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SANS 60079-11:2012

Edition 4 and IEC corr. 1

IEC 60079-11:2011

Edition 6 and corr. 1

SOUTH AFRICAN NATIONAL STANDARD

Explosive atmospheres

Part 11: Equipment protection by intrinsic safety "i"

This national standard is the identical implementation of IEC 60079-11:2011 and IEC corrigendum 1, and is adopted with the permission of the International Electrotechnical Commission.

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SANS 60079-11:2012
Edition 4 and IEC corr. 1
IEC 60079-11:2011
Edition 6 and corr. 1

Table of changes

Change No.	Date	Scope
IEC corr. 1	2012	Corrected to modify the applicability of acceptance criteria, to modify a note to the table on temperature classification of tracks on printed circuit boards (table 3), to replace the figure of an example of separation of intrinsically safe and non-intrinsically safe terminals through use of a partition (figure 1b), to modify the requirements for type 2 transformer construction, to change marking requirements, to replace the figure of moulding over un-mounted components (figure D.3a) and the figure of a typical system (figure G.1).

National foreword

This South African standard was approved by National Committee SABS TC 65, *Explosion prevention*, in accordance with procedures of the SABS Standards Division, in compliance with annex 3 of the WTO/TBT agreement.

This SANS document was published in June 2012.

This SANS document supersedes SANS 60079-11:2007 (edition 3).

IEC 60079-11
(Sixth edition – 2011)

Explosive atmospheres –

Part 11: Equipment protection by intrinsic safety "I"

CEI 60079-11
(Sixième édition – 2011)

Atmosphères explosives –

Partie 11: Protection de l'équipement par sécurité intrinsèque « i »

CORRIGENDUM 1

Changes to the French version appear further in the document.

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

Replace existing row 26.4.4 by the following new row:

26.4.4	26.4.4	Acceptance criteria	Applies	Applies	Excluded except when 6.1.2.3a) is applied

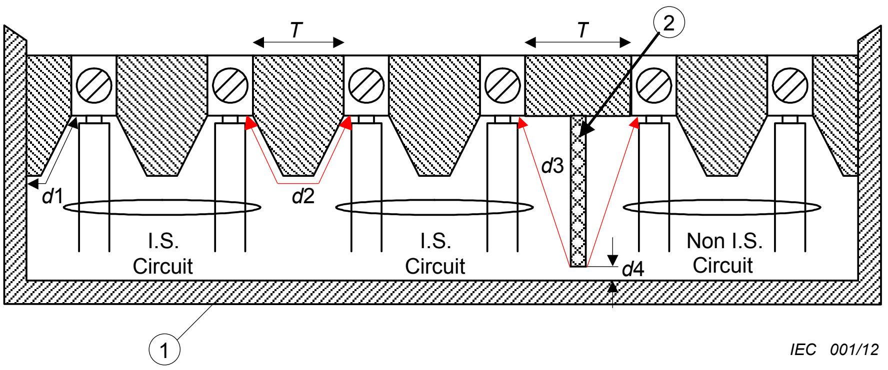
Table 3 – Temperature classification of tracks on printed circuit boards (in a maximum ambient temperature of 40 °C)

Replace the eighth footnote by the following new footnote:

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. Additionally, if the track goes under the component, apply the factor specified for tracks passing under components dissipating 0,25W or more.

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

Replace the drawing in Figure 1b by the following drawing:



8.2.3 Transformer construction

Replace the existing fourth paragraph by the following new paragraph:

For type 2 construction, the windings shall be wound one over another with either

a) solid insulation in accordance with Table 5 between the windings, or
b) an earthed screen (made of copper foil) between the windings or an equivalent wire winding (wire screen). The thickness of the copper foil or the wire screen shall be in accordance with Table 6.

12.1 General

Replace the existing fifth and sixth paragraphs by the following new paragraphs:

In the case of apparatus meeting the requirements of 6.1.2.3 a), the IP rating shall be marked.

In the case of apparatus meeting the requirements of 6.1.2.3 c), the certificate number shall include the "X" suffix in accordance with the marking requirements of IEC 60079-0 and the specific conditions of use listed on the certificate shall detail the requirements.

Replace the existing eighth paragraph by the following new paragraph:

Where it is necessary to protect the apparatus from external physical impact in order to prevent the impact energy of 10.7 exceeding the specified values, details of the requirements shall be specified as special conditions for safe use and the certificate number shall include the "X" suffix in accordance with the marking requirements of IEC 60079-0 and the specific conditions of use listed on the certificate shall detail the requirements.

Figure D.3a – Moulding over un-mounted components

Replace the existing drawing by the following new drawing:

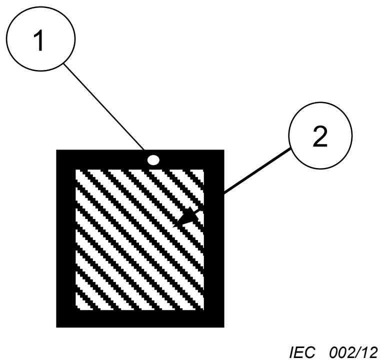
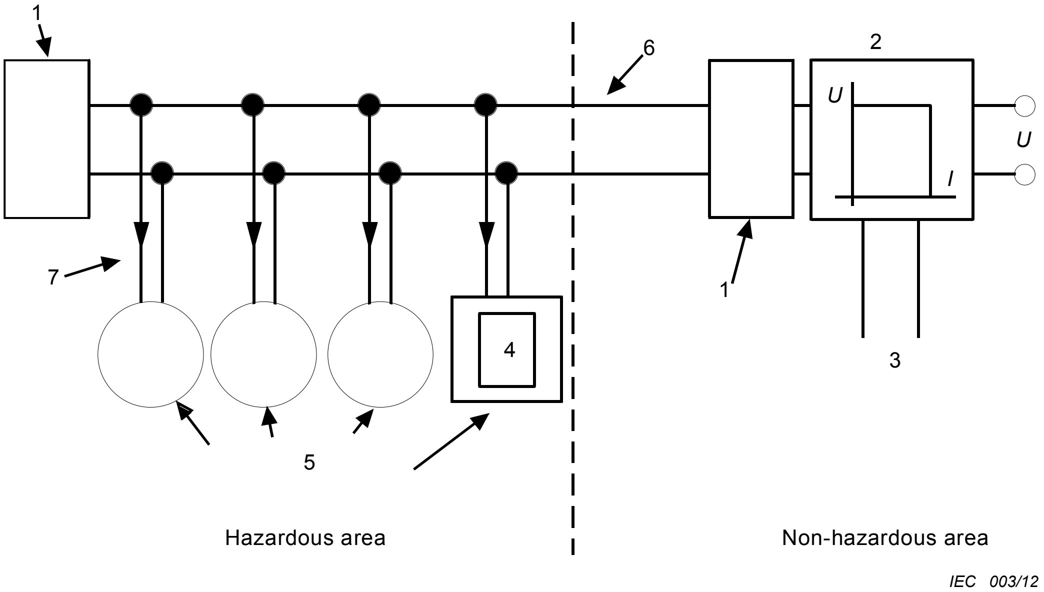


Figure G.1 – Typical system

Replace the existing drawing by the following new drawing:


1
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Hazardous area
Non-hazardous area
IEC 003/12

IEC 60079-11

Edition 6.0 2011-06

INTERNATIONAL STANDARD

NORME INTERNATIONALE

colour inside

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

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

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COMMISSION ELECTROTECHNIQUE INTERNATIONALE

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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8) Attention is drawn to the Normative references cited in this publication. Use of the referenced publications is indispensable for the correct application of this publication.
9) Attention is drawn to the possibility that some of the elements of this IEC Publication may be the subject of patent rights. IEC shall not be held responsible for identifying any or all such patent rights.

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

This sixth edition cancels and replaces the fifth edition of IEC 60079-11 published in 2006, the first edition of IEC 61241-11 published in 2005, and the new Annex G replaces the apparatus requirements of the second edition of IEC 60079-27 published in 2008. This sixth edition constitutes a technical revision of these publications.

NOTE IEC 60079-25 cancels and replaces the remaining subject matter of IEC 60079-27.

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

- Inclusion of non-edition specific references to IEC 60079-0.
- The merging of the apparatus requirements for FISCO from IEC 60079-27.
- The merging of the requirements for combustible dust atmospheres from IEC 61241-11.

- Clarification of the requirements for accessories connected to intrinsically safe apparatus; such as chargers and data loggers.
- Addition of new test requirements for opto-isolators.
- Introduction of Annex H about ignition testing of semiconductor limiting power supply circuits.

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

FDIS	Report on voting
31G/207/FDIS	31G/213/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: *Explosive atmospheres*, can be found on the IEC website.

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

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

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

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 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 equipment in which the electrical circuits themselves are incapable of causing an explosion in the surrounding explosive atmospheres.

This standard is also applicable to electrical equipment or parts of electrical equipment located outside the explosive atmosphere or protected by another Type of Protection listed in IEC 60079-0, where the intrinsic safety of the electrical circuits in the explosive atmosphere may depend upon the design and construction of such electrical equipment or parts of such electrical equipment. The electrical circuits exposed to the explosive 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.

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 requirements in this standard are applicable to both intrinsically safe apparatus and associated apparatus the term "apparatus" is used throughout the standard.

This standard is for electrical equipment only; therefore the term "equipment" used in the standard always means "electrical equipment".

If associated apparatus is placed in the explosive atmosphere, it shall 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 – Applicability of specific clauses of IEC 60079-0

Clause or subclause of IEC 60079-0			IEC 60079-0 clause application to IEC 60079-11		
			Intrinsically safe apparatus		Associated apparatus
Ed. 5.0 (2007) (informative)	Ed. 6.0 (2011) (informative)	Clause / Subclause title (normative)	Group I and Group II	Group III	
1	1	Scope	Applies	Applies	Applies
2	2	Normative references	Applies	Applies	Applies
3	3	Terms and definitions	Applies	Applies	Applies
4	4	Equipment grouping	Applies	Applies	Applies
4.1	4.1	Group I	Applies	Excluded	Applies
4.2	4.2	Group II	Applies	Excluded	Applies

Clause or subclause of IEC 60079-0			IEC 60079-0 clause application to IEC 60079-11		
			Intrinsically safe apparatus		Associated apparatus
Ed. 5.0 (2007) (informative)	Ed. 6.0 (2011) (informative)	Clause / Subclause title (normative)	Group I and Group II	Group III	
4.3	4.3	Group III	Excluded	Applies	Applies
4.4	4.4	Equipment for a particular explosive atmosphere	Applies	Applies	Applies
5.1	5.1	Environmental influences	Applies	Applies	Applies
5.1.1	5.1.1	Ambient temperature	Applies	Applies	Applies
5.1.2	5.1.2	External source of heating or cooling	Applies	Applies	Applies
5.2	5.2	Service temperature	Applies	Applies	Applies
5.3.1	5.3.1	Determination of maximum surface temperature	Applies	Applies	Excluded
5.3.2.1	5.3.2.1	Group I electrical equipment	Applies	Excluded	Excluded
5.3.2.2	5.3.2.2	Group II electrical equipment	Applies	Excluded	Excluded
5.3.2.3	5.3.2.3	Group III electrical equipment	Excluded	Applies	Excluded
5.3.3	5.3.3	Small component temperature for Group I or Group II electrical equipment	Applies	Excluded	Excluded
6.1	6.1	General	Applies	Applies	Applies
6.2	6.2	Mechanical strength of equipment	Excluded except when 6.1.2.3a) is applied	Excluded except when 6.1.3 a) is applied.	Excluded except when 6.1.2.3a) is applied
6.3	6.3	Opening times	Excluded	Excluded	Excluded
6.4	6.4	Circulating currents in enclosures (e.g. of large electrical machines)	Excluded	Excluded	Excluded
6.5	6.5	Gasket retention	Excluded except when 6.1.2.3a)is applied	Excluded except when 6.1.3 a) is applied.	Excluded except when 6.1.2.3a) is applied
6.6	6.6	Electromagnetic and ultrasonic radiating equipment	Applies	Applies	Excluded
7.1.1	7.1.1	Applicability	Excluded except when 6.1.2.3a) is applied	Excluded except when 6.1.3 a) is applied.	Excluded except when 6.1.2.3a) is applied
7.1.2	7.1.2.1	Specification of materials	Excluded except when 6.1.2.3a) is applied	Excluded except when 6.1.3 a) is applied.	Excluded except when 6.1.2.3a) is applied
7.1.3	7.1.2.2	Plastic materials	Excluded except when 6.1.2.3a) is applied	Excluded except when 6.1.3 a) is applied.	Excluded except when 6.1.2.3a) is applied
7.1.4	7.1.2.3	Elastomers	Excluded except when 6.1.2.3a) is applied	Excluded except when 6.1.3 a) is applied.	Excluded except when 6.1.2.3a) is applied
7.2	7.2	Thermal endurance	Excluded except when 6.1.2.3a) is applied	Excluded except when 6.1.3 a) is applied.	Excluded except when 6.1.2.3a) is applied

Clause or subclause of IEC 60079-0			IEC 60079-0 clause application to IEC 60079-11		
			Intrinsically safe apparatus		Associated apparatus
Ed. 5.0 (2007) (informative)	Ed. 6.0 (2011) (informative)	Clause / Subclause title (normative)	Group I and Group II	Group III	
7.3	7.3	Resistance to light	Excluded except when 6.1.2.3a) is applied	Excluded except when 6.1.3 a) is applied.	Excluded except when 6.1.2.3a) is applied
7.4	7.4	Electrostatic charges on external non-metallic materials	Applies	Applies	Excluded
NR	7.5	Accessible metal parts	Applies	Applies	Excluded
7.5	NR	Threaded holes	Excluded except when 6.1.2.3a) is applied	Excluded except when 6.1.3 a) is applied.	Excluded except when 6.1.2.3a) is applied
8.1	8.1	Material composition	Applies	Applies	Excluded
8.1.1	8.2	Group I	Applies	Excluded	Excluded
8.1.2	8.3	Group II	Applies	Excluded	Excluded
8.1.3	8.4	Group III	Excluded	Applies	Excluded
8.2	NR	Threaded holes	Excluded except when 6.1.2.3a) is applied	Excluded except when 6.1.3 a) is applied.	Excluded except when 6.1.2.3a) is applied
9	9	Fasteners	Excluded	Excluded	Excluded
10	10	Interlocking devices	Excluded	Excluded	Excluded
11	11	Bushings	Excluded	Excluded	Excluded
12	12	Materials used for cementing	Excluded except when 6.1.2.3a) is applied	Excluded except when 6.1.3 a) is applied.	Excluded except when 6.1.2.3a) is applied
13	13	Ex Components	Applies	Applies	Applies
14	14	Connection facilities and termination compartments	Excluded	Excluded	Excluded
15	15	Connection facilities for earthing or bonding conductors	Excluded	Excluded	Excluded
16	16	Entries into enclosures	Excluded except when 6.1.2.3a) is applied	Excluded except when 6.1.3 a) is applied.	Excluded except when 6.1.2.3a) is applied
17	17	Supplementary requirements for rotating machines	Excluded	Excluded	Excluded
18	18	Supplementary requirements for switchgear	Excluded	Excluded	Excluded
19	19	Supplementary requirements for fuses	Excluded	Excluded	Excluded
20	20	Supplementary requirements for plugs, socket outlets and connectors	Excluded	Excluded	Excluded
21	21	Supplementary requirements for luminaires	Excluded	Excluded	Excluded
22	22	Supplementary requirements for caplights and handlights	Modified	Modified	Excluded
23.1	23.1	General	Applies	Applies	Applies

Clause or subclause of IEC 60079-0			IEC 60079-0 clause application to IEC 60079-11		
			Intrinsically safe apparatus		Associated apparatus
Ed. 5.0 (2007) (informative)	**Ed. 6.0 (2011) (informative)**	**Clause / Subclause title (normative)**	**Group I and Group II**	**Group III**	
23.2	23.2	Batteries	Excluded	Excluded	Excluded
23.3	23.3	Cell types	Applies	Applies	Applies
23.4	23.4	Cells in a battery	Applies	Applies	Applies
23.5	23.5	Ratings of batteries	Applies	Applies	Applies
23.6	23.6	Interchangeability	Applies	Applies	Applies
23.7	23.7	Charging of primary batteries	Applies	Applies	Applies
23.8	23.8	Leakage	Applies	Applies	Applies
23.9	23.9	Connections	Applies	Applies	Applies
23.10	23.10	Orientation	Applies	Applies	Applies
23.11	23.11	Replacement of cells or batteries	Applies	Applies	Applies
23.12	23.12	Replaceable battery pack	Applies	Applies	Applies
24	24	Documentation	Applies	Applies	Applies
25	25	Compliance of prototype or sample with documents	Applies	Applies	Applies
26.1	26.1	General	Applies	Applies	Applies
26.2	26.2	Test configuration	Applies	Applies	Applies
26.3	26.3	Tests in explosive test mixtures	Applies	Applies	Applies
26.4.1	26.4.1	Order of tests	Excluded except when 6.1.2.3a) is applied	Excluded except when 6.1.3 a) is applied.	Excluded except when 6.1.2.3a) is applied
26.4.1.1	26.4.1.1	Metallic enclosures, metallic parts of enclosures and glass parts of enclosures	Excluded except when 6.1.2.3a) is applied	Excluded except when 6.1.3 a) is applied.	Excluded except when 6.1.2.3a) is applied
26.4.1.2	26.4.1.2	Non-metallic enclosures or non-metallic parts of enclosures	Excluded except when 6.1.2.3a) is applied	Excluded except when 6.1.3 a) is applied.	Excluded except when 6.1.2.3a) is applied
26.4.1.2.1	26.4.1.2.1	Group I electrical equipment	Excluded except when 6.1.2.3a) is applied	Excluded	Excluded except when 6.1.2.3a) is applied
26.4.1.2.2	26.4.1.2.2	Group II and Group III electrical equipment	Excluded except when 6.1.2.3a) is applied	Excluded except when 6.1.3 a) is applied.	Excluded except when 6.1.2.3a) is applied
26.4.2	26.4.2	Resistance to impact	Excluded except when 6.1.2.3a) is applied	Excluded except when 6.1.3 a) is applied.	Excluded except when 6.1.2.3a) is applied
26.4.3	26.4.3	Drop test	Applies	Applies	Excluded except when 6.1.2.3a) is applied
26.4.4	26.4.4	Acceptance criteria	Excluded except when 6.1.2.3a) is applied	Excluded except when 6.1.3 a) is applied.	Excluded except when 6.1.2.3a) is applied
26.4.5	26.4.5	Degree of protection (IP) by enclosures	Applies	Applies	Applies
26.5.1.1	26.5.1.1	General	Applies	Applies	Excluded
26.5.1.2	26.5.1.2	Service temperature	Modified	Modified	Modified

