

TECHNICAL REPORT



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

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Part 2: Explanatory information related to IEC 62368-1



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

This second edition cancels and replaces the first edition published in 2011. This edition constitutes a technical revision.

This second edition updates the first edition of IEC 62368-2 published in 2011 to take into account changes made to IEC 62368-1:2010 as identified in the Foreword of IEC 62368-1:2014.

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
108/540/DTR	108/553/RVC

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 standard, 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).

In this standard, "HBSDT" stands for Hazard Based Standard Development Team, which is the Working Group of 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 considered to need further background reference information or explanation of their content to benefit the reader are included. Therefore, not all numbered subclauses are cited. Unless otherwise noted, all references are to clauses, subclauses, annexes, figures or tables are located in IEC 62368-1:2014.

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AUDIO/VIDEO, INFORMATION AND COMMUNICATION TECHNOLOGY EQUIPMENT –

Part 2: Explanatory information related to IEC 62368-1:2014

Clause 0 Principles of this product safety standard

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

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 62368-1:2014:

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
c) information for end users	4. behavioral safeguards 5. instructional safeguards

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 standard may require an equipment safeguard solely for the protection of a skilled person while performing servicing activity.

Clause 1 Scope

Purpose: To identify the purpose and applicability of this standard 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.

Clause 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 standard. As such, referenced documents are indispensable for the application of this standard. 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 standards. Therefore 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 standard. Their use is specified, where necessary, for the application of the requirements of this standard.

Clause 3 Terms, definitions and abbreviations

Rationale: is provided for definitions that deviate from IEC 60050 definitions or from pilot standard 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 standard.

Rationale: The 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 standard 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 standard.
Rationale: The 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 standard 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 standard.
Rationale: See 3.3.5.1, basic insulation.

3.3.5.5 solid insulation

Source: IEC 60664-1:2007, 3.4
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.

3.3.5.6 supplementary insulation

Source: IEC 60050-195:1998, 195-06-07
Purpose: To support the concept of safeguards as used in this standard.
Rationale: See 3.3.5.1, basic insulation.

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

3.3.7.8 reasonably foreseeable misuse

Source: ISO IEC Guide 51:2014, definition 3.14
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 standard 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 standard, 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 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 definition is modified to use the phrase “to reduce the likelihood of”. IEC 62368-1 does not use the word “hazard”.

3.3.14.4 prospective touch voltage

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

Purpose: To properly identify electric shock energy source voltages.

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

3.3.14.9 working voltage

Source: IEC 60664-1:2007, definition 3.5

Purpose: To distinguish between r.m.s. working voltage and peak working voltage.

Rationale: The IEC 60664-1 definition is modified to delete “r.m.s”. IEC 62368-1 uses both r.m.s. working voltage and peak 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 standard, for completeness, it was decided to retain this definition.

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

Clause 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 standards. Rationale is also provided for further explanation of new concepts and requirements in this standard.

Reasonable foreseeable misuse

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

functional insulation

Rationale: This standard 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 and reinforced insulation may also serve as functional insulation, in which case the insulation is not faulted.

functional components

Rationale: This standard 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, supplementary, 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 standard 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 IEC component standards.

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

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

Rationale: To facilitate a smooth transition from the legacy standards IEC 60065 and IEC 60950-1 to IEC 62368-1, including by the component supply chain, this standard allows for acceptance of both components and sub-assemblies investigated to the legacy standards. Individual component requirements within these standards 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.

4.2.1

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, 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.

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.

4.2.3

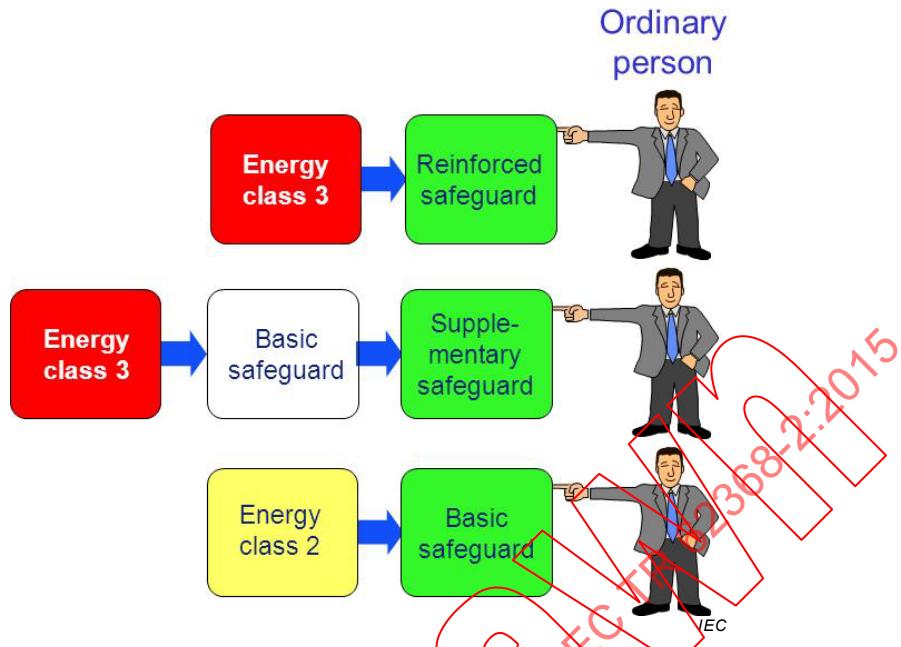
Class 3 energy source

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 of the safeguards applicable to class 3 are required.

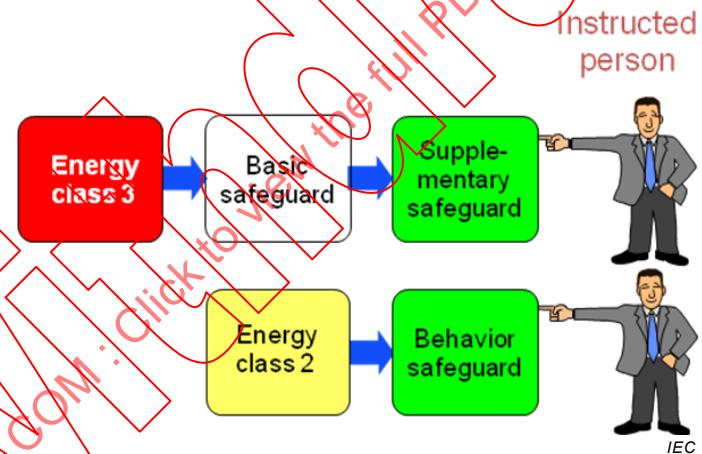
4.3.2

Safeguards for protection of an ordinary person



4.3.3

Safeguards for protection of an instructed person



4.3.4

Safeguards for protection of a skilled person

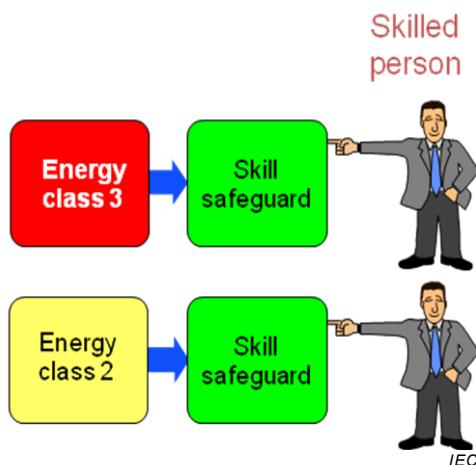


Table 1 – General summary of required safeguards

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

Table 1 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 standard.

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 standard 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.

4.4.4 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.

4.4.4.6 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.

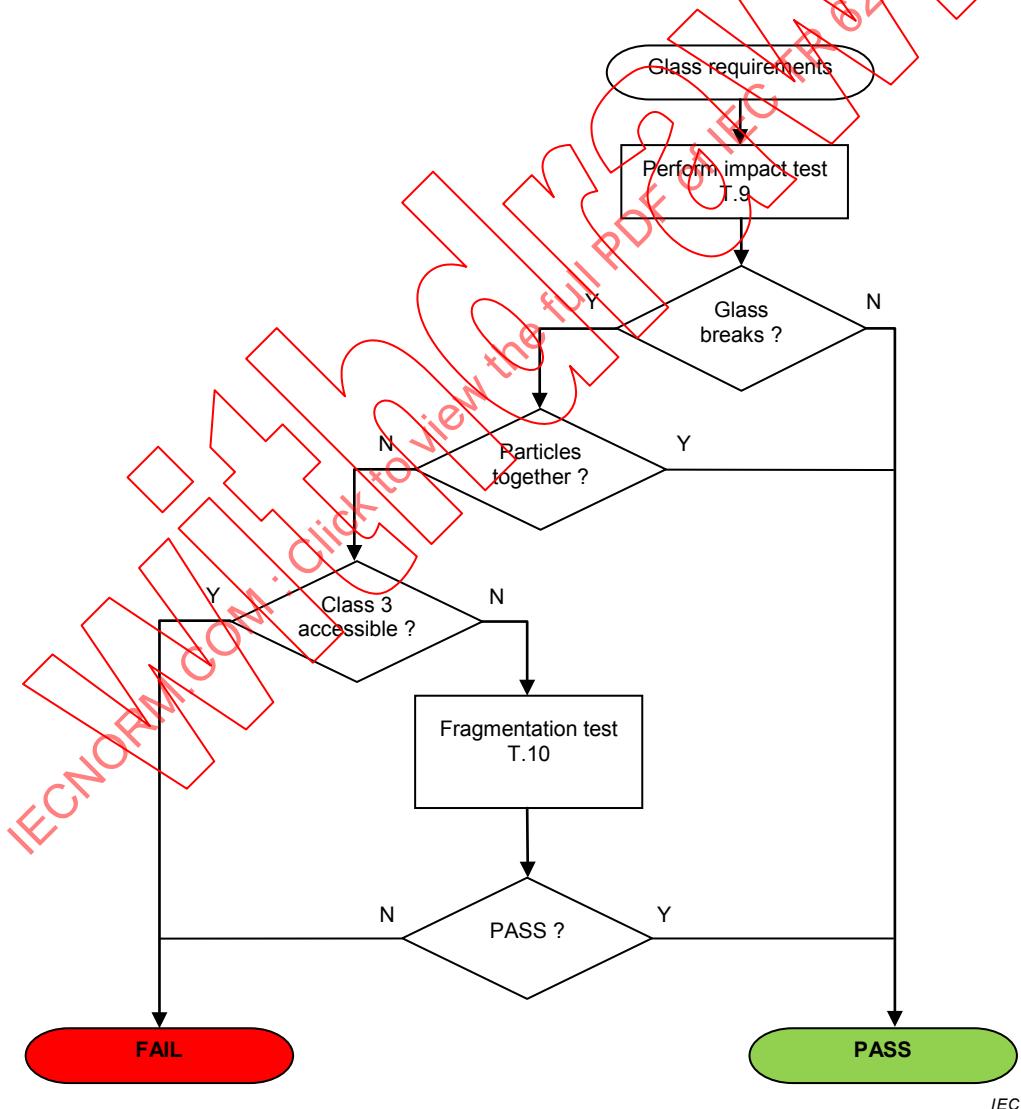
Platen glass has a long history of being exempted, because it is quite obvious for people that, if broken, the broken glass is hazardous and contact should be avoided. There is no known history of serious injuries with this application. Platen glass is the glass that is typically used in scanners, copiers, 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.

CRT's 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 following flow chart shows the intent for the requirements.



4.4.4.9 Compliance criteria

The value of 30 g for the weight limit is chosen based on the maximum dimension 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 standard 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, including 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 clause 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.

Clause 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 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 standards 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 TC108, 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 6.5.3).

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 ($\sim 1 \text{ cm}^2$);
- 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 and any isolated circuits where both contacts are easily available to touch.

A simplified application of these requirements in the standard 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 5 mA 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.

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 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 1 and Figure 2, Table 2 and Table 3 in this technical report) 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 1 and Figure 2, Table 2 in this technical report) 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 1 and Figure 2, Table 2 and Table 3 in this technical report) is the ES3 zone.

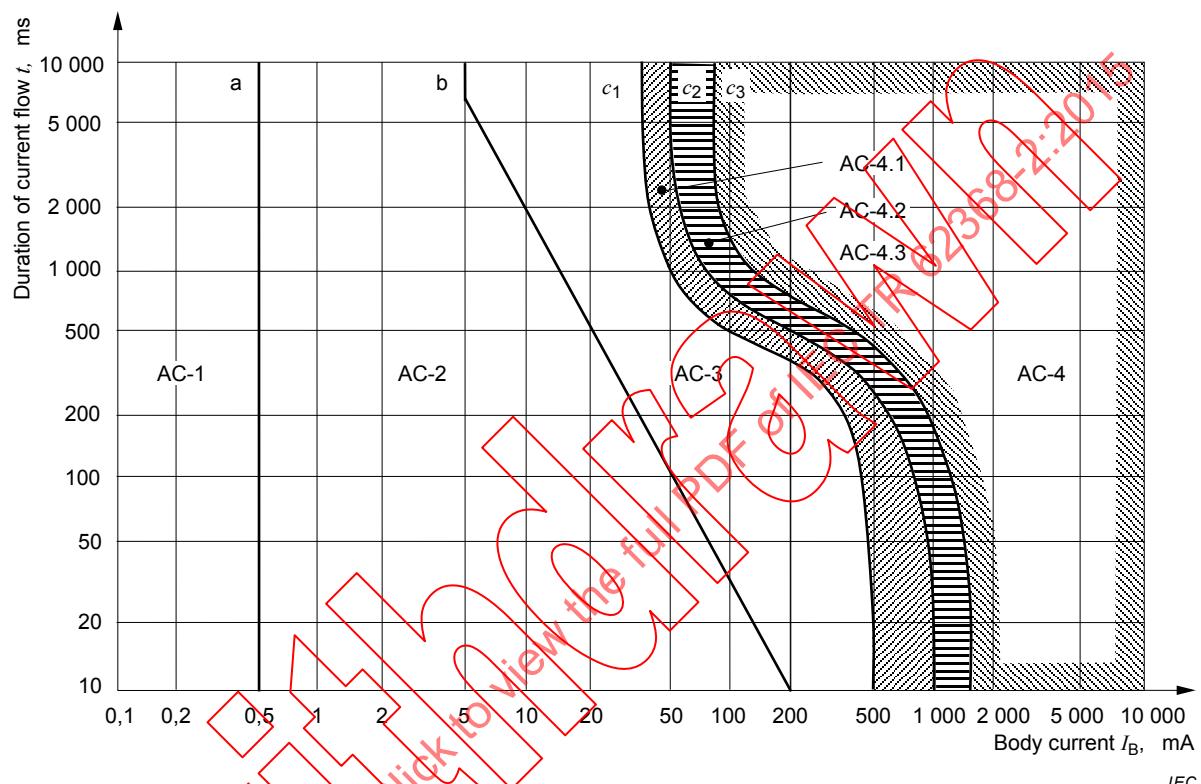
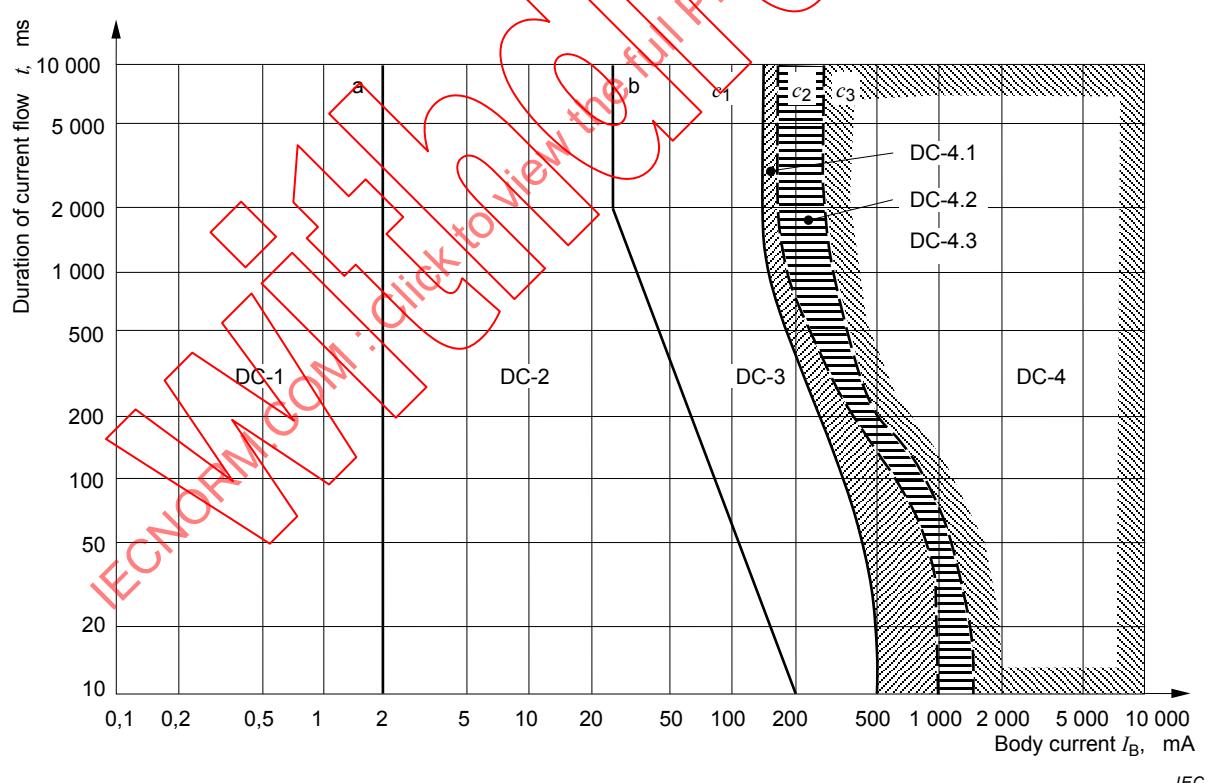


Figure 1 – Conventional time/current zones of effects of a.c. currents (15 Hz to 100 Hz) on persons for a current path corresponding to left hand to feet (see IEC TS 60479-1:2005, Figure 20)

**Table 2 – Time/current zones for a.c. 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 which flows in the path left hand to feet. For other current paths the heart current factor has to be considered.



