IEC/TR 62368-2

Edition 1.0 2011-06

TECHNICAL REPORT

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

colour inside

IEC/TR 62368-2:2011(E)

IEC Central Office
3, rue de Varembé
CH-1211 Geneva 20
Switzerland
Email: inmail@iec.ch
Web: www.iec.ch

About IEC publications

The technical content of IEC publications is kept under constant review by the IEC. Please make sure that you have the latest edition, a corrigenda or an amendment might have been published.

- Catalogue of IEC publications: www.iec.ch/searchpub

The IEC on-line Catalogue enables you to search by a variety of criteria (reference number, text, technical committee,…). It also gives information on projects, withdrawn and replaced publications.

- IEC Just Published: www.iec.ch/online_news/justpub

Stay up to date on all new IEC publications. Just Published details twice a month all new publications released. Available on-line and also by email.

- Electropedia: www.electropedia.org

The world's leading online dictionary of electronic and electrical terms containing more than 20 000 terms and definitions in English and French, with equivalent terms in additional languages. Also known as the International Electrotechnical Vocabulary online.

- Customer Service Centre: www.iec.ch/webstore/custserv

If you wish to give us your feedback on this publication or need further assistance, please visit the Customer Service Centre FAQ or contact us:

Email: csc@iec.ch
Tel.: +41 22 919 02 11
Fax: +41 22 919 03 00

IEC/TR 62368-2

Edition 1.0 2011-06

TECHNICAL REPORT

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

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

PRICE CODE XD

ICS 33.160.01; 35.020

ISBN 978-2-88912-542-5

INTERNATIONAL ELECTROTECHNICAL COMMISSION

AUDIO/VIDEO, INFORMATION AND COMMUNICATION TECHNOLOGY EQUIPMENT –

Part 2: Explanatory information related to IEC 62368-1

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
2) The formal decisions or agreements of IEC on technical matters express, as nearly as possible, an international consensus of opinion on the relevant subjects since each technical committee has representation from all interested IEC National Committees.
3) IEC Publications have the form of recommendations for international use and are accepted by IEC National Committees in that sense. While all reasonable efforts are made to ensure that the technical content of IEC Publications is accurate, IEC cannot be held responsible for the way in which they are used or for any misinterpretation by any end user.
4) In order to promote international uniformity, IEC National Committees undertake to apply IEC Publications transparently to the maximum extent possible in their national and regional publications. Any divergence between any IEC Publication and the corresponding national or regional publication shall be clearly indicated in the latter.
5) IEC itself does not provide any attestation of conformity. Independent certification bodies provide conformity assessment services and, in some areas, access to IEC marks of conformity. IEC is not responsible for any services carried out by independent certification bodies.
6) All users should ensure that they have the latest edition of this publication.
7) No liability shall attach to IEC or its directors, employees, servants or agents including individual experts and members of its technical committees and IEC National Committees for any personal injury, property damage or other damage of any nature whatsoever, whether direct or indirect, or for costs (including legal fees) and expenses arising out of the publication, use of, or reliance upon, this IEC Publication or any other IEC Publications.
8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

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

IEC 62368-2, which is a technical report, has been prepared by subcommittee TC108: Safety of electronic equipment within the field of audio/video, information technology and communication technology.

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

Enquiry draft	Report on voting
108/439/DTR	108/452/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 (also in green if colour is available);

– tables and figures that are included in the rationale have linked fields (shaded in grey if “field shading” is active).

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 62368-1:2010.

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

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

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

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

AUDIO/VIDEO, INFORMATION AND COMMUNICATION TECHNOLOGY EQUIPMENT –

Part 2: Explanatory information related to IEC 62368-1

Clause 0 Introduction – Principles of this product safety standard

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

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. The TC108 experts are experts in hardware safety, and have little or no expertise to properly address functional safety requirements.

———————

Clause 3 Terms and definitions

Rationale is provided for definitions that deviate from IEV definitions or from pilot standard definitions.

3.3.2.1 electrical enclosure

Source: IEV 195-06-13

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

Rationale: The IEV definition is modified to use the term “safeguard” in place of the word “protection”. The word “safeguard” identifies a physical “thing” whereas the word “protection” identifies the act of protecting. This 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: IEV 195-06-06

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

Rationale: The IEV definition is modified to use the term “safeguard” in place of the word “protection”. The word “safeguard” identifies a physical “thing” whereas the word “protection” identifies the act of protecting. This 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: IEV 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: IEV 195-06-07

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

Rationale: See 3.3.5.1, basic insulation.

3.3.6.6 restricted access area

Source: IEV 195-04-04

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

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

3.3.7.8 reasonably foreseeable misuse

Source: ISO/IEC Guide 51:1999, definition 3.14

Purpose: To describe that the standard does not generally address foreseeable misuse.

Rationale: The scope excludes consideration of foreseeable misuse that might lead do an injury. 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. 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: IEV 826-18-02

Purpose: To use the terms used in this standard.

Rationale: The IEV 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: IEV 826-18-01

Purpose: To use the terms used in this standard.

Rationale: The IEV definition is modified to use the phrase "to reduce the likelihood of". IEC 62368-1 does not use the word "hazard".

3.3.14.5 prospective touch voltage

Source: IEV 195-05-09

Purpose: To properly identify electric shock energy source voltages.

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

3.3.14.10 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 60335-1:2001, 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.

functional insulation

Purpose: To explain why the standard has no requirements for 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 must be based upon physical examination of the equipment, 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

Purpose: To identify the conditions for consideration of functional components as safeguards.

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 must 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 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.

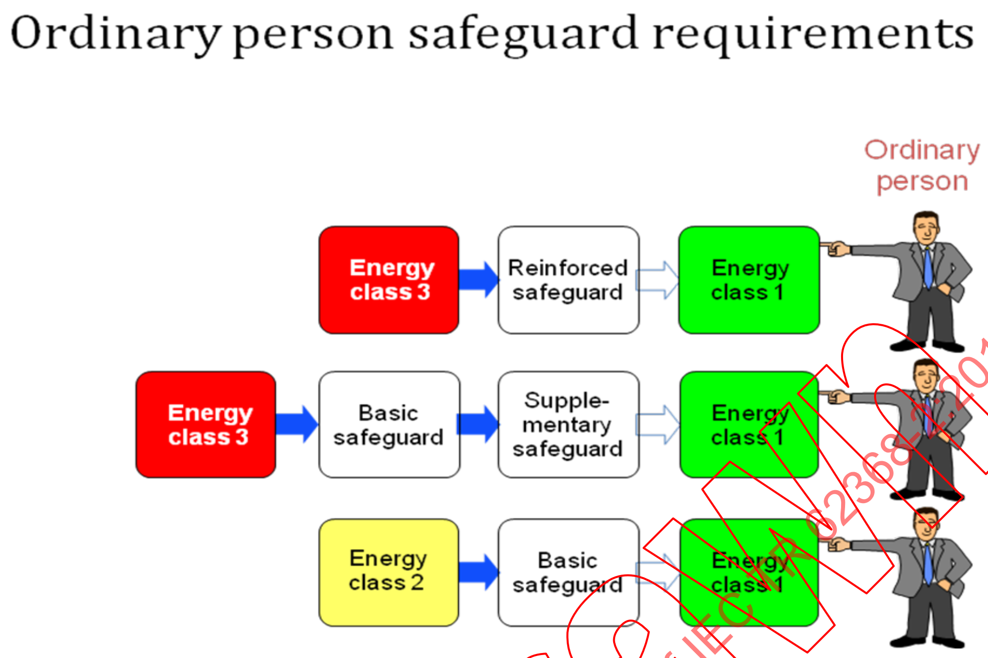
In some cases, a pair of functional components may comprise a safeguard. If the fault of one of the components in the pair is mitigated by the second component, then the pair must be designated as a double safeguard. For example, if two diodes are employed in series to protect a battery from reverse charge, then the pair must comprise a double safeguard and the components must 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 must not exceed the ES2 limits specified for a charged capacitor. Again, the two components comprise a double safeguard and the values of each component must be 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.

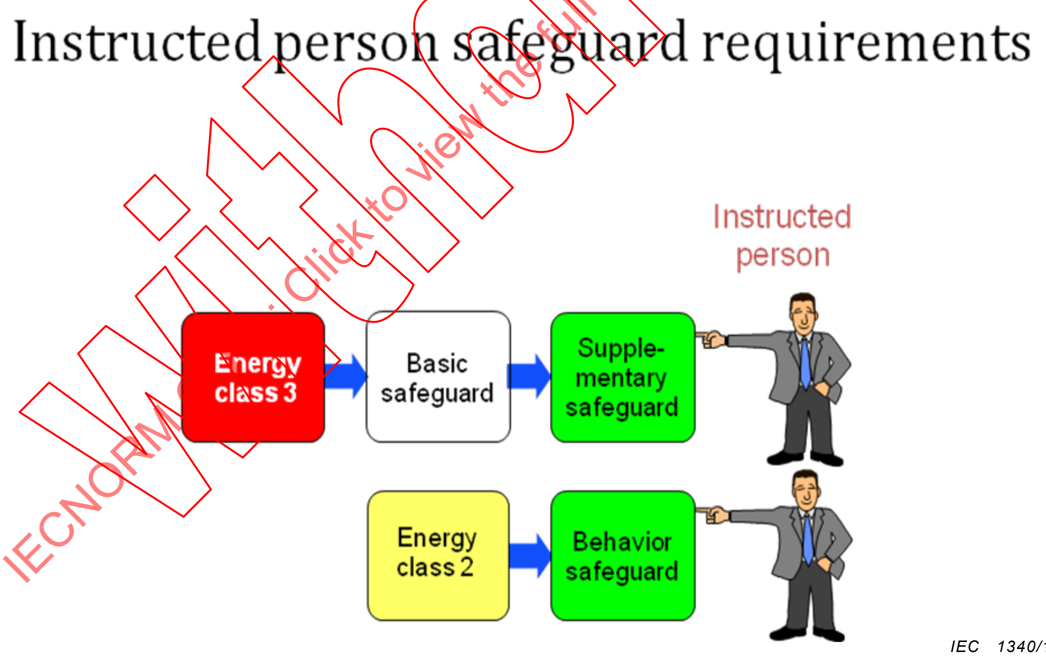
Rationale: This standard includes requirements for safeguard components. A safeguard component is a component specifically designed and manufactured for both functional and safeguard parameters. Examples of safeguard components are capacitors complying with IEC 60384-14 and other IEC component standards.

4.3.2 Safeguards for protection of an ordinary person



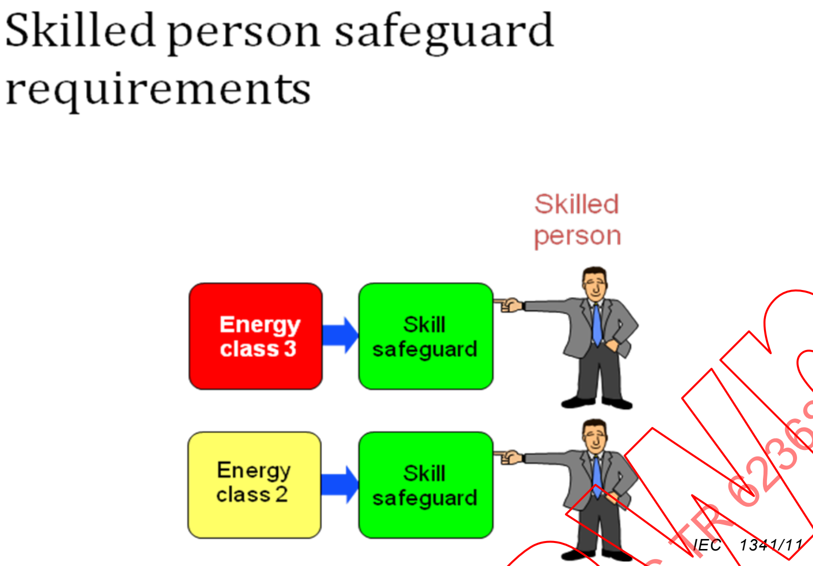
IEC 1339/11

4.3.3 Safeguards for protection of an instructed person



IEC 1340/11

4.3.4 Safeguards for protection of a skilled person



4.4.3 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 must 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.

4.4.5 Safeguard robustness

Purpose: To require safeguards to be robust.

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

————————

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.

5.2.1 Electrical energy source classifications

Source: IEC/TS 60479-1 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.

Purpose: ES1 may be accessible to an ordinary person with no safeguards

Rationale: 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 1 and Table 2 in this standard).

Purpose: ES2 may be accessible to an instructed person with no safeguards and to an ordinary person under a fault condition of a basic safeguard.

Rationale: 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 1 in this standard).

Purpose: ES3 is not accessible to an ordinary person nor to an instructed person under normal conditions or under a fault condition of a safeguard. Parts and circuits classed ES3 may be accessible to a skilled person.

Rationale: IEC/TS 60479-1; zone AC-3 and zone DC-3; harmful physiological effects may occur (see Figure 1 and Figure 2, Table 1 and Table 2 in this standard).

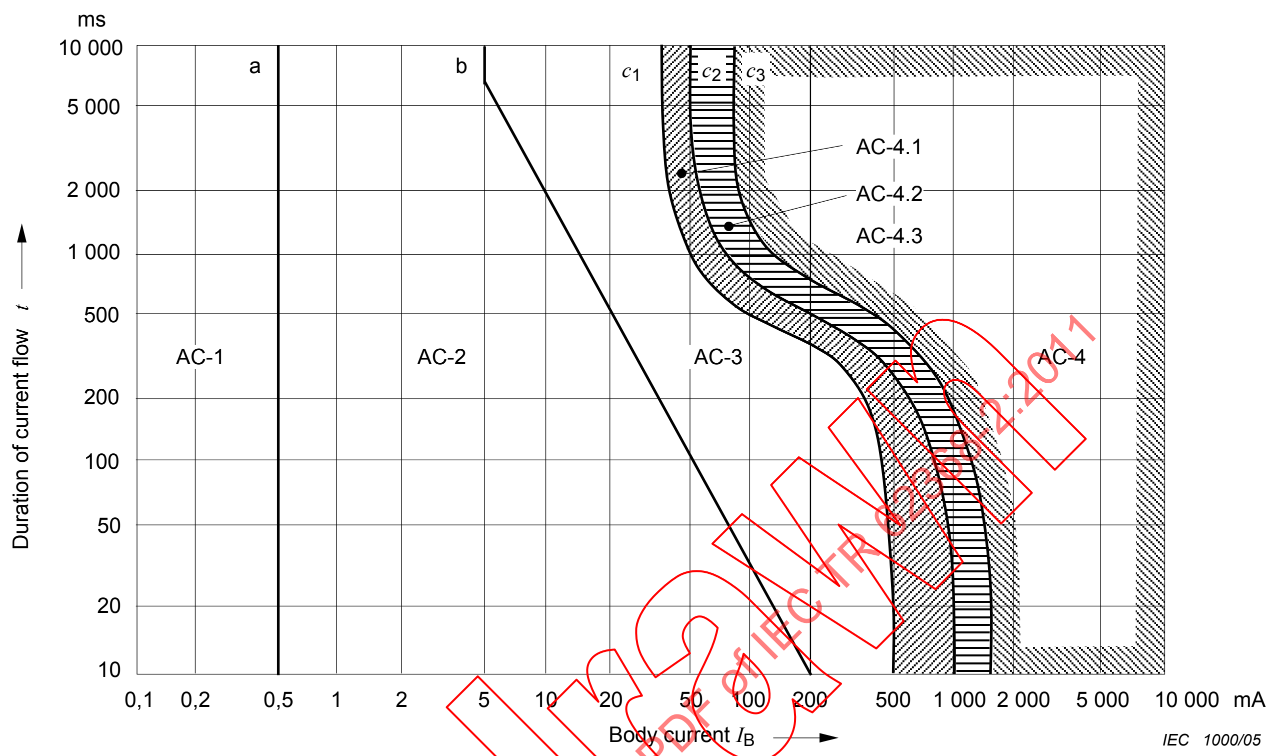


Figure 1 – Conventional time/current zones of effects of a.c. currents (15 Hz to 100 Hz) on persons for a current path corresponding to left hand to feet (see IEC/TS 60479-1:2005, Figure 20)

Table 1 – 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	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.
	$c_1 - c_2$	AC-4.1 Probability of ventricular fibrillation increasing up to about 5 %.
	$c_2 - c_3$	AC-4.2 Probability of ventricular fibrillation up to about 50 %.
	Beyond curve c_3	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.