Clause or subclause of IEC 60079-0			IEC 60079-0 clause application to IEC 60079-11		
			Intrinsically safe apparatus		Associated apparatus
Ed. 5.0 (2007) (informative)	Ed. 6.0 (2011) (informative)	Clause / Subclause title (normative)	Group I and Group II	Group III	
26.5.1.3	26.5.1.3	Maximum surface temperature	Modified	Modified	Modified
26.5.2	26.5.2	Thermal shock test	Excluded except when 6.1.2.3a) is applied	Excluded except when 6.1.3 a) is applied.	Excluded except when 6.1.2.3a) is applied
26.5.3	26.5.3	Small component ignition test (Group I and Group II)	Applies	Excluded	Excluded
26.6	26.6	Torque test for bushings	Excluded	Excluded	Excluded
26.7	26.7	Non-metallic enclosures or non-metallic parts of enclosures	Excluded except when 6.1.2.3a) is applied	Excluded except when 6.1.3 a) is applied.	Excluded except when 6.1.2.3a) is applied
26.8	26.8	Thermal endurance to heat	Excluded except when 6.1.2.3a) is applied	Excluded except when 6.1.3 a) is applied.	Excluded except when 6.1.2.3a) is applied
26.9	26.9	Thermal endurance to cold	Excluded except when 6.1.2.3a) is applied	Excluded except when 6.1.3 a) is applied.	Excluded except when 6.1.2.3a) is applied
26.10	26.10	Resistance to light	Excluded except when 6.1.2.3a) is applied	Excluded except when 6.1.3 a) is applied.	Excluded except when 6.1.2.3a) is applied
26.11	26.11	Resistance to chemical agents for Group I electrical equipment	Excluded except when 6.1.2.3a) is applied	Excluded	Excluded
26.12	26.12	Earth continuity	Excluded	Excluded	Excluded
26.13	26.13	Surface resistance test of parts of enclosures of non-metallic materials	Applies	Applies	Excluded
26.15	26.14	Measurement of capacitance	Applies	Applies	Excluded
NR	26.15	Verification of ratings of ventilating fans	Excluded	Excluded	Excluded
NR	26.16	Alternative qualification of elastomeric sealing O-rings	Excluded except when 6.1.2.3a) is applied	Excluded except when 6.1.3 a) is applied.	Excluded except when 6.1.2.3a) is applied
27	27	Routine tests	Applies	Applies	Applies
28	28	Manufacturer's responsibility	Applies	Applies	Applies
29	29	Marking	Applies	Applies	Applies
30	30	Instructions	Applies	Applies	Applies
Annex A (Normative)	Annex A (Normative)	Supplementary requirements for cable glands	Excluded	Excluded	Excluded
Annex B (Normative)	Annex B (Normative)	Requirements for Ex Components	Applies	Applies	Applies
Annex C (Informative)	Annex C (Informative)	Example of rig for resistance to impact test	Applies	Applies	Excluded except when 6.1.2.3a) is applied

Clause or subclause of IEC 60079-0			IEC 60079-0 clause application to IEC 60079-11		
			Intrinsically safe apparatus		Associated apparatus
Ed. 5.0 (2007) (informative)	**Ed. 6.0 (2011) (informative)**	**Clause / Subclause title (normative)**	**Group I and Group II**	**Group III**	
Annex D (Informative)	NR	Alternative risk assessment method encompassing "equipment protection levels" for Ex equipment	Applies	Applies	Applies
Annex E (Informative)	Annex D (Informative)	Motors supplied by converters	Excluded	Excluded	Excluded
NR	Annex E (Informative)	Temperature rise testing of electric machines	Excluded	Excluded	Excluded
NR	Annex F (Informative)	Guideline flowchart for tests of non-metallic enclosures or non-metallic parts of enclosures (26.4)	Excluded except when 6.1.2.3a) is applied	Excluded except when 6.1.3 a) is applied.	Excluded except when 6.1.2.3a) is applied
Applies – This requirement of IEC 60079-0 is applied without change. Excluded – This requirement of IEC 60079-0 does not apply. Excluded except – This requirement of IEC 60079-0 does not apply except when the conditions stated are met. Modified – This requirement of IEC 60079-0 is modified as detailed in this standard. NR – No requirements.					
NOTE The clause numbers in the above table are shown for information only. The applicable requirements of IEC 60079-0 are identified by the clause title which is normative. This table was written against the specific requirements of IEC 60079-0, ed. 6.0. The clause numbers for the previous edition are shown for information only. This is to enable the General requirements IEC 60079-0, ed. 5.0, to be used where necessary with this part of IEC 60079. Where there were no requirements, indicated by NR, or there is a conflict between requirements, the later edition requirements take precedence.					

2 Normative references

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

IEC 60079-0, *Explosive atmospheres – Part 0: Equipment – General requirements*

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

IEC 60079-25, *Explosive atmospheres – Part 25: Intrinsically safe electrical systems*

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

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

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

IEC 61158-2, *Industrial communication networks – Fieldbus specifications – Part 2: Physical layer specification and service definition*

IEC 62013-1, *Caplights for use in mines susceptible to firedamp – Part 1: General requirements – Construction and testing in relation to the risk of explosion*

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 given in IEC 60079-0, and the following apply.

3.1
general

3.1.1
intrinsic safety "i"
type of protection based on the restriction of electrical energy within equipment and of interconnecting wiring exposed to the explosive atmosphere to a level below that which can cause ignition by either sparking or heating effects

3.1.2
associated apparatus
electrical equipment 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

NOTE Associated apparatus may be either:

a) electrical equipment which has another type of protection listed in IEC 60079-0 for use in the appropriate explosive atmosphere, or

b) electrical equipment not so protected and which, therefore, is not normally used within an explosive atmosphere, for example a recorder which is not itself in an explosive atmosphere, but is connected to a thermocouple situated within an explosive atmosphere where only the recorder input circuit is intrinsically safe.

3.1.3
intrinsically safe apparatus
electrical equipment 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 atmosphere

3.1.5
simple apparatus
electrical component or combination of components of simple construction with well-defined electrical parameters and 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 circuit 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

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

3.9
FISCO
abbreviation of Fieldbus Intrinsically Safe Concept

3.10
infallibility

3.10.1
infallible component
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

NOTE 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.

3.10.2
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

NOTE 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.

3.10.3
infallible separation
infallible insulation
separation or insulation between electrically conductive parts that is considered as not subject to short circuits as specified in IEC 60079-11

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

3.12
live maintenance
maintenance activities carried out while the associated apparatus, intrinsically safe apparatus and circuits are energized

3.13
electrical parameters

3.13.1
maximum input voltage
U_i
maximum voltage (peak a.c. or d.c.) that can be applied to the connection facilities of apparatus without invalidating the type of protection

3.13.2
maximum input current
I_i
maximum current (peak a.c. or d.c.) that can be applied to the connection facilities of apparatus without invalidating the type of protection

3.13.3
maximum input power
P_i
maximum power that can be applied to the connection facilities of apparatus without invalidating the type of protection

3.13.4
maximum internal capacitance
C_i
maximum equivalent internal capacitance of the apparatus which is considered as appearing across the connection facilities

3.13.5
maximum internal inductance
L_i
maximum equivalent internal inductance of the apparatus which is considered as appearing at the connection facilities

3.13.6
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

3.13.7
maximum output voltage
U_o
maximum voltage (peak a.c. or d.c.) that can appear at the connection facilities of the apparatus at any applied voltage up to the maximum voltage

3.13.8
maximum output current
I_o
maximum current (peak a.c. or d.c.) in apparatus that can be taken from the connection facilities of the apparatus

3.13.9
maximum output power
P_o
maximum electrical power that can be taken from the apparatus

3.13.10
maximum external capacitance
C_o
maximum capacitance that can be connected to the connection facilities of the apparatus without invalidating the type of protection

3.13.11
maximum external inductance
L_o
maximum value of inductance that can be connected to the connection facilities of the apparatus without invalidating the type of protection

3.13.12
maximum external inductance to resistance ratio
L_o/R_o
maximum value of ratio of inductance to resistance that can be connected to the external connection facilities of the electrical apparatus without invalidating intrinsic safety

3.13.13
maximum r.m.s. a.c. or d.c. voltage
U_m
maximum voltage that can be applied to the non intrinsically safe connection facilities of associated apparatus without invalidating the type of protection

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 Um may be different at different sets of connection facilities, and may be different for a.c. and d.c. voltages.

3.14
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.

3.15
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.

3.16
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.

3.17
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.

3.18
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.

3.19
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.

3.20
encapsulation
encapsulate
process of applying a compound to enclose or placing in or as if in a capsule

3.21
casting
process of pouring a liquid compound at normal ambient pressure into a cast

3.22
moulding
process of placing an object in a tool with a shaping cavity and with plastic material being introduced around the inserted component with pressure applied to either partially or totally encapsulate the inserted component

NOTE This process may also be referred to as injection moulding, over-moulding or insert moulding.

3.23
galvanic isolation
arrangement within an apparatus which permits the transfer of signal or power between two circuits without any direct electrical connection between the two

NOTE Galvanic isolation frequently utilizes either magnetic (transformer or relay) or optocoupled elements.

4 Grouping and classification of intrinsically safe apparatus and associated apparatus

Intrinsically safe and associated apparatus which has a type of protection listed in IEC 60079-0 for use in the appropriate explosive atmosphere, shall be grouped in accordance with equipment grouping requirements of IEC 60079-0 and shall have a maximum surface temperature or temperature class assigned in accordance with the temperature requirements of IEC 60079-0.

Associated apparatus which has no such type of protection shall only be grouped in accordance with the equipment grouping requirements 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 intrinsically safe connection facilities in accordance with 6.2.

The intrinsically safe 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). The certificate number for associated apparatus relying on SELV or PELV circuits shall include the "X" suffix in accordance with the marking requirements of IEC 60079-0 and the specific conditions of use listed on the certificate shall detail the precautions necessary.

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 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.

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 a) and b) shall be 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) shall be 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) shall be 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 and under the conditions specified in this standard.

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.

NOTE The concept of countable 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.

For Group III, the spark ignition tests to the requirements of Group IIB shall be applied to circuits exposed to dust.

5.6 Thermal ignition compliance

5.6.1 General

All surfaces of components, enclosures, wiring and the tracks on printed circuit boards which may come in contact with explosive atmospheres shall be assessed and/or tested for the maximum temperature. The maximum temperature allowable after the application of faults, as provided in 5.2, 5.3 and 5.4, shall be in accordance with the temperature requirements of IEC 60079-0. Tests, when 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 atmosphere by for example, heating or burning of the printed circuit boards, coatings or component packaging.

5.6.2 Temperature for small components for Group I and Group II

Requirements for temperatures of small components used in Group I or Group II equipment are provided in the small component temperature for Group I or Group II electrical equipment requirements of IEC 60079-0 and the test requirements are provided in the small component ignition test of IEC 60079-0.

The 5 K and 10 K margin of safety required by the maximum surface temperature requirements of IEC 60079-0 does not apply to the maximum surface temperature values, 200 °C, 275 °C and 950 °C shown in the table for the assessment of temperature classification according to component size at 40 °C ambient temperature in IEC 60079-0.

NOTE Where a catalytic or other chemical reaction can result specialist advice should be sought.

5.6.3 Wiring within intrinsically safe apparatus for Group I and Group II

The maximum permissible current corresponding to the maximum wire temperature due to self-heating shall either be taken from Table 2 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 maximum 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 (Temperature class =T4)

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

I_f = 1,6 A (determined experimentally or specified by the wire manufacturer)

T = 1 083 °C

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

Applying the equation

I = 1,3 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 2 – 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 IEC 60079-0, Table 3a) and 3b) where derating is required for ambient temperatures greater than 40 °C.

5.6.4 Tracks on printed circuit boards for Group I and Group II

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 3.

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 Table 3, 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.

In the absence of testing, where dust is excluded and the maximum power does not exceed 3,3 W, the tracks are suitable for Group I.

Refer to the assessment of temperature classification for component surface areas ≥ 20 mm^2 table in IEC 60079-0. Variation in maximum power dissipation with ambient temperature in IEC 60079-0 where a derating is required for ambient temperatures greater than 40 °C.

Table 3 – Temperature classification of tracks on printed circuit boards (in a maximum ambient temperature of 40 °C)

Minimum track width	Maximum permissible current for temperature classification		
	T1 to T4 and Group I	T5	T6
mm	A	A	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	1,7
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 The value given for maximum permissible current, in amperes, is the r.m.s. a.c. or d.c. value.			
This table applies to printed boards 1,6 mm or thicker with a single layer of copper of 33 μm thickness For boards with a thickness between 0,5 mm and 1,6 mm, divide the maximum current specified by 1,2. For boards with conducting tracks on both sides, divide the maximum current specified by 1,5. For multilayer boards, for the track layer under consideration, divide the maximum current specified by 2. For 18 μm copper thickness, divide the maximum current by 1,5. For 70 μm copper thickness, multiply the maximum current by 1,3. 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. 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 for tracks passing under components dissipating 0.25W or more. For ambient temperature up to 60 °C, divide the maximum current by 1,2. For ambient temperature up to 80 °C, divide the maximum current by 1,3.			

5.6.5 Intrinsically safe apparatus and component temperature for Group III

For determination of maximum surface temperature for intrinsically safe apparatus of Group III, refer to IEC 60079-0, temperature measurement. In particular the measurement shall be made using the specified values of U_i and I_i for the intrinsically safe apparatus without a 10 % safety factor. The temperature shall be that of the surface of the intrinsically safe apparatus that is in contact with the dust. For example, for intrinsically safe apparatus protected by enclosure of at least IP5X, the surface temperature of the enclosure shall be measured.

Alternatively intrinsically safe apparatus shall be considered suitable for total immersion, or an uncontrolled dust layer thickness, if the matched power dissipation in any component is in accordance with Table 4, and the continuous short-circuit current is less than 250 mA. The intrinsically safe apparatus shall be marked T135 °C.

Table 4 – Maximum permitted power dissipation within a component immersed in dust

Maximum ambient temperature	°C	40	70	100
Permitted power	mW	750	650	550

5.7 Simple apparatus

The following 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 with the exception of Clause 12. The manufacturer or intrinsically safe system designer shall demonstrate compliance with this clause, including material data sheets and test reports, if applicable.

The following aspects shall always be considered:

- simple apparatus shall not achieve safety by the inclusion of voltage and/or current-limiting and/or suppression devices;
- simple apparatus shall not contain any means of increasing the available voltage or current, for example DC-DC converters;
- 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 6.3.13. Its terminals shall conform to 6.2.1;
- non-metallic enclosures and enclosures containing light metals when located in the explosive atmosphere shall conform to the electrostatic charges on external non-metallic materials requirements and metallic enclosures and parts of enclosures requirements of IEC 60079-0;
- when simple apparatus is located in the explosive atmosphere, the maximum surface temperature shall be assessed. 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 and Group III applications. For other types of simple apparatus the maximum temperature shall be assessed in accordance with 5.6 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 6.3.5 or 6.6.

6.1 Enclosures

6.1.1 General

Where intrinsic safety can be impaired by ingress of moisture or dust or 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)

6.1.2 Enclosures for Group I or Group II apparatus

6.1.2.1 General

Intrinsically safe and associated apparatus which rely on the spacings in Table 5 or Annex F shall be provided with an enclosure meeting the requirements of 6.1.2.2 or 6.1.2.3 as applicable.

6.1.2.2 Apparatus complying with Table 5

Apparatus meeting the separation requirements of Table 5 shall be provided with an enclosure meeting the requirements of IP20 in accordance with IEC 60529 or greater according to the intended use and environmental conditions.

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

6.1.2.3 Apparatus complying with Annex F

Apparatus meeting the separation requirements of Tables F.1 or F.2 shall be provided with protection to achieve pollution degree 2. This can be achieved by one of the following:

a) an enclosure meeting the requirements of IP54 or greater according to the intended use and environmental conditions in accordance with IEC 60529. For such enclosures the clauses of IEC 60079-0 identified in Table 1 additionally apply.
b) an enclosure meeting the requirements of IP20 or greater according to the intended use and environmental conditions in accordance with IEC 60529 provided that separations are obtained by using coating type 1 or type 2 or casting compound or through solid insulation. The enclosure does not need to be subjected to the tests for enclosures in IEC 60079-0; however for portable apparatus, the drop test of IEC 60079-0 still applies.
c) an enclosure meeting the requirements of IP20 and by restricted installation, provided that the restricted installation requirements shall be specified as Specific Conditions of Use and the certificate number shall include the "X" suffix in accordance with the marking

requirements of IEC 60079-0 and the Specific Conditions of Use listed on the certificate shall detail the installation requirements.

6.1.3 Enclosures for Group III apparatus

Where the intrinsic safety of intrinsically safe apparatus can be impaired by ingress of dust or by access to conducting parts, for example if the circuits contain infallible creepage distances, an enclosure is necessary by one of the following:

a) Where separation is accomplished by meeting the requirements for clearance or creepage distances of Table 5 or Annex F, the enclosure shall provide a degree of protection of at least IP5X, according to IEC 60529. For such enclosures the 6.1.2.3 a) shall additionally apply.
b) Where separation is accomplished by meeting the requirements for distances under coating, casting compound or separation distances through solid insulation of Table 5 or Annex F, the enclosure shall provide a degree of protection of at least IP2X, according to IEC 60529. The enclosure does not need to be subjected to the tests for enclosures in IEC 60079-0; however for portable apparatus, the drop test of IEC 60079-0 still applies.

Enclosures for Group III associated apparatus shall meet the requirements of 6.1.2.

6.2 Facilities for connection of external circuits

6.2.1 Terminals

In addition to satisfying the requirements of 6.3, 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 should 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.