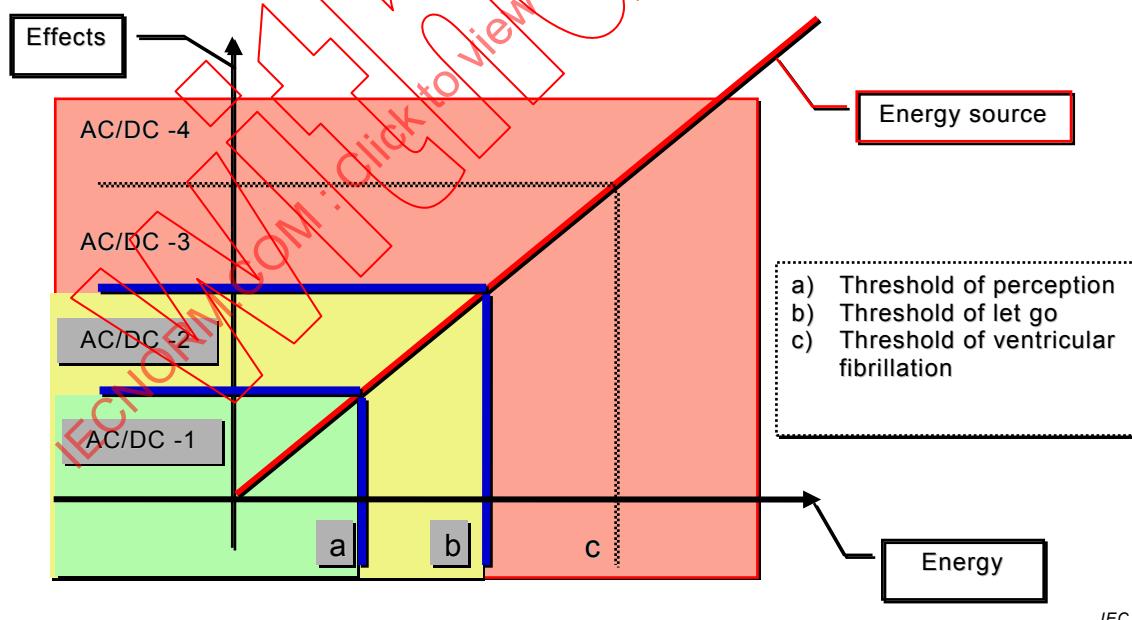
**Figure 2 – Conventional time/current zones of effects of d.c. currents on persons
for a longitudinal upward current path (see IEC TS 60479-1:2005, Figure 22)**

**Table 3 – Time/current zones for d.c. 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	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.
	$c_1 - c_2$	DC-4.1 Probability of ventricular fibrillation increasing up to about 5 %.
	$c_2 - c_3$	DC-4.2 Probability of ventricular fibrillation up to about 50 %.
	Beyond curve c_3	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 1 and Figure 2 in this technical report (see IEC TS 60479-1:2005, Figures 20 and 22) are transferred into a graph: effects = (f) energy (see Figure 3 in this technical report).



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Figure 3 – Illustration that limits depend on both voltage and current

Within the standard 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.

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

In the standard 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 1 and Figure 2 in this technical report (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 1 and Figure 2 in this technical report (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 1 and Figure 2 in this technical report (see IEC TS 60479-1:2005, Figures 20 and 22).

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 1 and Figure 2 in this technical report (see IEC TS 60479-1:2005, Figures 20 and 22).

The basis for setting limits for combined a.c. and d.c. touch current is from the work of Dalziel which provides clear data for men, women and children. Since 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, Table 4 address the Dalziel investigations.

Under single fault conditions of a relevant basic or supplementary safeguard, touch current is measured according to 5.1.2 of IEC 60990:1999. 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 above 2 mA r.m.s., which has been done here. IEC TC108 has decided that parts under single fault conditions of relevant basic or supplementary safeguards should be measured per Figure 5 of IEC 60990:1999 (let-go network). Therefore, since 5.1.2 makes reference to both Figure 4 and Figure 5 of IEC 60990:1999, for clarification Table 5 is mentioned directly in this subclause 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; zone AC-2 and zone DC-2).

Because harmful physiological effects may occur when touching ES3, (IEC TS 60479-1; 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.

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.

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 (μ F)	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 d.c. current values of Table 4, assuming 25 mA gives a voltage of 120 V d.c. (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 120 V d.c. 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:

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

$$1 + \frac{\log t_2 - \log t}{\log t - \log t_1}$$

and

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

$$1 + \frac{\log V_2 - \log V}{\log V - \log V_1}$$

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 d.c. voltages.

For ES2, the voltage limits have been calculated by using the d.c. current values of curve b Figure 2 in this technical report and the resistance values of Table 10 of IEC TS 60479-1:2005, column for 5 % of the population (see Table 5 in this technical report).

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 2 in this technical report.

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:

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

$$1 + \frac{\log t_2 - \log t}{\log t - \log t_1}$$

and

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

$$1 + \frac{\log I_2 - \log I}{\log I - \log I_1}$$

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, d.c., 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.

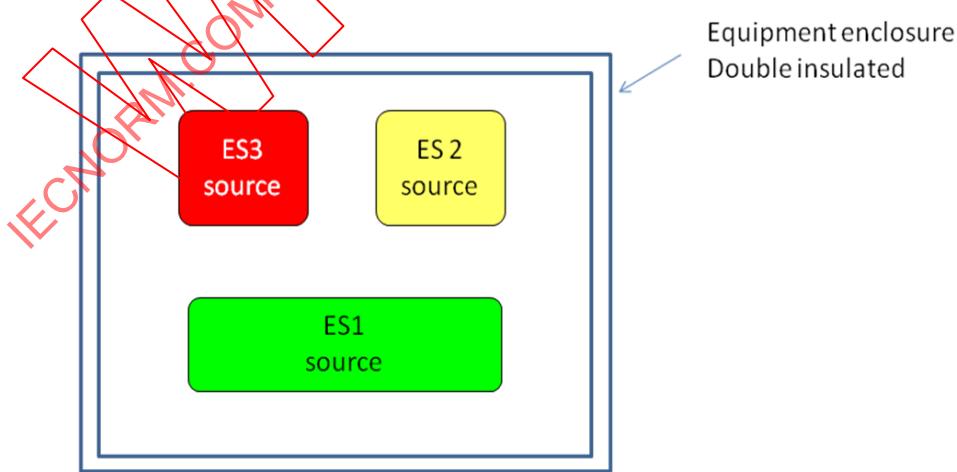
Rationale: The proposed limits for touch voltages at terminals involving audio signals that may be contacted by persons have been extracted without deviation from IEC 60065. Reference: 9.1.1.2 a) of IEC 60065:2014. Under single fault conditions, 10.2 of IEC 60065:2014 does not permit an increase in acceptable 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 r.m.s.;
- the National Electrical Code (USA) permits accessible terminals with maximum output voltage of 120 V r.m.s.

5.3.2

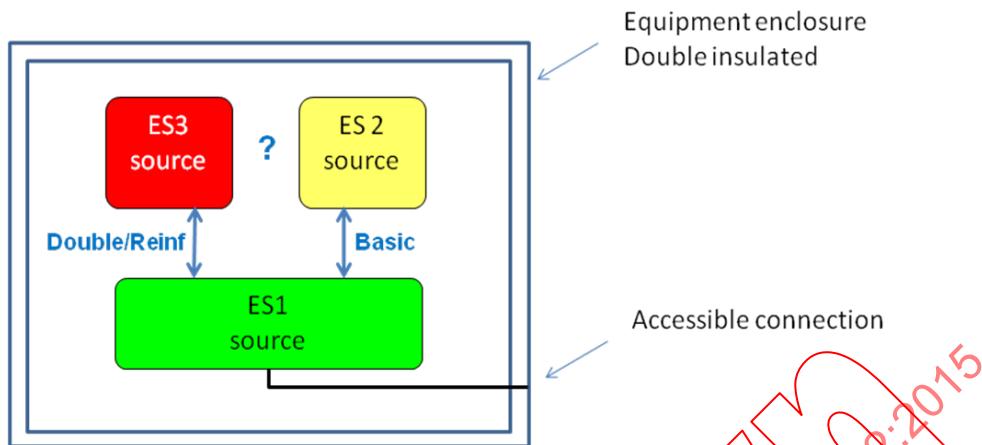
Accessibility to electrical energy sources and safeguards



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What are the requirements between the non-accessible sources?

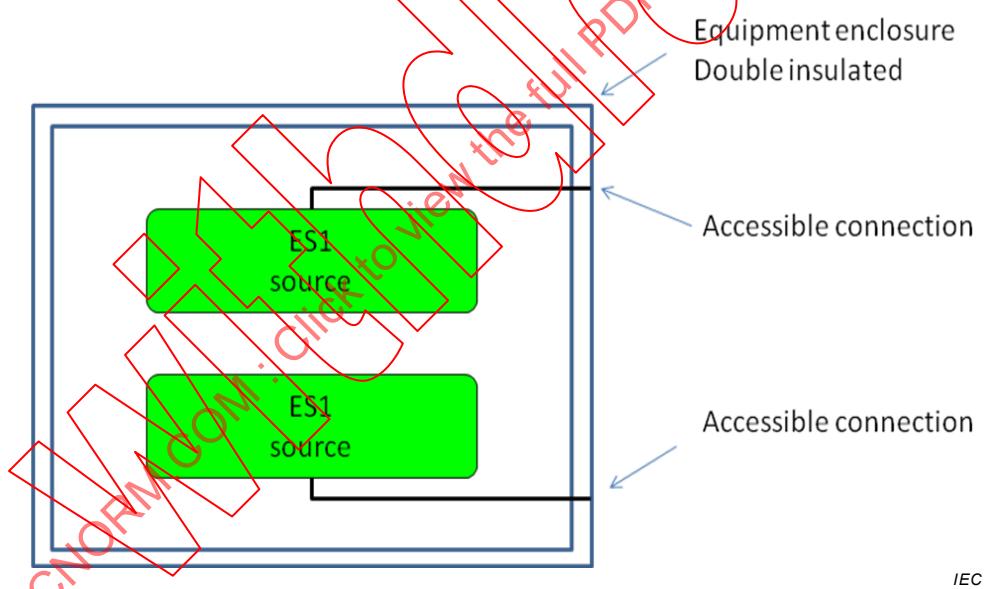
Answer: None. As the enclosure is double insulated, the sources are not accessible.



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

Answer:

- Basic insulation between ES1 and ES2
- Double 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 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 \Rightarrow 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 \Rightarrow no safeguard (functional insulation)

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, Annex V.

Rationale: For voltage below 420 V peak (300 V r.m.s.) no clearance breakdown will occur according to "Paschen-law".

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 TC 108 MT2 (formerly WG 6) as well as from 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 standard.
- Depending on the grade of safeguard (basic safeguard, supplementary safeguard, reinforced safeguard) the requirements differ.
- Components complying with their component standards (for example, IEC 60384-14 for capacitances) have to be verified for their application.
- The components listed in this subclause of the new standard have a separation function.

5.4.1.1 Insulation

Source: IEC 60664-1

Purpose: Provide a reliable safeguard

Rationale: Solid basic, supplementary, 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.

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 11:

- 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

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

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 standard 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 included (Transient overvoltages are covered in the required withstand voltage). Ringing signals are not carrying 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.

5.4.1.8.2 RMS working voltage

Source: IEC 60664-1:2007, 3.5

Rationale: RMS working voltage is used when determining minimum creepage distance.

5.4.1.8.3 Peak working voltage

Source: IEC 60664-1:2007, 3.8

Rationale: In other product safety standards, “Circuit supplied from the mains” has been used for a “primary circuit”. “Circuit isolated from the mains” has been 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.

5.4.1.10 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).

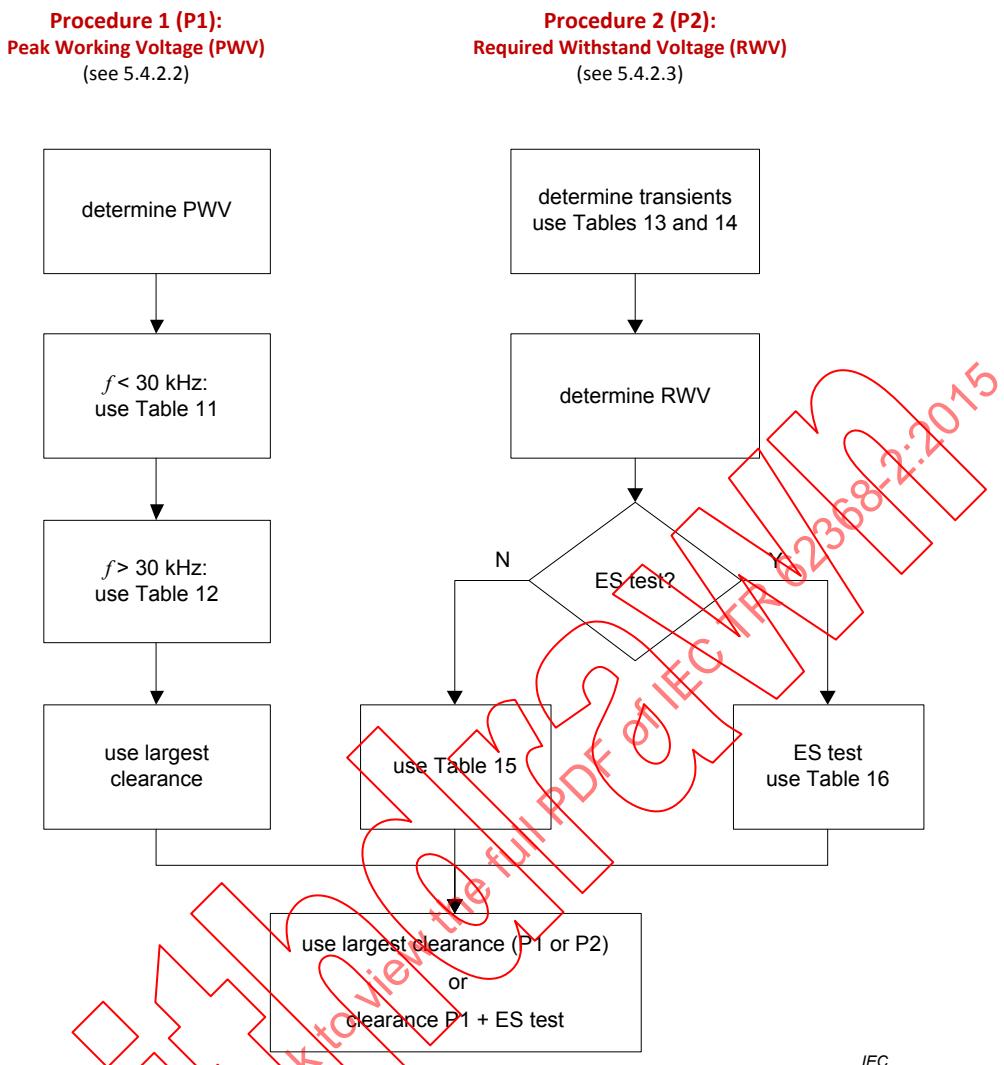
Minimum clearances of safety components shall comply with the requirements of their applicable component safety standard.