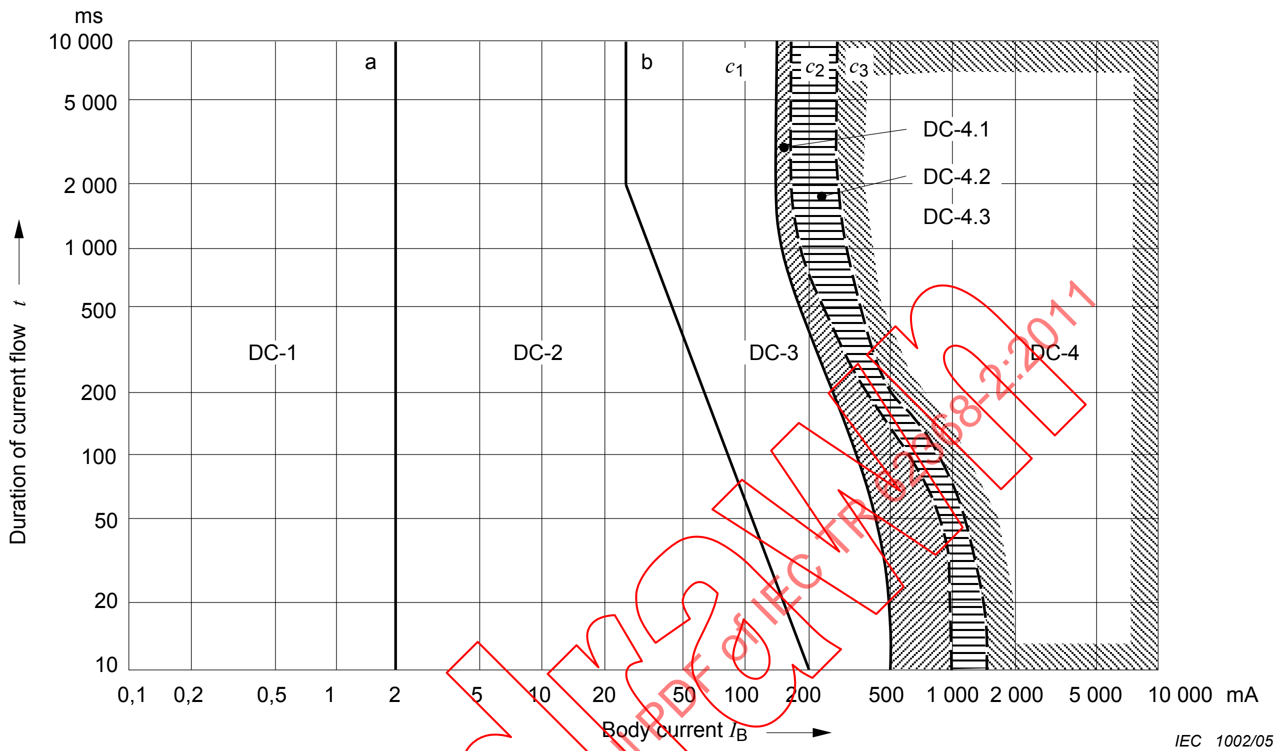


Figure 2 – Conventional time/current zones of effects of d.c. currents on persons for a longitudinal upward current path (see IEC/TS 60479-1:2005, Figure 22)

Table 2 – 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 effects for an injury increas continuously with the energy transferred to the body. To demonstrate this principle Figure 1 and Figure 2 in this standard (see IEC/TS 60479-1:2005, Figures 20 and 22) are transferred into a graph: effects = (f) energy (see Figure 3 in this standard).

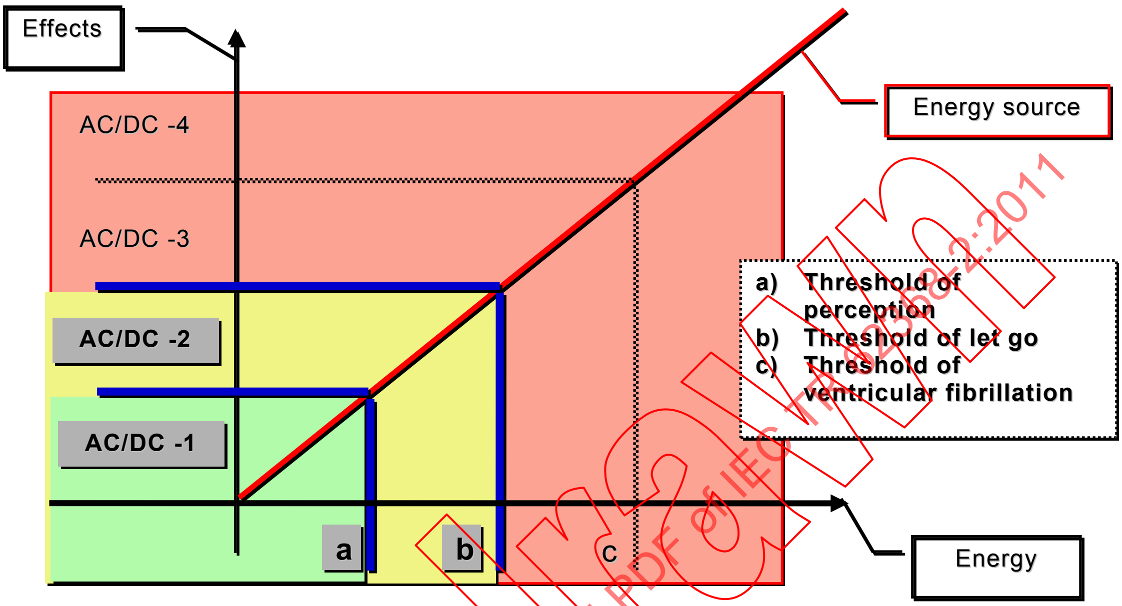


Figure 3 – Illustration that limits depend on both voltage and current

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.

It was found to be not 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 standard (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 standard (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 standard (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 d.c. and low frequency a.c. currents

Source: IEC/TS 60479-1, Dalziel, Effect of Wave Form on Let-Go Currents; AIEE Electrical Engineering Transactions, Dec 1943, Vol 62.

Purpose: Current values for ES Sources.

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 standard (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 we are working with consumer appliances under this standard we need to provide protection for children, which are generally considered the most severe case.

The formulas of IEC 62368-1:2010, Table 4 addresses the Dalziel investigations.

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

Source: IEC 60950-1 and IEC 61201:2007(see Table 3 in this standard)

Purpose: Voltage values for ES sources.

Rationale: In most cases the electrical power source is a voltage source. Therefore it is practical for the design and testing of electrical equipment to specify voltage limits.

The values chosen in the table are for dry conditions only.

Typically, physically larger people in the population have lower internal body resistance because of their larger cross sectional area. Physically small people in the population generally have higher internal body resistance. Some measurements of body impedances show that the body impedance is not greatly influenced by the body weight. Therefore there is not sufficient correlation between the body weight (children or adults) and the physiological current values corresponding to a particular effect.

– ES-1 and ES-2 voltage limits are taken from IEC 60950-1, based on experience.
– ES-1 voltage limits correspond to the limits of SELV circuits of IEC 60950-1 and to Table A.1 of IEC/TS 61201:2001 environmental situation 3 (dry).
– ES-2 voltage limits correspond to the limits of TNV circuits of IEC 60950-1 and to Table A.1 of IEC/TS 61201:2001 environmental situation 3 (dry) "single fault."

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 we are working with consumer appliances under this standard we need to provide protection for children, the worst case.

The formulas of IEC 62368-1:2010, Table 5 addresses the Dalziel investigations.

Table 3 – Limits for steady-state voltages (see IEC 61201:2007)

Environmental situation	No fault	Single fault	Two faults
1	0 V	0 V	16 V a.c. 35 V d.c.
2	16 V a.c. 35 V d.c.	33 V a.c. 70 V d.c.[b]	Not applicable
3	33 V a.c. [a] 70 V d.c. [b]	55 V a.c. [a] 140 V d.c. [b]	Not applicable
4	Special applications		

[a] For a non-grippable part with a contact area less than 1 cm^2, limits are 66 V and 80 V respectively.

[b] For charging a battery, limits are 75 V and 150 V.

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

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

Purpose: Voltage values for ES Sources with higher frequencies.

Rationale: The effect of a.c. current with higher frequencies (above 100 Hz) is documented in IEC/TS 60479-2. With increasing frequency an increasing current has the same effect to the human body (Figures 9 and 12 of IEC/TS 60479-2:2007). For high frequency currents of about 100 mA burns may occur. Therefore the maximum HF current limit is specified to 100 mA. The formula used for the ES1 limits of the HF current is already used in IEC 60215 and in IEC 60950-1. The body impedance falls with increasing frequency. The effect is documented in IEC/TS 60479-1. Therefore the voltage limits has a different formula than the formula for the current.

5.2.2.3 Capacitance limits

Table 7 – Electrical energy source limits for a charged capacitor

Source: IEC/TR 61201:2007 (Annex A)

Purpose: Limits for capacitances.

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 61201:2007.

The values for ES2 are derived from Table A.2 (IEC 61201:2007).

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

While Table 4 in this standard shows a value of 60 kV for 0,133 nF capacitor, because this value results in an energy greater than 350 mJ (using ½ CV^2 formula), it was changed to 50 kV.

Table 4 – Limit values of accessible capacitance (threshold of pain) – (IEC 61201:2007)

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

5.2.2.4 Single pulse limits

Table 8 – Voltage limits for single pulses

Table 9 – Current limits for single pulses

Source: IEC/TS 60479-1:2005

Purpose: Values for ES Sources of single pulses.

Rationale: For ES1 the limit of single pulse should not exceed the ES-1 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 standard (IEC/TS 60479-1:2005, Figure 22) and the resistance values of Table 10, column for 5 % of the population (see Table 5 in this standard).

The current limits of single pulses in Table 9 for ES-1 levels are from curve a and for ES-2 are from curve b of Figure 2 in this standard (IEC/TS 60479-1:2005, Figure 22).

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 10 – Electrical energy source limits for repetitive pulses

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

Purpose: To define current and voltage limits for repetitive pulses.

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 8 (voltage) or Table 9 (current) are used.

5.2.2.6 Ringing signals

Source: EN 41003

Purpose: 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 60065:2001; IEC 62368-1:2010, Annex E

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 60065:2001. Reference: IEC 60065:2001, 9.1.1.1a). Under single fault conditions, 10.1 of IEC 60065:2001 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 Protection of an ordinary person

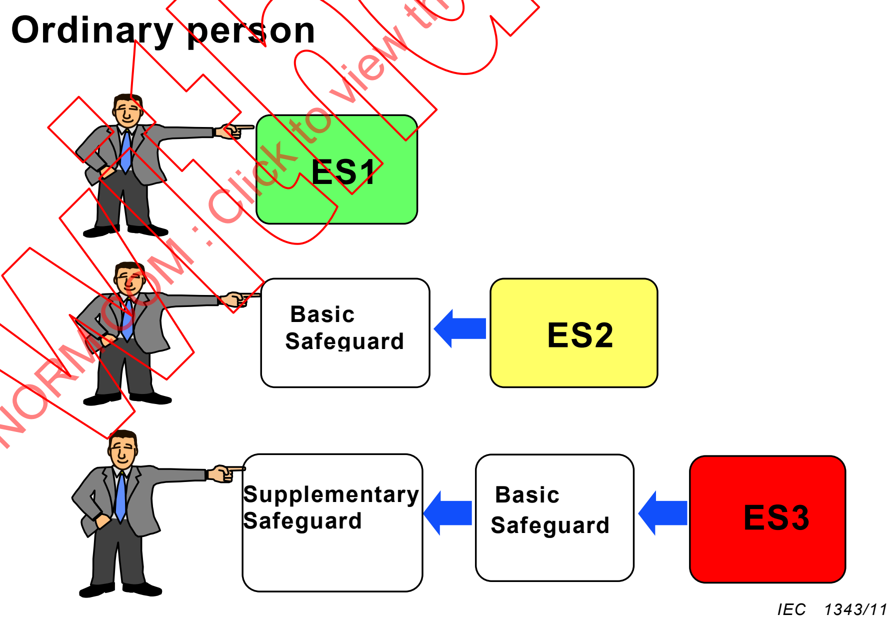


Figure 4 – Safeguards between an energy source and an ordinary person

5.3.2.1 Safeguards between energy source ES1 and an ordinary person

Source: IEC/TS 60479-1

Purpose: No requirement for a safeguard.

Rationale: Because there is usually no reaction of the human body when touching ES1, access is permitted (IEC/TS 60479-1; zone AC-1 and zone DC-1). See Figure 4 in this standard.

5.3.2.2 Safeguards between energy source ES2 and an ordinary person

Source: IEC/TS 60479-1

Purpose: At least one equipment safeguard.

Rationale: Because there may be a reaction of the human body when touching ES2, protection is required. But 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). See Figure 4 in this standard.

5.3.2.3 Safeguards between energy source ES3 and an ordinary person

Source: IEC/TS 60479-1

Purpose: At least two safeguards, one basic and one supplementary.

Rationale: Because harmful physiological effects may occur when touching ES3, (IEC/TS 60479-1; zone AC-3 and zone DC-3), protection is required including after a fault of one safeguard. See Figure 4 in this standard.

