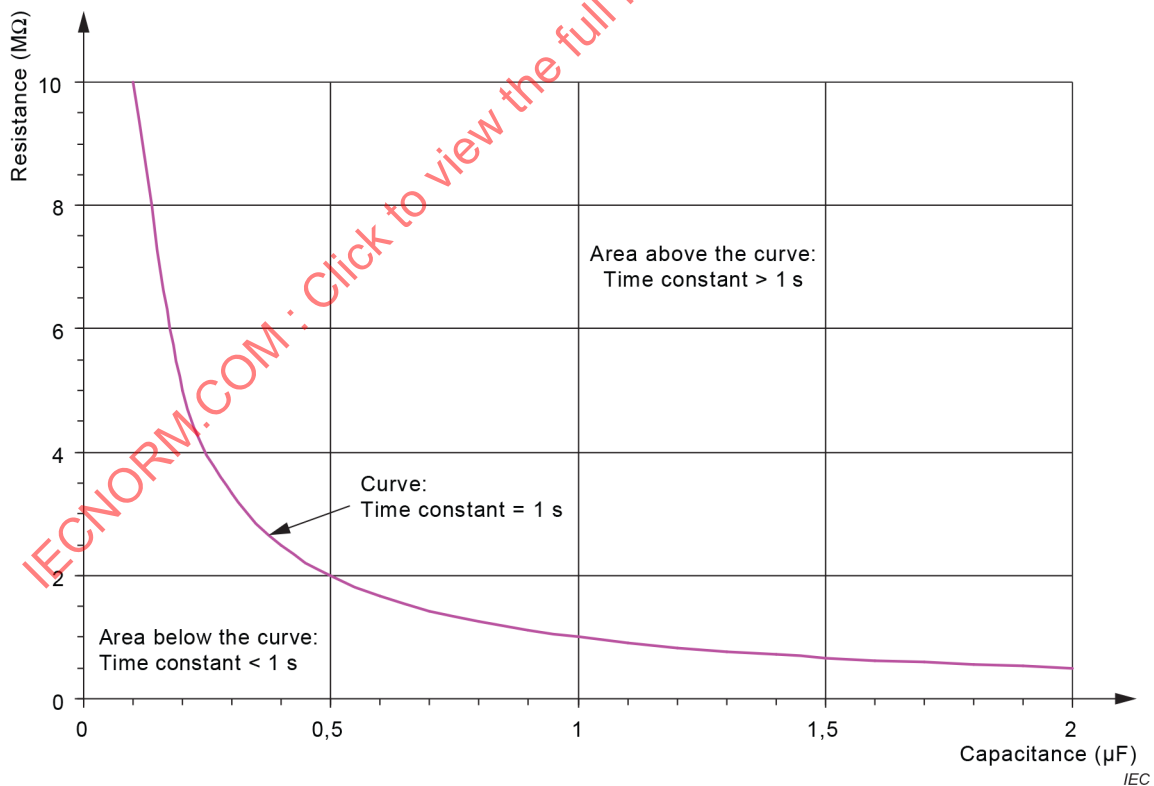


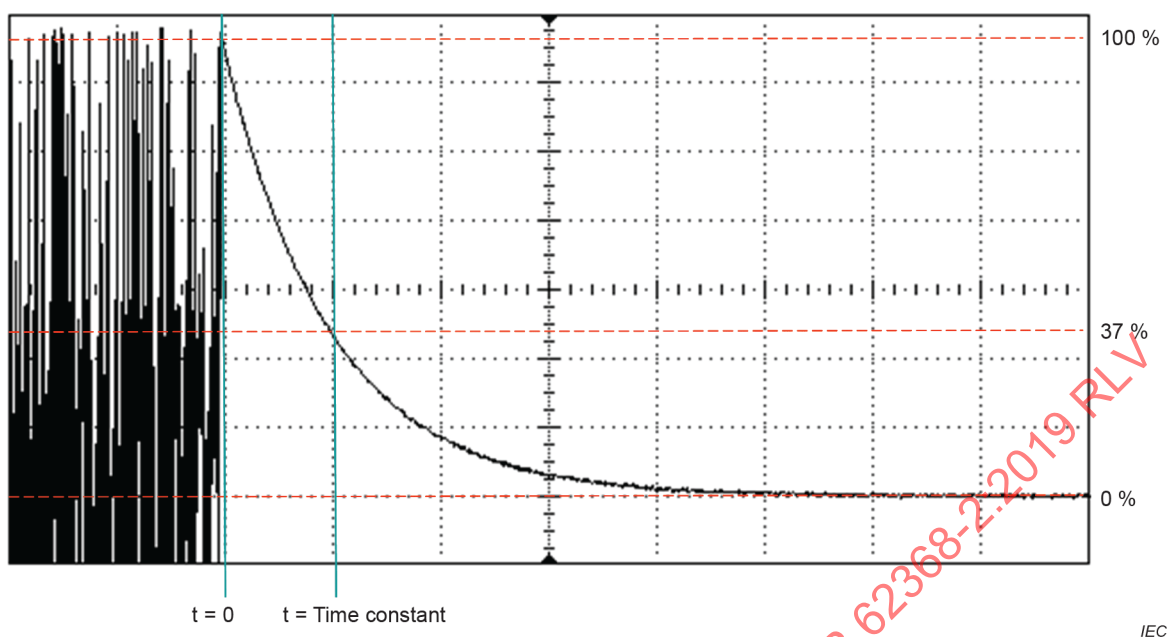
Figure B.3 – Combinations of EUT resistance and capacitance for 1 s time constant

B.7 Time constant measurement.

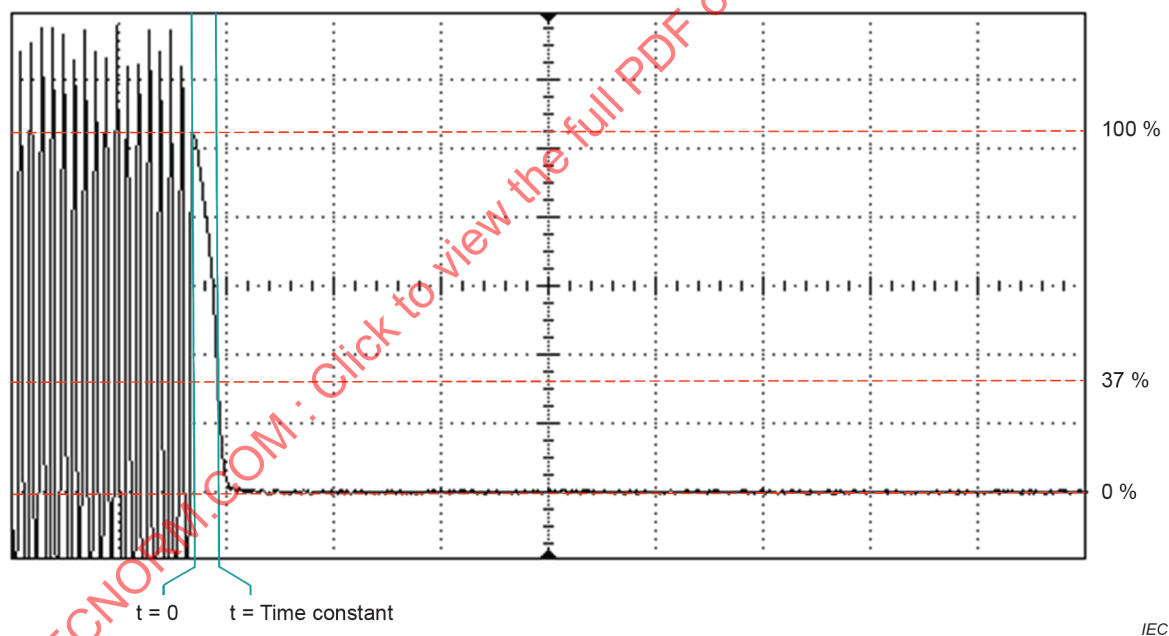
The objective is to measure and determine the EUT time constant.

Measurement of the time constant is done with an oscilloscope connected to the **mains** input terminals of the equipment under test (EUT). **Mains** is applied to the EUT, the EUT is turned off, and then the **mains** is disconnected from the EUT. The EUT is turned off because the load circuits of the EUT may serve to discharge the EUT capacitance. The resulting oscilloscope waveform, the AC **mains** voltage followed by the discharge of the total capacitance, is shown in Figure B.4 in this document.

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a) 240 V mains followed by capacitor discharge
V = 50 V/div, H = 1 s/div



b) 240 V mains followed by capacitor discharge
V = 50 V/div, H = 0,2 s/div

Figure B.4 – 240 V mains followed by capacitor discharge

The time constant is the time duration measured from the instant of disconnection to a point that is 37 % of the voltage at the instant of disconnection.

The problem is that the process of measurement affects the measured time constant. This is because the oscilloscope probe has a finite resistance and capacitance, see Figure B.5 in this document.

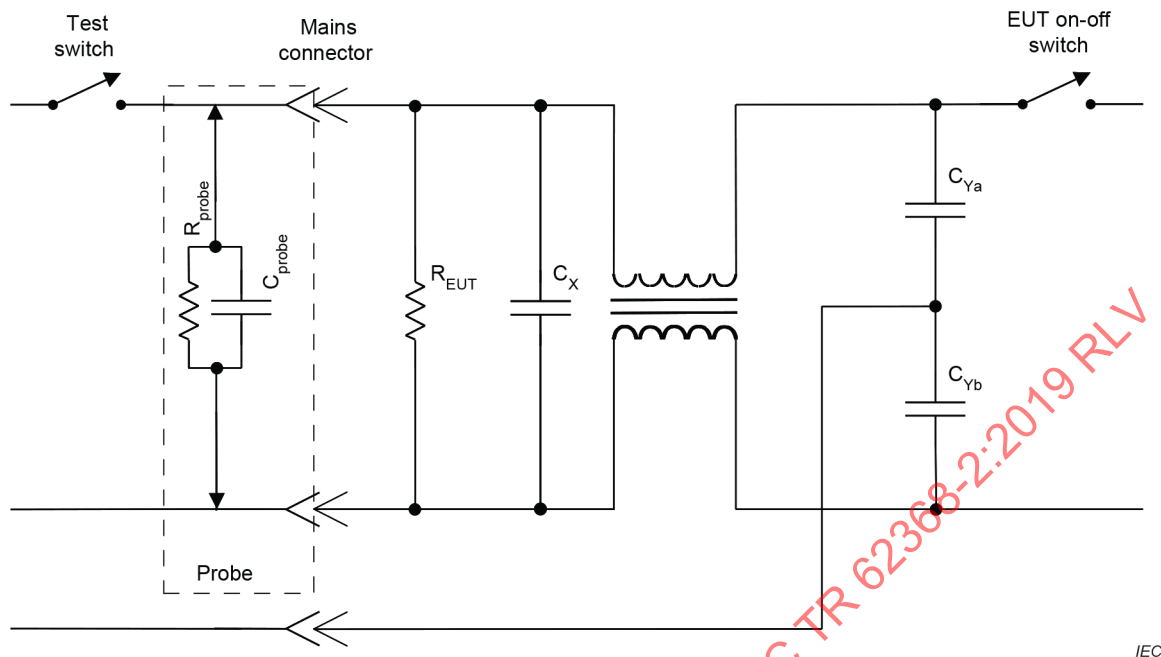


Figure B.5 – Time constant measurement schematic

The probe resistance, R_{probe} , is in parallel to the EUT resistance, R_{EUT} . And, the probe capacitance, C_{probe} , is in parallel with the EUT capacitance, C_{EUT} .

The measured time constant, $T_{measured}$, is a function of the Thevenin equivalent circuit comprised of R_{total} and C_{total} . The measured time constant is given by:

$$T_{measured} = R_{total} \times C_{total}$$

where:

$T_{measured}$ is the measured time for the voltage to change by 63 %

R_{total} is the total resistance, both the probe and the EUT

C_{total} is the total capacitance, both the probe and the EUT

R_{total} is:

$$R_{total} = \frac{R_{probe} \times R_{EUT}}{R_{probe} + R_{EUT}}$$

C_{total} is:

Combining terms, the measured time constant is:

$$T_{measured} = \left(\frac{R_{probe} \times R_{EUT}}{R_{probe} + R_{EUT}} \right) \times (C_{probe} + C_{EUT})$$

In this formula, $T_{measured}$, R_{probe} , and C_{probe} are known. $T_{measured}$ is measured with a given probe. R_{probe} and C_{probe} are determined from the probe specifications (see examples in

Table B.1 in this document). Elsewhere, we shall see that C_{probe} is very small and can be ignored.

$$C_{total} = C_{EUT}$$

The measured time constant can now be expressed as:

$$T_{measured} = \left(\frac{R_{probe} \times R_{EUT}}{R_{probe} + R_{EUT}} \right) \times C_{total}$$

B.8 Effect of probe resistance

As has been shown, the EUT discharge resistance, R_{EUT} , is 10 MΩ or less in order to achieve a 1 s time constant with a 0,1 μF capacitor or larger.

R_{total} is comprised of both the EUT discharge resistance R_{EUT} , and the probe resistance, R_{probe} .

If R_{EUT} is 10 MΩ and C_{EUT} is 0,1 μF, then we know that T_{EUT} is 1 s. If we measure the time constant with a 100 MΩ probe, the parallel combination of R_{EUT} and R_{probe} is about 9,1 MΩ and the measured time constant, $T_{measured}$, will be:

$$T_{measured} = R_{total} \times C_{total}$$

$$T_{measured} = 9,1 M\Omega \times 0,1 \mu F$$

$$T_{measured} = 0,91 s$$

So, for a C_{EUT} of 0,1 μF capacitance and a R_{EUT} of 10 MΩ, a measured time constant (using a 100 MΩ probe), $T_{measured}$, of 0,91 s would indicate a EUT time constant, T_{EUT} , of 1 s.

If we substitute a 10 MΩ probe for the same measurement, then R_{total} , the parallel combination of R_{EUT} (10 MΩ) and R_{probe} (10 MΩ), is 5 MΩ. The measured time constant, $T_{measured}$, will be:

$$T_{measured} = R_{total} \times C_{total}$$

$$T_{measured} = 5 M\Omega \times 0,1 \mu F$$

$$T_{measured} = 0,5 s$$

So, for a C_{EUT} of 0,1 μF capacitance and a R_{EUT} of 10 MΩ, the measured time constant (using a 10 MΩ probe), $T_{measured}$, is 0,5 s and would indicate a EUT time constant, T_{EUT} , of 1 s.

B.9 Effect of probe capacitance

According to the document, C_{EUT} is 0,1 μF or more. Also, according to the document, C_{probe} is 25 pF or less. Assuming the worst case for C_{probe} , the total capacitance is:

$$C_{total} = C_{probe} + C_{EUT}$$

$$C_{total} = 0,000025\mu F + 0,1\mu F$$

$$C_{total} = 0,100025\mu F$$

The worst-case probe capacitance is extremely small (0,025 %) compared to the smallest C_{EUT} capacitance (0,1 μF) and can be ignored. We can say that:

$$C_{total} = C_{EUT}$$

B.10 Determining the time constant

According to the document, T_{EUT} may not exceed 1 s.

$$T_{EUT} = 1$$

$$1 = R_{EUT} \times C_{EUT}$$

where:

R_{EUT} is 10 M Ω or less

C_{EUT} is 0,1 μF or more

The problem is to determine the values for R_{EUT} and C_{EUT} . Once these values are known, the equipment time constant, T_{EUT} , can be determined by calculation.

As shown in Figure B.1 in this document, R_{EUT} can be measured directly with an ohmmeter applied to the **mains** input terminals, i.e., between L1 and L2. Care is taken that the capacitances are fully discharged when the resistance measurement is made. Any residual charge will affect the ohmmeter and its reading. Of course, if the circuit is provided with a discharge resistor, then the capacitances will be fully discharged. If the circuit does not have a discharge resistor, then the ohmmeter will provide the discharge path, and the reading will continuously increase.

C_{EUT} can also be measured directly with a capacitance meter. Depending on the particular capacitance meter, R_{EUT} may prevent accurate measurement of C_{EUT} . For the purposes of this paper, we assume that the capacitance meter cannot measure the C_{EUT} . In this case, we measure the time constant and compensate for the probe resistance.

So, the time constant is measured, and the probe resistance is accounted for.

Since probe resistance is more or less standardized, we can calculate curves for 100 M Ω and 10 M Ω probes for all maximum values of R_{EUT} and C_{EUT} . The maximum values for combinations of R_{EUT} , C_{EUT} (C_{total}), R_{probe} , R_{total} and $T_{measured}$ are given in Table B.3 in this document. (R_{probe} and R_{total} values are rounded to 2 significant digits.)

Table B.3 – Maximum $T_{measured}$ values for combinations of R_{EUT} and C_{EUT} for T_{EUT} of 1 s

T_{EUT} s	C_{EUT} (C_{total}) μF	R_{EUT} $M\Omega$	R_{probe} $M\Omega$	R_{total} $M\Omega$	$T_{measured}$ s
1	0,1	10	100	9,1	0,91
1	0,2	5	100	4,8	0,95
1	0,3	3,3	100	3,2	0,97
1	0,4	2,5	100	2,4	0,97
1	0,5	2	100	2,0	0,98
1	0,6	1,7	100	1,6	0,98
1	0,7	1,4	100	1,4	0,99
1	0,8	1,25	100	1,2	0,99
1	0,9	1,1	100	1,1	0,99
1	1,0	1	100	1,0	0,99
1	0,1	10	10	5,0	0,50
1	0,2	5	10	3,3	0,67
1	0,3	3,3	10	2,5	0,75
1	0,4	2,5	10	2,0	0,80
1	0,5	2	10	1,7	0,83
1	0,6	1,7	10	1,4	0,86
1	0,7	1,4	10	1,25	0,88
1	0,8	1,25	10	1,1	0,89
1	0,9	1,1	10	1,0	0,90
1	1,0	1	10	0,91	0,91

For each value of R_{EUT} and R_{probe} we can calculate the worst-case measured time constants, $T_{measured}$ for a T_{EUT} of 1 s. These are shown in Figure B.6 in this document.

The process is:

- With the unit disconnected from the **mains** and the power switch “off,” measure the resistance between the poles of the EUT. Repeat with the power switch “on” as the filter may be on the load side of the power switch. Select the higher value as R_{EUT} .
- Connect the oscilloscope probe between L1 and L2 as shown in Figure B.5 in this document. For safety during this test, use a 1:1 isolating transformer between the **mains** and the EUT. Set the scope sweep speed to 0,2 ms per division (2 s full screen).
- When the display is about 1 or 2 divisions from the start, turn the test switch off, and measure the time constant as shown in Figure B.4 in this document. This step may need to be repeated several times to get a suitable waveform on the oscilloscope. This step should be performed twice, once with the EUT power switch “off” and once with the EUT power switch “on.” Select the maximum value. This value is $T_{measured}$.
- Plot R_{EUT} and $T_{measured}$ on the chart, Figure B.6 in this document.

If the point is below the curve of the probe that is used to measure the time constant, then the EUT time constant, T_{EUT} , is less than 1 s.

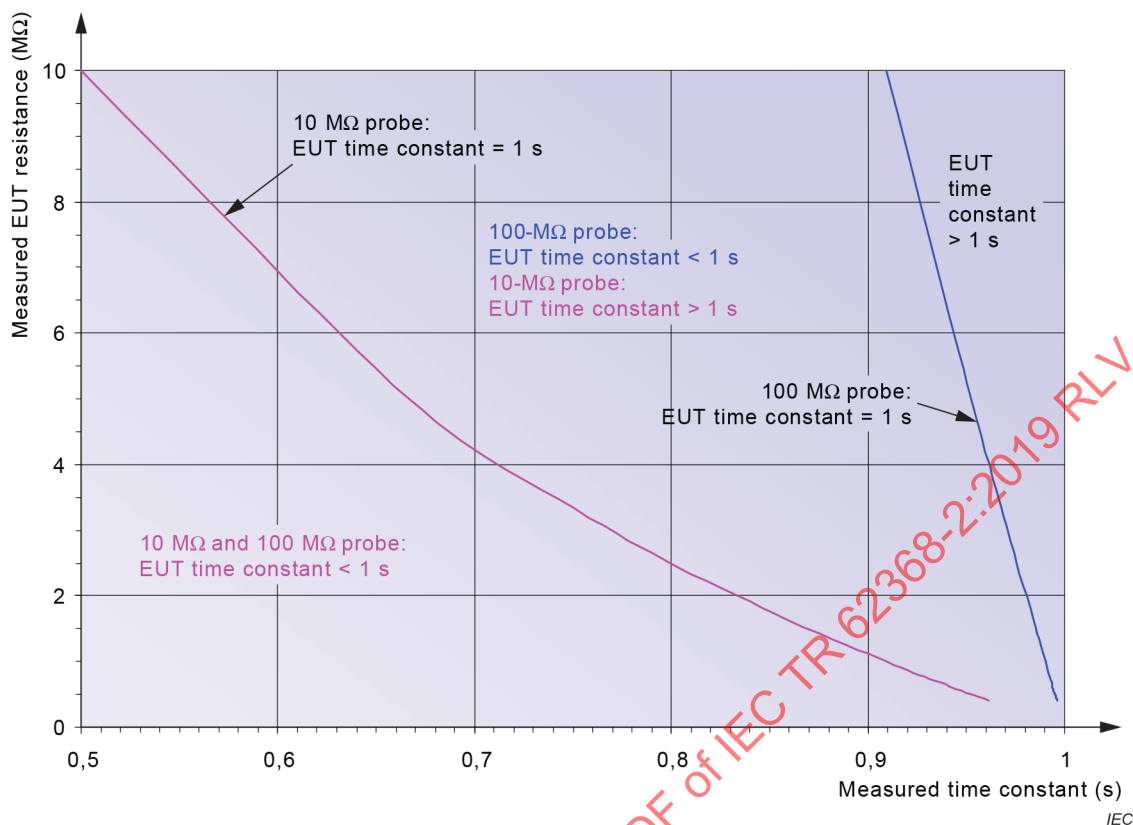


Figure B.6 – Worst-case measured time constant values for 100 MΩ and 10 MΩ probes

B.11 Conclusion

Measurement of the time constant can be made with any probe, not just a 100 MΩ probe. Ideally, the probe input resistance should be at least equal to the worst-case EUT discharge resistance (10 MΩ for **pluggable equipment type A**) or higher. The effect of the probe input resistance is given by the equation for R_{total} . 100 MΩ probes, while approaching ideal in terms of the effect on the measured time constant, are bulky and expensive and not necessary.

The document is a bit misleading by ignoring a 9 % error when a 100 MΩ probe is used to measure the time constant associated with a 10 MΩ discharge resistor (see Figure B.5 in this document).

Annex C (informative)

Background information related to resistance to candle flame ignition

In line with SMB decision 135/20, endorsing the ACOS/ACEA JTF recommendations, the former Clause 11 was added to the document up to CDV stage. However, the CDV was rejected and several national committees indicated that they wanted to have the requirements removed from the document. At the same time, several countries indicated that they wanted the requirements to stay, while others commented that they should be limited to CRT televisions only.

IEC TC 108 decided to publish the requirements as a separate document so that the different issues can be given appropriate consideration.

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² This publication was withdrawn.

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COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

ÉQUIPEMENTS DES TECHNOLOGIES DE L'AUDIO/VIDÉO, DE L'INFORMATION ET DE LA COMMUNICATION –

Partie 2: Précisions relatives à l'IEC 62368-1:2018

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L'IEC 62368-2, qui est un rapport technique, a été établie par le comité d'études 108 de l'IEC: Sécurité des appareils électroniques dans le domaine de l'audio, de la vidéo, du traitement de l'information et des technologies de la communication.

Cette troisième édition met à jour la deuxième édition de l'IEC 62368-2 parue en 2014 afin de prendre en compte les modifications apportées à l'IEC 62368-1:2014 identifiées dans l'Avant-propos de l'IEC 62368-1:2018.

Ce Rapport technique est donné à titre informatif uniquement. En cas de contradiction entre l'IEC 62368-1 et l'IEC TR 62368-2, les exigences de l'IEC 62368-1 prévalent sur le présent Rapport technique.

Le texte de ce rapport technique est issu des documents suivants:

Projet d'enquête	Rapport de vote
108/708/DTR	108/711/RVDTR

Le rapport de vote indiqué dans le tableau ci-dessus donne toute information sur le vote ayant abouti à l'approbation de ce rapport technique.

Dans le présent document, les caractères d'imprimerie suivants sont utilisés:

- notes/rapport explicatif: petits caractères romains;
- les tableaux et figures inclus dans le justificatif comportent des champs liés (en gris si le "grisé de zone" est actif)
- termes définis dans l'IEC 62368-1: en **gras**.

Dans le présent document, le terme (HBSDT) qui est utilisé est l'acronyme de Hazard Based Standard Development Team, qui est le groupe de travail du Comité d'études 108 de l'IEC chargé du développement et de la maintenance de l'IEC 62368-1.

Cette publication a été rédigée selon les Directives ISO/IEC, Partie 2.

Une liste de toutes les parties de la série IEC 62368, sous le titre général *Équipements des technologies de l'audio/vidéo, de l'information et de la communication*, peut être consultée sur le site web de l'IEC.

Dans le présent document, seuls les paragraphes de l'IEC 62368-1 dont il est estimé qu'ils ont besoin d'informations générales ou d'explications complémentaires pour aider le lecteur à appliquer les exigences pertinentes sont inclus. Par conséquent, les paragraphes numérotés ne sont pas tous cités. Sauf indication contraire, toutes les références concernent les articles, paragraphes, annexes, figures ou tableaux de l'IEC 62368-1:2018.

Les entrées du document peuvent comporter une ou deux des sous-rubriques suivantes en plus de la déclaration Justificatif:

Source – lorsque la source est connue et qu'il s'agit d'un document accessible au grand public, une référence est fournie.

Objet – si cela s'avère nécessaire, et s'il peut être utile à la compréhension du Justificatif, la déclaration Objet a été ajoutée.

Le comité a décidé que le contenu de cette publication ne sera pas modifié avant la date de stabilité indiquée sur le site web de l'IEC sous "<http://webstore.iec.ch>" dans les données relatives à la publication recherchée. À cette date, la publication sera

- reconduite,
- supprimée,
- remplacée par une édition révisée, ou
- amendée.

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INTRODUCTION

L'IEC 62368-1 est fondée sur les principes de l'ingénierie de la sécurité établie sur le danger, qui représente une manière différente de développer et de spécifier des considérations relatives à la sécurité par rapport à la pratique actuelle. Tandis que le présent document diffère des documents traditionnels de l'IEC relatifs à la sécurité dans son approche et alors que l'IEC 62368-1 est considérée apporter plusieurs avantages, il n'est pas prévu que son introduction et son évolution entraînent des modifications significatives de la philosophie de sécurité existante qui a conduit au développement des exigences en matière de sécurité contenues dans l'IEC 60065 et l'IEC 60950-1. La philosophie qui sous-tend la création de l'IEC 62368-1 consiste à simplifier les problèmes créés par la fusion des technologies des ATI et de la CE. Les techniques utilisées sont nouvelles et exigent par ailleurs un processus d'apprentissage. Une certaine expérience est également nécessaire dans leur application. En conséquence, le comité recommande que cette édition du document soit considérée comme une variante à l'IEC 60065 ou l'IEC 60950-1 au moins pendant la période transitoire recommandée.

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ÉQUIPEMENTS DES TECHNOLOGIES DE L'AUDIO/VIDÉO, DE L'INFORMATION ET DE LA COMMUNICATION –

Partie 2: Précisions relatives à l'IEC 62368-1:2018

0 Principes de la présente norme relative à la sécurité des produits

L'Article 0 est donné à titre informatif et justifie les articles normatifs du document.

0.5.1 Généralités

L'ISO/IEC Guide 51:2014, 6.3.5 indique:

“Lorsque l'on réduit les risques, l'ordre de priorité doit être le suivant:

- a) prévention intrinsèque;*
- b) protecteurs et dispositifs de protection;*
- c) informations pour les utilisateurs finaux.*

La prévention intrinsèque constitue la première et la plus importante étape du processus de réduction du risque, car les mesures de prévention inhérentes aux caractéristiques du produit ou du système ont de bonnes chances de rester efficaces en permanence. En revanche, l'expérience montre que des protecteurs et des dispositifs de protection, même bien conçus, peuvent présenter une défaillance ou être contournés, et que l'information pour l'utilisation peut ne pas être suivie.

Des protecteurs et des dispositifs de protection doivent être utilisés chaque fois que l'application de mesures de prévention intrinsèque ne permet raisonnablement ni d'éliminer les dangers ni de réduire suffisamment les risques associés. Des mesures de prévention complémentaires mettant en œuvre d'autres équipements (équipement d'arrêt d'urgence, par exemple) peuvent être nécessaires.

L'utilisateur final a un rôle à jouer dans la procédure de réduction du risque en se conformant à l'information mise à sa disposition par le concepteur/fournisseur. Toutefois, les informations pour l'utilisation ne doivent pas être substituées à la mise en œuvre correcte de mesures de prévention intrinsèque, de protecteurs ou de mesures de prévention complémentaires.”

En général, ce principe est utilisé dans l'IEC 62368-1. Le tableau ci-dessous compare la hiérarchie exigée dans l'ISO/IEC Guide 51 et celle de l'IEC 62368-1:2018.

ISO/IEC Guide 51	IEC 62368-1
a) prévention intrinsèque	1. prévention intrinsèque en limitant tous les dangers d'énergie à la classe 1
b) protecteurs et dispositifs de protection	2. protections de l'équipement
	3. protections de l'installation
	4. protections individuelles
c) informations pour les utilisateurs finaux.	5. protections de comportement
	6. protections par instructions

L'appréciation du risque a été considérée comme faisant partie intégrante de l'IEC 62368-1, comme indiqué ci-après (de l'ISO/IEC Guide 51) (Figure 1) dans le présent document. Voir également le flux de processus du HBSE (Hazard Based Safety Engineering) (Figure 2) dans le présent document, qui donne également des informations détaillées supplémentaires pour procéder à la comparaison ci-dessus.

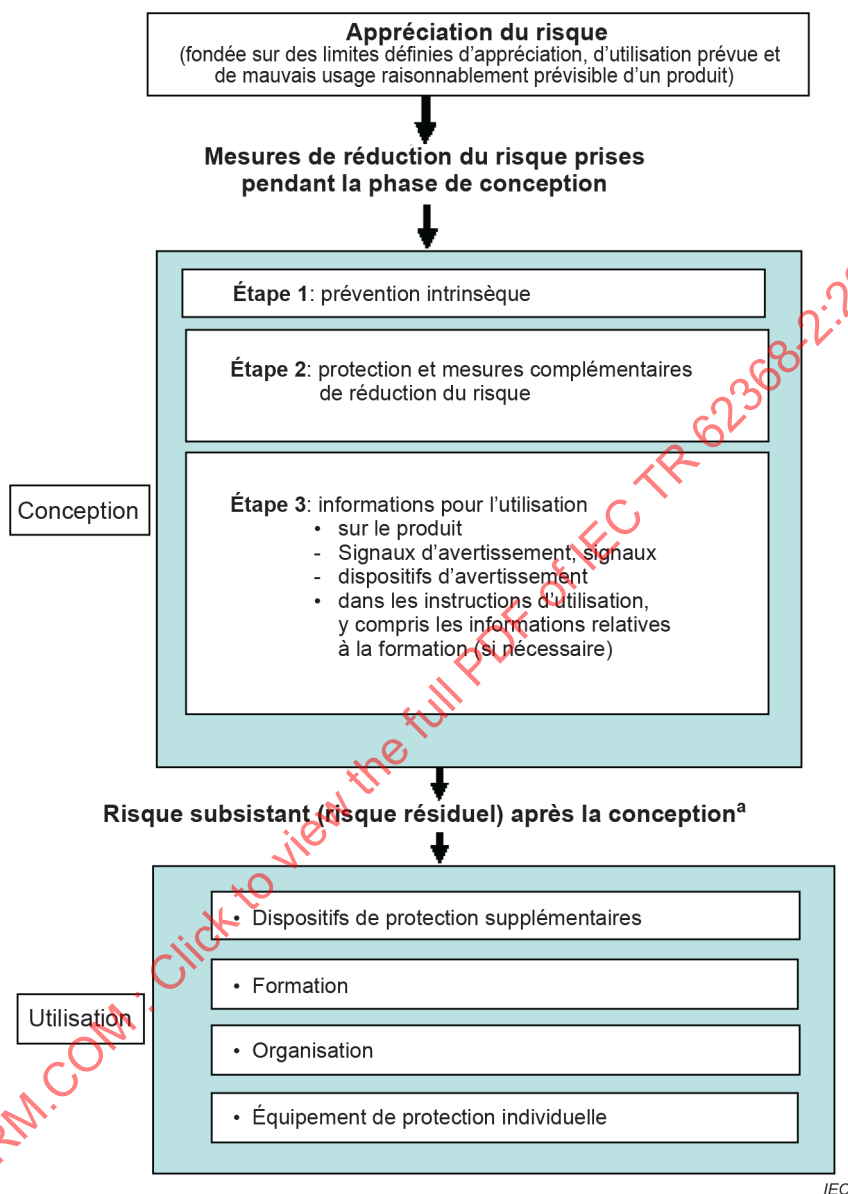


Figure 1 – Réduction du risque comme indiqué dans l'ISO/IEC Guide 51

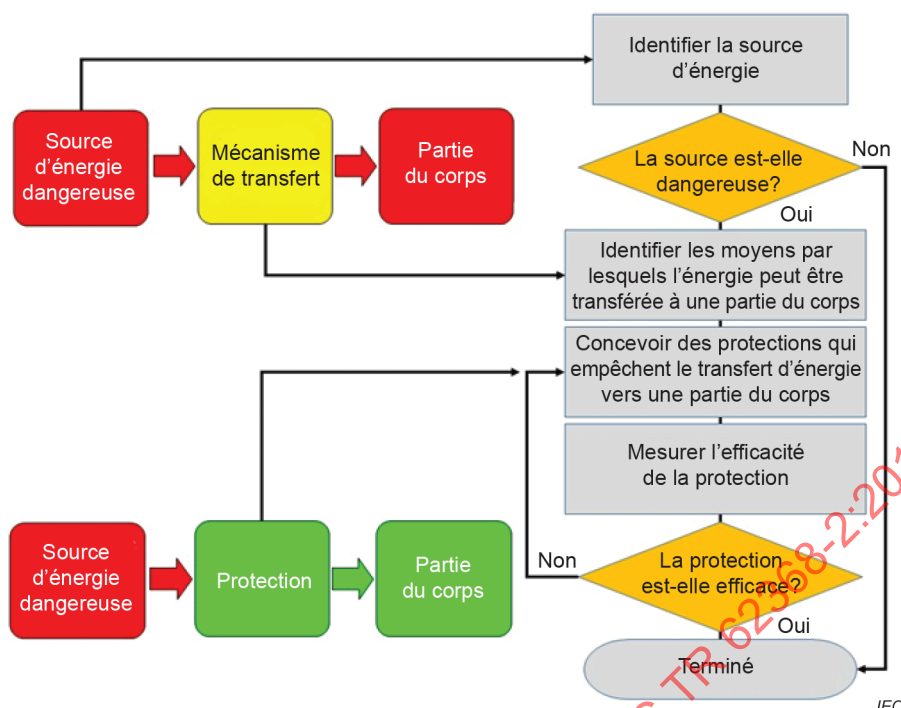


Figure 2 – Diagramme de processus HBSE

0.5.7 Protections dans des conditions d'entretien par une personne qualifiée

Objet: Expliquer l'objet des exigences de fournir des **protections** contre une réaction involontaire.