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*.



IEC

Example:

Assuming:

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

Procedure 1:

Table 11 requires 2,54 mm

Table 12 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 and Table 12

Procedure 2:

Transients (OVC 2): 2 500 V

RWV = 2 500 V

Table 15 requires 3,0 mm

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

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

5.4.2.2 Procedure for determining clearance using peak working voltage

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

Rationale: 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. 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 a.c. mains transient voltages

Source: IEC 60664-1:2007, 4.3.3.3

Rationale: Table 13 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.

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 10/700 μ s 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 10/700 μ s 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 4 in this technical report 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 earth, functional earth inside or immediately outside the equipment. It is assumed that all earths are bonded together. Figure 5 in this technical report shows the definition of the various voltages for coaxial-cable interfaces.

An overview of insulation requirements is given in Table 6.

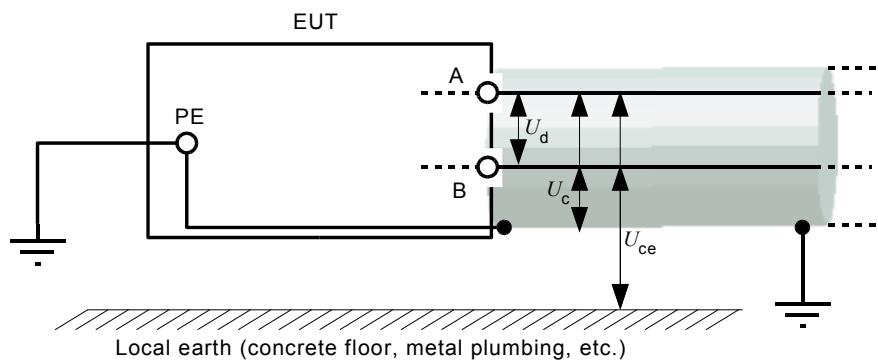


Figure 4a - Paired conductor interface—shielded cable

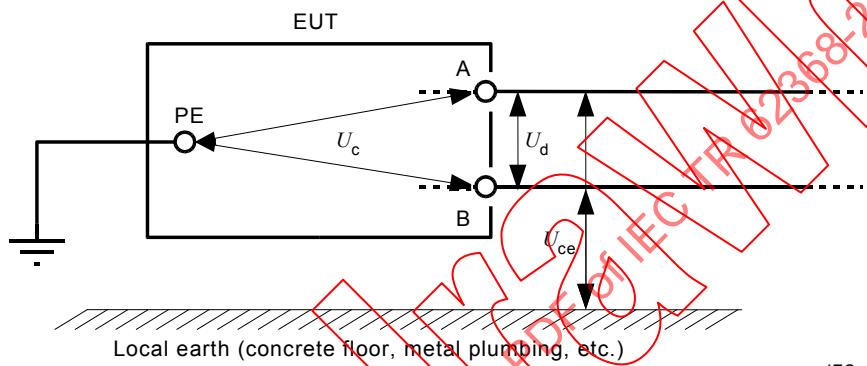


Figure 4b - Paired conductor interface—unshielded cable

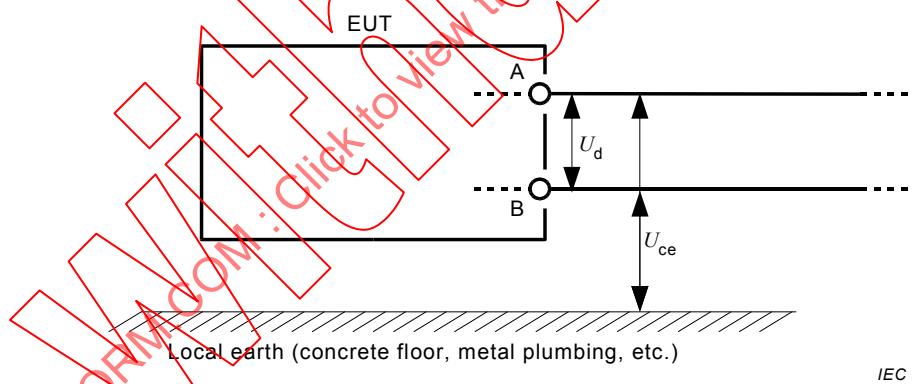


Figure 4c - Paired conductor interface — no earth

Figure 4 – Illustration of transient voltages on paired conductor external circuits

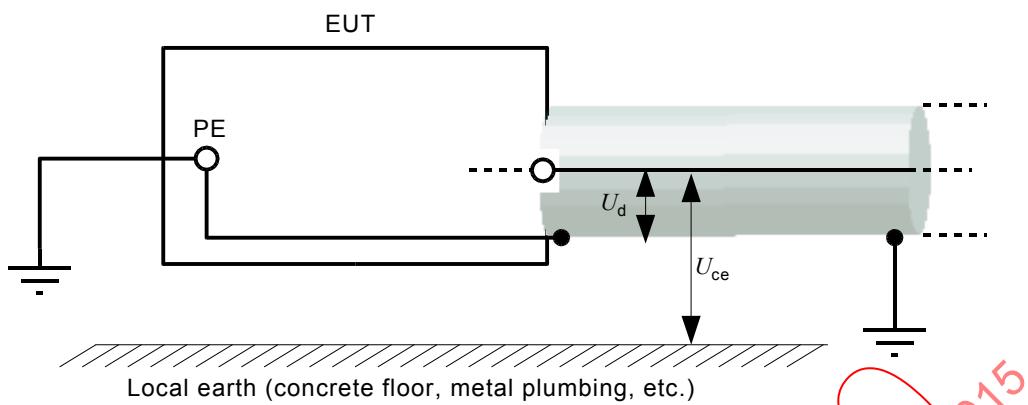


Figure 5a - Coaxial cable interface — earthed at both ends

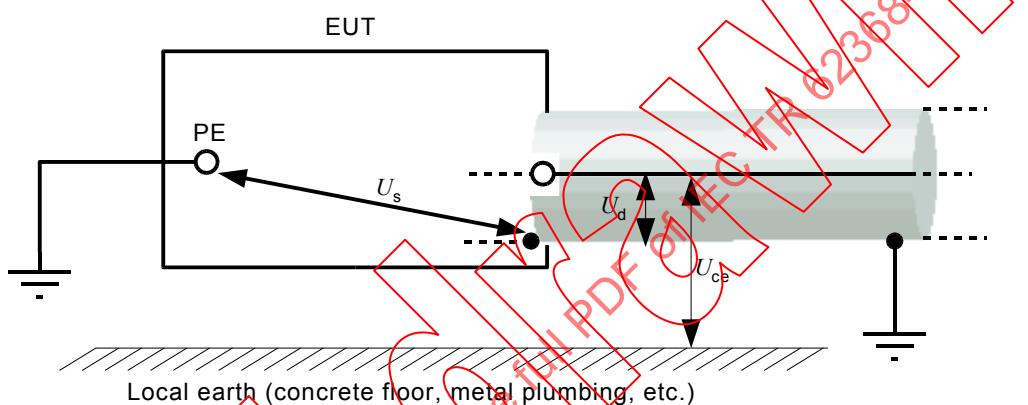


Figure 5b - Coaxial cable interface — earthed at building entrance or other equipment, not earthed at equipment

Figure 5 – 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 unearthing	Separation (to floating metal parts and other floating ES1 circuits)	Electric strength test (using Table 16) between unearthing ES1 and other unearthing ES1 and floating parts
ES2	Basic insulation (to ES1 and metal parts)	Clearances; creepage; and solid insulation and by electric strength test (using Table 16) between ES2 and ES1 and metal parts
ES3	Double or reinforced (to ES1, ES2 and metal parts)	Clearances; creepage; and solid insulation requirements including electric strength test (using Table 16)

Table 14 – External circuit transient voltages

Rationale: When the d.c. power distribution system is located outside the building, transient over-voltages can be expected. Transients are not present if the d.c. power system is connected to protective earth 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 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 standard.

Table 15 – 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 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 have a varying slope, and include a “discontinuity.” The values of Table 15 are shown in Figure 6.

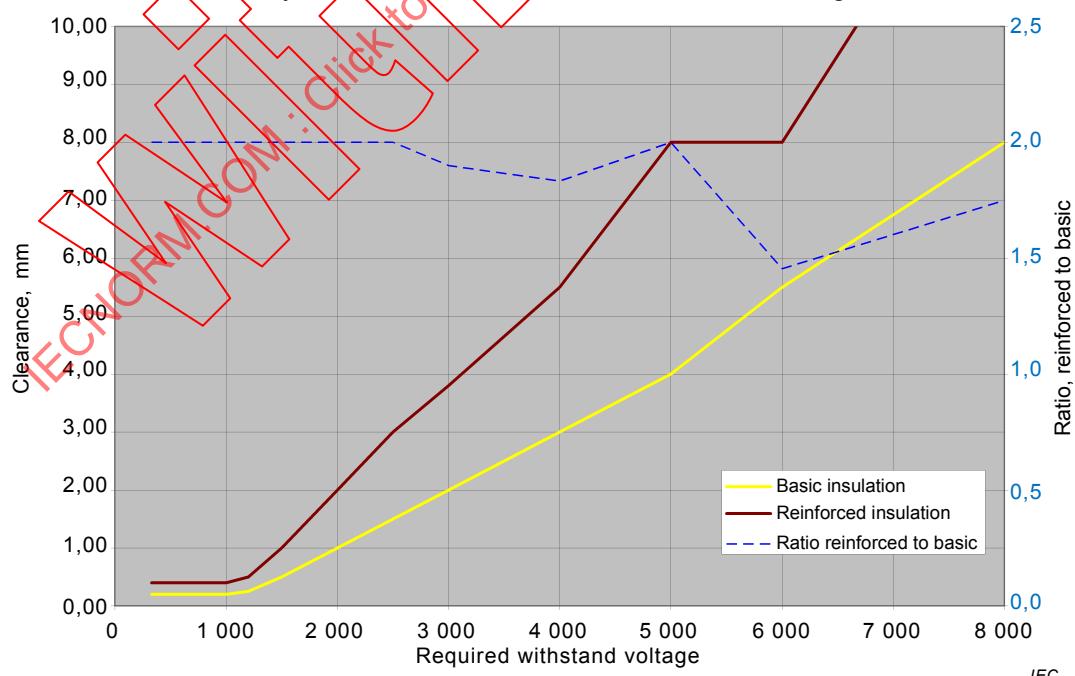


Figure 6 – Basic and reinforced insulation in Table 15 of IEC 62368-1:2014 – Ratio reinforced to basic

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, 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: 14,0 mm
- 12 000 V is indeterminate because there is no preferred voltage above 12 000 V.

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, 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:

$$400 \text{ V} \times 1,6 = 640 \text{ V} \text{ interpolated to } 0,20 \text{ mm}$$

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:

- $400 \text{ V} \times 1,6 = 640 \text{ V}$ 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
- $2\ 000\text{ V} \times 1,6 = 1\ 320\text{ V}$ interpolated to 2,2 mm
- $3\ 000\text{ V} \times 1,6 = 4\ 800\text{ V}$ interpolated to 3,8 mm
- $10\ 000\text{ V} \times 1,6 = 13\ 000\text{ V}$ 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 7 illustrates the differences between Rule 1, Rule 2 and Table 15 of IEC 62368-1:2014.

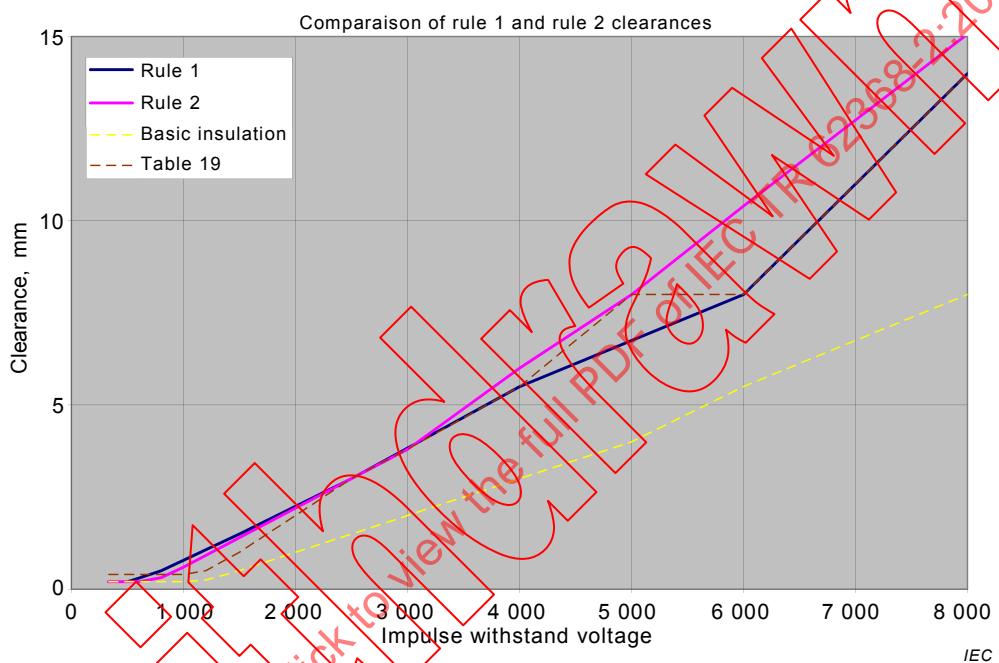


Figure 7 – Reinforced clearances according to Rule 1, Rule 2, and Table 15

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 (the brown line in Figures 1 and 2). 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 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 V to 12 000 V: 1,57

For Rule 2, all of the reinforced clearances 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 of IEC 62368-1.

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. 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 a.c. voltage with the values of Table 16.

Rationale:

The impulse test voltages in Table 16 are taken from IEC 60664-1:2007, Table F.5. The calculation for the a.c. r.m.s. values as well as the d.c. values are based on the values given in Table A.1 of IEC 60664-1:2007 (see Table 7 in this technical report 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 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 = $2\ 500\ V = 2\ 500\ (\text{thickness of enamel} / 5 + \text{air gap} / 1) = 2\ 500\ (0,04 / 5 + 2 / 1 \text{ for } 2\ \text{mm air gap}) = 2\ 500\ (0,008 + 2) = (10\ \text{V across enamel} + 2\ 490\ \text{V across air gap})$

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	Test voltage across air gap	Test voltage across enamel
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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. 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. We are always on the safe side.

Material: Polyamide, dielectric constant = 2,5

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	Test voltage across air gap	Test voltage across enamel
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. 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. We are always on the safe 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 a.c. voltage with the values of Table 17 and the multiplication factors for altitudes higher than 2 000 m.

Rationale: Table 17 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, Annex O figures are similar/identical to figures in IEC 60664-1.

Tests of IEC 62368-1:2014, 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 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 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 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 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 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 are the same as in Table F.4 of IEC 60664-1:2007.

Values in Table 19 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 – 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 and reinforced insulation.