5.3.3 Protection of an instructed person

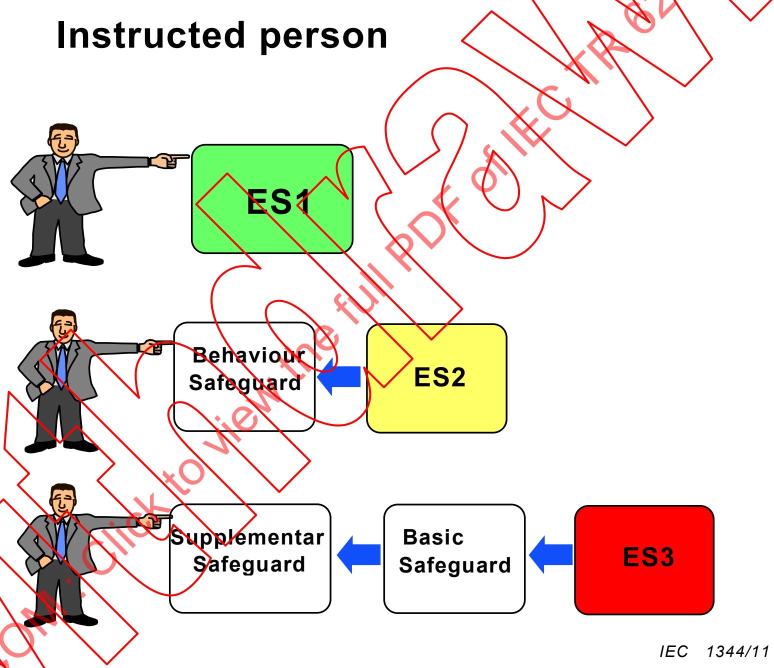


Figure 5 – Safeguards between an energy source and an instructed person

5.3.3.1 Safeguards between ES1 or ES2 and an instructed person

Source: IEC/TS 60479-1

Purpose: No requirement for a safeguard.

Rationale: For ES1: because there is usually no reaction of the human body when touching ES1 access is permitted (IEC/TS 60479-1; zone AC-1 and zone DC-1). (See Figure 5 in this standard.)

For ES2: An instructed person is instructed that there may be a reaction of the human body when touching ES2 but no harmful physiological effects may occur when touching ES2 (IEC/TS 60479-1; zone AC-2 and zone DC-2). (See Figure 5 in this standard).

5.3.3.2 Safeguards between ES3 and an instructed person

Source: IEC/TS 60479-1

Purpose: At least two safeguards, one basic and one supplementary.

Rationale: Because harmful physiological effects may occur when touching ES3, (IEC/TS 60479-1; zone AC-3 and zone DC-3), a protection is required including after a fault of one safeguard. (See Figure 5 in this standard.)

5.3.4 Protection of a skilled person

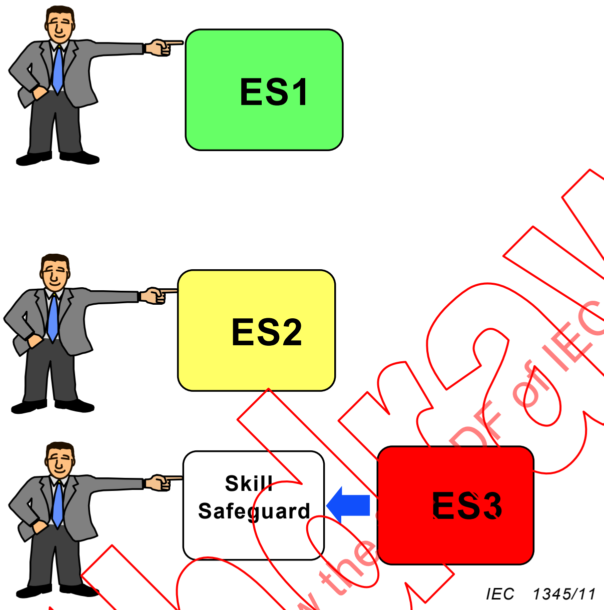


Figure 6 – Safeguards between energy sources and a skilled person

5.3.4.1 Safeguards between ES1 or ES2 and a skilled person

Source: IEC/TS 60479-1

Purpose: No requirement for a safeguard.

Rationale: For ES1: Because there is usually no reaction of the human body when touching ES1 access is permitted (IEC/TS 60479-1; zone AC-1 and zone DC-1). (See Figure 6 in this standard.)

For ES2: A skilled person has the knowledge that there may be a reaction of the human body when touching ES2, but that there are no harmful physiological effects when touching ES2 (IEC/TS 60479-1; zone AC-2 and zone DC-2). (See Figure 6 in this standard.)

5.3.4.2 Safeguards between ES3 and a skilled person

Purpose: Unintentional contact has to be prevented.

Rationale: A skilled person has the knowledge that there may be harmful physiological effects when touching ES3. (See Figure 6 in this standard.)

5.3.5 Safeguards between energy sources

5.3.5.2 Safeguards between ES1, ES2 and ES3

Purpose: At least one basic safeguard between ES1 and ES2.

Rationale: ES1 could be accessible for an ordinary person; ES2 should not therefore, the same protection as for ES2 applies (see 5.3.2.2).

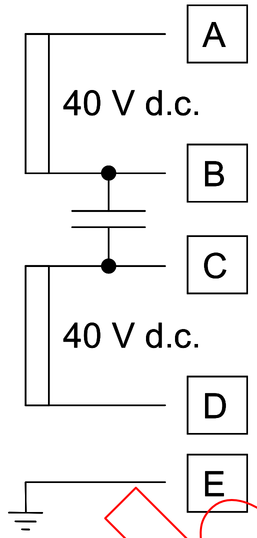
Purpose: At least two safeguards between ES1 and ES3, one basic and one supplementary.

Rationale: ES1 could be accessible for an ordinary person; ES3 should not, even after a single fault, therefore the same protection as for ES3 (see 5.3.2.3).

Purpose: Example of determination of ES1 class for interconnected sources.

Rationale: ES1 circuits must be examined for voltage and current for both normal operating condition and single fault condition. If the voltage does not exceed the ES1 limit or, under single fault conditions, the ES2 limit, then the current does not need to be measured. Several examples are provided.

Example A, normal operating condition

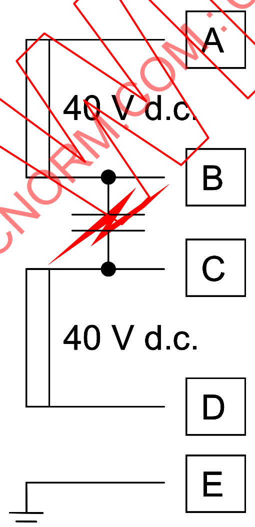


EXAMPLE A normal operating conditions	volts d.c.				
	A	**B**	**C**	**D**	**E**
A	0	40	0	0	n/a
B	40	0	0	0	n/a
C	0	0	0	40	n/a
D	0	0	40	0	n/a
E	n/a	n/a	n/a	n/a	n/a

IEC 1346/11

All voltages are within ES1 limits. Terminals A, B, C, D, and E may be accessible. If A, B, C, or D is connected to E, the results are the same.

Example B, single fault conditions (capacitor short-circuit)



EXAMPLE B single fault conditions	volts d.c.				
	A	**B**	**C**	**D**	**E**
A	0	40	40	*80*	n/a
B	40	0	0	40	n/a
C	40	0	0	40	n/a
D	*80*	40	40	0	n/a
E	n/a	n/a	n/a	n/a	n/a

IEC 1347/11

All voltages that exceed ES1 limits are within ES2 limits (shown in italics, blue if color is available), therefore the two sources are ES1.

The capacitor is not required to be a safeguard.

Terminals A, B, C, D, and E may be accessible. If A, B, C, or D is connected to E, the results are the same.

5.3.5.3 Protection of ES2 against ES3

Purpose: At least two safeguards between ES2 and ES3, one basic and one supplementary.

Rationale: ES2 could be accessible for an instructed person or after a single fault for an ordinary person; ES3 should not, even after a single fault. Therefore the same protection as for ES3 applies (see 5.3.2.3 and 5.3.3.2).

5.3.6.2 Contact requirements

Source: IEC 61140:2001, 8.1.1; IEC 62368-1:2010, 4.3

Purpose: Determination of accessible parts for adults and children. Tests are in IEC 62368-1:2010, Annex V.

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

5.3.6.3 Compliance

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

5.3.6.4 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 WG6) 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 (IEC 62368-1:2010, 5.4.2 and 5.4.3)

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 Frequency

Source: IEC 60664-4

Purpose: To address insulation requirements for frequencies above 30 kHz.

Rationale: Above 30 kHz, IEC 60664-4 identifies deteriorating means, and effects need to be considered.

5.4.1.5 Maximum operating temperatures for insulating materials

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

Purpose: Temperature limits given in Table 14:

- limits for insulation materials including electrical insulation systems, including winding insulation (Classes A, E, B, F, H, N, R and C) are taken from IEC 60085 (see IEC 62368-1:2010, G.7);
- 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 (5.4.1.4) 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.

5.4.1.6 Pollution degrees

Source: IEC 60664-1

Purpose: To use same description as in source.

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.

5.4.1.7 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.

5.4.1.8 Insulation in circuits generating starting pulses

Source: IEC 60950-1, IEC 60664-1

Purpose: For clearances:

a) clearance can be determined in accordance with 5.4.2.7; or
b) an electric strength test can be applied using regular test procedures and at a test voltage as given in 5.4.11.1; or
c) simulate the internally generated pulse trains by means of an external pulse generator, with a peak that is not less than the peak of the test voltage determined in 5.4.11.1 and whose pulse width is not smaller than the pulse width of the starter impulse.

5.4.1.9 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.

5.4.1.9.1 General

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.

5.4.1.9.2 RMS working voltage

Source: IEC 60664-1:2007, 3.5

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

Rationale: See IEC 60664-1:2007, 3.5.

5.4.1.9.3 Peak working voltage

Source: IEC 60664-1:2007, 3.8

Purpose: The peak working voltage is used when determining the required impulse withstand voltage for minimum clearances and test voltages for the electric strength test.

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.

5.4.1.11 Thermoplastic parts on which conductive metallic parts are directly mounted

Source: ISO 306 and IEC 60695-2 series

Purpose: 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.

Rationale: See 5.4.1.4 of this standard.

5.4.2 Clearances

5.4.2.1 General

Source: 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.

Purpose: To provide a reliable safeguard.

Rationale: Overvoltages and transients that may enter the equipment, and peak voltages that may be generated within the equipment, do not break down the clearance (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.

5.4.2.2 Compliance

Source: IEC 60664-1:2007, 5.1.1

Rationale: IEC 62368-1:2010, Annex O figures are similar/identical to figures in IEC 60664-1.

Tests of IEC 62368-1:2010, 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.

5.4.2.3 Procedure for determining minimum clearances

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

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

5.4.2.4.1 Determination of a.c. mains transient voltages

Source: IEC 60664-1:2007, 4.3.3.3

Rationale: Table 15 is derived from Table 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.

5.4.2.4.3 Determination of external circuit transient voltages

Source: ITU-T K.21

Purpose: 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.).

Rationale: Practical approach.

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

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

Purpose: 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.

Rationale: 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.

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

Rationale: Practical approach, no real technical data available

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 7 in this standard 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 8 in this standard shows the definition of the various voltages for coaxial-cable interfaces.

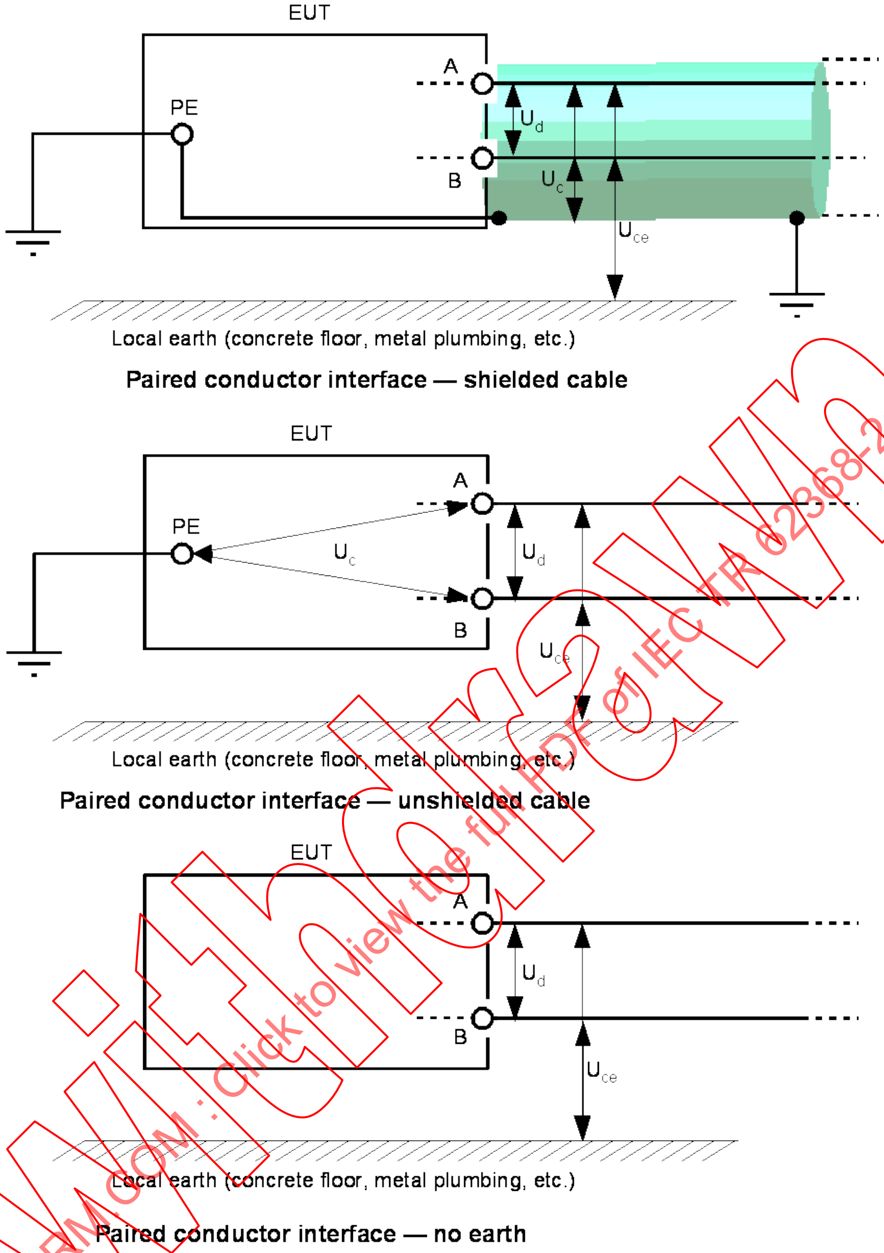
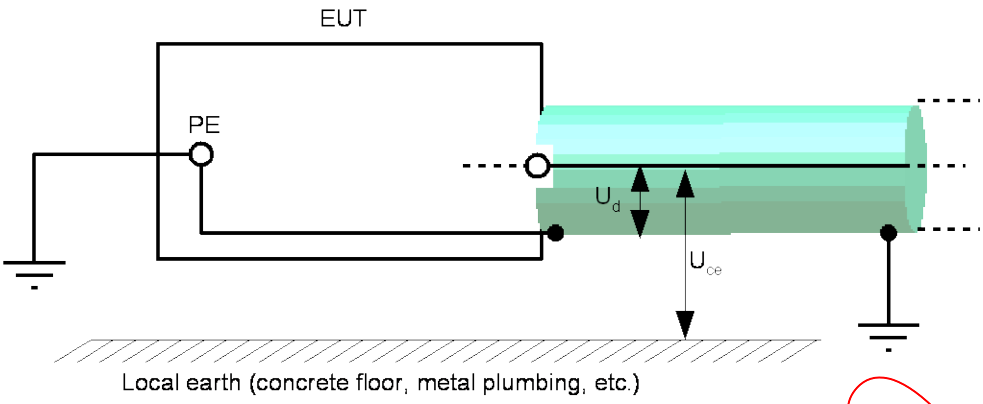
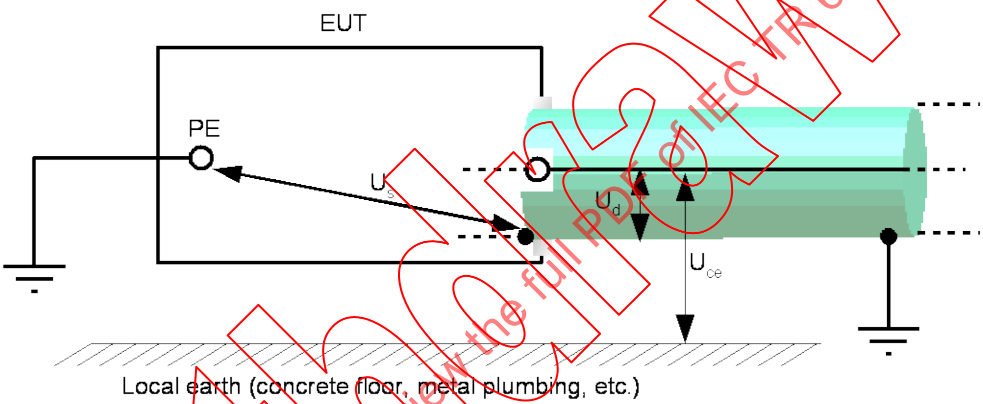


Figure 7 – Illustration of transient voltages on paired conductor external circuits



Coaxial cable interface —earthed at both ends



Coaxial cable interface — earthed at building entrance or other equipment, not earthed at equipment

Figure 8 – Illustration of transient voltages on coaxial-cable external circuits

Table 16 – External circuit transient voltages

Purpose: Transients have an influence, if the d.c. system extends beyond the building structure.