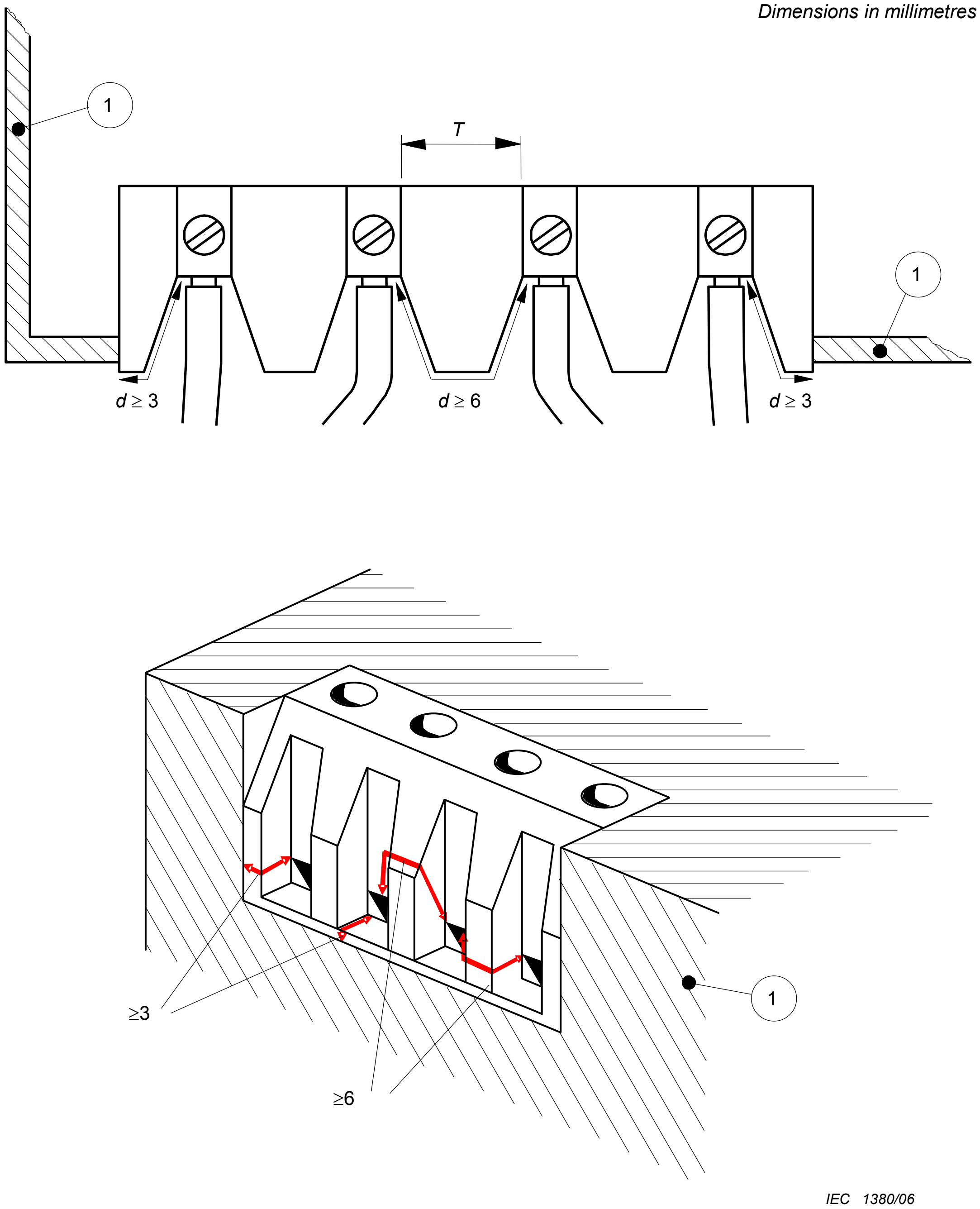
Where separate intrinsically safe circuits are being considered, the clearance distance between bare conducting parts of external connection facilities shall meet the following:

– 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



Key

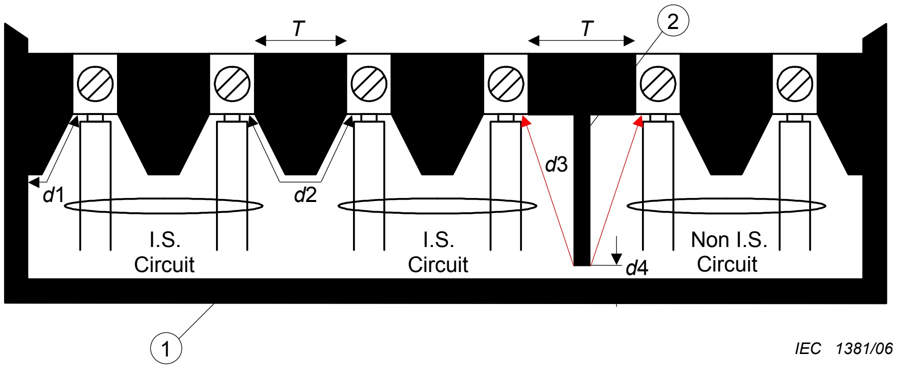
1 Conductive cover

T Distances in accordance with 6.3

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



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 6.3

*d*1 ≥ 3 mm; when cover is conductive and earthed

*d*2 ≥ 6 mm

*d*3 ≥ 50 mm or *d*4 ≤ 1,5 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_o/R_o) for resistance limited power source

The maximum external inductance to resistance ratio (L_o/R_o) 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_o.

$$\frac{L_o}{R_o} = \frac{8eR_s + (64e^2R_s{}^2 - 72U_o{}^2 eL_s)^{½}}{4{,}5\,U_o{}^2} \ \text{H/}\Omega$$

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 $$\frac{L_o}{R_o} = \frac{32\,eR_s}{9U_o{}^2} \ \text{H/}\Omega$$

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.

6.2.5 Requirements for connections and accessories for IS apparatus when located in the non-hazardous area

Intrinsically safe apparatus may be provided with connection facilities that are restricted to use in a non-hazardous area e.g. data downloading and battery charging connections. Such facilities shall be provided with protection to ensure the ratings of the safety components within the intrinsically safe equipment comply with 7.1. The use of a fuse protected shunt Zener assembly complying with 7.3 and 7.5.2 shall be considered sufficient protection for voltage limitation.

Where these connections are provided for the connection of battery charger see also 7.4.9.

Protection circuitry and components may reside either in the intrinsically safe apparatus or the non-hazardous area equipment. If any part of the protection circuit is located in the non-hazardous area accessory, it shall be assessed in accordance with this standard and the non-hazardous area accessory shall be stated in the documentation.

The maximum voltage U_m that can be applied to these non-hazardous area connections shall be stated in the documentation, and marked on the intrinsically safe apparatus. The U_m at the connection facilities shall be assumed to be the normal mains supply voltage e.g. 250 V a.c. unless marked otherwise.

NOTE If U_m is less than 250 V a.c., this should not be derived from unassessed equipment.

Additionally, the circuit of the intrinsically safe apparatus shall be provided with means to prevent the delivery of ignition-capable energy to these safe area connections when in the hazardous area.

NOTE These requirements do not apply to the use of connections by the manufacturer during production, test, repair or overhaul.

6.3 Separation distances

6.3.1 General

Requirements for separation distances are given in 6.3.2 to 6.3.14. An alternative method for the dimensioning of separation distances is given in Annex F.

6.3.2 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 of Table 5 or Annex F under the conditions of 6.1.2.2, 6.1.2.3 or 6.1.3 shall not be subject to a fault.

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. Creepage distance requirements shall not apply where earthed printed circuit board tracks separate conductive tracks requiring separation, but clearance requirements shall still be applied. Clearance requirements shall not apply where an earthed metallic partition of sufficient height does not allow a discharge between components requiring separation.

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 a thickness and appropriate CTI in accordance with Table 5 is placed between the conductive parts, the clearances, creepage distances and other separation distances shall be measured around the partition provided that either the partition has a thickness of at least 0,9 mm, or conforms to 10.6.3 if of lesser thickness.

NOTE 2 Methods of assessment are given in Annex C.

6.3.2.1 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.

6.3.2.2 Distances according to Annex F

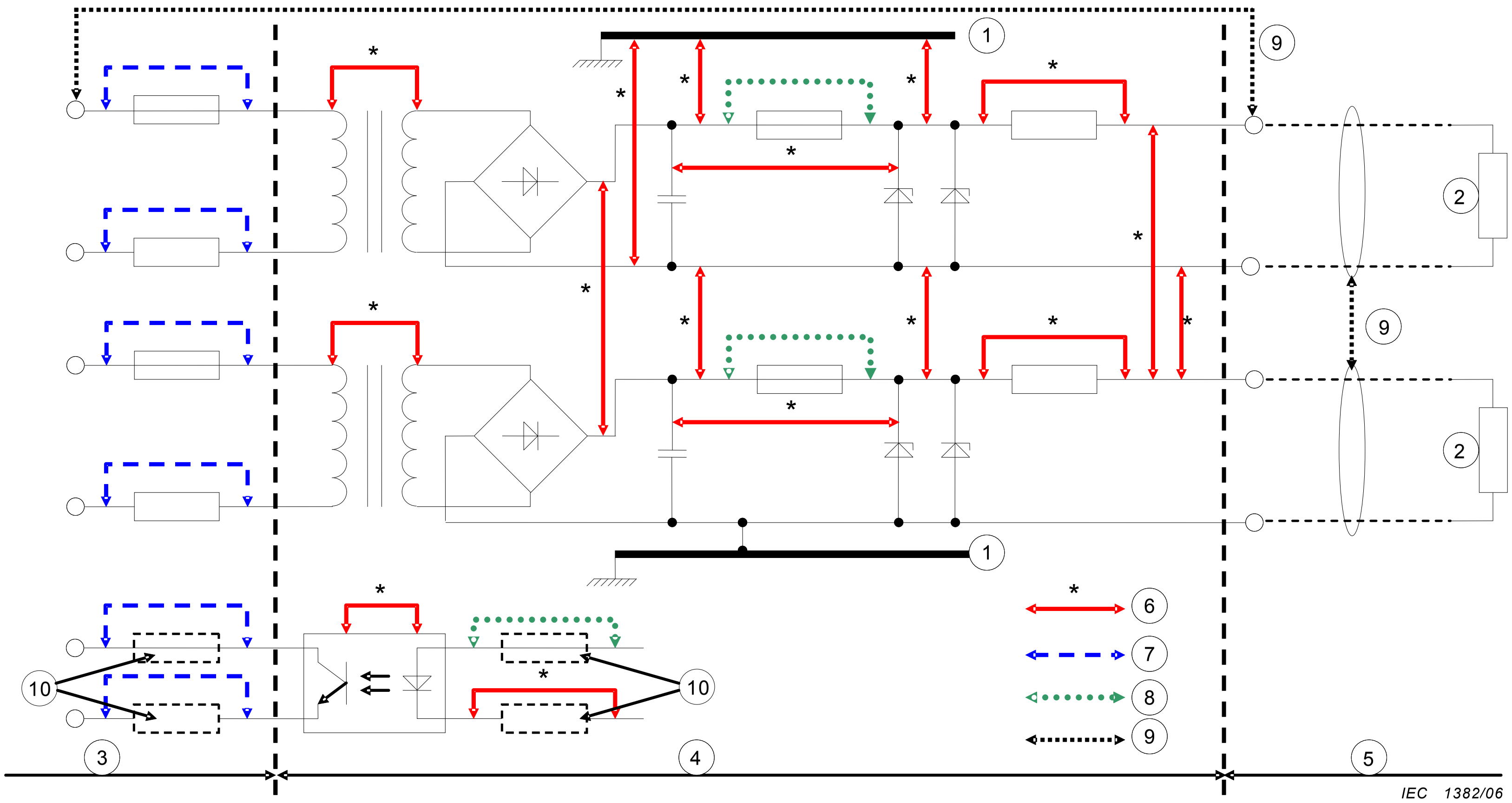
For Levels of Protection “ia” and “ib”, if separation distances are less than the values specified in Annex F, they shall be considered to fault as provided in F.3.1 if this impairs intrinsic safety.

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.

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)[a]	
Level of protection	ia, ib	ic	ia, ib	ic	ia, ib	ic	ia, ib	ic	ia, ib	ic	ia	ib, ic
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	100
60	3,0	0,8	1,0	0,3	0,5	0,3	3,0	1,9	1,0	0,6	100	100
90	4,0	0,8	1,3	0,3	0,7	0,3	4,0	2,1	1,3	0,6	100	100
190	5,0	1,5	1,7	0,6	0,8	0,6	8,0	2,5	2,6	1,1	175	175
375	6,0	2,5	2,0	0,6	1,0	0,6	10,0	4,0	3,3	1,7	175	175
550	7,0	4,0	2,4	0,8	1,2	0,8	15,0	6,3	5,0	2,4	275	175
750	8,0	5,0	2,7	0,9	1,4	0,9	18,0	10,0	6,0	2,9	275	175
1 000	10,0	7,0	3,3	1,1	1,7	1,1	25,0	12,5	8,3	4,0	275	175
1 300	14,0	8,0	4,6	1,7	2,3	1,7	36,0	13,0	12,0	5,8	275	175
1 575	16,0	10,0	5,3		2,7		49,0	15,0	16,3		275	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				

[a] Evidence of compliance with the CTI requirements of insulating materials shall be provided by the manufacturer. At voltages up to 10 V, the CTI of insulating materials is not required to be specified.



Key

1) Chassis
2) Load
3) Non-intrinsically safe circuit defined by U_m
4) Part of intrinsically safe circuit not itself intrinsically safe
5) Intrinsically safe circuit
6) Dimensions to which Table 5 or Annex F are applicable
7) Dimensions to which general industrial standards are applicable
8) Dimensions to 7.3
9) Dimensions to 6.2.1 for output terminals between separate Intrinsically safe circuits and between Intrinsically safe to non intrinsically safe circuits
10) Protective components as applicable in accordance with 8.9

Figure 2 – Example of separation of conducting parts

6.3.3 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:

   $\sqrt{2} \times$ 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, that opens the circuit shall not be considered when evaluating the creepage distance, but shall be considered when evaluating clearances.

6.3.4 Clearance

Insulating partitions that do not meet the requirements of 6.3.2 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 6.3.2.

6.3.5 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 solid insulation 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 6.3.13.

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.

6.3.6 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 6.3.13 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 manufacturer 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.

NOTE 4 Separation between adjacent tracks on intermediate layers of printed circuit boards should be considered as separation distances through solid insulation.

6.3.7 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 × separation through solid insulation (column 4);

clearance (column 2) = 3 × separation through casting compound (column 3);

equivalent clearance = actual clearance + (3 × any additional separation through encapsulant) + (6 × 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.

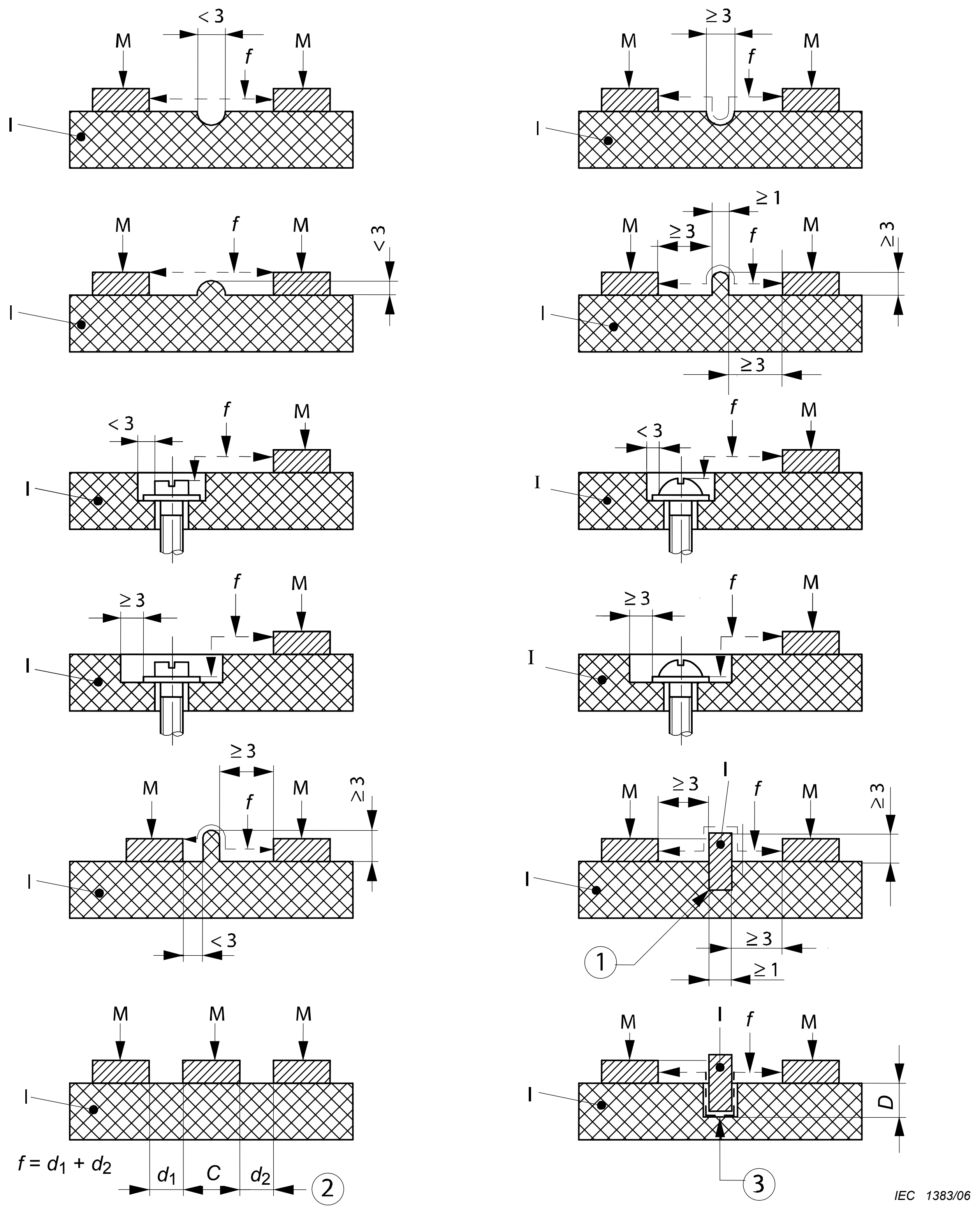
For Level of Protection “ic”, the above results shall not be less than the clearance value specified in Table 5.

6.3.8 Creepage distance

For the creepage distances specified in column 5 of Table 5, the insulating material shall conform to column 7 of Table 5 or Annex F where applicable, which specify 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 6.3.2.



Dimensions in millimetres

Key

f Creepage distance

M Metal

I Insulating material

1 Cemented joint

2 The central metal is not electrically connected

3 Uncemented joint. Exposed height of partition > *D*

Figure 3 – Determination of creepage distances

6.3.9 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 an additional coat is applied, provided that no damage occurs 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 a Type 1 coating in accordance with IEC 60664-3 is considered as a conformal coating and an additional coating is not required. The manufacturer shall provide evidence of compliance with these requirements.

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 the documentation requirements 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. The distances within the coating shall be in accordance with column 6 of Table 5.

Where bare conductors or conductive parts emerge from the coating the comparative tracking index (CTI) in column 7 of Table 5 or column 7 of Table F.2 or material group as specified in F.3.1 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 should have suitable elastic coating that does not crack. Radical differences from this format require special consideration.

6.3.10 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 6.3.9, the requirements of 6.3.4 and 6.3.8 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 6.3.9 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;
   1) the separation is in accordance with 6.3.2 between the conductive part of the component and the track, or
   2) failure results in a less onerous condition.

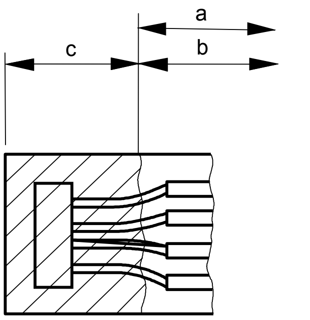


Figure 4a – Partially coated board

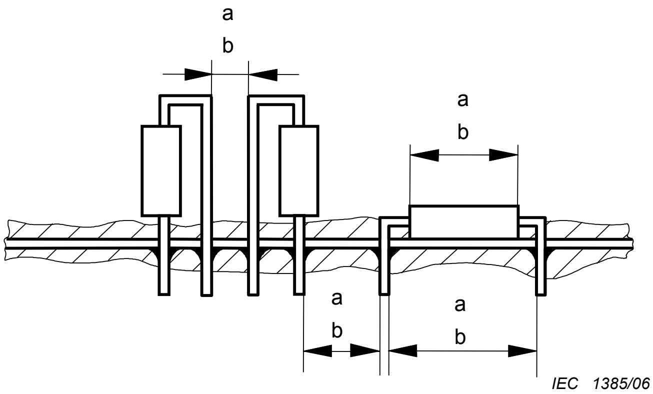


Figure 4b – Board with soldered leads protruding

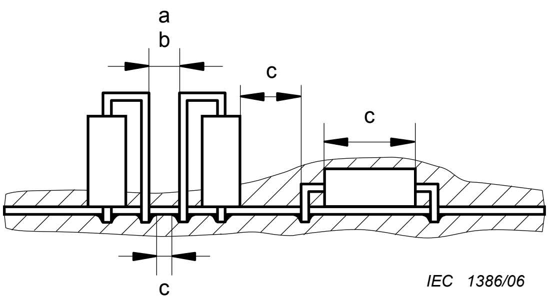


Figure 4c – Board with soldered leads folded or cropped

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

Key

a Apply clearance distance requirements of 6.3.4

b Apply creepage distance requirements of 6.3.8

c Apply distance under coating requirements of 6.3.9

Figure 4 – Creepage distances and clearances on printed circuit boards

6.3.11 Separation by earthed screens

Where separation between circuits or parts of circuits is provided by an earthed 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.

6.3.12 Internal wiring

Insulation, except for varnish and similar coatings, covering the conductors of internal wiring shall be considered as solid insulation (see 6.3.6).

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 6.3.7 except when one of the following apply:

– the cores of either the intrinsically safe or the non-intrinsically safe circuit are enclosed in an earthed 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 when tested in accordance with 10.3.