Rationale: Some (very) old standards 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, it had to be mechanically robust, which was tested with a hammer blow of 0,5 Nm.
 The wire standards 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 inaccessible insulations.
 The VDE standard for telecom equipment (VDE 0804) did not include any thickness requirements, but the insulation had to be adequate for the application.
 The standard 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 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 since 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 standard 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 or reinforced insulation, provided they are protected against external mechanical influences.

Each layer is qualified for the full voltage for supplementary 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 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 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 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/AMD 1:2009/AMD 2:2013; IEC 60065:2014

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 r.m.s., 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.

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.10.3.2 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 standard for many years (see Figure 8 in this technical report).

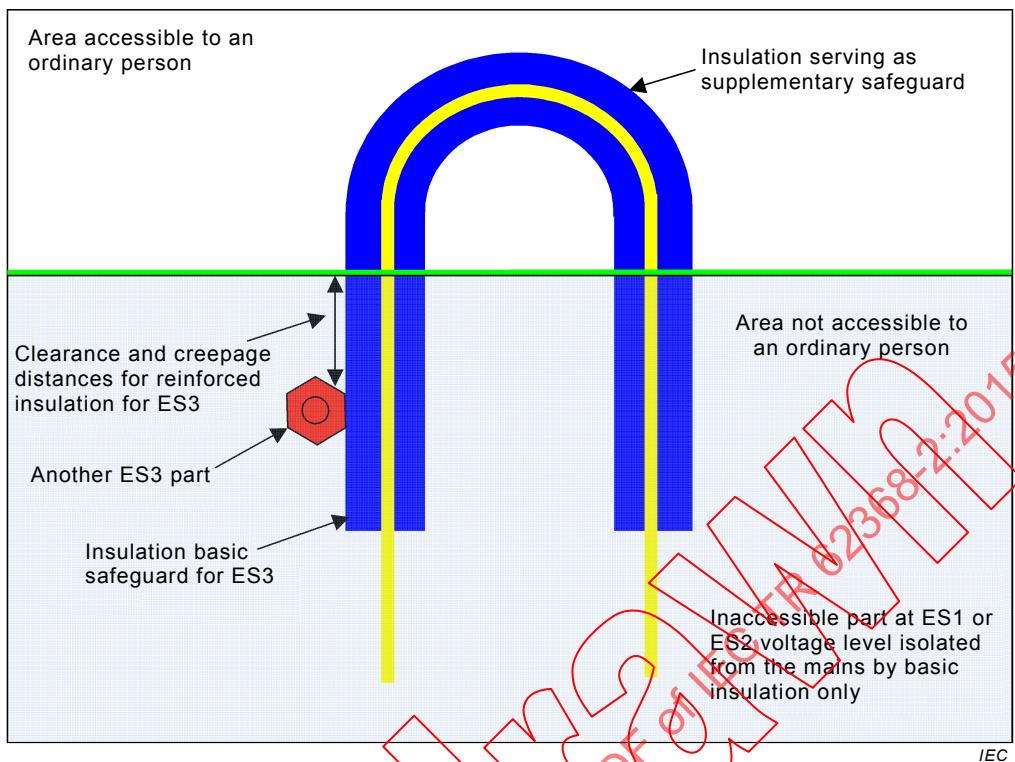


Figure 8 – Example illustrating accessible internal wiring

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

Table 26 – 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 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 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 – Test voltages for electric strength tests based on peak working 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 – 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.

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 μ s (terminal equipment). This transient of 1,5 kV 10/700 μ s does not cause a hazardous electric shock, but it is very uncomfortable to persons effected 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.

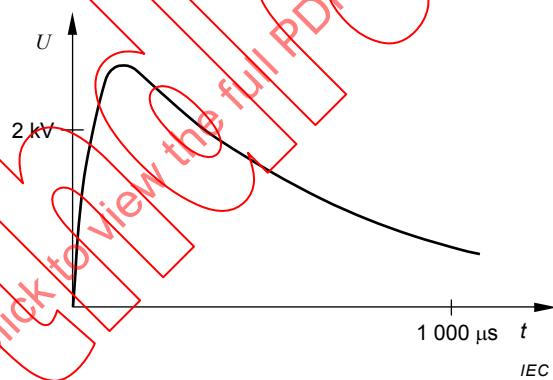
The separation is required between the external circuit subjected to transients and all parts, which may accessible to ordinary persons or instructed persons. The likelihood a transient occurs and a body contact with an accessible part occurs at the same time increases with the contact time. Therefore non-conductive parts and unearthing parts of the equipment maintained in continuous contact with the body during normal use (for example 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

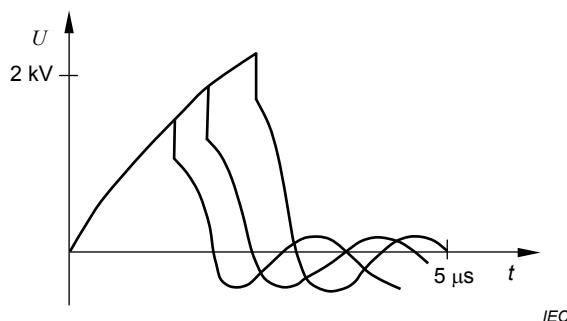
The impulse test is performing an impulse test by using the impulse generator for the 10/700 μ s impulse (see test generator D.1 of Annex D). With the recorded waveforms it could be judged whether a breakdown of insulation has occurred or the surge suppression device has worked properly.

The examples in Figure 9, Figure 10, Figure 11 and Figure 12 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 9 – 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 10 – Waveforms on insulation during breakdown without surge suppressors

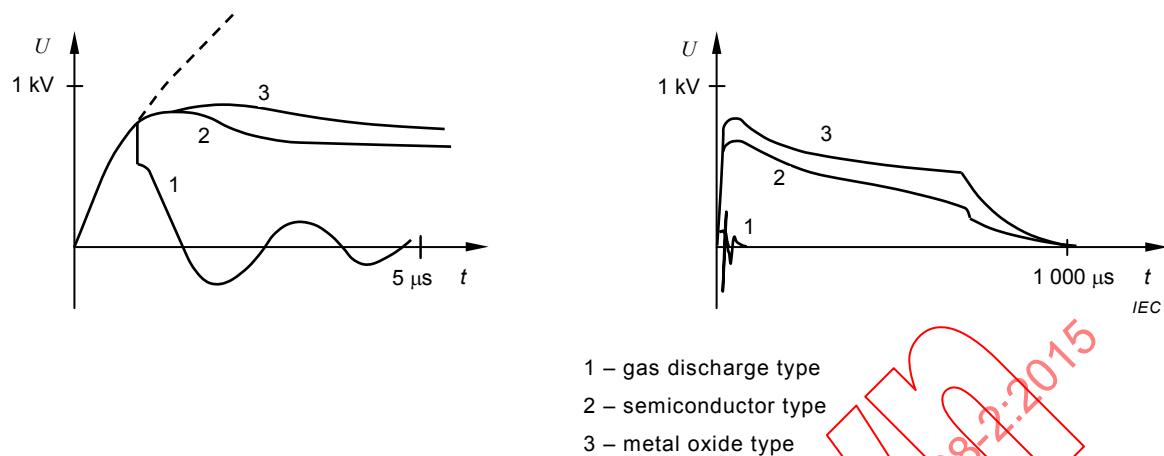


Figure 11 – Waveforms on insulation with surge suppressors in operation

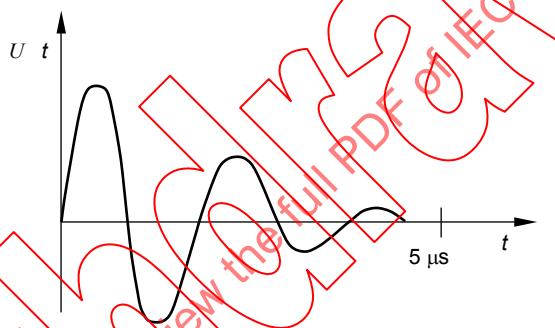


Figure 12 – Waveform on short-circuited surge suppressor and insulation

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 a simple test with an r.m.s. voltage. But if for example surge suppressors are used to reduce the transients from the external circuits within the equipment this r.m.s. 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, which 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 outlet exists with no earth contact. This situation will not be changed in the near future.

To provide a protection for such situations a separation between an external circuit intended to be connected to communication networks outside the building (for example telecommunication networks) 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 according 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 which 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.

Example 1

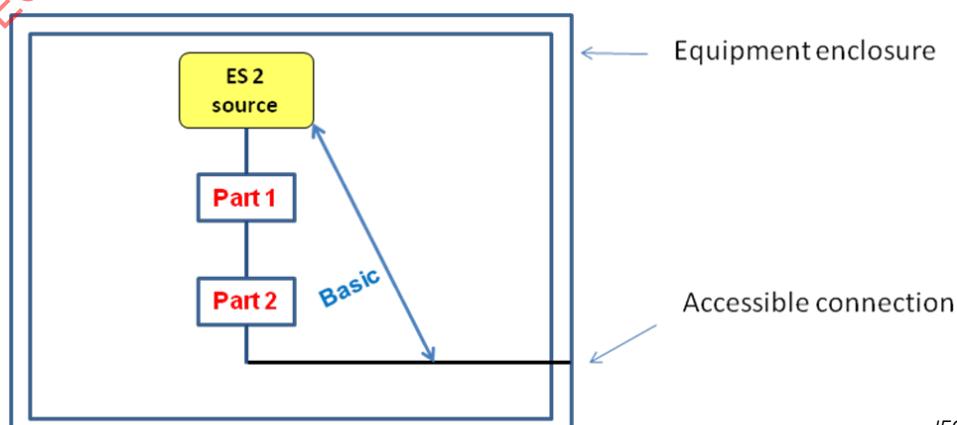


Figure 13 – Example for an ES2 source

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.

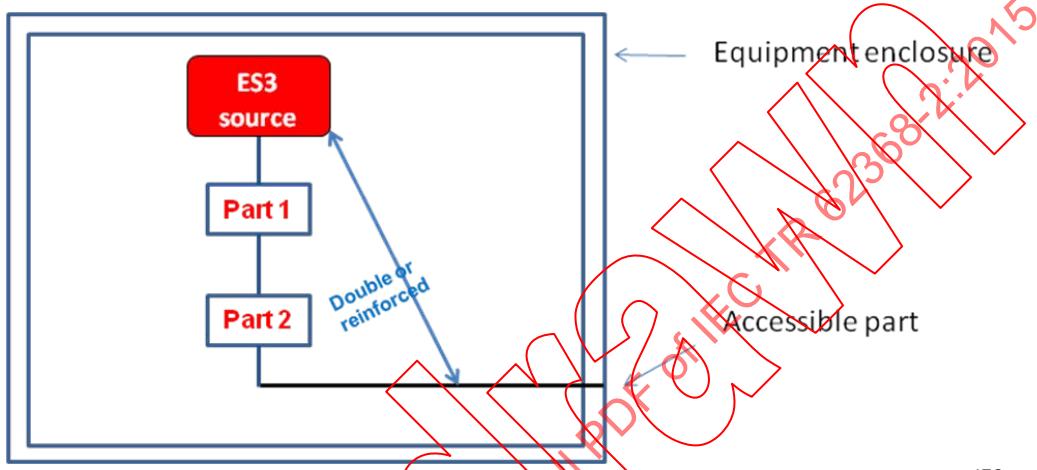
The basic safeguard in parallel with the part(s) is to comply with:

- the creepage 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



IEC

Figure 14 – 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 requirements; and
- the clearance requirements,

for double 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 standards

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 standard.

Rationale:

Safety requirements of a relevant standard 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: 2 s delay time represent the typical access time after connector disconnection. 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:

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

where:

C is in μF ;

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

E_{max} is the maximum charge voltage or mains peak voltage;

l_n 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:

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

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.

A method used by several other standards, 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 ten measurements will be 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 standard. 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 SPD's

Rationale: See Annex A of this Technical Report for background information on the use of SPD's.

It should be noted that the issue is still under discussion in 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

5.6 Protective conductor

See Figure 15 in this technical report for an overview of protective earthing and protective bonding conductors.

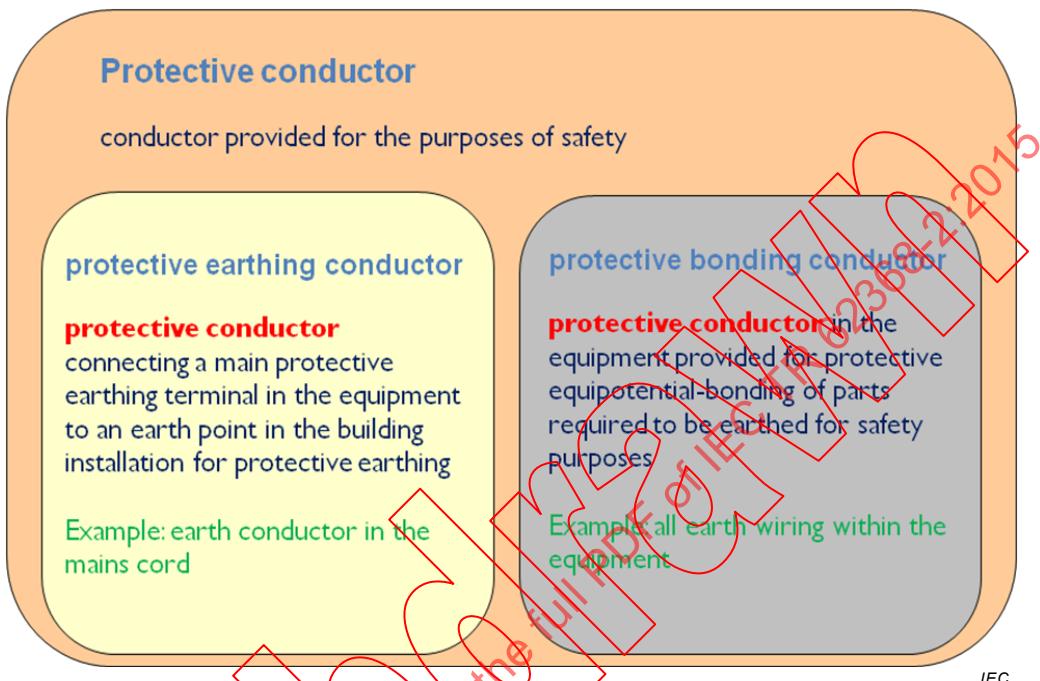


Figure 15 – Overview of protective conductors

5.6.1 General

Source: IEC 60364-5-54, IEC 61140, IEC 60950-1

Purpose: The protective earth 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.

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 standard for many years.

¹ This publication was withdrawn.

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 standard for many years.

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 standard for many years.

5.6.7 Reliable earthing

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 type A.

Rationale: Permanently connected equipment is considered to provide a reliable earth connection because it is wired by an electrician.

Pluggable 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

5.7.4 Earthed accessible conductive parts

Rationale: Figure 16 in this technical report 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.

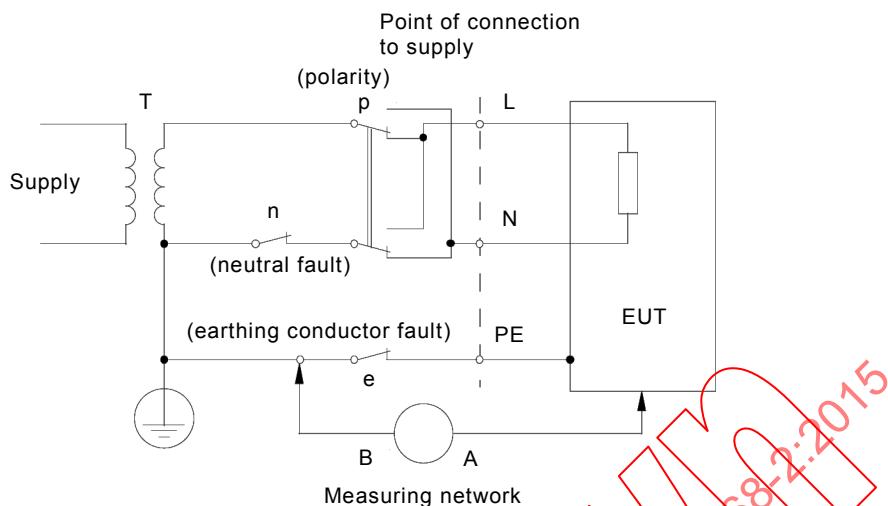


Figure 16 – Example of a typical touch current measuring network

5.7.5 Protective conductor current

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).