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.

5.4.2.5.1 Mains transient voltages

Source: IEC 60950-1 and IEC 60664-1:2007 (3.1)

Rationale: The rules are developed in alignment to IEC 60664-1.

5.4.2.5.2 DC source transient voltages

Rationale: Transient overvoltages are attenuated by the capacitive filtering.

5.4.2.5.4 Combination of transient voltages

Rationale: Clearance is affected by the largest of the determined transients. The likelihood of their simultaneous occurrence is very low.

5.4.2.6 Measurement of transient voltage levels

Rationale: Test method is taken from IEC 60950-1:2005, Annex G.

5.4.2.7 Determination of the minimum clearances

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

Rationale: Values in Tables 18 and 17 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 according to 5.4.2.7, 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.

For frequencies above 30 kHz the values given in Table 19 are the same as in Table 1 of IEC 60664-4:2005.

5.4.2.8 Minimum clearances based on 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 21.

Rationale: The impulse test voltages in Table 21 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 6 in this standard 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 (thickness of enamel/5 + air gap/1) = 2 500 (0,04 / 5 + 2 / 1 for 2 mm air gap) = 2 500 (0,008 + 2) = (10 V across enamel + 2 490 V across air gap)

Table 6 – 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 21	Test voltage across air gap	Test voltage across enamel
Material: Polyester, dielectric constant = 5							
0,04	2	2 500	2 490	10	2 950	12	2 938
0,04	1	2 500	2 480	20	2 950	24	2 926
0,04	0,6	2 500	2 467	33	2 950	39	2 911
For 2 500 V peak impulse (transient for 230 V system), the homogenous field distance is 0,6 mm (from Table A.1 of IEC 60664-1:2007). Our test voltage for 2 500 V peak is 2 950 V peak from Table 21. 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) × 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 20. We are always on the safe side.							
Material: Polyamide, dielectric constant = 2,5							
0,04	2	2 500	2 480	20	2 950	23	2 927
0,04	1	2 500	2 460	40	2 950	46	2 904
0,04	0,6	2 500	2 435	65	2 950	76	2 874
For 2 500 V peak impulse (transient for 230 V system), the homogenous field distance is 0,6 mm (from Table A.1 of IEC 60664-1:2007). Our test voltage for 2 500 V peak is 2 950 V peak from Table 21. 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) × 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 20. We are always on the safe side.							

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

Source: IEC 60664-1, 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 22 and the multiplication factors for altitudes higher than 2 000 m.

Rationale: Table 22 is developed using Figure A.1 of IEC 60664-1:2007, curve number 2 for case A using impulse test.

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.18.3 (Coated boards). Consequently the values for voltages up to 455 V in Table G.12 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.

5.4.3.2.1 Test conditions

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.

5.4.3.2.2 Material group and CTI

Source: IEC 60112

Rationale: Classification as given in IEC 60112.

5.4.3.3 Compliance

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

Rationale: Values in Table 23 are the same as in Table F.4 of IEC 60664-1:2007.

Values in Table 24 are the same as in Table 2 of IEC 60664-4.

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.18), 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

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 must pass thermal cycling (see 5.4.7), humidity test (see 5.4.10) and electric strength test (see 5.4.11). 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: Method a) [type testing of 5.4.11.1 (electric strength testing at 160 % of the normal value after thermal cycling and humidity conditioning), and routine electric strength test of 5.4.11.2] has been used since many years, especially in North America.

Method b) refers to G.16, which references IEC 60747-5-5.

5.4.4.5 Insulating compound forming cemented joints

Source: IEC 60950-1

Purpose: Three versions of joints are addressed:

a) if the distances along the path comply with the clearances and creepage distances for Pollution degree 2, no testing is required;
b) if the distances along the path comply with the clearances and creepage distances for Pollution degree 1, the test for PD 1 (see 5.4.8) is required;
c) if the distances along the path are less than the distances for pd 1, the requirements for distance through insulation of 5.4.4.3 apply. The samples have to pass the tests of 5.4.11 (electric strength testing at 160 % of the normal value after thermal cycling and humidity conditioning).

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) and c) are 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.

5.4.4.6.1 General requirements

Source: IEC 60950-1, IEC 61558-1:2005

Purpose: No dimensional or constructional requirements for insulation in thin sheet material used as Basic Insulation, is aligned to the requirements of IEC 61558-1:2005.

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.

Rationale: The requirements are based on extensive tests performed on thin sheet material by manufacturers and test houses involved in IEC TC74 (now TC108) work.

5.4.4.6.2 Separable thin sheet material

Source: IEC 60950-1

Purpose: For two layers, test each layer with the electric strength test of 5.4.11 for the applicable insulation grade. For three layers, test all combinations of two layers together with the electric strength test of 5.4.11 for the applicable insulation grade.

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

Rationale: The requirements are based on extensive tests performed on thin sheet material by manufacturers and test houses involved in IEC TC74 (now TC108) work.

5.4.4.6.3 Non-separable thin sheet material

Source: IEC 60950-1

Rationale: For testing non-separable layers, all the layers must have the same material and thickness. If not, samples of different materials must be 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 must remain 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

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

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

Rationale: 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

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.

NOTE Same requirement as in IEC 60950-1:2005, and IEC 60065:2001.

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.

5.4.4.9 Solid insulation requirements at frequencies higher than 30 kHz

Source: IEC 60664-4

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.14.3.2 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

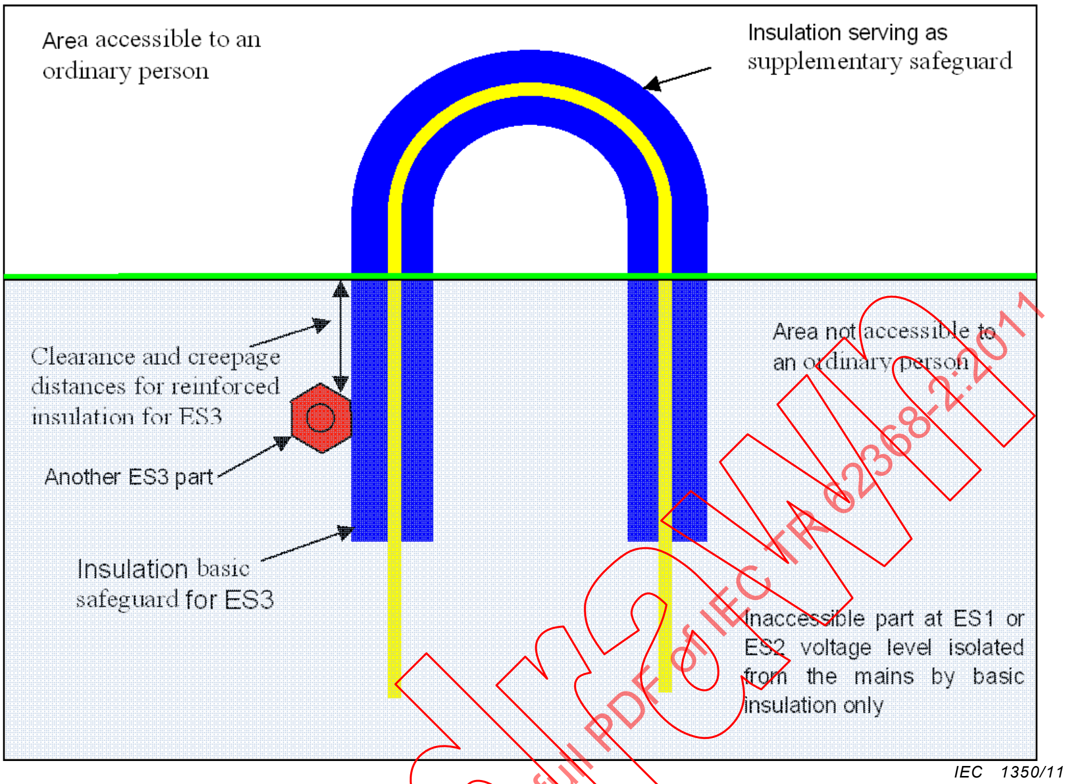


Figure 9 – Example illustrating accessible internal wiring

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 9 in this standard.)

5.4.7 Thermal cycling test procedure

Source: IEC 60950-1; Alternative: IEC 60664-1:2007, 6.1.3.2

Purpose: To simulate lifetime aging of materials.

Rationale: To avoid insulation breakdown during the expected life-time of the product.

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

Source: IEC 60950-1

Purpose: To simulate a Pollution degree 1 environment. Sequence: thermal cycling, humidity conditioning, electric strength testing.

Rationale: To avoid cracks or voids in the insulating material to maintain the integrity of the insulating material.

5.4.9 Tests for semiconductor components and for cemented joints

Source: IEC 60950-1

Purpose: To simulate lifetime stresses on adjoining materials.

Sequence: thermal cycling

One sample: electric strength testing at 160 % of test voltage

Two samples: Humidity conditioning, electric strength testing at 160 % of test voltage.

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

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

5.4.10 Humidity conditioning

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

Purpose: Material preparations for dielectric strength test

Rationale: Prerequisite for further testing.

5.4.11 Electric strength test

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

Purpose: Current should not flow as a result of the application of the test voltage

Rationale: To avoid insulation breakdown.

This method has been successfully used for products in the scope of this standard for many decades.

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 31 – Test voltages for electric strength tests based on transient voltages

Source: IEC 60664-1

Purpose: Dielectric strength test voltages based on transient overvoltages.

Rationale: To deal with withstand voltages and cover transients.

The basic and supplementary insulations must 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 32 – Test voltages for electric strength tests based on peak working voltages

Source: IEC 60664-1

Purpose: Dielectric strength test.

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, 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, 5.3.3.2.3 (1,32 × U_p for basic Insulation, or 1,65 × U_p for reinforced insulation).

Table 33 – Test voltages for electric strength tests based on temporary overvoltages

Source: IEC 60664-1

Purpose: Dielectric strength test.

Rationale: Temporary overvoltages (IEC 60664-1, 5.3.3.2.2) need to be considered as they may be present up to 5 s.

Example:

The insulation in question is part of mains connected circuits:

a) the rated mains voltage is below 150 V r.m.s:

The temporary overvoltage is U_n + 1 200 V = 1 320 V r.m.s. or 1 910 V peak for 150 V mains voltage;

b) the rated mains voltage is above 150 V r.m.s:

The temporary overvoltage is U_n + 1 200 V = 1 440 V r.m.s. or 2 110 V peak for over 150 V mains voltage.

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.

5.5.2.3 Safeguards against capacitor discharge

Source: IEC/TS 61201:2007, Annex A

Purpose: After 2 s the touch voltage on the connector pins shall not exceed ES1 levels for ordinary persons or ES2 levels for instructed persons.

Rationale: 2 s delay time represent the typical access time after connector disconnection.

5.5.2.7 Resistors as a basic safeguard and a supplementary safeguard

Source: IEC 60950-1

Purpose: Resistors have to pass specific high voltage tests and have to have basic insulation between the terminals.

Tests, see G.14.

Rationale: Engineering practice.

5.5.2.8 SPD as a basic safeguard

Source: IEC 61051-1 and IEC 61051-2

Purpose: The MOV has to comply with G.10 and one side of the MOV has to be earthed in a reliable manner.

Rationale: Engineering practice.

5.5.2.9 Other components as a basic safeguard between ES1 and ES2

Purpose: Components have to be used in their specified ratings, minimum two components.

Rationale: The likelihood of a fault of these two components is comparable with the likelihood of a fault of one specific component generally used as basic safeguard (same acceptable risk).

5.5.3.1 General requirements

Source: Relevant IEC safety standard.

Purpose: The insulation of components has to be in compliance with reinforced insulation requirements of 5.4.1, or with the safety requirements of the relevant IEC standard.

Rationale: Reinforced insulation is accepted in general. Safety requirements of a relevant standard are accepted if they are adequate for their application, for example, Y1 capacitors of IEC 60384-14.

5.5.3.6 Resistors

Source: IEC 60950-1

Purpose: Resistors have to pass specific high voltage tests and have to have reinforced insulation between the terminals.

Test G.14.

Rationale: Engineering practice.

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

Source: IEC 60065

Purpose: Resistors have to pass the voltage surge test or impulse test of G.14.2.

Rationale: Engineering practice

5.6 Protective conductor

See Figure 10 in this standard for an overview of protective earthing and protective bonding conductors.