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

6.3.13 Dielectric strength requirement

The insulation between an intrinsically safe circuit and the frame of the electrical equipment or parts which may be earthed shall 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 2 U + 1 000 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 2 U, 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.

6.3.14 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 6.3.2. 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 6.3.2 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 intrinsically safe 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 mm^2 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.

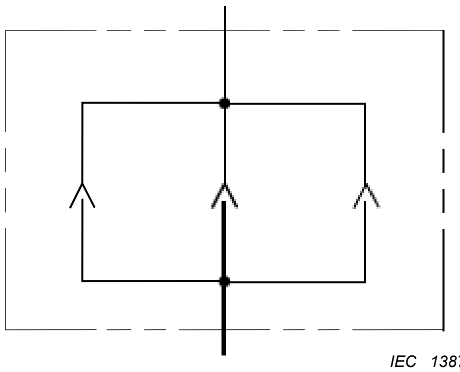


Figure 5a – Example of three independent connecting elements

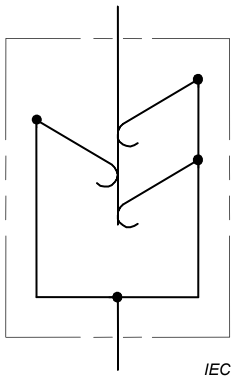


Figure 5b – Example of three connecting elements which are not independent

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

6.6.1 General

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

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

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

Encapsulation may be applied by casting, moulding or pouring.

Where encapsulation is used, it shall conform to the following and where appropriate it applies also to any potting box or parts of an enclosure used in the encapsulation process:

a) have a temperature rating, specified by the manufacturer of the compound or apparatus, which is at least equal to the maximum temperature achieved by any component under encapsulated conditions;
b) alternatively temperatures higher than the compound's rating shall be accepted provided that they do not cause damage to the compound. When the temperature of the compound exceeds its continuous operating temperature (COT), no visible damage of the compound that could impair the type of protection shall be evident, such as cracks in the compound, exposure of encapsulated parts, flaking, impermissible shrinkage, swelling, decomposition, or softening. In addition, the compound shall not show evidence of overheating that would adversely affect the protection;
c) have at its free surface a CTI value of at least that specified in Table 5 or Annex F if any bare conductive parts protrude from the compound;
d) only materials passing the test in 10.6.1 shall have its free surface exposed and unprotected, thus forming part of the enclosure;
e) be adherent to all conductive parts, components and substrates except when they are totally enclosed by the compound;
f) the compound shall be free of voids, except that encapsulation of components containing free space (transistors, relays, fuses etc) is allowed.
g) be specified by its generic name and type designation given by the manufacturer of the compound.

NOTE Further guidance is given in Annex D.

6.6.2 Encapsulation used for the exclusion of explosive atmospheres

Where casting is used to exclude an explosive atmosphere from components and intrinsically safe circuits, it shall conform to 6.3.5.

Where moulding is used to exclude an explosive atmosphere from components and intrinsically safe circuits, the minimum thickness to the free surface shall comply with column 4 of Table 5, see Figures D.3a and D.3b.

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

NOTE Examples of the application of 6.6.2 are; fuses, piezo-electric devices with their suppression components and energy storage devices with their suppression components.

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, 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.

For Levels of Protection "ia", "ib" and "ic" transformers, fuses, thermal trips, relays, opto-couplers and switches are allowed to operate at their normal ratings in order to function correctly.

The effects of mounting conditions, ambient temperature and other environmental influences, and the service temperature requirements of IEC 60079-0 shall be taken into account when determining component rating. For example, in a semiconductor the power dissipation shall not exceed two-thirds of the power which is required to reach the maximum allowed junction temperature 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 CU^2, where C is capacitance in farads, U 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.

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 8.5 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 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 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 6.3.

NOTE 1 Microfuses conforming to IEC 60127 series 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 series 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 6.3.

7.4 Primary and secondary cells and batteries

7.4.1 General

Contrary to the batteries requirements 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 1 The parallel battery requirement of batteries 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.

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 shall be confirmed by their manufacturer as being safe for use in any particular intrinsically safe or associated apparatus. The documentation and, if practicable, the marking for the apparatus shall draw attention to the safety precautions to be observed.

NOTE 2 Cells that comply with the requirements of UL1642 or IEC 62133 or other relevant safety standards are considered to meet this requirement.

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

If the cells or batteries have to be recharged in hazardous areas, the charging circuits shall be fully specified as part of the apparatus. The charging system shall be such that, even when faults in accordance with 5.2, 5.3 or 5.4 are applied to the charging system, the charger voltage and current do not exceed the limits specified by the manufacturer.

NOTE 4 If the charger itself is used in the hazardous area it should also utilise types of protection suitable for the area of use.

7.4.2 Battery construction

The spark ignition capability and surface temperature of cells and batteries used in intrinsically safe apparatus 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 plastic 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) swaged, 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 compound specified by the manufacturer of the 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.

7.4.3 Electrolyte leakage and ventilation

Cells and batteries shall either 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 Equipment Group IIC, the requirement of degassing apertures or limitation of hydrogen concentration does not apply.

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.

For rechargeable or non-rechargeables cells 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.

7.4.4 Cell voltages

For the purpose of evaluation and test, the cell voltage shall be that specified in the primary cell table and secondary cells table of IEC 60079-0. When a cell is not listed in these tables, it shall be tested in accordance with 10.4 to determine the maximum open circuit voltage, and the nominal voltage shall be that specified by the cell manufacturer.

7.4.5 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.

7.4.6 Batteries in equipment protected by other types 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 removed and the enclosure is opened in the explosive atmosphere.

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

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.

7.4.7 Batteries used and replaced in explosive 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 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 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.

7.4.8 Batteries used but not replaced in explosive 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 atmosphere, it shall either be protected in accordance with 7.4.7 or alternatively it may be housed in a compartment secured with special fasteners, for example those specified in 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 apparatus or apparatus carried on the person, ready for use, such as radio receivers and transceivers shall be subjected to the drop test 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 battery or 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) or d) of 12.3.

7.4.9 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) limiting the output in accordance with this standard, or;

b) for Group II intrinsically safe 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 the text of warning markings table of IEC 60079-0). The separation distances between the charging contacts shall comply with 6.3 considering the open-circuit voltage of the battery.

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 diode rated in accordance with 7.1 is considered as an adequate means of limiting transients for circuits connected at the Zener diode.

Semiconductors shall be capable of carrying, without open-circuiting, the current which would flow at their place of installation if they failed in the short-circuit mode, multiplied by the appropriate safety factor. 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., may be 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 independent active voltage limitation semiconductor circuits may be used in associated apparatus provided the transient conditions of 7.5.1 are met. These circuits shall also be tested in accordance with 10.1.5.3.

7.5.3 Series current limiters

The use of three series blocking diodes in circuits of Level of Protection "ia" is permitted, however, other semiconductors and controllable semiconductor devices shall be used as series current-limiting devices only in Level of Protection "ib" or "ic" apparatus.

However, for power limitation purposes, Level of Protection "ia" apparatus may use series current limiters consisting of controllable and non-controllable semiconductor devices.

NOTE The use of semiconductors and controllable semiconductor devices as current-limiting devices for spark ignition limitation is not permitted for Level of Protection "ia" apparatus because of their possible use in areas in which a continuous or frequent presence of an explosive atmosphere may coincide with the possibility of a brief transient which could cause ignition. The maximum current that may be delivered may have a brief transient but will not be taken as I_o, because the compliance with the spark ignition test of 10.1 would have established the successful limitation of the energy in this transient.

7.6 Failure of components, connections and separations

For Levels of Protection "ia" and "ib", where a component is rated in accordance with 7.1, its failure shall be a countable fault. For Level of Protection "ic", where a component is rated in accordance with 7.1, it shall not be considered to fail.

The application of 5.2 and 5.3 shall include the following:

a) where a component is not rated in accordance with 7.1, its failure shall be a non-countable fault. Where a component is rated in accordance with 7.1, its failure shall be a countable fault;
b) where a fault can lead to a subsequent fault or faults, then the primary and subsequent faults shall be considered to be a single fault;
c) the failure of resistors to any value of resistance between open circuit and short circuit shall be taken into account (but see 8.5)

   For thermal assessment, film or wirewound resistors operated up to 100 % of their rated power shall not be considered to fail;
d) semiconductor devices shall be considered to fail to short circuit or to open circuit and to the state to which they can be driven by failure of other components;
   – for surface temperature classification, failure of any semiconductor device to a condition where it dissipates maximum power shall be taken into account. However, diodes (including LED's and Zener diodes) operated within the requirements of 7.1 shall only be considered for the power they shall dissipate in the forward conducting mode, or Zener mode, if applicable;

- integrated circuits can fail so that any combination of short and open circuits can exist between their external connections. Although any combination can be assumed, once that fault has been applied, it cannot be changed, for example by application of a second fault. Under this fault situation any capacitance and inductance connected to the device shall be considered in their most onerous connection as a result of the applied fault;
- when considering the voltage available on the external pins of an integrated circuit that includes voltage converters (for example for voltage increase or voltage inversion in EEPROMS), the internal voltages need not be considered, provided that in normal operation the enhanced voltage is not present at any external pin and no external components like capacitors or inductors are used for the conversion. If the enhanced voltage is available at any external pin, then the enhanced voltage shall be assumed to be present on all external pins of the integrated circuit;

  NOTE It is not a requirement of this standard that the manufacturer's specification for the integrated circuit needs to be verified.

e) connections shall be considered to fail to open-circuit and, if free to move, may connect to any part of the circuit within the range of movement. The initial break is one countable fault and the reconnection is a second countable fault (but see 8.8);

f) clearances, creepage and separation distances shall be taken into account in accordance with 6.3;

g) failure of capacitors to open-circuit, short-circuit and any value less than the maximum specified value shall be taken into account (but see 8.6);

h) failure of inductors to open-circuit and any value between nominal resistance and short-circuit but only to inductance to resistance ratios lower than that derived from the inductor specifications shall be taken into account (but see 8.4.2);

i) open-circuit failure of any wire or printed circuit track, including its connections, shall be considered as a single countable fault (but see 8.8).

Insertion of the spark test apparatus to effect an interruption, short-circuit or earth fault shall not be considered as a countable fault but as a test in normal operation.

Infallible connections in accordance with 8.8 and separations in accordance with 6.3 shall not be considered as producing a fault and the spark test apparatus shall not be inserted in series with such connections or across such separations.

Where infallible connections are not protected by an enclosure with a rating of at least IP20 when exposing connection facilities, the spark test apparatus may be inserted in series with such connections.

Where infallible separations are not encapsulated or covered by a coating in accordance with Clause 6.3 or are not protected by an enclosure with a rating of at least IP20 when exposing connection facilities, the spark test apparatus may be inserted across such separations.

7.7 Piezo-electric devices

Piezo-electric devices shall be tested in accordance with 10.7.

7.8 Electrochemical cells for the detection of gases

Electrochemical cells used for detection of gases shall be considered for their addition to voltages and currents which may affect spark ignition assessment and testing. However, they need not be considered for their addition to the power for thermal ignition assessment of the apparatus.

8 Infallible components, infallible assemblies of components and infallible connections on which intrinsic safety depends

8.1 Level of Protection "ic"

The requirements of 8.2 to 8.9 do not apply to Level of Protection "ic".

8.2 Mains transformers

8.2.1 General

Infallible mains transformers shall be considered as not being capable of failing to a short-circuit between any winding supplying an intrinsically safe circuit and any other winding. Short-circuits within windings and open circuits of windings shall be considered to occur. The combination of faults which would result in an increased output voltage or current shall not be considered.

8.2.2 Protective measures

The input circuit of infallible mains transformers intended for supplying intrinsically safe circuits shall be protected either by a fuse conforming to 7.3 or by a suitably rated circuit-breaker.

If the input and output windings are separated by an earthed metal screen (see type 2b) construction in 8.2.3), each non-earthed input line shall be protected by a fuse or circuit-breaker.

Where, in addition to the fuse or circuit-breaker, an embedded thermal fuse or other thermal device is used for protection against overheating of the transformer, a single device shall be sufficient.

Fuses, fuseholders, circuit-breakers and thermal devices shall conform to an appropriate recognized standard.

NOTE It is not a requirement of this standard that the manufacturer's specification for the fuses, fuseholders, circuit-breakers and thermal devices needs to be verified.

8.2.3 Transformer construction

All windings for supplying intrinsically safe circuits shall be separated from all other windings by one of the following types of construction.

For type 1 construction, the windings shall be placed either

a) on one leg of the core, side by side, or

b) on different legs of the core.

The windings shall be separated in accordance with Table 5.

For type 2 construction, the windings shall be wound one over another with either

- solid insulation in accordance with Table 5 between the windings, or
- an earthed screen (made of copper foil) between the windings or an equivalent wire winding (wire screen). The thickness of the copper foil or the wire screen, shall be in accordance with Table 6.

NOTE This ensures that, in the event of a short-circuit between any winding and the screen, the screen will withstand, without breakdown, the current which flows until the fuse or circuit-breaker functions.

Manufacturer's tolerances shall not reduce the values given in Table 6 by more than 10 % or 0,1 mm, whichever is the smaller.

Table 6 – Minimum foil thickness or minimum wire diameter of the screen in relation to the rated current of the fuse

Rating of the fuse	A	0,1	0,5	1	2	3	5
Minimum thickness of the foil screen	mm	0,05	0,05	0,075	0,15	0,25	0,3
Minimum diameter of the wire of the screen	mm	0,2	0,45	0,63	0,9	1,12	1,4

The foil screen shall be provided with two mechanically separate leads to the earth connection, each of which is rated to carry the maximum continuous current which could flow before the fuse or circuit-breaker operates, for example 1,7 I_n for a fuse.

A wire screen shall consist of at least two electrically independent layers of wire, each of which is provided with an earth connection rated to carry the maximum continuous current which could flow before the fuse or circuit-breaker operates. The only requirement of the insulation between the layers is that it shall be capable of withstanding a 500 V test in accordance with 10.3.

The cores of all mains supply transformers shall be provided with an earth connection, except where earthing is not required for the type of protection, for example when transformers with insulated cores are used. For transformers using ferrite cores, there is no requirement for grounding the core, but the ferrite shall be considered as conductive for segregation purposes, unless adequate information is available to prove that the core material is insulating.

Windings supplying separate intrinsically safe circuits shall be separated from each other and all other windings in accordance to Table 5.

The transformer windings shall be consolidated, for example by impregnation or encapsulation.

NOTE Use of impregnation to consolidate the windings may not meet the requirements for separation.

8.2.4 Transformer type tests

The transformer together with its associated devices, for example fuses, circuit breakers, thermal devices and resistors connected to the winding terminations, shall maintain a safe electrical isolation between the power supply and the intrinsically safe circuit even if any one of the output windings is short-circuited and all other output windings are subjected to their maximum rated electrical load.

Where a series resistor is either incorporated within the transformer, or encapsulated with the transformer so that there is no bare live part between the transformer and the resistor, or mounted so as to provide creepage distances and clearances conforming to Table 5, and if the resistor remains in circuit after the application of Clause 5, then the output winding shall not be considered as subject to short-circuit except through the resistor.

Transformers shall be tested in accordance with 10.10.

8.2.5 Routine test of mains transformers

Each mains transformer shall be tested in accordance with 11.2.

8.3 Transformers other than mains transformers

The infallibility and failure modes of these transformers shall conform to 8.2.

NOTE These transformers can be coupling transformers such as those used in signal circuits or transformers for other purposes, for example those used for inverter supply units.

The construction and testing of these transformers shall conform to 8.2 except that they shall be tested at the load that gives maximum power dissipation in the transformer without open circuiting the windings, to ensure that the insulation is rated correctly. Where it is not practicable to operate the transformer under alternating current conditions, each winding shall be subjected to a direct current of 1,7 I_n in the type test of 8.2.4. However, the routine test in accordance with 11.2 shall use a reduced voltage between the input and output windings of 2 *U* + 1 000 V r.m.s. or 1 500 V, whichever is the greater, *U* being the highest rated voltage of any winding under test.

If such transformers are connected on both sides to intrinsically safe circuits, then a reduced voltage of 500 V between the primary winding and the secondary winding shall be applied for a routine test, as given in 11.2

When such transformers are connected to non-intrinsically safe circuits derived from mains voltages, then either protective measures in accordance with 8.2.2 or a fuse and Zener diode shall be included at the supply connection in accordance with 8.9 so that unspecified power shall not impair the infallibility of the transformer creepage distances and clearances. The rated input voltage of 8.2.4 shall be that of the Zener diode.

When such transformers are connected to intrinsically safe circuits and a fuse is not present, then each winding shall be subjected to the maximum current that can flow under the faults specified in Clause 5.

8.4 Infallible windings

8.4.1 Damping windings

Damping windings used as short-circuited turns to minimize the effects of inductance shall be considered not to be subject to open-circuit faults if they are of reliable mechanical construction, for example seamless metal tubes or windings of bare wire continuously short-circuited by soldering.

8.4.2 Inductors made by insulated conductors

Inductors made from insulated conductors shall not be considered to fail to a lower resistance or higher inductance than their rated values (taking into account the tolerances) if they comply with the following:

– the nominal conductor diameter of wires used for inductor wiring shall be at least 0,05 mm;

– the conductor shall be covered with at least two layers of insulation, or a single layer of solid insulation of thickness greater than 0,5 mm between adjacent conductors, or be made of enamelled round wire in accordance with:

  a) grade 1 of IEC 60317-3, IEC 60317-7, IEC 60317-8 or IEC 60317-13.

     There shall be no failure with the minimum values of breakdown voltage listed for grade 2 and when tested in accordance with Clause 14 of IEC 60317-3, IEC 60317-7 IEC 60317-8 or IEC 60317-13, there shall be no more than six faults per 30 m of wire irrespective of diameter, or

  b) grade 2 of IEC 60317-3, IEC 60317-7, IEC 60317-8 or IEC 60317-13.

     The manufacturer shall provide evidence of conformance with the above requirements.

     NOTE It is not a requirement of this standard that the conformity of the manufacturer's specification of the insulation to Grade 1 or Grade 2 needs to be verified.

– windings after having been fastened or wrapped shall be dried to remove moisture before impregnation with a suitable substance by dipping, trickling or vacuum impregnation. Coating by painting or spraying is not recognized as impregnation;

– the impregnation shall be carried out in compliance with the specific instructions of the manufacturer of the relevant type of impregnating substance and in such a way that the spaces between the conductors are filled as completely as possible and that good cohesion between the conductors is achieved;
– if impregnating substances containing solvents are used, the impregnation and drying process shall be carried out at least twice.

8.5 Current-limiting resistors

Current-limiting resistors shall be one of the following types:

a) film type;
b) wire wound type with protection to prevent unwinding of the wire in the event of breakage;
c) printed resistors as used in hybrid and similar circuits covered by a coating conforming to 6.3.9 or encapsulated in accordance with 6.6.

An infallible current-limiting resistor shall be considered as failing only to an open-circuit condition which shall be considered as one countable fault.

A current-limiting resistor shall be rated in accordance with the requirements of 7.1, to withstand at least 1,5 times the maximum voltage and to dissipate at least 1,5 times the maximum power that can arise in normal operation and under the fault conditions defined in Clause 5. Faults between turns of correctly rated wire wound resistors with coated windings shall not be taken into account. The coating of the winding shall be assumed to comply with the required CTI value in accordance with Table 5 at its manufacturer's voltage rating.

Cold resistance (at the minimum ambient temperature) of fuses and filaments of the bulbs may be considered as infallible current limiting resistors where they are used within their normal operating conditions. The filament of the bulb is only permitted to be assessed as current limiting component for hand lights and cap lights. In the absence of available information, this may be taken as the minimum resistance at the minimum ambient temperature when measured as required in 10.4.