5.7.6 Prospective touch voltage and touch current due to external circuits

5.7.6.1 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.

- 1) 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.
- 2) Each 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 many 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.

5.7.6.2 Prospective touch voltage and touch current to external circuits

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 (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 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.

5.7.7 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 unearthing (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 a.c. 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 17).

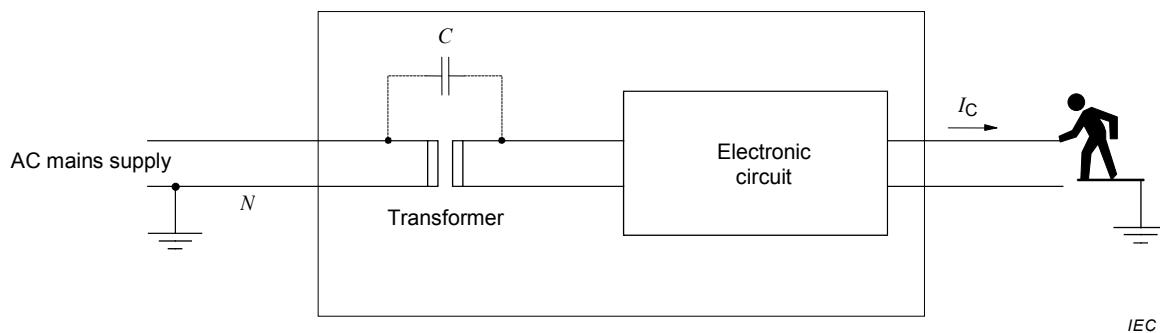


Figure 17 – Touch current from a floating circuit

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 technical report, 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 18). Any leakage current from the mains transformer (see a.1), will be conducted to earth and will not pass through the body.

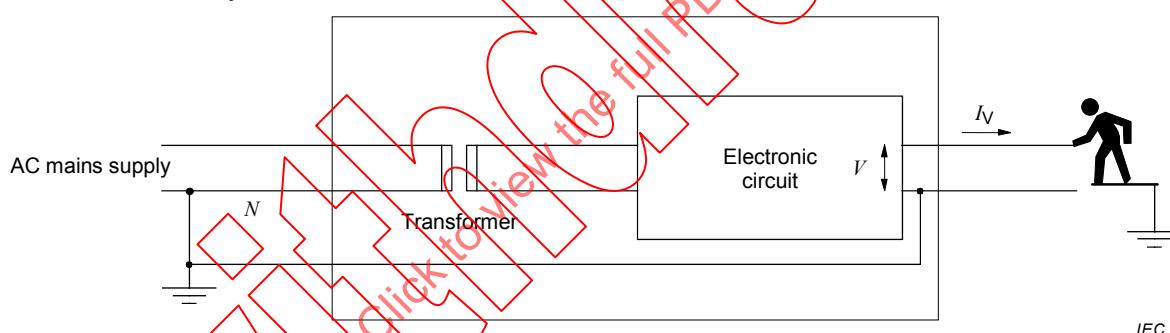


Figure 18 – Touch current from an earthed circuit

In this standard, the body current (I_V) is limited by specifying maximum voltage values for the accessible circuit, which shall be a SELV circuit or (with restricted accessibility) a TNV 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 19).

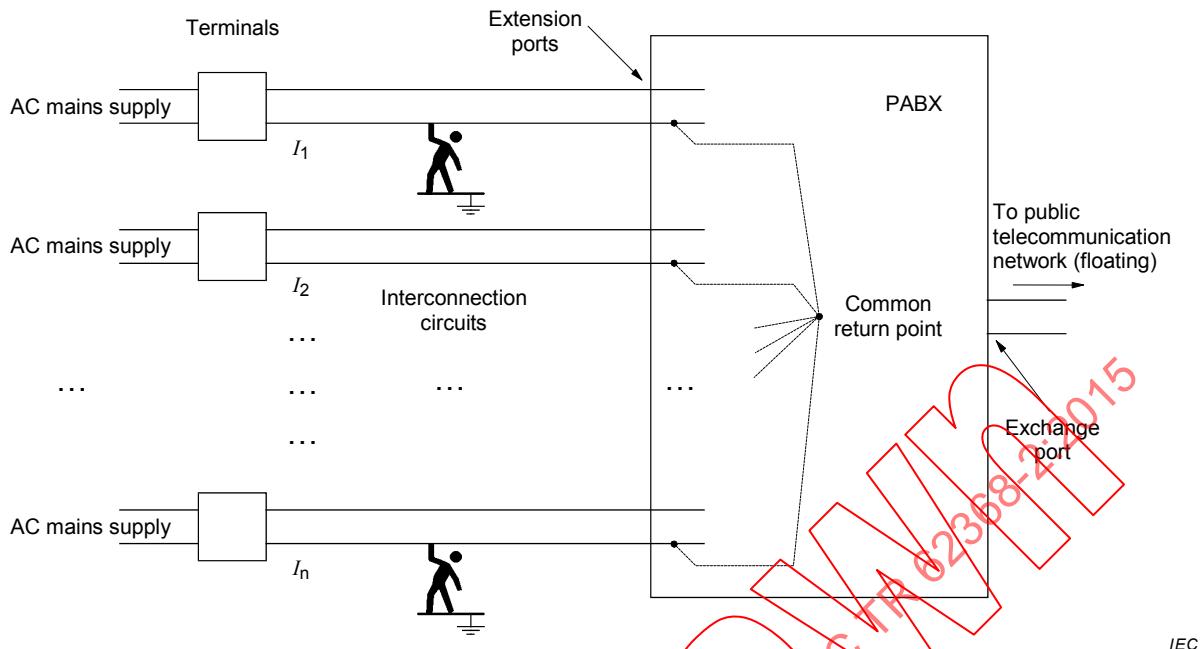


Figure 19 – Summation of touch currents in a PABX

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 earth. 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.

Clause 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 standards, 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 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).

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 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 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 standard.

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 vs. 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 r.m.s. (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 to 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 r.m.s. 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.

6.2.3.2

Resistive PIS

Source:

IEC 60065

Rationale:

Resistive potential ignition sources can result from a fault that causes overheating 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 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.

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

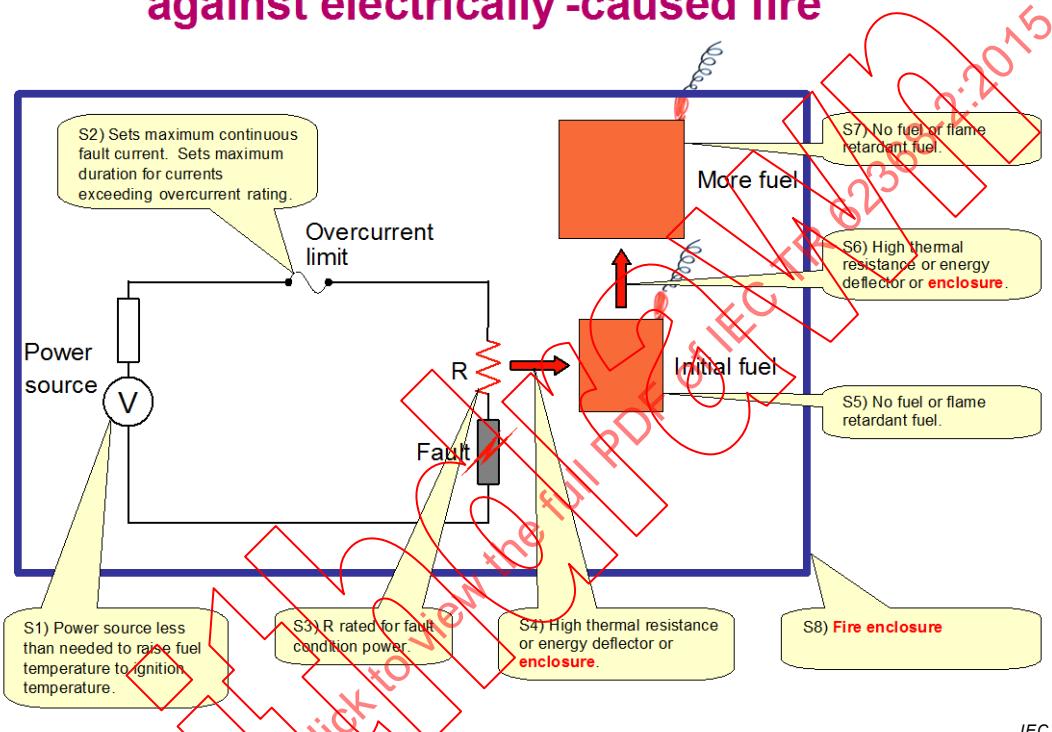


Figure 20 – Possible safeguards against electrically-caused fire

There are several basic safeguards and supplementary safeguards against electrically-caused fire under abnormal operating conditions and single fault conditions (see Figure 20, Table 8 and Table 9 in this technical report). 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 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 21 in this technical report 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	S1, S2, S3, S5 S2
	Sufficient distance or solid barrier interposed between any combustible material and each potential ignition source	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

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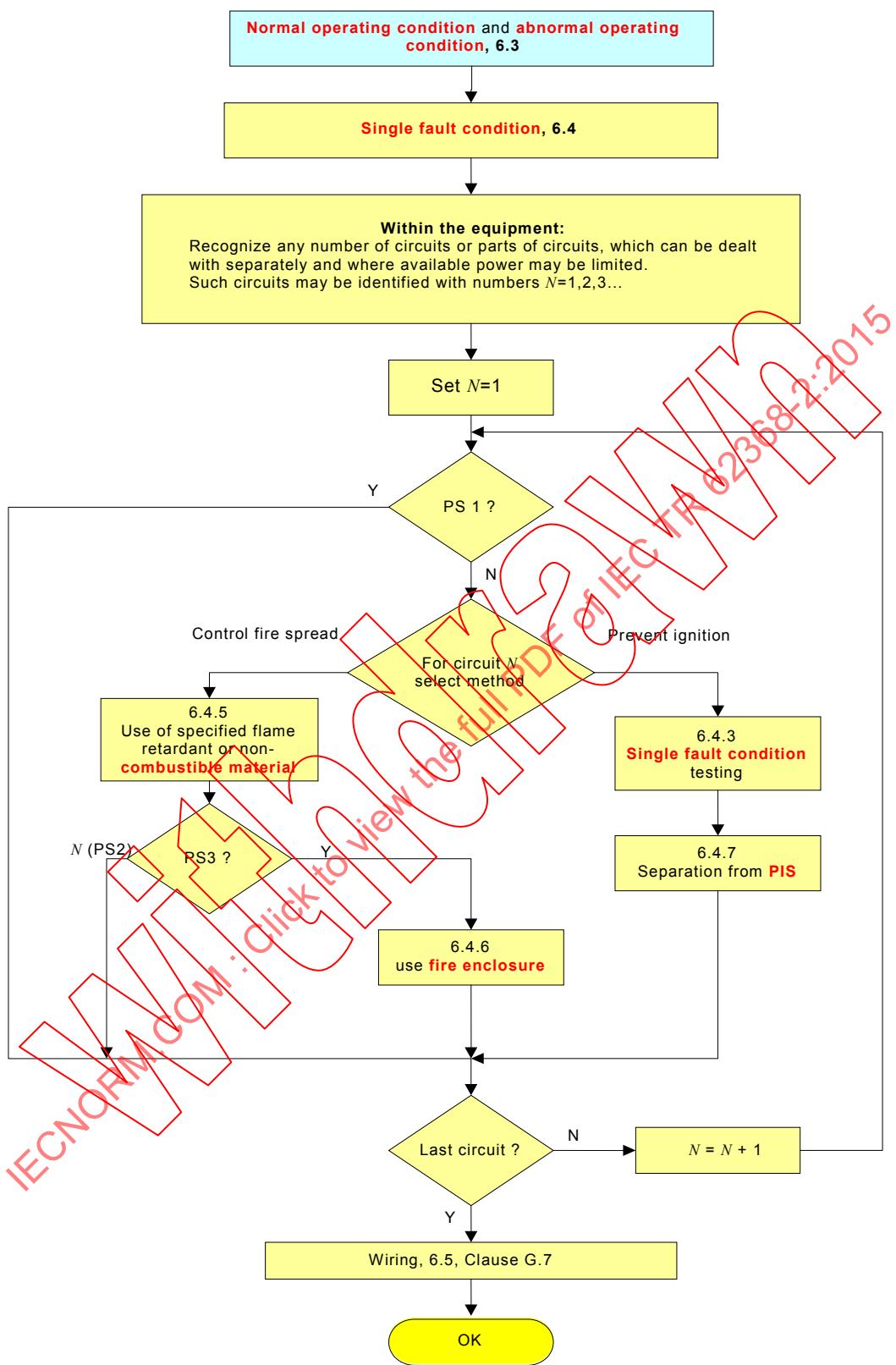


Figure 21 – Fire clause flow chart

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.

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.		
		Ignition is not allowed
		$T_{max} \leq 90\% \text{ auto ignition temperature according to ISO 871; or}$ $T_{max} \leq 300 \text{ °C}$
PS1	6.3.1	<p>Combustible materials for components and other parts outside fire enclosures (including electrical enclosures, mechanical enclosures and decorative parts), shall have a flammability classification of at least:</p> <ul style="list-style-type: none"> – 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. <p>NOTE Where an enclosure also serves as a fire enclosure, the requirements for fire enclosures apply.</p> <p>These requirements do not apply to:</p> <ul style="list-style-type: none"> – 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.
PS2		
PS3		

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 normal and abnormal operation 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 technical report. 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 standard'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 $240\text{ V} \times 16\text{ A}$), 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 a.c. 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 22 in this technical report).