Justificatif: Par définition, une **personne qualifiée** a reçu la formation et a acquis de l'expérience pour identifier toutes les sources d'énergie de classe 3 auxquelles elle peut être exposée. Toutefois, au cours de l'entretien d'une source d'énergie de classe 3 dans un emplacement, une **personne qualifiée** peut être exposée à une autre source d'énergie de classe 3 dans un autre emplacement.

Dans cette situation, l'un des deux événements suivants est possible. Tout d'abord, un événement peut déclencher une réaction involontaire de la **personne qualifiée**, provoquant le contact avec la source d'énergie de classe 3 située dans l'autre emplacement. En second lieu, l'espace dans lequel se trouve la **personne qualifiée** peut être exigu et étroit, et un contact involontaire avec une source d'énergie de classe 3 dans l'autre emplacement peut être probable.

Dans cette situation, le présent document peut exiger une **protection de l'équipement** uniquement pour protéger une **personne qualifiée** qui procède à une opération d'entretien.

1 Domaine d'application

Objet: Identifier l'objet et l'applicabilité du présent document et les éléments exclus du domaine d'application.

Justificatif: Le domaine d'application exclut les exigences de sécurité fonctionnelle. La sécurité fonctionnelle est traitée dans l'IEC 61508-1. Étant donné que le domaine d'application inclut les ordinateurs qui peuvent commander les systèmes de sécurité, les exigences de sécurité fonctionnelle incluent nécessairement celles relatives aux processus et logiciels informatiques.

Les exigences indiquées dans l'IEC 60950-23 ont pu être modifiées et ajoutées à l'IEC 62368 comme un autre document –X . Toutefois, compte tenu de l'IEC 62368-1 qui est fondée sur les dangers, les exigences de l'IEC 60950-23 ont été intégrées dans le corps de l'IEC 62368-1 et rendues plus génériques.

L'ajout des exigences de l'IEC 60950-23 vise à maintenir l'objectif général des exigences techniques de l'IEC 60950-23, à les intégrer dans l'IEC 62368-1 en se conformant au format global de l'IEC 62368-1 et à simplifier et faciliter leur application.

Traditionnellement, les robots relèvent des domaines d'application des documents ISO, gérés en général par le comité technique 299 de l'ISO. Le comité technique 299 de l'ISO dispose de groupes de travail sur les robots d'assistance à la personne et les robots de service, et produit, par exemple, l'ISO 13482, *Robots et composants robotiques – Exigences de sécurité pour les robots de soins personnels*.

2 Références normatives

La liste des références normatives répertorie tous les documents cités en référence normative dans le corps du document. À ce titre, les documents cités en référence sont indispensables à l'application du présent document. Pour les références datées, seule l'édition citée s'applique. Pour les références non datées, la dernière édition du document cité en référence s'applique (y compris les amendements).

Dernièrement, des laboratoires d'essai ont voulu utiliser la dernière édition dès sa publication, ce qui a posé un problème. Cette situation ayant créé de graves problèmes pour les fabricants, étant donné qu'ils n'avaient aucune chance de s'adapter, il a été estimé qu'il convenait de prévoir une période de transition raisonnable. Cette disposition correspond aux décisions précédentes prises par le SMB, qui autorise à mentionner les périodes de transition dans l'avant-propos des documents. Par conséquent, le comité d'études 108 de l'IEC a décidé d'indiquer cette information dans l'introduction de l'article sur les références normatives, afin de demander aux laboratoires d'essai de tenir compte d'une période de transition, d'une date d'entrée en vigueur ou d'une date de suppression établie pour le document.

Ces documents sont cités en référence, en tout ou partie ou en tant qu'exigences alternatives à celles contenues dans le présent document. Leur utilisation est spécifiée, le cas échéant, pour l'application des exigences du présent document. Le fait qu'une norme apparaisse dans la liste ne signifie pas que la conformité au document ou à ses parties soit exigée.

3 Termes, définitions et abréviations

Le justificatif est fourni pour les définitions qui s'écartent des définitions IEC ou de celles de la publication fondamentale ou groupée de sécurité.

3.3.2.1 enveloppe électrique

Source: IEC 60050-195:1998, 195-06-13

Objet: Venir à l'appui du concept de **protections** utilisé dans le présent document.

Justificatif: La définition de l'IEV a été modifiée pour utiliser le terme anglais "**safeguard**" (protections) à la place du mot "protection". Le mot "**safeguard**" (protection) identifie un "élément" physique, alors que le mot "protection" identifie l'action de protéger. Le présent document définit les exigences d'utilisation des **protections** physiques et les exigences relatives à ces mêmes **protections**. Les moyens de **protection** assurent la "protection" contre les blessures provoquées par le matériel.

3.3.5.1 isolation principale

Source: IEC 60050-195:1998, 195-06-06

Objet: Venir à l'appui du concept de **protections** utilisé dans le présent document.

Justificatif: La définition de l'IEV a été modifiée pour utiliser le terme anglais "**safeguard**" (protections) à la place du mot "protection". Le mot "**safeguard**" (protection) identifie un "élément" physique, alors que le mot "protection" identifie l'action de protéger. Le présent document définit les exigences d'utilisation des **protections** physiques et les exigences relatives à ces mêmes **protections**. Les moyens de **protection** assurent la "protection" contre les blessures provoquées par le matériel.

3.3.5.2 double isolation

Source: IEC 60050-195:1998, 195-06-08

Objet: Venir à l'appui du concept de **protections** utilisé dans le présent document.

Justificatif: Voir 3.3.5.1, **isolation principale**.

3.3.5.6 matériau isolant solide

Source: IEC 60050-212:2015, 212-11-02

3.3.5.7 isolation supplémentaire

Source: IEC 60050-195:1998, 195-06-07

Objet: Venir à l'appui du concept de **protections** utilisé dans le présent document.

Justificatif: Voir 3.3.5.1, **isolation principale**.

3.3.6.9 zone d'accès limité

Source: IEC 60050-195:1998, 195-04-04

Objet: Utiliser les concepts de "**personne avertie**" et de "**personne qualifiée**" tels qu'ils le sont dans le présent document.

Justificatif: La définition de l'IEV a été modifiée pour utiliser les termes "**personne avertie**" et "**personne qualifiée**" plutôt que "**personne** électriquement avertie" et "**personne** électriquement qualifiée."

3.3.7.7 mauvais usage raisonnablement prévisible

Source: ISO/IEC Guide 51:2014, 3.7

Justificatif: Le mauvais usage dépend des objectifs personnels, de la manière dont les personnes perçoivent le matériel et de l'éventuelle utilisation du matériel (d'une manière non prévue par le fabricant) pour atteindre ces objectifs personnels. Le matériel relevant du domaine d'application du présent document va du petit matériel portable au matériel volumineux et installé de façon permanente. Il n'y a aucun rapport entre les matériels permettant de prévoir le comportement humain donnant lieu à un mauvais usage du matériel et les blessures qui en découlent. Lorsqu'un éventuel **mauvais usage raisonnablement prévisible** qui peut donner lieu à des blessures n'est pas couvert par les exigences du document, les fabricants sont invités à prendre en considération tout **mauvais usage raisonnablement prévisible** du matériel et à prévoir des **protections**, selon le cas, afin d'éviter les blessures en cas de mauvais usage de ce type. (Tous les **mauvais usages raisonnablement prévisibles** du matériel ne donnent pas lieu à des blessures ou des blessures potentielles.)

3.3.8.1 personne avertie

Source: IEC 60050-826:2004, 826-18-02

Justificatif: La définition de l'IEV a été modifiée pour utiliser les termes "sources d'énergie", "personne **qualifiée**" et "**protection de précaution**". La définition est renforcée à l'aide du terme "avertie" plutôt que "informée".

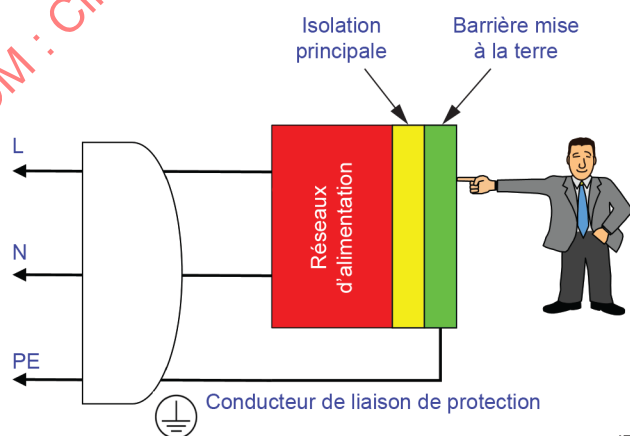
3.3.8.3 personne qualifiée

Source: IEC 60050-826:2004, 826-18-01

Justificatif: La définition de l'IEV a été modifiée pour utiliser l'expression "pour réduire la probabilité de". En règle générale, l'IEC 62368-1 a tendance à ne pas utiliser le mot "danger".

3.3.11.9 conducteur de liaison de protection

Justificatif: Le **conducteur de liaison de protection** n'est pas une **protection** complète, mais une partie du composant destinée à la **protection** du système de mise à la terre. Le **conducteur de liaison de protection** fournit un chemin de courant de défaut entre une partie (isolée d'ES3 par une **isolation principale** uniquement) et la borne de **mise à la terre de protection** du matériel (voir la Figure 3 du présent document).



IEC

Figure 3 – Conducteur de liaison de protection faisant partie intégrante d'une protection

Les parties qui doivent être mises à la terre par l'intermédiaire d'un **conducteur de liaison de protection** sont celles qui sont uniquement séparées d'ES3 par une **isolation principale**, et qui sont connectées aux parties **accessibles**.

Seul le trajet de courant de défaut doit être un **conducteur de liaison de protection**. D'autres connexions de terre des parties conductrices **accessibles** peuvent être réalisées à l'aide d'un conducteur de terre fonctionnelle à la borne PE du matériel ou à un **conducteur de liaison de protection**.

3.3.14.3 tension de contact présumée

Source: IEC 60050-195:1998, 195-05-09
 Objet: Identifier correctement les tensions de source d'énergie de choc électrique.
 Justificatif: La définition de l'IEV a été modifiée pour supprimer le mot "animal". Le mot "personne" a également été supprimé, toutes les exigences du document concernant les personnes.

3.3.14.8 tension de service

Source: IEC 60664-1:2007, 3.5
 Objet: faire la distinction entre la **tension de service en valeur efficace** et la crête de la **tension de service**.
 Justificatif: La définition de l'IEC 60664-1 a été modifiée pour supprimer "valeur efficace". L'IEC 62368-1 utilise les termes de **tension de service efficace** et la crête de la **tension de service**, chacun d'eux étant défini.

3.3.15.2 construction de classe II

Source: IEC 60335-1:2010, 3.3.11
 Objet: Même si le terme n'est pas utilisé dans le document, il a été décidé, pour des raisons d'exhaustivité, de conserver cette définition.
 Justificatif: Le mot "appareil" a été remplacé par "matériel".

4 Exigences générales

Objet: Expliquer comment examiner et déterminer si la sécurité est concernée ou ne l'est pas.
 Justificatif: Pour établir si la sécurité est concernée ou ne l'est pas, les circuits et la construction sont examinés afin de déterminer si les conséquences d'éventuelles conditions de défaut peuvent provoquer des blessures. La sécurité est concernée si, dans le cadre d'une **condition de premier défaut**, les conséquences du défaut sont à l'origine d'un risque de blessure.

Si une condition de défaut provoquait un risque de blessure, la partie, le matériel ou l'appareil dont le défaut a été simulé peut comporter une **protection**.

Un justificatif est donné pour les questions relatives à l'omission de certaines exigences traditionnelles dont font état d'autres documents relatifs à la sécurité. Le justificatif est également fourni pour donner des explications approfondies sur les nouveaux concepts et exigences du présent document.

Mauvais usage raisonnablement prévisible

Justificatif: Outre l'Annexe M, le présent document ne précise pas particulièrement de mauvais usage prévisible, ou de **conditions anormales de fonctionnement**. Néanmoins, les exigences du document couvrent toutes sortes de mauvais usages prévisibles (la couverture des ouvertures de ventilation, les bourrages papier, le calage des moteurs, etc.).

isolation fonctionnelle

Justificatif: Le présent document ne contient aucune exigence relative à l'**isolation fonctionnelle**. Par nature, l'**isolation fonctionnelle** n'assure aucune fonction de **protection** contre les chocs électriques ou les incendies d'origine électrique et peut donc être mise en défaut. Évidemment, toutes les **isolations fonctionnelles** ne sont pas mises en défaut, ce qui serait très chronophage. Il convient que les sites présentant des défauts d'**isolation fonctionnelle** fassent l'objet d'un examen physique du matériel selon le schéma électrique.

Noter que l'**isolation principale** et l'**isolation renforcée** peuvent également faire office d'**isolation fonctionnelle**, auquel cas l'isolation n'est pas mise en défaut.

composants fonctionnels

Justificatif: Le présent document ne contient aucune exigence relative aux composants fonctionnels. Par nature, les composants fonctionnels individuels n'assurent aucune fonction de **protection** contre les chocs électriques, les incendies d'origine électrique, les blessures thermiques, etc., et peuvent donc être soumis aux essais de défaut. Évidemment, tous les composants fonctionnels ne sont pas mis en défaut, ce qui serait très chronophage. Il convient que les composants pouvant être soumis aux essais de défaut s'appuient sur un examen physique du matériel, sur les schémas électriques et, si un défaut de ce composant peut se traduire par des conditions de choc électrique, sur les conditions d'inflammation et de propagation du feu, les conditions de blessures thermiques, etc.

Comme avec tous les essais de **condition de premier défaut** (Article B.4), la mise en défaut d'un composant fonctionnel ne doit provoquer aucune conséquence en matière de sécurité (une conséquence bénigne, par exemple) ou une **protection principale**, une **protection supplémentaire** ou une **protection renforcée** doit rester effective.

Dans certains cas, une paire de composants peut être composée d'une **protection**. Si le défaut de l'un des composants de la paire est atténué par le second composant, la paire est alors appelée **protection double**. Par exemple, si deux diodes sont utilisées en série pour protéger une **batterie** contre les charges inversées, la paire est alors composée d'une **protection double**, et il convient de limiter les composants à ceux du fabricant et aux numéros de série réellement soumis à l'essai. Un second exemple est celui d'un condensateur X et d'une résistance de décharge. Si la résistance de décharge se met en défaut en circuit ouvert, le condensateur X n'est alors pas déchargé. Par conséquent, la valeur du condensateur X ne doit pas dépasser les limites ES2 spécifiées pour un condensateur chargé. Encore une fois, les deux composants sont composés d'une **protection double**, et les valeurs de chaque composant sont limitées aux valeurs d'ES1 dans les **conditions normales de fonctionnement** et aux valeurs d'ES2 dans les **conditions de premier défaut**.

4.1.1 Application des exigences d'acceptation des matériaux, composants et sous-ensembles

Objet: Accepter les composants comme des **protections**.

Justificatif: Le présent document contient des exigences relatives aux composants des **protections**. Un composant de **protection** est un composant spécifiquement conçu et fabriqué pour les paramètres fonctionnels et de **protection**. Des exemples de composants de **protection** sont les condensateurs conformes à l'IEC 60384-14 et d'autres composants conformes à leur document IEC respectif.

Acceptation des composants et des exigences relatives aux composants de l'IEC 60065 et de l'IEC 60950-1

Objet: Accepter les composants et les sous-assemblages examinés en fonction des documents existants (IEC 60065 et IEC 60950-1) ainsi que les composants satisfaisant aux exigences de composant individuel de ces documents pendant la période de transition.

Justificatif: Pour faciliter la transition entre les documents existants (IEC 60065 et IEC 60950-1) et l'IEC 62368-1, y compris par la chaîne d'alimentation du composant, le présent document permet d'accepter les composants et sous-assemblages examinés en fonction des documents existants. Les exigences relatives au composant individuel de ces documents peuvent être utilisées pour assurer la conformité à l'IEC 62368-1 sans autre examen, outre le fait de prendre en considération l'utilisation appropriée du composant ou du sous-assemblage dans le produit final.

Cela signifie, par exemple, que si une alimentation à découpage est certifiée conforme à l'IEC 60065 ou à l'IEC 60950-1, ce composant peut être utilisé dans le matériel évalué selon l'IEC 62368-1 sans examen supplémentaire, outre le fait de prendre en considération l'utilisation appropriée du composant (utilisation dans les limites de ses caractéristiques assignées électriques, par exemple).

Cela signifie également, par exemple, qu'étant donné que l'IEC 60950-1 permet au câblage et aux câbles isolés au polychlorure de vinyle (PVC), au tétrafluoroéthylène (TFE), au polytétrafluoroéthylène (PTFE), à l'éthylène-propylène fluoré (FEP), au polychloroprène ou au polyimide de satisfaire aux exigences matérielles des parties à l'intérieur de l'**enveloppe ignifuge** sans nécessairement procéder à un essai d'inflammabilité, le même fil pouvant être utilisé pour satisfaire aux exigences de 6.5.2 pour l'isolation sur le câblage utilisé dans les circuits PS2 ou PS3 et sans nécessairement procéder à un essai d'inflammabilité conformément à la série IEC 60332 ou à l'IEC TS 60695-11-21, comme cela est en principe exigé en 6.5.1.

4.1.5 Aspects relatifs aux constructions et composants non traités spécifiquement

Pour les constructions non couvertes, il convient de prendre en considération la hiérarchie des protections conformément au Guide ISO/IEC 51.

4.1.6 Orientation lors du transport et de l'utilisation

Voir également 4.1.4

En règle générale, il est pris pour hypothèse d'installer et d'utiliser le matériel conformément aux instructions du fabricant. Toutefois, dans certains cas, lorsque le matériel peut être installé par une **personne ordinaire**, il est reconnu qu'il est de pratique courante de monter le matériel en fonction des besoins si des trous de vis sont prévus, plus particulièrement s'ils permettent un montage dans des supports aisément accessibles. Ainsi, l'exception est ajoutée à 4.1.6.

Exemples illustrant ce qui précède: un élément du matériel (un poste de télévision ou un vidéoprojecteur, par exemple), équipé de trous de montage de vis permettant de le fixer au mur ou sur une autre surface au moyen des supports verticaux ou inclinables disponibles dans le commerce, doit également tenir compte du fait que la surface de montage elle-même peut ne pas être verticale.

Il est également reconnu que les **équipements transportables**, par nature, peuvent être transportés dans toutes les orientations possibles.

4.1.8 Liquides et composants remplis de liquide (LFC)

La restriction de un litre (1 l) a été indiquée en 4.1.8, certaines exigences de l'Article G.15 trouvant leur origine parmi les exigences indiquées dans les documents et souvent appliquées à de plus petits systèmes. Toutefois, ce type de limitation n'interdit pas toujours d'appliquer 4.1.8 et l'Article G.15 aux systèmes de volumes de liquide plus importants, mais peut avoir un impact direct (automatique) sur l'applicabilité aux systèmes plus importants.

4.2 Classifications des sources d'énergie

La classification des sources d'énergie peut être réalisée que la source soit **accessible** ou pas. Les exigences relatives aux parties peuvent être différentes selon que la partie est **accessible** ou pas.

4.2.1 Source d'énergie de classe 1

Une source d'énergie de classe 1 est une source réputée ne pas provoquer de douleur ou de blessure. Par conséquent, une source d'énergie de classe 1 peut être **accessible** par une personne.

Dans certaines conditions particulières de fonctionnement anormal ou de **conditions de premier défaut**, une source d'énergie de classe 1 peut atteindre les limites de classe 2. Toutefois, cette source reste toujours une source d'énergie de classe 1. Dans ce cas, une **protection par instructions** peut être exigée.

Dans les **conditions normales de fonctionnement** et les **conditions anormales de fonctionnement**, l'énergie d'une source de classe 1, en contact avec une partie du corps, peut être détectable, mais ne provoque aucune douleur ni n'est susceptible de blesser. En ce qui concerne les incendies, l'énergie d'une source de classe 1 n'est pas susceptible de provoquer une inflammation.

Dans les **conditions de premier défaut**, une source d'énergie de classe 1, en contact avec une partie du corps, peut être douloureuse, mais n'est pas susceptible de blesser.

4.2.2 Source d'énergie de classe 2

Une source d'énergie de classe 2 est une source qui peut provoquer une douleur, mais qui n'est pas susceptible de blesser sérieusement. Par conséquent, une source d'énergie de classe 2 peut ne pas être **accessible** par une **personne ordinaire**. Toutefois, une source d'énergie de classe 2 peut être **accessible** par :

- une **personne avertie**; et
- une **personne qualifiée**.

L'énergie d'une source de classe 2, en contact avec une partie du corps, peut être douloureuse, mais n'est pas susceptible de blesser. En ce qui concerne les incendies, l'énergie d'une source de classe 2 peut provoquer une inflammation dans certaines conditions.

4.2.3 Source d'énergie de classe 3

Une source d'énergie de classe 3 est une source susceptible de blesser. Par conséquent, une source d'énergie de classe 3 ne peut pas être **accessible** par une **personne ordinaire** ou une **personne avertie**. Une source d'énergie de classe 3 peut en général être **accessible** à une **personne qualifiée**.

Une source peut être déclarée comme une source d'énergie de classe 3 sans mesurage, auquel cas toutes les **protections** applicables à la classe 3 sont exigées.

L'énergie de la classe 3, en contact avec une partie du corps, peut provoquer des blessures. En ce qui concerne les incendies, l'énergie d'une source de classe 3 peut provoquer une inflammation et la propagation des flammes en présence de combustible.

4.3.2 Protections destinées à protéger une personne ordinaire

Les **protections** exigées destinées à protéger une **personne ordinaire** sont indiquées à la Figure 4.

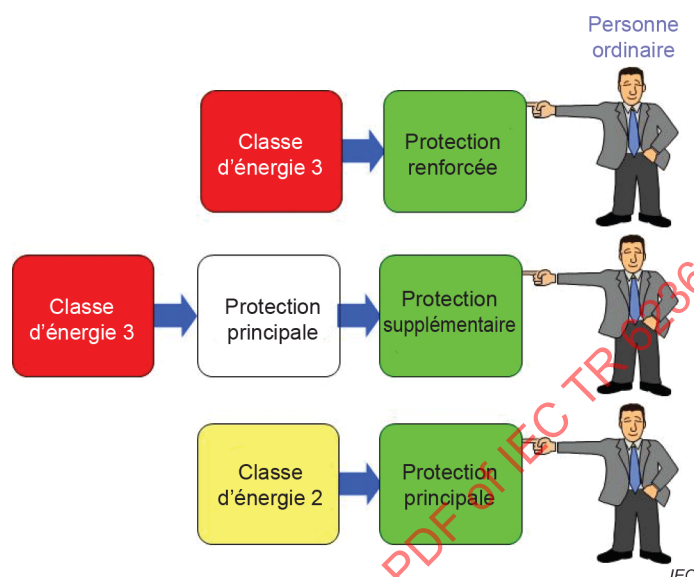


Figure 4 – Protections destinées à protéger une personne ordinaire

4.3.3 Protections destinées à protéger une personne avertie

Les **protections** exigées destinées à protéger une **personne avertie** sont indiquées à la Figure 5.

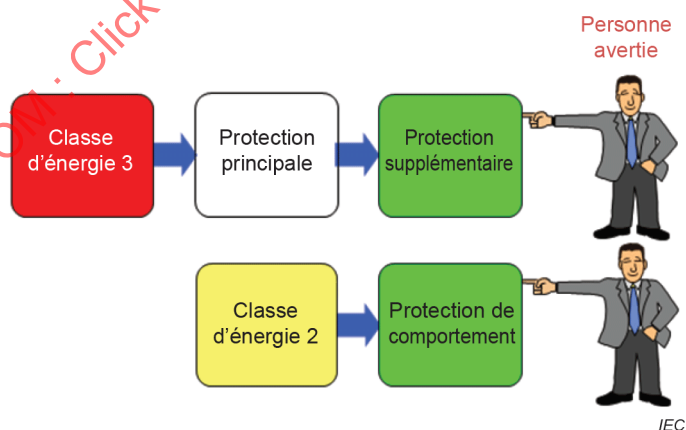


Figure 5 – Protections destinées à protéger une personne avertie

4.3.4 Protections destinées à protéger une personne qualifiée

Les **protections** exigées destinées à protéger une **personne qualifiée** sont indiquées à la Figure 6.

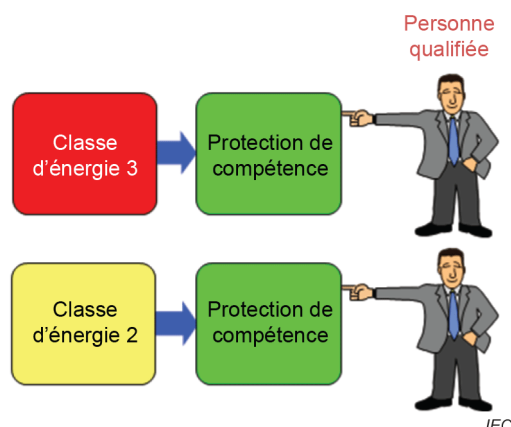


Figure 6 – Protections destinées à protéger une personne qualifiée

Le Tableau 1 du présent document donne un aperçu général du nombre exigé de **protections** en fonction de la source d'énergie et de la personne à laquelle la source d'énergie est **accessible**. Les différents articles donnent des exigences qui parfois s'écartent du principe général énoncé ci-dessus. Ces cas sont clairement définis dans les sections du document relatives aux exigences.

Tableau 1 – Récapitulatif général des protections exigées

Personne	Nombre de protections exigées à placer entre une source d'énergie et une personne		
	Classe 1	Classe 2	Classe 3
Personne ordinaire	0	1	2
Personne avertie	0	0	2
Personne qualifiée	0	0	0 ou 1

Pour une **personne qualifiée**, aucune **protection** n'est en principe exigée pour une source d'énergie de classe 3. Toutefois, en présence de plusieurs sources d'énergie de classe 3 **accessibles** ou si la source d'énergie ne s'impose pas comme une évidence, une **protection** peut être exigée.

4.4.2 Composition d'une protection

Objet: Spécifier les critères de conception et de construction d'une **protection** unique (principale, supplémentaire ou renforcée) composée de plusieurs éléments (un composant ou un appareil, par exemple).

Justificatif: Il n'est pas nécessaire que la **protection** soit un composant simple et homogène. En effet, certaines parties du présent document exigent qu'une **protection** unique soit composée d'au moins deux éléments. Par exemple, pour une isolation mince, au moins deux couches sont exigées pour être qualifiées d'**isolations supplémentaires**. Un autre exemple est une liaison de protection et une **mise à la terre pour des raisons de protection**, les deux étant composées de fils, de bornes, de vis, etc.

Si une **protection** est composée d'au moins deux éléments, il convient alors que la fonction de la **protection** ne soit pas compromise par la défaillance de l'un des éléments. Par exemple, s'il convient de desserrer une vis fixant le fil d'une **mise à la terre pour des raisons de protection**, le courant admissible du circuit de **mise à la terre pour des raisons de protection** peut alors être compromis, rendant sa fiabilité incertaine.

4.4.3 Robustesse de la protection

Justificatif: Il convient que les **protections** soient suffisamment robustes pour résister aux contraintes de l'utilisation prévue tout au long de la durée de vie du matériel. Les exigences de robustesse sont spécifiées dans les différents articles.

4.4.3.4 Essais de choc

Justificatif: L'**équipement stationnaire** peut, dans certains cas, être conçu pour une installation particulière dans laquelle certaines surfaces ne peuvent pas être soumises à un choc lorsqu'elles sont installées comme prévu. Dans ces cas, l'essai de choc n'est pas nécessaire lorsqu'il est clair que le côté de l'installation ne peut pas être soumis à un choc.

4.4.3.6 Essais de choc sur le verre

Source: IEC 60065

Objet: Vérifier qu'un verre qui se brise ne provoque pas de blessure de la peau par coupure ni n'expose à des dangers de classe 3 derrière le verre.

Justificatif: S'agissant du verre, deux types de dangers peuvent se présenter en cas de bris:

- accessibilité aux arêtes vives du verre brisé lui-même
- exposition à des dangers d'énergie de classe 3 si le verre est utilisé pour l'**enveloppe** ou une partie de celle-ci.

Si le verre se brise lors de l'essai de choc, T.9 est appliqué pour vérifier que les fragments propulsés sont de niveau MS2 ou moins.

La glace d'exposition en est depuis longtemps dispensée, car il semble évident pour tout le monde que le verre brisé est dangereux et qu'il convient de ne pas le toucher. Il n'existe pas d'antécédents graves de blessures avec cette application. Le verre d'exposition est un verre qui est en général utilisé dans les scanners, les photocopieurs, etc. Les accidents sont rares, probablement parce que ces équipements sont la plupart du temps également protégés par un capot, ce qui réduit les chances de choc sur le verre.

Les tubes cathodiques en sont dispensés, car ils font l'objet d'exigences distinctes.

La valeur d'essai des équipements posés au sol est plus élevée, car la probabilité qu'ils soient heurtés par des personnes ou des chariots à une force supérieure à celle d'une utilisation normale est plus importante.

L'exemption concernant le verre de certaines tailles inférieures est issue de l'IEC 60065. Aucun motif valable, autre que l'absence d'accidents graves connus dans le domaine, ne justifie l'exemption. Le HBSDT a décidé de maintenir cette exemption.

Le diagramme de la Figure 7 du présent document présente l'objet des exigences.

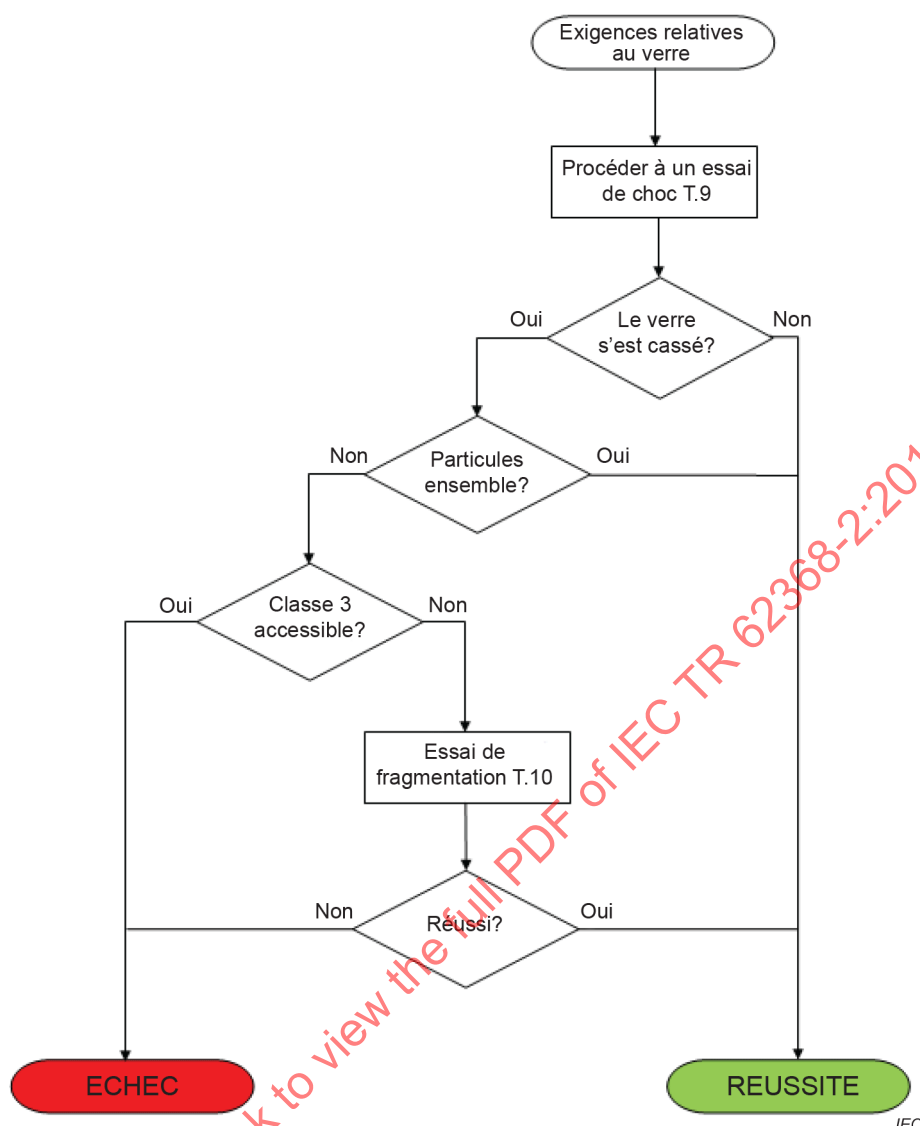


Figure 7 – Diagramme présentant l'objet des exigences relatives au verre

4.4.3.10 Critères de conformité

La valeur de 30 g pour la limite de poids est choisie en considérant la dimension maximale d'un côté de 50 mm. Le poids d'un morceau de verre type de (50 x 50 x 4) mm (2,80 g/cm³ environ) est d'environ 30 g.

4.6 Fixation des conducteurs

Source: IEC 60950-1

Objet: Réduire la probabilité que les conducteurs puissent se déplacer et réduisent les **lignes de fuite** et les **distances dans l'air**.

Justificatif: Ces exigences ont été appliquées avec succès pendant de nombreuses années pour les produits relevant du domaine d'application du présent document.

4.7 Équipement pour insertion directe dans des socles d'alimentation

Source: IEC 60065:2014, 15.5

IEC 60950-1:2013, 4.3.6

IEC 60335-1:2010, 22.3

IEC 60884-1:2013, 14.23.2

Objet: Déterminer que les équipements qui possèdent des broches intégrées destinées à être insérées dans les socles **d'alimentation** n'imposent pas de couple excessif aux socles de prises de courant en raison de la masse et de la configuration de l'équipement. Ce type d'équipements est souvent appelé "équipement à enficher directement" ou "transformateur à enficher directement".

Justificatif: Les socles doivent satisfaire aux exigences de sécurité de l'IEC 60884-12013, *Prises de courant pour usages domestiques et analogues – Partie 1: Exigences générales*, y compris le paragraphe 14.23.2. Les exigences donnent lieu à des conceptions de socle présentant certaines limites. Il n'est pas admis que les équipements possédant des broches intégrées destinées à être insérées dans les socles **d'alimentation** dépassent ces limites de conception.

4.9 Probabilité d'incendie ou de choc dû à l'entrée d'objets conducteurs

Objet: Le présent paragraphe a pour objet d'établir des exigences d'ouverture pour réduire le plus possible le risque de chute d'objets conducteurs étrangers dans l'équipement, pouvant mettre des parties en parallèle dans les circuits de classe 2 ou de classe 3 ou entre les circuits PS, pouvant provoquer une inflammation ou un choc électrique.

Il est considéré comme improbable qu'une personne lance accidentellement un objet qui pourrait ensuite tomber dans l'équipement à une hauteur de plus de 1,80 m.

5 Blessure due à un choc électrique

Objet: L'Article 5 classe les sources d'énergie électrique et donne les critères de détermination de la classe de source d'énergie de chaque partie conductrice. Les critères de la classe de source d'énergie incluent les caractéristiques courant-tension de la source, la durée et la capacité. Chaque partie conductrice, qu'elle transporte du courant ou pas, ou qu'elle soit mise à la terre ou pas, doit être classée ES1, ES2 ou ES3 par rapport à la terre et à toutes les autres parties conductrices simultanément **accessibles**.