NOTE The bulb needs to be protected by a type of protection other than intrinsic safety.

8.6 Capacitors

8.6.1 Blocking capacitors

Either of the two series capacitors in an infallible arrangement of blocking capacitors shall be considered as being capable of failing to short or open circuit. The capacitance of the assembly shall be taken as the most onerous value of either capacitor and a safety factor of 1,5 shall be used in all applications of the assembly.

Blocking capacitors shall be of a high reliability solid dielectric type. Electrolytic or tantalum capacitors shall not be used. The external connections of each capacitor and of the assembly shall comply with 6.3 but these separation requirements shall not be applied to the interior of the blocking capacitors.

The insulation of each capacitor shall conform to the dielectric strength requirements of 6.3.13 applied between its electrodes and also between each electrode and external conducting parts. Where blocking capacitors are used between intrinsically safe circuits and non-intrinsically safe circuits, the blocking capacitors shall be assessed as a capacitive coupling between these circuits. The energy transmitted shall be calculated using U_m and the most onerous value of either capacitor and shall be in accordance with the permissible ignition energy of 10.7. All possible transients shall be taken into account, and the effect of the highest nominal operating frequency (as that supplied by the manufacturer) in that part of the circuit shall be considered.

Where such an assembly also conforms to 8.9, it shall be considered as providing infallible galvanic isolation for direct current.

8.6.2 Filter capacitors

Capacitors connected between the frame of the apparatus and an intrinsically safe circuit shall conform to 6.3.13. Where their failure by-passes a component on which the intrinsic safety of the circuit depends, they shall also maintain infallible separation or conform to the requirements for blocking capacitors in 8.6.1. A capacitor meeting the infallible separation requirements of 6.3, both externally and internally shall be considered to provide infallible separation and only one is required.

NOTE The normal purpose of capacitors connected between the frame and the circuit is the rejection of high frequencies for example feed through capacitors.

8.7 Shunt safety assemblies

8.7.1 General

An assembly of components shall be considered as a shunt safety assembly when it ensures the intrinsic safety of a circuit by the utilization of shunt components.

Where diodes or Zener diodes are used as the shunt components in an infallible shunt safety assembly, they shall form at least two parallel paths of diodes. In Level of Protection "ia" shunt safety assemblies, only the failure of one diode shall be taken into account in the application of Clause 5. Diodes shall be rated to carry the current which would flow at their place of installation if they failed in the short-circuit mode.

NOTE 1 To prevent spark ignition when a connection breaks, encapsulation in accordance with 6.3.5 may be required.

NOTE 2 The shunt components used in these assemblies may conduct in normal operation.

Where shunt safety assemblies are subjected to power faults specified only by a value of U_m, the components of which they are formed shall be rated in accordance with 7.1. Where the components are protected by a fuse, the fuse shall be in accordance with 7.3 and the components shall be assumed to carry a continuous current of 1,7 I_n of the fuse. The ability of the shunt components to withstand transients shall either be tested in accordance with 10.8 or be determined by comparison of the fuse-current time characteristic of the fuse and the performance characteristics of the device.

Where a shunt safety assembly is manufactured as an individual apparatus rather than as part of a larger apparatus, then the construction of the assembly shall be in accordance with 9.1.2.

When considering the utilization of a shunt safety assembly as an infallible assembly, the following shall be considered:

a) the shunt safety assembly shall not be considered to fail to an open-circuit condition;
b) the voltage of the assembly shall be that of the highest voltage shunt path;
c) the failure of either shunt path to short-circuit shall be considered as one fault;
d) circuits using shunt thyristors shall be tested in accordance with 10.1.5.3.

8.7.2 Safety shunts

A shunt safety assembly shall be considered as a safety shunt when it ensures that the electrical parameters of a specified component or part of an intrinsically safe circuit are controlled to values which do not invalidate intrinsic safety.

Safety shunts shall be subjected to the required analysis of transients when they are connected to power supplies defined only by U_m in accordance with 8.7.1, except when used as follows:

a) for the limitation of the discharge from energy storing devices, for example inductors or piezo-electric devices;

b) for the limitation of voltage to energy storing devices, for example capacitors.

An assembly of suitably rated bridge-connected diodes shall be considered as an infallible safety shunt.

8.7.3 Shunt voltage limiters

A shunt safety assembly shall be considered as a shunt voltage limiter when it ensures that a defined voltage level is applied to an intrinsically safe circuit.

Shunt voltage limiters shall be subjected to the required analysis of transients when they are connected to power supplies defined only by U_m in accordance with 8.7.1, except when the assembly is fed from one of the following:

a) an infallible transformer in accordance with 8.2;

b) a diode safety barrier in accordance with Clause 9;

c) a battery in accordance with 7.4;

d) an infallible shunt safety assembly in accordance with 8.7.

8.8 Wiring, printed circuit board tracks, and connections

Wiring, printed circuit board tracks, including its connections which forms part of the apparatus, shall be considered as infallible against open circuit failure in the following cases:

a) for wires:

   1) where two wires are in parallel, or

   2) where a single wire has a diameter of at least 0,5 mm and has an unsupported length of less than 50 mm or is mechanically secured adjacent to its point of connection, or

   3) where a single wire is of stranded or flexible ribbon type construction has a cross-sectional area of at least 0,125 mm^2 (0,4 mm diameter), is not flexed in service and is either less than 50 mm long or is secured adjacent to its point of connection;

b) for printed circuit board tracks:

   1) where two tracks of at least 1 mm width are in parallel, or

   2) where a single track is at least 2 mm wide or has a width of 1 % of its length, whichever is greater.

      In both the above cases, the printed circuit board track shall comply with either of the following:

      – each track is formed from copper cladding having a nominal thickness of not less than 33 μm; or

      – the current carrying capacity of a single track or a combination of tracks is tested in accordance with 10.12;

   3) where tracks on different layers are connected by either a single via of at least 2 mm circumference or two parallel vias of at least 1 mm circumference, and these vias are joined to each other in accordance with 8.8b) 1) or 8.8b) 2).

      The vias shall comply with either of the following:

      – not less than 33 μm plating thickness; or

      – the current carrying capacity of a single via is tested in accordance with 10.12;

c) for connections (excluding external plugs, sockets and terminals):

1) where there are two connections in parallel; or
2) where there is a single soldered joint in which the wire passes through the board (including through-plated holes) and is soldered or has a crimped connection or is brazed or welded; or
3) where there is a soldered joint of a surface mount component mounted in accordance with the component manufacturer's recommendations; or
4) where there is a single connection which conforms to IEC 60079-7; or
5) where there is an internal connector within the enclosure, and the connection is comprised of at least three independent connecting elements for "ia" and at least two for "ib", with these elements connected in parallel (see Figure 5). Where the connector may be removed at an angle, one connection element shall be present at, or near to, each end of the connector.

NOTE When the connector is completely disconnected, the circuits should remain intrinsically safe.

8.9 Galvanically separating components

8.9.1 General

An infallible isolating component conforming to the following shall be considered as not being capable of failing to a short-circuit across the infallible separation.

8.9.2 Isolating components between intrinsically safe and non-intrinsically safe circuits

Isolating components shall comply with the following.

a) The requirements of Table 5 shall also apply to the isolating element except that for inside sealed devices, e.g. opto-couplers, column 5, 6 and 7 shall not apply. If Table F.1 is applied, column 2 shall not apply.
b) The non-intrinsically safe circuit connections shall be provided with protection to ensure that the ratings of the devices in accordance with 7.1 are not exceeded. For example, the inclusion of a single shunt Zener diode protected by a suitably rated fuse according to 7.3, or a thermal device, shall be considered as sufficient protection. For this purpose Table 5 shall not be applied to the fuse and Zener diode. The Zener diode power rating shall be at least 1,7 I_n times the diode maximum Zener voltage. 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. In some applications the intrinsically safe circuit connections may require the application of similar protective techniques to avoid exceeding the rating of the isolating component. Alternatively optical isolators shall comply with the test requirements of 10.11.

   NOTE 1 The test in 10.11 is only intended to apply to devices that are close-coupled single packaged devices.

c) The components shall comply with the dielectric strength requirements in accordance with 6.3.13 between the non-intrinsically safe circuit terminals and the intrinsically safe terminals. The manufacturer's insulation test voltage for the infallible separation of the component shall be not less than the test voltage required by 6.3.13.

Galvanically separating relays shall conform to 6.3.14 and any winding shall be capable of dissipating the maximum power to which it is connected.

NOTE 2 Derating of the relay winding in accordance with 7.1 is not required.

8.9.3 Isolating components between separate intrinsically safe circuits

Isolating components shall be considered to provide infallible separation of separate intrinsically safe circuits if the following conditions are satisfied:

a) the rating of the device shall be according to 7.1 (with the exceptions given in that clause still being applicable) unless it can be shown that the circuits connected to these terminals cannot invalidate the infallible separation of the devices. Protective techniques (such as those indicated in 8.9.2) may be necessary to avoid exceeding the rating of the isolating component;
b) the device shall comply with the dielectric strength requirements in accordance with 6.3.13. The manufacturer's insulation test voltage for the infallible separation of the component under test shall be not less than the test voltage required by 6.3.13.

9 Supplementary requirements for specific apparatus

9.1 Diode safety barriers

9.1.1 General

The diodes within a diode safety barrier limit the voltage applied to an intrinsically safe circuit and a following infallible current-limiting resistor limits the current which can flow into the circuit. These assemblies are intended for use as interfaces between intrinsically safe circuits and non-intrinsically safe circuits, and shall be subject to the routine test of 11.1.

The ability of the safety barrier to withstand transient faults shall be tested in accordance with 10.8.

Safety barriers containing only two diodes or diode chains and used for Level of Protection "ia" shall be acceptable as infallible assemblies in accordance with 8.7, provided the diodes have been subjected to the routine tests specified in 11.1.2. In this case, the failure of only one diode shall be taken into account in the application of Clause 5.

In Level of Protection "ic" safety barriers, the minimum requirement is a single diode and a current limiting resistor if operated within the requirements of 7.1.

9.1.2 Construction

9.1.2.1 Mounting

The construction shall be such that, when groups of barriers are mounted together, any incorrect mounting is obvious, for example by being asymmetrical in shape or colour in relation to the mounting.

9.1.2.2 Facilities for connection to earth

In addition to any circuit connection facility which may be at earth potential, the barrier shall have at least one more connection facility or shall be fitted with an insulated wire having a cross-sectional area of at least 4 mm^2 for the additional earth connection.

9.1.2.3 Protection of components

The assembly shall be protected against access, in order to prevent repair or replacement of any components on which safety depends either by encapsulation in accordance with 6.6 or by an enclosure which forms a non-recoverable unit. The entire assembly shall form a single entity.

9.2 FISCO apparatus

Apparatus that has been constructed in accordance with Annex G and is intended to be used within a FISCO system, shall be additionally marked as 'FISCO' followed by an indication of its function, i.e. power supply, field device or terminator. (See Clause 12).

9.3 Handlights and caplights

Caplights for Group I shall comply with IEC 60079-35-1.

Handlights and caplights for Groups II and III shall comply with the requirements of this standard.

10 Type verifications and type tests

10.1 Spark ignition test

10.1.1 General

All circuits requiring spark ignition testing shall be tested to show that they are incapable of causing ignition under the conditions specified in Clause 5 for the appropriate level of protection of apparatus.

Normal and fault conditions shall be simulated during the tests. Safety factors shall be taken into account as described in Annex A. The spark test apparatus shall be inserted in the circuit under test at each point where it is considered that an interruption, short circuit, or earth fault may occur. A circuit may be exempted from a type test with the spark-test apparatus if its structure and its electrical parameters are sufficiently well defined for its safety to be deduced from the reference curves, Figures A.1 to A.6 or Tables A.1 and A.2, by the methods described in Annex A.

Where voltages and currents are specified without specific tolerances, a tolerance of ±1 % is to be used.

NOTE A circuit assessed using the reference curves and tables may cause ignition when tested using the spark test apparatus. The sensitivity of the spark test apparatus varies, and the curves and tables are derived from a large number of such tests.

10.1.2 Spark test apparatus

The spark test apparatus shall be that described in Annex B except where Annex B indicates that it may not be suitable. In these circumstances, an alternative test apparatus of equivalent sensitivity shall be used and justification for its use shall be included in the definitive test and assessment documentation.

For Level of Protection "ia" and "ib", the use of the spark test apparatus to produce short circuits, interruptions and earth faults shall be a test of normal operation and is a non-countable fault

– at connection facilities,
– at internal connections or across internal creepage distances, clearances, distances through casting compound and distances through solid insulation not conforming to 6.1.2.2. or 6.1.2.3.

The spark test apparatus shall not be used

– across infallible separations, or in series with infallible connections,
– across creepage distances, clearances, distances through casting compound and distances through solid insulation conforming to Table 5 or Annex F,
– within associated apparatus other than at its intrinsically safe circuit terminals,
– between terminals of separate circuits conforming to 6.2.1, apart from the exceptions described in 7.6i).

For Level of Protection "ic", the spark test apparatus shall be considered for the following situations:

– at connection facilities,
– across separations less than the values specified in Table 5 or Annex F;
– in place of normally sparking contacts such as plugs/sockets, switches, pushbuttons, potentiometers;
– in place of components that are not suitably rated under normal operating conditions.

10.1.3 Test gas mixtures and spark test apparatus calibration current

10.1.3.1 Explosive test mixtures suitable for tests with a safety factor of 1,0 and calibration current of the spark test apparatus

The explosive test mixtures as given in Table 7 shall be used, according to the stated Equipment Group which is being tested. The explosive mixtures specified in this clause do not contain a safety factor. If a safety factor of 1,5 is required, the electrical values of the circuit shall be increased according to 10.1.4.2 a).

The sensitivity of the spark test apparatus shall be checked before each test series is carried out in accordance with 10.1.5. For this purpose, the test apparatus shall be operated in a 24 V d.c. circuit containing a 95 (± 5) mH air-cored coil. The current in this circuit shall be set at the value given in Table 7 for the appropriate group. The sensitivity shall be considered to be satisfactory if an ignition of the explosive test mixture occurs within 440 revolutions of the wire holder with the wire holder at positive polarity.

Table 7 – Compositions of explosive test mixtures adequate for 1,0 safety factor

Group	Compositions of explosive test mixtures Vol. % in air	Current in the calibration circuit mA
I	(8,3 ± 0,3) % methane	110 to 111
IIA	(5,25 ± 0,25) % propane	100 to 101
IIB	(7,8 ± 0,5) % ethylene	65 to 66
IIC	(21 ± 2) % hydrogen	30 to 30,5

In special cases, apparatus which is to be tested and marked for use in a particular gas or vapour shall be tested in the most easily ignited concentration of that gas or vapour in air.

NOTE The purity of commercially available gases and vapours is normally adequate for these tests, but those of purity less than 95 % should not be used. The effect of normal variations in laboratory temperature and air pressure and of the humidity of the air in the explosive test mixture is also likely to be small. Any significant effects of these variations will become apparent during the routine calibration of the spark test apparatus.

10.1.3.2 Explosive test mixtures suitable for tests with a safety factor of 1,5 and calibration current of the spark test apparatus

The preferred test mixtures are those specified in 10.1.3.1 with a safety factor applied by an increase of voltage or current as applicable. Where this is not practical and a more severe test mixture is used to achieve a factor of safety, a safety factor of 1,5 is considered as having been applied for the purpose of this standard when the composition shall be as given in Table 8.

Table 8 – Compositions of explosive test mixtures adequate for 1,5 safety factor

Group	Compositions of explosive test mixtures Volume %					Current in the calibration circuit mA
	Oxygen-hydrogen-air mixture			Oxygen-hydrogen mixture		
	Hydrogen	Air	Oxygen	Hydrogen	Oxygen	
I	52 ± 0,5	48 ± 0,5	–	85 ± 0,5	15 ± 0,5	73 to 74
IIA	48 ± 0,5	52 ± 0,5	–	81 ± 0,5	19 ± 0,5	66 to 67
IIB	38 ± 0,5	62 ± 0,5	–	75 ± 0,5	25 ± 0,5	43 to 44
IIC	30 ± 0,5	53 ± 0,5	17 ± 0,5	60 ± 0,5	40 ± 0,5	20 to 21

10.1.4 Tests with the spark test apparatus

10.1.4.1 Circuit test

The circuit to be tested shall be based on the most incendive circuit that can arise, toleranced in accordance with Clause 7 and taking into account between 0 and 110 % of the mains supply voltage.

The spark test apparatus shall be inserted in the circuit under test at each point where it is considered that an interruption or interconnection may occur. Tests shall be made with the circuit in normal operation, and also with one or two faults, as appropriate to the level of protection of apparatus in accordance with Clause 5, and with the maximum values of the external capacitance (C_o) and inductance (L_o) or inductance to resistance ratio (L_o/R_o) for which the apparatus is designed.

Each circuit shall be tested for the following number of revolutions, with a tolerance of ${}^{+10}_{\ 0}$ % of the wire holder in the spark test apparatus:

a) for d.c. circuits, 400 revolutions (5 min), 200 revolutions at each polarity;

b) for a.c. circuits, 1 000 revolutions (12,5 min);

c) for capacitive circuits, 400 revolutions (5 min), 200 revolutions at each polarity. Care shall be taken to ensure that the capacitor has sufficient time to recharge (at least three time constants). The normal time for recharge is about 20 ms and where this is inadequate it shall be increased by removing one or more of the wires or by slowing the speed of rotation of the spark test apparatus. When wires are removed, the number of revolutions shall be increased to maintain the same number of sparks.

After each test in accordance with a), b) or c), calibration of the spark test apparatus shall be repeated. If the calibration does not conform to 10.1.3, the ignition test on the circuit under investigation shall be considered invalid.

NOTE Bent and frayed tungsten wires of the spark test apparatus can change its sensitivity. This may cause invalid test results.

10.1.4.2 Safety factors

NOTE The purpose of the application of a safety factor is to ensure either that a type test or assessment is carried out with a circuit which is demonstrably more likely to cause ignition than the original, or that the original circuit is tested in a more readily ignited gas mixture. In general, it is not possible to obtain exact equivalence between different methods of achieving a specified factor of safety, but the following methods provide acceptable alternatives.

Where a safety factor of 1,5 is required it shall be obtained by one of the following methods:

a) increase the mains (electrical supply system) voltage to 110 % of the nominal value to allow for mains variations, or set other voltages, for example batteries, power supplies and voltage limiting devices at the maximum value in accordance with Clause 7, then:
   1) for inductive and resistive circuits, increase the current to 1,5 times the fault current by decreasing the values of limiting resistance, if the 1,5 factor cannot be obtained, further increase the voltage;
   2) for capacitive circuits, increase the voltage to obtain 1,5 times the fault voltage. Alternatively when an infallible current-limiting resistor is used with a capacitor, consider the capacitor as a battery and the circuit as resistive.

   When using the curves in Figures A.1 to A.6 or Tables A.1 and A.2 for assessment, this same method shall be used.
b) use the more easily ignited explosive test mixtures in accordance with Table 8.

Where a safety factor of 1,0 is required the test mixture specified in Table 7 shall be used.

10.1.5 Testing considerations

10.1.5.1 General

Spark ignition tests shall be carried out with the circuit arranged to give the most incendive conditions. For simple circuits of the types for which the curves in Figures A.1 to A.6 apply, a short-circuit test is the most onerous. For more complex circuits, the conditions vary and a short-circuit test may not be the most onerous, for example, for constant voltage current-limited power supplies, the most onerous condition usually occurs when a resistor is placed in series with the output of the power supply and limits the current to the maximum which can flow without any reduction in voltage.