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 ≤ 4 000 W)	6.4.3	<p>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</p> <p>Sustained flaming > 5 s is not allowed</p> <p>Separation from arcing PIS and resistive PIS according to 6.4.7</p> <ul style="list-style-type: none"> – Distances have to comply with Figures 37, 38, 39 and 40; or – In case the distance between a PIS and combustible material is less than specified in figures 37, 38, 39 and 40; – Mass of combustible material < 4 g, or – Shielded from the PIS by a fire barrier, or – Flammability requirements: <ul style="list-style-type: none"> • V-1 class material; VTM-1 class material or HF-1 class material, or needle flame in Clause S.2, or • Relevant component IEC standard <p>Using protective devices that comply with G.3.1, G.3.2, G.3.3 and G.3.4 or the relevant IEC component standards for such devices;</p> <p>Using components that comply with G.5.3, G.5.4 or the relevant IEC component standard;</p> <p>Components associated with the mains shall comply with: the relevant IEC component standards; and the requirements of other clauses of IEC 62368-1</p>

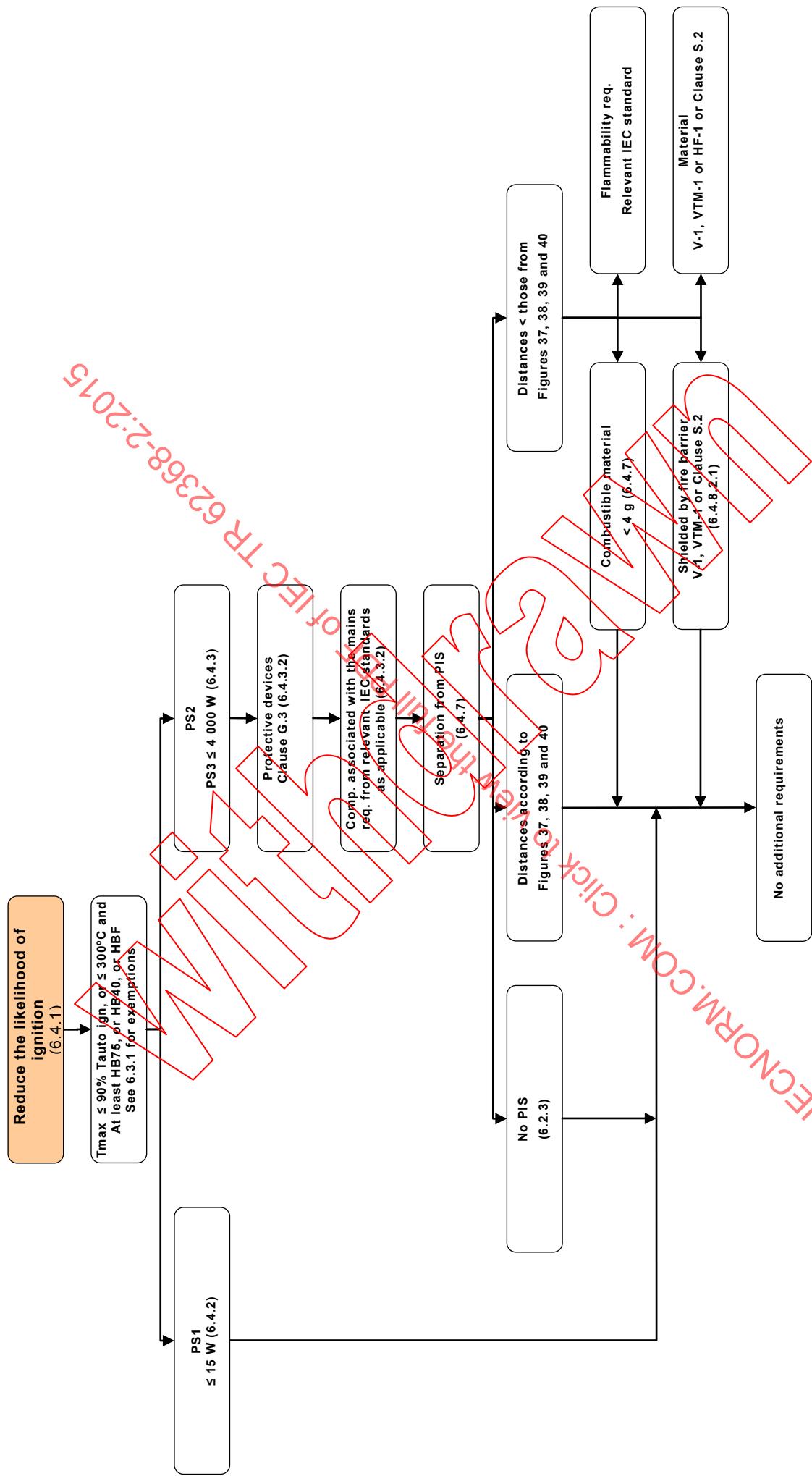


Figure 22 – Prevent ignition flow chart

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 23, Figure 24 and Table 12 in this technical report).

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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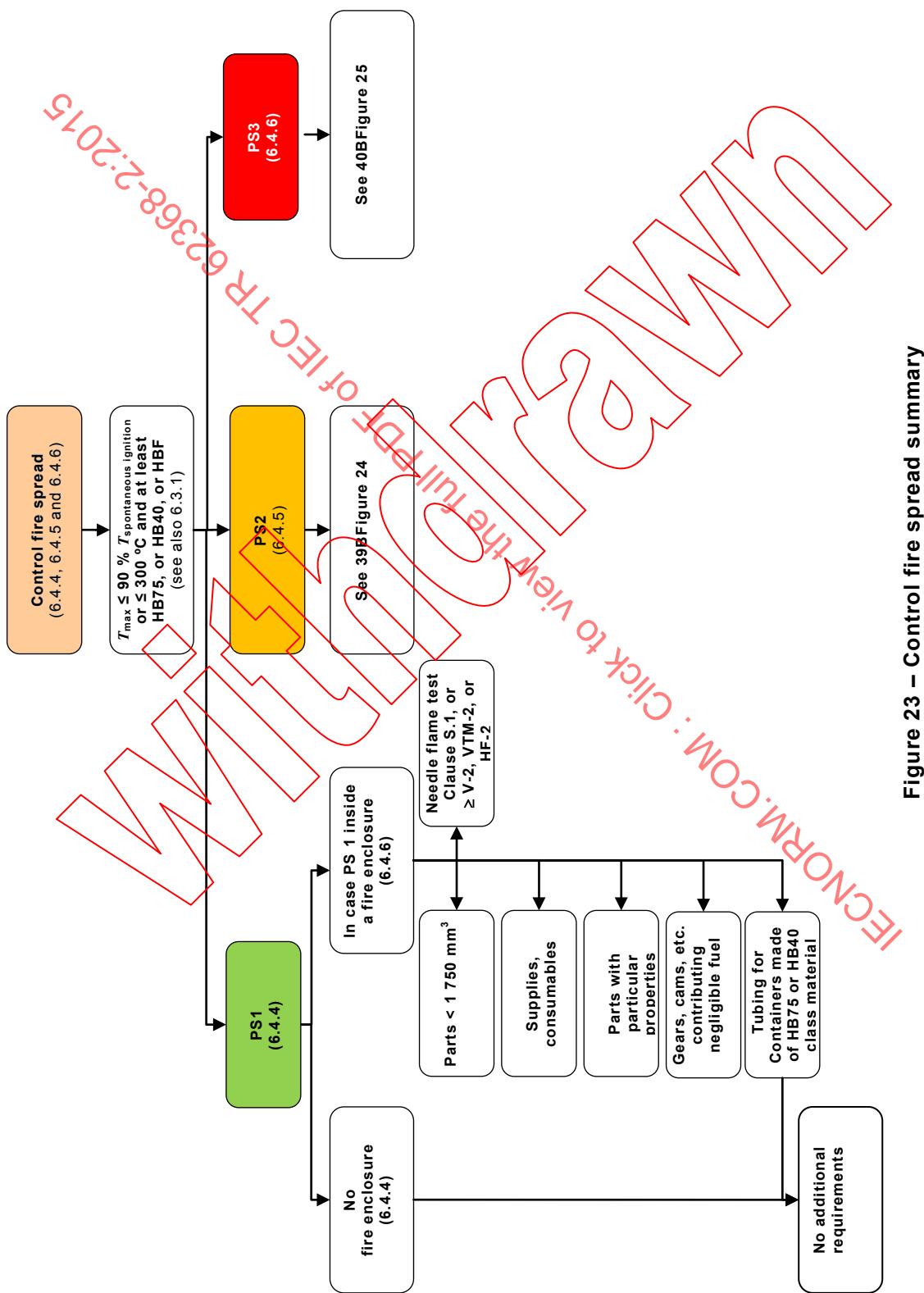


Figure 23 – Control fire spread summary

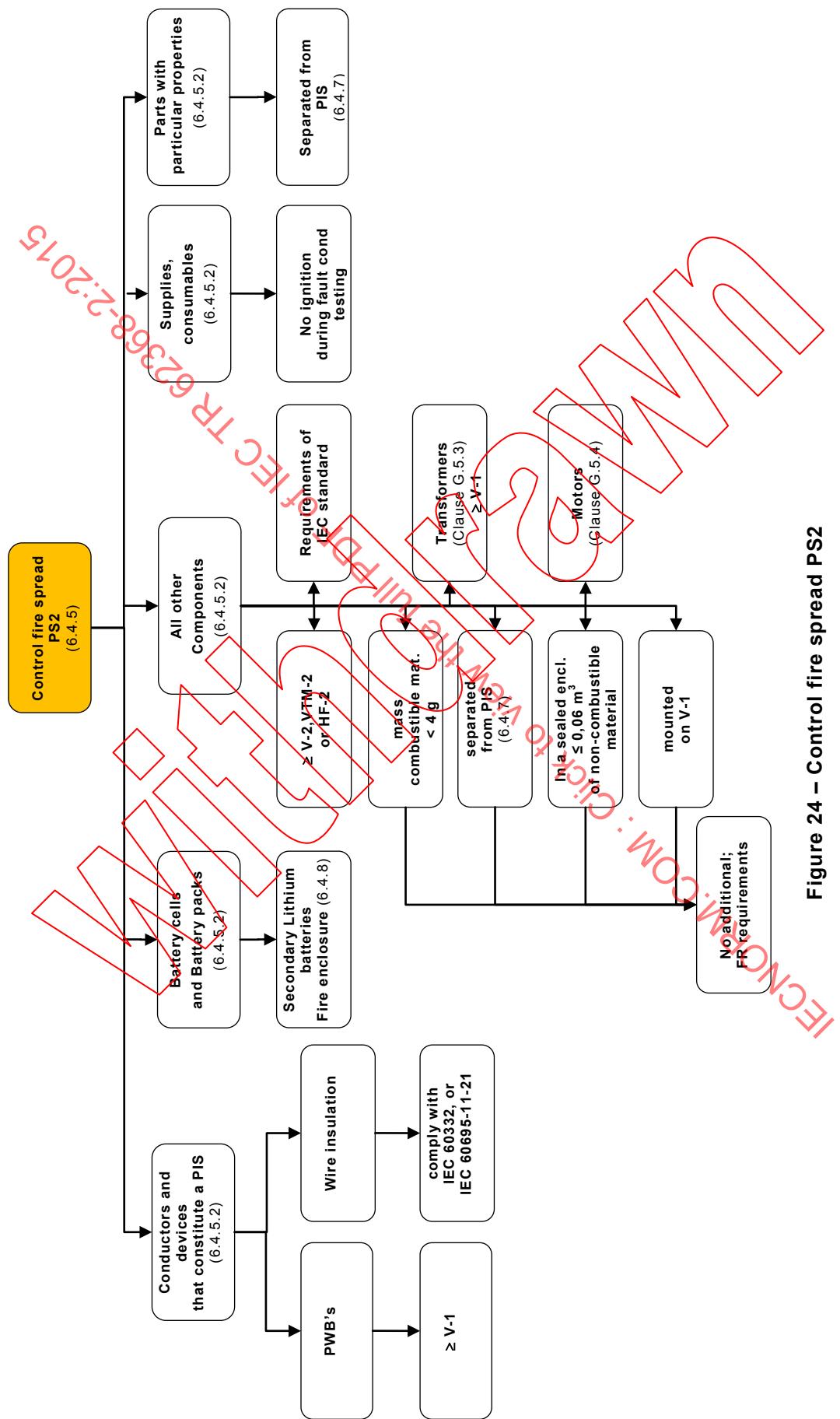


Figure 24 – Control fire spread PS2

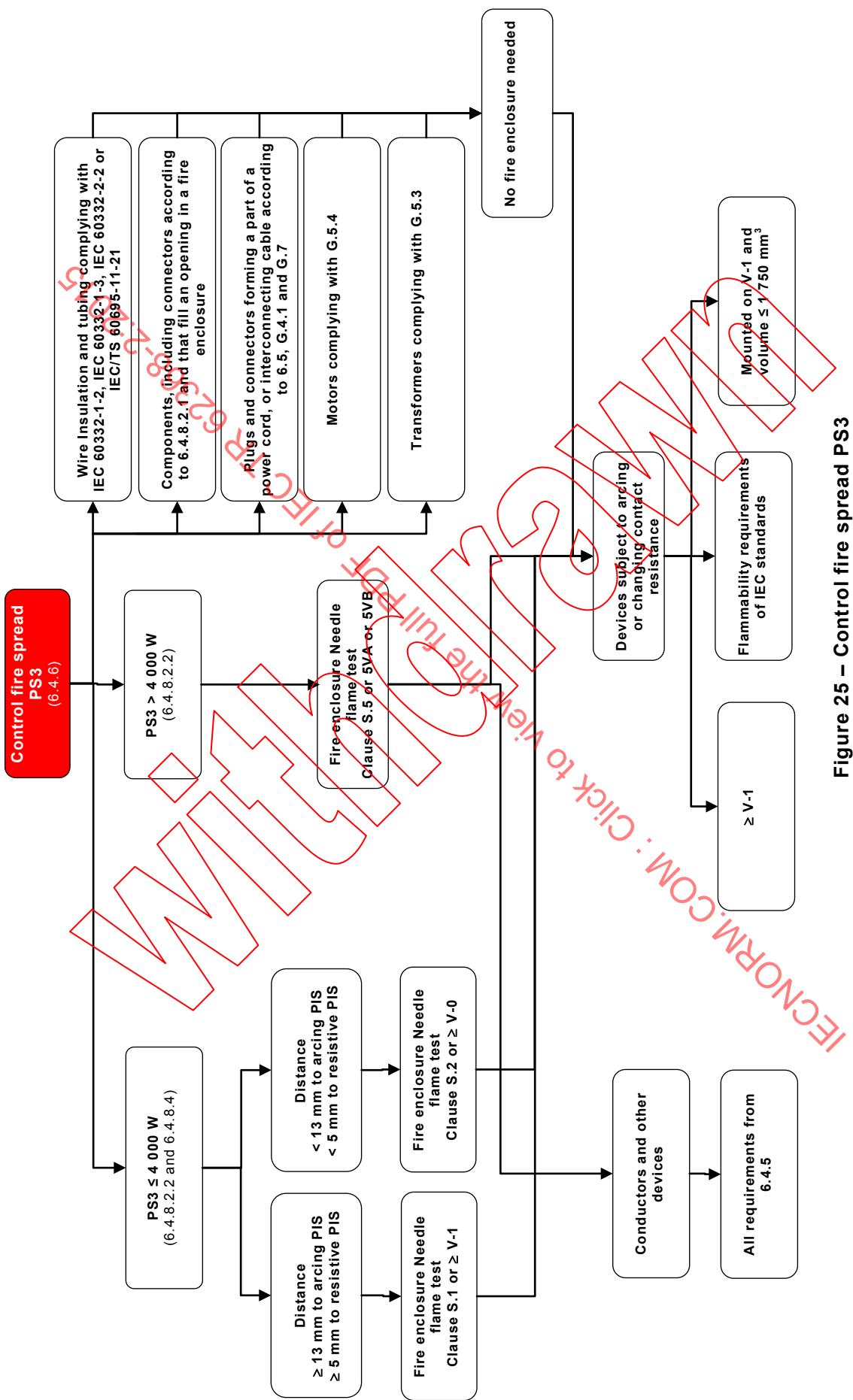


Figure 25 – Control fire spread PS3

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).

6.4.3.2 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 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 standards.

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 standards are also considered to comply given these standards 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 or reinforced safeguard.

6.4.3.3 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 to 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 standard 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.

- b) Where the measured current quickly exceeds the fuse pre-arc 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.
- c) Where the measured current does not initially exceed the fuse pre-arc 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-arc characteristics. It is assumed the measured current through the short circuit can be graphed and compared with the fuse manufacturer's pre-arc 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 after 3 s ≤ 500 W ≤ 3 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 (≤ 100 W after 5 s)	6.4.4	<p>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.</p> <p>The limiting of power available to PS2 circuits is the basic safeguard used to minimize the available energy of an ignition source.</p> <p>A supplementary safeguard is required to control the spread of fire from any possible PIS to other parts of the equipment</p>
	6.4.5	<p>For conductors and devices with a PIS the following apply:</p> <ul style="list-style-type: none"> – Printed boards shall be at least V-1 class material – Wire insulation shall comply with IEC 60332 series or IEC 60695-11-21 <p>Devices subject to arcing or changing contact resistance (for example pluggable connectors) shall comply with one of the following</p> <ul style="list-style-type: none"> – Materials V-1 class material; or – Comply with IEC component standard flammability requirements; or – Mounted on V-1 class material and volume ≤ 1 750 mm³
		Battery cells and battery packs shall comply with Annex M.

Method 2: Control fire spread	
	<p>All other components:</p> <ul style="list-style-type: none"> – 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 <p>Separated from PIS according to 6.4.7,</p> <p>Distances have to comply with Figures 37; 38; 39 and 40, or</p> <p>In case distances do not comply with Figures 37; 38; 39 and 40</p> <ul style="list-style-type: none"> – 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 standard 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 <p>The following shall be separated from a PIS according to 6.4.7 or shall not ignite due to fault conditional testing</p> <ul style="list-style-type: none"> – 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
PS3 (> PS2)	<p>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.</p> <p>6.4.6</p> <p>Fire spread in PS3 circuit shall be controlled by;</p> <ul style="list-style-type: none"> – 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 <p>Exemptions:</p> <ul style="list-style-type: none"> – 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
	<p>6.4.6 For PS2 or a PS3 circuit within a fire en- closure</p> <p>See all requirements for PS2 (6.4.5)</p>

Method 2: Control fire spread	
6.4.6 For a PS1 circuit within a fire enclosure	<p>Combustible materials: Needle flame test in Clause S.1 or V-2 class material or VTM-2 class material or HF-2 class material</p> <p>Exemptions:</p> <ul style="list-style-type: none"> – Parts with a size less than $1\ 750\ mm^3$ – 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 $< 3\ mm$, or HB40 class material if the thinnest significant thickness of the material is $\geq 3\ mm$, 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 Clause 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 $1\ 750\ mm^3$ 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 standard) 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 materials is similar to that of V-1 materials in the small scale testing. The use of VTM-2 or HF-2 rated 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 standard 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 standard. 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 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.