Limite de 240 VA

L'IEC 62368-1 ne formule aucune exigence en matière de danger d'énergie 240 VA déjà mentionnée au 2.1.1.5 de l'IEC 60950-1:2013.

L'origine/la justification de l'exigence de danger d'énergie 240 VA dans les documents existants n'a jamais été précisément déterminée, et il semble que les limites VA peuvent trouver leur origine dans les spécifications d'un fabricant appliquées aux barres omnibus exposées dans les ordinateurs centraux dès les années 60, et qu'elles s'adressaient au personnel d'entretien qui les mettait involontairement en parallèle avec une pièce métallique.

Toutefois, lorsque le comité d'études 108 de l'IEC a lancé le projet IEC 62368-1, il s'agissait de porter un regard nouveau sur la sécurité des produits à l'aide du HBSE et de ne remonter à une exigence existante que si la science en matière de sécurité et le HBSE le justifiaient. Après de nombreuses études réalisées par le comité d'études 108 de l'IEC, l'exigence de 240 VA a été abandonnée, car:

- elle ne reposait sur aucun élément scientifique éprouvé ni aucune base technique sûre;
- la valeur de 240 VA était relativement arbitraire; et

- dans la pratique, l'exigence était difficile à appliquer de manière cohérente (sur une carte imprimée ou dans une alimentation à découpage, par exemple).

En même temps, les condensateurs de l'Article 5 font l'objet de limites d'énergie, qui restent une préoccupation plus légitime et qui représentaient le second ensemble d'exigences en matière de dangers d'énergie dans l'IEC 60950-1, le premier étant 240 VA en régime établi.

De plus, d'autres exigences de l'IEC 62368-1 limitent l'exposition à des niveaux élevés de puissance (VA), y compris une limite VA pour les sorties des sources à puissance limitée (LPS – *limited power source*) si elles sont exigées par l'Annexe Q (pour les sorties reliées au câblage du bâtiment, comme exigé en 6.5.2).

Brûlure électrique (eBurn)

L'analyse du courant de structure généré par l'augmentation des formes d'onde sinusoïdale de fréquence indique que le courant continue à augmenter avec la fréquence. La même analyse indique que le **courant de contact**, qui est actualisé avec la fréquence, se stabilise.

Le document ci-dessous donne une description exhaustive de l'analyse: "Touch Current Comparison, Looking at IEC 60990 Measurement Circuit Performance – Part 1: Electric Burn"; Peter E Perkins; IEEE PSES Product Safety Engineering Newsletter, Vol 4, No 2, Nov 2008.

La fréquence de transfert du circuit de sursaut et celle du circuit de non-lâcher-immobilisation sont différentes en raison des courbes de réponse du corps de facteur de fréquence séparées liées aux niveaux de courant. L'analyse permet d'identifier la fréquence de transfert lorsque le courant de brûlure électrique dépasse le **courant de contact**. Dans ces conditions, une personne qui touche le circuit est immobilisée et ne peut pas le lâcher. La fréquence de transfert est déterminée dans l'analyse. Il convient que la personne qui touche le circuit puisse toujours le lâcher.

Les conditions générales qui s'appliquent aux circuits eBurn sont les suivantes:

- la limite eBurn s'applique uniquement aux signaux sinusoïdaux HF;
- il convient de limiter la zone de contact à un léger contact du bout du doigt (environ 1 cm²);
- il convient que le contact ne dure pas plus de 1 s. À cette durée de contact courte, il n'est pas raisonnable de définir différents niveaux pour différentes personnes;

Cette exigence s'applique aux circuits **accessibles** dont les deux pôles peuvent être touchés, y compris tous les circuits mis à la terre isolés de l'**alimentation** et tous les circuits isolés dont les deux contacts peuvent être facilement touchés.

Une application simplifiée de cette exigence dans les documents limite l'accessibilité des courants sinusoïdaux HF au-dessus d'une fréquence spécifiée. Les limites de fréquence de 22 kHz et de 36 kHz s'appliquent lorsque le courant eBurn coupe la limite de 5 mA pour les circuits de mesure ES1 et ES2. Cela permet de vérifier que la personne qui touche le circuit peut s'en dégager dans ces conditions.

Limite de 1 MHz

Les effets du courant électrique sur le corps humain sont décrits dans la série IEC 60479, les exigences de l'IEC 62368-1 en étant tirées. Les effets par rapport à la fréquence sont bien connus et correctement pris en compte pour ces exigences. Les effets sur le corps passent d'effets conduits à des brûlures de surface à fréquence radio à des fréquences supérieures approchant 100 kHz. Dans le cadre d'un accord à long terme, les

documents de sécurité de l'IEC exposent les effets du courant à 1 MHz qui sont correctement mesurés selon les techniques indiquées ici. Au-dessus de 1 MHz, il s'agit d'un problème de CEM. À moins que le courant ne soit fourni en tant que principe d'action fonctionnel de l'équipement, il convient que l'évaluation du choc électrique ne soit pas nécessaire au-dessus de 1 MHz. Si cela s'avère essentiel pour le fonctionnement de l'équipement, les niveaux de courant haute fréquence doivent être particulièrement mesurés à l'aide de techniques haute fréquence correctes (y compris en classant les circuits) et, le cas échéant, correctement protégés pour éviter toute blessure corporelle.

5.2.1 Classifications des sources d'énergie électrique

Source: IEC TS 60479-1:2005 et IEC 61201

Objet: Définir la limite entre les sources d'énergie dangereuses et non dangereuses pour les **conditions normales de fonctionnement** et les **conditions anormales de fonctionnement**.

Justificatif: Les effets d'une source électrique sur les personnes dépendent du courant qui traverse le corps humain. Ces effets sont décrits dans l'IEC TS 60479-1.

L'IEC TS 60479-1 (voir la Figure 20 et la Figure 22, le Tableau 11 et le Tableau 13); zone AC-1 et zone DC-1; en règle générale aucune réaction (la Figure 8 et la Figure 9, le Tableau 2 et le Tableau 3 du présent document) n'est prise pour valeurs d'ES1.

L'IEC TS 60479-1 (voir la Figure 20 et la Figure 22, le Tableau 11 et le Tableau 13); zone AC-2 et zone DC-2; en règle générale aucun effet physiologique néfaste (voir la Figure 8 et la Figure 9, le Tableau 2 du présent document) n'est pris pour valeurs d'ES2.

L'IEC TS 60479-1; zone AC-3 et zone DC-3; des effets physiologiques néfastes peuvent se produire (voir la Figure 8 et la Figure 9, le Tableau 2 et le Tableau 3 du présent document) est la zone ES3.

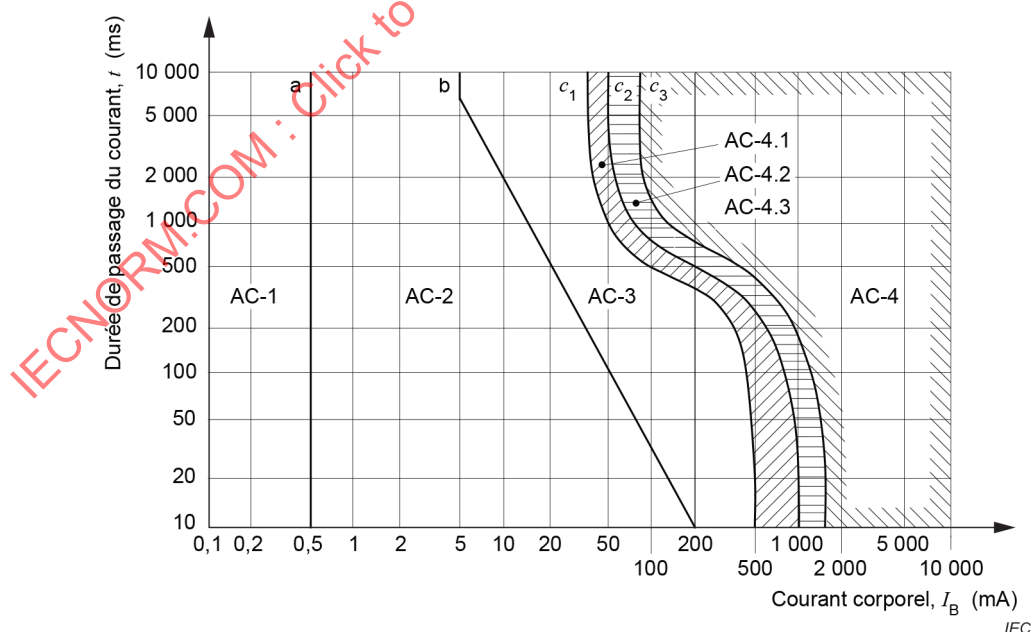


Figure 8 – Zones temps/courant conventionnelles des effets des courants alternatifs (15 Hz à 100 Hz) sur les personnes pour un trajet correspondant main gauche à pieds (voir l'IEC TS 60479-1:2005, Figure 20)

Tableau 2 – Zones temps/courant en courant alternatif 15 Hz à 100 Hz pour un trajet main à pieds (voir l'IEC TS 60479-1:2005, Tableau 11)

Zones	Limites	Effets physiologiques
AC-1	jusqu'à la courbe a de 0,5 mA	Perception possible, mais en général pas de sursaut
AC-2	0,5 mA jusqu'à la courbe b	Perception et contractions musculaires involontaires probables, mais en général pas d'effet physiologique électrique néfaste
AC-3	Courbe b et au-dessus	Fortes contractions musculaires involontaires Respiration difficile. Perturbations réversibles des fonctions cardiaques. Une immobilisation peut se produire. Les effets augmentent avec l'amplitude du courant. En règle générale, pas de lésion organique à prévoir.
AC-4 ^a	Au-dessus de la courbe c_1 $c_1 - c_2$ $c_2 - c_3$ Au-delà de la courbe c_3	Des effets pathophysiologiques peuvent se produire, comme un arrêt cardiaque, un arrêt respiratoire, des brûlures ou autres lésions cellulaires. La probabilité de fibrillation ventriculaire augmente avec l'amplitude du courant et le temps. AC-4.1 La probabilité de fibrillation ventriculaire augmente jusqu'à environ 5 %. AC-4.2 La probabilité de fibrillation ventriculaire augmente jusqu'à environ 50 %. AC-4.3 La probabilité de fibrillation ventriculaire au-dessus de 50 %.

^a Pour des durées de passage du courant inférieures à 200 ms, la fibrillation ventriculaire ne se déclenche que dans la période de vulnérabilité si les seuils correspondants sont dépassés. Concernant la fibrillation ventriculaire, ce chiffre porte sur les effets du courant qui circule dans le trajet main gauche à pieds. Pour d'autres trajets du courant, le facteur de courant cardiaque doit être pris en considération.

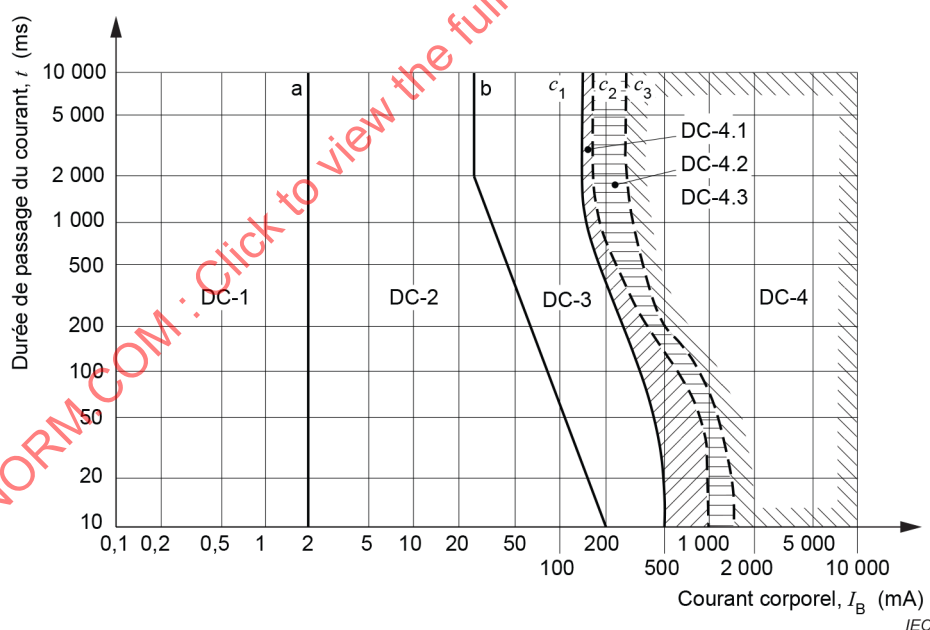


Figure 9 – Zones temps/courant conventionnelles des effets des courants continus sur les personnes pour un trajet longitudinal montant (voir l'IEC TS 60479-1:2005, Figure 22)

Tableau 3 – Zones temps/courant en courant continu pour un trajet main à pieds (voir l'IEC TS 60479-1:2005, Tableau 13)

Zones	Limites	Effets physiologiques
DC-1	Jusqu'à la courbe a de 2 mA	Légère sensation de picotement possible lors de l'ouverture, de la fermeture ou de la variation rapide du passage du courant.
DC-2	2 mA jusqu'à la courbe b	Contractions musculaires involontaires probables, particulièrement lors de l'ouverture, de la fermeture ou de la variation rapide du passage du courant, mais en général aucun effet physiologique électrique néfaste
DC-3	Courbe b et au-dessus	De fortes réactions musculaires involontaires et des perturbations réversibles de la formation et la conduction de pulsations dans le cœur peuvent se produire, qui augmentent avec l'amplitude du courant et la durée. En règle générale, pas de lésion organique à prévoir.
DC-4 ^a	Au-dessus de la courbe c_1 $c_1 - c_2$ $c_2 - c_3$ Au-delà de la courbe c_3	Des effets pathophysiologiques peuvent se produire, comme un arrêt cardiaque, un arrêt respiratoire, des brûlures ou autres lésions cellulaires. La probabilité de fibrillation ventriculaire augmente avec l'amplitude du courant et le temps. DC-4.1 La probabilité de fibrillation ventriculaire augmente jusqu'à environ 5 %. DC-4.2 La probabilité de fibrillation ventriculaire augmente jusqu'à environ 50 %. DC-4.3 La probabilité de fibrillation ventriculaire au-dessus de 50 %.
^a Pour des durées de passage du courant inférieures à 200 ms, la fibrillation ventriculaire ne se déclenche que dans la période de vulnérabilité si les seuils correspondants sont dépassés. Concernant la fibrillation ventriculaire, ce chiffre porte sur les effets du courant qui circule dans le trajet main gauche à pieds et pour le courant montant. Pour d'autres trajets du courant, le facteur de courant cardiaque doit être pris en considération.		

La gravité d'une blessure augmente continuellement avec l'énergie transférée vers le corps. Pour démontrer ce principe, la Figure 8 et la Figure 9 du présent document (voir l'IEC TS 60479-1, Figure 20 et Figure 22) sont transférées dans un graphique: effet en fonction de l'énergie (voir la Figure 10 du présent document).

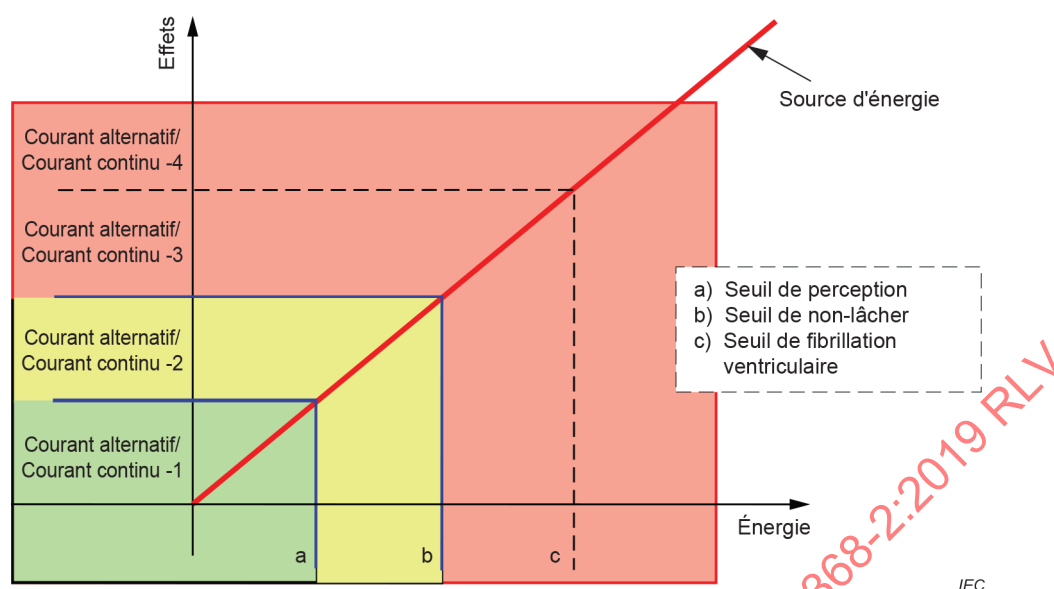


Figure 10 – Démonstration que les limites dépendent de la tension et du courant

Dans le document, seules les limites de la Zone 1 (vert) et de la Zone 2 (jaune) sont spécifiées.

La courbe “a” (limite de la Zone 1) est la limite pour les parties **accessibles** par une **personne ordinaire** en utilisation normale.

La courbe “b” (limite de la Zone 2) est la limite pour les parties **accessibles** par une **personne ordinaire** pendant (ou après) un premier défaut.

Le comité d'études 108 de l'IEC a considéré qu'il n'est pas acceptable d'aller jusqu'aux limites de la Zone 3 ou de la Zone 4.

Dans le document, trois (3) zones sont décrites comme étant des sources d'énergie électrique.

Cette classification est la suivante:

- source d'énergie électrique 1 (ES1): les niveaux sont d'une valeur telle qu'ils ne dépassent pas la courbe “a” (seuil de perception) de la Figure 8 et de la Figure 9 du présent document (voir l'IEC TS 60479-1:2005, Figure 20 et Figure 22).
- source d'énergie électrique 2 (ES2): les niveaux sont d'une valeur telle qu'ils dépassent la courbe “a”, mais ne dépassent pas la courbe “b” (seuil de non-lâcher) de la Figure 8 et de la Figure 9 du présent document (voir l'IEC TS 60479-1:2005, Figure 20 et Figure 22).
- source d'énergie électrique 3 (ES3): les niveaux sont d'une valeur telle qu'ils dépassent la courbe “b” de la Figure 8 et de la Figure 9 du présent document (voir l'IEC TS 60479-1:2005, Figure 20 et Figure 22).

5.2.2.1 Généralités

Lors de la classification d'un circuit ou d'une partie non **accessible**, ce circuit ou cette partie doit être considéré(e) comme **accessible** lors de la mesure de la **tension de contact présumée** et du **courant de contact**.

5.2.2.2 Limites de tension et de courant stables

Tableau 4 Limites de sources d'énergie électrique pour les sources d'énergie ES1 et ES2 stables

Source: IEC TS 60479-1:2005, Dalziel, Effect of Wave Form on Let-Go Currents; AIEE Electrical Engineering Transactions, Dec 1943, Vol 62.

Justificatif: Les limites de courant du Tableau 4, ligne 1 et ligne 2, sont déduites de la courbe a et de la courbe b, Figure 8 et Figure 9 du présent document (voir l'IEC TS 60479-1:2005, Figure 20 et Figure 22).

La base de détermination des limites pour le **courant de contact** en courant alternatif et en courant continu combiné provient des travaux de Dalziel, qui fournissent des données claires pour les hommes, les femmes et les enfants. Dans le diagramme de courant (Figure 22), le courant alternatif est toujours la valeur de crête (selon Dalziel). Dans le diagramme de tension (Figure 23), les points 30 V en courant alternatif et 50 V en courant alternatif sur le référentiel sont reconnus comme étant les valeurs efficaces en courant alternatif (voir le Tableau 4). Le comité d'études 108 de l'IEC travaillant sur des appareils grand public, il est nécessaire d'assurer la protection des enfants, qui sont en général considérés comme étant les personnes les plus vulnérables. Les formules de l'IEC 62368-1:2018, Tableau 4, concernent les examens de Dalziel.

Dans les **conditions de premier défaut** d'une **protection principale** ou d'une **protection supplémentaire** appropriée, le **courant de contact** est mesuré selon 5.1.2 de l'IEC 60990:2016. Toutefois, ce paragraphe de l'IEC 60990 cite en référence le réseau de perception/réaction de l'IEC 60990 (Figure 4) et le réseau de non-lâcher (Figure 5), dont le choix dépend de plusieurs facteurs. La Figure 5 s'applique aux limites de **courant de contact** supérieures à 2 mA en valeur efficace. Le comité d'études 108 de l'IEC a décidé qu'il convenait de mesurer les parties présentant des **conditions de premier défaut** au niveau des **protections principales** ou des **protections supplémentaires** appropriées selon la Figure 5 (réseau d'immobilisation de non-lâcher). Par conséquent, 5.1.2 citant en référence la Figure 4 et la Figure 5, pour clarification, le Tableau 4 est mentionné directement au 5.2.2.2.

Étant donné qu'en règle générale le corps humain ne réagit pas au contact d'ES1, l'accès par toute personne est autorisé (IEC TS 60479-1; zone AC-1 et zone DC-1).

Étant donné que le corps humain peut réagir au contact d'ES2, la protection est exigée pour une **personne ordinaire**. Une **protection** est suffisante, car il n'y a en général aucun effet physiologique néfaste en cas de contact avec ES2 (IEC TS 60479-1:2005; zone AC-2 et zone DC-2).

Étant donné que des effets physiologiques néfastes peuvent se produire en cas de contact avec ES3 (IEC TS 60479-1:2005; zone AC-3 et zone DC-3), une protection est exigée pour les **personnes ordinaires** et les **personnes averties**, y compris après un défaut d'une **protection**.

Lors de l'application des limites des sources d'énergie électrique pour le "courant alternatif et le courant continu combinés" (Tableau 4), si la composante en courant alternatif d'une source d'énergie en courant alternatif et en courant continu superposés ne dépasse pas 10 % de l'énergie en courant continu, la composante en courant alternatif peut alors être ignorée pour les besoins de l'application du Tableau 4. Cette considération est valable conformément à la définition de la **tension en courant continu** de 3.3.14.1, qui permet une ondulation crête à crête ne dépassant pas 10 % de la valeur moyenne à intégrer dans les considérations relatives à la **tension en courant continu**. Dans ce cas, il en résulte que lorsque le courant alternatif ne dépasse pas 10 % du courant continu, il est nécessaire de n'appliquer que les limites des sources d'énergie en courant continu du Tableau 4.

Lors du mesurage des tensions en courant alternatif et en courant continu, le courant alternatif et le courant continu doivent être mesurés entre les mêmes points de référence. Ne pas combiner les mesurages en mode

commun et les mesurages en mode différentiel. Ils doivent être évalués séparément.

Avec le Tableau 4, le mesurage du courant de contact ES1 spécifie le circuit de sursaut "a" prévu pour des limites inférieures à 2 mA en valeur efficace/2,8 mA crête et le courant de contact ES2 spécifie le circuit d'immobilisation de non-lâcher "b" prévu pour des limites > 2 mA en valeur efficace/2,8 mA crête. Ces circuits sont adoptés de l'Article 5 de l'IEC 60990:2016.

Les **conditions normales de fonctionnement** de l'équipement pour les essais de courant de contact sont présentées en 5.7.2 et à l'Article B.2 de l'IEC 62368-1:2018, qui inclut le fonctionnement de toutes les commandes de l'opérateur. Les **conditions anormales de fonctionnement** sont spécifiées à l'Article B.3 de l'IEC 62368-1:2018. Les **conditions de premier défaut** (à l'intérieur de l'équipement), spécifiées à l'Article B.4 de l'IEC 62368-1:2018, incluent les défauts d'une **protection principale** ou d'une **protection supplémentaire** appropriée.

5.2.2.3 Limites de capacité

Tableau 5 Limites de sources d'énergie électrique pour un condensateur chargé

Source: IEC TS 61201:2007 (Annexe A)

Justificatif: Si la source d'énergie est un condensateur, la classe de source d'énergie est déterminée à partir de la tension de charge et de la capacité. Les limites de capacité sont déduites de l'IEC TS 61201:2007, voir le Tableau 4 du présent document).

Les valeurs d'ES2 sont déduites du Tableau A.2 de l'IEC TS 61201:2007.

Les valeurs d'ES1 sont calculées en divisant par deux les valeurs du Tableau A.2 de l'IEC TS 61201:2007.

Tableau 4 – Valeurs limites de la capacité accessible (seuil de douleur)

<i>U</i> V	<i>C</i> μF	<i>U</i> kV	<i>C</i> nF
70	42,4	1	8,0
78	10,0	2	4,0
80	3,8	5	1,6
90	1,2	10	0,8
100	0,58	20	0,4
150	0,17	40	0,2
200	0 091	60	0 133
250	0 061		
300	0 041		
400	0 028		
500	0 018		
700	0 012		

5.2.2.4 Limites d'impulsion unique

Tableau 6 Limites de tension pour les impulsions uniques

Justificatif: Les valeurs reposent sur les valeurs de courant continu du Tableau 4, en prenant pour hypothèse que 25 mA donnent une tension de 120 V en courant continu (résistance du corps de 4,8 kΩ). La valeur la plus basse est de 120 V, car, dans les **conditions de premier défaut**, la tension d'ES1 peut atteindre 120 V en courant continu sans limite de temps.

Le tableau permet une interpolation linéaire, car la différence est considérée comme étant très faible. Toutefois, la formule suivante peut être utilisée pour une interpolation plus précise des valeurs log-log établies sur ce tableau. La variable t ou V est la "valeur intermédiaire" inconnue souhaitée et peut être déterminée lorsque l'un des éléments suivants est connu:

$$V = \text{Antilog} \frac{\log V_2 + \log V_1 \times \frac{\log t_2 - \log t}{\log t_2 - \log t_1}}{1 + \frac{\log t_2 - \log t}{\log t_2 - \log t_1}}$$

et

$$t = \text{Antilog} \frac{\log t_2 + \log t_1 \times \frac{\log V_2 - \log V}{\log V_2 - \log V_1}}{1 + \frac{\log V_2 - \log V}{\log V_2 - \log V_1}}$$

où:

- t est la durée exigée à déterminer si la tension V $U_{\text{crête}}$ est connue (ou t est connu et il est nécessaire de déterminer V)
- t_1 est la durée adjacente à t correspondant à la tension V_1 $U_{\text{crête}}$
- t_2 est la durée adjacente à t correspondant à la tension V_2 $U_{\text{crête}}$
- V est la valeur de tension $U_{\text{crête}}$ connue si la durée t doit être déterminée (ou V doit être déterminé si la durée t est connue)
- V_1 est la valeur de la tension $U_{\text{crête}}$ adjacente à V correspondant à la durée t_1
- V_2 est la valeur de la tension $U_{\text{crête}}$ adjacente à V correspondant à la durée t_2

Tableau 7 Limites de courant pour les impulsions uniques

Source: IEC TS 60479-1:2005

Justificatif: Pour ES1, il convient que la limite de l'impulsion unique ne dépasse pas les limites de tension stables ES1 pour les **tensions en courant continu**.

Pour ES2, les limites de tension ont été calculées en utilisant les valeurs de courant continu de la courbe b (Figure 9 du présent document) et les valeurs de résistance du Tableau 10 de l'IEC TS 60479-1:2005, colonne "5 % de la population" (voir le Tableau 5 du présent document).

Les limites de courant des impulsions uniques du Tableau 7 pour les niveaux ES1 sont issues de la courbe a, et celles pour les niveaux ES2 sont issues de la courbe b de la Figure 9 du présent document.

Le tableau permet une interpolation linéaire, car la différence est considérée comme étant très faible. Toutefois, la formule suivante peut être utilisée pour une interpolation plus précise des valeurs log-log établies sur ce tableau. La variable t ou I est la "valeur intermédiaire" inconnue souhaitée et peut être déterminée lorsque l'un des éléments suivants est connu:

$$I = \text{Antilog} \frac{\log I_2 + \log I_1 \times \frac{\log t_2 - \log t}{\log t - \log t_1}}{1 + \frac{\log t_2 - \log t}{\log t - \log t_1}}$$

et

$$t = \text{Antilog} \frac{\log t_2 + \log t_1 \times \frac{\log I_2 - \log I}{\log I - \log I_1}}{1 + \frac{\log I_2 - \log I}{\log I - \log I_1}}$$

où:

t est la durée exigée à déterminer si le courant électrique I est connu (ou t est connu et il est nécessaire de déterminer I)

t_1 est la durée adjacente à t correspondant au courant électrique I_1

t_2 est la durée adjacente à t correspondant au courant électrique I_2

I est la valeur du courant $I_{\text{crête}}$ connue si la durée t doit être déterminée (ou I doit être déterminée si la durée t est connue)

I_1 est la valeur de $I_{\text{crête}}$ adjacente à I correspondant à la durée t_1

I_2 est la valeur de $I_{\text{crête}}$ adjacente à I correspondant à la durée t_2

Tableau 5 – Résistance totale du corps humain R_T pour un trajet du courant main à main en courant continu, pour des surfaces de contact importantes dans des conditions sèches

Touch voltage V	Values for the total body resistance R_T (Ω) that are not exceeded for		
	5 % of the population	50 % of the population	95 % of the population
25	2 100	3 875	7 275
50	1 600	2 900	5 325
75	1 275	2 275	4 100
100	1 100	1 900	3 350
125	975	1 675	2 875
150	875	1 475	2 475
175	825	1 350	2 225
200	800	1 275	2 050
225	775	1 225	1 900
400	700	950	1 275
500	625	850	1 150
700	575	775	1 050
1 000	575	775	1 050
Asymptotic value	575	775	1 050
NOTE 1 Some measurements indicate that the total body resistance R_T for the current path hand to foot is somewhat lower than for a current path hand to hand (10 % to 30 %). NOTE 2 For living persons the values of R_T correspond to a duration of current flow of about 0,1 s. For longer durations R_T values may decrease (about 10 % to 20 %) and after complete rupture of the skin R_T approaches the initial body resistance R_0. NOTE 3 Values of R_T are rounded to 25 Ω.			

Anglais	Français
Touch voltage	Tension de contact
Values for the total body resistance $R_T(\Omega)$ that are not exceeded for	Valeurs de la résistance totale du corps humain $R_T(\Omega)$ qui ne sont pas dépassées pour
5% of the population	5 % de la population
50% of the population	50 % de la population
95% of the population	95 % de la population
Asymptotic value	Valeur asymptotique
Some measurements indicate that the total body resistance R_T for the current path hand to foot is somewhat lower than for a current path hand to hand (10 % to 30 %)	Certains mesurages indiquent que la résistance totale du corps humain R_T pour un chemin du courant main à pied est parfois inférieur à un chemin du courant main à main (10 % à 30 %)
For living persons the values of R_T correspond to a duration of current flow of about 0,1 s.	Pour les personnes physiques, les valeurs de R_T correspondent à une durée de circulation du courant d'environ 0,1 s
For longer durations R_T values may decrease (about 10 % to 20 %) and after complete rupture of the skin R_T approaches the initial body resistance R_O	Pour des durées plus longues, les valeurs de R_T peuvent diminuer (environ 10 % à 20 %) et après rupture complète de la peau, R_T approche la résistance initiale du corps humain R_O
Values of R_T are rounded to 25 Ω	Les valeurs de R_T sont arrondies à 25 Ω

5.2.2.6 Signaux de sonnerie

Source: EN 41003

Objet: Établir les limites des signaux de sonnerie de réseau téléphonique analogique.

Justificatif: Pour les informations détaillées, voir le justificatif pour l'Annexe H. Si la source d'énergie est un signal de sonnerie de réseau téléphonique analogique tel que défini à l'Annexe H, la classe de source d'énergie retenue est ES2 (conformément à l'IEC 60950-1:2005, Annexe M).

5.2.2.7 Signaux audio

Source: IEC 60065:2014

Objet: Établir les limites des tensions de contact pour les signaux audio.

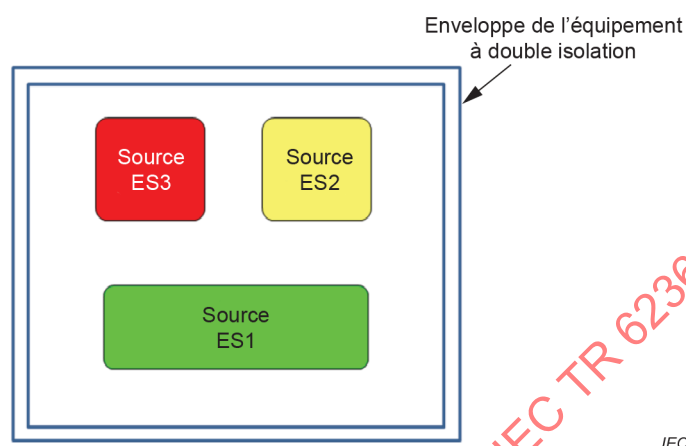
Justificatif: Les limites proposées pour les tensions de contact au niveau des bornes impliquant des signaux audio et qui peuvent être touchées par des personnes ont été extraites sans s'écarter de l'IEC 60065. Référence: IEC 60065:2014, 9.1.1.2 a). Dans les **conditions de premier défaut**, 10.2 de l'IEC 60065:2014 ne permet pas d'augmenter les limites de tension de contact acceptables.

Les limites proposées sont plus importantes d'un point de vue quantitatif que les limites acceptées du Tableau 5 et du Tableau 6, mais elles ne sont pas considérées comme dangereuses pour les raisons suivantes:

- la sortie est mesurée charge déconnectée (charge la plus défavorable);
- il est très difficile de définir la zone de contact des connecteurs et du câblage en raison de leurs formes complexes. La zone de contact est considérée comme réduite en raison de la construction des connecteurs;
- en principe, il est recommandé à l'utilisateur, dans le manuel d'instructions qui accompagne l'équipement, de procéder à toutes les connexions avec l'équipement hors tension.

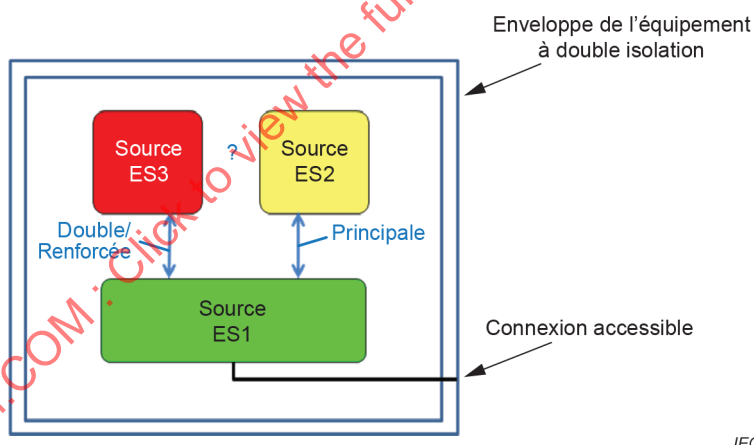
- outre le fait d'être sous tension, l'équipement doit lire un certain programme à une sortie élevée avec la charge déconnectée, afin d'obtenir les limites proposées (très improbable, mais possible). Historiquement, aucun cas de blessure n'a été recensé pour les amplificateurs à sortie non écrêtée inférieure à 71 V en valeur efficace;
- le National Electrical Code (USA) autorise les bornes **accessibles** avec une tension de sortie maximale de 120 V en valeur efficace.

5.3.2 Accessibilité des sources d'énergie électrique et des protections



Quelles sont les exigences entre les sources non **accessibles**?

