

INTERNATIONAL STANDARD

NORME INTERNATIONALE

**Explosive atmospheres –
Part 11: Equipment protection by intrinsic safety "i"**

**Atmosphères explosives –
Partie 11: Protection de l'équipement par sécurité intrinsèque «i»**

Withdrawing



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EXPLOSIVE ATMOSPHERES –

Part 11: Equipment protection by intrinsic safety "i"

INTERPRETATION SHEET 1

This interpretation sheet has been prepared by subcommittee 31G: Intrinsically-safe apparatus, of IEC technical committee 31: Equipment for explosive atmospheres.

The text of this interpretation sheet is based on the following documents:

DISH	Report on voting
31G/310/DISH	31G/313/RVDISH

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

Background

IEC 60079-11:2006 subclause 10.5.3 b) states the following:

The maximum surface temperature shall be determined as follows:

All current-limiting devices external to the cell or battery shall be short-circuited for the test. Any external sheath (of paper or metal, etc.) not forming part of the actual cell enclosure shall be removed for the test. The temperature shall be determined on the outer enclosure of each cell or battery and the maximum figure taken. The test shall be carried out both with internal current-limiting devices in circuit and with the devices short-circuited using 10 cells in each case. The 10 samples having the internal current-limiting devices short-circuited shall be obtained from the cell/battery manufacturer together with any special instructions or precautions necessary for safe use and testing of the samples.

The intent of the cited paragraphs is to simulate an internal short inside a cell, by shorting the cell's external terminals for the purpose of thermal assessment.

It was found that two details have been misinterpreted in this subclause:

- The subjects of this subclause are cells or batteries, while the intent is clearly to simulate internal shorts inside cells and not inside batteries in which case the shorts could be interpreted as being external to the cell(s) within a battery.

- b) It is unclear what constitutes a current limiting device that protects against internal shorts.

A separator with shutdown function may be interpreted as a current limiting device that protects against internal shorts by its function, but since it is a constructional part of the cell that is not removable without invalidating the functionality of the basic cell, it is not a current limiting device for the purposes of implementing the standard. Conversely, a CID (Current interruption device), for example, is a switch that is triggered by increased pressure inside the cell, and the cell's functionality is not invalidated by the absence of the CID.

The reference to internal current limiting devices that protect against internal shorts in edition 6 was included to address unknown future cell technologies which could include such current limiting devices, however at this time no such current limiting devices are known.

Question

For either Level of Protection "ia" or "ib", what are the current limiting devices that are required to be disabled (or equivalent e.g. not fitted, short-circuited or removed) by IEC 60079-11:2006, Subclause 10.5.3 b), and what are the current limiting devices that need not be disabled?

Answer

All discrete protective devices that can be schematically represented as individual devices apart from the cell are to be disabled for the purposes of testing according to IEC 60079-11:2006, Subclause 10.5.3 b), regardless if they are located inside the cell or if they are external to the cell. This includes, but is not limited to resistors, fuses, resettable fuses (NTC, PTC, PPTC), CID (current interruption device), semiconductors, etc.

Features that provide essential cell functions, such as a separator with shutdown function or the ohmic resistance of the electrolyte, are not considered current limiting devices in the sense of this clause and need not be shorted or removed, and such cells can be considered for Level of Protection "ia".

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

EXPLOSIVE ATMOSPHERES –

Part 11: Equipment protection by intrinsic safety "i"

FOREWORD

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International Standard IEC 60079-11 has been prepared by subcommittee 31G: Intrinsically safe apparatus, of IEC technical committee 31: Equipment for explosive atmospheres.

This fifth edition cancels and replaces the fourth edition published in 1999 and constitutes a full technical revision.

The significant changes with respect to the previous edition are listed below:

- introduction of level of protection "ic" (this level of protection has been introduced to allow removal of the 'energy limitation' concept from 60079-15);
- introduction of Annex F that allows reduction in segregation distance requirements when the pollution degree has been reduced by installation or enclosure;
- introduction of alternative spark test apparatus construction when used with high current circuits;
- introduction of Annex E that provides a method for transient energy test;

- changes in the table of 'Temperature classification of tracks on PCB's' to allow correlation with IPC-2152;
- allowing alternative methods of rating resistors when used to limit the discharge from capacitance;
- introduction of methods to deal with the spark ignition energy consideration when high current low voltage cells and batteries are used;
- introduction of tests to measure the maximum pressure in sealed battery containers;
- introduction of methods to deal with fault application on voltage enhancement IC's;
- introduction of infallible connection methods for SMD's (surface mount devices);
- introduction of alternative methods to deal with the spark ignition energy in circuits with both inductance and capacitance;
- introduction of alternative high voltage test for transformers;
- introduction of methods to assess the reduction of effective capacitance when protected by series resistances;
- introduction of Group I data for permitted short circuit current and permitted capacitance in the tables of Annex A.

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

FDIS	Report on voting
31G/159/FDIS	31G/161/RVD

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

This standard supplements and modifies the general requirements of IEC 60079-0, except as indicated in Table 1 (see Scope).

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

A list of all parts of the IEC 60079 series, under the general title: *Explosives atmospheres*, can be found on the IEC website.

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

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

The contents of the interpretation sheet 1 of December 2019 have been included in this copy.

EXPLOSIVE ATMOSPHERES –

Part 11: Equipment protection by intrinsic safety "i"

1 Scope

This part of IEC 60079 specifies the construction and testing of intrinsically safe apparatus intended for use in an explosive gas atmosphere and for associated apparatus, which is intended for connection to intrinsically safe circuits which enter such atmospheres.

This type of protection is applicable to electrical apparatus in which the electrical circuits themselves are incapable of causing an explosion in the surrounding explosive atmospheres.

This standard is also applicable to electrical apparatus or parts of electrical apparatus located outside the explosive gas atmosphere or protected by another type of protection listed in IEC 60079-0, where the intrinsic safety of the electrical circuits in the explosive gas atmosphere may depend upon the design and construction of such electrical apparatus or parts of such electrical apparatus. The electrical circuits exposed to the explosive gas atmosphere are evaluated for use in such an atmosphere by applying this standard.

The requirements for intrinsically safe systems are provided in IEC 60079-25. The requirements for intrinsically safe concepts for fieldbus are provided in IEC 60079-27.

This standard supplements and modifies the general requirements of IEC 60079-0, except as indicated in Table 1. Where a requirement of this standard conflicts with a requirement of IEC 60079-0, the requirements of this standard shall take precedence.

If associated apparatus is placed in the explosive gas atmosphere, it must be protected by an appropriate type of protection listed in IEC 60079-0, and then the requirements of that method of protection together with the relevant parts of IEC 60079-0 also apply to the associated apparatus.

Table 1 – Exclusion of specific clauses of IEC 60079-0

Clause or subclause of IEC 60079-0		Intrinsically safe apparatus	Associated apparatus
4.2.2	Group II – Surface temperature marking	Applies	Excluded
5.3	Maximum surface temperature	Applies	Excluded
5.4	Surface temperature and ignition temperature	Applies	Excluded
5.5	Small components	Applies	Excluded
6.3	Opening times	Excluded	Excluded
7.1.1	Applicability	Applies	Excluded
7.1.2	Specification of materials	Applies	Excluded
7.1.3*	Plastic materials	Excluded	Excluded
7.2*	Thermal endurance	Excluded	Excluded
7.3	Electrostatic charges on external non-metallic materials of enclosures	Applies	Excluded
7.3.2	Avoidance of a build-up electrostatic charge	Applies	Excluded
7.4	Threaded holes	Excluded	Excluded

Table 1 (continued)

Clause or subclause of IEC 60079-0		Intrinsically safe apparatus	Associated apparatus
8.1	Material composition	Applies	Excluded
8.2	Threaded holes	Excluded	Excluded
9	Fasteners	Excluded	Excluded
10	Interlocking devices	Excluded	Excluded
11	Bushings	Excluded	Excluded
12	Materials used for cementing	Excluded	Excluded
14	Connection facilities and terminal compartments	Excluded	Excluded
15	Connection facilities for earthing or bonding conductors	Excluded	Excluded
16.5	Conductor temperature	Excluded	Excluded
17	Supplementary requirements for rotating electrical machines	Excluded	Excluded
18	Supplementary requirements for switchgear	Excluded	Excluded
19	Supplementary requirements for fuses	Excluded	Excluded
20	Supplementary requirements for plugs and sockets	Excluded	Excluded
21	Supplementary requirements for luminaires	Excluded	Excluded
22	Supplementary requirements for caplights and handlights	Excluded	Excluded
23.1	Batteries	Applies	Excluded
26.4	Tests of enclosures	Applies	Excluded
26.5.1	Temperature measurement	Applies	Excluded
26.5.2	Thermal shock test	Excluded	Excluded
26.5.3	Small component ignition test	Applies	Excluded
26.6	Torque test for bushings	Excluded	Excluded
26.7*	Non-metallic enclosures or non-metallic parts of enclosures	Excluded	Excluded
26.8*	Thermal endurance to heat	Excluded	Excluded
26.9*	Thermal endurance to cold	Excluded	Excluded
26.10*	Resistance to light	Excluded	Excluded
26.11*	Resistance to chemical agents for Group I electrical apparatus	Excluded	Excluded
26.12	Earth continuity	Excluded	Excluded
26.13	Surface resistance test of parts of enclosures or non-metallic materials	Applies	Excluded
26.14	Charging tests	Applies	Excluded
26.15	Measurement of capacitance	Applies	Excluded
Annex A	Ex cable glands	Excluded	Excluded
* indicates that these requirements apply for 6.1.2a) only.			

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of IEC 60079. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60079-0:2004, *Electrical apparatus for explosive gas atmospheres – Part 0: General requirements*

IEC 60079-7, *Explosive atmospheres – Part 7: Equipment protection by increased safety "e"*

IEC 60079-25, *Electrical apparatus for explosive gas atmospheres – Part 25: Intrinsically safe systems*

IEC 60079-27, *Electrical apparatus for explosive gas atmospheres – Part 27: Fieldbus intrinsically safe concept (FISCO) and Fieldbus non-incendive concept (FNICO)*

IEC 60085, *Electrical insulation – Thermal classification*

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

IEC 60127 (all parts), *Miniature fuses*

IEC 60317-3, *Specifications for particular types of winding wires – Part 3: Polyester enamelled round copper wire, class 155*

IEC 60317-7, *Specifications for particular types of winding wires – Part 7: Polyimide enamelled round copper wire, class 220*

IEC 60317-8, *Specifications for particular types of winding wires – Part 8: Polyesterimide enamelled round copper winding wire, class 180*

IEC 60317-13, *Specifications for particular types of winding wires – Part 13: Polyester or polyesterimide overcoated with polyamide-imide enamelled round copper wire, class 200*

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

IEC 60664-1:2002, *Insulation coordination for equipment within low-voltage systems – Part 1: Principles, requirements and tests* ¹⁾
Amendment 1 (2000)
Amendment 2 (2002)

¹⁾ A consolidated edition 1.2 exists, that comprises IEC 60664-1 and its amendments 1 and 2.

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

ANSI/UL 248-1, *Low-Voltage Fuses – Part 1: General Requirements*

3 Terms and definitions

For the purposes of this document, the terms and definitions in IEC 60079-0, as well as the following apply.

3.1 General

3.1.1

intrinsic safety “i”

type of protection based on the restriction of electrical energy within apparatus and of interconnecting wiring exposed to the potentially explosive atmosphere to a level below that which can cause ignition by either sparking or heating effects

3.1.2

associated apparatus

electrical apparatus which contains both energy-limited and non-energy-limited circuits and is constructed so that the non energy-limited circuits cannot adversely affect the energy-limited circuits

NOTE 1 Associated apparatus may be either:

- a) electrical apparatus which has an alternative type of protection included in this standard for use in the appropriate explosive gas atmosphere,
- b) electrical apparatus not so protected and which therefore is not to be used within an explosive gas atmosphere, for example, a recorder which is not of itself in an explosive gas atmosphere but is connected to a thermocouple situated within an explosive gas atmosphere where only the recorder input circuit is energy limited.