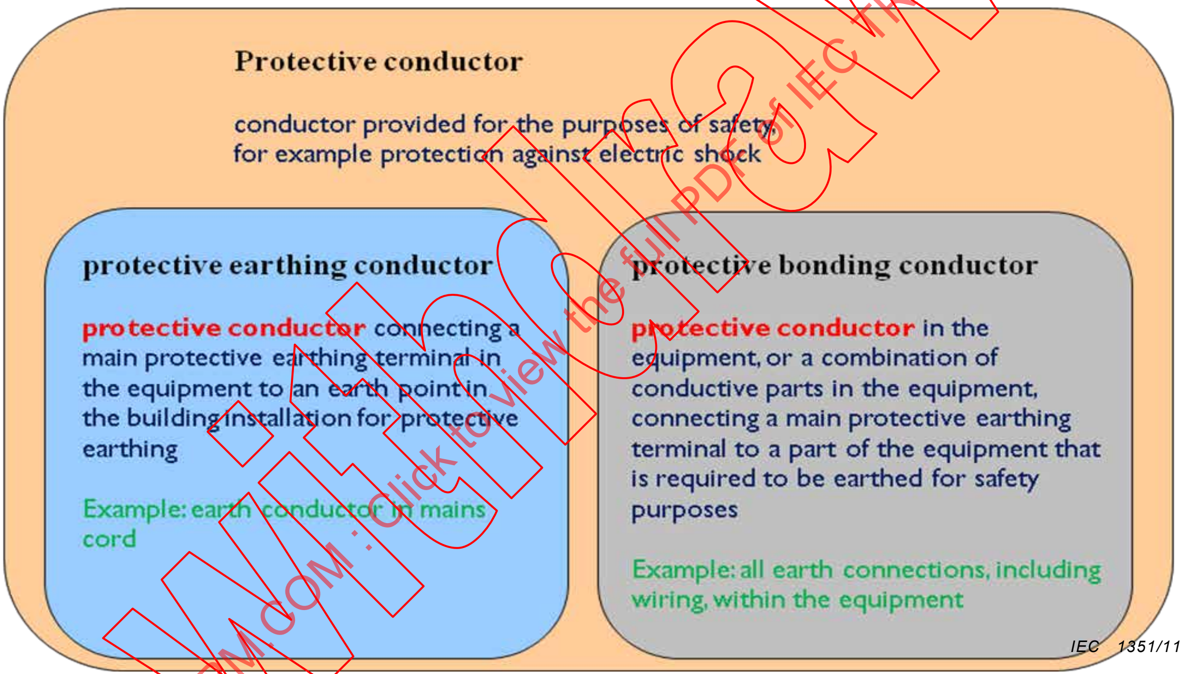


Figure 10 – Overview of protective conductors

5.6.1 General requirements

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

Purpose: No excessive resistance and sufficient current-carrying capacity

Rationale: Shall carry fault current and keep the touch voltage low.

Purpose: Shall not contain switches or overcurrent protective devices.

Rationale: No possibility to interrupt the conductor.

Purpose: Disconnection or protective contactor shall not interrupt conductors to other parts.

Rationale: To keep earth integrity.

Purpose: Protective bonding conductors shall make earlier and break later than the supply connections.

Rationale: To keep earth integrity.

Purpose: Not be subjected to significant corrosion (see Annex N).

Rationale: Keep earth integrity

5.6.3 Colour of insulation

Source: IEC 60446[1]
Purpose: Insulation shall be green-and yellow.
Rationale: For clear identification.

5.6.4 Test for low current-carrying protective conductors

Source: IEC 60950-1
Purpose: Maximum current 1,5 times the maximum available current.
Rationale: To demonstrate the current capability, no fire hazard.

5.6.5.2 Fault current-carrying protective conductors

Source: IEC 60364-5-52
Rationale: To demonstrate the fault current capability.

5.6.6 Protective conductors as a supplementary safeguard

5.6.6.1 General

Source: IEC 60364-5-52
Rationale: To demonstrate the fault current capability and the capability of the termination.

5.6.6.2 Size of protective earthing conductors and terminals

Source: IEC 60950-1
Rationale: To demonstrate the fault current capability and the capability of the termination.

5.6.6.3 Size of protective bonding conductors and terminals

Source: IEC 60950-1
Rationale: To demonstrate the fault current capability and the capability of the termination.

5.6.6.4 Resistance of protective conductors and their terminations

Source: IEC 60998-1, IEC 60999-1, IEC 60999-2, IEC 60950-1
Rationale: To demonstrate the fault current capability and the capability of the termination.

5.6.7 Protective earthing conductors serving as a double or reinforced safeguard

Source: IEC 60364-5-54, IEC 60950-1, IEC 60227, IEC 60245
Purpose: The reinforced protective conductor and its termination have to be robust enough so that the interruption of the protective conductor is prevented in any case (interruption is not to be assumed).
Rationale: See also 5.6.6.

The permanently connected equipment provides reliable earthing.

The dimension is similar to a PEN conductor as in IEC 60364-5-54 (> 10 mm^2) or the PE conductor is protected by the sheathed supply cord. Mechanical protection is made to achieve robust earth connection.

1 This publication was withdrawn.

Pluggable type B is also acceptable as IEC 60309 type plugs are more reliable and earth is always present as it is wired by an electrician. According to IEC SC23H the following tests apply for industrial plugs and sockets:

– 5 000 (for 16 A accessories) insertions and withdrawals of the plug and socket (no current on the earth connection) followed by
  - a temperature rise test (this test is performed also on the earth connection); and
  - a withdrawal test to verify the reliability of the connection.

Sheath thickness of a cord larger than 0,6 mm and a screen in accordance with IEC 60227 or IEC 60245 series of standards [(heavy duty PVC sheathed flexible cord according to IEC 60227 (designation 60227; IEC 53, IEC 54, and IEC 57)] or heavy duty rubber-sheathed flexible cord according to IEC 60245 (designation 60245; IEC 53, IEC 54, and IEC 57).

Conductor terminations according to Table 36 have served as reliable connection means for products complying with IEC 60950-1 for many years.

5.6.8 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 when the hazard is coming from the mains or from an external circuit.

Rationale: Permanently connected equipment is considered to provide a reliable earth connection if the hazard is coming from the mains or from an external circuit.

Only pluggable equipment type B earth connection is considered as reliable as a permanently connected earth, when the hazard is coming from the mains side only. Disconnection of earth disconnects mains as well. See also 5.6.7.1.

For stationary pluggable equipment type A or B where the hazard is coming from the external circuit, a separate earth wire from the pluggable equipment to building earth is required for the earth to be reliable (because earth gets disconnected when the equipment is unplugged).

5.7 Prospective touch voltage, touch current and protective conductor current

Source: IEC 60990

Purpose: Current limits as given in 5.2.2.

5.7.5 Earthed accessible conductive parts

Figure 11 in this standard 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.

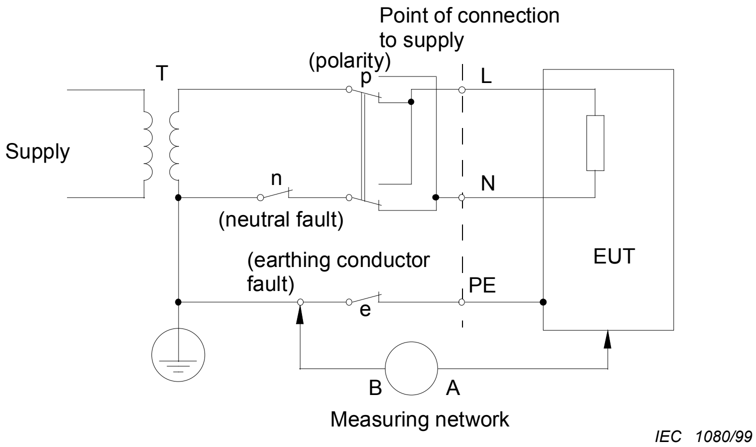


Figure 11 – Example of a typical touch current measuring network

5.7.6 Protective conductor current

Source: IEC 61140, IEC 60950-1

Purpose: The protective conductor current shall not exceed 5 % of the measured input current.

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).

5.7.7 Prospective touch voltage and touch current due to external circuits

Source: IEC 60728-11, safety requirements for cable networks for TV signals, sound signals and interactive devices

5.7.8 Summation of touch currents from external circuits

Source: IEC 60950-1

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

Rationale: When limiting the touch current value to each external circuit, more circuits can be connected together before reaching the touch current limit. This allows better utilization of resources.

———————————

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 5) 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 circuits 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) must be 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 must be 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 load 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.

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 where 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).
– The 500 W value was chosen as a reasonable short term value for circuits that normally operate at 15 W or less. It was considered important to limit the initial power levels, however the choice of the value was not considered critical. Most small power sources that are otherwise limited to 15 W would not be expected to have a very high initial power.
– 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 16, ID 11, 12, 13, and 14) 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 x 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 rms (Paschen's Law), most low voltage arc-heating occurs in direct contact with a fuel. For voltages greater than 300 V, arcing can occur through air.

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

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

Once the basic parameters of voltage and power are met, there are 3 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).

6.2.3.2 Resistive PIS

Source: IEC 60065

Rationale: Resistive potential ignition sources can result from a fault that causes over-heating of any impedance in a low-resistance that does not otherwise cause an overcurrent protection to operate. This can happen in any circuit where the power to the resistive heating source is greater than 15 W (see above).

Under single fault conditions, this clause requires that two conditions must 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.

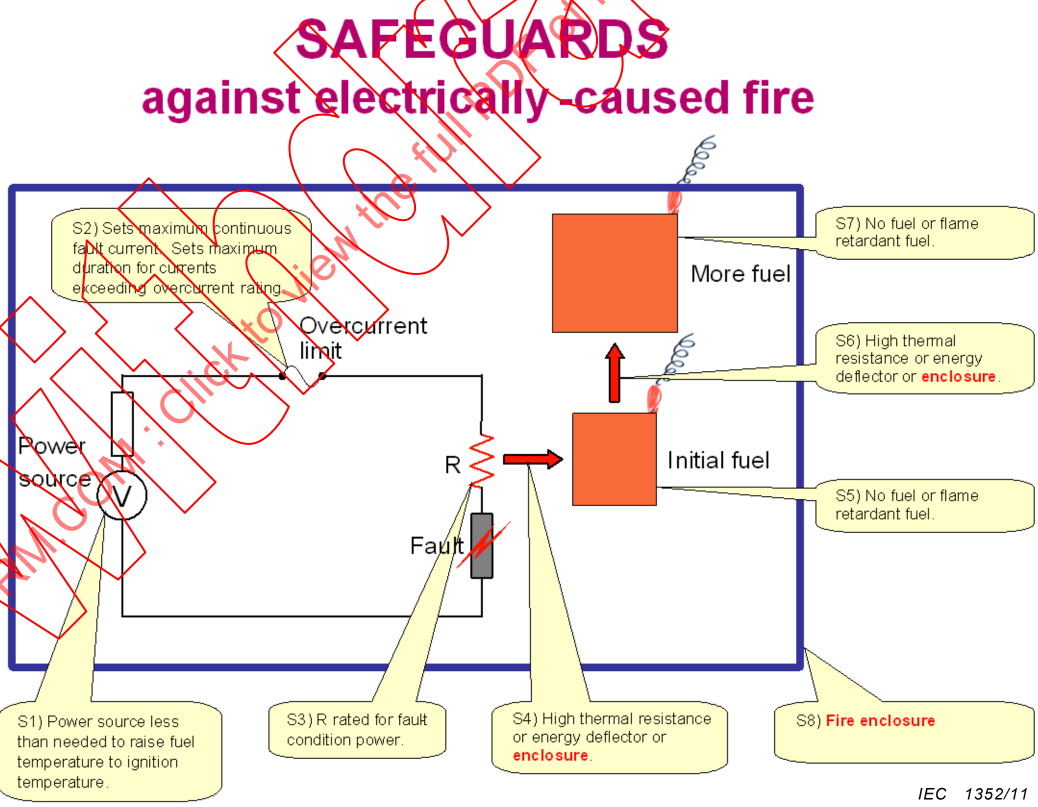


Figure 12 – Possible safeguards against electrically-caused fire

There are several basic safeguards and supplementary safeguards against electrically-caused fire under abnormal operating conditions and single fault conditions (see Figure 12, Table 7 and Table 8 in this standard). 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

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

B) Protection under abnormal operating conditions and 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 13 in this standard for a fire clause flow chart.

Table 7 – 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

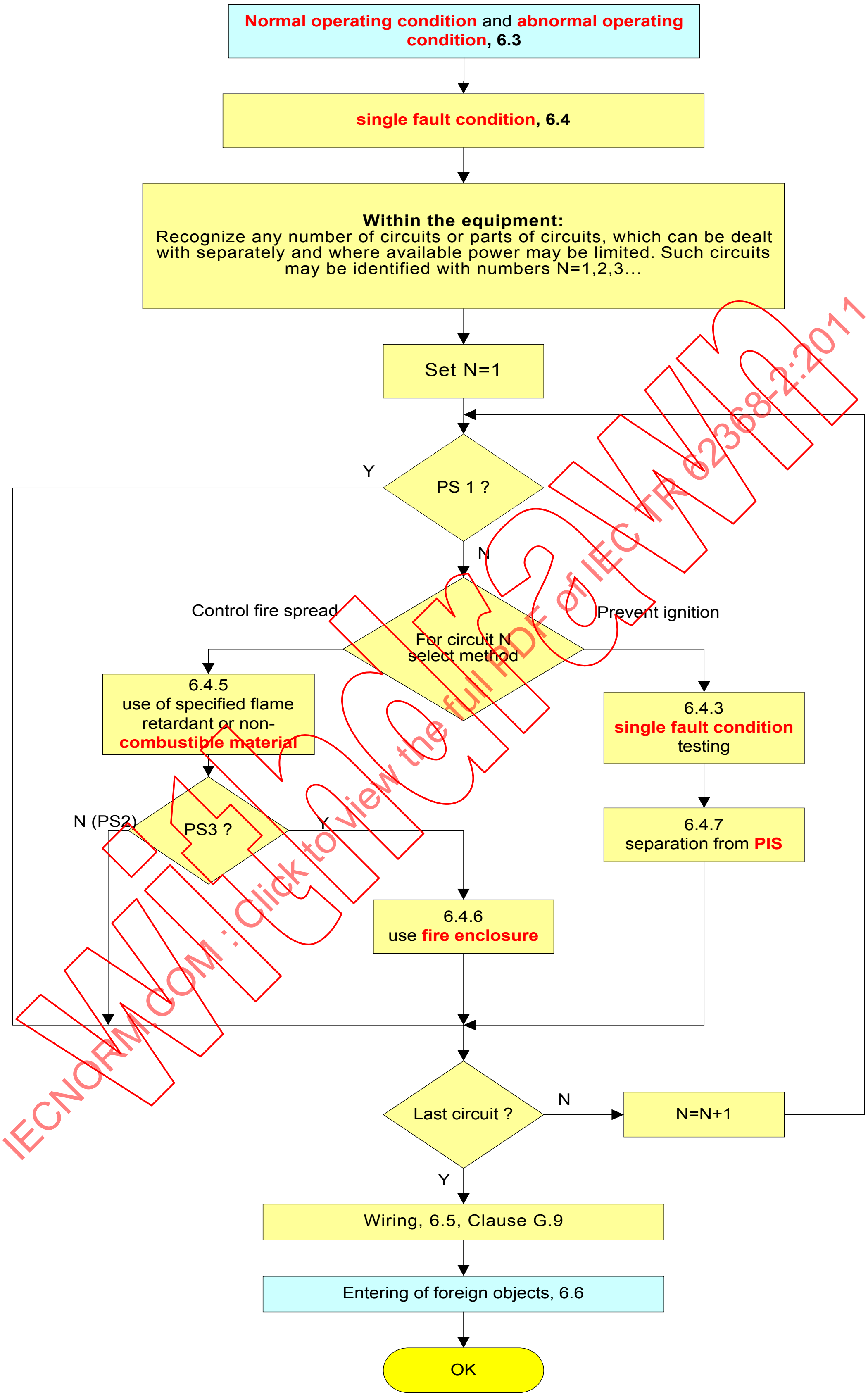


Figure 13 – Fire clause flow chart

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 8 – Basic safeguards against fire under normal operating conditions and abnormal operating conditions

Normal operating conditions and abnormal operating conditions		
The objective of this subclause is to define requirements to reduce the likelihood of ignition under **normal operating conditions** and **abnormal operating conditions**.		
PS1 **PS2** **PS3**	6.3.1	Ignition is not allowed
		T_{max} ≤ 90 % auto ignition temperature according to ISO 871; or T_{max} ≤ 300 °C
		- 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: • HB75 if the thinnest significant thickness of this material is < 3 mm, or • HB40 if the thinnest significant thickness of this material is ≥ 3 mm, or • HBF. NOTE Where an enclosure also serves as a fire enclosure, the requirements for fire enclosures apply. These requirements do not apply to: • parts with a size of less than 1 750 mm³; • supplies, consumable materials, media and recording materials; • parts that are required to have particular properties in order to perform intended functions, such as synthetic rubber rollers and ink tubes; • gears, cams, belts, bearings and other parts that would contribute negligible fuel to a fire, including labels, mounting feet, key caps, knobs and the like.