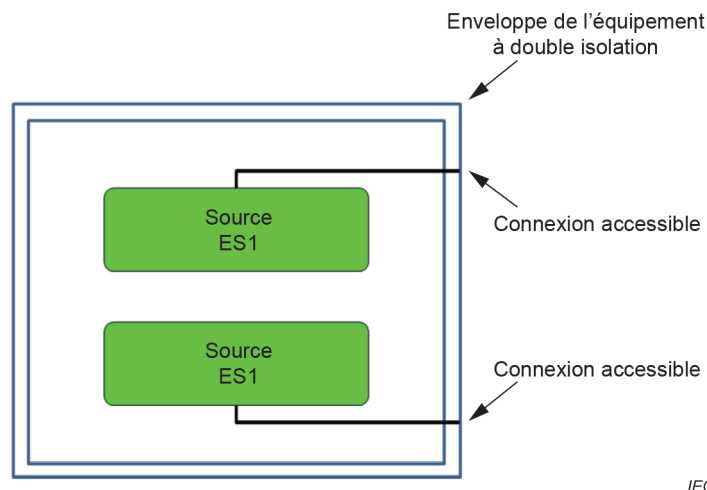
Réponse: Aucune. L'**enveloppe** étant à double isolation, les sources ne sont pas **accessibles**.



À présent, il existe une connexion **accessible**. Quelles sont les exigences entre les sources dans ce cas?

Réponse:

- **isolation principale** entre ES1 et ES2
- **Double isolation** ou **isolation renforcée** entre ES1 et ES3
- L'isolation entre ES2 et ES3 dépend de l'isolation entre ES1 et ES2



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À présent, il existe deux connexions **accessibles** à partir de sources indépendantes. Quelles sont les exigences entre les sources dans ce cas?

Réponse:

- Selon l'Article B.4, il est nécessaire de court-circuiter l'isolement ou l'un des composants entre les sources
- Si l'une des deux sources ES1 atteint la ⇒ **protection principale** des niveaux ES2
- Si les sources ES1 restent dans les limites d'ES1, ⇒ aucune **protection (isolation fonctionnelle)**

Pour les **équipements en extérieur**, des limites de tension inférieures s'appliquent, car l'impédance du corps est réduite à la moitié de la valeur dans les conditions humides (voir l'IEC TS 60479--1 et l'IEC TS 61201).

Si un **équipement de classe III** est acceptable dans une application en intérieur, ladite application n'introduit pas d'autres exigences de **protection**.

5.3.2.2 Exigences en matière de contact

Source: IEC 61140:2001, 8.1.1

Objet: Détermination des parties **accessibles** aux adultes et aux enfants. Les essais sont présentés à l'Annexe V de l'IEC 62368-1:2018.

Justificatif: Aucune rupture dans l'air ne se produit au-dessous d'une tension de 323 V crête ou continue conformément à la loi de Paschen (au niveau de la mer). L'IEC 62368-1:2018 utilise une tension de crête de 420 V (300 V en valeur efficace) pour ajouter une marge de sécurité supplémentaire.

5.3.2.3 Critères de conformité

La raison qui justifie d'accepter différentes exigences pour les composants est que le fournisseur ne peut pas fabriquer différents composants pour chaque application finale.

5.3.2.4 Bornes utilisées pour connecter un fil dénudé

Source: IEC 60065

Objet: Empêcher le contact avec les parties ES2 ou ES3.

Justificatif: Constructions acceptées utilisées dans le secteur audio/vidéo depuis de nombreuses années.

5.4 Matériaux d'isolation et exigences

Justificatif: Les exigences, méthodes d'essai et critères de conformité sont tirés des véritables résultats obtenus par le comité d'études 108 de l'IEC MT2 (anciennement WG6 ou GT6) et du comité d'études 108 de l'IEC MT1.

- Le choix et l'application des composants doivent prendre en compte la nécessité de résistance électrique, thermique et mécanique, la fréquence de la **tension de service** et l'environnement de travail (température, pression, humidité et pollution).
- Les composants doivent présenter une résistance électrique, une résistance thermique, une résistance mécanique, des dimensions et d'autres propriétés conformes aux spécifications du document.
- Les exigences diffèrent en fonction du niveau de **protection (protection principale, protection supplémentaire, protection renforcée)**.
- Les composants conformes à leur document respectif (IEC 60384-14 pour les capacités, par exemple) doivent être vérifiés pour leur application.
- Les composants figurant dans le présent paragraphe du nouveau document ont une fonction de séparation.

5.4.1.1 Isolation

Source: IEC 60664-1

Objet: Assurer une **protection** fiable

Justificatif: Des **isolation principale, isolation supplémentaire et isolation renforcée** solides doivent être en mesure de résister durablement aux contraintes électrique, mécanique, thermique et environnementale qui peuvent se produire pendant la durée de vie anticipée de l'équipement.

Les **distances dans l'air** et les **lignes de fuite** peuvent être divisées en parties conductrices non connectées (flottantes) intercalées, comme les contacts non utilisés d'un connecteur, à condition que la somme des distances individuelles satisfasse aux exigences minimales spécifiées (voir la Figure O.4).

5.4.1.4 Températures de fonctionnement maximales pour les matériaux, composants et systèmes

Source: IEC 60085, IEC 60364-4-43, ISO 306, IEC 60695-10-2

Justificatif: Limites de température données au Tableau 9:

- les limites des matériaux isolants incluant les systèmes d'isolation électrique, y compris l'isolation d'enroulement (Classes A, E, B, F, H, N, R et 250), sont prises de l'IEC 60085;
- les limites pour l'isolation du câblage interne et externe, y compris les cordons d'alimentation avec marquage de la température, sont celles indiquées par le marquage ou les caractéristiques assignées fixées par le fabricant (du composant);
- les limites pour l'isolation du câblage interne et externe, y compris les cordons d'alimentation sans marquage de la température de 70 °C sont citées en référence dans l'IEC 60364-4-3 pour la température ambiante de 25 °C;

- les limites pour l'isolation thermoplastique reposent sur:
 - les données obtenues dans le cadre de l'essai B50 Vicat de l'ISO 306;
 - l'essai à la bille conformément à l'IEC 60695-10-2;
 - si l'examen des caractéristiques physiques du matériau indique clairement qu'il satisfait aux exigences de l'essai à la bille;
 - l'expérience acquise avec une valeur de 125 °C pour les parties d'un circuit alimentées par le **réseau d'alimentation**.

5.4.1.4.3 Critères de conformité

Tableau 9 Limites de températures pour les matériaux, composants et systèmes

Justificatif	Concernant la condition "a", le comité d'études a considéré pendant de nombreuses années que le gradient thermique entre la surface externe et les enroulements internes serait limité à un différentiel de 10 °C en moyenne. Par conséquent, les limites de température pour l'isolation de la surface externe mesurées à l'aide d'un thermocouple sont 10 °C inférieures aux valeurs obtenues dans le cadre d'un mesurage similaire réalisé avec un thermocouple intégré dans le ou les enroulements, ces limites étant au moins 5 °C inférieures à la température au point chaud admise par l'IEC 60085 en tant que facteur de sécurité supplémentaire. Toutefois, certaines constructions modernes de transformateur présentant d'importantes densités de puissance peuvent avoir des gradients thermiques plus importants, et certains mesurages thermiques de l'isolation de transformateur de surface extérieure dans l'équipement/le système peuvent être influencés par le refroidissement forcé ou des effets similaires. Par conséquent, si l'imagerie thermique, la modélisation informatique ou un mesurage réel indique un gradient thermique supérieur à une moyenne de 10 °C entre la température de surface du transformateur et le ou les enroulements du transformateur, il convient d'utiliser la méthode de mesure de l'élévation de la température de résistance et les limites d'un thermocouple intégré (température maximale de 100 °C pour la classe 105 (A), par exemple) pour déterminer la conformité d'un transformateur au Tableau 9, les hypothèses de départ n'étant plus vraies. Par exemple, un matériau assigné à 124 °C utilisant la méthode d'élévation de la température de résistance est considéré comme adapté pour les classes dont la température est inférieure (classe E et classe A) et pas pour les classes dont la température est supérieure (classe B, classe F, classe H, classe N, classe R et classe 250).

5.4.1.5 Degrés de pollution

Source:	IEC 60664-1
Justificatif:	Aucune valeur correspondant au degré de pollution 4 (la pollution génère une conductivité permanente) n'est incluse, car il est peu probable que ce type de conditions soit présent si les produits sont utilisés dans le cadre du domaine d'application du document.

5.4.1.5.2 Essai pour l'environnement de degré de pollution 1 et pour un composé isolant

Le contrôle de conformité réalisé par examen visuel s'applique aux cartes à une seule couche et à plusieurs couches sans la nécessité d'un découpage pour contrôler les vides, les espaces, etc.

5.4.1.6 Isolation dans les transformateurs à dimensions variables

- Source: IEC 60950-1
- Objet: Tenir compte de la **tension de service** réelle le long de l'enroulement d'un transformateur.
- Justificatif: Description d'une méthode de détermination de la pertinence de l'**isolation solide** sur toute la longueur de l'enroulement d'un transformateur.

5.4.1.7 Isolation dans les circuits générant des impulsions de démarrage

- Source: IEC 60950-1, IEC 60664-1
- Objet: Éviter la rupture de l'isolation due aux impulsions de démarrage.
- Justificatif: Cette méthode a été utilisée avec succès pendant de nombreuses années pour les produits relevant du domaine d'application du présent document.

5.4.1.8 Détermination de la tension de service

- Source: IEC 60664-1:2007, 3.5; IEC 60950-1
- Justificatif: La **tension de service** n'inclut pas les signaux de courte durée (les transitoires, par exemple). Les tensions de crête récurrentes ne sont pas incluses. Les surtensions transitoires sont couvertes dans la **tension de tenue requise**. Les signaux de sonnerie ne transportent pas de transitoires externes.

5.4.1.8.1 Généralités

- Justificatif: L'**isolation fonctionnelle** n'est pas traitée à l'Article 5, car elle n'assure pas la protection contre les chocs électriques. Les exigences relatives à l'**isolation fonctionnelle** sont couvertes par l'Article 6, qui porte sur la protection contre les incendies d'origine électrique.
- Source: IEC 60664-1:2007, 3.8
- Justificatif: Dans l'IEC 62368-1, "Circuit alimenté par le **réseau d'alimentation**" est utilisé pour un "circuit primaire". "Circuit isolé du **réseau d'alimentation**" est utilisé pour un "circuit secondaire".
- "**Circuit externe**" est défini comme **extérieur** à l'équipement. ES1 peut être extérieur à l'équipement.
- Pour un **circuit externe** fonctionnant au niveau d'ES2 et ne quittant pas le bâtiment, le transitoire est de 0 V. Dans ce cas, il est donc nécessaire de prendre en compte la tension de crête de sonnerie.

5.4.1.8.2 Tension de service efficace

- Source: IEC 60664-1:2007, 3.5
- Justificatif: La **tension de service** efficace est utilisée lors de la détermination de la **ligne de fuite** minimale. Sauf spécification contraire, la tension de service est la valeur efficace.

5.4.1.10 Parties thermoplastiques sur lesquelles les parties métalliques conductrices sont montées directement

- Source: ISO 306 et série IEC 60695-2
- Justificatif: La température des parties thermoplastiques dans les **conditions normales de fonctionnement** doit être 15 K inférieure à la température de ramollissement d'une partie non métallique. La température des parties de support dans un circuit alimenté par le **réseau d'alimentation** ne doit pas être inférieure à 125 °C.

5.4.2 Distances dans l'air

5.4.2.1 Exigences générales

Source: IEC 60664-1:2007

Justificatif: La dimension d'une **distance dans l'air** est déterminée à partir de la tension de tenue aux chocs exigée pour cette **distance dans l'air**. Ce concept est issu de l'IEC 60664-1:2007, 5.1. De plus, les **distances dans l'air** sont affectées par le plus grand des transitoires déterminés. La probabilité d'occurrence simultanée de transitoires est très faible et n'est pas prise en compte.

Les surtensions et transitoires qui peuvent entrer dans l'équipement, et les tensions de crête qui peuvent être générées à l'intérieur de l'équipement, n'interrompent pas la **distance dans l'air** (voir l'IEC 60664-1:2007, 5.1.5 et 5.1.6).

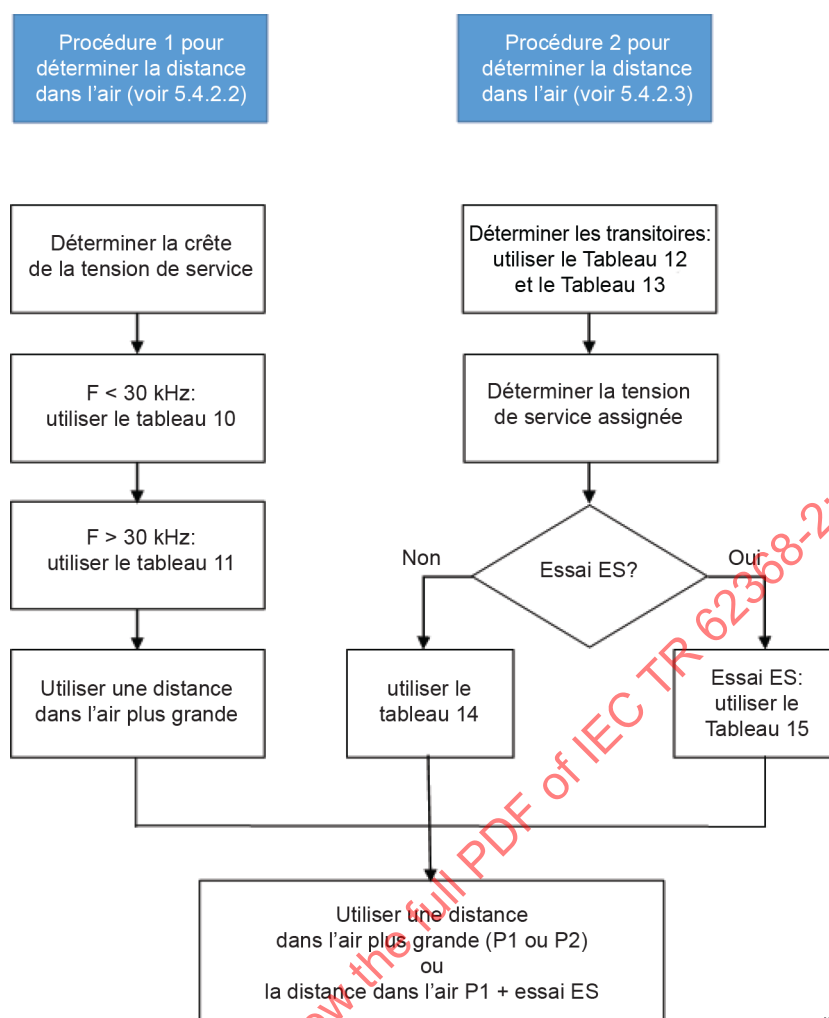
Les **distances dans l'air** minimales des composants de sécurité doivent satisfaire aux exigences de leur document de sécurité de composant applicable.

Les **distances dans l'air** entre la surface isolante extérieure d'un connecteur et les parties conductrices au niveau de tension ES3 doivent satisfaire aux exigences de l'**isolation principale** uniquement, si les connecteurs sont fixés à l'équipement, situés à l'intérieur de l'**enveloppe électrique** extérieure de l'équipement et **accessibles** uniquement après avoir déposé un sous-assemblage qui doit être en place pendant le fonctionnement normal.

Par hypothèse, la probabilité d'occurrence de deux facteurs (le dépôt du sous-assemblage et l'occurrence d'une surtension transitoire) est limitée et le danger est potentiel.

Source: série IEC 60664-2, *Guide d'application*

Justificatif: La méthode est déduite de la série IEC 60664-2, *Guide d'application*.



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Exemple:

Hypothèse:

- une alimentation électrique SMPS,
- connexion au **réseau d'alimentation** en courant alternatif,
- une crête de la tension de service (PWV) de 800 V,
- des fréquences au-dessus et au-dessous de 30 kHz,
- des **distances dans l'air** exigées,
- **surtensions temporaires**: 2 000 V

Procédure 1:

Le Tableau 10 exige 2,54 mm

Le Tableau 11 exige 0,44 mm

Le résultat est 2,54 mm

NOTE Toutes les crêtes de tension de service inférieures à 1 200 V font l'objet d'une exigence de **distance dans l'air** inférieure à 3 mm pour le Tableau 10 et le Tableau 11

Résultat final:

- 3,0 mm ou
- essai ES à 4,67 KV et 2,54 mm

Procédure 2:

Transitoires (OVC 2): 2 500 V

RWV = 2 500 V

Le Tableau 14 exige 3,0 mm

La tension d'essai ES exigée selon le Tableau 15 est de 4,67 KV

Le résultat est de 3,0 mm ou essai ES à 4,67 KV

ATTENTION:

Pour un produit avec une connexion au câble coaxial, différentes valeurs doivent être utilisées étant donné qu'un transitoire et une **tension de tenue requise** différents sont exigés.

5.4.2.2 Procédure 1 pour déterminer la distance dans l'air

Justificatif: Concernant le premier tiret de 5.4.2.2, il est indiqué qu'une cause de la détermination de la valeur de crête des tensions stables qui sont inférieures à la tension de crête du **réseau d'alimentation** inclut, par exemple, une détermination conforme aux deuxième et troisième tirets de 5.4.2.3.3 dans laquelle le filtrage est en place pour diminuer les tensions de crête prévues.

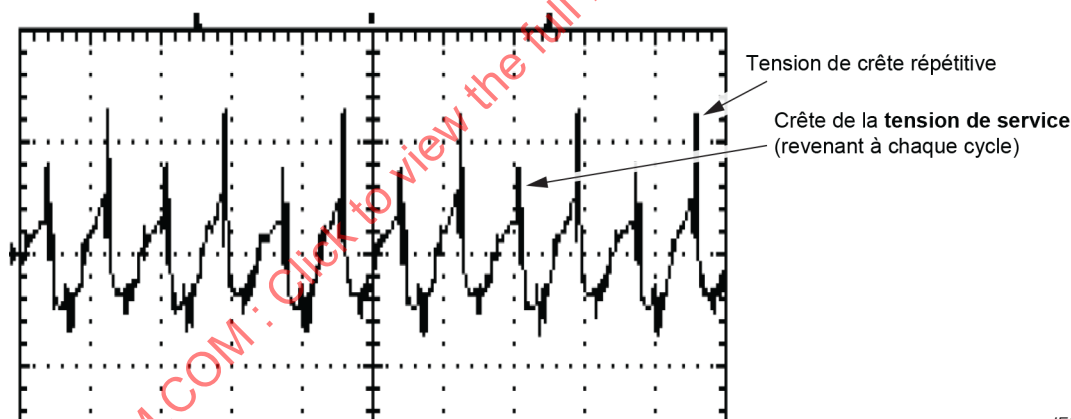
De la même manière, concernant le second tiret de 5.4.2.2, un exemple de cas dans lequel la tension de crête récurrente est limitée à 1,1 fois la tension du **réseau d'alimentation** peut consister à utiliser certaines formes de dispositifs de protection contre les surtensions qui réduisent la catégorie de surtension.

Crête de la tension de service par rapport à la tension de crête répétitive.

Les deux termes font l'objet de discussions. La crête de la **tension de service** est la valeur de crête de la forme d'onde qui se produit à chaque cycle, et qui est donc considérée comme partie intégrante de la **tension de service**.

Une tension de crête récurrente est une crête qui ne se produit pas à chaque cycle de la forme d'onde, mais qui se reproduit selon un certain intervalle, en général à une fréquence inférieure à la fréquence de forme d'onde.

La Figure 11 du présent document donne un exemple de forme d'onde dans laquelle la tension de crête récurrente se produit tous les deux cycles de la forme d'onde principale.



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Figure 11 – Présentation de la tension de service

Tableau 10 Distances dans l'air minimales pour des tensions avec des fréquences jusqu'à 30 kHz

Justificatif: Le comité d'études 108 de l'IEC a noté que, si les règles de l'IEC 60664-1 sont respectées, pour les valeurs de **distance dans l'air** renforcée, certaines valeurs étaient plus de deux fois supérieures aux exigences de l'**isolation principale**. Ce même comité a pensé qu'il convenait que ce ne soit pas le cas et a décidé de limiter l'exigence relative à l'**isolation renforcée** à deux fois la valeur de l'**isolation principale**, s'écartant donc de l'IEC 60664-1.

De plus, les règles normales d'arrondi ont été appliquées aux valeurs du tableau.

5.4.2.3.2.2 Détermination des tensions transitoires du réseau d'alimentation en courant alternatif

Source: IEC 60664-1:2007, 4.3.3.3

Justificatif: Le Tableau 12 est déduit du Tableau F.1 de l'IEC 60664-1:2007.

Le terme utilisé dans l'IEC 60664-1 est "tension assignée de tenue aux chocs". Les produits couverts par l'IEC 62368-1 sont également exposés aux transitoires provenant des **circuits externes**, un autre terme étant donc nécessaire pour indiquer la source différente.

L'**équipement en extérieur** qui fait partie intégrante de l'installation du bâtiment ou dont les surtensions transitoires peuvent dépasser celles de la catégorie de surtension II, doit être conçu pour la catégorie de surtension III ou la catégorie de surtension IV, sauf si une protection additionnelle doit être prévue à l'intérieur ou l'extérieur de l'équipement. Dans ce cas, les instructions d'installation doivent indiquer la nécessité de ce type de protection additionnelle.

5.4.2.3.2.3 Détermination des tensions transitoires du réseau d'alimentation en courant continu

Justificatif: Les surtensions transitoires sont atténuées par le filtrage capacitif.

5.4.2.3.2.4 Détermination des tensions transitoires du circuit externe

Source: UIT-T K.21

Justificatif: Les transitoires ont un impact sur les circuits et l'isolation. Par conséquent, il est nécessaire de tenir compte des transitoires sur les **circuits externes**. Les transitoires sont nécessaires uniquement pour le dimensionnement des **protections**. Il convient de ne pas utiliser les transitoires pour classer les sources d'énergie (ES1, ES2, etc.).

Les **circuits externes** sont réputés recevoir une tension transitoire de 1,5 kV de crête avec une forme d'onde de 10/700 μ s à partir de sources à l'extérieur du bâtiment.

Le transitoire prévu est indépendant de l'application (télécom, réseau local ou autre). Par conséquent, par hypothèse, le même transitoire apparaît pour tous les types d'applications. La valeur de 1,5 kV 10/700 μ s est issue de l'UIT-T K.21.

Les **circuits externes** utilisant un câble coaxial mis à la terre sont réputés ne recevoir aucun transitoire qui doit être pris en compte à partir des sources extérieures au bâtiment.

En raison du blindage mis à la terre du câble coaxial, un éventuel transitoire sur le câble extérieur est réduit au niveau du blindage mis à la terre à l'entrée du câble dans le bâtiment.

Aucun transitoire ne doit être pris en compte pour les **circuits externes** à l'intérieur du même bâtiment.

Les transitoires d'une interface sont définis en fonction des bornes dans lesquelles la tension est définie. Dans la plupart des cas, les tensions pertinentes sont communes (U_c) et les tensions en mode différentiel (U_d) au niveau de l'interface. Pour les parties **tenues à la main** ou d'autres parties en contact fréquent avec le corps humain (un combiné téléphonique, par exemple), la tension par rapport à la terre locale (U_{ce}) peut être pertinente. La Figure 12 du présent document représente la définition de différentes tensions pour une interface de conducteur à paires.

Les transitoires des interfaces de câble coaxial sont compris entre le conducteur central et le blindage (U_d) du câble si le blindage est mis à la terre au niveau de l'équipement. Si le blindage est isolé de la terre au niveau de l'équipement, la tension blindage à la terre (U_s) est alors importante. La mise à la terre du blindage peut consister à relier le blindage à la **mise à la terre pour des raisons de protection**, à la terre fonctionnelle à l'intérieur ou immédiatement à l'extérieur de l'équipement. Toutes les terres sont par hypothèse reliées ensemble. La Figure 13 du présent document représente la définition de différentes tensions pour des interfaces de câble coaxial.

Un aperçu des exigences d'isolation est donné au Tableau 6 du présent document.

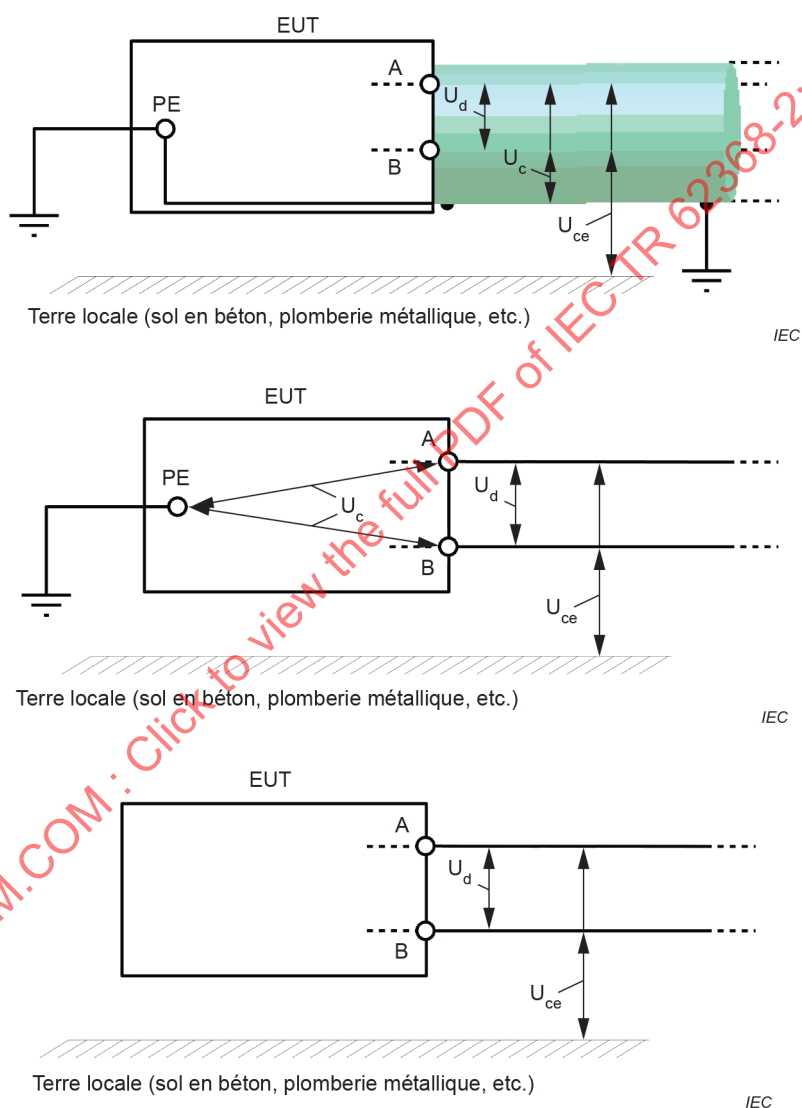


Figure 12 – Présentation des tensions transitoires sur les circuits externes de conducteur à paires

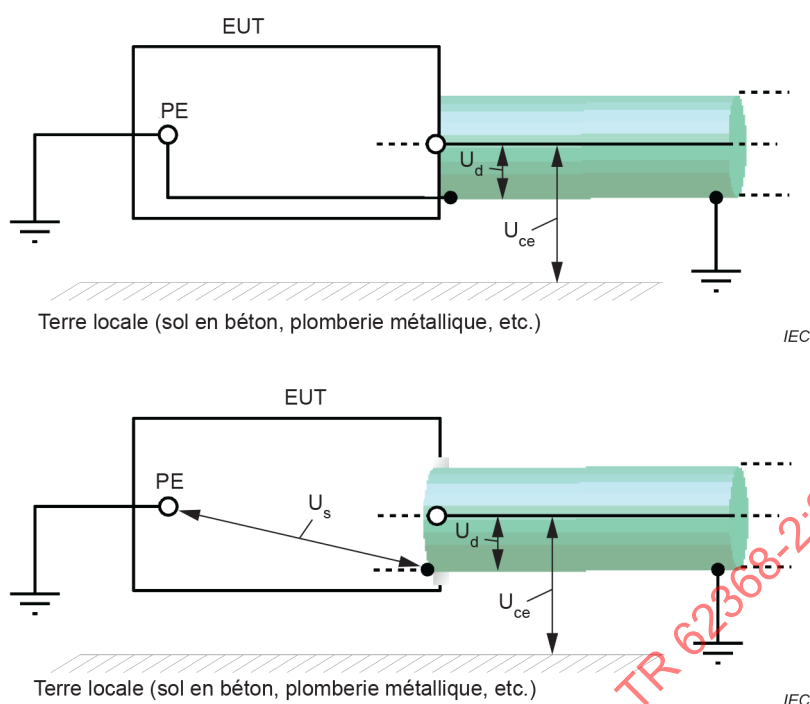


Figure 13 – Présentation des tensions transitoires sur les circuits externes de câble coaxial

Tableau 6 – Exigences d'isolation pour les circuits externes

Circuit externe à l'étude	Isolation	Exigence
ES1 mis à la terre	Aucune	Aucune
ES1 non mis à la terre	Séparation (vers les parties métalliques flottantes et autres circuits ES1 flottants)	Essai de rigidité diélectrique (à l'aide du Tableau 15) entre ES1 non mis à la terre et un autre ES1 et des parties flottantes non mis à la terre
ES2	Isolation principale (ES1 et parties métalliques)	Distances dans l'air; ligne de fuite; et isolation solide et par essai de rigidité diélectrique (à l'aide du Tableau 15) entre ES2 et ES1 et les parties métalliques
ES3	Double isolation ou isolation renforcée (ES1, ES2 et les parties métalliques)	Exigences de distances dans l'air; de ligne de fuite; et d'isolation solide incluant l'essai de rigidité diélectrique (à l'aide du Tableau 15)

Tableau 13 Tensions transitoires de circuit externe

Justificatif: Lorsque le système de distribution d'alimentation en courant continu se trouve à l'extérieur du bâtiment, des surtensions transitoires peuvent être prévues. Les transitoires ne sont pas présents si le système d'alimentation en courant continu est relié à la **mise à la terre pour des raisons de protection** et se trouve entièrement à l'intérieur d'un bâtiment.

5.4.2.3.2.5 Détermination des niveaux de tension transitoire par mesurage

Source: La méthode d'essai est issue de l'IEC 60950-1:2013, Annexe G.

5.4.2.3.4 Détermination des distances dans l'air avec la tension de tenue requise

Source: IEC 60664-1:2007, Tableau F.2, Cas A (champ hétérogène) et Cas B (champ homogène)

Justificatif: Les valeurs du Tableau 14 sont issues de l'IEC 60664-1:2007, Tableau F.2 Cas A (champ hétérogène) et Cas B (champ homogène) et incluent les valeurs explicites d'**isolation renforcée**. Les **distances dans l'air** pour l'**isolation renforcée** ont été calculées selon 5.1.6 de l'IEC 60664-1:2007. Pour l'**isolation renforcée**, 5.1.6 indique que la **distance dans l'air** doit correspondre à la tension assignée de tenue aux chocs, laquelle est immédiatement supérieure pour les tensions dans la série préférentielle. Pour les tensions qui ne sont pas dans la série préférentielle, il convient que la **distance dans l'air** repose sur 160 % de la **tension de tenue requise** pour l'**isolation principale**.

Lors de la détermination de la **tension de tenue requise**, il convient d'admettre une interpolation lorsque les tensions de crête répétitives internes sont supérieures aux tensions de crête du **réseau d'alimentation** ou si la **tension de tenue requise** est supérieure aux valeurs de tension transitoire du **réseau d'alimentation**.

Aucune valeur correspondant au degré de pollution 4 (la pollution génère une conductivité permanente) n'est incluse, car il est peu probable que ce type de conditions soit présent lorsque les produits sont utilisés dans le cadre du domaine d'application du document.

Tableau 14 Distances dans l'air minimales avec la tension de tenue requise

Justificatif: L'IEC 62368-1 suit les règles et exigences des publications fondamentales de sécurité de l'IEC, dont l'une est la série IEC 60664. L'IEC 60664-1 spécifie les **distances dans l'air** pour l'**isolation principale** et l'**isolation supplémentaire**. Les **distances dans l'air** pour l'**isolation renforcée** ne sont pas spécifiées. 5.1.6 spécifie plutôt les règles de détermination des **distances dans l'air** renforcées.

La pente des **distances dans l'air** renforcées du Tableau 14 est très variable et inclut une "discontinuité". Les valeurs du Tableau 14 sont indiquées à la Figure 14 du présent document.

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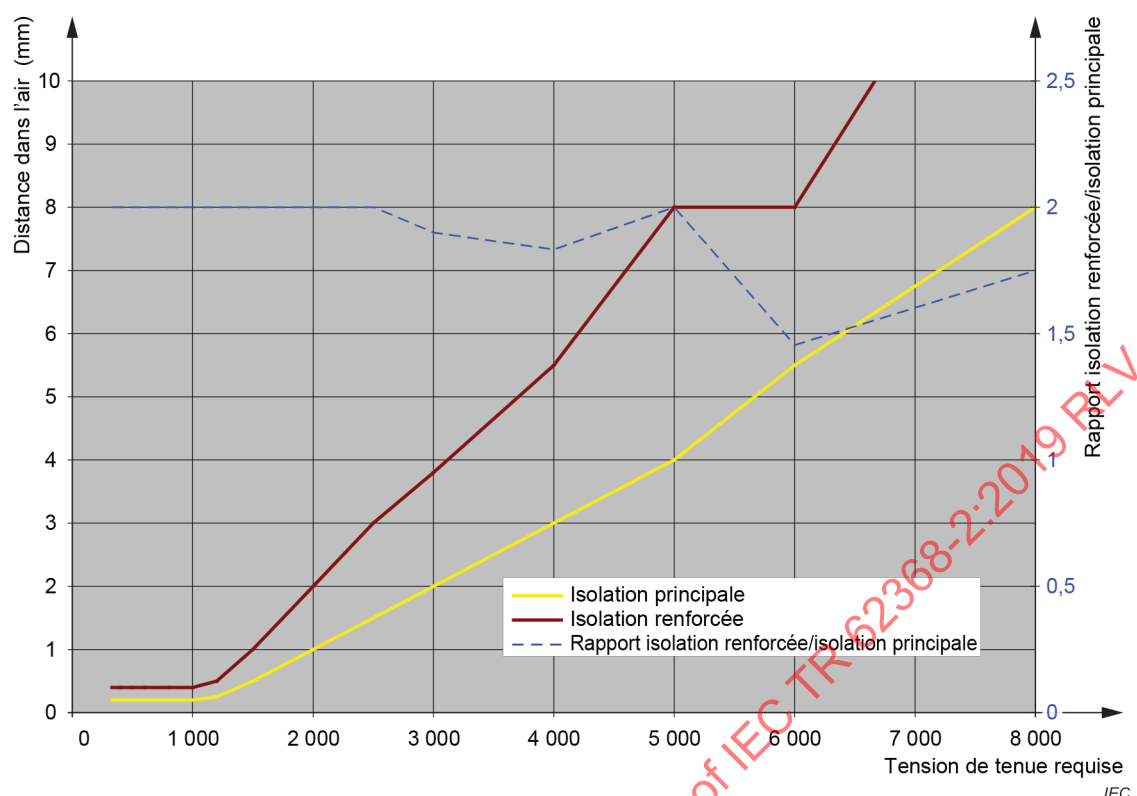


Figure 14 – Isolation principale et isolation renforcée du Tableau 14 de l'IEC 62368-1:2018. Rapport isolation renforcée/isolation principale

La pente de la ligne marron (**distance dans l'air renforcée**) n'est pas constante, comme l'est celle de la ligne jaune (**distance dans l'air principale**). Le rapport isolation renforcée/isolation principale (ligne bleue) varie de 2:1 au maximum à 1,49:1 au minimum. D'un point de vue physique, cela n'est pas raisonnable. Il convient que le rapport soit pratiquement constant.