[Definition 3.2 of IEC 60079-0]

NOTE 2 For the purposes of this standard associated apparatus is also electrical apparatus which contains both intrinsically safe circuits and non-intrinsically safe circuits and is constructed so that the non-intrinsically safe circuits cannot adversely affect the intrinsically safe circuits and includes

- a) electrical apparatus which has another type of protection listed in IEC 60079-0 for use in the appropriate explosive gas atmosphere, or
- b) electrical apparatus not so protected and which, therefore, shall not be used within an explosive gas atmosphere, for example a recorder which is not itself in an explosive gas atmosphere, but is connected to a thermocouple situated within an explosive atmosphere where only the recorder input circuit is intrinsically safe, or
- c) chargers or interfaces not used in the hazardous area, but which are connected to hazardous area equipment in the safe area for charging, data downloading, etc.

[IEV 426-11-03, modified]

3.1.3

intrinsically safe apparatus

electrical apparatus in which all the circuits are intrinsically safe circuits

3.1.4

intrinsically safe circuit

circuit in which any spark or any thermal effect produced in the conditions specified in this standard, which include normal operation and specified fault conditions, is not capable of causing ignition of a given explosive gas atmosphere

3.1.5

simple apparatus

electrical component or combination of components of simple construction with well-defined electrical parameters which is compatible with the intrinsic safety of the circuit in which it is used

3.2

coating

insulating material such as varnish or dry film laid on the surface of the assembly

NOTE Coating and base material of a printed board form an insulating system that may have properties similar to solid insulation.

[Definition 3.5 of IEC 60664-3]

3.3

conformal coating

electrical insulating material applied as a coating to loaded printed wire boards to produce a thin layer conforming to the surface in order to provide a protective barrier against deleterious effects from environmental conditions

[Definition 2.1 of IEC 61086-1]

3.4

control drawing

drawing or other document that is prepared by the manufacturer for the intrinsically safe or associated apparatus, detailing the electrical parameters to allow for interconnections to other circuits or apparatus

3.5

diode safety barrier

assemblies incorporating shunt diodes or diode chains (including Zener diodes) protected by fuses or resistors or a combination of these, manufactured as an individual apparatus rather than as part of a larger apparatus

3.6

entity concept

method used to determine acceptable combinations of intrinsically safe apparatus and associated apparatus through the use of intrinsically safe parameters assigned to connection facilities

3.7

faults

3.7.1

countable fault

fault which occurs in parts of electrical apparatus conforming to the constructional requirements of IEC 60079-11 (this standard)

3.7.2

fault

any defect of any component, separation, insulation or connection between components, not defined as infallible by IEC 60079-11, upon which the intrinsic safety of a circuit depends

3.7.3

non-countable fault

fault which occurs in parts of electrical apparatus not conforming to the constructional requirements of IEC 60079-11

3.8

normal operation

operation of apparatus conforming electrically and mechanically with its design specification and used within the limits specified by the manufacturer

NOTE 1 The limits specified by the manufacturer may include persistent operational conditions, e.g. operation of a motor on a duty cycle

NOTE 2 Variation of the supply voltage within stated limits and any other operational tolerance is part of normal operation

[Definition 3.19 of IEC 60079-0]

NOTE 3 This includes opening, shorting and earthing of the external interconnecting cable.

3.9

free space

intentionally created space surrounding components or space inside components

3.10

fuse rating

I_n

current rating of a fuse as specified in IEC 60127, ANSI/UL 248-1 or in the manufacturer's specification

3.11

infallibility

3.11.1

infallible component or infallible assembly of components

component or assembly of components that is considered as not subject to certain fault modes as specified in IEC 60079-11

The probability of such fault modes occurring in service or storage is considered to be so low that they are not to be taken into account.

3.11.2

infallible connection

connections, including joints and interconnecting wiring and printed circuit board tracks, that are not considered according to IEC 60079-11 as becoming open-circuited in service or storage

The probability of such fault modes occurring in service or storage is considered to be so low that they are not to be taken into account.

3.11.3

infallible separation or insulation

separation or insulation between electrically conductive parts that is considered as not subject to short circuits as specified in IEC 60079-11

The probability of such fault modes occurring in service or storage is considered to be so low that they are not to be taken into account.

3.12

internal wiring

wiring and electrical connections that are made within the apparatus by its manufacturer

3.13

live maintenance

maintenance activities carried out while the associated apparatus, intrinsically safe apparatus and circuits are energized

3.14

maximum external inductance to resistance ratio

L_o/R_o

maximum value of ratio of inductance to resistance which may be connected to the external connection facilities of the electrical apparatus without invalidating intrinsic safety

3.15

maximum internal inductance to resistance ratio

L_i/R_i

maximum value of ratio of inductance to resistance which is considered as appearing at the external connection facilities of the electrical apparatus

3.16

maximum r.m.s. a.c. or d.c. voltage

U_m

maximum voltage that can be applied to the non energy-limited connection facilities of associated apparatus without invalidating the type of protection

[Definition 3.12.11 of IEC 60079-0]

NOTE 1 This additionally applies to the maximum voltage that can be applied to non-intrinsically safe connection facilities of intrinsically safe apparatus (for example, charging connections on battery operated apparatus, where charging is only done in the non-hazardous area).

NOTE 2 The value of U_m may be different at different sets of connection facilities, and may be different for a.c. and d.c. voltages.

3.17

overvoltage category

numeral defining a transient overvoltage condition

[Definition 1.3.10 of IEC 60664-1]

NOTE Overvoltage categories I, II, III and IV are used, see 2.2.2.1 of IEC 60664-1.

3.18

pollution degree

numeral characterizing the expected pollution of the micro-environment

[Definition 1.3.13 of IEC 60664-1]

NOTE Pollution degrees 1, 2, 3 and 4 are used.

3.19

protective extra-low voltage (PELV)

extra-low voltage system which is not electrically separated from earth but which otherwise satisfies the requirements for SELV

NOTE A 50 V centre-tapped earth system is a PELV system.

3.20

rated insulation voltage

r.m.s. withstand voltage value assigned by the manufacturer to the equipment or to a part of it, characterizing the specified (long-term) withstand capability of its insulation

[Definition 1.3.9.1 of IEC 60664-1]

NOTE The rated insulation voltage is not necessarily equal to the rated voltage of equipment which is primarily related to functional performance.

3.21**recurring peak voltage**

maximum peak value of periodic excursions of the voltage waveform resulting from distortions of an a.c. voltage or from a.c. components superimposed on a d.c. voltage

NOTE Random overvoltages, for example due to occasional switching, are not considered as recurring peak voltages.

3.22**safety extra-low voltage (SELV)**

extra-low voltage system (i.e. normally not exceeding 50 V a.c. or 120 V ripple-free d.c.) electrically separated from earth and from other systems in such a way that a single fault cannot give rise to an electric shock

NOTE A 50 V earth free system is a SELV system.

3.23**spacings****3.23.1****clearance**

shortest distance in air between two conductive parts

NOTE This distance applies only to parts that are exposed to the atmosphere and not to parts which are insulated parts or covered with casting compound.

3.23.2**distance through casting compound**

shortest distance through a casting compound between two conductive parts

3.23.3**distance through solid insulation**

shortest distance through solid insulation between two conductive parts

3.23.4**creepage distance**

shortest distance along the surface of an insulating medium in contact with air between two conductive parts

3.23.5**distance under coating**

shortest distance between conductive parts along the surface of an insulating medium covered with insulating coating

3.24**void**

unintentional space created as a consequence of the encapsulation process

4 Grouping and classification of intrinsically safe apparatus and associated apparatus

Intrinsically safe apparatus and associated apparatus shall be grouped and classified in accordance with Clauses 4 and 5 of IEC 60079-0.

5 Levels of protection and ignition compliance requirements of electrical apparatus

5.1 General

Intrinsically safe apparatus and intrinsically safe parts of associated apparatus shall be placed in levels of protection "ia", "ib" or "ic".

The requirements of this standard shall apply to all levels of protection unless otherwise stated. In the determination of level of protection "ia", "ib" or "ic", failure of components and connections shall be considered in accordance with 7.6. Failure of separations between conductive parts shall be considered in accordance with 6.3. The determination shall include opening, shorting and earthing of the external interconnecting cable.

The maximum intrinsically safe entity parameters for the intrinsically safe apparatus and associated apparatus shall be determined taking into account the requirements for spark ignition compliance of 5.5 and thermal ignition compliance of 5.6.

For circuits of associated apparatus which are connected to safety extra low-voltage circuits (SELV) or protective extra low-voltage circuits (PELV) circuits, U_m shall only be applied as a 'common mode' voltage, with the nominal operating voltage applied for the differential mode signal between the circuit conductors. (Typical examples are RS-232, RS-485 or 4-20 mA circuits). Apparatus relying on SELV or PELV circuits shall be marked with an "X" as required by item i) of 29.2 of IEC 60079-0.

Where live maintenance procedures are specified by the manufacturer in the documentation provided, the effects of this live maintenance shall not invalidate intrinsic safety and this shall be considered during the testing and assessment.

NOTE 1 Apparatus may be specified with more than one level of protection, and may have different parameters for each level of protection.

NOTE 2 Guidance on the assessment of intrinsically safe circuits for spark ignition circuits is contained in Annex A. Details of the spark test apparatus are given in Annex B.

NOTE 3 For the application of U_m , U_i in the following clauses, any voltage up to the maximum voltage may be applied for the assessment.

NOTE 4 The value of U_m may be different at different sets of connection facilities, and may be different for a.c. and d.c. voltages.

5.2 Level of protection "ia"

With U_m and U_i applied, the intrinsically safe circuits in electrical apparatus of level of protection "ia" shall not be capable of causing ignition in each of the following circumstances:

- a) in normal operation and with the application of those non-countable faults which give the most onerous condition;

- b) in normal operation and with the application of one countable fault plus those non-countable faults which give the most onerous condition;
- c) in normal operation and with the application of two countable faults plus those non-countable faults which give the most onerous condition.

The non-countable faults applied may differ in each of the above circumstances.

In testing or assessing the circuits for spark ignition, the following safety factors shall be applied in accordance with 10.1.4.2:

- for both a) and b) 1,5
- for c) 1,0

The safety factor applied to voltage or current for determination of surface temperature classification shall be 1,0 in all cases.

If only one countable fault can occur, the requirements of b) are considered to give a level of protection of "ia" if the test requirements for "ia" can then be satisfied. If no countable faults can occur the requirements of a) are considered to give a level of protection of "ia" if the test requirements for "ia" can then be satisfied.

5.3 Level of protection "ib"

With U_m and U_i applied, the intrinsically safe circuits in electrical apparatus of level of protection "ib" shall not be capable of causing ignition in each of the following circumstances:

- a) in normal operation and with the application of those non-countable faults which give the most onerous condition;
- b) in normal operation and with the application of one countable fault plus the application of those non-countable faults which give the most onerous condition.

The non-countable faults applied may differ in each of the above circumstances.

In testing or assessing the circuits for spark ignition, a safety factor of 1,5 shall be applied in accordance with 10.1.4.2. The safety factor applied to the voltage or current for the determination of surface temperature classification shall be 1,0 in all cases.

If no countable fault can occur the requirements of a) are considered to give a level of protection of "ib" if the test requirements for "ib" can be satisfied.

5.4 Level of protection "ic"

With U_m and U_i applied, the intrinsically safe circuits in electrical apparatus of level of protection "ic" shall not be capable of causing ignition in normal operation. Where distances are critical for safety, they shall meet the requirements of Table 5 or Table F.2.