6.3.2 Compliance

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.1.7 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 9 in this standard. 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 9 – 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 V x 16 A), common in the office place or the home, could use the ignition protection methods, and to provide a reasonable and practical separation of product types. It is recognized that this is not representative of fault currents available but is a convenient and representative separation based on equipment connected to normal office and home mains circuits where experience with potential ignition sources safeguards is more common.

Limit values below 4 000 W create a problem for the 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 10 and Figure 14 in this standard).

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 10 – 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	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
		Sustained flaming > 5 s is not allowed
		Separation from arcing PIS and resistive PIS according to 6.4.7 • Distances have to comply with Figures 41, 42, 43 and 44; or • In case the distance between a PIS and combustible material is less than specified in figures 41, 42, 43 and 44 ○ Mass of combustible material < 4 g, or ○ Shielded from the PIS by a fire barrier, or ○ Flammability requirements: ▪ V-1 class material; VTM-1 class material or HF-1 class material, or needle flame in Clause S.2, or ▪ Relevant component IEC standard
		Using protective devices that comply with G.2 to G.5 or the relevant IEC component standards for such devices;
		Using components that comply with G.7, G.8 or the relevant IEC component standard;
		Components associated with the mains shall comply with: ▪ the relevant IEC Component standards; and ▪ the requirements of other clauses of IEC 62368-1

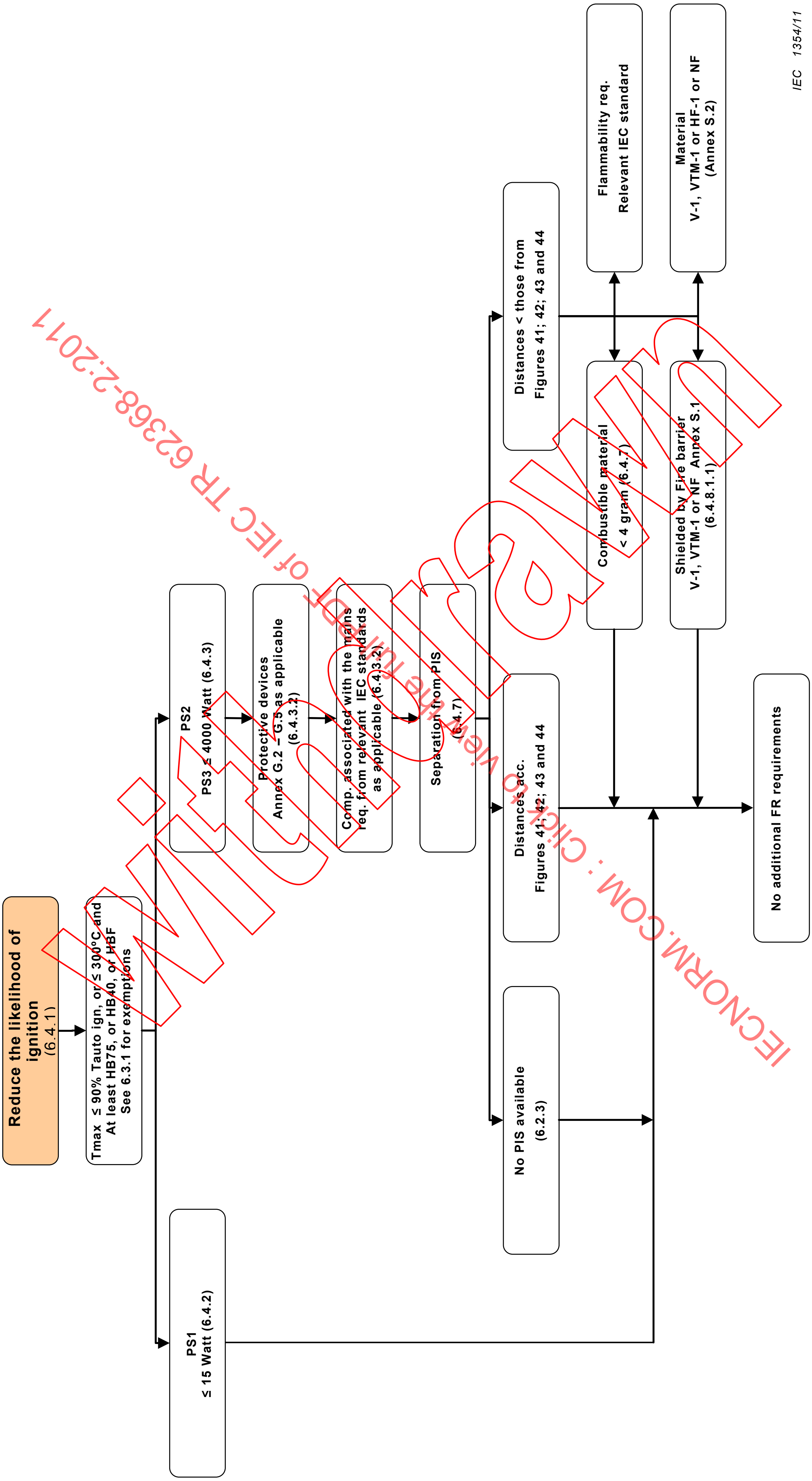


Figure 14 – Prevent ignition flow chart

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 15, Figure 16 and Table 11 in this standard).

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.

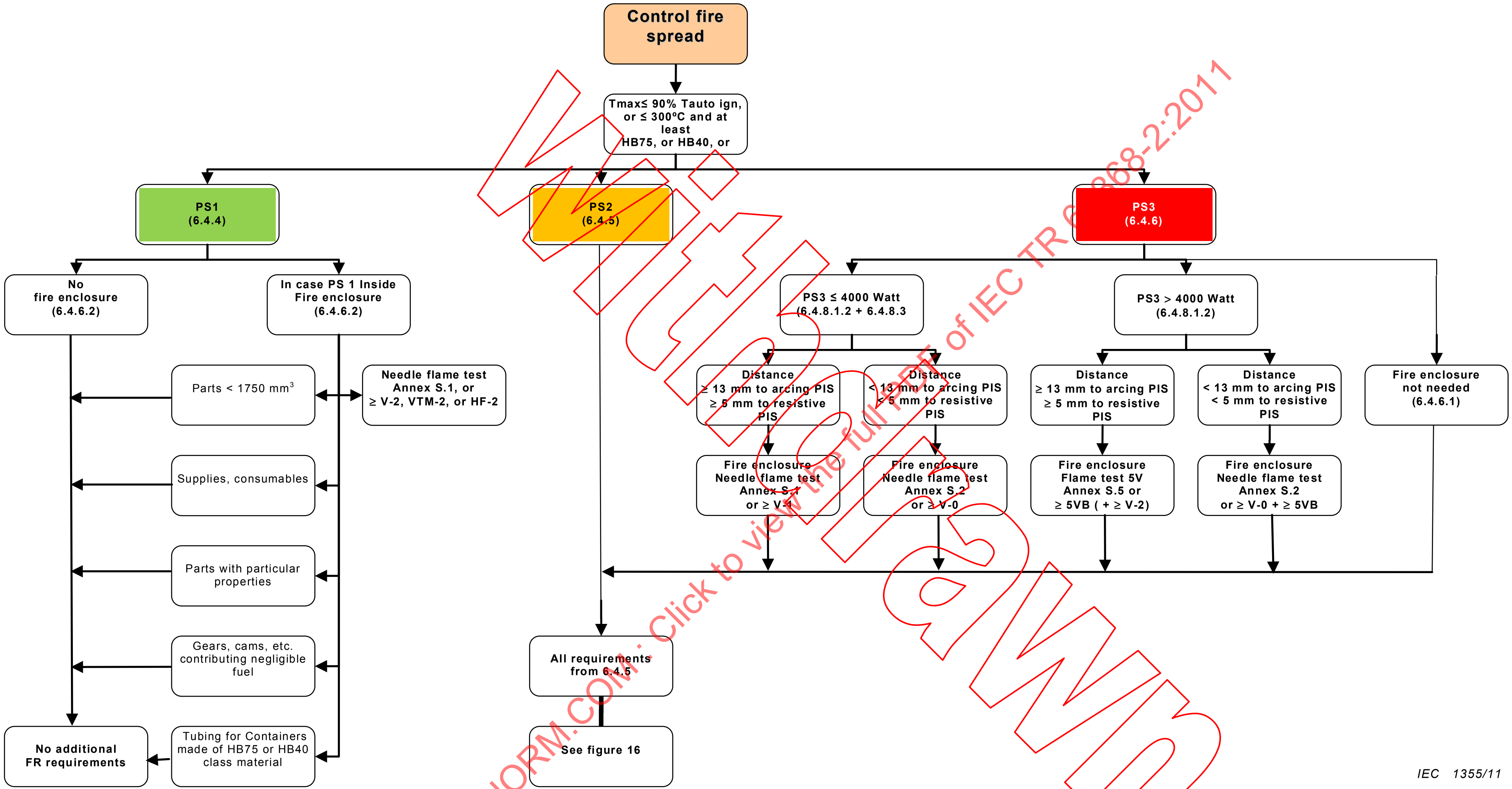


Figure 15 – Control fire spread summary 1

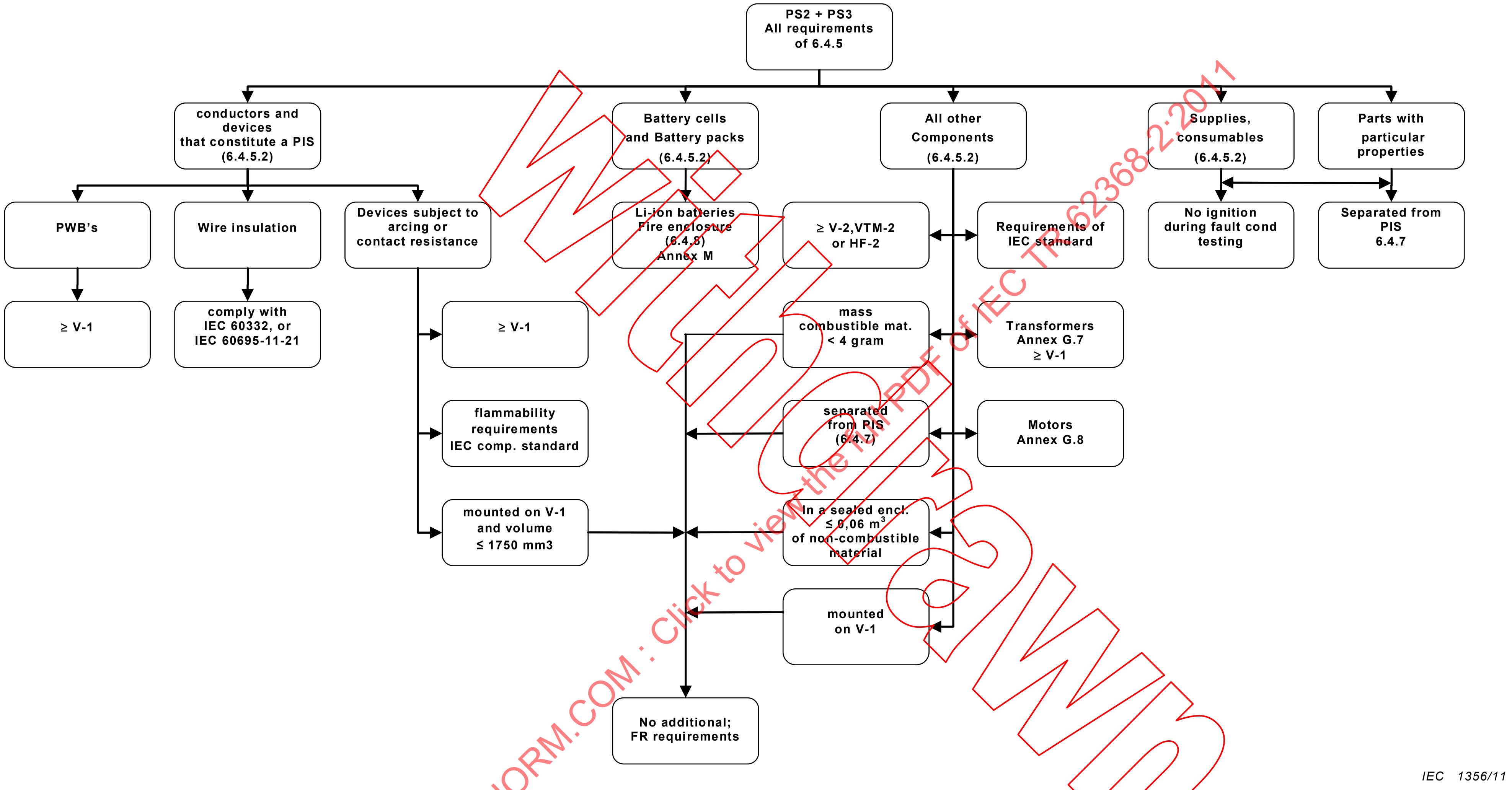


Figure 16 – Control fire spread summary 2

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 must be 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 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 5 s is used. 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 is half of the 10 s value related that is considered to be common experience for ignition of 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 must be proven reliable by repeating the single fault condition two more times (total of three times). This is a method used historically in IEC 60065.

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

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

Limit by fusing: The reliability of protection devices must be 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.

a) Where the measured current is always below the fuse manufacturer's pre-arcing characteristics (i.e. 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-arcing characteristics (i.e. 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-arcing characteristics, but does at some time after introduction of the fault. The test is repeated with the short circuit in place and the temperature measured at the time where measured current exceeds the fuse pre-arcing characteristics. It is assumed the measured current through the short circuit can be graphed and compared with the fuse manufacturer's pre-arcing curves provided on the fuse datasheet to determine the test time.

6.4.4 Control of fire spread in PS1 circuits

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

Table 11 – 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)	6.4.5	The objective of this subclause is to describe the supplementary safeguards needed to reduce the likelihood of fire spread from a PIS in PS2 circuits to nearby combustible materials. The limiting of power available to PS2 circuits is the basic safeguard used to minimize the available energy of an ignition source. A supplementary safeguard is required to control the spread of fire from any possible PIS to other parts of the equipment

		For conductors and devices with a PIS the following apply:
		• Printed boards shall be at least V-1 class material
		• Wire insulation shall comply with IEC 60332 series or IEC 60695-11-21
		• Devices subject to arcing or changing contact resistance (e.g. pluggable connectors) shall comply with one of the following
		  ○ Materials V-1 class material; or
		  ○ Comply with IEC component standard flammability requirements; or
		  ○ Mounted on V-1 class material and volume ≤ 1 750 mm^3

		Battery cells and battery packs shall comply with Annex M.