Dans l'IEC 60664-1:2007, les valeurs de l'**isolation principale** sont données au Tableau F.2. Aucune valeur n'est donnée pour l'**isolation renforcée**. Le Tableau F.2 cite en référence 5.1.6 pour l'**isolation renforcée**.

Règle 1, tensions de tenue aux chocs de la série préférentielle

Le paragraphe 5.1.6 de l'IEC 60664-1:2007 stipule:

“En ce qui concerne les tensions de tenue aux chocs, les **distances dans l'air** de l'**isolation renforcée** doivent être dimensionnées comme spécifié dans le Tableau F.2 correspondant à la tension assignée de tenue aux chocs immédiatement supérieure dans la série préférentielle de 4.2.3 à celle indiquée pour l'**isolation principale**.”

NOTE 1 L'IEC 62368-1 utilise le terme “**tension de tenue requise**” à la place du terme IEC 60664-1 “tension de tenue aux chocs prescrite”

NOTE 2 L'IEC 62368-1 utilise le terme “**tension transitoire du réseau d'alimentation**” à la place du terme IEC 60664-1 “tension assignée de tenue aux chocs”

La série préférentielle de valeurs de tension assignée de tenue aux chocs selon 4.2.3 de l'IEC 60664-1:2007 est la suivante:
330 V, 500 V, 800 V, 1 500 V, 2 500 V, 4 000 V, 6 000 V, 8 000 V, 12 000 V

En appliquant la Règle 1, la **distance dans l'air** renforcée (champ hétérogène, **degré de pollution** 2, Tableau F.2) pour:

- 330 V serait la **distance dans l'air** de l'**isolation principale** pour 500 V: 0,2 mm
- 500 V serait la **distance dans l'air** de l'**isolation principale** pour 800 V: 0,2 mm
- 800 V serait la **distance dans l'air** de l'**isolation principale** pour 1 500 V: 0,5 mm
- 1 500 V serait la **distance dans l'air** de l'**isolation principale** pour 2 500 V: 1,5 mm
- 2 500 V serait la **distance dans l'air** de l'**isolation principale** pour 4 000 V: 3,0 mm
- 4 000 V serait la **distance dans l'air** de l'**isolation principale** pour 6 000 V: 5,5 mm
- 6 000 V serait la **distance dans l'air** de l'**isolation principale** pour 8 000 V: 8,0 mm
- 8 000 V serait la **distance dans l'air** de l'**isolation principale** pour 12 000 V: 14 mm

La valeur 12 000 V est indéterminée, car il n'y a pas de tension préférentielle au-dessus de 12 000 volts.

Règle 2, 160 % de tensions de tenue aux chocs autres que la série préférentielle

Concernant les circuits hors **réseau d'alimentation**, le paragraphe 5.1.6 de l'IEC 60664-1 stipule:

“Si, conformément à 4.3.3.4.2, la tension de tenue aux chocs prescrite pour l'isolation principale diffère d'une valeur de la série préférentielle, l'isolation renforcée doit être dimensionnée pour supporter 160 % de la tension de tenue aux chocs exigée pour l'isolation principale.”

Les tensions de tenue aux chocs autres que la série préférentielle (de l'IEC 60664-1:2007, Tableau F.2) sont les suivantes: 400 V, 600 V, 1 200 V, 2 000 V, 3 000 V, 10 000 V et toutes les tensions supérieures à 12 000 V.

En appliquant la Règle 2, la **distance dans l'air** renforcée (champ hétérogène, **degré de pollution** 2, Tableau F.2) pour:

400 V x 1,6 = 640 V interpolés à 0,20 mm.

La valeur de 640 V ne se trouvant pas dans la liste, l'**isolation renforcée** est déterminée par interpolation. L'interpolation donne la **distance dans l'air** renforcée de 0,2 mm.

En appliquant la Règle 2 aux tensions de tenue aux chocs du Tableau F.2 ne se trouvant pas dans la série préférentielle:

- 400 V x 1,6 = 640 V interpolés à 0,20 mm
- 600 V x 1,6 = 960 V interpolés à 0,24 mm
- 1 200 V x 1,6 = 1 920 V interpolés à 0,92 mm
- 2 000 V x 1,6 = 3 200 V interpolés à 2,2 mm
- 3 000 V x 1,6 = 4 800 V interpolés à 3,8 mm
- 10 000 V x 1,6 = 16 000 V interpolés à 19,4 mm
- 15 000 V à 100 000 V x 1,6 et interpolés selon la règle.

Différences de distance dans l'air pour la Règle 1 et la Règle 2

Les deux règles (la Règle 1 pour les tensions de tenue aux chocs de la série préférentielle et la Règle 2 pour les tensions de tenue aux chocs autres que la série préférentielle) donnent des **distances dans l'air** différentes pour les mêmes tensions. Ces différences se produisent, car la pente, mm/kV, des deux méthodes est légèrement différente. La pente correspondant à la Règle 1 n'est pas constante. La pente correspondant à la Règle 2 est pratiquement constante. La Figure 15 du présent document représente les différences entre la Règle 1, la Règle 2 et le Tableau 14 de l'IEC 62368-1:2018.

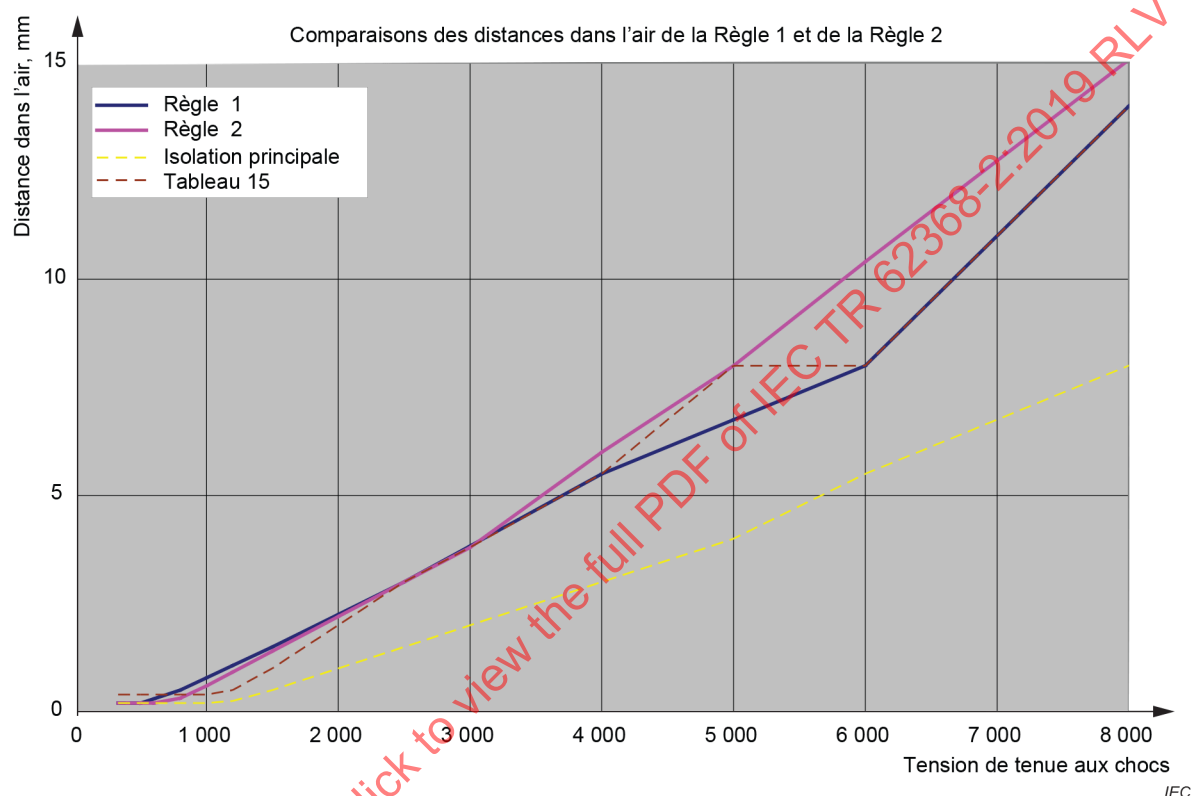


Figure 15 – Distances dans l'air renforcées selon la Règle 1, la Règle 2 et le Tableau 14

Si les deux valeurs pour la Règle 1 et la Règle 2 sont combinées en un ensemble de valeurs, les valeurs sont les mêmes que celles du Tableau 14 (la ligne marron de la Figure 14 et de la Figure 15 du présent document). Conformément au 5.1.6 de l'IEC 60664-1, seules les tensions de tenue aux chocs autres que celles de la série préférentielle sont soumises à la règle des 160 %. Par conséquent, les **distances dans l'air** passent des critères de la Règle 1 à ceux de la Règle 2, puis inversement. Ce processus donne les variations de pente radicales de la ligne (marron) des **distances dans l'air** renforcées du Tableau 14.

D'un point de physique, il convient que les **distances dans l'air** de l'**isolation renforcée** soient une proportion constante des **distances dans l'air** de l'**isolation principale**. Toutefois, la proportion entre les étapes de la Règle 1 (série préférentielle des tensions de tenue aux chocs) est la suivante:

- 330 V à 500 V: 1,52
- 500 V à 800 V: 1,60
- 800 V à 1 500 V: 1,88
- 1 500 V à 2 500 V: 1,67

– 2 500 V à 4 000 V:	1,60
– 4 000 V à 6 000 V:	1,50
– 6 000 V à 8 000 V:	1,33
– 8 000 V à 12 000 V:	1,50
Proportion moyenne, 330 à 12 000:	1,57

Pour la Règle 2, toutes les **distances dans l'air** de l'**isolation renforcée** reposent sur exactement 1,6 fois la tension de tenue aux chocs de la série non préférentielle pour l'**isolation principale**.

Les deux règles appliquées selon 5.1.6 de l'IEC 60664-1:2007 donnent les exigences de pente variable de la **distance dans l'air** pour l'**isolation renforcée** de l'IEC 62368-1.

Le comité d'études 108 de l'IEC a noté que, si les règles de l'IEC 60664-1 sont respectées, pour les valeurs de **distances dans l'air** pour l'**isolation renforcée**, certaines valeurs étaient plus de deux fois supérieures aux exigences de l'**isolation principale**. Le comité d'études 108 de l'IEC a pensé qu'il convenait que ce ne soit pas le cas et a décidé de limiter l'exigence relative à l'**isolation renforcée** à deux fois la valeur de l'**isolation principale**, s'écartant donc de l'IEC 60664-1.

De plus, les règles normales d'arrondi ont été appliquées aux valeurs du tableau.

5.4.2.4 Détermination du caractère approprié d'une distance dans l'air établi d'après l'essai de rigidité diélectrique

Source: IEC 60664-1:2007, Tableau F.5
Objet: Les essais sont effectués à l'aide d'une tension de choc ou d'une tension en courant alternatif avec les valeurs du Tableau 15.

Justificatif: Les tensions d'essai de choc du Tableau 15 sont issues de l'IEC 60664-1:2007, Tableau F.5. Le calcul des valeurs efficaces en courant alternatif et des valeurs en courant continu repose sur les valeurs indiquées au Tableau A.1 de l'IEC 60664-1:2007 (voir le Tableau 7 du présent document pour plus d'explications).

Cet essai n'est pas adapté aux champs homogènes. Il est destiné à une véritable conception comprise dans les limites du champ homogène et du champ hétérogène.

Les calculs de la chute de tension sur une distance pendant l'essai de rigidité diélectrique peuvent être arrondis à 0,1 mm immédiatement supérieur. Si la valeur calculée est supérieure à la valeur de la ligne suivante, la ligne suivante peut être utilisée.

Matériau en email: Le matériau le plus souvent utilisé est la résine de polyester ou le polyester

Constante diélectrique du polyester: 5 (peut varier)

Constante diélectrique de l'air: 1

La formule utilisée pour le calcul (divisions de tension inversement proportionnelles à la constante diélectrique)

Transitoire = 2 500 V = 2 500 (épaisseur de l'email/5 + distance/1) = 2 500 (0,04/5 + 2/1) pour une distance de 2 mm) = 2 500 (0,008 + 2) = (10 V sur l'email + 2 490 V sur la distance)

En fonction de la condition a du Tableau 15, même si U est une **tension de tenue requise** supérieure à 12,0 kV, il existe une exception lors de l'utilisation du Tableau F.5 de l'IEC 60664-1:2007.

Tableau 7 – Chute de tension sur la distance et l'isolation solide en série

Épaisseur de l'émail mm	Distance mm	Transitoire sur un système 240 V	Tension transitoire sur la distance	Tension transitoire à travers l'émail	Tension d'essai de l'impulsion de crête pour un transitoire de crête de 2 500 V issu du Tableau 16	Tension d'essai sur la distance	Tension d'essai à travers l'émail
Matériau: Polyester, constante diélectrique = 5							
0,04	2	2 500	2 490	10	2 950	12	2 938
0,04	1	2 500	2 480	20	2 950	24	2 926
0,04	0,6	2 500	2 467	33	2 950	39	2 911
Pour une impulsion de crête de 2 500 V (transitoire pour système de 230 V), la distance du champ homogène est de 0,6 mm (Tableau A.1 de l'IEC 60664-1:2007). La tension d'essai pour la crête de 2 500 V est la crête de 2 950 V (Tableau 15). Cela signifie qu'il est nécessaire de maintenir une distance minimale de 0,79 mm à travers le champ homogène pour satisfaire à l'essai de choc de 2 950 V. Cela donne une marge de $(0,19/0,6) \times 100 = 3,2 \%$. Dans la pratique, la distance est supérieure étant donné qu'il ne s'agit pas d'un véritable champ homogène. Par conséquent, il est inutile de vérifier la conformité au Tableau 14. Une approche conservatrice est toujours utilisée.							
Matériau: Polyamide, constante diélectrique = 2,5							
0,04	2	2 500	2 480	20	2 950	23	2 927
0,04	1	2 500	2 460	40	2 950	46	2 904
0,04	0,6	2 500	2 435	65	2 950	76	2 874
Pour une impulsion de crête de 2 500 V (transitoire pour système de 230 V), la distance du champ homogène est de 0,6 mm (Tableau A.1 de l'IEC 60664-1:2007). La tension d'essai pour la crête de 2 500 V est la crête de 2 950 V (Tableau 15). Cela signifie qu'il est nécessaire de maintenir une distance minimale de 0,78 mm à travers le champ homogène pour satisfaire à l'essai de choc de 2 950 V. Cela donne une marge de $(0,18/0,6) \times 100 = 3,0 \%$. Dans la pratique, la distance est supérieure étant donné qu'il ne s'agit pas d'un véritable champ homogène. Par conséquent, il est inutile de vérifier la conformité au Tableau 14. Une approche conservatrice est toujours utilisée.							

5.4.2.5 Facteurs de multiplication pour des altitudes supérieures à 2 000 m au-dessus du niveau de la mer

Source: IEC 60664-1:2007, courbe numéro 2 pour le cas A utilisant l'essai de choc.

Objet: L'essai est effectué à l'aide d'une tension de choc ou d'une tension en courant alternatif avec les valeurs du Tableau 16 et les facteurs de multiplication pour des altitudes supérieures à 2 000 m.

Justificatif: Le Tableau 16 est développé à l'aide de la Figure A.1 de l'IEC 60664-1:2007, courbe numéro 2 du cas A dans le cadre de l'essai de choc.

5.4.2.6 Critères de conformité

Source: IEC 60664-1:2007, 5.1.1

Justificatif: IEC 62368-1:2018, les chiffres de l'Annexe O sont similaires/identiques à ceux de l'IEC 60664-1:2007

Les essais de l'IEC 62368-1:2018, Annexe T, simulent l'occurrence de forces mécaniques:

- 10 N appliqués aux composants et parties qui peuvent être touchés pendant le fonctionnement ou l'entretien. Simule le contact accidentel avec un doigt ou une partie de la main;
- 30 N appliqués aux **enveloppes** intérieures et aux barrières **accessibles** aux **personnes ordinaires**. Simule le contact accidentel avec une partie de la main;
- 100 N appliqués aux **enveloppes** extérieures de l'**équipement transportable** et de l'équipement portable. Simule la force prévue appliquée pendant l'utilisation ou le mouvement;

- 250 N appliqués aux **enveloppes** extérieures (sauf celles couvertes en T.4). Simule la force prévue appliquée par une partie du corps sur la surface de l'équipement. Ces forces ne sont pas réputées être appliquées sur la surface inférieure d'un équipement lourd (> 18 kg).

Pendant les essais de force, les surfaces métalliques ne doivent pas entrer en contact avec des parties sous tension ES2 ou ES3.

5.4.3 Lignes de fuite

Source: IEC 60664-1:2007, 3.3

Objet: Éviter le contournement le long d'une surface ou la rupture de l'isolation.

Justificatif: Préserver l'intégrité de la **protection**.

Dans l'IEC 60664-1:2007, Tableau F.4, la colonne 2 et la colonne 3 pour les circuits imprimés sont supprimées, aucun élément ne justifiant les très petites **lignes de fuite** pour les circuits imprimés dans la colonne 2 et la colonne 3 (le seul justificatif étant qu'il figure dans la publication fondamentale de sécurité, IEC 60664-1).

Toutefois, rien ne justifie que les **lignes de fuite** sont différentes pour les circuits imprimés et d'autres matériaux d'isolation dans la même condition (même DP et même IRC).

De plus, les **lignes de fuite** pour les circuits imprimés de la colonne 2 et de la colonne 3 sont en conflit avec les exigences de G.13.3 (Circuits imprimés avec revêtement). Par conséquent, les valeurs des tensions jusqu'à 455 V du Tableau G.16 ont été remplacées.

Les **lignes de fuite** entre la surface isolante extérieure d'un connecteur et les parties conductrices au niveau de tension ES3 doivent satisfaire aux exigences de l'**isolation principale** uniquement, si les connecteurs sont fixés à l'équipement, situés à l'intérieur de l'**enveloppe électrique** extérieure de l'équipement et **accessibles** uniquement après avoir déposé un sous-assemblage qui doit être en place pendant le fonctionnement normal.

Par hypothèse, la probabilité d'occurrence de deux facteurs (le dépôt du sous-assemblage et l'occurrence d'une surtension transitoire) est limitée et le danger est potentiel.

5.4.3.2 Méthode d'essai

Source: IEC 60664-1:2007, 3.2

Objet: Mesurage de la **ligne de fuite**.

Justificatif: Préserver l'intégrité de la **protection** après les essais mécaniques.

Les chiffres de l'Annexe O sont similaires/identiques à ceux de l'IEC 60950-1 et de l'IEC 60664-1.

Les essais de l'Annexe T, simulent l'occurrence de forces mécaniques:

- 10 N appliqués aux composants et parties susceptibles d'être touchés par une **personne qualifiée** pendant l'entretien, lorsque le déplacement de la partie réduit la **ligne de fuite**. Simule le contact accidentel avec un doigt ou une partie de la main.
- 30 N appliqués aux **enveloppes** intérieures et aux barrières **accessibles** aux **personnes ordinaires**. Simule le contact accidentel avec une partie de la main.
- 100 N appliqués aux **enveloppes** extérieures de l'**équipement transportable** et de l'**équipement portable**. Simule la force prévue appliquée pendant l'utilisation ou le mouvement.

- 250 N appliqués aux **enveloppes** extérieures (sauf celles couvertes en T.4). Simule la force prévue en cas d'appui contre la surface de l'équipement. Ces forces ne sont pas réputées être appliquées sur la surface inférieure d'un équipement lourd (> 18 kg).

Les **lignes de fuite** sont mesurées après les essais de force de l'Annexe T.

5.4.3.3 Groupe de matériaux et IRC

Source: IEC 60112

Justificatif: Classification conforme à l'IEC 60112.

5.4.3.4 Critères de conformité

Source: IEC 60664-1:2007, Tableau F.4; IEC 60664-4 pour les fréquences supérieures à 30 kHz

Justificatif: Les valeurs du Tableau 17 sont identiques à celles du Tableau F.4 de l'IEC 60664-1:2007.

Les valeurs du Tableau 18 sont identiques à celles du Tableau 2 de l'IEC 60664-4:2005 et sont utilisées pour les fréquences jusqu'à 400 kHz.

5.4.4 Isolation solide

Source: IEC 60950-1, IEC 60664-1

Objet: Éviter la rupture de l'**isolation solide**.

Justificatif: Préserver l'intégrité des **protections**.

L'exclusion des revêtements en email à base de solvant pour les isolations de sécurité repose sur l'expérience sur le terrain. Toutefois, avec l'avènement de nouveaux matériaux d'isolation, ces matériaux peuvent être acceptables à l'avenir pour satisfaire aux essais adaptés.

À l'exception des cartes imprimées (voir G.13), l'**isolation solide** doit satisfaire aux exigences de 5.4.4.4 à 5.4.4.7, selon le cas.

5.4.4.2 Distance minimale à travers l'isolation

Source: IEC 60950-1:2005

Objet: Distance minimale à travers l'isolation de 0,4 mm pour l'**isolation supplémentaire** et l'**isolation renforcée**.

Justificatif: Certains (très) anciens documents exigeaient pour les isolations uniques 2 mm dti (*distance through insulation* – distance à travers l'isolation) pour l'**isolation renforcée** et 1 mm pour l'**isolation supplémentaire**. Si cette isolation a également fait office d'**enveloppe** extérieure pour l'**équipement de classe II**, elle devait être solide d'un point de vue mécanique, ce qui a fait l'objet d'un essai avec un coup de marteau de 0,5 Nm.

Les documents relatifs aux fils n'ont pas fait la distinction entre les niveaux d'isolation et exigeaient une épaisseur de 0,4 mm pour le matériau isolant PVC. Cette valeur a été considérée comme étant adaptée pour la protection contre les chocs électriques en cas de contact avec l'isolation, si elle a été interrompue. Ce concept a également été introduit dans le VDE 0860 (devenu l'IEC 60065), dans lequel la valeur de 0,4 mm a été présentée en premier. Pour les produits informatiques, cette valeur a d'abord été uniquement acceptée dans les isolations **accessibles**.

Le document VDE pour l'équipement télécom (VDE 0804) ne contenait pas d'exigences en matière d'épaisseur, mais l'isolation devait être adaptée pour l'application.

Le document VDE 0730 pour les équipements domestiques avec moteurs électriques, présenté en 1976, contenait les exigences d'une épaisseur d'isolation de 0,5 mm entre les enroulements d'entrée et de sortie d'un transformateur. Ce concept a été présenté par d'anciens collègues d'IBM et de Siemens (contre l'avis des personnes du comité des transformateurs).

De même, le VDE 0110 (Coordination de l'isolement, qui est devenu la série IEC 60664) indiquait une épaisseur d'isolation minimale de 0,5 mm pour une tension d'alimentation de 250 V, afin de couvrir les effets d'une rupture d'isolation.

Cette épaisseur de 0,5 mm est ensuite passée à 0,4 mm (dans l'IEC 60950-1), avec la référence au VDE 0860 (IEC 60065), dans lequel cette valeur était déjà utilisée.

Il est intéressant de noter que la valeur de 0,31 mm déduite du Tableau 2A de l'IEC 60950-1 est également liée à 0,4 mm. La valeur de 0,31 mm est la valeur minimale de l'épaisseur d'isolation moyenne de 0,4 mm, selon les experts des fabricants de fils.

5.4.4.3 Composé isolant constituant une isolation solide

- Source: IEC 60950-1
- Objet: Distance minimale à travers l'isolation de 0,4 mm pour l'**isolation supplémentaire** et l'**isolation renforcée**.
- Justificatif: Les mêmes exigences de distance à travers l'isolation que celles de l'**isolation solide** s'appliquent (voir 5.4.4.2). L'isolant est soumis à un cycle thermique (voir 5.4.1.5.3), à un essai d'humidité (voir 5.4.8) et à un essai de rigidité diélectrique (voir 5.4.9). L'isolant est examiné pour détecter des fissures et des vides.

5.4.4.4 Isolation solide dans des dispositifs à semiconducteurs

- Source: IEC 60950-1, UL 1577
- Objet: Aucune exigence d'épaisseur minimale pour l'**isolation solide**.
- Justificatif: – l'**essai de type** de 5.4.9.1 (essai de rigidité diélectrique à 160 % de la valeur normale après les cycles thermiques et le conditionnement hygroscopique) et l'essai de rigidité diélectrique de routine de 5.4.9.2 ont été utilisés pendant de nombreuses années, particulièrement en Amérique du Nord.
- voir G.12, qui cite l'IEC 60747-5-5 en référence.

5.4.4.5 Composé isolant constituant des joints scellés

- Source: IEC 60950-1
- Justificatif: a) Les distances le long du trajet satisfont aux exigences PD 2 quel que soit le joint;
- b) s'applique si la protection permet de générer un environnement PD 1;
- c) s'applique s'il est traité comme un environnement d'**isolation solide**; aucune **distance dans l'air** et aucune **ligne de fuite** ne s'appliquent;
- d) ne s'applique pas aux cartes imprimées, si la température de la carte est inférieure à 90 °C, le risque de décollement de carte à basses températures étant jugé faible.

Les optocoupleurs ne font pas l'objet des exigences du présent paragraphe, car le document exige que les optocoupleurs satisfassent à l'IEC 60747-5-5, qui couvre suffisamment les joints scellés.

5.4.4.6.1 Exigences générales

Source: IEC 60950-1, IEC 61558-1:2005

Justificatif: Aucune exigence de dimension ou de construction de l'isolation dans les matériaux en fines couches utilisés comme **isolation principale** n'est alignée sur les exigences de l'IEC 61558-1.

Au moins deux couches sans épaisseur minimale sont exigées pour l'**isolation supplémentaire** ou l'**isolation renforcée**, à condition qu'elles soient protégées contre les influences mécaniques extérieures.

Chaque couche est qualifiée pour l'ensemble de la tension pour l'**isolation supplémentaire** ou l'**isolation renforcée**.

Les exigences reposent sur des essais approfondis réalisés sur des matériaux à fines couches par les fabricants et les laboratoires d'essai concernés par les travaux du comité d'études 74 de l'IEC (désormais comité d'études 108 de l'IEC).

5.4.4.6.2 Matériau en fines couches séparables

Source: IEC 60950-1

Justificatif: Pour deux couches, soumettre chaque couche à l'essai de rigidité diélectrique de 5.4.9 pour le niveau d'isolation applicable. Pour trois couches, soumettre toutes les combinaisons de deux couches à l'essai de rigidité diélectrique de 5.4.9 pour le niveau d'isolation applicable.

Chaque couche est qualifiée pour l'ensemble de la tension pour l'**isolation supplémentaire** ou l'**isolation renforcée**.

Les exigences reposent sur des essais approfondis réalisés sur des matériaux en fines couches par les fabricants et les laboratoires d'essai concernés par les travaux du comité d'études 74 de l'IEC (désormais comité d'études 108 de l'IEC).

5.4.4.6.3 Matériau en couches minces non séparables

Source: IEC 60950-1

Justificatif: Pour les essais de couches non séparables, toutes les couches doivent avoir le même matériau et la même épaisseur. Si ce n'est pas le cas, des échantillons de différents matériaux sont soumis à l'essai comme indiqué en 5.4.4.6.2 pour les couches séparables. Lors de l'essai des couches non séparables, le principe utilisé est le même que pour les couches séparables.

Lors de l'essai de deux couches séparables, chacune d'elles est soumise à l'essai pour la tension d'essai exigée. Deux couches sont soumises à l'essai pour deux fois la tension d'essai exigée, chaque couche étant soumise à l'essai pour cette même tension. Lors de l'essai de deux couches non séparables, la tension d'essai totale reste la même (deux fois la tension d'essai exigée, par exemple). Par conséquent, deux couches non séparables sont soumises à l'essai à 200 % de la tension d'essai exigée.

Lors de l'essai de trois couches séparables, chaque combinaison de deux couches est soumise à l'essai pour la tension d'essai exigée. Par conséquent, une seule couche est soumise à l'essai pour la moitié de la tension d'essai exigée, et trois couches sont soumises à l'essai pour 150 % de cette même tension.

5.4.4.6.4 Modalité d'essai normalisée pour un matériau en couches minces non séparables

Source: IEC 60950-1

Justificatif: tension d'essai de 200 % de U_{essai} si deux couches sont utilisées.

tension d'essai de 150 % de U_{essai} si au moins trois couches sont utilisées.

Voir le justificatif en 5.4.4.6.3. La modalité peut être appliquée aux couches séparables et aux couches non séparables tant que le matériau et l'épaisseur du matériau sont identiques pour toutes les couches.

5.4.4.6.5 Essai de mandrin

Source: IEC 61558-1:2005, 26.3.3; IEC 60950-1:2013; IEC 60065:2011

Objet: Il convient que cet essai détecte une rupture de la couche interne des couches non séparées.

Justificatif: Cette procédure d'essai est issue de l'IEC 61558-1, 26.3.3, la tension d'essai étant de 150 % U_{essai} ou 5 kV en valeur efficace, selon la valeur la plus élevée.

5.4.4.7 Isolation solide des composants bobinés

Source: IEC 60950-1, IEC 61558-1

Objet: Identifier les exigences de construction de l'isolation des fils de bobinage et d'isolation entre les bobines.

Justificatif: Les exigences ont été utilisées dans l'IEC 60950-1 pendant de nombreuses années et sont alignées sur celles de l'IEC 61558-1.

Les transformateurs planaires ne sont pas considérés comme des composants bobinés et doivent satisfaire à G.13.

5.4.4.9 Exigences relatives à une isolation solide à des fréquences supérieures à 30 kHz

Source: IEC 60664-4:2005

Objet: Identifier les exigences pour l'**isolation solide** exposée à des tensions aux fréquences supérieures à 30 kHz.

Justificatif: Les exigences sont issues des données présentées à l'Annexe C de l'IEC 60664-4:2005. L'essai de l'**isolation solide** peut être réalisé à des fréquences de lignes (voir 6.2 de l'IEC 60664-4:2005).

En général, la résistance du champ électrique de rupture de l'isolation peut être déterminée conformément à l'IEC 60243-1 (Rigidité diélectrique des matériaux isolants – Méthodes d'essai – Partie 1) comme indiqué en 5.3.2.2.1 de l'IEC 60664-1:2007 (voir ci-dessous).

5.3.2.2.1 Fréquence de la tension

La fréquence de la tension appliquée a un impact important sur la rigidité diélectrique. Le chauffage diélectrique et la probabilité d'instabilité thermique augmentent approximativement en proportion de la fréquence. La résistance du champ électrique de rupture de l'isolation présentant une épaisseur de 3 mm mesurée à une fréquence industrielle conforme à l'IEC 60243-1 est comprise entre 10 kV/mm et 40 kV/mm. L'augmentation de la fréquence diminue la rigidité diélectrique de la plupart des matériaux isolants.

NOTE L'influence des fréquences supérieures à 30 kHz sur la rigidité diélectrique est décrite dans l'IEC 60664-4.

Le Tableau 20 présente la résistance du champ électrique de certains matériaux couramment utilisés. Ces valeurs correspondent à une fréquence de 50 Hz à 60 Hz.

Le Tableau 21, qui repose sur la Figure 6 de l'IEC 60664-4:2005, présente le facteur de réduction pour la valeur de la résistance du champ électrique de rupture de l'isolation à des fréquences plus élevées. La résistance du champ électrique des matériaux chute de manière différente à des fréquences plus élevées. La réduction de la propriété d'isolation doit être prise en considération lorsque la méthode de calcul est remplacée par l'essai ES alternatif à la fréquence du **réseau d'alimentation**, comme indiqué après le sixième alinéa de 5.4.4.9. Le Tableau 21 concerne les matériaux d'au moins 0,75 mm d'épaisseur. Le Tableau 22 concerne les matériaux de moins de 0,75 mm d'épaisseur.

Le multiplicateur 1,2 est issu de l'IEC 60664-4:2005, 7.5.1, dans lequel la tension d'extinction de décharge partielle (DP) doit inclure une marge de sécurité de 1,2 fois la tension périodique crête la plus élevée.

5.4.5 Isolation des bornes d'antenne

Source: IEC 60065

Objet: Éviter la rupture de la **protection** d'isolation.

Justificatif: L'isolation doit être en mesure de résister aux chocs dus à des surtensions présentes dans les bornes d'antenne. Ces surtensions sont provoquées par l'accumulation de charge électrostatique, mais pas par les effets de foudre. Une tension maximale de 10 kV est prise pour hypothèse. L'essai associé de G.10.4 simule cette situation en utilisant une tension d'essai de 10 kV déchargée sur un condensateur de 1 nF.

5.4.6 Isolation du câblage interne en tant que partie d'une protection supplémentaire

Source: IEC 60950-1

Objet: Spécifier les exigences de construction du câblage interne **accessible**

Justificatif: Le câblage interne **accessible** isolé d'ES3 par l'**isolation principale** nécessite uniquement une **isolation supplémentaire**. Si le câblage est correctement acheminé, de manière à ne pas être manipulé par une **personne ordinaire**, une **isolation supplémentaire** de moins de 0,4 mm d'épaisseur est acceptée dans l'IEC 60950-1. Toutefois, l'isolation doit toujours présenter une certaine épaisseur minimale et une capacité de rigidité diélectrique. Les valeurs données ont été utilisées avec succès pendant de nombreuses années pour les produits couverts par le présent document (voir la Figure 16 du présent document).

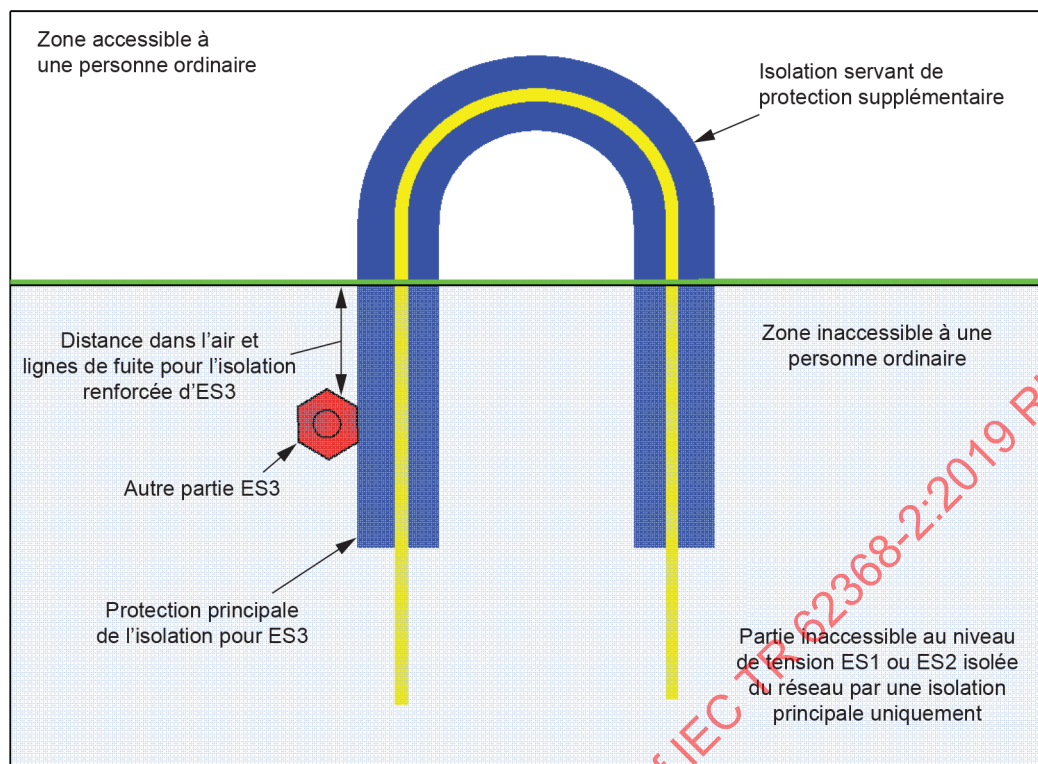


Figure 16 – Exemple illustrant le câblage interne accessible

5.4.7 Essais pour les composants à semiconducteurs et pour les joints scellés

Source: IEC 60950-1

Objet: Simuler les contraintes de durée de vie sur les matériaux attenants.