Non-linear power supplies require special consideration. See Annex H for information on an alternative method for the ignition testing of semiconductor limiting power supply circuits.

10.1.5.2 Circuits with both inductance and capacitance

Where a circuit contains energy stored in both capacitance and inductance, it may be difficult to assess such a circuit from the curves in Figures A.1 to A.6, for example, where the capacitive stored energy may reinforce the power source feeding an inductor. Where the total inductance, or capacitance assessed against the requirements of Clause 5, is less than 1 % of the value allowable by using the ignition curves or tables given in Annex A, then the maximum allowable capacitance, or inductance, respectively, may be taken as that allowed by the curves or tables.

The circuit shall be assessed for compliance with either of the following methods:

a) tested with the combination of capacitance and inductance, or
b) where linear (resistive current limiting) circuits are being considered
   1) the values of L_o and C_o determined by the ignition curves and table given in Annex A are allowed for;
      – distributed inductance and capacitance e.g. as in a cable or,
      – if the total L_i of the external circuit (excluding the cable) is < 1 % of the L_o value or,
      – if the total C_i of the external circuit (excluding the cable) is < 1 % of the C_o value.
   2) the values of L_o and C_o determined by the ignition curves and table given in Annex A shall be reduced to 50 % if both of the following conditions are met;
      – the total L_i of the external circuit (excluding the cable) ≥ 1 % of the L_o value and
      – the total C_i of the external circuit (excluding the cable) ≥ 1 % of the C_o value.

      The reduced capacitance of the external circuit (including cable) shall not be greater than 1 μF for Groups I, IIA, and IIB and 600 nF for Group IIC.

The values of L_o and C_o determined by this method shall not be exceeded by the sum of all of the L_i plus cable inductances in the circuit and the sum of all of C_i plus cable capacitances respectively.

10.1.5.3 Circuits using shunt short-circuit (crowbar) protection

After the output voltage has stabilized, the circuit shall be incapable of causing ignition for the appropriate level of protection of apparatus in the conditions of Clause 5. Additionally, where the type of protection relies on operation of the crowbar caused by other circuit faults, the let-through energy of the crowbar during operation shall not exceed the following value for the appropriate group:

- Group IIC apparatus 20 μJ
- Group IIB and Group III apparatus 80 μJ
- Group IIA apparatus 160 μJ
- Group I apparatus 260 μJ

As ignition tests with the spark test apparatus are not appropriate for testing the crowbar let-through energy, this let-through energy shall be assessed, for example from oscilloscope measurements.

NOTE A method of performing this test is available in Annex E.

10.1.5.4 Results of spark tests

No ignition shall occur in any test series at any of the chosen test points.

10.2 Temperature tests

All temperature data shall be referred to a reference ambient temperature of 40 °C or the maximum ambient temperature marked on the apparatus. Tests to be based on a reference ambient temperature shall be conducted at any ambient temperature between 20 °C and the reference ambient temperature. The difference between the ambient temperature at which the test was conducted and the reference ambient temperature shall then be added to the temperature measured unless the thermal characteristics of the component are non-linear, for example batteries.

Temperatures shall be measured by any convenient means. The measuring element shall not substantially lower the measured temperature.

An acceptable method of determining the rise in temperature of a winding is as follows:

- measure the winding resistance with the winding at a recorded ambient temperature;
- apply the test current or currents and measure the maximum resistance of the winding, and record the ambient temperature at the time of measurement;
- calculate the rise in temperature from the following equation:

$$t = \frac{R}{r}(k + t_1) - (k + t_2)$$

where

t is the temperature rise, in kelvins;

r is the resistance of the winding at the ambient temperature t_1, in ohms;

R is the maximum resistance of the winding under the test current conditions, in ohms;

t_1 is the ambient temperature, in degrees Celsius, when r is measured;

t_2 is the ambient temperature, in degrees Celsius, when R is measured;

k is the inverse of the temperature coefficient of resistance of the winding at 0 °C and has the value of 234,5 K for copper.

10.3 Dielectric strength tests

Dielectric strength tests shall be in accordance with the appropriate IEC standard.

Where there is no such standard, the following test method shall be used. The test shall be performed either with an alternating voltage of substantially sinusoidal waveform at a power frequency between 48 Hz and 62 Hz or with a d.c. voltage having no more than 3 % peak-to-peak ripple at a level 1,4 times the specified a.c. voltage.

The supply shall have sufficient volt-ampere capacity to maintain the test voltage, taking into account any leakage current which may occur.

The voltage shall be increased steadily to the specified value in a period of not less than 10 s and then maintained for at least 60 s.

The applied voltage shall remain constant during the test. The current flowing during the test shall not exceed 5 mA r.m.s. at any time.

10.4 Determination of parameters of loosely specified components

Ten unused samples of the component shall be obtained from any source or sources of supply and their relevant parameters shall be measured. Tests shall normally be carried out at, or referred to, the specified maximum ambient temperature, for example 40 °C, but where necessary, temperature-sensitive components, shall be tested at lower temperatures to obtain their most onerous conditions.

The most onerous values for the parameters, not necessarily taken from the same sample, obtained from the tests on the 10 samples shall be taken as representative of the component.

10.5 Tests for cells and batteries

10.5.1 General

Rechargeable cells or batteries shall be fully charged and then discharged at least twice before any tests are carried out. On the second discharge, or the subsequent one as necessary, the capacity of the cell or battery shall be confirmed as being within its manufacturer's specification to ensure that tests can be carried out on a fully charged cell or battery which is within its manufacturer's specification.

When a short-circuit is required for test purposes the resistance of the short-circuit link, excluding connections to it, either shall not exceed 3 mΩ or have a voltage drop across it not exceeding 200 mV or 15 % of the cell e.m.f. The short-circuit shall be applied as close to the cell or battery terminals as practicable.

10.5.2 Electrolyte leakage test for cells and batteries

Ten test samples shall be subjected to the most onerous of the following:

a) short circuit until discharged (not applicable for Level of Protection 'ic');
b) application of input or charging currents within the manufacturer's recommendations;
c) charging a battery within the manufacturer's recommendations with one cell fully discharged or suffering from polarity reversal.

The conditions above shall include any reverse charging due to conditions arising from the application of 5.2 and 5.3. They shall not include the use of an external charging circuit which exceeds the charging rates recommended by the manufacturer of the cell or battery.

The test samples shall be placed with any case discontinuities, for example seals, facing downward or in the orientation specified by the manufacturer of the device, over a piece of blotting paper for a period of at least 12 h after the application of the above tests. There shall be no visible sign of electrolyte on the blotting paper or on the external surfaces of the test samples. Where encapsulation has been applied to achieve conformance to 7.4.2, examination of the cell at the end of the test shall show no damage which would invalidate conformance with 7.4.2.

10.5.3 Spark ignition and surface temperature of cells and batteries

If a battery comprises a number of discrete cells or smaller batteries combined in a well-defined construction conforming to the segregation and other requirements of this standard, then each discrete element shall be considered as an individual component for the purpose of testing. Except for specially constructed batteries where it can be shown that short-circuits between cells cannot occur, the failure of each element shall be considered as a single fault. In less well-defined circumstances, the battery shall be considered to have a short-circuit failure between its external terminals.

Cells and batteries shall be tested or assessed as follows.

a) Spark ignition assessment or testing shall be carried out at the cell or battery external terminals, except where a current-limiting device is included and the circuit between this device and the cell or battery is encapsulated according to 6.6. The test or assessment shall then include the current-limiting device.

   Where the apparatus contains cells that shall not be changed in the explosive atmosphere, the spark ignition discharge at the terminals of a single cell does not require to be tested, provided that the single cell delivers a peak open-circuit voltage of less than 4,5 V.

   When the internal resistance of a cell or battery is to be included in the assessment of intrinsic safety, its minimum resistance value shall be specified. Alternatively, if the cell/battery manufacturer is unable to confirm the minimum value of internal resistance, the most onerous value of short-circuit current from a test of 10 samples of the cell/battery together with the peak open-circuit voltage in accordance with 7.4.4 of the cell/battery shall be used to determine the internal resistance.

   NOTE 1 Some cell types, for example nickel cadmium, may exhibit a maximum short-circuit current at temperatures lower than normal ambient.

b) Cells shall be tested at any temperature between laboratory ambient and the specified maximum ambient that gives the most onerous conditions and the values obtained shall be used directly in the temperature class assessment. The cells shall be arranged in a way as to simulate the thermal effects of their intended position in the complete apparatus. The temperature shall be determined on the hottest surface of the cell that may be exposed to the explosive atmosphere and the maximum figure taken. If an external sheath is fitted then the temperature shall be measured at the interface of the sheath and the metal surface of the cell or battery.

   The maximum surface temperature shall be determined as follows:

   For 'ia' and 'ib' all current-limiting devices external to the cell or battery shall be short-circuited for the test. 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. If the internal current limiting devices protect against internal shorts then these devices need not be removed. However, such devices shall only be considered for Level of Protection 'ib'.

   NOTE 2 If leakage of electrolyte occurs during this test, then the requirements of 7.4.3 should also be considered.

   NOTE 3 While determining the maximum surface temperature of a battery comprising more than one cell in series connection, provided that the cells are adequately segregated from each other, only one cell should be shorted at one time to determine this maximum surface temperature. (This is based on the extreme unlikelihood of more than one cell shorting at one time.)

c) For 'ic' the maximum surface temperature shall be determined by testing in normal operating conditions with all protection devices in place.

10.5.4 Battery container pressure tests

Five samples of the battery container shall be subjected to a pressure test to determine the venting pressure. Pressure shall be applied to the inside of the container. The pressure is to be gradually increased until venting occurs. The maximum venting pressure shall be recorded and shall not exceed 30 kPa.

The maximum recorded venting pressure shall be applied to a sample of the battery container for a period of at least 60 s. After testing the sample shall be subjected to a visual inspection. There shall be no visible damage or permanent deformation.

If separation distances within the battery container are based on Table 5, then the pressure test need not be carried out on a sample that has been submitted to the thermal endurance tests of IEC 60079-0. If separation distance on an assembled printed circuit board within the battery container is based on Annex F then the pressure test shall be carried out on a sample that has been submitted to the thermal endurance tests and additionally, if portable apparatus, the drop test of IEC 60079-0.

10.6 Mechanical tests

10.6.1 Casting compound

A force of 30 N shall be applied perpendicular to the exposed surface of casting compound with a 6 mm diameter flat ended metal rod for 10 s. No damage to or permanent deformation of the encapsulation or movement greater than 1 mm shall occur.

Where a free surface of casting compound occurs and forms part of the enclosure, in order to ensure that the compound is rigid but not brittle, the impact tests shall be carried out on the surface of the casting compound in accordance with IEC 60079-0 using the drop height *h* in row a) of the tests for resistance to impact table of IEC 60079-0.

10.6.2 Determination of the acceptability of fuses requiring encapsulation

Where fuses are required to be encapsulated, and the encapsulation could enter the interior of the fuse and affect safety, the following test is to be performed on five samples of each fuse before encapsulation is applied.

With the test samples at an initial temperature of (25 ± 2) °C, they shall be immersed suddenly in water at a temperature of (50 ± 2) °C to a depth of not less than 25 mm for at least 1 min. The devices are considered to be satisfactory if no bubbles emerge from the sample during this test.

Alternatively, a test can be applied where five samples of the fuse are examined after the encapsulation to ensure that the compound has not entered the interior.

10.6.3 Partitions

Partitions shall withstand a minimum force of 30 N applied by a (6 ± 0.2) mm diameter solid test rod. The force shall be applied to the approximate centre of the partition for at least 10 s. There shall be no deformation of the partition that would make it unsuitable for its purpose.

10.7 Tests for intrinsically safe apparatus containing piezoelectric devices

Measure both the capacitance of the device and also the voltage appearing across it when any part of the intrinsically safe apparatus which is accessible in service is impact tested in accordance with the "high" column of Tests for resistance to impact table in IEC 60079-0 carried out at (20 ± 10) °C using the test apparatus in IEC 60079-0. For the value of voltage, the higher figure of the two tests on the same sample shall be used.

When the intrinsically safe apparatus containing the piezoelectric device includes a guard to prevent a direct physical impact, the impact test shall be carried out on the guard with both the guard and the intrinsically safe apparatus mounted as intended by the manufacturer.

The maximum energy stored by the capacitance of the crystal at the maximum measured voltage shall not exceed the following:

– for Group I apparatus: 1 500 μJ
– for Group IIA apparatus: 950 μJ
– for Group IIB apparatus: 250 μJ
– for Group IIC apparatus: 50 μJ

Where the electrical output of the piezoelectric device is limited by protective components or guards, these components or guards shall not be damaged by the impact in such a way as to allow the type of protection to be invalidated.

Where it is necessary to protect the intrinsically safe apparatus from external physical impact in order to prevent the impact energy exceeding the specified values, details of the requirements shall be specified as special conditions for safe use and the certificate number shall include the "X" suffix in accordance with the Marking requirements of IEC 60079-0 and the specific conditions of use listed on the certificate shall detail the installation requirements.

10.8 Type tests for diode safety barriers and safety shunts

The following tests are used to demonstrate that the safety barrier or safety shunt can withstand the effects of transients.

Infallibly rated resistors shall be considered to be capable of withstanding any transient to be expected from the specified supply.

The diodes shall be shown to be capable of withstanding the peak U_m divided by the value (at the minimum ambient temperature) of the fuse resistance and any infallible resistance in series with the fuse, either by the diode manufacturer's specification or by the following test.

Subject each type of diode in the direction of utilization (for Zener diodes, the Zener direction) to five rectangular current pulses each of 50 μs duration repeated at 20 ms intervals, with a pulse amplitude of the peak of the U_m divided by the "cold" resistance value of the fuse at the minimum ambient temperature (plus any infallible series resistance which is in circuit). Where the manufacturer's data shows a pre-arcing time greater than 50 μs at this current, the pulse width shall be changed to represent the actual pre-arcing time. Where the pre-arcing time cannot be obtained from the available manufacturer's data, 10 fuses shall be subjected to the calculated current, and their pre-arcing time measured. This value, if greater than 50 μs, shall be used.

The diode voltage shall be measured at the same current before and after this test. The test current shall be typically that specified by the component manufacturer. The measured voltages shall not differ by more than 5 % (the 5 % includes the uncertainties of the test apparatus). The highest voltage elevation observed during the test shall be used as the peak value of a series of pulses to be applied in a similar manner as above to any semiconductor current-limiting devices. After testing, these devices shall again be checked for conformity to the component manufacturer's specification.

From a generic range manufactured by a particular manufacturer, it is necessary to test only a representative sample of a particular voltage to demonstrate the acceptability of the generic range.

10.9 Cable pull test

The cable pull test shall be carried out as follows:

- apply a tensile force of minimum value 30 N on the cable in the direction of the cable entrance into the apparatus for the duration of at least 1 h;
- although the cable sheath may be displaced, no visible displacement of the cable terminations shall be observed;
- this test shall not be applied to individual conductors which are permanently connected and do not form part of a cable.

10.10 Transformer tests

The requirement for safe electrical isolation is satisfied if the transformer passes the routine test, the type test described below and subsequently withstands a test voltage (see 10.3) of 2 U + 1 000 V or 1 500 V, whichever is the greater, between any winding(s) used to supply intrinsically safe circuits and all other windings, U being the highest rated voltage of any winding under test.

The input voltage is set to the rated voltage of the transformer. The input current shall be adjusted up to 1,7 $I_{n}\,{}^{0}_{+10\%}$ of the fuse or to the maximum continuous current which the circuit-breaker will carry without operating by increasing the load on the secondary windings. Where the increase of load is limited by reaching a short circuit on all secondary windings, the test shall proceed using the rated input voltage and the maximum input current reached under these conditions.

The test shall continue for at least 6 h or until the non-resetting thermal trip operates. When a self-resetting thermal trip is used, the test period shall be extended to at least 12 h.

For type 1 and type 2a) transformers, the transformer winding temperature shall not exceed the permissible value for the class of insulation given in IEC 60085. The winding temperature shall be measured in accordance with 10.2.

For type 2b) transformers where insulation from earth of the windings used in the intrinsically safe circuit is required, then the requirement shall be as above. However, if insulation from earth is not required, then the transformer shall be accepted providing that it does not burst into flames.

10.11 Optical isolators tests

10.11.1 General

The following tests shall be performed if optical isolators are used to provide isolation between intrinsically safe circuits and non-intrinsically safe circuits and are not adequately protected against overload by external protection components (see 8.9.2).

The samples shall successfully comply with both the tests specified in 10.11.2 and 10.11.3.

10.11.2 Thermal conditioning, dielectric and carbonisation test

The maximum temperature measured at the receiver side and at the transmitter side shall be determined by overloading the devices. These shall then be subjected to thermal conditioning and dielectric strength tests. A carbonisation test shall then be conducted to check for formation of internal creepage paths.

10.11.2.1 Overload test at the receiver side

This test shall be conducted on five samples.

The transmitter side of the optical isolator shall be operated with the rated load values (e.g. $I_f = I_N$).

The receiver side shall be operated with a specific power (e.g. between collector and emitter), which shall not damage the components. This value shall be determined either by preliminary tests or taken from the data sheet.

After thermal equilibrium has been reached, the power shall be increased. After thermal equilibrium has been reached again, the power shall be increased further in steps, until thermal equilibrium, and so on, until the receiver semiconductor is damaged. This will terminate or drastically reduce the power dissipation.

The maximum surface temperature of the receiver side just before the damage of the receiver shall be recorded for each sample together with the ambient temperature.

10.11.2.2 Overload test at the transmitter side

This test shall be conducted on five samples.

The receiver side of the optical isolator is operated at the rated values of voltage and current (e.g. V_{C-E}, I_C).

The transmitter side shall be operated with a specific power, which shall not damage the components. This value shall either be determined by preliminary tests or taken from the data sheet.

After thermal equilibrium has been reached, the power shall be increased. After thermal equilibrium has been reached again, the power shall be increased further in steps, until thermal equilibrium, and so on, until the transmitter semiconductor is damaged. This will terminate or drastically reduce the power dissipation.

The maximum surface temperature of the transmitter side just before the damage of the transmitter shall be recorded for each sample together with the ambient temperature.

10.11.2.3 Thermal conditioning and dielectric strength test

All 10 samples used in 10.11.2.1 and 10.11.2.2 shall be placed in an oven for $6\ ^{0}_{+0.2}$ h at the maximum surface temperature recorded from 10.11.2.1 or 10.11.2.2 increased by at least 10 K but at most 15 K.

After the optical isolators have cooled down to (25 ± 2) °C they shall be subjected to dielectric strength test with a voltage of 1,5 kV (a.c. 48 Hz to 62 Hz) applied between intrinsically safe and non-intrinsically safe terminals and within 10 s increased to $3\ ^{0}_{+5\%}$ kV. This voltage shall be applied for (65 ± 5) s.

During this test, there shall be no breakdown of the insulation between the receiver and the transmitter and the leakage current shall not exceed 5 mA.

10.11.2.4 Carbonisation test

10.11.2.4.1 Receiver side

Using the five samples of 10.11.2.1, a d.c. voltage of $375\ ^{0}_{+10\%}$ V shall be applied for $30\ ^{0}_{+1}$ min across the terminals (e.g. collector and emitter) of the failed receiver semiconductor, to test the formation of an internal creepage path caused by the heated plastic material (carbonisation).

During the last 5 min of this test, the current shall not exceed 5 mA.