The 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 26 in this technical report 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.

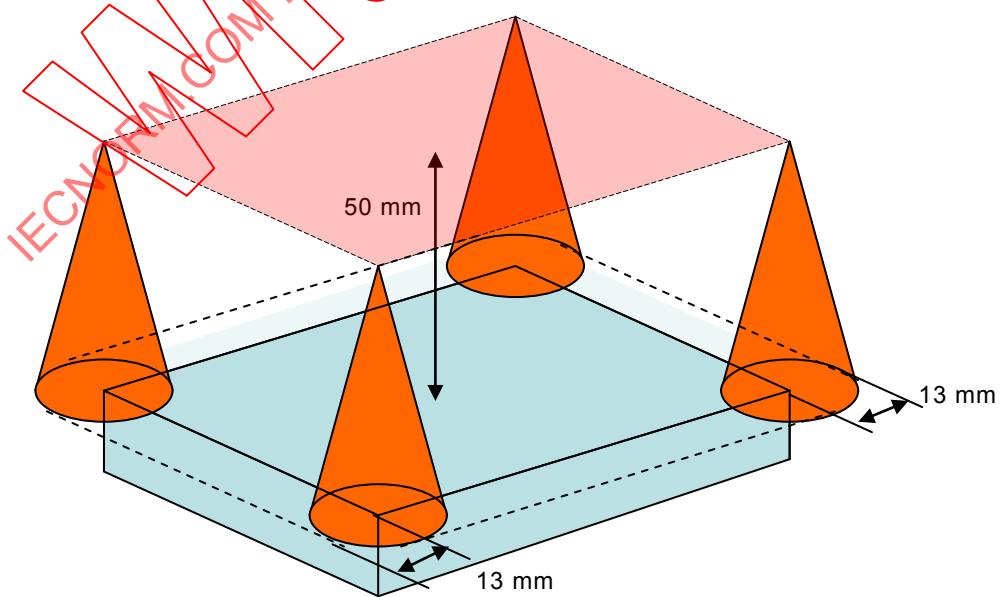


Figure 26 – Fire cone application to large component

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 PIS's 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). Should a PIS be mounted 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 40 – 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 technical report).

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 standard; 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 flammability classification of 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 materials based on product weight lacked sufficient rationale. This has been improved and related to power available to a fault in this standard.

IEC 60065 – V-2 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 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 $< 4\ 000\text{ W}$) and S.5 (for $> 4\ 000\text{ W}$). 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 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.

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 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 have 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.

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.1) 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.

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 is taken into account 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 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 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 are 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 have been used in IEC 60065 and proven historically adequate.

There are several options for opening compliance (see Table 14 in this technical report). 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 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.

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 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”.

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 6.4.8.2.3				
Bottom openings		See 6.4.8.2.4				

6.4.8.3.5 Integrity of the 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.

6.4.8.3.6 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 or 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 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 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).

6.5.2 Compliance criteria

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 standards 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 standards.

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.

6.5.3 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 Clause 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.

Clause 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.

Clause 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 technical report). 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 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 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 standard makes it impossible to identify specific hazards within the body of this standard. 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 below and in a flowchart (Figure 27 in this technical report) 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	<p>Hierarchy of hazard management:</p> <ol style="list-style-type: none"> 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	<p>Hierarchy of hazard management:</p> <ol style="list-style-type: none"> 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	<p>Hierarchy of hazard management:</p> <ol style="list-style-type: none"> 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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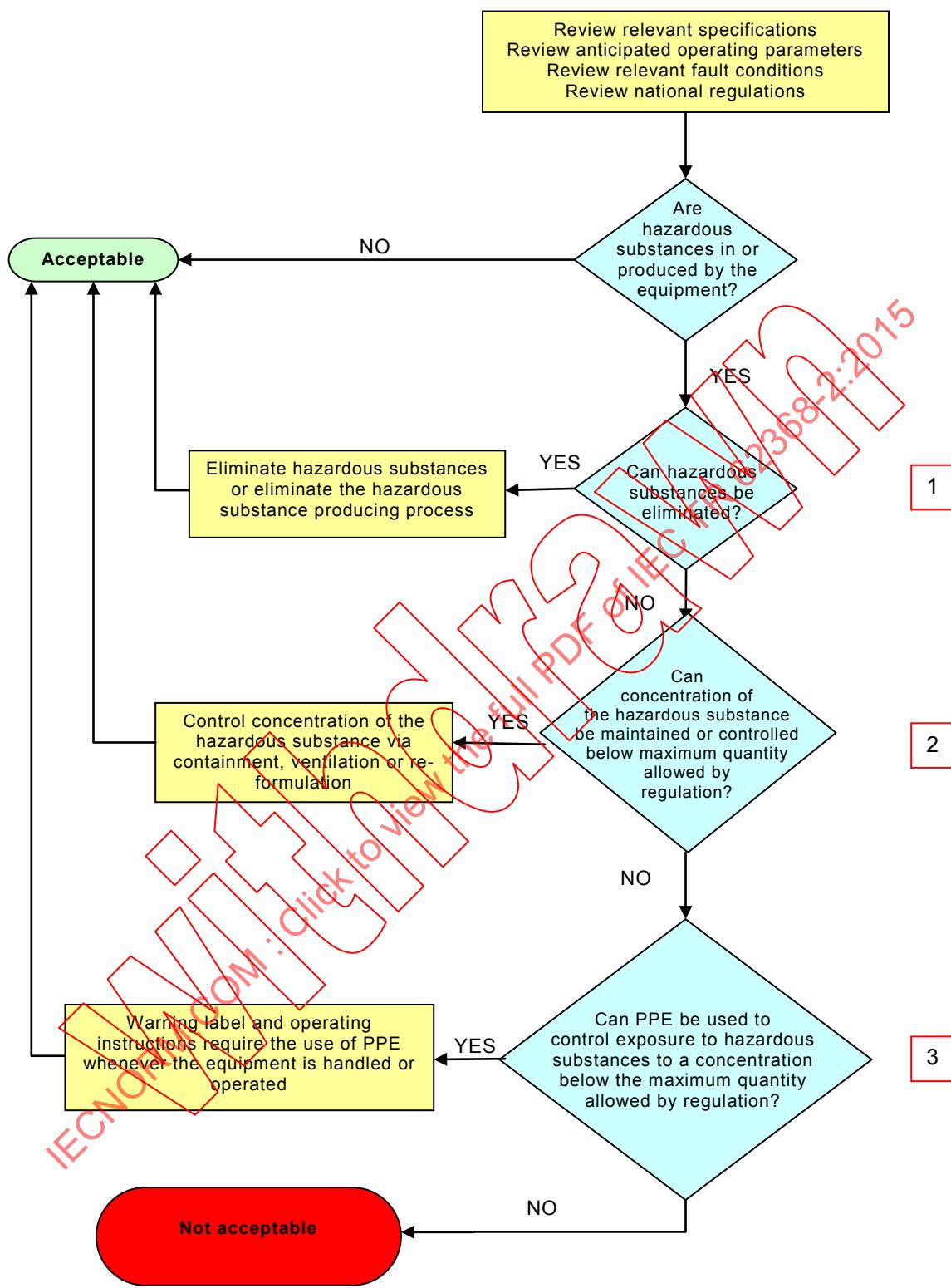


Figure 27 – Flowchart demonstrating the hierarchy of hazard management

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 28 in this technical report shows the main types of chemical health hazards and their transfer mechanisms.

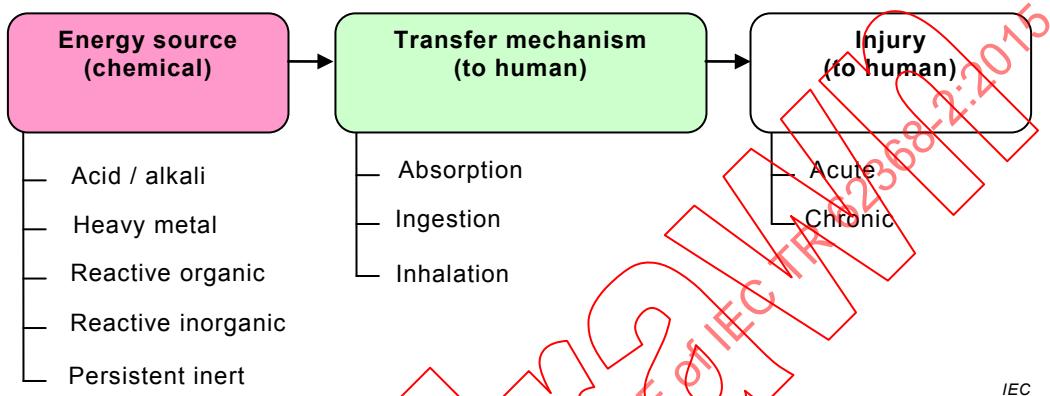


Figure 28 – Model for chemical injury

Clause 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 conditions, abnormal 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 43 and Figure 44 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).

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 standard 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: 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. TC 108 plans to work on these values in the future.

Line 6 – Wall/ceiling 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. TC 108 plans to work on these values in the future.

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 source 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 standard. 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.

8.5.4.2 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 60065:2014

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 inch). 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 or ceiling**

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 standards for many years.

8.7.2

Test methods

Figure 29 gives a graphical view of the different tests required by Test 2 and show the directions that the forces are applied.

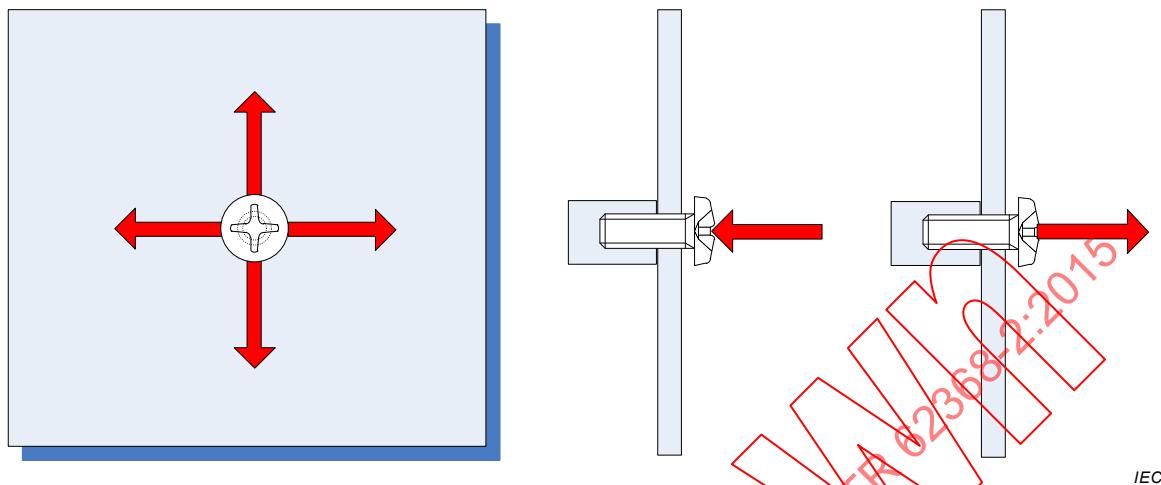


Figure 29 – Direction of forces to be applied

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 standard 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 jambs 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 mm 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 mounted equipment

8.11.1 General

Source: UL/CSA 60950-1:2005

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.

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.

8.11.4 Mechanical strength test, 250 N, including end stops

Source: UL/CSA 60950-1:2005

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.

Clause 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 standard 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 30 in this technical report) 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.

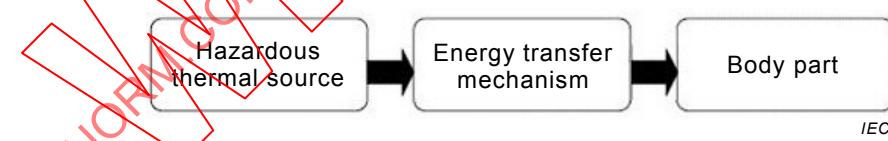


Figure 30 – Model for a burn injury

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, 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 $\leq 10\%$ 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, Note of 5.7.3). Requirements for persons with impaired neurological systems are not considered in this standard 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 standard, as this type of application is more appropriate to medical device standards.

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 standard (Ref: ASTM 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 13732-1:2006, 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 standard.

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.

To prevent thermally-caused injury, a safeguard is interposed between the body part and the energy source (see Figure 31 in this technical report). More than one safeguard may be used to meet the requirements for thermal burn hazard protection.

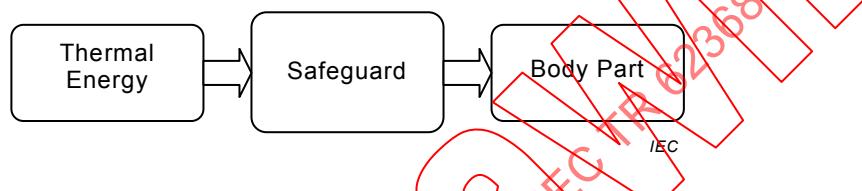


Figure 31 – Model for safeguards against thermal burn injury

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 32 in this technical report, presumes contact to a surface by an ordinary person where a thermal hazard is not present. In this case, no safeguard is required.



Figure 32 – Model for absence of a thermal hazard

b) Thermal hazard is present with a physical safeguard in place

The second model, see Figure 33 in this technical report, 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), 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.

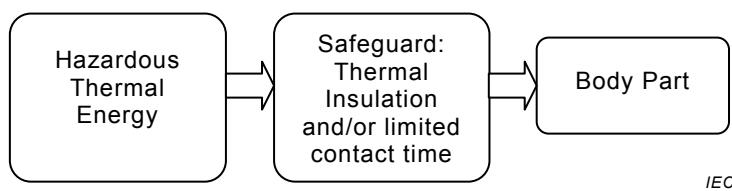


Figure 33 – Model for presence of a thermal hazard with a physical safeguard in place

c) Thermal hazard is present with a behavioural safeguard in place

The third model, see Figure 34 in this technical report, 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.

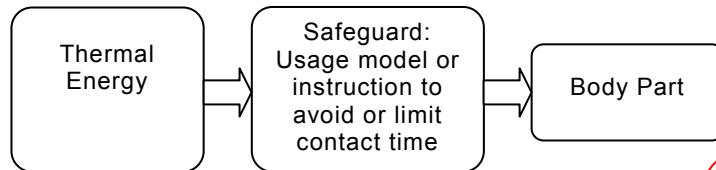


Figure 34 – Model for presence of a thermal hazard with behavioural safeguard in place

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.

9.2.2 TS1

Rationale: The lowest thermal energy source is TS1. TS1 represents a level of thermal energy that generally will not cause a burn injury.

9.2.3 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.

9.2.4 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 standard. All surfaces may be treated as TS3 if not otherwise classified.

9.2.4 TS3

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.

9.2.6 Touch temperature levels**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 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 PDA's. 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 according to IEC Guide 117:2010, Table 2. The TS1 temperature limits in Table 37 for these surfaces are based on the burn threshold limits in IEC Guide 117 for contact durations of 1 s (see IEC Guide 117:2010, Figures A.1 to A.6). More conservative values than those in the 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, 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, 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, Table 3).

Factors for consideration in determining test conditions

For consistency with other parts of the standard 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 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

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 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 standard, 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.

9.4.1

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.

9.4.2 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.

Clause 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.

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 standard. 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.

10.4 Safeguards against visible, infra-red, and ultra-violet radiation

Source: IEC 62471

Rationale: Excessive optical radiation may damage the retina and cause vision impairment or blindness. The limits in the referenced standards 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.