Détecter les défauts en appliquant des tensions d'essai élevées après le conditionnement de l'échantillon.

Éviter les vides, les espaces ou les fissures dans le matériau isolant, et le décollement dans le cas des cartes imprimées à plusieurs couches.

Justificatif: Cette méthode a été utilisée avec succès pendant de nombreuses années pour les produits relevant du domaine d'application du présent document.

5.4.8 Conditionnement hygroscopique

Source: IEC 60950-1 et IEC 60065. Variante conformément à l'IEC 60664-1:2007, 6.1.3.2

Objet: Préparation du matériau pour l'essai de rigidité diélectrique. Condition préalable à d'autres essais.

Un climat tropical constitue un environnement réputé présenter des températures et une humidité élevées la majeure partie de l'année. Le document n'indique pas les niveaux de température ou d'humidité typiques d'un climat tropical. Les autorités nationales définissent si leur pays exige que les produits satisfassent aux exigences en matière de climat tropical. Seuls quelques pays (Singapour et la Chine, par exemple) ont indiqué dans le schéma CB qu'ils exigeaient de réaliser ce type d'essais.

5.4.9 Essai de rigidité diélectrique

Source: IEC 60664-1: 2007

Objet: Soumettre à l'essai l'isolation afin d'éviter la rupture.

Justificatif: Les valeurs des tensions d'essai sont déduites du Tableau F.5 de l'IEC 60664-1:2007, mais l'essai dure 60 s.

Cette méthode a été utilisée avec succès pendant de nombreuses années pour les produits relevant du domaine d'application de l'IEC 60065 et de l'IEC 60950-1.

L'essai de **tension en courant continu** avec une tension d'essai égale à la valeur de crête de la tension en courant alternatif n'équivaut pas totalement à l'essai de tension en courant alternatif en raison des différentes caractéristiques de tenue de l'**isolation solide** pour ces types de tensions. Toutefois, dans le cas d'une contrainte pure de **tension en courant continu**, l'essai de **tension en courant continu** est approprié. Pour remédier à cette situation, l'essai de courant continu est réalisé avec les deux polarités.

Tableau 25 Tensions d'essai pour les essais de rigidité diélectrique fondées sur les tensions transitoires

Source: IEC 60664-1:2007

Justificatif: Traiter les tensions de tenue et couvrir les transitoires.

L'**isolation principale** et l'**isolation supplémentaire** doivent résister à une tension d'essai égale à la tension de crête transitoire. La tension d'essai de l'**isolation renforcée** doit être égale au transitoire de la suivante dans la série préférentielle. Selon 5.1.6 de l'IEC 60664-1:2007, l'utilisation de la valeur d'essai 160 % pour l'**isolation principale** comme valeur d'essai pour l'**isolation renforcée** s'applique uniquement si d'autres valeurs que celles de la série préférentielle sont utilisées.

L'**isolation fonctionnelle** n'est pas concernée, car elle est réputée ne pas assurer la protection contre les chocs électriques.

Tableau 26 Tensions d'essai pour les essais de rigidité diélectrique fondées sur les valeurs de crête des tensions de service et des tensions de crête récurrentes

Source: IEC 60664-1:2007

Justificatif: La colonne B couvre les **tensions de service** répétitives et exige des tensions d'essai plus élevées en raison d'une contrainte plus importante sur l'isolation.

Il est nécessaire de prendre en considération les tensions de crête récurrentes (IEC 60664-1:2007, 5.3.3.2.3) lorsqu'elles sont supérieures aux valeurs de **surtension temporaire** ou dans les circuits séparés du **réseau d'alimentation**.

Si les tensions de crête récurrentes sont supérieures aux valeurs de **surtension temporaire**, ces tensions doivent être utilisées et multipliées par le facteur indiqué dans l'IEC 60664-1:2007, 5.3.3.2.3.

Tableau 27 Tensions d'essai pour les essais de rigidité diélectrique fondées sur les surtensions temporaires

Source: IEC 60664-1:2007

Justificatif: Il est nécessaire de prendre en considération les **surtensions temporaires** (IEC 60664-1:2007, 5.3.3.2.2), car elles peuvent être présentes pendant 5 s. La tension d'essai pour l'**isolation renforcée** est égale à deux fois la valeur de l'**isolation principale**.

5.4.10 Protections contre les tensions transitoires des circuits externes

Source: IEC 62151:2000, Article 6

Objet: Protéger les personnes contre le contact avec les **circuits externes** soumis à des transitoires (les réseaux de télécommunication, par exemple).

Justificatif: Les **circuits externes** sont destinés à connecter l'équipement à un autre équipement. Les connexions à un équipement déporté sont assurées par l'intermédiaire de réseaux de communication, qui peuvent quitter le bâtiment. Il s'agit, par exemple, de réseaux de télécommunication et de réseaux Ethernet. Les tensions de fonctionnement des réseaux de communication se situent généralement dans les limites d'ES1 (Ethernet, par exemple) ou d'ES2 (les réseaux de télécommunication, par exemple).

Lorsqu'ils quittent le bâtiment, les réseaux de communication peuvent faire l'objet de surtensions transitoires dues aux décharges atmosphériques et aux défauts dans les systèmes de distribution d'alimentation. Ces transitoires dépendent de l'infrastructure des câbles et non de la tension de fonctionnement du réseau de communication. Les transitoires prévus sur les réseaux de télécommunication sont spécifiés dans les recommandations UIT-T. La valeur de transitoire indiquée au Tableau 13 ID 1 est issue de l'UIT-T K.21, soit 1,5 kV 10/700 μ s (équipement de terminal). Ce transitoire de 1,5 kV 10/700 μ s ne provoque aucun choc électrique dangereux, mais il est très inconfortable pour les personnes sensibles à ce type de transitoire. Pour éviter les dangers secondaires, une séparation est exigée entre un **circuit externe** connecté à des réseaux de communication soumis à des transitoires.

Le transitoire ne provoquant pas de choc électrique dangereux, il n'est pas nécessaire que l'élément de séparation soit une **protection renforcée** ni une **protection principale** au sens de l'IEC 62368-1. Il est suffisant de ne prévoir qu'une séparation conforme à l'essai de rigidité diélectrique. Par conséquent, cette séparation ne fait l'objet d'aucune exigence de **distance dans l'air**, de **ligne de fuite** ni d'épaisseur d'**isolation solide**.

La séparation est exigée entre le **circuit externe** soumis aux transitoires et toutes les parties, qui peuvent être **accessibles** aux **personnes ordinaires** ou aux **personnes averties**.

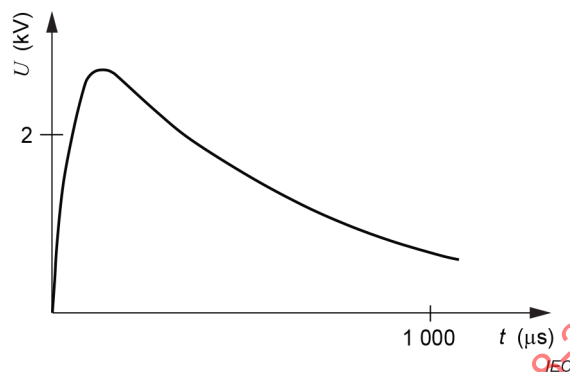
La probabilité qu'un transitoire et qu'un contact corporel avec une partie **accessible** se produisent en même temps augmente avec le temps de contact. Par conséquent, les parties non conductrices et les parties non mises à la terre de l'équipement étant maintenues en contact permanent avec le corps pendant le fonctionnement normal (un combiné téléphonique, un casque d'écoute, des repose-poignets, par exemple), il convient que la séparation résiste à une tension d'essai plus élevée.

Deux procédures d'essai de rigidité diélectrique sont spécifiées en 5.4.10.2.

5.4.10.2.2 Essai de choc

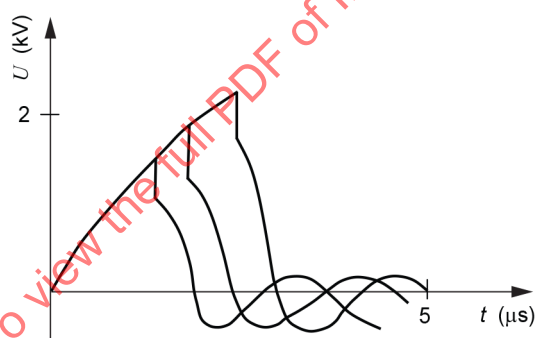
L'essai de choc est réalisé à l'aide d'un générateur d'impulsions de 10/700 μ s (voir le générateur d'essai D.1 de l'Annexe D). Les formes d'onde enregistrées peuvent permettre de déterminer si une rupture de l'isolation s'est produite ou si le parasurtenseur a correctement fonctionné.

Les exemples de la Figure 17, de la Figure 18, de la Figure 19 et de la Figure 20 du présent document peuvent aider à déterminer si un parasurtenseur a fonctionné ou non ou si une rupture de l'isolation s'est produite ou non.



Les formes d'onde des impulsions consécutives sont identiques.

Figure 17 – Forme d'onde sur l'isolation sans parasurtenseur et sans rupture



IEC

Les formes d'onde des impulsions consécutives ne sont pas identiques. La forme d'impulsion varie d'une impulsion à l'autre tant qu'un chemin de résistance stable à travers l'isolation n'a pas été établi. La rupture peut être clairement constatée sur la forme de l'oscillogramme de tensions d'impulsion.

Figure 18 – Formes d'onde sur l'isolation pendant la rupture sans parasurtenseur

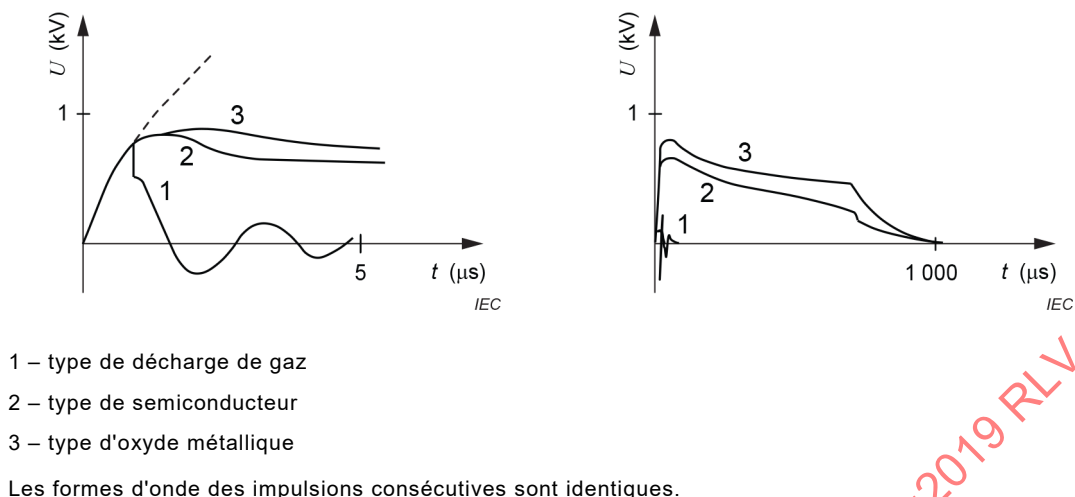


Figure 19 – Formes d'onde sur l'isolation avec parasurtenseurs en fonctionnement

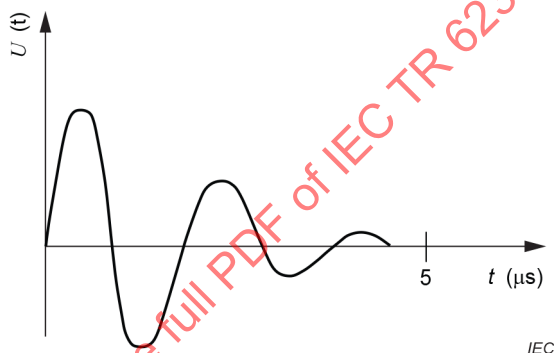


Figure 20 – Forme d'onde sur parasurtenseur court-circuité et isolation

5.4.10.2.3 Essai en régime constant

L'essai en régime constant permet de procéder à un essai de rigidité diélectrique selon 5.4.9.1. Il s'agit d'un simple essai avec une tension efficace. Toutefois, si les parasurtenseurs sont par exemple utilisés pour réduire les transitoires provenant des **circuits externes** à l'intérieur de l'équipement, cet essai de tension efficace peut ne pas être adapté. Dans ce cas, un essai de choc est plus approprié.

5.4.11 Séparation entre des circuits externes et la terre

Source: IEC 62151:2000, 5.3

Objet: Protéger les personnes qui travaillent sur les réseaux de communication et les utilisateurs d'autres équipements connectés au réseau contre les dangers inhérents à l'équipement.

Justificatif: L'équipement de classe I fournit l'**isolation principale** entre le **réseau d'alimentation** et les parties conductrices mises à la terre à connecter à un conducteur PE, lequel doit être relié à la borne de mise à la terre dans l'installation du bâtiment afin d'assurer la sécurité de leur utilisation. Dans un environnement isolé, ce type de borne de terre n'est pas présent dans l'installation du bâtiment. Néanmoins, l'utilisation d'un **équipement de classe I** dans ce type d'environnement isolé est toujours sûre. En effet, en cas de rupture de l'isolation dans l'équipement (défaut de l'**isolation principale**), la seconde barrière est fournie par l'environnement isolé (s'apparentant à une **isolation supplémentaire**).

La situation est différente avec la connexion de l'équipement par l'intermédiaire d'un **circuit externe** à un réseau de communication entre l'extérieur de l'installation du bâtiment et un environnement déporté. Nul ne sait si l'environnement déporté est isolé ou non isolé. Pendant et après un défaut de l'**isolation principale** dans un **équipement de classe I** (entre le **réseau d'alimentation** et les parties conductrices) placé dans une installation isolée (non mise à la terre), les parties conductrices deviennent actives (potentiel du **réseau d'alimentation**). Si à présent les parties conductrices ne sont pas séparées du **circuit externe**, la tension du **réseau d'alimentation** est transférée à l'installation déportée par l'intermédiaire du réseau de communication. Cette situation est dangereuse dans l'environnement déporté et peut l'être pour les personnes présentes dans ce même environnement.

De même, dans les anciennes installations de bâtiment, les socles de prise de courant ne sont pas équipés de contact de terre. Cette situation perdurera dans un avenir proche.

Dans ce type de situation, pour assurer la protection, une séparation est exigée entre un **circuit externe** destiné à être connecté à des réseaux de communication à l'extérieur du bâtiment (des réseaux de télécommunication, par exemple) et les parties mises à la terre.

Pour cette séparation, il est suffisant de satisfaire aux exigences de 5.4.11.2 vérifiées par essai selon 5.4.11.3. Cette séparation ne fait l'objet d'aucune exigence de **distance dans l'air**, de **ligne de fuite** ni d'épaisseur d'**isolation solide**.

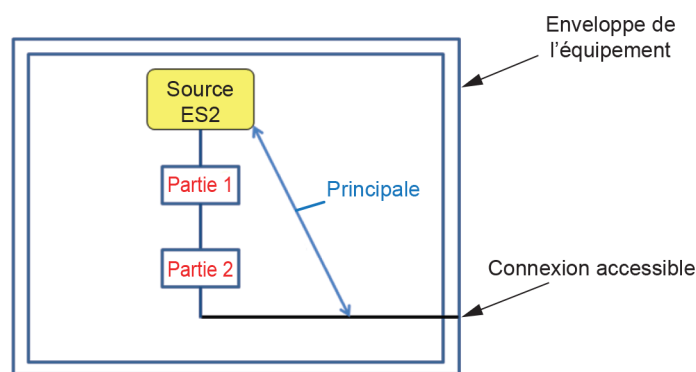
5.5 Composants comme protections

Justificatif: Pour la défaillance d'une **protection** et d'un composant ou dispositif qui n'est pas une **protection**:

Défaillance de **protection**: Une défaillance est considérée comme la défaillance d'une **protection** si la partie elle-même ou sa fonction, dans les **conditions normales de fonctionnement**, participe au passage d'une classe ES à une classe ES inférieure. Dans ce cas, la fiabilité de la partie est évaluée en appliquant les exigences relatives au composant de **protection** de 5.5 et les exigences associées de l'Annexe G. Lors de l'établissement d'ES1, les limites ES2 s'appliquent pendant la **condition de premier défaut** de ces parties. Si aucune exigence relative au composant n'est indiquée en 5.5 ou à l'Annexe G, la défaillance est considérée comme une défaillance de non-**protection**.

Défaillance de non-**protection**: Une défaillance est considérée comme une défaillance de non-**protection** si la partie elle-même ou sa fonction, dans les **conditions normales de fonctionnement**, ne participe pas au passage d'une classe ES à une classe ES inférieure. Dans ce cas, il n'est pas utile d'évaluer la fiabilité de la partie. Lors de l'établissement d'ES1, les limites ES1 s'appliquent pour la **condition de premier défaut** de ces parties. Le cas échéant, 5.3.1 s'applique. La Figure 21 et la Figure 22 du présent document donnent des exemples pratiques d'exigences lorsque des composants ordinaires mettent l'isolation en parallèle.

Exemple 1



IEC

Figure 21 – Exemple de source ES2

Le premier défaut d'un composant ou d'une partie peut ne pas donner lieu à un dépassement des niveaux ES1 par la partie **accessible**, sauf si la partie satisfait aux exigences en matière de **protection principale**.

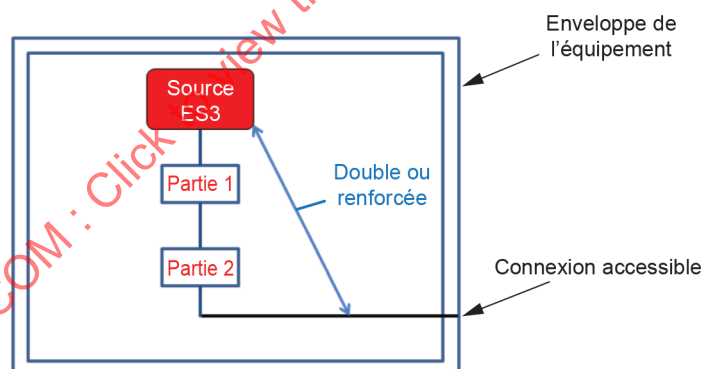
La **protection principale** en parallèle avec la ou les parties doit satisfaire:

- aux exigences de **ligne de fuite**; et
- aux exigences de **distance dans l'air**

pour l'**isolation principale**.

Il n'existe aucune autre exigence pour les composants ou les parties si la partie **accessible** reste à ES1.

Exemple 2



IEC

Figure 22 – Exemple de source ES3

Le premier défaut d'un composant ou d'une partie peut ne pas donner lieu à un dépassement des niveaux ES1 par la partie **accessible**, sauf si les parties satisfont aux exigences en matière de protection double ou de **protection renforcée**.

La protection double ou la protection renforcée en parallèle avec la ou les parties doit satisfaire:

- aux exigences de **ligne de fuite**; et
- aux exigences de **distance dans l'air**,

pour la **double isolation** ou l'**isolation renforcée**.

Il n'existe aucune autre exigence pour les composants ou les parties si la partie **accessible** reste à ES1.

5.5.2.1 Exigences générales

- Source: documents de composants IEC pertinents
- Objet: L'isolation des composants doit satisfaire aux exigences d'isolation correspondantes de 5.4.1 ou aux exigences de sécurité du document IEC pertinent.
- Justificatif: Les exigences de sécurité d'un document pertinent sont acceptées si elles sont adaptées pour leur application (condensateurs Y2 de l'IEC 60384-14, par exemple).

5.5.2.2 Décharge du condensateur après déconnexion d'un connecteur

- Source: IEC TS 61201:2007, Annexe A
- Justificatif: Le temps d'attente de 2 s correspond au temps d'accès classique après déconnexion d'un connecteur. Lors de la détermination de la tension **accessible** 2 s après la déconnexion d'un connecteur, la tolérance du condensateur X n'est pas prise en considération.

Si un condensateur est déchargé par une résistance (une résistance de fuite, par exemple), la valeur correcte de la résistance peut être calculée à l'aide de la formule suivante:

$$R = (2 / C) \times [1 / I_n(E / E_{\max})] \text{ M}\Omega$$

où:

C est exprimé en microfarads

E est égal à 60 pour une **personne ordinaire** ou à 120 pour une **personne avertie**

$E_{\max}$ est la tension de charge maximale ou la tension de crête du **réseau d'alimentation**

I_n est la fonction de logarithme naturel

NOTE 1 Lorsque le **réseau d'alimentation** est déconnecté, la capacité est composée des condensateurs X et des condensateurs Y, et d'autres capacités possibles. Le circuit est analysé pour déterminer la capacité totale entre les pôles du connecteur ou de la fiche.

NOTE 2 Si la **tension assignée du réseau d'alimentation** de l'équipement est de 125 V, la valeur maximale de la résistance de décharge est donnée par:

$$R = 1,85 / C \text{ M}\Omega$$

NOTE 3 Si la **tension assignée du réseau d'alimentation** de l'équipement est de 250 V, la valeur maximale de la résistance de décharge est donnée par:

$$R = 1,13 / C \text{ M}\Omega$$

NOTE 4 La valeur absolue des calculs ci-dessus est utilisée pour la valeur de la résistance de décharge.

La méthode d'essai inclut une erreur maximale de temporisation d'environ 9 % inférieure à la durée calculée pour une décharge capacitive. Cette erreur a été jugée acceptable pour des raisons de cohérence avec les pratiques passées.

Pour la mesure du cas le plus défavorable, il convient de veiller à mesurer la décharge à la crête de la tension d'entrée. Pour ce faire, un système de commande automatique qui se désactive à la tension de crête peut être utilisé.

Une méthode utilisée dans plusieurs autres documents (l'IEC 60065 et l'IEC 60335-1, par exemple) consiste à répéter le mesurage 10 fois et à enregistrer la valeur maximale. Par hypothèse, l'un des dix mesurages est suffisamment proche de la valeur de crête.

Une autre possibilité peut consister à utiliser un oscilloscope pendant le mesurage, de manière à pouvoir déterminer si le mesurage a été réalisé proche de la valeur maximale.

Il n'est pas utile de prendre en considération les **conditions de premier défaut** si le composant satisfait aux exigences pertinentes du document. Par exemple, il n'est pas utile de mettre en défaut une résistance connectée en parallèle avec un condensateur dont la tension devient **accessible** lors de la déconnexion d'un connecteur si la résistance satisfait à 5.5.6.

5.5.6 Résistances

Source: IEC 60950-1 et IEC 60065

Justificatif: Lorsqu'un groupe de résistances est utilisé, les résistances sont en série. L'ensemble du chemin est composé d'un câble métallique, d'une extrémité hélicoïdale (métal) et du corps de la résistance. La **distance dans l'air** et la **ligne de fuite** traversent uniquement le corps de la résistance. L'ensemble du chemin est donc composé des chemins métalliques conducteurs et des corps de résistance (tous en série). Dans ce cas, la Figure O.4 devient pertinente pour déterminer la **distance dans l'air** et la **ligne de fuite** totales.

5.5.7 Dispositifs de protection contre les surtensions ou parafoudres (SPD)

Justificatif: Voir la pièce jointe A pour des informations générales relatives à l'utilisation des dispositifs de protection contre les surtensions.

Il convient de noter que la question est toujours d'actualité au sein du comité d'études 108 de l'IEC. Le justificatif sera adapté dès la fin de la discussion.

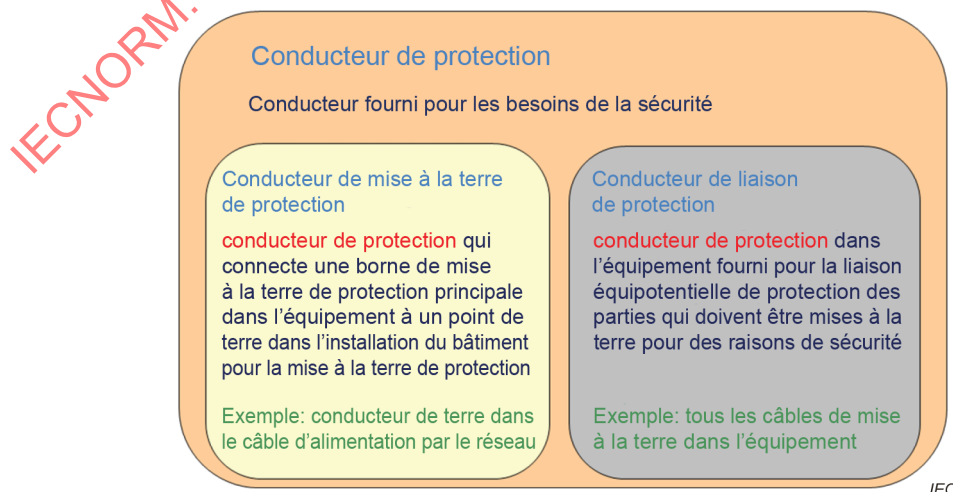
5.5.8 Isolation entre le réseau d'alimentation et un circuit externe composé d'un câble coaxial

Source: IEC 60065:2014, 10.2 et IEC 60950-1:2005, 1.5.6.

Justificatif: Le conditionnement supplémentaire de G.10.2 est issu de l'IEC 60950-1:2005, 1.5.6 Condensateurs en parallèle sur l'isolation

5.6 Conducteur de protection

Voir la Figure 23 du présent document pour un aperçu de la **mise à la terre pour des raisons de protection** et des conducteurs de liaison de protection.



IEC

Figure 23 – Aperçu des conducteurs de protection

5.6.1 Généralités

Source: IEC 60364-5-54, IEC 61140, IEC 60950-1

Objet: Il convient que la **mise à la terre pour des raisons de protection** ne présente pas de résistance excessive, qu'elle dispose d'un courant admissible suffisant et qu'elle ne soit pas interrompue dans toutes les circonstances.

5.6.2.2 Couleur de l'isolation

Source: IEC 60446¹

Objet: Identifier clairement la connexion de terre.

Une tresse de mise à la terre est un matériau conducteur (en général du cuivre) composé d'au moins trois bandes entrelacées, se chevauchant en diagonale.

Il convient de noter que l'IEC 60227-1:2007 formule des exigences particulières relatives à l'utilisation de la combinaison de couleurs suivante:

4.1.3 Combinaison des couleurs verte et jaune

En ce qui concerne le conducteur identifié par la combinaison des couleurs verte et jaune, la répartition de ces couleurs doit être conforme aux dispositions suivantes (en accord avec l'IEC 60173): sur toute longueur de conducteur de 15 mm, une de ces couleurs doit couvrir au moins 30 % et au plus 70 % de la surface du conducteur, l'autre couleur couvrant le reste.

NOTE Information sur l'emploi des couleurs vert et jaune et bleu.

Il est entendu que les couleurs verte et jaune, lorsqu'elles sont combinées comme il est spécifié ci-dessus, sont exclusivement reconnues comme un moyen permettant une identification du conducteur constitutif destiné à être utilisé pour la mise à la terre ou pour une protection analogue, et que la couleur bleue est destinée à permettre l'identification du conducteur constitutif destiné à être relié au neutre. Si, toutefois, il n'y a pas de conducteur neutre, le bleu peut servir pour identifier n'importe quel conducteur, à l'exception du conducteur de terre ou de protection.

5.6.3 Exigences relatives aux conducteurs de mise à la terre de protection

Source: IEC 60950-1

Objet: Le **conducteur de protection** renforcé doit être suffisamment robuste pour empêcher l'interruption du **conducteur de protection** à tout moment (l'interruption n'étant pas prise pour hypothèse).

Justificatif: Ces exigences ont été appliquées avec succès pendant de nombreuses années pour les produits relevant du domaine d'application du présent document.

Si un conduit est utilisé et qu'un cordon ou un conducteur en sort sans être protégé, alors les valeurs du Tableau 30 ne peuvent pas être utilisées pour le conducteur qui sort du conduit.

Pour les **équipements enfichables de type B** et les **équipements reliés en permanence**, une connexion de mise à la terre est toujours réputée être présente. Le conducteur de mise à la terre peut donc être considéré comme une **protection renforcée**.

¹ Cette publication a été retirée.

5.6.4 Exigences relatives aux conducteurs de liaison de protection

- Source: IEC 60950-1
- Objet: Démontrer la capacité de courant de défaut et la capacité de la terminaison.
- Justificatif: Ces exigences et essais ont été utilisés avec succès pendant de nombreuses années pour les produits relevant du domaine d'application du présent document (voir la Figure 3 du présent document).

5.6.5 Bornes des conducteurs de protection

5.6.5.1 Exigences

- Source: IEC 60998-1, IEC 60999-1, IEC 60999-2, IEC 60950-1
- Objet: Démontrer la capacité de courant de défaut et la capacité de la terminaison.
- Justificatif: Pendant de nombreuses années, les extrémités des conducteurs conformes au Tableau 32 ont servi de moyens de connexion fiables pour les produits conformes à l'IEC 60950-1.
- La valeur de 25 A a été choisie pour couvrir la valeur assignée minimale du courant de protection dans tous les pays.

5.6.6.2 Méthode d'essai

- Source: IEC 60950-1
- Justificatif: Cette méthode a été utilisée avec succès pendant de nombreuses années pour les produits relevant du domaine d'application du présent document.

5.6.7 Connexion fiable d'un conducteur de mise à la terre de protection

- Source: IEC 60309 (Prises de courant pour usages industriels)
- Objet: Décrire une mise à la terre fiable assurée par l'**équipement relié en permanence**, l'**équipement enfichable de type B** et l'**équipement enfichable de type A**.
- Justificatif: L'**équipement relié en permanence** est réputé fournir une connexion de terre fiable, car il est câblé par un électricien.
- L'**équipement enfichable de type B** est réputé fournir une connexion de terre fiable, car les fiches de type IEC 60309 sont plus fiables et la terre est toujours présente, car un électricien a procédé au câblage.
- Pour l'**équipement enfichable stationnaire de type A** dont une **personne qualifiée** vérifie la bonne connexion du conducteur de terre.

5.7 Tension de contact présumée, courant de contact et courant du conducteur de protection

- Source: IEC 60990

5.7.3 Montage de l'équipement, connexions d'alimentation et connexions de mise à la terre

- Justificatif: L'équipement conçu pour plusieurs connexions au **réseau d'alimentation**, si elles sont exigées, doit être soumis aux essais ci-dessous:
- chaque connexion est soumise à l'essai individuellement pendant que les autres sont déconnectées,
 - chaque connexion est soumise à l'essai pendant que les autres sont connectées, les **conducteurs de mise à la terre de protection** étant reliés ensemble.

Pour plusieurs connexions simultanées, le document exige que chaque connexion doive être soumise à l'essai pendant que les autres sont connectées, les **conducteurs de mise à la terre de protection** étant reliés ensemble. Si le **courant de contact** dépasse la limite indiquée en 5.2.2.2, il doit être mesuré individuellement.

Cela signifie que si le **courant de contact** total avec toutes les connexions soumises à l'essai ensemble ne dépasse pas la limite, l'équipement satisfait à l'exigence. Dans le cas contraire, et si chacun des courants de contact de conducteur individuel ne dépasse pas la limite, l'équipement satisfait également à l'exigence.

5.7.5 Parties conductrices accessibles mises à la terre

Justificatif: La Figure 24 du présent document donne un exemple de configuration d'essai classique pour le **courant de contact** à partir d'un équipement monophasé sur des schémas étoiles TN ou TT. D'autres systèmes de distribution peuvent être consultés dans l'IEC 60990.

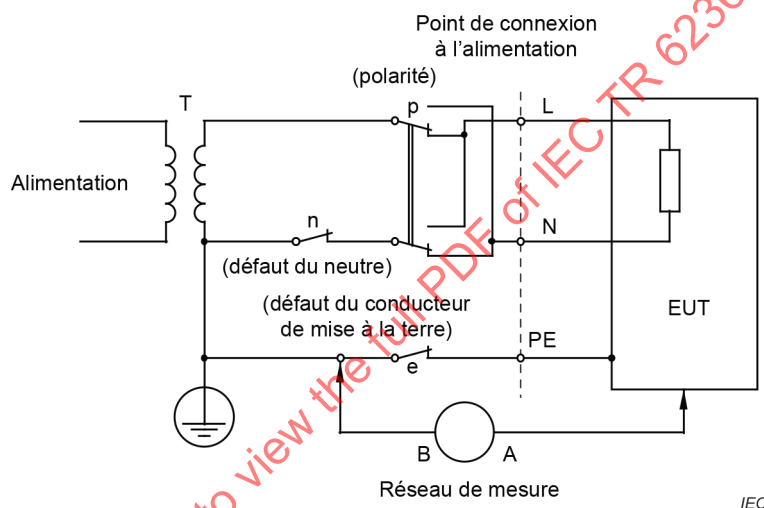


Figure 24 – Exemple d'un réseau de mesure classique du courant de contact

5.7.6 Exigences si le courant de contact dépasse les limites ES2

Source: IEC 61140:2001, IEC 60950-1

Justificatif: La valeur de 5 % a été utilisée dans l'IEC 60950-1 pendant longtemps et est considérée comme acceptable. La valeur de 5 % correspond également au courant maximal admis du **conducteur de protection** (7.5.2.2 de l'IEC 61140:2001).

Si le **courant du conducteur de protection** dépasse 10 mA, l'IEC 61140 exige un **conducteur de mise à la terre de protection** renforcée avec une dimension de 10 mm² pour les conducteurs en cuivre et de 16 mm² pour les conducteurs en aluminium, ou une seconde borne pour un second **conducteur de mise à la terre de protection**. Cet alinéa de l'IEC 62368-1 tient compte de cette disposition en exigeant un **conducteur de mise à la terre de protection** double ou renforcée selon 5.6.3.

Le paragraphe 7.5.2.2 de l'IEC 61140:2001 exige d'insérer des informations relatives à la valeur du **courant du conducteur de protection** dans la documentation et dans le manuel d'instructions. Il s'agit d'aider à déterminer si l'équipement présentant un **courant du conducteur de protection** élevé est compatible avec le dispositif à courant différentiel résiduel qui peut se trouver dans l'installation du bâtiment.

Le fabricant doit indiquer la valeur du **courant du conducteur de protection** dans les instructions d'installation si le courant dépasse 10 mA, afin de satisfaire aux exigences du 7.6.3.5 de l'IEC 61140:2001.

5.7.7 Tension de contact présumée et courant de contact causés par des circuits externes

5.7.7.1 Courant de contact provenant de câbles coaxiaux

- Source: IEC 60728-11
- Objet: Éviter d'avoir un écran non mis à la terre d'un réseau coaxial à l'intérieur d'un bâtiment.
- Justificatif: Un écran mis à la terre d'un réseau coaxial réduit le risque de choc électrique.