Method 2: Control fire spread		

		All other components:
		• Mounted on V-1 class material, or
		• Materials V-2 class material, VTM-2 class material, or HF-2 class material, or
		• Mass of combustible material < 4 g, provided that when the part is ignited the fire does not spread to another part, or
		• Separated from PIS according to 6.4.7,
		• Distances have to comply with Figures 41; 42; 43 and 44, or
		• In case distances do not comply with Figures 41; 42; 43 and 44
		  ○ 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 60695-11-2 as described in Clause S.2; or
		• Comply with IEC component standard flammability requirements, or comply with G.7 and G.8
		• Insulation materials used in transformers, bobbins, V-1 class material
		• In a sealed enclosure ≤ 0,06 m^3 made of non-combustible material and having no ventilation openings
		
		The following shall be separated from a PIS according to 6.4.7 or shall not ignite due to fault conditional testing
		• Supplies, consumables, media and recording materials
		• Parts which are required to have particular properties in order to perform intended functions, such as synthetic rubber rollers and ink tubes

	The objective of this subclause is to describe the supplementary safeguards needed to reduce the likelihood of fire spread from a PIS in PS3 circuits to nearby combustible materials.	
	6.4.6.2	Fire spread in PS3 circuit shall be controlled by; – the use of a fire enclosure as specified in 6.4.8. and – applying all requirements for PS2 circuits as specified in 6.4.5 Exemptions • Wire and tubing insulation complying with IEC 60332 series or IEC 60695-11-21 • Components, including connectors complying with 6.4.8.1.1 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.9 and G.21 • Transformers complying with G.7 • Motors complying with G.8
PS3 **(> PS2)**	6.4.6.2 For PS2 or a PS3 circuit within a fire enclosure	See all requirements for PS2 (6.4.5)
	6.4.6.2 For a PS1 circuit within a fire enclosure	Combustible materials: • Needle flame test in Clause S.1 or V-2 class material or VTM-2 class material or HF-2 class material Exemptions • Parts with a size less than 1 750 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 ≥ 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.

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 m^2 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 must either be isolated from any PIS or through single fault condition testing demonstrate that they will simply not ignite in their application.

6.4.5.3 Compliance

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.

6.4.6.2 Requirements

Source: IEC 60950-1

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 Annex G.

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 45. 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 17 in this standard 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.

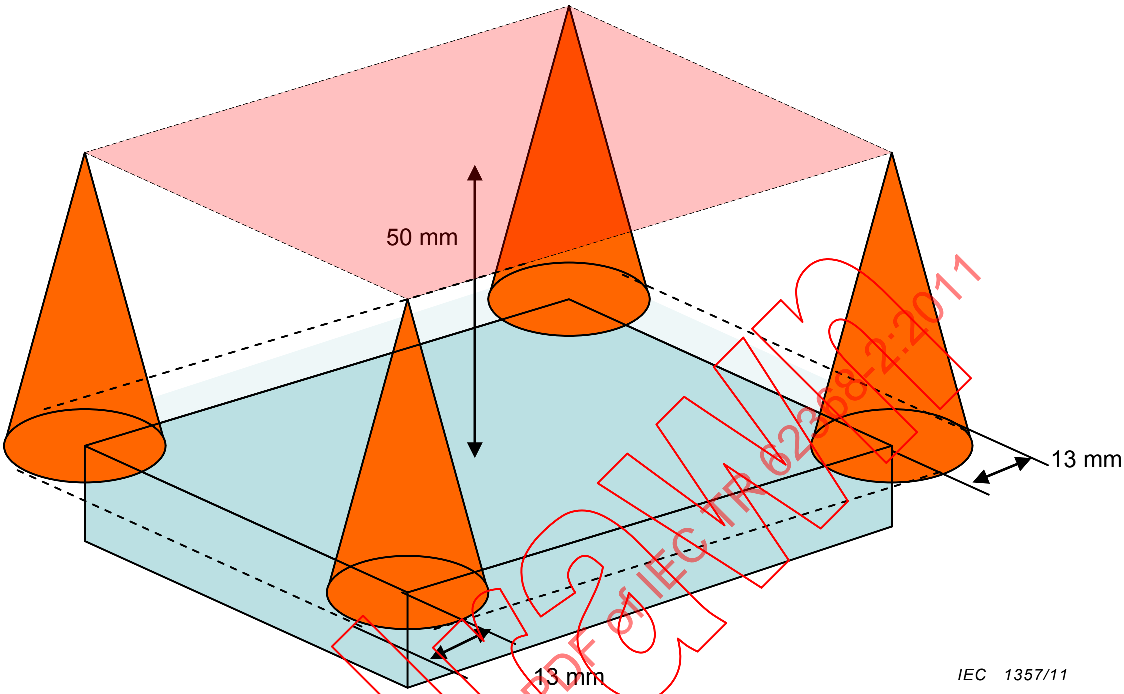


Figure 17 – Fire cone application to large component

The fire cone is placed at each corner. The locus of the outside lines connecting each fire cone defines the keep-out volume.

Figure 45 – 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 46 – A two dimensional representation of an ignition source intended to provide more clarity.

Figure 47 – 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, it must be supplied by a PS2 or PS3 source. However 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 44 – 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 12 in this standard).

Table 12 – Fire barrier and fire enclosure flammability requirements

Flammability requirements		
Fire barrier	6.4.8.1.1	Fire barrier requirements • Non-combustible material or • Needle flame test Clause S.1 or ≥ V-1 class material or VTM-1 class material
	6.4.8.3	Separation of a PIS to a fire barrier • Distance ≥ 13 mm to an arcing PIS and • Distance ≥ 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 6.4.8.2.3 and 6.4.8.2.4 allowed or • ≥ V-0 class material
Fire enclosure	6.4.8.1.2	Fire enclosure materials: • Non-combustible, or • For PS3 ≤ 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 • ≥ V-1 class material; or • needle flame test Clause S.1
	6.4.8.3	Separation of a PIS to a fire enclosure • Distance ≥ 13 mm to an arcing PIS and • Distance ≥ 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 6.4.8.2.3 and 6.4.8.2.4 allowed; or • ≥ V-0 class material

6.4.8.1.1 Requirements for a fire barrier

Source: IEC 60065, IEC 60950-1

Rationale: Barriers used to separate PIS from flammable fuels must 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 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.

6.4.8.1.2 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 W) and S.5 (for > 4 000 W). This test is based on the needle flame test which is currently an option for enclosure testing in both IEC 60950-1 and IEC 60065.

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

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

6.4.8.1.3 Compliance

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

6.4.8.2 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).

6.4.8.2.1 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.

6.4.8.2.2 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 must 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.

6.4.8.2.3 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 45) plus a tolerance of 2 mm. 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 must take 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.

6.4.8.2.4 Bottom openings and bottom opening properties

Source: IEC 60065, IEC 60950-1

Rationale: The location of openings locations are restricted for barriers inside the flame cone of Figure 46 and for enclosures, inside the cone and directly below to protect against flammable drips from burning thermoplastic. 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 13 in this standard). 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 39 come directly from IEC 60950-1 where they have been historically adequate and have demonstrated compliance with the S.3 performance testing. Table 39 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 39.

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 mm^2 and a round opening of 29 mm^2. In IEC 60950-1 the requirement was 40 mm^2, 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 13 – 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		

6.4.8.2.5 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.

6.4.8.2.6 Compliance

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

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

Source: IEC 60065, IEC 60950-1

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

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

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

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

a) no additional opening,

b) no enlargement of existing holes,

c) compliance with the fire enclosure opening requirements.

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

The option to use V-0 or 5 V 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).

6.5.3 Compliance

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 (see Table 14 in this standard).

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.

Table 14 – Other flammability requirements

Other flammability requirements		
Internal and external wiring	6.5	The wire insulation in PS2 and PS3 circuits shall comply with IEC 60332 series or IEC/TS 60695-11-21

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.

6.5.4 Requirements for interconnection to building wiring

Source: IEC 60950-1

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, 6.7 prescribes the appropriate safeguards and limits associated for PS2 and PS3 sources.

Telecommunication wiring must also be 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 must be equivalent to 0,4 mm diameter wiring (26 AWG) and have a default 1,3 A current limit established. This value has been used in IEC 60950-1 for the smaller telecommunication wiring.

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

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

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

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

Annex Q 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 Likelihood of fire due to entry of foreign objects

Purpose: The purpose of this clause is to establish opening requirements that would minimize the risk of foreign objects falling into the equipment that could bridge parts within PS2 or PS3 circuits, or between PS circuits that could result in ignition. It is applied for both method 1 and method 2.

For transportable equipment, the safeguards prescribed in IEC 60950-1 need to be checked and included where necessary. The goals of MT2 for transportable equipment were specifically to address equipment that was battery powered where ignition would be possible during transport.

6.7 Safeguards against fire due to the connection of secondary equipment

Source: IEC 60950-1

Rationale: This subclause addresses potential fire hazards due to connected of accessories 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 Chemically-caused injury

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 standard). 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 may cause or contribute to failure of safeguards against fire, electric shock, or personal injury due to spillages.

The number of different chemical materials that may be used in the wide variety of equipment covered by this 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:

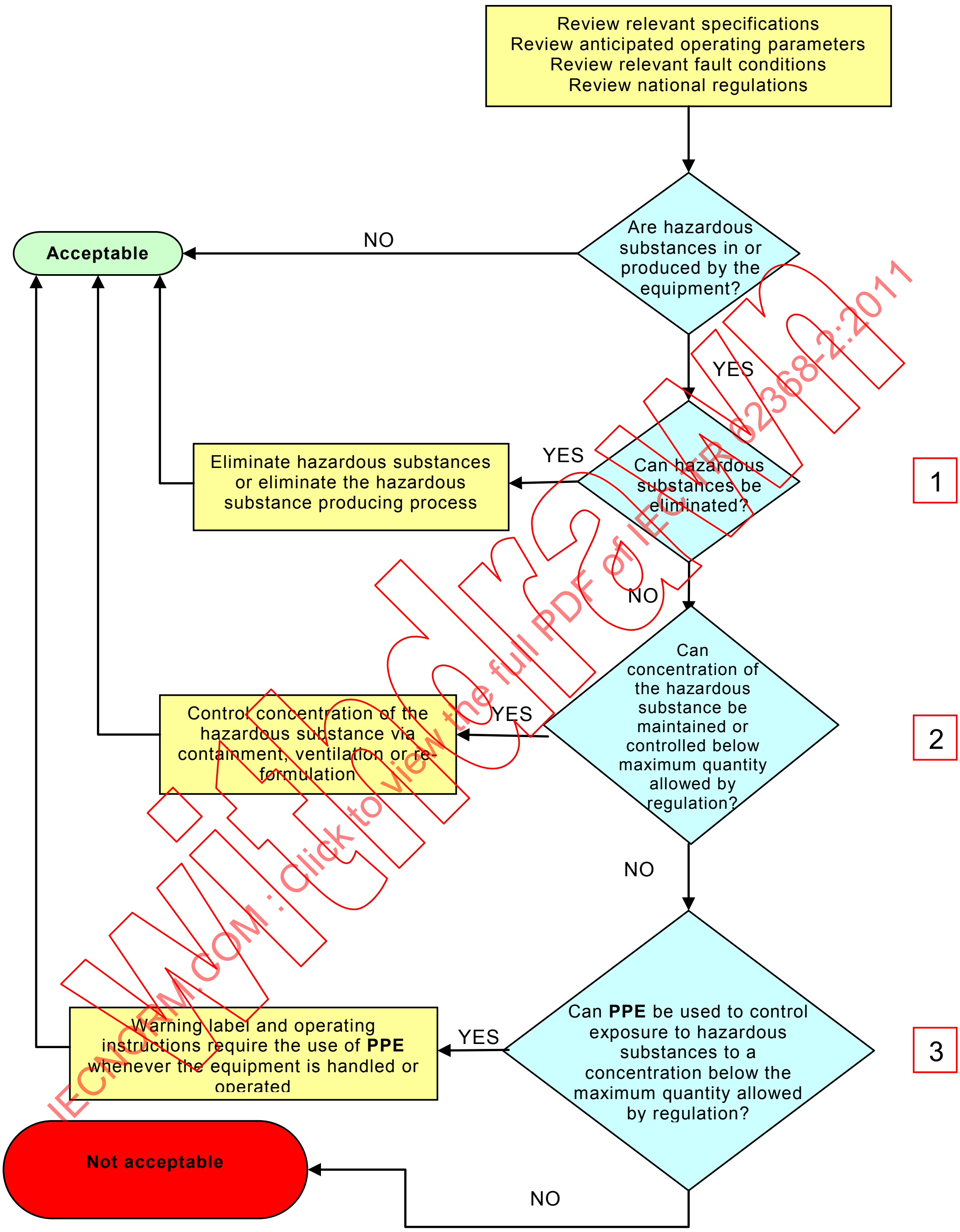
An injury can be either acute or chronic. Acute injuries are injuries with immediate and serious consequences (for example, a strong acid in the lungs) or the injury can be mild and result in irritation or headache. Chronic injuries are injuries with long term consequences and can be as serious as acute 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 18 in this standard) demonstrating the hierarchy of hazard management.

Table 15 – Control of chemical hazards

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



IEC 1358/11

Figure 18 – 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 19 in this standard shows the main types of chemical health hazards and their transfer mechanisms.

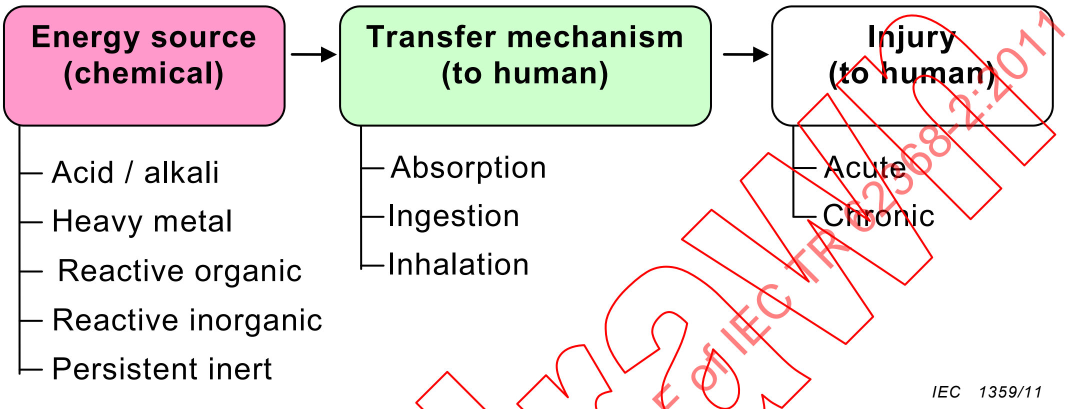


Figure 19 – Model for chemical injury

Clause 8 **Mechanically-caused injury**

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 40 – 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 47 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).

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).

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 Protection against mechanical energy sources

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

8.3.2 Protection of ordinary persons

Rationale: An equipment safeguard is needed between an ordinary person and MS2. Two equipment safeguards are needed between an ordinary person and MS3.