10.11.2.4.2 Transmitter side

Using the five samples of 10.11.2.2, a d.c. voltage of 375 $^{0}_{+10\%}$ V shall be applied for 30 $^{0}_{+1}$ min across the terminals of the failed transmitter (e.g. diode), to test the formation of an internal creepage path caused by the heated plastic material (carbonisation).

During the last 5 min of this test the current shall not exceed 5 mA.

10.11.3 Dielectric and short-circuit test

10.11.3.1 General

Optical isolators shall be subjected to a dielectric strength test, followed by a short-circuit current test and if applicable to the current limited short-circuit current test described below, followed by a dielectric strength test.

10.11.3.2 Pre-test dielectric

Three new samples shall be used for this test, with an additional three samples if 10.11.3.4 applies.

Prior to the short-circuit current tests, the samples of the optical isolator shall be capable of withstanding without breakdown a dielectric strength test of 4 $^{0}_{+5\%}$ kV rms applied between the intrinsically safe side and the non-intrinsically safe side of the optical isolator.

10.11.3.3 Short-circuit current test

Three samples of the optical isolator shall be subjected to a short-circuit current test. The open circuit voltage of the test circuit shall be U_m. The available instantaneous short-circuit current capacity of the test circuit shall be at least 200 A. The test circuit shall be connected to the optical isolator so that the test current flows through the non-intrinsically safe side of the optical isolator. Protective components or assemblies that form part of the circuit are permitted to remain connected for the test.

10.11.3.4 Current limited short-circuit current test

Where optical isolators have protective series fuses or current-limiting resistors, three additional samples of the optical isolator shall be subjected to 1,7 times the nominal current rating of the fuse or 1,5 times the calculated short-circuit current through the resistor under fault conditions, until temperatures reach equilibrium.

10.11.3.5 Dielectric strength test

Each sample shall withstand without breakdown a dielectric strength test of 2 U + 1 000 V or 1 500 V rms, whichever is greater, applied between the intrinsically safe side and the non-intrinsically safe side of the optical isolator for (65 ± 5) s.

During these tests the optical isolators shall not explode or catch fire throughout the short-circuit current tests, and the current shall not exceed 1 mA during the dielectric strength tests.

10.12 Current carrying capacity of infallible printed circuit board connections

The current carrying capacity of the connection shall be tested for at least 1 h with a current of 1,5 times the maximum continuous current which can flow in the connection under normal and fault condition. The application of this test current should not cause the connection to fail to open-circuit or to be separated from its substrate at any point.

11 Routine verifications and tests

11.1 Routine tests for diode safety barriers

11.1.1 Completed barriers

A routine test shall be carried out on each completed barrier to check correct operation of each barrier component and the resistance of any fuse. The use of removable links to allow this test shall be acceptable provided that intrinsic safety is maintained with the links removed.

11.1.2 Diodes for 2-diode "ia" barriers

The voltage across the diodes shall be measured as specified by their manufacturer at ambient temperature before and after the following tests:

a) subject each diode to a temperature of 150 °C for 2 h;

b) subject each diode to the pulse current test in accordance with 10.8.

11.2 Routine tests for infallible transformers

For routine tests, the voltages applied to infallible transformers shall conform to the values given in Table 10, where U is the highest rated voltage of any winding under test. The test voltage shall be applied for a period of at least 60 s.

Alternatively, the test may be carried out at 1,2 times the test voltage, but with reduced duration of at least 1 s.

The applied voltage shall remain constant during the test. The current flowing during the test shall not increase above that which is expected from the design of the circuit and shall not exceed 5 mA r.m.s. at any time.

During these tests, there shall be no breakdown of the insulation between windings or between any winding and the core or the screen.

Table 10 – Routine test voltages for infallible transformers

Where applied	RMS test voltage		
	Mains transformer	Non-mains transformer	Transformers with both primary and secondary windings in an intrinsically safe circuit
Between input and output windings	4 U or 2 500 V, whichever is the greater	2 U + 1 000 V or 1 500 V, whichever is the greater	500 V
Between all the windings and the core or screen	2 U or 1 000 V, whichever is the greater	2 U or 500 V, whichever is the greater	500 V
Between each winding which supplies an intrinsically safe circuit and any other output winding	2 U + 1 000 V or 1 500 V, whichever is the greater	2 U or 500 V, whichever is the greater	500 V
Between each intrinsically safe circuit winding	2 U or 500 V, whichever is the greater	2 U or 500 V, whichever is the greater	500 V

12 Marking

12.1 General

Intrinsically safe apparatus and associated apparatus shall carry at least the minimum marking specified in IEC 60079-0. The text of the warning markings, when applicable, shall be derived from the text of warning marking table of IEC 60079-0.

Apparatus meeting the requirements of 5.4 shall be marked with the symbol "ic". Where it is necessary to include marking from one of the other methods of protection listed in IEC 60079-0, the symbol "ic" shall occur first.

For associated apparatus the symbol Ex ia, Ex ib or Ex ic (or ia or ib or ic, if Ex is already marked) shall be enclosed in square brackets.

NOTE 1 All relevant parameters should be marked, for example U_m, L_i, C_i, L_o, C_o, wherever practicable.

NOTE 2 Standard symbols for marking and documentation are given in Clause 3 of this standard and in IEC 60079-0.

Practical considerations may restrict or preclude the use of italic characters or of subscripts, and a simplified presentation may be used, for example Uo rather than U_o.

In the case of apparatus meeting the requirements of 6.1.1.3 a), the IP rating shall be marked.

In the case of apparatus meeting the requirements of 6.1.1.3 c), the certificate number shall include the "X" suffix in accordance with the marking requirements of IEC 60079-0 and the specific conditions of use listed on the certificate shall detail the requirements.

In the case of apparatus not meeting the requirements of 6.3.13, the certificate number shall include the "X" suffix in accordance with the marking requirements of IEC 60079-0 and the specific conditions of use listed on the certificate shall detail the requirements.

Where it is necessary to protect the apparatus from external physical impact in order to prevent the impact energy of 10.7 exceeding the specified values, details of the requirements shall be specified as special conditions for safe use and the certificate number shall include the "X" suffix in accordance with the marking requirements of IEC 60079-0 and the specific conditions of use listed on the certificate shall detail the requirement.

For apparatus complying with the requirements of Annex G, each piece of apparatus shall additionally be marked with the word "FISCO" followed by an indication of its function, i.e. power supply, field device or terminator.

Where apparatus is dual marked so that it can be used in both a FISCO system and a conventional intrinsically safe system, care shall be taken to differentiate between the FISCO marking and the marking for the conventional intrinsically safe system.

In the case of FISCO power supplies, output parameters U_o, I_o, C_o, L_o, P_o and L_o/R_o and FISCO field devices or terminators, input and internal parameters U_i, I_i, C_i, L_i, P_i and L_i/R_i need not be marked.

12.2 Marking of connection facilities

Connection facilities, terminal boxes, plugs and sockets of intrinsically safe apparatus and associated apparatus shall be clearly marked and shall be clearly identifiable. Where a colour is used for this purpose, it shall be light blue for the intrinsically safe connections.

Where parts of an apparatus or different pieces of apparatus are interconnected using plugs and sockets, these plugs and sockets shall be identified as containing only intrinsically safe circuits. Where a colour is used for this purpose, it shall be light blue.

In addition, sufficient and adequate marking shall be provided to ensure correct connection for the continued intrinsic safety of the whole.

NOTE It may be necessary to include additional labels, for example on or adjacent to plugs and sockets, to achieve this. If clarity of intention is maintained, the apparatus label may suffice.

12.3 Warning markings

Where any of the following warning markings are required on the apparatus, the text as described in Table 11, following the word "WARNING," may be replaced by technically equivalent text. Multiple warnings may be combined into one equivalent warning.

Table 11 – Text of warning markings

Item	Reference	WARNING Marking
a)	7.4.1	WARNING – USE ONLY *YYYYY* BATTERIES (where Y is the cell manufacturers name and the type number of the cell or battery).
b)	7.4.8	WARNING – DO NOT REPLACE BATTERY WHEN AN EXPLOSIVE ATMOSPHERE IS PRESENT
c)	7.4.9	WARNING – DO NOT CHARGE THE BATTERY IN HAZARDOUS LOCATION
d)	7.4.8	WARNING – DO NOT OPEN WHEN AN EXPLOSIVE ATMOSPHERE IS PRESENT

12.4 Examples of marking

The following are examples of marking.

a) Self-contained intrinsically safe apparatus

C TOME LTD
PAGING RECEIVER TYPE 3
Ex ia IIC T4
–25 °C ≤ Ta ≤ +50 °C
IECEx ExCB 04.****
Serial No. XXXX

b) Intrinsically safe apparatus designed to be connected to other apparatus

M HULOT	
TRANSDUCTEUR TYPE 12	
Ex ib IIB T4	
ACB No: Ex05****	
L_i: 10 μH	C_i: 1 200 pF
U_i: 28 V	I_i: 250 mA
P_i: 1,3 W	

c) Associated apparatus

J SCHMIDT A.G.	
STROMVERSORGUNG TYP 4	
[Ex ib] I	
ACB No: Ex05****	
U_m: 250 V	P_o: 0,9 W
I_o: 150 mA	U_o: 24 V
L_o: 20 mH	C_o: 4,6 µF

d) Associated apparatus protected by a flameproof enclosure

PIZZA ELECT. SpA	
Ex d [ia] IIB T6	
ACB No: Ex05****	
U_m: 250 V	P_o: 0,9 W
U_o: 36 V	I_o: 100 mA
C_o: 0,31 µF	L_o: 15 mH
Serial No. XXXX	

e) Intrinsically safe apparatus Level of Protection "ic"

M HULOT	
TRANSDUCTEUR TYPE 12A	
Ex ic IIB T4	
ACB No: Ex05****	
U_i: 28 V	C_i = 0

f) Intrinsically safe apparatus Level of Protection 'ib' with 'ia' outputs

PRAHA ELECT	
Ex ib [ia IIC] IIB T6	
ACB No: Ex09****	
U_i: 30 V	Uo: 5.6V
I_i: 93 mA	P_o: 0.014 W
Li: 0.01 mH	I_o: 10 mA
C_i: 0.031 µF	L_o: 0.15 mH
Serial No. XXXX	C_o: 35 uF

where ACB represents the initials of the certifying body, as applicable.

13 Documentation

The documentation shall include the instructions required by the instructions requirements of IEC 60079-0, and shall include the following information as applicable:

a) electrical parameters for the entity concept:

1) power sources: output data such as U_o, I_o, P_o and, if applicable, C_o, L_o and/or the permissible L_o/R_o ratio;

2) power receivers: input data such as U_i, I_i, P_i, C_i, L_i and the L_i/R_i ratio;

b) any special requirements for installation, live maintenance and use;

NOTE A control drawing is a recommended form of consolidating connection information and special requirements for installation and use.

c) the maximum value of U_m which may be applied to terminals of non-intrinsically safe circuits or associated apparatus;

d) any special conditions which are assumed in determining the type of protection, for example that the voltage is to be supplied from a protective transformer or through a diode safety barrier;

e) conformance or non-conformance with 6.3.13;

f) the designation of the surfaces of any enclosure only in circumstances where this is relevant to intrinsic safety;

g) the environmental conditions for which the apparatus is suitable;

h) If Annex F has been applied, the documentation shall state the ambient pollution degree and overvoltage category.

Annex A
(normative)

Assessment of intrinsically safe circuits

A.1 Basic criteria

An intrinsically safe circuit shall satisfy three basic criteria:

a) no spark ignition shall result when the circuit is tested, or assessed as required by Clause 10 for the specified level of protection (see Clause 5) and grouping (see Clause 4) of electrical apparatus;

b) the temperature classification of intrinsically safe apparatus shall be carried out in accordance with 5.6 and the temperatures requirements of IEC 60079-0 so as to ensure that ignition is not caused by hot surfaces. Temperature classification shall not apply to associated apparatus;

c) the circuit shall be adequately separated from other circuits.

NOTE 1 Criterion a) may be satisfied by assessment. Information relating to voltage, current and circuit parameters such as capacitance and inductance at the boundary for ignition is necessary. The circuit can then be assessed as intrinsically safe in regard to spark ignition.

NOTE 2 Criterion b) may be satisfied by estimating the maximum surface temperatures of components from knowledge of their thermal behaviour and the maximum power to which they may be subjected under the appropriate fault conditions.

NOTE 3 Criterion c) may be satisfied by the provision of adequate creepage distances and clearances, and by the use of components conforming to Clause 8, for example transformers and current-limiting resistors.

A.2 Assessment using reference curves and tables

Where the circuit to be assessed for ignition capability approximates to the simple circuit from which the curve is derived, Figures A.1 to A.6 or Tables A.1 and A.2 shall be used in the assessment. The fault conditions in accordance with Clause 5 and the safety factors in accordance with 10.1.4.2 shall also be taken into account.

Generally, the following procedure shall be applied:

– determine the worst practical situation taking account of component tolerances, supply voltage variations, insulation faults and component faults;

– then apply the appropriate safety factors, which depend on the type of circuit (see 10.1.4.2) as well as on the level of protection of the electrical apparatus (see Clause 5), in order to derive a circuit to be subjected to assessment;

– then check that the parameters of the resultant circuit are acceptable according to the reference curves in Figures A.1 to A.6 or according to Tables A.1 and A.2.

The circuit derived for assessment purposes may be tested using the spark-test apparatus if testing is preferred to assessment.

NOTE The information provided in Figures A.1 to A.6 and Tables A.1 and A.2 relates only to simple circuits and it may be difficult in some cases to apply the information to the design of practical circuits. For example, many power supplies have non-linear output characteristics and are not assessable from the reference curves because Figure A.1 can only be used when the circuit can be represented by a cell or battery and a series current-limiting resistor. Because of this, non-linear circuits, for example constant current circuits, will give ignition at lower values of current than would be predicted from Figure A.1 on the basis of open-circuit voltage and short-circuit current. In some types of non-linear circuit, the maximum permitted current may be only one-fifth of that predicted from reference curves. Great care is therefore needed to ensure that assessments are made only when the circuit under consideration can, for practical purposes, be represented by one of the simple circuits for which information is provided. The information available is limited and cannot cover all the detailed problems that arise in the design of intrinsically safe circuits.

A.3 Examples of simple circuits

a) Simple inductive circuit

To illustrate the procedure in more detail, consider a circuit for Group IIC consisting of a power supply comprising a 20 V battery with a suitably mounted infallible 300 Ω current-limiting resistor feeding into a 1 100 Ω, 100 mH inductor as shown in Figure A.7.

The 300 Ω and 1 100 Ω values are minimum values and 100 mH is a maximum value. Two separate assessments are made: one to ensure that the power supply itself is intrinsically safe and the other to take account of the effect of the connected load as follows.

1) Power supply

The steps in the assessment are the following.

i) The value of the current-limiting resistor is quoted as 300 Ω minimum and this represents the worst situation as far as the resistor is concerned. If this resistor does not conform to the requirements for infallibility (see 8.5), application of a single fault (see Clause 5) would produce a modified circuit in which the resistor would be assumed to be short-circuited. With such a fault, the power supply would not be intrinsically safe.

It is also necessary to determine a maximum value for the battery voltage in accordance with 7.4.4. Assume the maximum battery voltage derived is 22 V.

ii) The maximum short-circuit current is 22/300 = 73,3 mA.

Since the circuit is resistive, application of the requirements of Clause 5 and 10.1.4.2 give rise to a modified circuit in which the short-circuit current is increased to 1,5 × 73,3 = 110 mA.

iii) From Table A.1, it can be seen that, for Group IIC, the minimum igniting current for a resistive circuit at 22 V is 337 mA. The power supply can therefore be assessed as intrinsically safe in regard to spark ignition.

2) Connection of load

The steps in the assessment are as follows.

i) The maximum battery voltage is 22 V. Since 300 Ω and 1 100 Ω are minimum values, the maximum possible current in the load is 22/(300 + 1 100) = 15,7 mA. No faults need to be applied since the 300 Ω resistor is infallible and short-circuit failure of the inductor leads to the circuit considered above.

ii) Application of the requirements of Clause 5 and 10.1.4.2 requires that, for a safety factor of 1,5, the current in the circuit be increased to 1,5 × 15,7 = 23,6 mA.

iii) Reference to Figure A.4 for Group IIC shows that, for a 100 mH inductor, the minimum igniting current for a source of 24 V is 28 mA. The circuit can therefore be assessed as intrinsically safe in regard to spark ignition for Group IIC applications.

NOTE 1 For open-circuit voltages significantly below 24 V, Figure A.6 should be used.

NOTE 2 The above assessment assumes that the inductor is air-cored. If the inductor is not air-cored, such assessments can be regarded as only approximate and it is necessary to test the circuit with the spark-test apparatus (Annex B) in order to establish whether or not it is intrinsically safe. In practice, if the assessment is based on a measured inductance value, the actual minimum igniting current is usually, although not always, greater than the assessed value.

b) Simple capacitive circuit

Consider now the circuit of Figure A.8 which is intended for Group I application. It consists of a 30 V battery connected to a 10 μF capacitor through a suitably mounted infallible 10 kΩ resistor. For the purpose of this example, the values of 30 V and 10 μF are taken as maximum values, and 10 kΩ as a minimum value.

Two separate assessments are made: one to ensure that the power supply itself is intrinsically safe and the other to take account of the presence of the capacitor.

1) Power supply

Since the procedure is almost exactly that described in a) 1), no detail need be given. The power supply circuit alone can be readily assessed as being intrinsically safe in regard to spark ignition with a safety factor exceeding 100.

2) Capacitor

The steps in the assessment are as follows.