Les interfaces externes coaxiales sont très souvent reliées à des antennes pour recevoir les signaux TV et sonores. Les antennes installées à l'extérieur des bâtiments sont exposées à des décharges atmosphériques externes (coup de foudre indirect, par exemple). Pour protéger le réseau d'antennes et l'équipement relié à ce type d'antennes, il est nécessaire de prévoir un chemin jusqu'à la terre par l'intermédiaire de l'écran du réseau coaxial.

Chaque équipement alimenté par le **réseau d'alimentation** délivre un **courant de contact** à un **circuit externe** coaxial par l'intermédiaire de la capacité parasite et du condensateur (s'il est fourni) entre le **réseau d'alimentation** et l'interface coaxiale. Ce **courant de contact** est limité par l'exigence imposant à chaque équipement individuel de satisfaire aux exigences en matière de **courant de contact** (valeur sûre) à mesurer conformément à l'IEC 60990. Dans un bâtiment, de nombreux équipements individuels (des postes de télévision, par exemple) peuvent être connectés à un réseau coaxial (un système de distribution par câble, par exemple). Dans ce cas, chacun des **courants de contact** provenant de chaque équipement individuel s'ajoute dans le blindage du câble coaxial. Avec le blindage mis à la terre d'un câble coaxial, le **courant de contact** dispose d'un chemin de retour à la source, le blindage du câble coaxial restant sûr au contact.

5.7.7.2 Tension de contact présumée et courant de contact associés à des câbles conducteurs à paires

- Source: IEC 62151
- Objet: Éviter une **tension de contact présumée** excessive et des courants excessifs provenant de l'équipement dans les réseaux de communication (des réseaux de télécommunication, par exemple).
- Justificatif: Tous les mesurages du **courant de contact** conformément à l'IEC 60990 déterminent le courant entre le **réseau d'alimentation** et les parties **accessibles**. Les circuits ES1 peuvent être **accessibles** par une **personne ordinaire** et sont donc inclus dans le mesurage conformément à l'IEC 60990. Les circuits de classe ES2 n'étant pas **accessibles**, ils ne sont pas concernés par les mesurages de l'IEC 60990.

Étant donné que les circuits ES2 peuvent être **accessibles** à des **personnes averties** et peuvent devenir **accessibles** à une **personne ordinaire** pendant un premier défaut, le **courant de contact** vers le **circuit externe** doit être limité, afin de protéger les personnes qui travaillent sur les réseaux ou sur un autre équipement, qui sont connectés au **circuit externe** par l'intermédiaire d'un réseau.

Une interface externe, numéro d'identification 1 du Tableau 13 est par exemple la connexion à un réseau de télécommunication. Le personnel d'entretien des réseaux et des équipements de télécommunication intervient souvent alors que l'équipement est sous tension. Par conséquent, les réseaux de télécommunication fonctionnent avec une tension qui ne dépasse pas la classe d'énergie ES2.

La limitation du **courant de contact** à une valeur de 0,25 mA (inférieure à ES2) se justifie par l'expérience pratique. Très souvent, l'équipement de télécommunication est composé de plusieurs **circuits externes**, numéro d'identification 1 du Tableau 13 (connexion à un réseau de télécommunication, par exemple). Dans ce type de configurations, une somme des **courants de contact** peut se produire (voir 5.7.7). Avec la limitation à 0,25 mA par **circuit externe** individuel, jusqu'à 20 **circuits externes** peuvent être reliés ensemble sans exigence supplémentaire. En 5.7.7, cette valeur de 0,25 mA est par hypothèse le **courant de contact** entre un réseau et l'équipement.

5.7.8 Somme des courants de contact provenant de circuits externes

Source: IEC 60950-1

Objet: Éviter des **courants de contact** excessifs lorsque plusieurs **circuits externes** sont connectés.

Justificatif: Lors de la limitation de la valeur du **courant de contact** à chaque **circuit externe** individuel (comme cela est exigé en 5.7.6.2), plusieurs circuits peuvent être reliés ensemble avant d'atteindre la limite du courant de **contact**. Cette opération permet une meilleure utilisation des ressources.

Des informations détaillées relatives aux **courants de contact provenant de circuits externes** sont données à l'Annexe W de l'IEC 60950-1:2005.

a) Courant de contact provenant de circuits externes

Deux mécanismes assez différents permettent de déterminer le courant traversant un corps humain qui touche un **circuit externe**, selon que le circuit est mis à la terre ou pas. Cette distinction entre des circuits (flottants) mis à la terre et non mis à la terre n'est pas la même que celle entre un équipement de classe I et un équipement de classe II. Les circuits flottants peuvent exister dans un **équipement de classe I** et les circuits mis à la terre le peuvent dans un équipement de classe II. Les circuits flottants sont souvent, mais pas exclusivement, utilisés dans les équipements de télécommunication, les circuits mis à la terre étant utilisés dans les équipements de traitement de données (mais pas exclusivement non plus).

Afin de prendre en considération le cas le plus défavorable, la présente annexe prend pour hypothèse le caractère flottant des réseaux de télécommunication, et la mise à la terre de l'alimentation du **réseau d'alimentation** en courant alternatif et des corps humains (**personnes qualifiées, personnes averties ou personnes ordinaires**). Il convient de noter qu'une **personne qualifiée** et une **personne avertie** peuvent toucher certaines parties qui ne sont pas **accessibles** par une **personne ordinaire**. Un circuit "mis à la terre" signifie que le circuit est directement mis à la terre ou, d'une certaine manière, référencé par rapport à la terre de sorte que son potentiel par rapport à la terre soit fixe.

a.1) Circuits flottants

Si le circuit n'est pas mis à la terre, le courant (I_c) traversant le corps humain est une "fuite" à travers la capacité parasite ou la capacité ajoutée (C) sur l'isolation dans le transformateur du **réseau d'alimentation** (voir la Figure 25 du présent document).

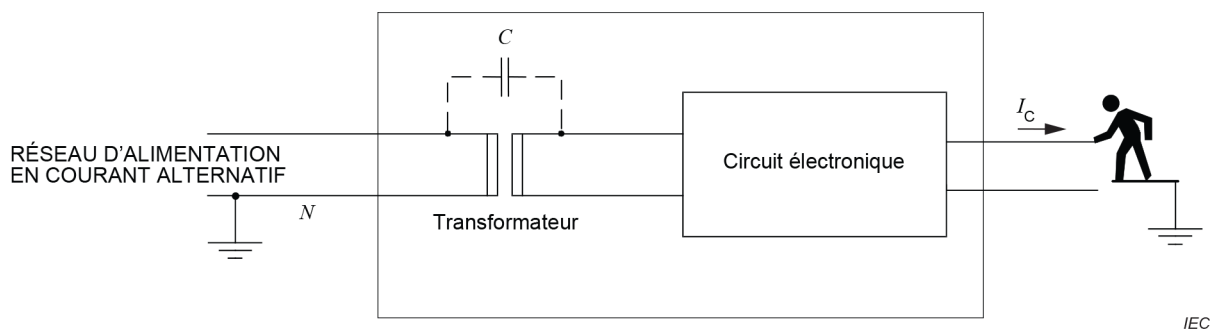


Figure 25 – Courant de contact provenant d'un circuit flottant

Ce courant provient d'une tension relativement élevée, source d'impédance élevée, et sa valeur n'est quasiment pas affectée par la tension de fonctionnement sur le **circuit externe**. Dans le présent document, le courant de structure (I_c) est limité en appliquant un essai à l'aide de l'instrument de mesure de l'Annexe D de l'IEC 60950-1:2005, qui simule grossièrement un corps humain.

a.2) Circuits mis à la terre

Si le **circuit externe** est mis à la terre, le courant qui traverse le corps humain (I_v) est dû à la tension de fonctionnement (V) du circuit, qui est une source de faible impédance comparée au corps (voir la Figure 26 du présent document). Un courant de fuite provenant du transformateur du **réseau d'alimentation** (voir a.1) est amené jusqu'à la terre et ne traverse pas le corps.

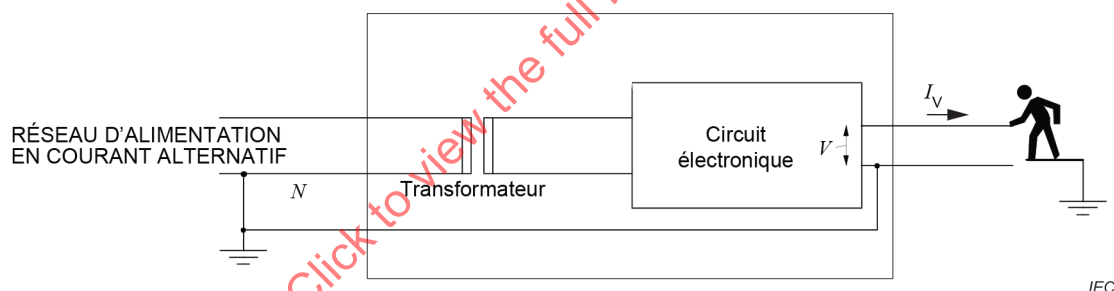
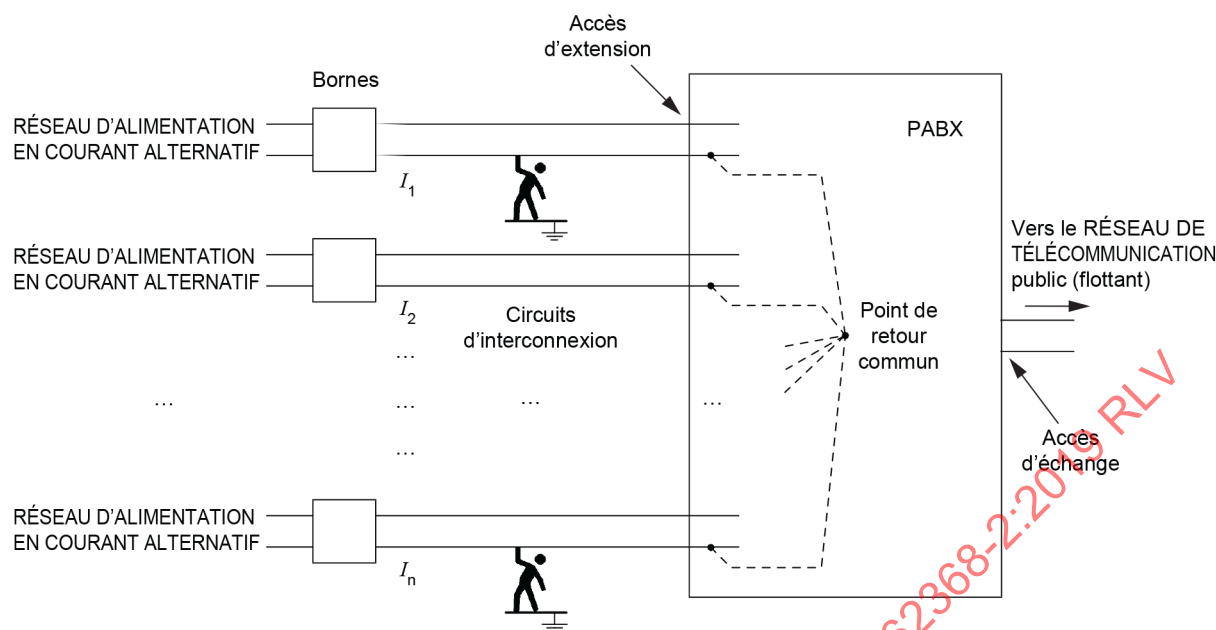


Figure 26 – Courant de contact provenant d'un circuit mis à la terre

Dans le présent document, le courant de structure (I_v) est limité en spécifiant des valeurs de tension maximale pour le circuit **accessible**, qui doit être un circuit ES1 ou (avec une **accessibilité** restreinte) un circuit ES2.

b) Interconnexion de plusieurs équipements

Le fait de pouvoir connecter plusieurs équipements à un seul équipement central dans une topologie "en étoile" est une caractéristique des équipements de traitement de l'information, et en particulier des applications de télécommunication. Il s'agit, par exemple, de postes téléphoniques supplémentaires ou de terminaux de données connectés à un PABX, qui peut comporter des dizaines ou des centaines d'accès. Cet exemple est utilisé dans la description suivante (voir la Figure 27 du présent document).



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Figure 27 – Somme de courants de contact dans un PABX

Chaque équipement de terminal peut délivrer un courant à un corps humain qui touche le circuit d'interconnexion (I_1 , I_2 , etc.), ajouté à un courant provenant des circuits d'accès de PABX. Si plusieurs circuits sont connectés à un point commun, leurs **courants de contact** individuels s'ajoutent, ce qui représente un risque possible pour un corps humain mis à la terre qui touche le circuit d'interconnexion.

Différentes manières d'éviter ce risque sont prises en considération dans les paragraphes suivants.

b.1) Isolation

Isoler tous les circuits d'interconnexion les uns des autres et de la terre, et limiter I_1 , I_2 , etc., comme indiqué en a.1. Cette opération implique soit d'utiliser dans le PABX une alimentation séparée pour chaque accès, soit de disposer d'un transformateur de basse tension (signal) individuel pour chaque accès. Ces solutions peuvent ne pas être rentables.

b.2) Retour commun, isolé de la terre

Connecter tous les circuits d'interconnexion à un point de retour commun isolé de la terre. (ce type de connexions à un point commun peut dans certains cas être nécessaire pour des raisons fonctionnelles.) Dans ce cas, le courant total provenant de tous les circuits d'interconnexion traverse le corps humain mis à la terre qui touche le fil d'un circuit d'interconnexion. Ce courant peut uniquement être limité en contrôlant les valeurs I_1 , I_2 , .. I_n . En relation avec le nombre d'accès sur le PABX. Toutefois, la valeur du courant total est probablement inférieure à $I_1 + I_2 + \dots + I_n$ en raison des harmoniques et d'autres effets.

b.3) Retour commun, connecté à la terre de protection

Connecter tous les circuits d'interconnexion à un point de retour commun et connecter ce point à la **mise à la terre pour des raisons de protection**. La situation décrite en a.2) s'applique quel que soit le nombre d'accès. Étant donné que la sécurité dépend de la présence de la connexion de terre, il peut s'avérer nécessaire d'utiliser des installations de mise à la terre à intégrité élevée, en fonction de la valeur maximale du courant total qui peut circuler.

5.8 Protection contre le retour de tension en entrée dans les alimentations de secours par batterie

Source: IEC 62040-1:2017, IEC 62368-1, UL 1778 5^e édition

Objet: Établir les exigences relatives à certains systèmes d'alimentation de secours par **batterie** faisant partie intégrante de l'équipement et qui ont la capacité de retourner au **réseau d'alimentation** de l'équipement en mode d'énergie stockée. Il s'agit, par exemple, des alimentations de distribution de réseau de télévisions par câble et d'autres alimentations intégrales évaluées dans le présent document avec une option de secours par **batterie**.

Justificatif: Principes de la protection contre le **retour de tension en entrée**

Les alimentations de secours par **batterie** stockent et génèrent de l'énergie dangereuse. Ces énergies peuvent être présentes au niveau des bornes d'entrée de l'unité.

Une **protection contre le retour de tension en entrée** consiste à éviter que des **personnes ordinaires**, des **personnes averties** ou des **personnes qualifiées** ne soient involontairement exposées à ce type de dangers.

Il convient qu'une **protection mécanique contre le retour de tension en entrée** satisfasse à une exigence de distance minimale. Si ce n'est pas le cas, la fermeture du dispositif mécanique (des contacts) peut être forcée, ce qui n'est pas considéré comme un défaut. La **protection contre le retour de tension en entrée** fonctionne avec tous les dispositifs à semiconducteur dans une seule phase du chemin d'alimentation du **réseau d'alimentation** ayant fait l'objet du défaut.

Une **protection contre le retour de tension en entrée** fonctionne dans toutes les **conditions normales de fonctionnement**. Il convient que ce principe concerne toutes les conditions de charge de sortie ou de source d'entrée que le fabricant juge normales. Toutefois, il est de pratique commune de ne procéder aux essais qu'à pleine charge ou à vide, sauf si l'analyse des circuits révèle que d'autres conditions seraient moins favorables. Les circuits qui commandent la **protection contre le retour de tension en entrée** sont destinés à tolérer les premiers défauts.

Pour ce faire, la **protection contre le retour de tension en entrée** peut déconnecter les câbles d'alimentation du **réseau d'alimentation** de la source d'énergie interne, désactiver l'onduleur et retirer la ou les sources d'énergie dangereuses, réduire la source à un niveau sûr ou placer une protection adaptée entre la **personne ordinaire**, la **personne avertie** ou la **personne qualifiée** et l'énergie dangereuse. ES1 est défini dans le corps du présent document. La méthode de mesure est la suivante:

- Pour les équipements enfichables, elle est déterminée en ouvrant toutes les phases, le neutre et la masse.
- Pour les équipements **reliés en permanence**, le neutre et la masse ne sont pas retirés pendant les essais de **retour de tension en entrée**.

Les mesurages sont réalisés au niveau des connexions d'entrée de l'unité entre les phases, entre la phase et le neutre, la phase et le neutre et la masse, en utilisant le modèle d'impédance du corps humain comme dispositif de mesure.

Exigences de distance pour la déconnexion mécanique:

Une distance est uniquement exigée si la protection contre le retour de tension en entrée est par nature mécanique. La distance est définie comme étant la **distance dans l'air**. Plusieurs éléments sont à prendre en considération lors de la détermination de l'exigence de **distance dans l'air**:

- En fonctionnement normal, l'espace entre les pôles des phases doit satisfaire aux exigences en matière d'**isolation principale** (voir 5.4.2).

- Si l'unité fonctionne sur l'onduleur, la source est considérée comme une alimentation secondaire, qui ne présente aucun transitoire (voir 5.4.2).

Pour une unité à sorties flottantes, l'ouverture de toutes les phases et du neutre à l'aide de la **distance dans l'air** exigée pour l'**isolation principale** est considérée comme acceptable. Si la sortie est mise à la masse au châssis, l'**isolation renforcée** ou une isolation équivalente est exigée.

Essais de défaut

Tous les circuits de commande de la **protection contre le retour de tension en entrée** font l'objet d'une analyse des défaillances et d'essais.

Relais

Il convient que les relais du chemin de **réseau d'alimentation** dont l'ouverture est exigée pour assurer la protection mécanique soient en principe ouverts lorsqu'ils sont hors tension.

Si le relais ne satisfait pas aux exigences de **distance dans l'air**, le court-circuit du pôle/contact peut être considéré comme un premier défaut afin de simuler le soudage des contacts. La défaillance d'un seul contact de relais peut être détectée et l'onduleur désactivé pour éviter la rétroaction.

Un relais utilisé pour la protection mécanique doit être assigné en chevaux ou faire l'objet d'un essai d'endurance de 50 cycles à 600 % du courant de commutation normal.

Protection électronique

La protection électronique d'une **protection contre le retour de tension en entrée** est acceptable si le fonctionnement du dispositif de protection électronique est détecté et que l'onduleur est déconnecté en cas de détection d'un défaut. Cette exigence vaut également pour un relais dont la distance ou la **distance dans l'air** est inférieure sur l'ensemble de la protection mécanique.

Protection mécanique

La protection mécanique d'une **protection contre le retour de tension en entrée** est acceptable si elle empêche l'utilisateur d'accéder à un niveau supérieur à ES1 et si elle ne peut pas être aisément contournée sans l'aide d'un **outil**. Il convient que la valeur assignée de la tension de la protection mécanique ne soit pas inférieure à la tension déphasée maximale.

Circuits de commande

La défaillance, le circuit ouvert ou le court-circuit d'un composant des circuits de **protection contre le retour de tension en entrée** peuvent être analysés afin d'évaluer les effets sur le bon fonctionnement de la **protection contre le retour de tension en entrée**. Les essais peuvent être réalisés sur tous les composants si l'analyse des résultats peut être argumentée.

Les composants, tels que les résistances et les bobines d'inductance, sont considérés se mettre en défaut en circuit ouvert uniquement. En règle générale les condensateurs peuvent se mettre en défaut en circuit ouvert ou en court-circuit. Les dispositifs à semiconducteur se mettent en défaut typiquement en court-circuit puis ils s'ouvrent.

Les commandes de microprocesseur sont considérées comme acceptables si le circuit fonctionne en toute sécurité avec une seule ligne de commande ouverte ou court-circuitée pour commander la masse logique ou court-circuitée en Vcc, cas dans lequel ce type de défaut est susceptible de se produire. La défaillance du microprocesseur peut également être simulée en ouvrant la broche Vcc ou en court-circuitant la broche Vcc à la masse.

Si les circuits de commande sont totalement redondants ($N + 1$, par exemple), il n'est pas exigé de procéder à l'analyse des défaillances des composants individuels si la défaillance d'un circuit donne lieu à un mode de fonctionnement de sécurité intrinsèque.

6 Incendie d'origine électrique

Justificatif: Un incendie d'origine électrique est dû à la conversion de l'énergie électrique en énergie thermique, l'énergie thermique chauffant un matériau combustible pour pyrolyser le solide en gaz inflammable en présence d'oxygène. Le mélange obtenu est chauffé jusqu'à la température d'inflammation, suivie de la combustion de ce matériau combustible. La combustion obtenue, si elle est exothermique ou avec une énergie thermique supplémentaire convertie à partir de la source d'énergie, peut être entretenue, puis enflammer les matériaux combustibles à proximité, propageant le feu.

Le modèle à trois blocs (voir 0.7.2, Figure 6) des incendies d'origine électrique (en interne) porte sur la séparation des sources potentielles d'incendie provenant de matériaux combustibles. De plus, il peut également représenter un combustible enflammé et les protections placées entre les combustibles enflammés et les combustibles adjacents, voire les combustibles situés à l'extérieur de l'équipement.

6.2 Classification des sources de puissance (PS) et des sources potentielles d'incendie (PIS)

Justificatif: La première étape dans l'application du présent article consiste à déterminer les sources d'énergie contenant des **sources potentielles d'incendie** exigeant une **protection**. La puissance dont dispose chaque circuit peut en premier lieu être évaluée afin de déterminer l'énergie dont dispose un circuit. Ensuite, chaque point ou composant d'un circuit peut être soumis à l'essai afin de déterminer la puissance qui serait disponible en cas de défaut de ce composant. Avec ces informations, chaque partie des sources d'énergie de composant à l'intérieur du produit peut être classée comme une source spécifique d'incendie ou comme un composant à l'intérieur d'une source de puissance.

Tout au long du présent article, le terme "réduire la probabilité d'inflammation" est utilisé à la place des termes "empêcher" ou "éliminer".

6.2.2 Classifications du circuit de source de puissance

Source: IEC 60950-1, IEC 60065

Justificatif: Ces classifications de source de puissance commencent par l'énergie disponible la plus faible nécessaire à la mise à feu électronique (PS1) et incluent un niveau intermédiaire (PS2) dans lequel l'inflammation est possible, mais pour lequel la propagation du feu peut être localisée avec un contrôle efficace des matériaux ou des **protections** d'isolation. Le niveau d'énergie le plus élevé (PS3) implique une inflammation et une éventuelle propagation du feu au-delà de la source d'inflammation. Les critères des **protections** varient en fonction du type de source de puissance qui alimente le circuit.

Ce mesurage de puissance et cette classification des sources s'apparentent aux exigences d'essai LPS de l'IEC 60950-1, mais s'appliquent indépendamment, et les critères se limitent à la puissance disponible par opposition à la combinaison des critères exigés dans l'IEC 60950-1.

Tous les circuits et dispositifs connectés ou destinés à être connectés en tant que charge à chaque source de puissance mesurée sont classés comme faisant partie intégrante de cette source de puissance. Cette méthode d'essai détermine la puissance maximale disponible entre une source de puissance et un circuit qui y est connecté.

L'identification des points d'essai pour la détermination de la source de puissance est laissée à la discrétion du fabricant. Les points d'essai plus courants sont les sorties des circuits d'alimentation internes, les connecteurs, les accès et les connexions entre cartes. Toutefois, ces mesurages peuvent être réalisés en tout point d'un circuit.

Lors de l'évaluation de l'équipement (périphériques) connecté par l'intermédiaire de câbles à un accès d'équipement ou par l'intermédiaire d'un câble, l'impédance d'un câble de connexion peut être prise en compte dans la détermination de la classification PS d'un périphérique connecté. Par conséquent, il est acceptable de procéder au mesurage au niveau du connecteur d'alimentation ou après le câble côté accessoire.

L'emplacement du wattmètre est essentiel, car la puissance totale disponible auprès de la source de puissance (et non la puissance disponible au défaut) est mesurée pendant chaque condition de défaut. Étant donné que certains courants de défaut peuvent être limités par un dispositif de protection, les caractéristiques de temps et de coupure de courant du dispositif de protection utilisé sont prises en considération si elles ont un impact sur la valeur mesurée.

Cette méthode d'essai prend pour hypothèse la présence d'un premier défaut dans la source de puissance ou dans les circuits de charge du circuit faisant l'objet de la classification. Elle prend pour hypothèse:

- a) un défaut dans le circuit faisant l'objet de la classification, et
- b) un défaut dans la source de puissance qui alimente le circuit faisant l'objet de la classification,

chaque condition a) ou b) étant appliquée indépendamment.

La valeur la plus élevée de la puissance mesurée est considérée comme la valeur de classification du circuit PS.

6.2.2.2 Mesurage de la puissance pour le cas de défaut de charge le plus défavorable

Justificatif: Cette méthode d'essai détermine la puissance maximale disponible entre une source de puissance fonctionnant dans les conditions normales de fonctionnement et un circuit connecté à cette source de puissance, en prenant pour hypothèse la présence d'une condition de premier défaut dans le circuit faisant l'objet de la classification. Ce mesurage de puissance prend pour hypothèse que les conditions normales de fonctionnement sont établies avant d'appliquer le premier défaut à un dispositif ou une isolation dans le circuit de charge, afin de déterminer la puissance maximale disponible pour un circuit pendant un défaut.

Ce principe est différent pour les mesurages de puissance d'une **source potentielle d'incendie** lorsque la puissance mesurée disponible est celle de l'emplacement du défaut.

Une valeur de 125 % a été choisie pour obtenir selon un certain degré de certitude l'ouverture du fusible après un certain temps. À cet effet, la situation mesurée n'est pas continue. Il était impossible d'utiliser les caractéristiques d'interruption d'un fusible, car différents types de dispositifs d'interruption présentent des caractéristiques d'interruption totalement différentes. La valeur de 125 % constitue un compromis dont il convient qu'il couvre la majorité des situations.

6.2.2.3 Mesurage de la puissance dans le cas de défaut le plus défavorable de la source de puissance

Justificatif: Cette méthode d'essai détermine la puissance maximale disponible pour une charge normale provenant d'une source de puissance en prenant pour hypothèse la présence d'un premier défaut dans la source de puissance. Le défaut d'une source de puissance peut se traduire par une augmentation de la puissance consommée par un circuit de charge de fonctionnement normal.

6.2.2.4 PS1

Source: IEC 60065, IEC 60695, IEC 60950-1

Justificatif: Une source PS1 est considérée comme ayant trop peu d'énergie pour provoquer une inflammation dans les circuits et composants électroniques.

Il est exigé que la puissance disponible continue soit inférieure à 15 W afin d'obtenir une très faible probabilité d'inflammation. La valeur de 15 W a servi de seuil inférieur pour l'inflammation dans les composants électroniques dans de nombreux documents, y compris l'IEC 60950-1 et l'IEC 60065. Elle a également été couramment démontrée dans le cadre d'essais de défaut d'alimentation limité dans les circuits électroniques.

- Afin de faciliter le mesurage, il a été décidé de procéder au mesurage de 15 W après 3 s. La valeur de 3 s a été choisie pour faciliter le mesurage. Des valeurs d'à peine 100 ms et aussi élevées que 5 s ont également été considérées. Le fait d'établir rapidement une limite de 15 W (moins de 1 s) n'est pas pratique pour les besoins de l'essai et n'est pas considéré comme important pour l'inflammation de combustible classique. Il est admis qu'en principe, il faut 10 s aux thermoplastiques pour s'enflammer lorsqu'ils sont en contact direct avec une petite flamme (méthodes d'essai de matériau à petite échelle de l'IEC 60695).
- En principe, les mesurages doivent être réalisés régulièrement (toutes les secondes, par exemple) sur une période de 3 s en espérant qu'à l'issue, la puissance ne dépasse "jamais" 15 W.
- Historiquement, la puissance des circuits de télécommunication (numéro d'identification 1 du Tableau 13) est limitée par le réseau du bâtiment à des valeurs inférieures à 15 W, et les circuits qui y sont connectés sont considérés comme des circuits PS1 (IEC 60950-1).

Il convient de noter que l'énoncé relatif aux **circuits externes** n'est pas destiné à couvrir les technologies telles que USB et PoE. Il concerne uniquement les signaux de sonnerie analogiques.

6.2.2.5 PS2

Source: IEC 60695-11-10, IEC 60950-1

Justificatif: La source de puissance 2 implique un niveau d'énergie ayant la possibilité d'inflammation et exige une **protection**. La propagation de l'inflammation au-delà du composant enflammé d'origine est limitée par la contribution à faible énergie au défaut, puis par les **protections** permettant de contrôler la résistance à l'inflammation des combustibles situés à proximité.

La principale exigence consiste à limiter la puissance disponible pour ces circuits à 100 W au maximum. Cette valeur inclut la puissance disponible pour le fonctionnement normal et la puissance disponible pour une **condition de premier défaut**.

- Cette valeur a été utilisée dans l'IEC 60950-1 dans le même but, l'inflammation des composants internes étant possible, mais les **enveloppes ignifuges** n'étant pas exigées.

- La valeur de 100 W est souvent utilisée dans certaines réglementations du bâtiment ou réglementations en matière de feu pour identifier l'endroit où un câblage à faible puissance peut être utilisé à l'extérieur d'une **enveloppe** de confinement du feu.
- La valeur est également de 2 x 50 W, qui peut être associée à l'énergie de sources d'inflammation normalisées (flamme d'essai de l'IEC 60695-11-10) sur laquelle reposent les **classes d'inflammabilité du matériau** du classement V à petite échelle. Il est admis que la conversion de l'énergie électrique en énergie thermique est bien inférieure à 100 %, cette valeur étant donc compatible avec les **protections** demandées pour les circuits PS2, qui sont en général une isolation et des combustibles de classement V.

Le mesurage de 5 s pour PS2 permet de vérifier que les limites de puissance disponible sont limitées et pratiques pour les besoins du mesurage. La valeur est également utilisée dans la série IEC 60950 comme cité en référence ci-dessus. Aucune limite à court terme n'est considérée comme nécessaire, la possibilité d'inflammation étant présumée pour les composants des circuits à puissance limitée, en admettant qu'il faille en général au moins 10 s pour que les thermoplastiques pyrolysent, puis s'enflamment lorsqu'ils sont en contact direct avec une petite flamme de 50 W.

Il n'est pas nécessaire que les dispositifs de protection contre les surintensités (comme ceux de la série IEC 60950) soient fiables, car ces circuits sont utilisés dans le produit ou directement à côté de celui-là (n'étant pas largement distribués comme les circuits LPS de l'IEC 60950-1 LPS utilisés pour la connexion à l'alimentation du bâtiment). La fiabilité des circuits PS2 destinés à être utilisés dans le câblage du bâtiment est évaluée pour les **circuits externes** plus avant dans le présent document.

6.2.2.6 PS3

Justificatif: Les circuits PS3 sont des circuits qui ne sont pas classés PS1 ni PS2. Aucun essai de classification n'est exigé, ces circuits pouvant présenter des niveaux de puissance sans limites. Si un circuit n'est pas mesuré, il est réputé être un circuit PS3.

6.2.3 Classification des sources potentielles d'incendie

Justificatif: Avec chaque source de puissance, les points et composants d'un circuit peuvent être évalués pour déterminer si les **sources potentielles d'incendie** sont en outre identifiées. Ces sources d'inflammation sont classées en **source potentielle d'incendie causé par la formation d'un arc électrique** (pour les sources de formation d'arc électrique) ou en **source potentielle d'incendie causé par un phénomène résistif** (pour les sources de chauffage par résistance). Les critères des **protections** varient selon le type de **source potentielle d'incendie** concerné.

Les sources d'inflammation sont classées en fonction de leur aptitude à créer un arc ou à dissiper la chaleur excessive (résistive). Il est important de faire la distinction entre les types de sources d'inflammation, les distances dans l'air depuis les parties d'amorçage par rapport aux autres sources d'incendie résistives variant en raison d'une perte thermique plus élevée dans l'énergie rayonnée, comparée à la flamme conduite ou à la chaleur résistive ayant un impact direct sur un **matériau combustible**.

6.2.3.1 Source potentielle d'incendie causé par la formation d'un arc électrique

Source: IEC 60065

Justificatif: Les **sources potentielles d'incendie causé par la formation d'un arc électrique** sont réputées représenter une source d'énergie thermique résultant de la conversion de l'énergie électrique en un arc, qui peut entrer en contact direct ou indirect avec un matériau combustible.

Des niveaux de puissance inférieurs à 15 W (PS1) sont considérés comme trop bas pour déclencher un feu d'origine électrique dans des circuits électroniques. Cette valeur est utilisée dans l'IEC 60065 (voir également 6.2.1).

La tension minimale (50 V) exigée pour déclencher un arc est également issue de l'IEC 60065 et de l'expérience.

Pour les basses tensions, le défaut qui déclenche le chauffage par arc est en général le résultat d'une connexion desserrée (une connexion soudée brisée, un joint de brasure froide, un contact de connexion faible, un fil mal torsadé, une connexion à vis pas suffisamment serrée, etc.). Étant donné que la ventilation de l'air n'a pas lieu sous 300 V en valeur efficace (loi de Paschen), la plupart des chauffages par arc à basse tension se produisent en contact direct avec un combustible. Pour les tensions supérieures à 300 V, un arc électrique peut se produire dans l'air.

Le mesurage de la tension et du courant nécessaires à l'établissement d'une **source potentielle d'incendie causé par la formation d'un arc électrique** est lié à l'énergie dont dispose le défaut (par opposition à l'énergie disponible à partir d'une source de puissance). La valeur ($V_p \times I_{rms}$) spécifiée n'est ni W ni VA, mais plutôt un nombre calculé reflétant une tension de crête et un courant efficace. Elle n'est pas directement mesurable.

En règle générale, la formation d'un arc électrique sous 300 V est le résultat d'une déconnexion des connexions transportant le courant plutôt que de l'accouplement ou la connexion d'éventuelles connexions transportant le courant.

Dès que les paramètres principaux de tension et de puissance sont satisfaits, il existe trois conditions pour lesquelles les **protections** sont exigées:

- celles qui peuvent former un arc dans les **conditions normales de fonctionnement**;
- toutes les terminaisons dans lesquelles une défaillance électrique donnant lieu à un chauffage est la plus probable; et
- une séparation électrique qui peut être créée pendant une **condition de premier défaut** (l'ouverture d'une trace, par exemple).

Une connexion fiable est une connexion qui est réputée ne pas se déconnecter pendant toute la durée de vie de l'équipement. Les exemples présentés dans la note donnent une idée des types de connexions pouvant être considérés comme fiables.

Le fabricant peut déclarer un emplacement comme étant une **source potentielle d'incendie causé par la formation d'un arc électrique**.

6.2.3.2 Source potentielle d'incendie causé par un phénomène résistif

Source: IEC 60065

Justificatif: Les **sources potentielles d'incendie** résistives peuvent résulter d'un défaut qui provoque la surchauffe d'une impédance dans une faible résistance qui, sinon, ne déclenche pas la protection contre les surintensités. Ce phénomène peut se produire dans un circuit dont la puissance de la source de chauffage résistive est supérieure à 15 W (voir ci-dessus). Une **source potentielle d'incendie causé par un phénomène résistif** peut enflammer une partie en raison d'une dissipation de puissance excessive ou enflammer les matériaux et composants à proximité.