In testing or assessing the circuits for spark ignition, a safety factor of 1,0 shall be applied in accordance with 10.1.4.2. The safety factor applied to the voltage or current for the determination of surface temperature classification shall be 1,0 in all cases.

NOTE The concept of faults does not apply to this level of protection. Infallible components and assemblies, as in Clause 8, are not applicable. For level of protection "ic", the term 'infallible' should be read as 'meeting the requirements of 7.1'.

5.5 Spark ignition compliance

The circuit shall be assessed and/or tested for the successful limitation of the spark energy that may be capable of causing ignition of the explosive atmosphere, at each point where an interruption or interconnection may occur, in accordance with 10.1.

5.6 Thermal ignition compliance

5.6.1 General

All surfaces of components, enclosures and the wiring which may come in contact with explosive gas atmospheres shall be assessed and/or tested for the maximum temperature. The requirements for the maximum temperature allowable after the application of faults, as provided in 5.2, 5.3 and 5.4, are given in Clause 5 of IEC 60079-0.

Tests, if required, are specified in 10.2.

NOTE 1 The requirements of this clause are not applicable to associated apparatus protected by another type of protection listed in IEC 60079-0 or located outside the hazardous area.

NOTE 2 Care should be taken in the selection of materials to be used adjacent to components that could exhibit excessive temperatures such as cells, batteries, or components that could dissipate power greater than 1,3 W, under the fault conditions defined in Clause 5, to prevent the secondary ignition of the explosive gas atmosphere by for example, heating or burning of the printed circuit boards, coatings or component packaging.

5.6.2 Temperature for small components

Small components, for example transistors or resistors, whose temperature exceeds that permitted for the temperature classification, shall be acceptable providing that, when tested in accordance with 26.5.3 of IEC 60079-0, small components do not cause ignitions.

For Group I, the test mixture shall be $(6,5 \pm 0,3) \%$ methane in air.

Alternatively, where no catalytic or other chemical reactions can result, one of the following is acceptable:

- a) for Group II T4 and Group I temperature classification components shall conform to Table 2a), including the relevant reduction of permitted maximum dissipation with increased ambient temperature listed in Table 2b);
- b) for Group II T5 classification the surface temperature of a component with a surface area smaller than 10 cm^2 shall not exceed $150 \text{ }^{\circ}\text{C}$.

In addition the permitted higher temperature shall not invalidate the type of protection, for example, by causing the component or adjacent parts of the apparatus to exceed any safety related rating, or to deteriorate or be distorted so as to invalidate critical creepage and clearance distances.

Table 2 – Assessment of temperature classification according to component size and ambient temperature

Table 2a) – Requirements for T4 and Group I

Total surface area excluding lead wires	Group II T4	Group I Dust excluded
	Maximum surface temperature °C	
<20 mm ²	275	950
≥ 20 mm ² ≤ 10 cm ²	200	450
>10 cm ²	135	450

Table 2b) – Variation in maximum power dissipation with ambient temperature for components not less than 20 mm²

Maximum ambient temperature	° C	Apparatus group	40	50	60	70	80
Maximum power dissipation	W	Group II	1,3	1,25	1,2	1,1	1,0
		Group I	3,3	3,22	3,15	3,07	3,0

5.6.3 Wiring within apparatus

The maximum permissible current corresponding to the maximum wire temperature due to self-heating shall either be taken from Table 3 for copper wires, or can be calculated from the following equation for metals in general.

$$I = I_f \left[\frac{t(1+aT)}{T(1+at)} \right]^{1/2}$$

where

a is the temperature coefficient of resistance of the wire material (0,004 284 K⁻¹ for copper, 0,004 201 K⁻¹ for gold);

I is the maximum permissible current r.m.s., in amperes;

I_f is the current at which the wire melts at the specified ambient temperature, in amperes;

T is the melting temperature of the wire material in degrees Celsius (1 083 °C for copper, 1 064 °C for gold);

t is the threshold temperature, in degrees Celsius, of the applicable temperature class. The value of t is the wire temperature due to self-heating and ambient temperature.

Example: fine copper wire (Temp Code=T4)

$a = 0,004\,284\text{ K}^{-1}$

$I_f = 1,6\text{ A}$ (determined experimentally or specified by the wire manufacturer)

$T = 1\,083\text{ °C}$

t for T4 (small component, $t \leq 275\text{ °C}$)

Applying the equation

$I = 1,3 \text{ A}$ (This is the maximum normal or fault current which may be allowed to flow to prevent the wire temperature from exceeding 275 °C.)

**Table 3 – Temperature classification of copper wiring
(in a maximum ambient temperature of 40 °C)**

Diameter (see Note 4) mm	Cross-sectional area (see Note 4) mm ²	Maximum permissible current for temperature classification A		
		T1 to T4 and Group I	T5	T6
0,035	0,000 962	0,53	0,48	0,43
0,05	0,001 96	1,04	0,93	0,84
0,1	0,007 85	2,1	1,9	1,7
0,2	0,031 4	3,7	3,3	3,0
0,35	0,096 2	6,4	5,6	5,0
0,5	0,196	7,7	6,9	6,7

NOTE 1 The value given for maximum permissible current, in amperes, is the r.m.s. a.c. or d.c. value.

NOTE 2 For stranded conductors, the cross-sectional area is taken as the total area of all strands of the conductor.

NOTE 3 The table also applies to flexible flat conductors, such as in ribbon cable, but not to printed circuit conductors for which see 5.6.4.

NOTE 4 Diameter and cross-sectional area are the nominal dimensions specified by the wire manufacturer.

NOTE 5 Where the maximum power does not exceed 1,3 W the wiring can be assigned a temperature classification of T4 and is acceptable for Group I. For Group I where dust is excluded, a maximum power of 3,3 W is permitted for ambient temperatures of up to 40 °C. Refer to Table 2b) where derating is required for ambient temperatures greater than 40 °C.

5.6.4 Tracks on printed circuit boards

The temperature classification of tracks of printed circuit boards shall be determined using available data or by actual measurement.

Where the tracks are made of copper, the temperature classification may be determined using Table 4.

For example, on printed circuit boards of at least 0,5 mm thickness, having a conducting track of at least 33 µm thickness on one or both sides, by applying factors given in Notes 3, 4, 8, 9 of Table 4, a temperature classification of T4 or Group I shall be given to the printed tracks if they have a minimum width of 0,3 mm and the continuous current in the tracks does not exceed 0,444 A. Similarly, for minimum track widths of 0,5 mm, 1,0 mm and 2,0 mm, T4 shall be given for corresponding maximum currents of 0,648 A, 1,092 A and 1,833 A respectively.

Track lengths of 10 mm or less shall be disregarded for temperature classification purposes.

Where temperature classification of a track is to be experimentally determined, the maximum continuous current shall be used.

Manufacturing tolerances shall not reduce the values stated in this clause by more than 10 % or 1 mm, whichever is the smaller.

In the absence of testing, where the maximum power does not exceed 1,3 W, the tracks are suitable for a temperature classification of T4 or Group I.

For Group I, where dust is excluded, 3,3 W is allowable.

Refer to Table 2b) where a derating is required for ambient temperatures greater than 40 °C.

**Table 4 – Temperature classification of tracks on printed circuit boards
(in a maximum ambient temperature of 40 °C)**

Minimum track width mm	Maximum permissible current for temperature classification		
	T1 to T4 and Group I A	T5 A	T6 A
0,075	0,8	0,6	0,5
0,1	1,0	0,8	0,7
0,125	1,2	1,0	0,8
0,15	1,4	1,1	1,0
0,2	1,8	1,4	1,2
0,3	2,4	1,9	1,9
0,4	3,0	2,4	2,1
0,5	3,5	2,8	2,5
0,7	4,6	3,5	3,2
1,0	5,9	4,8	4,1
1,5	8,0	6,4	5,6
2,0	9,9	7,9	6,9
2,5	11,6	9,3	8,1
3,0	13,3	10,7	9,3
4,0	16,4	13,2	11,4
5,0	19,3	15,5	13,5
6,0	22,0	17,7	15,4

NOTE 1 The value given for maximum permissible current in amperes is the r.m.s. a.c. or d.c. value.

NOTE 2 This table applies to printed boards 1,6 mm or thicker with a single layer of copper of 33 µm thickness.

NOTE 3 For boards with a thickness between 0,5 mm and 1,6 mm, divide the maximum current specified by 1,2.

NOTE 4 For boards with conducting tracks on both sides, divide the maximum current specified by 1,5.

NOTE 5 For multilayer boards, for the track layer under consideration, divide the maximum current specified by 2.

NOTE 6 For 18 µm copper thickness, divide the maximum current by 1,5.

NOTE 7 For 70 µm copper thickness, multiply the maximum current by 1,3.

NOTE 8 For tracks passing under components dissipating 0,25 W or more either normally or under fault conditions, divide the maximum current specified by 1,5.

NOTE 9 At terminations of components dissipating 0,25 W or more either normally or under fault conditions, and for 1,00 mm along the conductor, either multiply the track width by 3 or divide the maximum current specified by 2. If the track goes under the component, apply the factor specified in note 8 in addition.

NOTE 10 For ambient temperature up to 60 °C, divide the maximum current by 1,2.

NOTE 11 For ambient temperature up to 80 °C, divide the maximum current by 1,3.

5.7 Simple apparatus

The following apparatus shall be considered to be simple apparatus:

- a) passive components, for example switches, junction boxes, resistors and simple semiconductor devices;
- b) sources of stored energy consisting of single components in simple circuits with well-defined parameters, for example capacitors or inductors, whose values shall be considered when determining the overall safety of the system;
- c) sources of generated energy, for example thermocouples and photocells, which do not generate more than 1,5 V, 100 mA and 25 mW.

Simple apparatus shall conform to all relevant requirements of this standard. The manufacturer or intrinsically safe system designer shall demonstrate compliance with this clause, including material data sheets and test reports, if applicable. The apparatus need not comply with Clause 12.

The following aspects shall always be considered:

- 1) simple apparatus shall not achieve safety by the inclusion of voltage and/or current-limiting and/or suppression devices;
- 2) simple apparatus shall not contain any means of increasing the available voltage or current, for example DC-DC converters;
- 3) where it is necessary that the simple apparatus maintains the integrity of the isolation from earth of the intrinsically safe circuit, it shall be capable of withstanding the test voltage to earth in accordance with 6.3.12. Its terminals shall conform to 6.2.1;
- 4) non-metallic enclosures and enclosures containing light metals when located in the explosive gas atmosphere shall conform to 7.3 and 8.1 of IEC 60079-0;
- 5) when simple apparatus is located in the explosive gas atmosphere, it shall be temperature classified. When used in an intrinsically safe circuit within their normal rating and at a maximum ambient temperature of 40 °C, switches, plugs, sockets and terminals will have a maximum surface temperature of less than 85 °C, so they can be allocated a T6 temperature classification for Group II applications and are also suitable for Group I applications. Other types of simple apparatus shall be temperature classified in accordance with Clause 4 of this standard.

Where simple apparatus forms part of an apparatus containing other electrical circuits, the whole shall be assessed according to the requirements of this standard.

NOTE 1 Sensors which utilize catalytic reaction or other electro-chemical mechanisms are not normally simple apparatus. Specialist advice on their application should be sought.

NOTE 2 It is not a requirement of this standard that the conformity of the manufacturer's specification of the simple apparatus needs to be verified.

6 Apparatus construction

NOTE The requirements given in this clause apply, unless otherwise stated in the relevant subclauses, only to those features of intrinsically safe apparatus and associated apparatus which contribute to this type of protection.

For example, the requirements for encapsulation with casting compound apply only if encapsulating is required to satisfy 6.3.4 or 6.6.

6.1 Enclosures

Where intrinsic safety can be impaired by access to conducting parts, for example if the circuits contain infallible creepage distances, an enclosure is necessary.