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 must indicate that the equipment safeguard must 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.

8.3.3 Protection of instructed persons

Rationale: No equipment safeguard needed for MS2. However 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. Two equipment safeguards are needed between MS3 and an instructed person.

8.3.4 Protection of skilled persons

Purpose: No equipment safeguard is normally needed for MS3.

Rationale: The skilled person has received training as the skill safeguard to know how to work with MS3 hazards. However an instructional safeguard in the form of a warning marking is necessary to supplement the instruction they have received, to remind them of the hazard locations that are not obvious.

However, 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

Purpose: Engineering judgment shall be used to class a mechanical energy source as MS1, MS2 or MS3 and an appropriate safeguard shall be provided as given in 8.4. 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 it must 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.

Rationale: 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 8.5.2 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 in to 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.

8.5.5.1 Protection against MS3 parts

Source: IEC 60950-1

Purpose: To protect against shattering rotating solid media and high pressure lamps that can expel particles with sufficient energy to injury the eye, requiring professional medical attention.

Source: IEC 61965, IEC 60950-1 and IEC 60065

Purpose: To protect from egress of imploded glass impacting a vulnerable part of the body.

Rationale: Cathode ray tubes (CRTs) having a maximum diagonal dimension smaller than 160 mm have not had a history of causing injury. These are considered MS1. This size of CRT is rapidly being replaced with other technologies.

A CRT having a maximum diagonal dimension larger than 160 mm is considered MS3 and requires a reinforced safeguard complying with Annex U.

8.5.5.2.1 Mechanical enclosure requirements for rotating solid media

Purpose: To protect from egress of fragmented media from impacting the eye.

Rationale: Studies have indicated that the fragmentation occurs most frequently with solid media in equipment such as CD-ROM drives rotating at more than 8 000 rpm (over 40X speed, note 1X is 200 rpm). Studies provided satisfactory information that the cause of these phenomena are related to defects within the CD-ROM media (reproducible), that are likely related to:

– how they are handled (or mishandled) by users, how they are stored, such as exposure through a window to direct sunlight, other direct heat sources, etc.,
– subjecting them to improper treatment such as bending or having objects placed on them that may cause cracks radiating out from the centre hub mounting edge.

There are two possibilities for the fragmented media to egress. During impact with the front door, it either releases or flexes enough to permit the fragment to escape. Two tests for this are possible. Both a static test and a dynamic test were considered, however it was felt that a static test was easier to assess and has enough safety margin to meet the need.

A value of 25 % of the media mass was chosen as practical worst case after analyzing fragment size from a number of CD media failures. An example of a 52X drive is as follows:

$$F = mv^2 / R_o \times 0{,}25 = 0{,}016 \times 66^2 \times 0{,}25/0{,}06 = 290{,}4 \text{ N}.$$

where

F is the force to be applied, ± 10 %;

m is the mass of the media;

v is the velocity of the outside diameter of the media;

R_o is the outer radius of the media.

8.6 Stability of equipment

Source: IEC 60950-1 and IEC 60065

Purpose: To align existing practice with the MS1, MS2 and MS3 energy sources (see Table 16 in this standard).

Rationale: Equipment weighing more than 25 kg is considered MS3, whether it is floor standing or supported above the floor.

Equipment weighing between 7 kg and not exceeding 25 kg is considered MS2 if floor standing and MS3 if supported above the floor.

Equipment with weight not exceeding 7 kg is considered MS1 if floor standing, but can be either MS2 or MS3 if supported above the floor. Also see carts and stands, and wall or ceiling mounted equipment.

Table 16 – Summary for 8.6

	Equipment subject to handling, moving and relocating				**Equipment contacted by children with either displays with moving images or devices with accessible controls**	
	Test 1	Test 2	Test 3		Test 4	Test 5
	Static stability		Relocation stability		Glass slide test	Non-floor standing horizontal force test
Subclause	8.6.2.2	8.6.2.2	8.6.2.3	8.6.2.3	8.6.3.1	8.6.3.2
Scope modifies	Floor standing	Floor standing with foothold less than 1 m high	Movable, relocatable by ordinary person during intended use and installation	Movable, relocatable by instructed persons or skilled persons during intended use and installation	Displays with moving images, equipment with accessible controls above floor Exempts floor standing	Displays with moving images, equipment with accessible controls above floor
Energy source	MS2 / MS3	MS3	MS2 / MS3	MS2 / MS3	MS2 / MS3	MS2 / MS3
Orientations of doors, covers, casters, feet, etc.	Least stable in accordance with operating conditions and instructions provided to 'any' person as appropriate	Doors closed - "as used"	Least stable in accordance with normal operating conditions and instructions provided to ordinary person	Doors closed - "as used"	Not defined	Least stable in accordance with normal operating conditions and instructions provided to ordinary person
Purpose	Equipment should remain stable when (intended or unintended) leaning or pushing on equipment to move, relocate or on-site service	Ensures equipment will not become unstable (causing the user to fall) when the user intentionally uses the equipment as a step	Ensures that expected physical contact with the equipment (intended or unintended) does not result in instability	Ensures that expected physical contact with the equipment (intended or unintended) does not result in instability	Ensures that products with moving images that attract children, will not topple when climbed upon	Ensures that equipment with accessible controls or moving images will not become unstable if handled (pulled, pushed) by children
Test and criteria	20 % of weight up to 250 N horizontal force applied up until the unit reaches 15° or 15° tip stability	800 N vertical force	10° tip stability	10° tip stability	Glass slide test at 10°	13 % of weight but no more than 100 N horizontal force or up to 15° tip stability for MS3

8.6.2.2 Static stability test

Purpose: 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.

8.6.2.3 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.

8.6.3 Non-floor standing equipment having controls that are accessed during normal use or having displays with moving images

Source: IEC 60065

Rationale: 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 of this subclause 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.

8.6.3.1 Glass slide test

Source: IEC 60065:2005, Amendment 2 (2010)

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.

8.6.3.2 Horizontal force test

Purpose: To simulate the force of a child climbing up on to equipment 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 in]. 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: The 4x the weight applied in the test has been a standard safety factor to cover the variations associated with the materials involved, vibration, material aging, mounting technique etc., with a minimum force of 50 N to simulate accidental contact.

8.8 Handle strength test method

Source: IEC 60065 and 60950-1

Rationale: 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 Compliance and test method

Rationale: There is no test for MS1 with only one handle. Having 2 handles facilitates transporting the equipment while carrying additional objects adding stress to the handles.

8.9 Wheels or casters attachment requirements

Purpose: To verify that wheels or casters are securely fixed to the equipment.

Source: UL 1667

Purpose: For wheel size, reduce the likelihood of the equipment on the cart or stand tipping while being moved from room to room where the wheels may encounter a variety of obstacles, such as: friction of different surfaces (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

Rationale: This requirement came from 60065 but the rationale is that 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 of similar carrier.

8.10.3 Cart, stand or carrier loading test and compliance

Purpose: To verify that a cart or stand can withstand foreseeable overloading without creating a hazardous situation.

Source: IEC 60065

Rationale: The 220 N force simulates the weight of a small child approximately 5 years of age, who may attempt to climb onto the cart or stand. The 30 mm circular cylinder simulates a child's foot. The 750 mm height is the approximate access height of the 5 year old child. The additional 440 N force test simulates potential additional materials or equipment being placed on the cart or stand. The additional 100 N simulates overloading by the user. Testing has been limited to 1 min as experience has shown that the likelihood of a test failure will occur within that time.

8.10.4 Cart, stand or carrier impact test

Purpose: To verify that a cart or stand can withstand a foreseeable impact without creating a hazardous situation.

Source: IEC 60065 and IEC 60950 series

Rationale: The 7 joules simulate intentional and accidental contact with the equipment and come from the T.9.2 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 Requirements

Source: UL/CSA 60950-1 second edition

Rationale: The potential hazardous energy source is a product that contains significant mass and which is mounted on slide-rails in a rack. A joint US/Canadian Adhoc researched and developed these requirements based on hazard based assessment and tests.

The center of gravity was chosen to apply the downward force because in general, when installing equipment in a rack, it is foreseeable that previously installed equipment of similar size/mass may be pulled out into the service position (fully extended) and used to set the new equipment on while positioning and installing the new slide/rails. In this scenario, it is not likely that the new equipment would be significantly off-centre from the installed equipment that it is being set on.

8.11.2 Mechanical strength test, variable N

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: 150 % 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.

8.11.3 Mechanical strength test, 250 N, including end stops

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 8.11.2, 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.

Source: UL/CSA 60950-1 second edition

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

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 is 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. The occurrence of a burn will depend on several parameters. The hazard based three block model applied to the occurrence of a burn (Figure 20 in this standard) 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.

IEC 1360/11

Figure 20 – 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 ISO 13732-1:2006, Figure 2). 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 ISO 13732-1:2006, Table 1). Although the temperature of the source has increased by just 25 %, the contact time necessary to cause a burn threshold has decreased by 90 %.

In practice, the actual thermal energy and duration of exposure required to cause a burn will also depend on the area of contact and condition of the skin. For simplification of the model and based upon practice in the past, it is assumed that the contact area will be ≤10 % of the body and applied to healthy, adult skin (see ISO 13732-1:2006, Table 1).

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: ATSM C 1055, X1.2.3.4, ASTM C 1057,7, Note 10).

NOTE 3 Considerations for burns generated by infrared (IR), visible, ultra violet light radiation and RF radiation sources are outside the scope of Clause 9 dealing with thermal burn injury.

C Types of burn injuries

Burn injuries are commonly classed as first degree, second degree or third degree in order of increasing severity:

First degree burn—the reaction to an exposure where the intensity or duration is insufficient to cause complete necrosis of the epidermis. The normal response to this level of exposure is dilation of the superficial blood vessels (reddening of the skin). No blistering occurs. (Reference: ASTM C1057)

Second degree burn—the reaction to an exposure where the intensity and duration is sufficient to cause complete necrosis of the epidermis but no significant damage to the dermis. The normal response to this exposure is blistering of the epidermis. (Reference: ASTM C1057)

Third degree burn—the reaction to an exposure where significant dermal necrosis occurs. Significant dermal necrosis with 75 % destruction of the dermis is a result of the burn. The normal response to this exposure is open sores that leave permanent scar tissue upon healing. (Reference: ASTM C1057)

ISO 13732-1:2006, 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 ISO 13732-1:2006, 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 21 in this standard). More than one safeguard may be used to meet the requirements for thermal burn hazard protection.

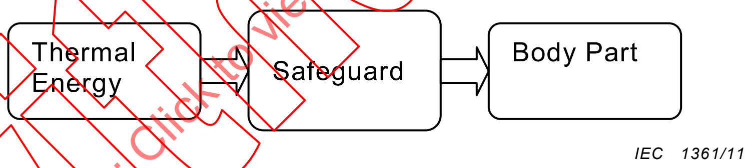


Figure 21 – Model for safeguards against thermal burn injury

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

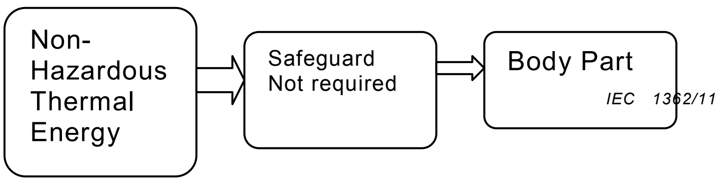
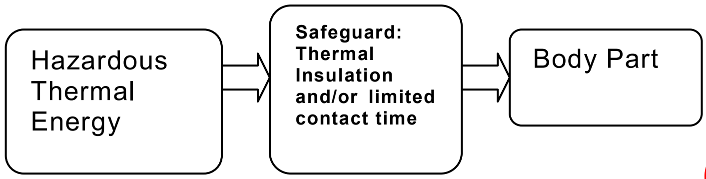


Figure 22 – Model for absence of a thermal hazard

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

The second model, in Figure 23 in this standard, presumes some contact with a surface by an ordinary person. The thermal energy source is above the threshold limit value for burns (Table 42), 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.



IEC 1363/11

Figure 23 – 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, in Figure 24 in this standard, 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.

IEC 1364/11

Figure 24 – 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. Under abnormal conditions, where it is obvious to an ordinary person that the equipment is malfunctioning, temperatures limits up to the short term TS2 limits may be applied to a TS1 surface. In this case, the user will be aware of the increased temperature so contact is considered unlikely. In the event of contact occurring, the TS2 limits ensure that a burn will not occur within normal reaction times. An example of this situation would be a non-functional computer monitor with no video display. In this case the short-term limits for TS2 surfaces would be applied. However, in the case of a computer system that continues to operate with a failed cooling fan, this situation may not be detectable to the user and the TS1 limits would continue to apply to the appropriate surfaces. Table 42 defines the upper limits for TS1 surfaces under normal conditions.

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 42 defines the upper limits for TS2 surfaces.

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.

9.2.5 Touch temperature levels (Table 42 – Touch temperature limits)

Source: The limits in Table 42 are primarily derived from data in ISO 13732-1:2006.

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 42 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. (Ref: ISO 13732-1:2006, Note of 4.1)

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.

For very long term contact (> 10 min), the temperature below which a burn will not occur converges towards 43 °C for most materials (see ISO 13732-1:2006, Table 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 42 are conservatively chosen as 48 °C for all materials.

Examples of products with surfaces where expected continuous contact durations greater than 1 min include joysticks, mice, mobile telephones, and PDAs. Any handles, knobs or grips on the equipment that are likely, under normal usage, to be touched or held for greater than 1 min are also included.

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 42 for contact durations up to 1 min are taken directly from ISO 13732-1:2006, Table 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.

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 42 for these surfaces are based on the burn threshold limits in ISO 13732-1:2006 for contact durations of up to 10 s (see ISO 13732-1:2006, Figure 2, Figure 5, Figure 6, Figure 7).

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 (see ISO 13732-1:2006, 5.5.2.1). The TS1 temperature limits in Table 42 for these surfaces are based on the burn threshold limits in ISO 13732:2006 for contact durations of 1 s (see ISO 13732-1:2006, Figure 2, Figure 5, Figure 6, Figure 7). More conservative values than those in ISO 13732-1:2006 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.

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 such ISO 13732-1 are permitted. For metal and glass surfaces, the limit is 100 °C (IEC 60065:2010, Table 3). For plastic and wood, the TS2 limits are applied for all surfaces.

For contact durations between 1 s and 10 s, ISO 13732-1:2006 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 (see ISO 13732-1:2006, 4.1). 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 ISO 13732-1:2006 (see ISO 13732-1:2006, 7.5.1). As most surfaces in IT equipment will have some texturing, values at the higher end of the spreads have been chosen.

When contact with a TS1 surface is unlikely due to its limited size or accessibility, a temperature up to 100 °C is acceptable if an instructional safeguard is provided on the equipment (see IEC 60950-1:2005, Table 4C, IEC 60065:2001, Table 3).

In the case where a surface must be hot in order to carry out its function, the occurrence of contact with the surface or a subsequent burn injury is unlikely if the user is made aware that the surface is hot. Thus, a temperature up to 100 °C or higher is acceptable if there is an effective instructional safeguard on the body of the equipment indicating that the surface is hot (see IEC 60950-1:2005, Table 4C, and IEC 60065:2001, Table 3).