Dans les **conditions de premier défaut**, le présent article exige la présence de deux conditions pour déterminer qu'une partie peut être une **source potentielle d'incendie causé par un phénomène résistif**. La première condition est que l'énergie de défaut disponible est suffisante pour le composant. La seconde condition est que la partie ou les matériaux adjacents peuvent s'enflammer.

La puissance disponible ne constitue pas une exigence relative à une **source potentielle d'incendie causé par un phénomène résistif** dans les **conditions normales de fonctionnement**, l'exigence concernant plutôt la dissipation de puissance de la partie dans les **conditions normales de fonctionnement**.

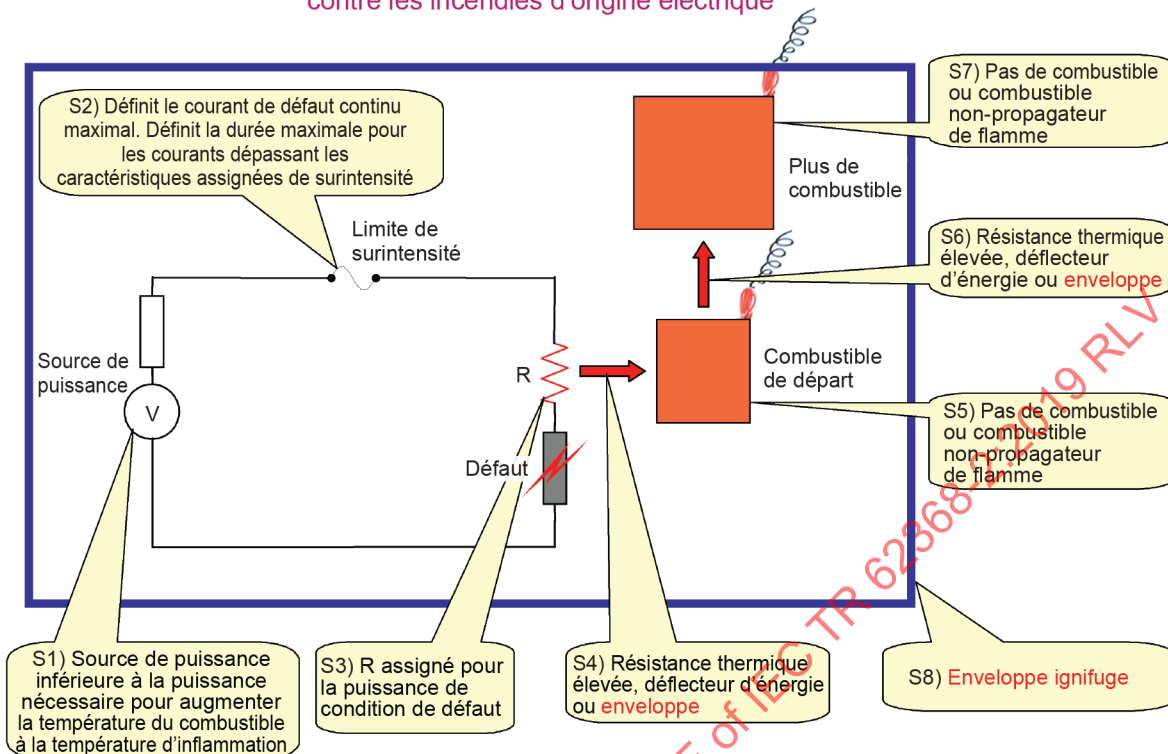
La valeur de 30 s a été utilisée dans l'IEC 60065 et s'est révélée suffisante. La valeur de 100 W a été utilisée dans l'IEC 60065 et s'est révélée adaptée.

Le fabricant peut déclarer un emplacement comme étant une **source potentielle d'incendie causé par un phénomène résistif**.

6.3 Protections contre les incendies dans les conditions normales de fonctionnement et des conditions anormales de fonctionnement

Justificatif: La **protection principale** dans les **conditions normales de fonctionnement** et les **conditions anormales de fonctionnement** consiste à réduire la probabilité d'incendie en limitant la température des combustibles. Cette opération peut consister à vérifier que la conversion d'énergie électrique disponible en énergie thermique ne dépasse pas la température d'inflammation de toute partie.

PROTECTIONS contre les incendies d'origine électrique



IEC

Figure 28 – Protections possibles contre les incendies d'origine électrique

Il existe plusieurs **protections principales** et **protections supplémentaires** contre les incendies d'origine électrique dans les **conditions anormales de fonctionnement** et les **conditions de premier défaut** (voir la Figure 29, le Tableau 8 et le Tableau 9 du présent document). Ces **protections** présentent, entre autres, les caractéristiques suivantes:

- S1) disposition d'une puissance insuffisante pour amener un matériau combustible à la température d'inflammation;
- S2) limitation du courant de défaut continu maximal; limitation de la durée maximale des courants de défaut dépassant le courant de défaut continu maximal (un fusible ou un dispositif analogue de protection contre les surintensités à déconnexion automatique, par exemple);
- S3) choix des caractéristiques assignées d'un composant en fonction des **conditions de premier défaut** plutôt que des **conditions normales de fonctionnement** (empêche la surchauffe du composant);
- S4) assurance d'une résistance thermique élevée du chemin de transfert d'énergie thermique entre la source d'énergie thermique et le matériau combustible (réduit la température et la vitesse de transfert de l'énergie vers le matériau combustible de sorte que ce dernier ne puisse pas atteindre la température d'inflammation); ou présence d'une barrière en **matériau non combustible**;
- S5) utilisation d'un matériau combustible initial le plus proche d'une **source potentielle d'incendie causé par la formation d'un arc électrique** ou d'une **source potentielle d'incendie causé par un phénomène résistif** dont les caractéristiques assignées de température dépassent la température de la source (empêche l'inflammation du combustible); ou d'un matériau combustible retardateur de flamme (empêche la combustion entretenue et la propagation du feu dans l'équipement); voire d'un **matériau non combustible** (métal ou céramique, par exemple);

- S6) assurance d'une résistance thermique élevée du chemin de transfert de l'énergie thermique entre le combustible initial et d'autres matériaux combustibles; ou isolation de la flamme du combustible initial en combustion des autres matériaux combustibles (empêche la propagation du feu dans l'équipement);
- S7) vérification du fait que le matériau à proximité soit un **matériau non combustible** (métal ou céramique, par exemple), soit un matériau retardateur de flamme (empêche la combustion entretenue et la propagation du feu dans l'équipement);
- S8) utilisation d'une **enveloppe** de confinement du **feu** (confine le feu dans l'équipement) ou une **enveloppe** à régulation d'oxygène (étouffe un incendie);
- S9) utilisation de connexions électriques fiables;
- S10) utilisation de composants et connexions de **batterie** irréversibles;
- S11) utilisation d'une protection mécanique (des barrières, un filet ou dispositifs similaires par exemple) avec des ouvertures limitées;
- S12) application d'instructions de fonctionnement, de **protections par instructions** et de mises en garde claires.

Méthodes de protection

A) Protection dans les conditions normales de fonctionnement et des conditions anormales de fonctionnement

Les matériaux et composants ne doivent pas dépasser leurs températures d'autoinflammation.

B) Protection dans les conditions de premier défaut

Deux méthodes permettent d'assurer la protection. L'une des méthodes peut être appliquée à différents circuits du même équipement:

- Empêcher l'inflammation: l'équipement est conçu de sorte que dans les **conditions anormales de fonctionnement** et les **conditions de premier défaut**, aucune partie ne s'enflamme;
- Contrôler la propagation du feu: choix et application des composants, du câblage, des matériaux et des mesures de construction visant à réduire la propagation des flammes et, si nécessaire, à l'aide d'une **enveloppe ignifuge**.

Les valeurs de ramollissement thermoplastique ou les indices thermiques relatifs (RTI – *relative thermal indices*) n'étaient pas considérés comme appropriés, car ils ne sont pas spécifiquement liés aux propriétés d'inflammation des matériaux combustibles.

La fiabilité d'un dispositif qui fonctionne comme une **protection** pendant le fonctionnement normal (lorsqu'il est laissé dans le circuit) doit être évaluée. Si un dispositif est extrait du circuit pendant les essais de fonctionnement normal, il n'est alors pas considéré comme une **protection**.

Les **conditions anormales de fonctionnement** qui ne donnent pas lieu à un premier défaut sont considérées d'une manière très semblable comme des **conditions normales de fonctionnement** si la condition est corrigée et le fonctionnement normal présumé être rétabli. Toutefois, les **conditions anormales de fonctionnement** qui donnent lieu à une **condition de premier défaut** doivent être traitées selon 6.4 plutôt que 6.3. Voir la Figure 29 du présent document pour un diagramme des causes d'incendie.

Tableau 8 – Exemples d'application de différentes protections

Cause	Méthodes de prévention/protection	Protection
Début d'incendie dans les conditions normales de fonctionnement	Température limite du matériau combustible	Principale
Début d'incendie dans les conditions anormales de fonctionnement et les conditions de premier défaut	Choisir la méthode de prévention de l'inflammation ou de contrôle de la propagation du feu	Supplémentaire
Circuit PS1	La puissance disponible faible réduit la probabilité d'inflammation	S1
Circuit PS2 ou PS3	Réduire la probabilité d'inflammation Utiliser des dispositifs de protection Distance suffisante ou barrière solide placée entre un matériau combustible et chaque source potentielle d'incendie	S1, S2, S3, S5 S2 S4 (S6)
Circuit PS2	Limiter la puissance disponible Distance suffisante ou barrière solide placée entre un matériau combustible et chaque source potentielle d'incendie Utiliser un matériau retardateur de flamme ou un matériau non combustible	S1, S2 S4, S6 S5
Circuit PS3	Utiliser toutes les options PS2 et: – Utiliser des enveloppes de confinement du feu – Utiliser des matériaux retardateurs de flammes ou des matériaux similaires	S8 S7
Câblage interne et externe	Construction fiable Limiter la température du fil et utiliser une isolation ignifuge	S9
Incendie provoqué par l'entrée d'objets étrangers et le court-circuit qui en résulte des bornes électriques des circuits PS2 et PS3	Empêcher l'entrée d'objets étrangers	S11
Cordons du réseau d'alimentation	Construction fiable Limiter la température du fil et utiliser une isolation ignifuge	S9
Incendie ou explosion dû(e) aux conditions anormales de fonctionnement des batteries	Limiter les courants de charge/décharge Limiter les courants de court-circuit Empêcher l'utilisation d'une mauvaise polarité	S1 S2 S10

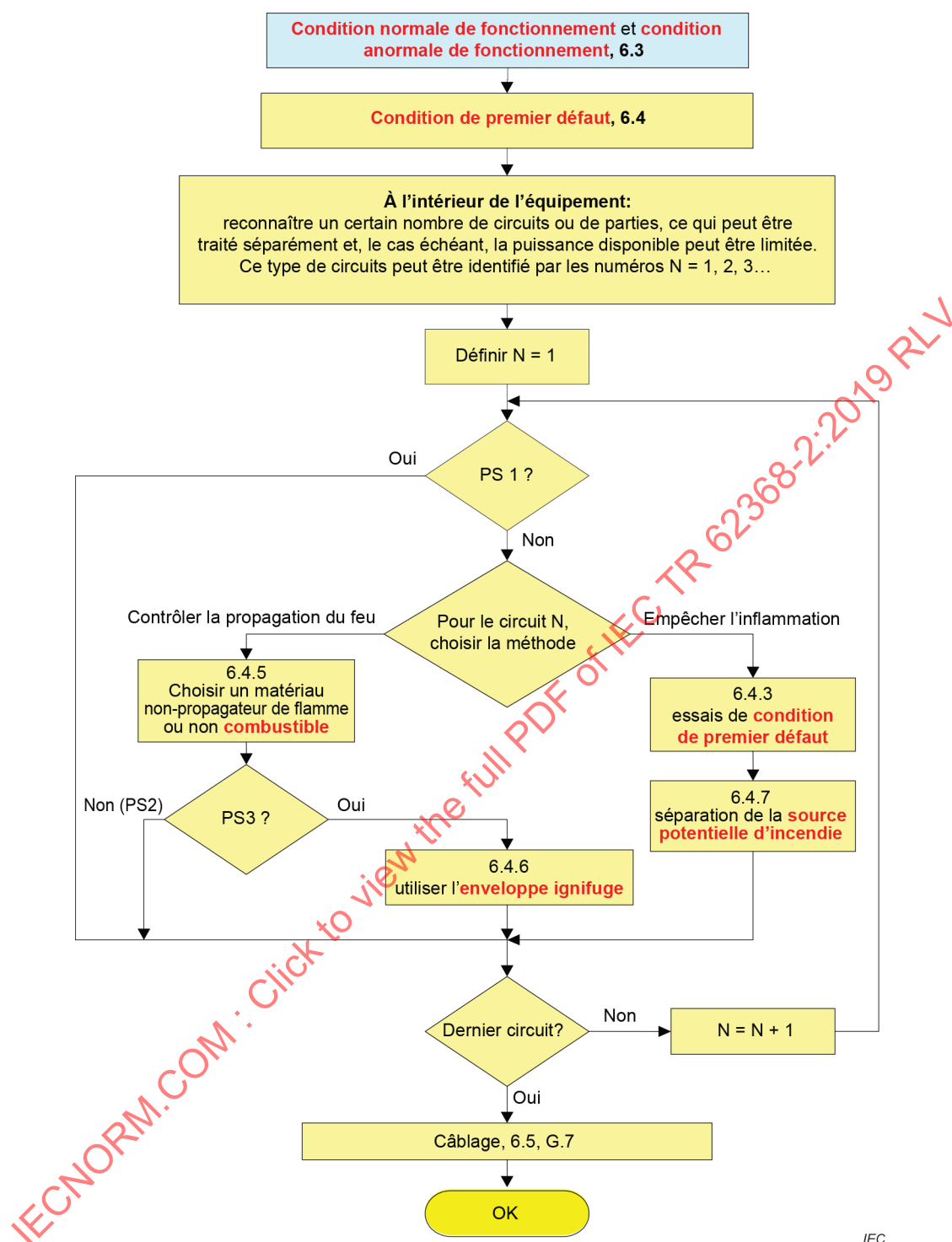


Figure 29 – Diagramme des causes d'incendie

6.3.1 Exigences

Source: IEC 60950-1, ISO 871

Justificatif: La température d'inflammation spontanée des matériaux mesurée par l'ISO 871 a été choisie comme point d'inflammation des combustibles. Les tableaux spécifiques aux matériaux ont été supprimés au profit d'une simple exigence ou d'une référence complète à la norme ASTM concernant les températures d'autoinflammation des matériaux.

La valeur de 300 °C pour les thermoplastiques est environ 10 % inférieure à la température d'inflammation la plus basse des matériaux communément utilisés dans des équipements TIC et CE. Cette valeur a également été utilisée dans l'IEC 60950-1. Le concepteur peut utiliser les fiches techniques des matériaux qui dépassent cette valeur, mais la spécification d'autoinflammation doit être réduite de 10 % afin d'adapter les variations et l'incertitude de mesure.

Dans le contexte d'un incendie, les **conditions anormales de fonctionnement** (événements bloqués, surcharge du connecteur, etc.) doivent être considérées simplement comme une **condition normale de fonctionnement**, sauf si la **condition anormale de fonctionnement** donne lieu à une **condition de premier défaut**.

Dans le cadre du contrôle de conformité, les fiches techniques des matériaux utilisés doivent être en premier lieu contrôlées afin de pouvoir évaluer les résultats des mesurages de l'échauffement.

L'essai au fil incandescent est une méthode d'essai de résistance au feu qui applique une source de chaleur à l'échantillon. L'essai offre un moyen de comparer la tendance d'un matériau à résister à l'inflammation, à l'autoextinction des flammes (en cas d'inflammation) et à ne pas propager l'incendie. Les fabricants utilisent cette méthode d'essai depuis de nombreuses années pour déterminer les caractéristiques de résistance à la flamme des matières plastiques conformément à l'IEC 60950-1, et ce, sans constatation de problèmes sur le terrain quant à la pertinence de l'essai. Ainsi, il convient que l'essai au fil incandescent reste une option par rapport aux caractéristiques assignées HB des matières plastiques hors de **l'enveloppe ignifuge ou des enveloppes mécaniques** et pour les circuits PS1 des boîtiers **d'enveloppes électriques**. Ce précédent a été défini dans l'IEC 60950-1 et il convient de l'inclure dans l'IEC 62368-1.

Tableau 9 – Protections principales contre l'incendie dans les conditions normales de fonctionnement et les conditions anormales de fonctionnement

Conditions normales de fonctionnement et conditions anormales de fonctionnement		
Le présent paragraphe a pour objectif de définir les exigences de réduction de la probabilité d'inflammation dans les conditions normales de fonctionnement et les conditions anormales de fonctionnement .		
PS1 PS2 PS3	6.3.1	L'inflammation n'est pas admise
		$T_{\max} \leq$ température d'autoinflammation de 90 % conformément à l'ISO 871; ou $T_{\max} \leq 300$ °C
		Les matériaux combustibles des composants et autres parties hors des enveloppes ignifuges (y compris les enveloppes électriques , les enveloppes mécaniques et les pièces de décoration), doivent avoir une classe d'inflammabilité du matériau d'au moins:
		– HB75 si l'épaisseur significative la plus mince de ce matériau est < 3 mm, ou – HB40 si l'épaisseur significative la plus mince de ce matériau est ≥ 3 mm, ou – HBF. NOTE Si une enveloppe sert également d'enveloppe ignifuge, les exigences relatives à ce type d'enveloppe s'appliquent. Ces exigences ne s'appliquent pas aux: – parties dont la taille est inférieure à 750 mm³; – alimentations, matériaux consommables, supports et matériaux d'enregistrement; – parties qui doivent présenter des propriétés particulières pour remplir les fonctions prévues (les rouleaux en caoutchouc synthétique et les tubes d'encre – engrenages, cames, courroies, roulements et autres parties qui apportent au feu une contribution négligeable comme combustible, y compris les étiquettes, pieds de fixation, capuchons de clés, boutons et similaires

6.3.2 Critères de conformité

Justificatif: Le régime établi pour les mesurages de températures supérieures à 300 °C exige une plus grande tolérance quant à la valeur de l'augmentation en raison de la difficulté à obtenir une lecture stable. Toutefois, la valeur de B.1.6 a été considérée comme adaptée étant donné qu'en général, ces valeurs n'augmentent plus, mais sont plutôt cycliques. La valeur de 3 °C sur une durée de 15 min a également été prise en considération pour le mesurage de ces températures très élevées, mais n'a pas été utilisée au profit de l'harmonisation avec d'autres articles.

L'utilisation de **protections** limitant la température dans les **conditions normales de fonctionnement** et les **conditions anormales de fonctionnement** est considérée comme acceptable uniquement si la **protection** ou le dispositif s'est révélé(e) être un dispositif fiable de contrôle de la température.

6.4 Protections contre l'incendie dans les conditions de premier défaut

6.4.1 Généralités

Source: IEC 60065, IEC 60950-1

Justificatif: La considération de l'article précédent vise à limiter la probabilité d'inflammation des combustibles dans les **conditions normales de fonctionnement** et les **conditions anormales de fonctionnement** avec une protection **principale**. Il convient d'utiliser tous les combustibles sous leurs températures d'inflammation et de les séparer des parties qui produisent un arc électrique.

Les exigences du présent article consistent à limiter l'inflammation ou la propagation du feu dans les **conditions de premier défaut** au moyen de **protections supplémentaires** (voir le Tableau 10 du présent document). Deux approches peuvent être utilisées conjointement ou indépendamment:

- la méthode 1 réduit le plus possible la possibilité d'inflammation par l'utilisation de **protections** appliquées à chaque point potentiel d'inflammation,
- la méthode 2 part du principe que l'inflammation des combustibles est limitée dans le produit et que, par conséquent, elle exige des **protections** qui limitent la propagation du feu au-delà du point d'inflammation initial ou dans le cas d'une énergie plus importante, au-delà de l'**enveloppe** de l'équipement.

Tableau 10 – Protections supplémentaires contre l'incendie dans les conditions de premier défaut

Conditions de premier défaut	
Deux méthodes permettent d'assurer la protection. L'une des méthodes peut être appliquée à différents circuits du même équipement (6.4.1)	
Méthode 1 Réduire la probabilité d'inflammation	L'équipement est conçu de telle sorte que dans les conditions de premier défaut, aucune partie ne doit s'enflammer. Cette méthode peut être utilisée pour tous les circuits dans lesquels la puissance en régime permanent disponible pour le circuit ne dépasse pas 4 000 W. Les exigences et essais appropriés sont détaillés en 6.4.2 et 6.4.3.
Méthode 2 Contrôle de la propagation du feu	Sélection et application des protections supplémentaires pour les composants, le câblage, les matériaux et les mesures de construction qui réduisent la propagation du feu et, si nécessaire, par l'utilisation d'une deuxième protection supplémentaire une enveloppe ignifuge par exemple. Cette méthode peut être utilisée pour tout type d'équipement. Les exigences appropriées sont détaillées en 6.4.4, 6.4.5 et 6.4.6.

L'utilisateur du document ou le concepteur du produit choisit une méthode à appliquer à chaque circuit (empêcher l'inflammation ou contrôler la propagation du feu). Une méthode peut être choisie pour un produit complet, une partie d'un produit ou un circuit.

Le niveau de puissance de 4 000 W a été choisi pour vérifier que les produits connectés au **réseau d'alimentation** basse puissance (moins de 240 V x 16 A), habituel dans les bureaux ou les domiciles, peuvent utiliser les méthodes de protection contre l'inflammation, et assurer une séparation raisonnable et pratique des types de produits. Il est admis que cette valeur n'est pas représentative des courants de défaut disponibles, mais qu'il s'agit d'une séparation pratique et représentative en fonction d'un équipement relié aux circuits du **réseau d'alimentation** domestique et professionnel normal faisant plus souvent l'expérience des **protections contre les sources potentielles d'incendie**.

Le fait de limiter les valeurs sous 4 000 W crée des problèmes pour le **réseau d'alimentation** en courant alternatif de pratiquement tous les équipements utilisés au domicile ou au bureau, ce qui n'est pas le but. Il est beaucoup plus judicieux d'utiliser une puissance de source d'énergie de 4 000 W en fonction de la tension du **réseau d'alimentation** et des caractéristiques assignées du dispositif de protection contre les surintensités, ce qui permet effectivement à tous les **équipements enfichables de type A** d'utiliser l'une ou l'autre des méthodes, et de limiter l'utilisation de sources d'énergie haute puissance à la méthode de contrôle de propagation du feu.

La valeur de 4 000 W peut être vérifiée par essai pour les circuits individuels. Toutefois, une note a été ajoutée pour préciser les types de produits dont la valeur est inférieure sans essai. Le calcul du produit de la tension nominale du **réseau d'alimentation** et des caractéristiques assignées du dispositif de protection contre les surintensités de ce réseau n'est pas une technique habituelle. Il convient en revanche que le produit de deux nombres ne dépasse pas 4 000 (voir le texte ci-dessous).

NOTE Tous les **équipements enfichables de type A** sont considérés comme n'excédant pas la valeur en régime permanent de 4 000 W. Les **équipements enfichables de type B** et les **équipements reliés en permanence** sont considérés comme n'excédant pas cette valeur en régime permanent si le produit de la tension nominale du **réseau d'alimentation** et de la valeur assignée du courant du dispositif de protection contre les surintensités de l'installation est inférieur à 4 000.

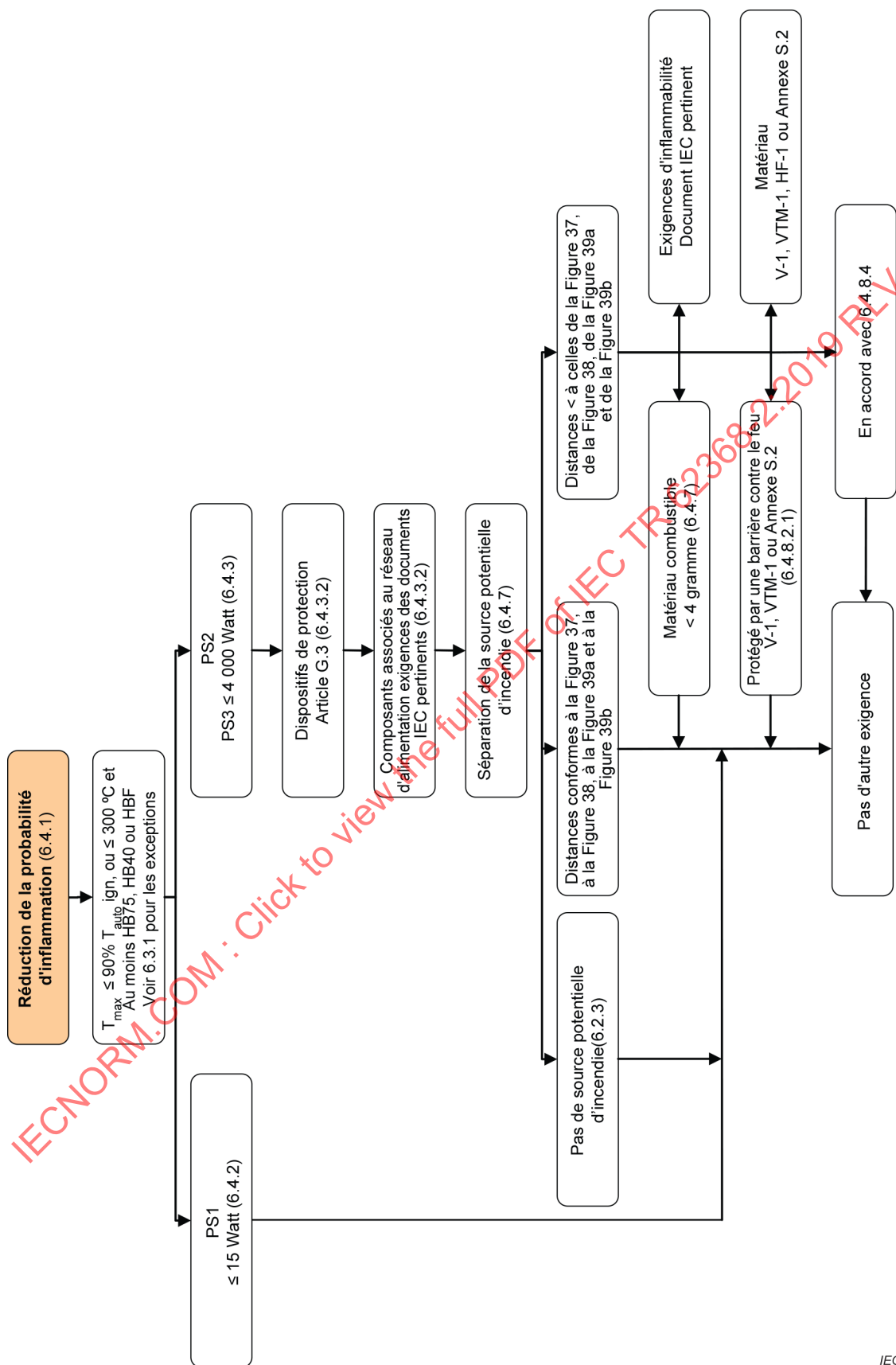
Méthode permettant d'empêcher l'inflammation: Définir les exigences de **protection** visant à empêcher l'inflammation et reposant essentiellement sur les essais de défaut et le choix et la conception des composants qui réduisent la probabilité de feu entretenu. Si une **source potentielle d'incendie** est identifiée, des **protections** supplémentaires sont exigées pour utiliser des barrières et le cône de feu "ne pas entrer" pour les matériaux non inflammables (voir le Tableau 11 et la Figure 30 du présent document).

La méthode permettant d'empêcher l'inflammation a été utilisée dans l'IEC 60065 dans laquelle le raccordement des produits est essentiellement à des circuits du **réseau d'alimentation** basse puissance (< 16 A). L'utilisation de cette méthode n'a pas été considérée comme suffisamment adaptée pour les circuits de **réseau d'alimentation** plus importants, car la taille du cône de feu ne tient pas suffisamment compte des sources d'incendie importantes habituelles dans les circuits de puissance plus élevée.

Cette approche limite l'utilisation des méthodes permettant d'empêcher l'inflammation aux produits dont les sources d'inflammation se caractérisent par les cônes de feu et les **conditions de premier défaut** décrits en 6.4.7.

Tableau 11 – Méthode 1: Réduire la probabilité d'inflammation

Méthode 1: Réduire la probabilité d'inflammation dans les conditions de premier défaut		
PS1 (≤ 15 W après 3 s)	6.4.2	Aucune protection supplémentaire n'est nécessaire pour la protection contre PS1. Un PS1 n'est pas réputé contenir suffisamment d'énergie pour permettre aux matériaux d'atteindre leurs températures d'inflammation.
PS2 ($> PS1$ et ≤ 100 W après 5 s)	6.4.3	Le présent paragraphe a pour objectif de définir les protections supplémentaires nécessaires à la réduction de la probabilité d'inflammation dans les conditions de premier défaut dans les circuits PS2 et les circuits PS3 dont la puissance disponible ne dépasse pas 4 000 W. Il est nécessaire de considérer toutes les protections supplémentaires selon la configuration de l'équipement.
et		Le feu entretenu > 10 s n'est pas admis et aucune partie environnante ne doit être enflammée.
PS3 ($> PS2$ et $\leq 4\,000$ W)		Séparation de la source potentielle d'incendie causé par la formation d'un arc électrique et de la source potentielle d'incendie causé par un phénomène résistif selon 6.4.7 – Les distances doivent être conformes aux Figures 37, 38, 39a et 39b; ou – Si la distance entre une source potentielle d'incendie et un matériau combustible est inférieure aux distances spécifiées aux Figures 37, 38, 39a et 39b; • Masse du matériau combustible < 4 g, ou • Protégé contre la PIS par une barrière contre le feu, ou • Exigences d'inflammabilité: ○ Matériau de classe V-1; matériau de classe VTM-1 ou matériau de classe HF-1, ou brûleur-aiguille spécifié à l'Article S.2, ou ○ Document IEC de composants pertinent
		Utilisation de dispositifs de protection conformes à G.3.1, G.3.2, G.3.3 et G.3.4 ou au document IEC de composants pertinent pour ce type de dispositifs;
		Utilisation de composants conformes à G.5.3 et G.5.4 ou au document IEC de composants pertinent;
		Les composants associés au réseau d'alimentation doivent satisfaire aux documents IEC de composants pertinents; et exigences des autres articles de l'IEC 62368-1

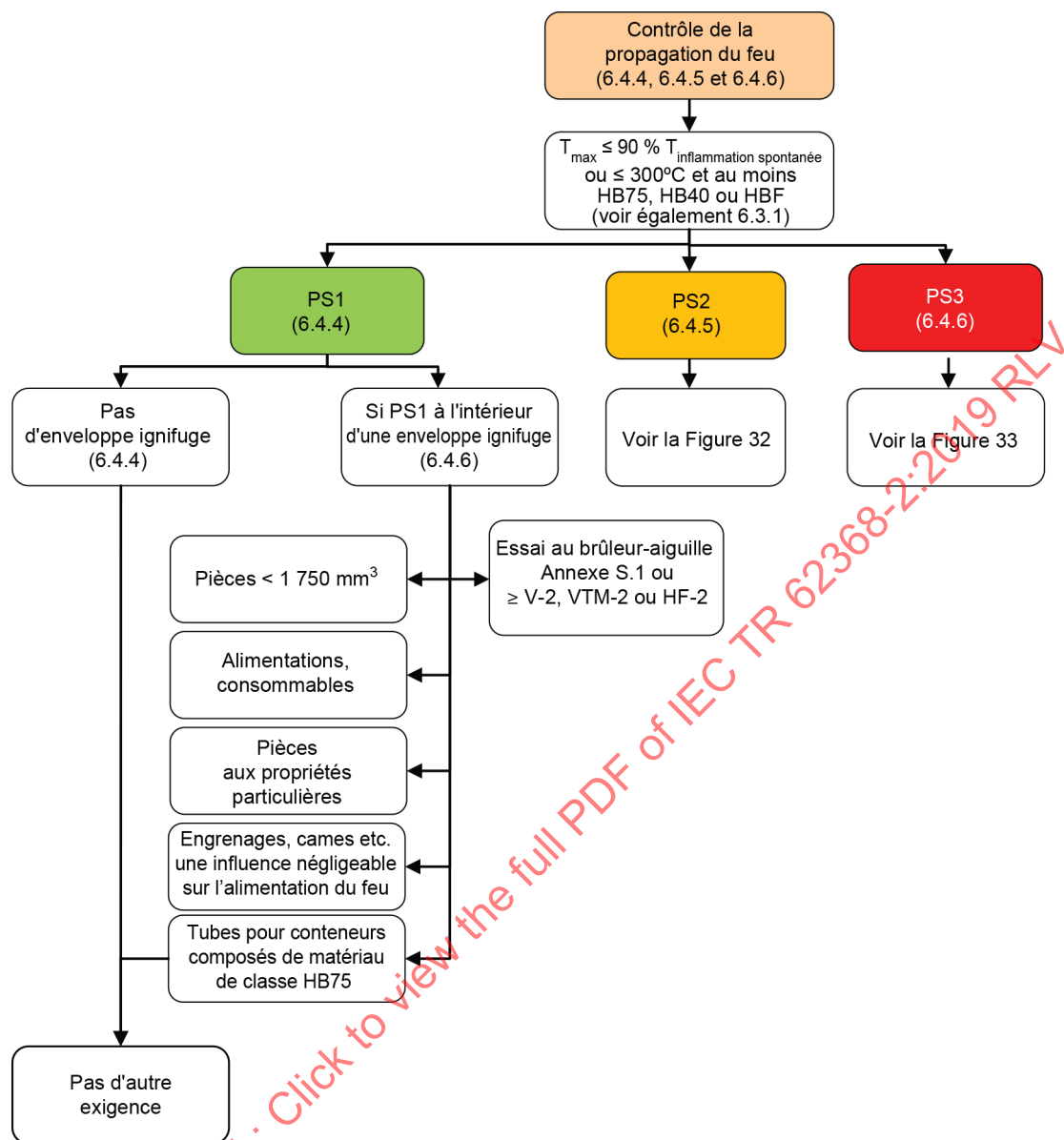


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Figure 30 – Diagramme de prévention de l'inflammation

Méthode de contrôle de la propagation du feu: Prévoir des **protections** liées à la propagation du feu provenant de sources d'incendie connues. Cette disposition implique très peu d'essais de performances (pas de **condition de premier défaut**) et une conception des **protections** de manière à réduire le plus possible la propagation des flammes dans le produit et au-delà de l'**enveloppe ignifuge**. Les **protections** décrites sont fonction du niveau de puissance, les sources de puissance plus élevée exigeant des **protections** plus importantes (voir la Figure 31, la Figure 32 et le Tableau 12 du présent document).

Cette séparation de puissance (4 000 W) est également utilisée dans la méthode de contrôle de la propagation du feu afin de délimiter les critères de **protection** pour les matériaux de l'**enveloppe ignifuge** (V-1 par rapport à 5 V). L'IEC 60950-1 a déjà utilisé le poids pour définir les critères de l'**enveloppe ignifuge**, et il a été estimé que l'utilisation de la puissance disponible était plus appropriée et en général plus représentative de la pratique courante.



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Figure 31 – Contrôle de la propagation du feu – Récapitulatif