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 standard 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: A11 to EN 60065:2002

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 kind 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:

$$L_{Aeq} = 10 \log \left[\frac{1}{t_2 - t_1} \int_{t_1}^{t_2} \frac{p_A^2}{p_0^2} dt \right]$$

This can be represented graphically as given in Figure 35.

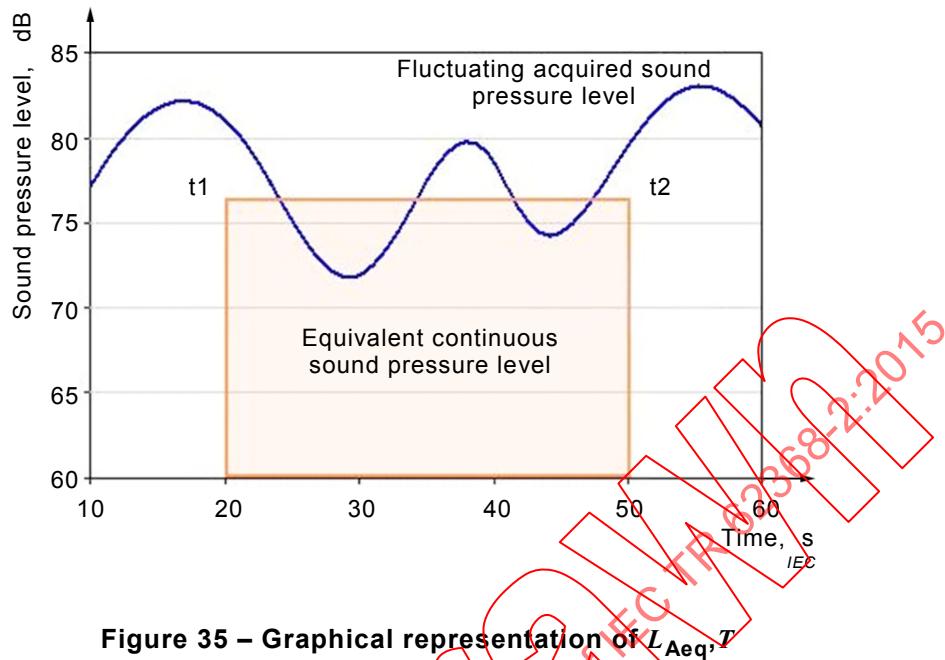


Figure 35 – Graphical representation of $L_{Aeq,T}$

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.

Clause 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/TC108/WG03 considered a value of 85 dB(A) to be safe for an overwhelming majority of the users of personal music players.

10.6.5.1

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 B

Normal operating condition tests, abnormal operating condition tests and single fault condition tests

B.1.6

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.

B.2 – B.3 – B.4 Operating modes

See Figure 36 in this technical report for an overview of operating modes.

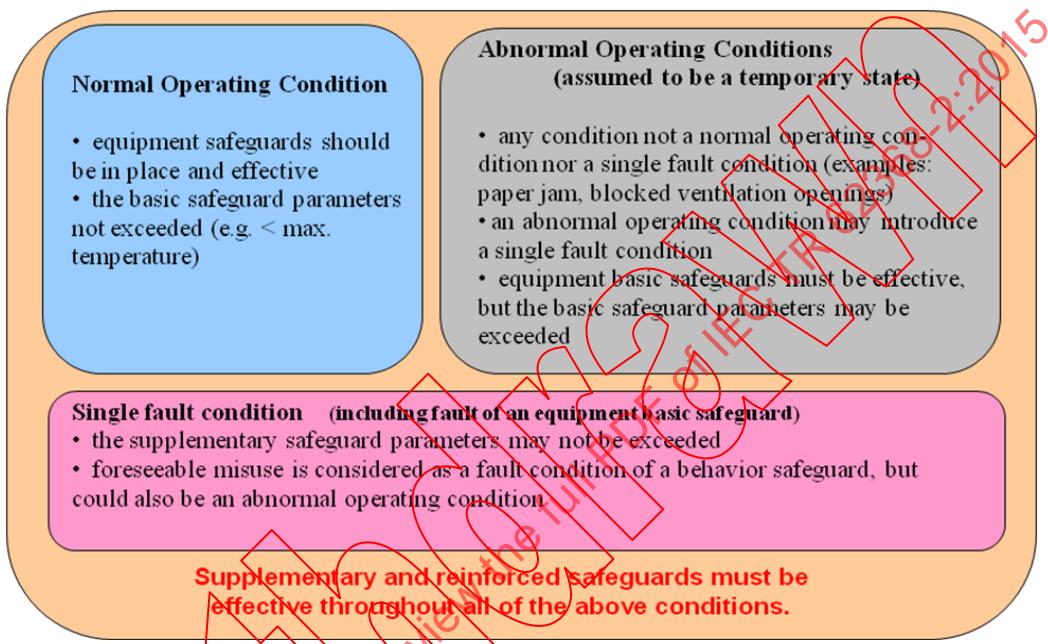


Figure 36 – Overview of operating modes

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 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 standard for many years.

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

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, 9.1.1.2 a). Under single fault conditions, 11.1 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 Table 5 and Table 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, it is highly unlikely. Historically, no known cases of injury have been recorded for amplifiers with a non-clipped output less than 71 V r.m.s.
- the National Electrical Code (USA) permits accessible terminals with a maximum output voltage of 120 V r.m.s.

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; NFPA79:2002, 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

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, SC 3C 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 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.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 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 operate normally after such tests.

G.2.1**Requirements**

Source: IEC 61810-1, for electromechanical relays controlling currents exceeding 0,2 A a.c. or d.c., if the voltage across the open relay contacts exceeds 35 V peak a.c. or 24 V d.c.

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 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

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 37 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 " $I_{\text{res}} \times U_{\text{max}}$ " 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 $U_{\text{max}} \times I_{\text{res}}$ 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.

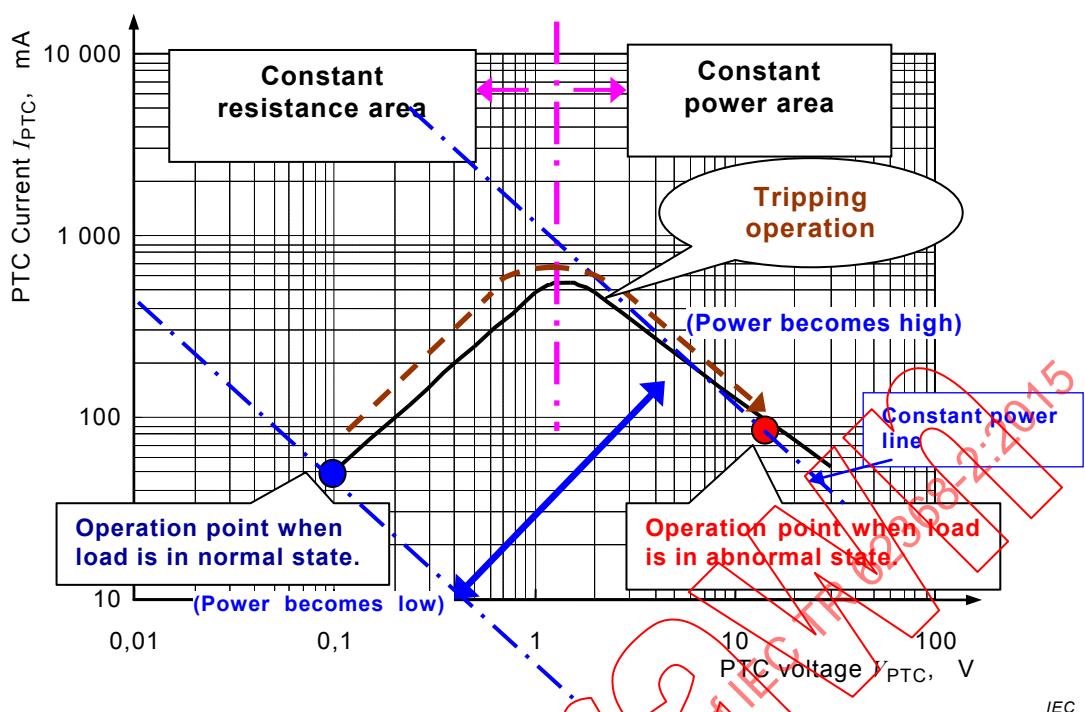


Figure 37 – Voltage-current characteristics (typical data)

If the PTC is installed in a PS1 circuit, the power dissipation of the PTC will be 15 W or less. In this state, the PTC is not considered to be a resistive PIS, regardless of its $I_{\text{res}} \times U_{\text{max}}$:

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 ES.

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, 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 testRationale: 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 standard for many years.

G.5.3.3 Transformer overload tests**Table G.3 – Temperature limits for transformer windings and for motor windings (except for the motor running overload test)**

Although the standard 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.5.4 Motors

Source: IEC 60950-1

Rationale: Requirements have been successfully used with products in the scope of this standard for many years.

G.7 Mains supply cords

Source: IEC 60245 (rubber insulation), IEC 60227 (PVC insulation), IEC 60364-5-54

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 due 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 standard, IEC TC 20 had no published standards 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.

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 standards 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 61051-2:1991/AMD 1:2009.

G.9 Integrated circuit (IC) current limiters

Source: IEC 60730-1

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.

G.11 Capacitors and RC units

Source: IEC 60384-14:2013

Rationale: Table G.8: Test voltage values aligned with those used in IEC 60384-14 (Tables 1, 2 and 10 of IEC 60384-14:2013).

Table G.9: Minimum number of Y capacitors based on required withstand voltage of Table 26 of IEC 62368-1:2014.

Table G.10: Maximum voltage that can appear across a Y capacitor based on the peak working voltage of Table 27 of IEC 62368-1:2014.

Table G.11: Minimum number of Y capacitors based on the test voltages (due to temporary overvoltages) of Table 28 of IEC 62368-1:2014.

Table G.12: Minimum number of X capacitors (line to line or line to neutral) based on the mains transient withstand voltage of Table 13 of IEC 62368-1:2014.

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 devices contain less than one liter 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 circuits, in proximity to an enclosed power supply (not open frame).

The liquid filled heat components are used in desk top 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 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 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.

Rationale: Certain voltages within telecommunication networks often exceed the steady state, safe-to-touch limits set within general safety standards. 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:

- a) contact by a large part of the human body, such as the back of the hand, is impossible;
- b) 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;
- c) 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 38 below 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.

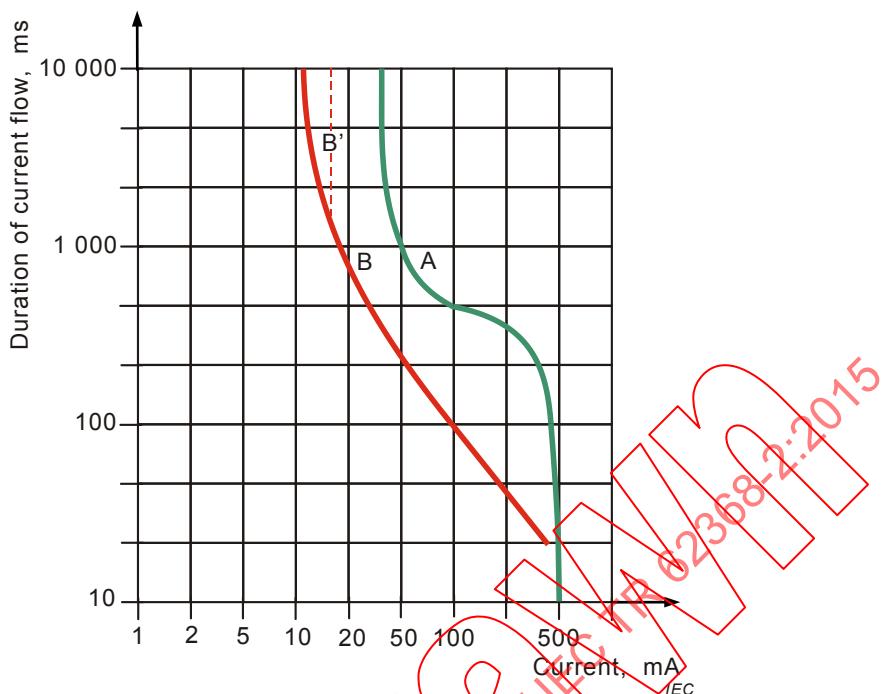


Figure 38 – Current limit curves

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 cm^2 to 100 cm^2 , which is a realistic value for mains operated domestic appliances. Practical telecommunication contact is likely to be much less than this, typically 10 cm^2 to 15 cm^2 for uninsulated wiring pliers or similar tools and less than 1 cm^2 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 cm^2 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 $5 \text{ k}\Omega$ 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 standard)] 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 cm^2 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 60851-6:2012

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.

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 60851-6:2012 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 standard. 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).

Annex M Equipment containing batteries and their protection circuits**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 standard 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 standard.

This annex addresses safeguards that are unique to batteries and that are not addressed in other parts of the standard. 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.

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 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.

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 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 conditions that may occur during use, transport, stock, and disposal, so that the equipment is well prepared for such conditions.

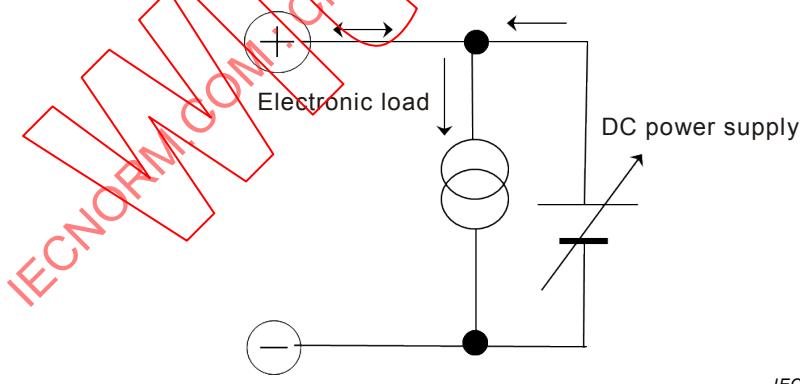
It is important that the key parameters (highest/lowest charging temperatures, maximum charging current, and upper limit charging voltage) during charging and discharging of the battery are not exceeded.

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 39.



IEC

Figure 39 – Example of a dummy battery circuit

M.4.3 Fire enclosure

Lithium-ion batteries are 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, 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-hour 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 an internal power dissipation can be detected by measuring a difference between voltage drops in the 24-hour period.

M.6.1.1**General requirements**

Examples:

An example of a battery standard containing an internal short test is IEC 62133.

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, 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 Safeguards 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, securing 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 40).

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.~~

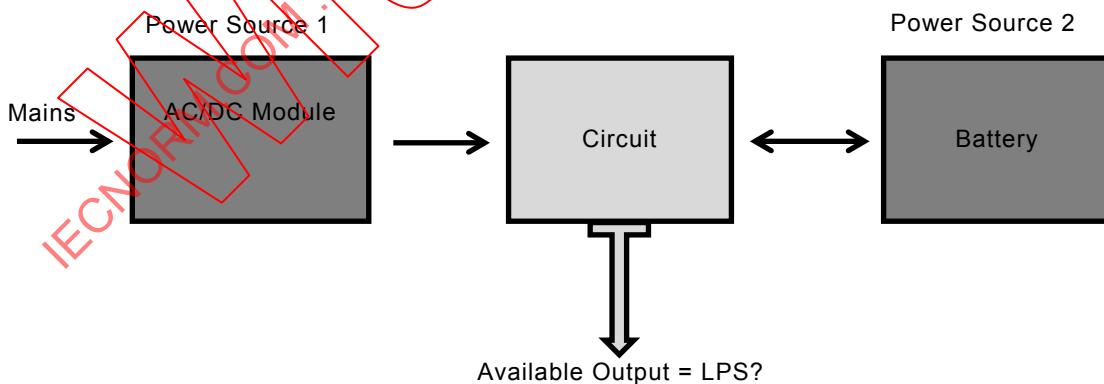


Figure 40 – Example of a circuit with two power sources

Annex R Limited short-circuit test

Source: IEC SC22 E

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 125 °C for printed wiring comes from laminate and PCB standards to accommodate.

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 enclosure or 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.

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 requirements used in this standard.

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.