The degree of protection required will vary according to the intended use; for example, a degree of protection of IP54 in accordance with IEC 60529 may be required for Group I apparatus.

The "enclosure" need not be physically the same for protection against contact with live parts and the ingress of solid foreign bodies and liquids.

The designation of the surfaces which form the boundaries of the enclosure shall be the responsibility of the manufacturer and shall be recorded in the definitive documentation (see Clause 13).

6.1.1 Apparatus complying with Table 5

Apparatus meeting the separation requirements of Table 5 shall be provided with an enclosure meeting the requirements of IP20 or greater.

The enclosure does not need to be subjected to the tests for enclosures in 26.4 of IEC 60079-0; however, the drop test 26.4.3 of IEC 60079-0 still applies.

6.1.2 Apparatus complying with Annex F

Apparatus meeting the separation requirements of Annex F shall be provided with protection to achieve pollution degree 2. This can be achieved by:

- a) an enclosure meeting the requirements of IP54 or greater in accordance with IEC 60529. The enclosure shall be subjected to the tests for enclosures in 26.4 of IEC 60079-0.
- b) an enclosure meeting the requirements of IP20 or greater in accordance with IEC 60529 provided that separations are obtained by using coating type 1 or type 2. The enclosure does not need to be subjected to the tests for enclosures in 26.4 of IEC 60079-0.
- c) installation, provided that requirements shall be specified as special conditions for safe use and the apparatus shall be marked with the symbol X according to item i) of 29.2 of IEC 60079-0.

6.2 Facilities for connection of external circuits

6.2.1 Terminals

In addition to satisfying the requirements of Table 5, terminals for intrinsically safe circuits shall be separated from terminals for non-intrinsically safe circuits by one or more of the methods given in a) or b).

These methods of separation shall also be applied where intrinsic safety can be impaired by external wiring which, if disconnected from the terminal, can come into contact with conductors or components.

NOTE 1 Terminals for connection of external circuits to intrinsically safe apparatus and associated apparatus should be so arranged that components will not be damaged when making the connections.

- a) When separation is accomplished by distance then the clearance between bare conducting parts of terminals shall be at least 50 mm.

NOTE 2 Care must be exercised in the layout of terminals and in the wiring method used so that contact between circuits is unlikely if a wire becomes dislodged.

- b) When separation is accomplished by locating terminals for intrinsically safe and non-intrinsically safe circuits in separate enclosures or by use of either an insulating partition or an earthed metal partition between terminals with a common cover, the following applies:
- 1) partitions used to separate terminals shall extend to within 1,5 mm of the enclosure walls, or alternatively shall provide a minimum distance of 50 mm between the bare conducting parts of terminals when measured in any direction around the partition;
 - 2) metal partitions shall be earthed and shall have sufficient strength and rigidity to ensure that they are not likely to be damaged during field wiring. Such partitions shall be at least 0,45 mm thick or shall conform to 10.6.3 if of lesser thickness. In addition, metal partitions shall have sufficient current-carrying capacity to prevent burn-through or loss of earth connection under fault conditions;
 - 3) non-metallic insulating partitions shall have an appropriate CTI, sufficient thickness and shall be so supported that they cannot readily be deformed in a manner that would defeat their purpose. Such partitions shall be at least 0,9 mm thick, or shall conform to 10.6.3 if of lesser thickness.

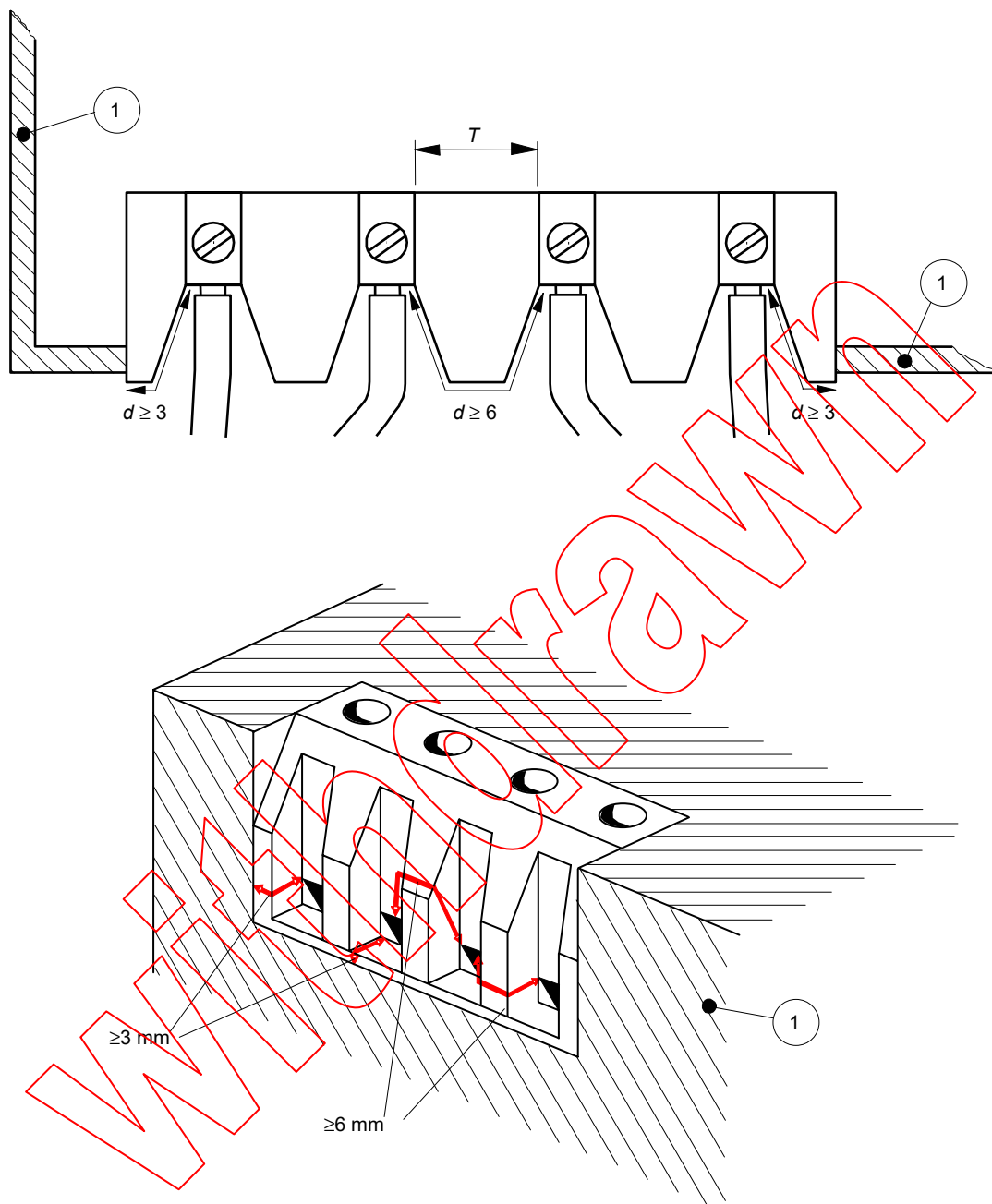
The clearances and creepage distances between the bare conducting parts of terminals of separate intrinsically safe circuits and to earthed or potential-free conducting parts shall be equal to or exceed the values given in Table 5.

Where separate intrinsically safe circuits are being considered, the clearance distance between bare conducting parts of external connection facilities shall meet the following:

- at least 6 mm between the separate intrinsically safe circuits;
- at least 3 mm from earthed parts, if connection to earth has not been considered in the safety analysis.

See Figure 1 when measuring distances around solid insulating walls or partitions. Any possible movement of metallic parts that are not rigidly fixed shall be taken into account.

Dimensions in millimetres



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Key

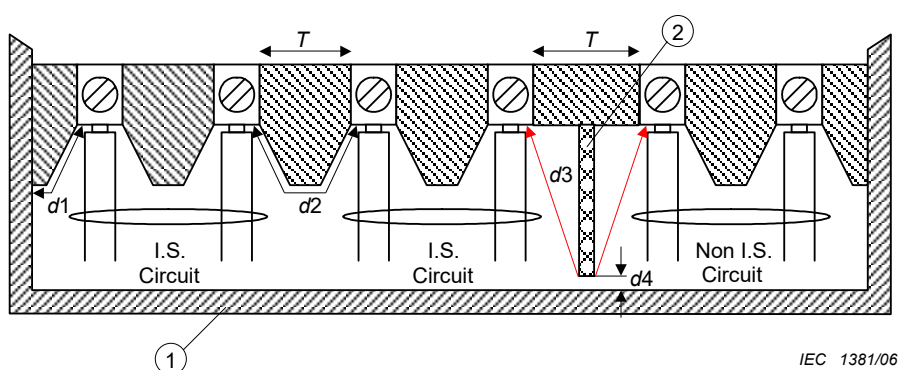
1 Conductive cover

T Distances in accordance with Table 5

d Clearance distance at external connection facilities of terminals in accordance with 6.2.1

NOTE The dimensions shown are the creepage and clearance distances around the insulation as indicated above, not the thickness of the insulation.

Figure 1a – Distance requirements for terminals carrying separate intrinsically safe circuits



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Key

- 1 Cover: non-conductive, or conductive and earthed
- 2 Partition in accordance with 6.2.1b); in this example, it shall be homogeneous with the base or cemented to it.
- T Distances in accordance with Table 5
- $d1 \geq 3 \text{ mm}$; when cover is conductive and earthed
- $d2 \geq 6 \text{ mm}$
- $d3 \geq 50 \text{ mm}$ or $d4 \leq 1,5 \text{ mm}$

NOTE The dimensions shown are the clearance distances around the insulation, as indicated above, not the thickness of the insulation.

Figure 1b – Example of separation of intrinsically safe and non-intrinsically safe terminals through use of a partition

Figure 1 – Separation of intrinsically safe and non-intrinsically safe terminals

6.2.2 Plugs and sockets

Plugs and sockets used for connection of external intrinsically safe circuits shall be separate from and non-interchangeable with those for non-intrinsically safe circuits.

Where intrinsically safe or associated apparatus is fitted with more than one plug and socket for external connections and interchange could adversely affect the type of protection, such plugs and sockets shall either be arranged, for example by keying, so that interchange is not possible, or mating plugs and sockets shall be identified, for example by marking or colour coding, to make interchanging obvious.

Where a plug or a socket is not prefabricated with its wires, the connecting facilities shall conform to 6.2.1. If, however, the connections require the use of a special tool, for example by crimping, such that there is no possibility of a strand of wire becoming free, then the connection facilities need only conform to Table 5.

Where a connector carries earthed circuits and the type of protection depends on the earth connection, then the connector shall be constructed in accordance with 6.5.

6.2.3 Determination of maximum external inductance to resistance ratio (L_0/R_0) for resistance limited power source

The maximum external inductance to resistance ratio (L_0/R_0) which may be connected to a resistance limited power source shall be calculated using the following formula. This formula takes account of a 1,5 factor of safety on current and shall not be used where C_s for the output terminals of the apparatus exceeds 1 % of C_0 .

$$\frac{L_o}{R_o} = \frac{8eR_s + (64e^2R_s^2 - 72U_o^2 eL_s)^{1/2}}{4,5 U_o^2} \quad \text{H}/\Omega$$

where

e is the minimum spark-test apparatus ignition energy in joules, and is for

- Group I apparatus: 525 μJ
- Group IIA apparatus: 320 μJ
- Group IIB apparatus: 160 μJ
- Group IIC apparatus: 40 μJ

R_s is the minimum output resistance of the power source, in ohms;

U_o is the maximum open circuit voltage, in volts;

L_s is the maximum inductance present at the power source terminals, in henries.

C_s is the maximum capacitance present at the power source terminals, in farads

If $L_s = 0$

then

$$\frac{L_o}{R_o} = \frac{32 e R_s}{9 U_o^2} \quad \text{H}/\Omega$$

Where a safety factor of 1 is required, this value for L_o/R_o shall be multiplied by 2,25.

NOTE 1 The normal application of the L_o/R_o ratio is for distributed parameters, for example cables. Its use for lumped values for inductance and resistance requires special consideration.

NOTE 2 L_o/R_o may be determined experimentally for non-linear power sources by testing the circuit with several discrete values of L_o and R_o using the spark tests in 10.1. The values of R_o used should range from practically a short circuit (maximum I_o) to practically open circuit (I_o nearly zero) and a trend established that ensures that the L_o/R_o will not result in failure of the spark test.

6.2.4 Permanently connected cable

Apparatus which is constructed with an integral cable for external connections shall be subjected to the pull test in 10.9 on the cable if breakage of the terminations inside the apparatus could result in intrinsic safety being invalidated, for example where there is more than one intrinsically safe circuit in the cable and breakage could lead to an unsafe interconnection.

6.3 Separation distances

Requirements for separation distances are given in 6.3.1 to 6.3.13. An alternative method for the dimensioning of separation distances is given in Annex F.

6.3.1 Separation of conductive parts

Separation of conductive parts between

- intrinsically safe and non-intrinsically safe circuits, or
- different intrinsically safe circuits, or
- a circuit and earthed or isolated metal parts,

shall conform to the following if the type of protection depends on the separation.

Separation distances shall be measured or assessed taking into account any possible movement of the conductors or conductive parts. Manufacturing tolerances shall not reduce the distances by more than 10 % or 1 mm, whichever is the smaller.

Separation distances that comply with the values in 6.1.1 or 6.1.2 shall not be subject to a fault.

6.3.1.1 Distances according to Table 5

For levels of protection “ia” and “ib”, smaller separation distances, which are less than the values specified in Table 5 but greater than or equal to one-third of that value, shall be considered as subject to countable short-circuit faults if this impairs intrinsic safety.

For levels of protection “ia” and “ib”, if separation distances are less than one-third of the values specified in Table 5, they shall be considered as subject to non-countable short-circuit faults if this impairs intrinsic safety.

For level of protection “ic”, if separation distances are less than the values specified in Table 5, they shall be considered as short-circuits if this impairs intrinsic safety.

6.3.1.2 Distances according to Annex F

For levels of protection “ia” and “ib”, if separation distances are less than the values specified in Annex F, they shall be considered as subject to non-countable short-circuit faults if this impairs intrinsic safety.

For level of protection “ic”, if separation distances are less than the values specified in Annex F, they shall be considered as short-circuits if this impairs intrinsic safety.

The fault mode of failure of segregation shall only be a short-circuit.

Separation requirements shall not apply where earthed metal, for example tracks of a printed circuit board or a partition, separates an intrinsically safe circuit from other circuits, provided that breakdown to earth does not adversely affect the type of protection and that the earthed conductive part can carry the maximum current that would flow under fault conditions.

NOTE 1 For example, the type of protection does depend on the separation to earthed or isolated metallic parts if a current-limiting resistor can be bypassed by short-circuits between the circuit and the earthed or isolated metallic part.

An earthed metal partition shall have strength and rigidity so that it is unlikely to be damaged and shall be of sufficient thickness and of sufficient current-carrying capacity to prevent burn-through or loss of earth under fault conditions. A partition either shall be at least 0,45 mm thick and attached to a rigid, earthed metal portion of the device, or shall conform to 10.6.3 if of lesser thickness.

Where a non-metallic insulating partition having an appropriate CTI is placed between the conductive parts, the clearances, creepage distances and other separation distances either shall be measured around the partition provided that the partition has a thickness of at least 0,9 mm, or shall conform to 10.6.3 if of lesser thickness.

NOTE 2 Methods of assessment are given in Annex C.

Table 5 – Clearances, creepage distances and separations

1	2		3		4		5		6		7
Voltage (peak value) V	Clearance mm		Separation distance through casting compound mm		Separation distance through solid insulation mm		Creepage distance mm		Distance under coating mm		Comparative tracking index (CTI)
	ia, ib	ic	ia, ib	ic	ia, ib	ic	ia, ib	ic	ia, ib	ic	
Level of protection											
10	1,5	0,4	0,5	0,2	0,5	0,2	1,5	1,0	0,5	0,3	-
30	2,0	0,8	0,7	0,2	0,5	0,2	2,0	1,3	0,7	0,3	100
60	3,0	0,8	1,0	0,3	0,5	0,3	3,0	1,9	1,0	0,6	100
90	4,0	0,8	1,3	0,3	0,7	0,3	4,0	2,1	1,3	0,6	100
190	5,0	1,5	1,7	0,6	0,8	0,6	8,0	2,5	2,6	1,1	175
375	6,0	2,5	2,0	0,6	1,0	0,6	10,0	4,0	3,3	1,7	175
550	7,0	4,0	2,4	0,8	1,2	0,8	15,0	6,3	5,0	2,4	175
750	8,0	5,0	2,7	0,9	1,4	0,9	18,0	10,0	6,0	2,9	175
1 000	10,0	7,0	3,3	1,1	1,7	1,1	25,0	12,5	8,3	4,0	175
1 300	14,0	8,0	4,6	1,7	2,3	1,7	36,0	13,0	12,0	5,8	175
1 575	16,0	10,0	5,3	*	2,7	*	49,0	15,0	16,3	*	175
3,3 k	*	18,0	9,0	*	4,5	*	*	32,0	*	*	*
4,7 k	*	22,0	12,0	*	6,0	*	*	50,0	*	*	*
9,5 k	*	45,0	20,0	*	10,0	*	*	100,0	*	*	*
15,6 k	*	70,0	33,0	*	16,5	*	*	150,0	*	*	*

NOTE 1 * No values for all voltages are proposed at present.

NOTE 2 Evidence of compliance with the CTI requirements of insulating materials must be provided by the manufacturer. At voltages up to 10 V, the CTI of insulating materials is not required to be specified.

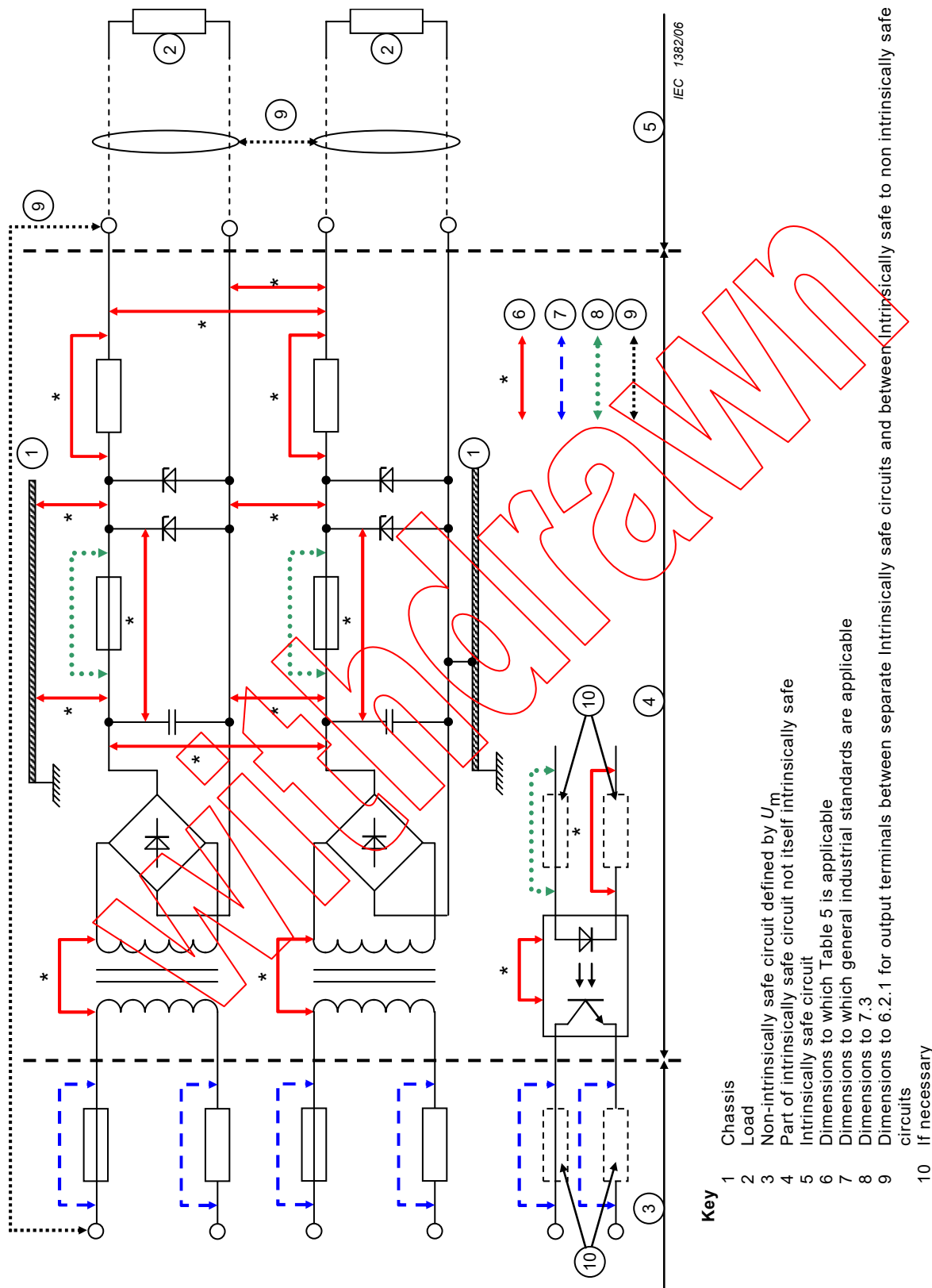


Figure 2 – Example of separation of conducting parts

6.3.2 Voltage between conductive parts

The voltage which is taken into account when using Table 5 or Annex F shall be the voltage between any two conductive parts for which the separation has an effect on the type of protection of the circuit under consideration, that is for example (see Figure 2) the voltage between an intrinsically safe circuit and

- part of the same circuit which is not intrinsically safe, or
- non-intrinsically safe circuits, or
- other intrinsically safe circuits.

The value of voltage to be considered shall be either of the following, as applicable.

- a) For circuits which are galvanically separated within the apparatus, the value of voltage to be considered between the circuits, shall be the highest voltage that can appear across the separation when the two circuits are connected together at any one point, derived from
- the rated voltages of the circuits, or
 - the maximum voltages specified by the manufacturer which may safely be supplied to the circuits, or
 - any voltages generated within the same apparatus.

Where one of the voltages is less than 20 % of the other, it shall be ignored. Mains supply voltages shall be taken without the addition of standard mains tolerances. For such sinusoidal voltages, peak voltage shall be considered to be the following:

$\sqrt{2} \times \text{r.m.s. value of the rated voltage.}$

- b) Between parts of a circuit: the maximum peak value of the voltage that can occur in either part of that circuit. This may be the sum of the voltages of different sources connected to that circuit. One of the voltages may be ignored if it is less than 20 % of the other.

In all cases voltages which arise during the fault conditions of Clause 5 shall, where applicable, be used to derive the maximum.

Any external voltage shall be assumed to have the value U_m or U_i declared for the connection facilities through which it enters. Transient voltages such as might exist before a protective device, for example a fuse, opens the circuit shall not be considered when evaluating the creepage distance, but shall be considered when evaluating clearances.

6.3.3 Clearance

In measuring or assessing clearances between conductive parts, insulating partitions of less than 0,9 mm thickness, or which do not conform to 10.6.3, shall be ignored. Other insulating parts shall conform to column 4 of Table 5.

For voltages higher than 1 575 V peak, an interposing insulating partition or earthed metal partition shall be used. In either case, the partition shall conform to 6.3.1.

6.3.4 Separation distances through casting compound

Casting compound shall meet the requirements of 6.6. For those parts that require encapsulation, the minimum separation distance between encapsulated conductive parts and components, and the free surface of the casting compound shall be at least half the values shown in column 3 of Table 5, with a minimum of 1 mm. When the casting compound is in

direct contact with and adheres to an enclosure of insulating material conforming to column 4 of Table 5, no other separation is required (see Figure D.1).

The insulation of the encapsulated circuit shall conform to 6.3.12.

The failure of a component which is encapsulated or hermetically sealed, for example a semiconductor, which is used in accordance with 7.1 and in which internal clearances and distances through encapsulant are not defined, is to be considered as a single countable fault.

NOTE Further guidance is given in Annex D.

6.3.5 Separation distances through solid insulation

Solid insulation is insulation which is extruded or moulded but not poured. It shall have a dielectric strength that conforms to 6.3.12 when the separation distance is in accordance with Table 5 or Annex F. The maximum current in the insulated wiring shall not exceed the rating specified by the manufacture of the wire.

NOTE 1 If the insulator is fabricated from two or more pieces of electrical insulating material which are solidly bonded together, then the composite may be considered as solid.

NOTE 2 For the purpose of this standard, solid insulation is considered to be prefabricated, for example sheet or sleeving or elastomeric insulation on wiring.

NOTE 3 Varnish and similar coatings are not considered to be solid insulation.

6.3.6 Composite separations

Where separations complying with Table 5 are composite, for example through a combination of air and insulation, the total separation shall be calculated on the basis of referring all separations to one column of Table 5. For example at 60 V:

clearance (column 2) = $6 \times$ separation through solid insulation (column 4);

clearance (column 2) = $3 \times$ separation through casting compound (column 3);

equivalent clearance = actual clearance + $(3 \times \text{any additional separation through encapsulant}) + (6 \times \text{any additional separation through solid insulation})$.

For levels of protection "ia" and "ib", for the separation to be infallible, the above result shall be not less than the clearance value specified in Table 5.

Any clearance or separation which is below one-third of the relevant value specified in Table 5 shall be ignored for the purpose of calculation.

For level of protection "ic", the above results shall not be less than the clearance value specified in Table 5.

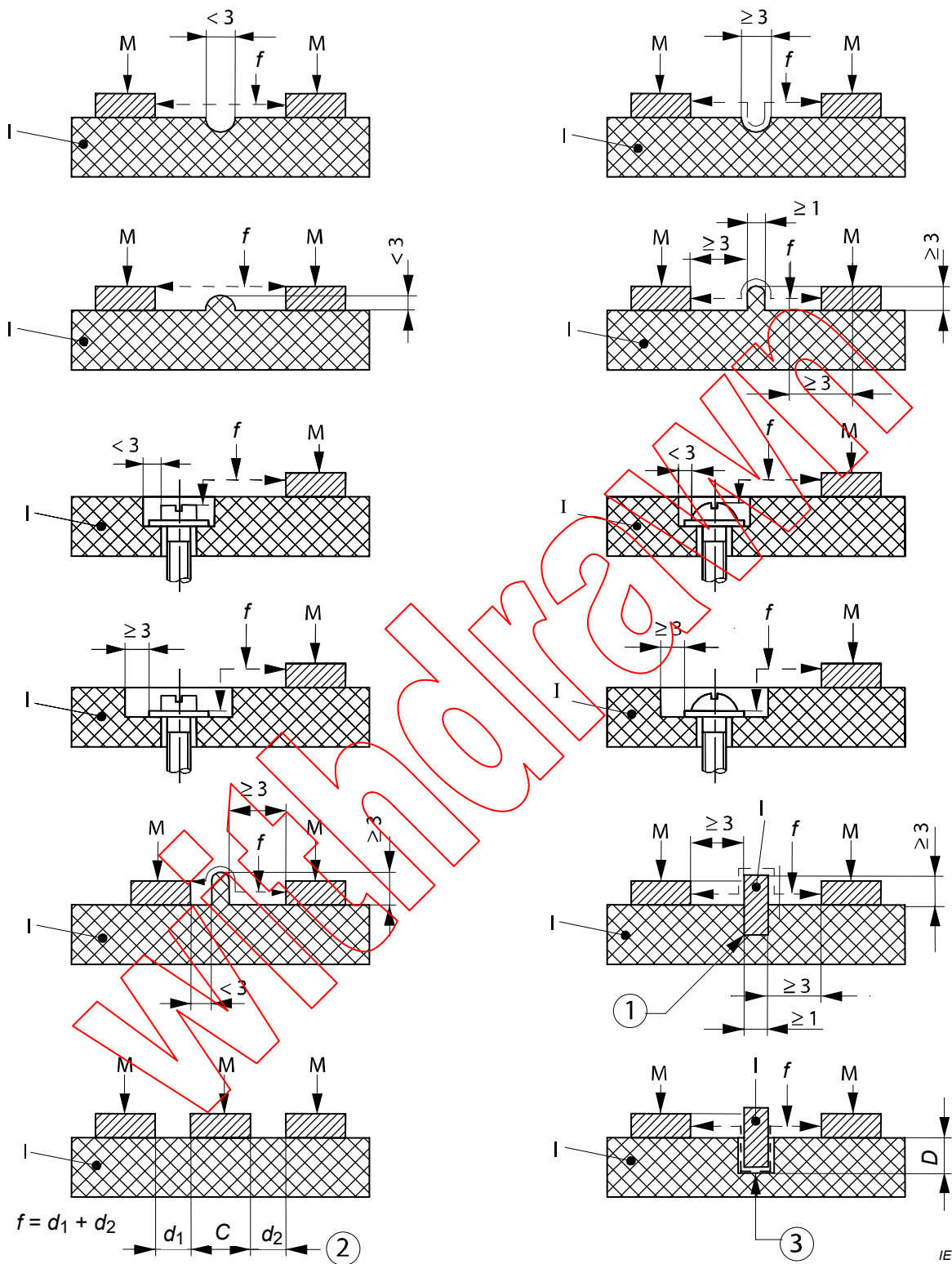
6.3.7 Creepage distance

For the creepage distances specified in column 5 of Table 5, the insulating material shall conform to column 7 of Table 5 which specifies the minimum comparative tracking index (CTI) measured in accordance with IEC 60112. The method of measuring or assessing these distances shall be in accordance with Figure 3.

Where a joint is cemented, the cement shall have insulation properties equivalent to those of the adjacent material.

Where the creepage distance is made up from the addition of shorter distances, for example where a conductive part is interposed, distances of less than one-third the relevant value in column 5 of Table 5 shall not be taken into account. For voltages higher than 1 575 V peak, an interposing insulating partition or earthed metallic partition shall be used. In either case, the partition shall conform to 6.3.1.

Withdrawn



IEC 1383/06

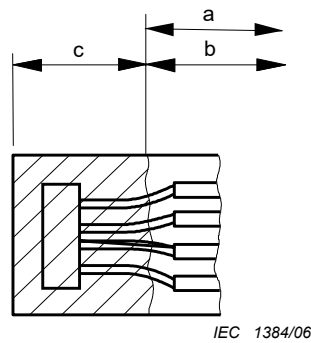


Figure 4a – Partially coated board

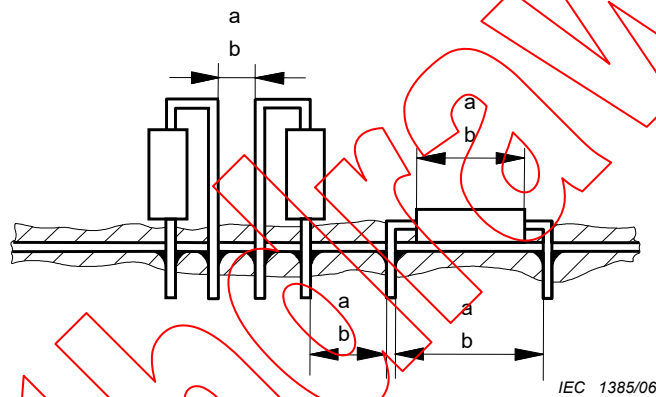


Figure 4b – Board with soldered leads protruding

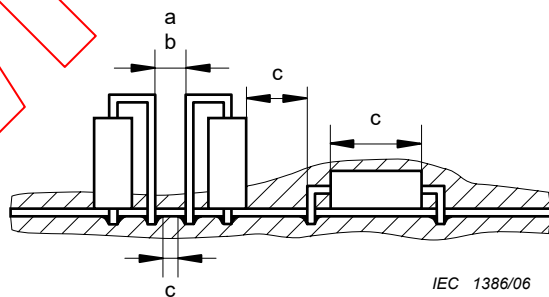


Figure 4c – Board with soldered leads folded or cropped

NOTE The thickness of the coating is not drawn to scale.

Key

- a Apply clearance distance requirements of 6.3.3
- b Apply creepage distance requirements of 6.3.7
- c Apply distance under coating requirements of 6.3.8

Figure 4 – Creepage distances and clearances on printed circuit boards

6.3.8 Distance under coating

A conformal coating shall seal the path between the conductors in question against the ingress of moisture and pollution, and shall give an effective lasting unbroken seal. It shall adhere to the conductive parts and to the insulating material. If the coating is applied by spraying, two separate coats shall be applied.

A solder mask alone is not considered as a conformal coating, but can be accepted as one of the two coats when another non-solder mask coat is applied by spraying, provided the solder mask is not damaged during soldering. Other methods of application require only one coat, for example dip coating, brushing, or vacuum impregnating. A solder mask that meets the requirements of Annex F for Type 1 coatings is considered as a conformal coating and an additional coating is not required. The manufacturer shall provide evidence of conformance with Annex F.

NOTE 1 It is not a requirement of this standard that the conformity of the manufacturer's specification of the coating needs to be verified.

The method used for coating the board shall be specified in the documentation according to Clause 24 of IEC 60079-0. Where the coating is considered adequate to prevent conductive parts, for example soldered joints and component leads, from protruding through the coating, this shall be stated in the documentation and confirmed by examination.

Where bare conductors or conductive parts emerge from the coating the comparative tracking index (CTI) in column 7 of Table 5 shall apply to both insulation and coating.

NOTE 2 The concept of distance under coating was developed for flat surfaces, for example non-flexible printed circuit boards. Flexible printed circuit boards must have suitable elastic coating that does not crack. Radical differences from this format require special consideration.

6.3.9 Requirements for assembled printed circuit boards

Where creepage and clearance distances affect the intrinsic safety of the apparatus, the printed circuit shall conform to the following (see Figure 4):

- a) when a printed circuit is covered by a conformal coating according to 6.3.8, the requirements of 6.3.3 and 6.3.7 shall apply only to any conductive parts which lie outside the coating, including, for example
 - tracks which emerge from the coating;
 - the free surface of a printed circuit which is coated on one side only;
 - bare parts of components able to protrude through the coating;
- b) the requirements of 6.3.8 shall apply to circuits or parts of circuits and their fixed components when the coating covers the connecting pins, solder joints and the conductive parts of any components;
- c) where a component is mounted over or adjacent to tracks on the printed circuit boards, a non-countable fault shall be considered to occur between the conductive part of the component and the track unless;
 - i) the separation is in accordance with 6.3.1 between the conductive part of the component and the track, or
 - ii) failure results in a less onerous condition.

6.3.10 Separation by earth screens

Where separation between circuits or parts of circuits is provided by a metallic screen, the screen, as well as any connection to it, shall be capable of carrying the maximum possible current to which it could be continuously subjected in accordance with Clause 5.

Where the connection is made through a connector, the connector shall be constructed in accordance with 6.5.

6.3.11 Internal wiring

Insulation, except for varnish and similar coatings, covering the conductors of internal wiring shall be considered as solid insulation (see 6.3.5).

The separation of conductors shall be determined by adding together the radial thicknesses of extruded insulation on wires which are lying side by side either as separate wires or in a cable form or in a cable.

The distance between the conductors of any core of an intrinsically safe circuit and that of any core of a non-intrinsically safe circuit shall be in accordance with column 4 of Table 5, taking into account the requirements of 6.3.6 except when one of the following apply:

- the cores of either the intrinsically safe or the non-intrinsically safe circuit are enclosed in an earth screen, or
- in levels of protection "ib" and "ic" electrical apparatus, the insulation of the intrinsically safe cores is capable of withstanding an r.m.s. a.c. test voltage of 2 000 V.

NOTE One method of achieving insulation capable of withstanding this test voltage is to add an insulating sleeve over the core.

6.3.12 Dielectric strength requirement

The insulation between an intrinsically safe circuit and the frame of the electrical apparatus or parts which may be earthed shall normally be capable of complying with the test described in 10.3 at an r.m.s. a.c. test voltage of twice the voltage of the intrinsically safe circuit or 500 V r.m.s., whichever is the greater.

Where the circuit does not satisfy this requirement the apparatus shall be marked with the symbol "X" and the documentation shall indicate the necessary information regarding the correct installation.

The insulation between an intrinsically safe circuit and a non-intrinsically safe circuit shall be capable of withstanding an r.m.s. a.c. test voltage of $2U + 1\,000\text{ V}$, with a minimum of 1 500 V r.m.s., where U is the sum of the r.m.s. values of the voltages of the intrinsically safe circuit and the non-intrinsically safe circuit.

Where breakdown between separate intrinsically safe circuits could produce an unsafe condition, the insulation between these circuits shall be capable of withstanding an r.m.s. test voltage of $2U$, with a minimum of 500 V r.m.s., where U is the sum of the r.m.s. values of the voltages of the circuits under consideration.

6.3.13 Relays

Where the coil of a relay is connected to an intrinsically safe circuit, the contacts in normal operation shall not exceed their manufacturer's rating and shall not switch more than the nominal value of 5 A r.m.s. or 250 V r.m.s. or 100 VA. When the values switched by the contacts exceed these values but do not exceed 10 A or 500 VA, the values for creepage distance and clearance from Table 5 for the relevant voltage shall be doubled.

For higher values, intrinsically safe circuits and non-intrinsically safe circuits shall be connected to the same relay only if they are separated by an earthed metal barrier or an insulating barrier conforming to 6.3.1. The dimensions of such an insulating barrier shall take into account the ionization arising from operation of the relay which would generally require creepage distances and clearances greater than those given in Table 5.

Where a relay has contacts in intrinsically safe circuits and other contacts in non-intrinsically safe circuits, the intrinsically safe and non-intrinsically safe contacts shall be separated by an insulating or earthed metal barrier conforming to 6.3.1 in addition to Table 5. The relay shall be designed such that broken or damaged contact arrangements cannot become dislodged and impair the integrity of the separation between intrinsically safe and non-intrinsically safe circuits.

Alternatively, segregation of relays may be assessed by application of Annex F, taking into account ambient conditions and applicable overvoltage categories as given in Annex F. The requirements for earthed metal or insulating barriers above shall also be applied in this case. If the insulating or earthed metal barrier is embedded in a closed relay enclosure then 10.6.3 shall be applied to the closed relay enclosure and not to the insulating or earthed metal barrier itself.

6.4 Protection against polarity reversal

Protection shall be provided within intrinsically safe apparatus to prevent invalidation of the type of protection as a result of reversal of the polarity of supplies to that apparatus or at connections between cells of a battery where this could occur. For this purpose, a single diode shall be acceptable.

6.5 Earth conductors, connections and terminals

Where earthing, for example of enclosures, conductors, metal screens, tracks on a printed circuit board, segregation contacts of plug-in connectors and diode safety barriers, is required to maintain the type of protection, the cross-sectional area of any conductors, connectors and terminals used for this purpose shall be such that they are rated to carry the maximum possible current to which they could be continuously subjected under the conditions specified in Clause 5. Components shall also conform to Clause 7.

Where a connector carries earthed circuits and the type of protection depends on the earthed circuit, the connector shall comprise at least three independent connecting elements for "ia" circuits and at least two for "ib" circuits (see Figure 5). These elements shall be connected in parallel. Where the connector can be removed at an angle, one connection shall be present at, or near to, each end of the connector.

Terminals shall be fixed in their mountings without possibility of self-loosening and shall be constructed so that the conductors cannot slip out from their intended location. Proper contact shall be assured without deterioration of the conductors, even if multi-stranded cores are used in terminals which are intended for direct clamping of the cores. The contact made by a terminal shall not be appreciably impaired by temperature changes in normal service. Terminals which are intended for clamping stranded cores shall include resilient intermediate part. Terminals for conductors of cross-sections up to 4 mm² shall also be suitable for the effective connection of conductors having a smaller cross-section. Terminals which comply with the requirements of IEC 60079-7 are considered to conform to these requirements.

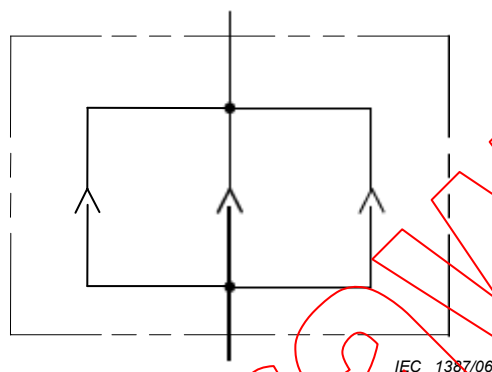


Figure 5a – Example of three independent connecting elements

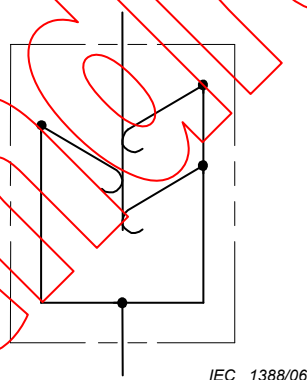


Figure 5b – Example of three connecting elements which are not independent

Figure 5 – Examples of independent and non-independent connecting elements

The following shall not be used:

- a) terminals with sharp edges which could damage the conductors;
- b) terminals which may turn, be twisted or permanently deformed by normal tightening;
- c) insulating materials which transmit contact pressure in terminals.

6.6 Encapsulation

Where a casting compound is used, it shall conform to the following:

- a) have a temperature rating, specified by the manufacturer of the casting compound or apparatus, which is at least equal to the maximum temperature achieved by any component under encapsulated conditions.

Alternatively higher temperatures than the rated casting compound temperature shall be accepted provided that they do not cause any damage to the casting compound that would adversely affect the type of protection;

- b) have at its free surface a CTI value of at least that specified in Table 5 if any bare conductive parts protrude from the casting compound;
- c) only materials passing the test in 10.6.1 shall have its free surface exposed and unprotected, thus forming part of the enclosure;
- d) be adherent to all conductive parts, components and substrates except when they are totally enclosed by the casting compound;
- e) be specified by its generic name and type designation given by the manufacturer of the casting compound.

For intrinsically safe apparatus, all circuits connected to the encapsulated conductive parts and/or components and/or bare parts protruding from the casting compound shall be intrinsically safe. Fault conditions within the casting compound shall be assessed but the possibility of spark ignition inside the encapsulation shall not be considered.

For associated apparatus, fault conditions within the casting compound shall be assessed.

The casting compound shall be free of voids, except that encapsulation of components containing free space (transistors, relays, fuses etc) is allowed.

If circuits connected to the encapsulated conductive parts and/or components and/or bare parts protruding from the casting compound are not intrinsically safe, they shall be protected by another type of protection listed in IEC 60079-0.

NOTE Further guidance is given in Annex D.

In addition, where a casting compound is used to reduce the ignition capability of hot components, for example diodes and resistors, the volume and thickness of the casting compound shall reduce the maximum surface temperature of the casting compound to the desired value.

7 Components on which intrinsic safety depends

7.1 Rating of components

For level of protection “ia” and “ib” in both normal operation and after application of the fault conditions given in Clause 5, any remaining components on which the type of protection depends, except such devices as transformers, fuses, thermal trips, relays, opto-couplers and switches, shall not operate at more than two-thirds of their maximum current, voltage and power related to the rating of the device, the mounting conditions and the temperature range specified. For level of protection “ic”, in normal operation, components on which the type of protection depends shall not operate at more than their maximum current and voltage and no more than two-thirds of their power. These maximum rated values shall be the normal commercial ratings specified by the manufacturer of the component.

NOTE 1 Transformers, fuses, thermal trips, relays, opto-couplers and switches are allowed to operate at their normal ratings in order to function correctly.

Account shall also be taken of the effects of the mounting conditions and ambient temperature range specified by the manufacturer of the apparatus and by 5.1 of IEC 60079-0. For example, in the case of a semiconductor the power dissipation shall not exceed two-thirds of that which will cause the maximum junction temperature to be reached under the particular mounting conditions.

The rating of components shall be as above when connected to any other apparatus used in the non-hazardous area, e.g. during charging, routine maintenance, data downloading operations, including the application of required faults in the intrinsically safe apparatus.

In-circuit programming connectors that are not accessible by the user, and which are only used at manufacture, during repair or overhaul, are exempt from the requirements of this clause.

Where a resistor and capacitor are connected in series to protect the discharge from the capacitor, the resistor may be considered to dissipate power in watts numerically equal to CV^2 , where C is capacitance in farads, V is voltage in volts.

Detailed testing or analysis of components and assemblies of components to determine the parameters, for example voltage and current, to which the safety factors are applied shall not be performed since the factors of safety of 5.2 and 5.3 obviate the need for detailed testing or analysis. For example, a Zener diode stated by its manufacturer to be 10 V + 10 % shall be taken to be 11 V maximum without the need to take into account effects such as voltage elevation due to rise in temperature.

NOTE 2 However, when determining the power rating or junction temperature, account should be taken of mounting conditions and ambient temperature, as indicated earlier in this clause.

7.2 Connectors for internal connections, plug-in cards and components

These connectors shall be designed in such a manner that an incorrect connection or interchangeability with other connectors in the same electrical apparatus is not possible unless it does not result in an unsafe condition or the connectors are identified in such a manner that incorrect connection is obvious.

Where the type of protection depends on a connection, the failure to open circuit of a connection shall be a countable fault in accordance with Clause 5.

If a connector carries earthed circuits and the type of protection depends on the earth connection, then the connector shall be constructed in accordance with 6.5.

7.3 Fuses

Where fuses are used to protect other components, $1,7 I_n$ shall be assumed to flow continuously. The cold resistance of the fuse at the minimum specified ambient temperature may be taken as an infallible resistance complying with 8.4 for current limiting purposes. (In the absence of available information, this may be taken as the minimum resistance at the minimum specified ambient temperature when measured on 10 samples as required in 10.4.) The fuse time-current characteristics shall ensure that the transient ratings of protected components are not exceeded. Where the fuse time-current characteristic is not available from the manufacturer's data, a type test shall be carried out in accordance with 10.4 on at least 10 samples. This test shows the capability of the sample to withstand 1,5 times any transient which can occur when U_m is applied through a fuse.

Fuses for levels of protection “ia” and “ib”, which may carry current when located in the explosive atmospheres, shall be encapsulated in accordance with 6.6.

The rupture of fuses for level of protection “ic”, is not considered for thermal ignition purposes.

Where fuses are encapsulated, the casting compound shall not enter the fuse interior. This requirement shall be satisfied by testing samples in accordance with 10.6.2 or by a declaration from the fuse manufacturer confirming acceptability of the fuse for encapsulation. Alternatively, the fuse shall be sealed prior to encapsulation.

Fuses used to protect components shall be replaceable only by opening the apparatus enclosure. For replaceable fuses the type designation and the fuse rating I_n , or the characteristics important to intrinsic safety shall be marked adjacent to the fuses.

Fuses shall have a rated voltage of at least U_m (or U_i in intrinsically safe apparatus and circuits) although they do not have to conform to Table 5. General industrial standards for the construction of fuses and fuseholders shall be applied and their method of mounting including the connecting wiring shall not reduce the clearances, creepage distances and separations afforded by the fuse and its holder. Where required for intrinsic safety, the distances to other parts of the circuit shall comply with 6.1.1 or 6.1.2.

NOTE 1 Microfuses conforming to IEC 60127 are acceptable.

A fuse shall have a breaking capacity not less than the maximum prospective current of the circuit in which it is installed. For mains electricity supply systems not exceeding 250 V a.c., the prospective current shall normally be considered to be 1 500 A a.c. The breaking capacity of the fuse is determined according to IEC 60127 or ANSI/UL 248-1 and shall be stated by the manufacturer of the fuses.

NOTE 2 Higher prospective currents may be present in some installations, for example at higher voltages.

If a current-limiting device is necessary to limit the prospective current to a value not greater than the rated breaking capacity of the fuse, this device shall be infallible in accordance with Clause 8 and the rated values shall be at least:

- current rating $1,5 \times 1,7 \times I_n$;
- voltage rating U_m or U_i ;
- power rating $1,5 \times (1,7 \times I_n)^2 \times$ maximum resistance of limiting device.

Creepage and clearance distances across the current limiting resistor and its connecting tracks shall be calculated using the voltage of $1,7 \times I_n \times$ maximum resistance of the current limiting resistor. The transient voltage shall not be considered. The separation distances between the resistor and other parts of the circuit shall comply with 6.1.1 or 6.1.2.

7.4 Primary and secondary cells and batteries

Contrary to 23.1 of IEC 60079-0 cells and batteries are permitted to be connected in parallel in intrinsically safe apparatus provided that intrinsic safety is not impaired.

NOTE The parallel battery requirement of 23.1 of IEC 60079-0 does not apply to cells and batteries in associated apparatus unless they are protected by one of the types of protection listed in IEC 60079-0.

7.4.1 General

Some types of cells and batteries, for example some lithium types, may explode if short-circuited or subjected to reverse charging. Where such an explosion could adversely affect intrinsic safety, the use of such cells and batteries must be confirmed by their manufacturer as being safe for use in any particular intrinsically safe or associated apparatus when 5.2, 5.3 or 5.4, as appropriate, is applied. The documentation and, if practicable, the marking for the apparatus shall draw attention to the safety precautions to be observed.

Where batteries are intended to be replaced by the user, the apparatus shall be marked with a warning label as specified in item a) of 12.3.

NOTE Attention is drawn to the fact that the cell or battery manufacturer often specifies precautions for the safety of personnel.

7.4.2 Electrolyte leakage and ventilation

Either cells and batteries shall be of a type from which there can be no spillage of electrolyte or they shall be enclosed to prevent damage by the electrolyte to the component upon which safety depends. Cells and batteries shall be tested in accordance with 10.5.2, or written confirmation shall be obtained from the cell/battery manufacturer that the product conforms to 10.5.2. If cells and batteries which leak electrolyte are encapsulated in accordance with 6.6, they shall be tested in accordance with 10.5.2 after encapsulation.

Where the apparatus contains cells or batteries that are charged within them, the battery manufacturer shall demonstrate that the concentration of hydrogen in the free volume of the battery container cannot exceed 2 % by volume, or the degassing apertures of all cells shall be so arranged that the escaping gases are not vented into any enclosure of the apparatus containing electrical or electronic components or connections. Alternatively, where the apparatus meets the requirements for Level of Protection “ia” or “ib” and apparatus group IIC, the requirement of degassing apertures or limitation of hydrogen concentration is not necessary.

NOTE 1 It is not a requirement of this standard that the conformity of the battery manufacturer's specification of the concentration of hydrogen needs to be verified.

The pressure above atmospheric inside the battery container shall not exceed 30 kPa (0,3 bar). Battery containers that are sealed shall be tested in accordance with 10.5.4.

NOTE 2 This may be achieved by a vent.

NOTE 3 In “sealed” cells, a higher pressure is permissible, but each cell should then be provided with a pressure relief device or means to limit the pressure to a value that can be contained by the cell, as specified by the manufacturer.

7.4.3 Cell voltages

For the purpose of evaluation and test, the cell voltage shall be that specified in Tables 6 and 7 of IEC 60079-0. When a cell is not listed in these tables, it shall be tested in accordance with 10.5 to determine the maximum open circuit voltage, and the nominal voltage shall be that specified by the cell manufacturer.

7.4.4 Internal resistance of cell or battery

Where required, the internal resistance of a cell or battery shall be determined in accordance with 10.5.3.

7.4.5 Batteries in apparatus protected by other means of protection

NOTE 1 This clause refers to equipment that is protected by flameproof (or other technique), but contains a battery and associated circuits that require intrinsic safety protection when the mains supply is withdrawn and the enclosure is opened in the explosive gas atmosphere.

The battery housing or means of attachment to apparatus shall be constructed so that the battery can be installed and replaced without adversely affecting the intrinsic safety of the apparatus.

Where a current limiting resistor is used to limit the current that may be withdrawn from the battery, it is to be rated in accordance with 7.1. Current limiting resistors in series with cells or batteries shall be rated at the maximum voltage U_m unless otherwise protected. In this instance protection can be achieved by use of a single zener diode rated in accordance with 7.1.

NOTE 2 Where a current-limiting device is necessary to ensure the safety of the battery output, there is no requirement for the current-limiting device to be an integral part of the battery.

7.4.6 Batteries used and replaced in explosive gas atmospheres

Where a battery requires current-limiting devices to ensure the safety of the battery itself and is intended to be used and to be replaced in an explosive gas atmosphere, it shall form a completely replaceable unit with its current-limiting devices. The unit shall be encapsulated or enclosed so that only the intrinsically safe output terminals and suitably protected intrinsically safe terminals for charging purposes (if provided) are exposed.

The unit shall be subjected to the drop test in accordance with 26.4.3 of IEC 60079-0 except that the prior impact test shall be omitted. The construction of the unit shall be considered adequate if the test does not result in the ejection or separation of the cells from the unit and/or current-limiting device in such a way as to invalidate the intrinsic safety of the unit.

7.4.7 Batteries used but not replaced in explosive gas atmospheres

If the cell or battery, requiring current-limiting devices to ensure the safety of the battery itself, is not intended to be replaced in the explosive gas atmosphere, it shall either be protected in accordance with 7.4.6 or alternatively it may be housed in a compartment with special fasteners, for example those specified by IEC 60079-0. It shall also conform to the following:

- a) the cell or battery housing or means of attachment shall be arranged so that the cell or battery can be installed and replaced without reducing the intrinsic safety of the apparatus;
- b) handheld electrical apparatus or electrical apparatus carried on the person, ready for use, such as radio receivers and transceivers shall be subjected to the drop test in accordance with 26.4.3 of IEC 60079-0 except that the prior impact test shall be omitted. The construction of the apparatus shall be considered adequate if the test does not result in the ejection or separation of the cells from the apparatus in such a way as to invalidate the intrinsic safety of the apparatus or battery;
- c) the apparatus shall be marked with a warning label as specified in item b) of 12.3 or item b) of 29.8 of IEC 60079-0.

7.4.8 External contacts for charging batteries

Cell or battery assemblies with external charging contacts shall be provided with means to prevent short-circuiting or to prevent the cells and batteries from delivering ignition-capable energy to the contacts when any pair of the contacts is accidentally short-circuited. This shall be accomplished in one of the following ways:

- a) blocking diodes or an infallible series resistor shall be placed in the charging circuits. For level of protection "ia" three diodes, for level of protection "ib" two diodes, and for level of protection "ic" one diode, shall be used. To protect these diodes or resistors against excess currents or voltages during charging, either a battery charger shall be defined or the diodes or resistor shall be protected by an appropriately rated fuse. The fuse shall either be encapsulated or shall not carry any current when situated in an explosive gas atmosphere;
- b) for Group II electrical apparatus, a degree of protection by enclosure of at least IP30 shall be provided for the suitably protected charging circuit and shall be marked with a warning label as specified in item c) of 12.3 (or item b) of 29.8 of IEC 60079-0). The separation distances between the charging contacts shall comply with 6.3 considering the open-circuit voltage of the battery.

The maximum voltage U_m which can be applied to these connection facilities shall be marked on the apparatus and may be stated in the control drawing.

7.4.9 Battery construction

The spark ignition capability and surface temperature of cells and batteries shall be tested or assessed in accordance with 10.5.3. The cell or battery construction shall be one of the following types:

- a) sealed (gas-tight) cells or batteries;
- b) sealed (valve-regulated) cells or batteries;
- c) cells or batteries which are intended to be sealed in a similar manner to items a) and b) apart from a pressure relief device.

Such cells or batteries shall not require addition of electrolyte during their life and shall have a sealed metallic or plastics enclosure conforming to the following:

- 1) without seams or joints, for example solid-drawn, spun or moulded, joined by fusion, eutectic methods, welding or adhesives sealed with elastomeric or plastics sealing devices retained by the structure of the enclosure and held permanently in compression, for example washers and "o" rings;
- 2) swagged, crimped, shrunk on or folded construction of parts of the enclosure which do not conform with the above or parts using materials which are permeable to gas, for example paper based materials, shall not be considered to be sealed;

- 3) seals around terminals shall be either constructed as above or be poured seals of thermosetting or thermoplastic compound;
- d) cells or batteries encapsulated in a casting compound specified by the manufacturer of the casting compound as being suitable for use with the electrolyte concerned and conforming to 6.6.

A declaration of conformance to a) or b) shall be obtained from the manufacturer of the cell or battery. Conformance to c) or d) shall be determined by physical examination of the cell or battery and where necessary its constructional drawings.

NOTE It is not a requirement of this standard that the conformity of the cell or battery manufacturer's specification needs to be verified.

7.5 Semiconductors

7.5.1 Transient effects

In associated apparatus, semiconductor devices shall be capable of withstanding the peak of the a.c. voltage and the maximum d.c. voltage divided by any infallible series resistance.

In an intrinsically safe apparatus, any transient effects generated within the apparatus and its power sources shall be ignored.

7.5.2 Shunt voltage limiters

Semiconductors may be used as shunt voltage limiting devices provided that they conform to the following requirements and provided that relevant transient conditions are taken into account. For example, the inclusion of a single fuse and zener rated in accordance with 7.1 is considered as an adequate means of limiting transients for circuits connected at the zener.

Semiconductors shall be capable of carrying, without open-circuiting, 1,5 times the current which would flow at their place of installation if they failed in the short-circuit mode. In the following cases, this shall be confirmed from their manufacturer's data by:

- a) diodes, diode connected transistors, thyristors and equivalent semiconductor devices having a forward current rating of at least 1,5 times the maximum possible short-circuit current for level of protection "ia" or "ib", and 1,0 times the maximum possible short-circuit current for level of protection "ic",
- b) Zener diodes being rated:
 - 1) in the Zener direction at 1,5 times the power that would be dissipated in the Zener mode, and
 - 2) in the forward direction at 1,5 times the maximum current that would flow if they were short-circuited for level of protection "ia" or "ib", and 1,0 times the maximum current that would flow if they were short-circuited for level of protection "ic".

For level of protection "ia", the application of controllable semiconductor components as shunt voltage limiting devices, for example transistors, thyristors, voltage/current regulators, etc., is permitted if both the input and output circuits are intrinsically safe circuits or where it can be shown that they cannot be subjected to transients from the power supply network. In circuits complying with the above, two devices are considered to be an infallible assembly.

For level of protection "ia", three thyristors may be used in associated apparatus provided the transient conditions of 7.5.1 are met. Circuits using shunt thyristors shall also be tested in accordance with 10.1.5.3.