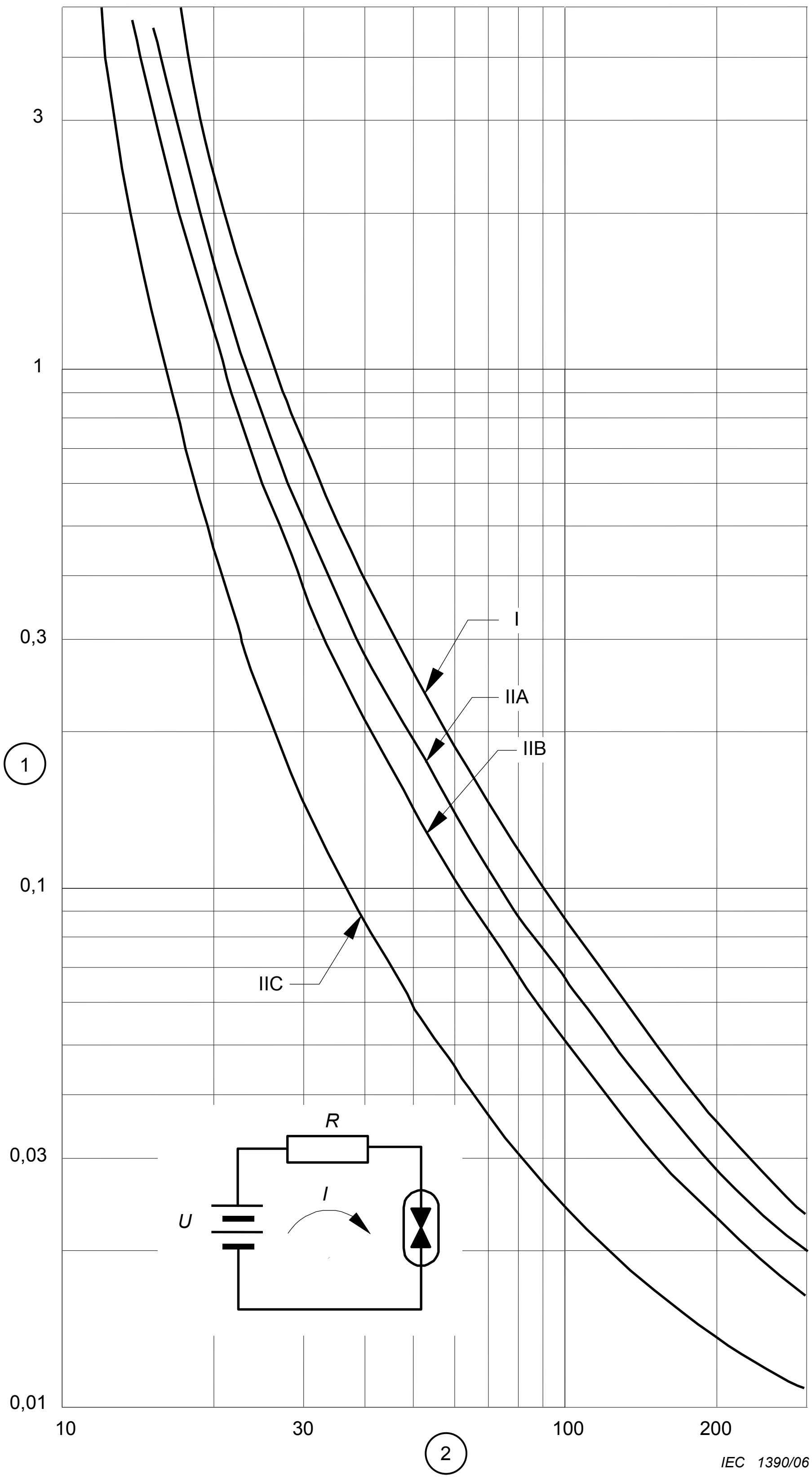
i) The maximum battery voltage is 30 V, and 10 μF is the maximum capacitance value. No faults are applied since the 10 kΩ resistor is infallible and either short-circuit or open-circuit failure of the capacitor gives rise to the circuit considered in b) 1).

ii) Application of the requirements of Clause 5 and 10.1.4.2 requires that, for a safety factor of 1,5, the voltage be increased to 1,5 × 30 V = 45 V.

iii) Reference to Figure A.2 for Group I shows that at 45 V the minimum value of capacitance to give ignition is only 3 μF and at 30 V only 7,2 μF, so that the circuit cannot be assessed as intrinsically safe.

NOTE 3 To modify the circuit so that it may be assessed as being intrinsically safe, there are several possibilities. The circuit voltage or capacitance values could be reduced, or an infallible resistor could be inserted in series with the 10 μF capacitor. Reference to Figure A.2 shows that the minimum igniting voltage for 10 μF is 26 V, so that the battery voltage would have to be reduced to 26/1,5 = 17,3 V if the value of 10 μF were to be maintained. Alternatively, the capacitance value could be reduced to 3 μF, or, since 10 μF + 5,6 Ω gives a minimum igniting voltage of 48 V, insertion of an infallible resistor having a minimum value of 5,6 Ω in series with the capacitor would also produce a circuit which could be assessed as intrinsically safe as regards spark ignition for Group I.

NOTE 4 One problem ignored in the above discussion is that, strictly speaking, the minimum igniting voltage curves for capacitive circuits in Figures A.2 and A.3 relate to a charged capacitor not directly connected to a power supply. In practice, provided the power supply considered by itself has a large safety factor, as in the above example, the reference curves can be applied. If, however, the power supply alone has only a minimum safety factor, interconnecting it with a capacitor can lead to a situation where the circuit is not intrinsically safe even though intrinsic safety may be inferred from Figures A.2 and A.3. In general, such circuits cannot be reliably assessed in the manner described above and should be tested with the spark test apparatus (see Annex B).

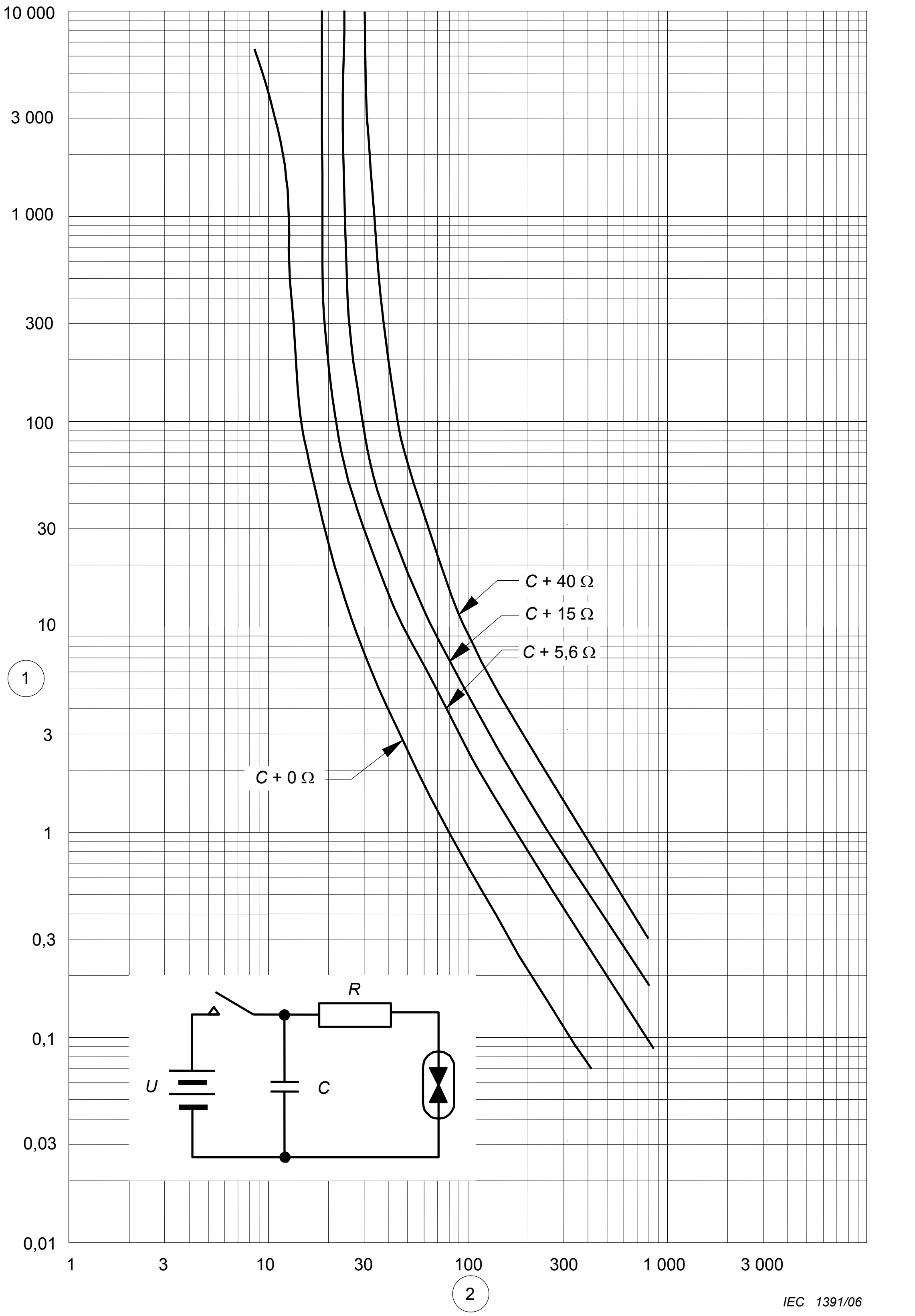


Key

1 Minimum ignition current *I* (A)

2 Source voltage *U* (V)

Figure A.1 – Resistive circuits



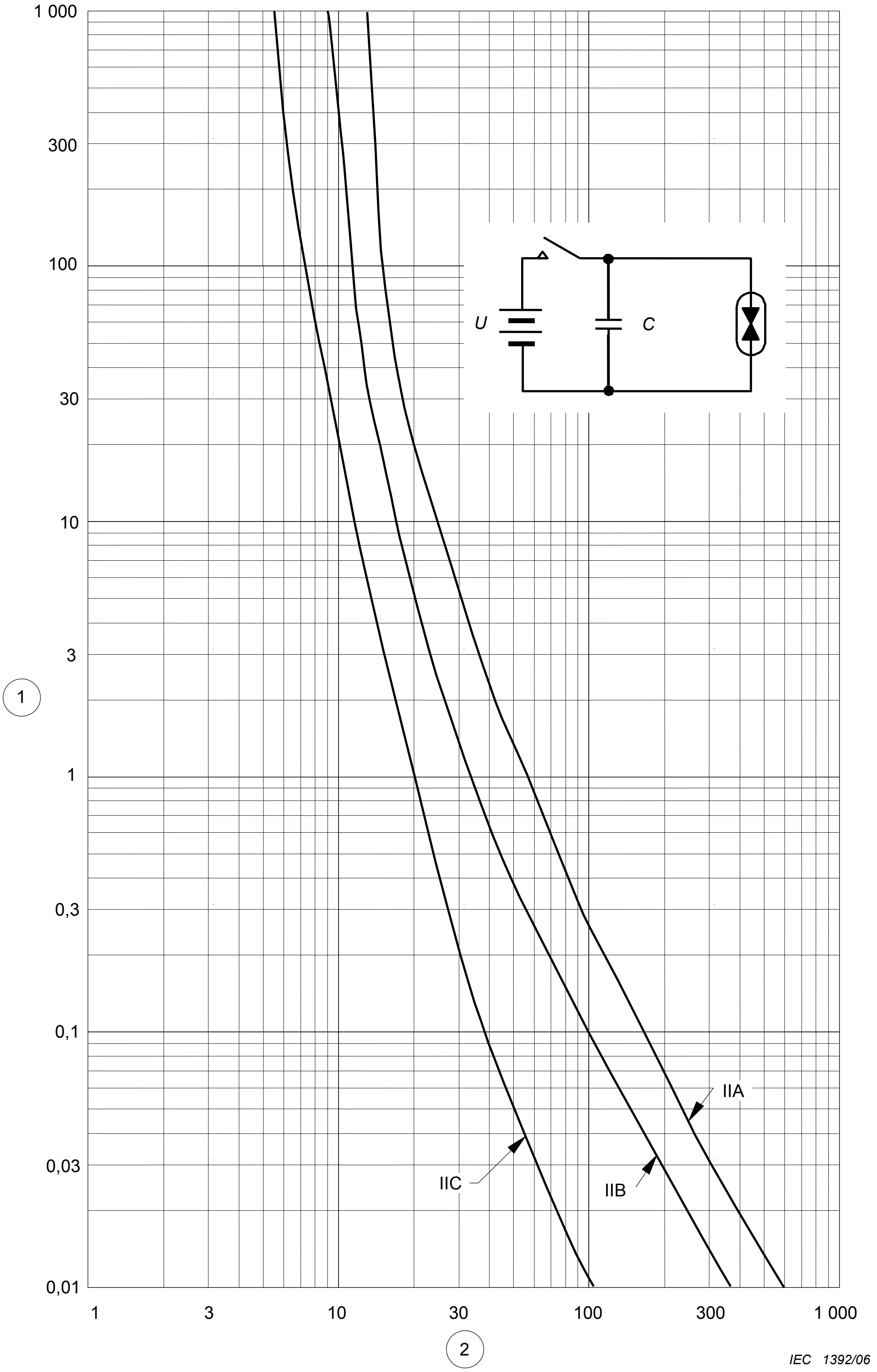
Key

1 Capacitance *C* (μF)

2 Minimum igniting voltage *U* (V)

NOTE The curves correspond to values of current-limiting resistance as indicated.

Figure A.2 – Group I capacitive circuits

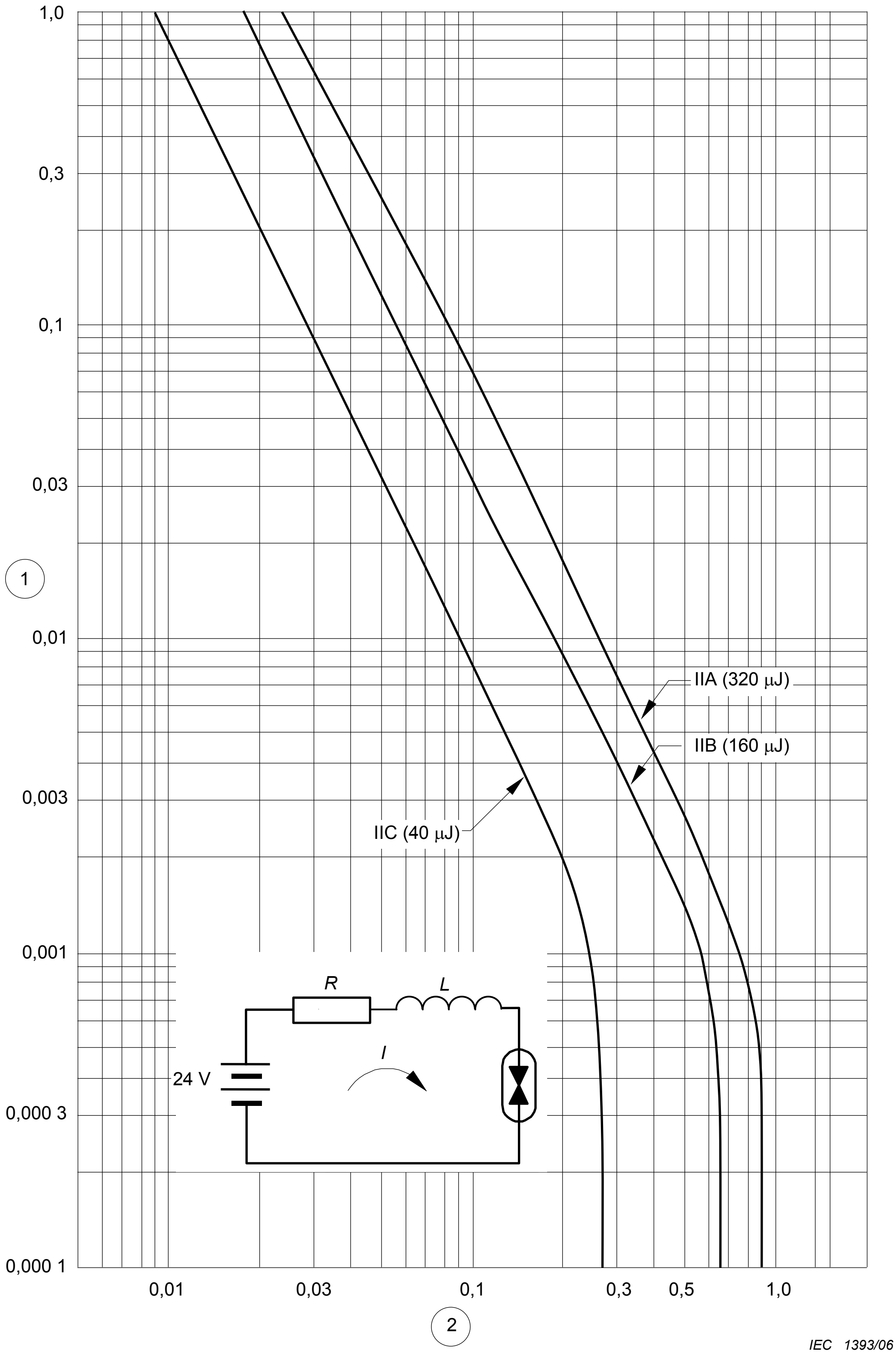


Key

1 Capacitance *C* (μF)

2 Minimum igniting voltage *U* (V)

Figure A.3 – Group II capacitive circuits



Key

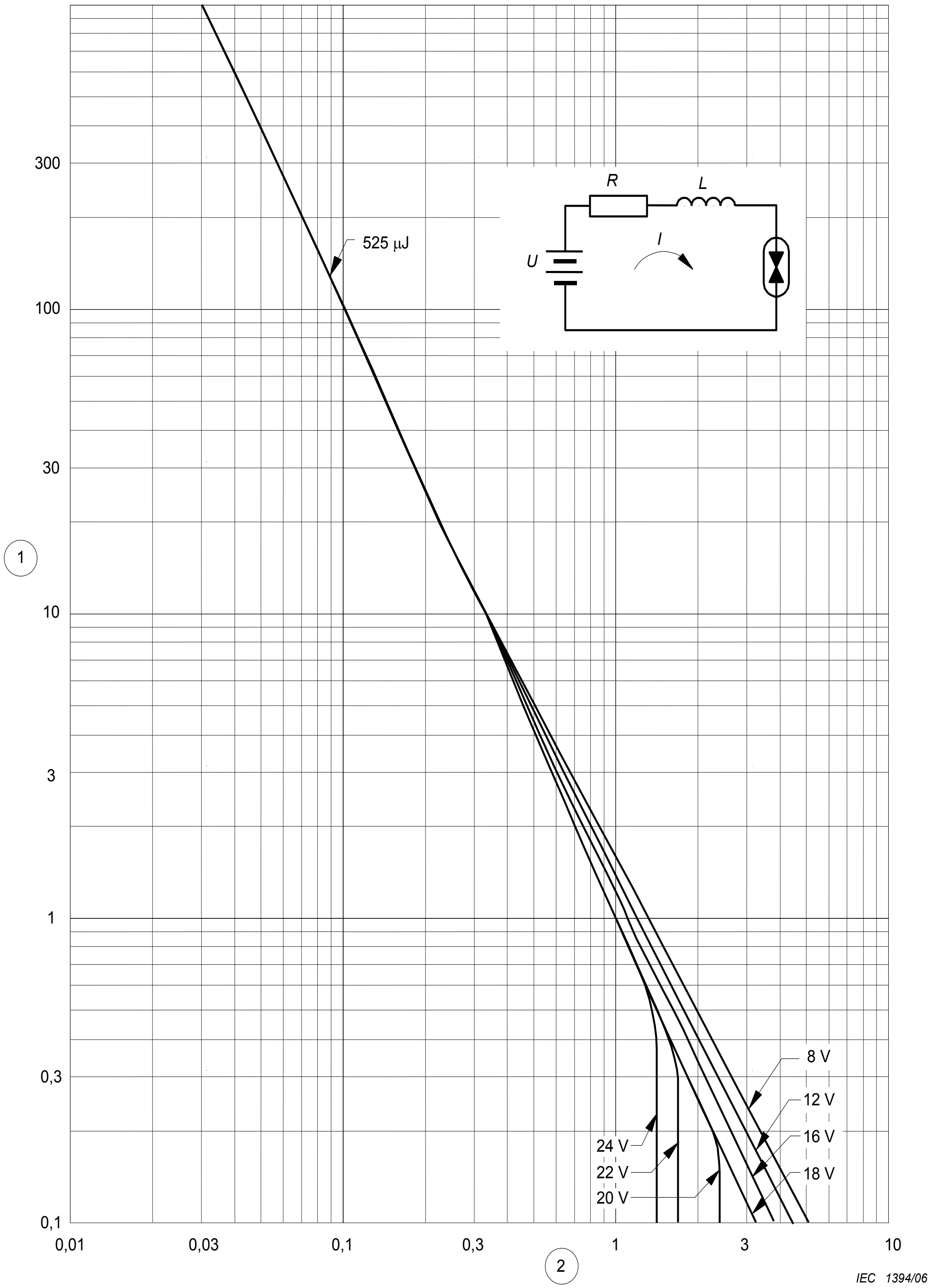
1 Inductance *L* (H)

2 Minimum igniting current *I* (A)

NOTE 1 The circuit test voltage is 24 V.

NOTE 2 The energy levels indicated refer to the constant energy portion of the curve.

Figure A.4 – Inductive circuits of Group II



Key

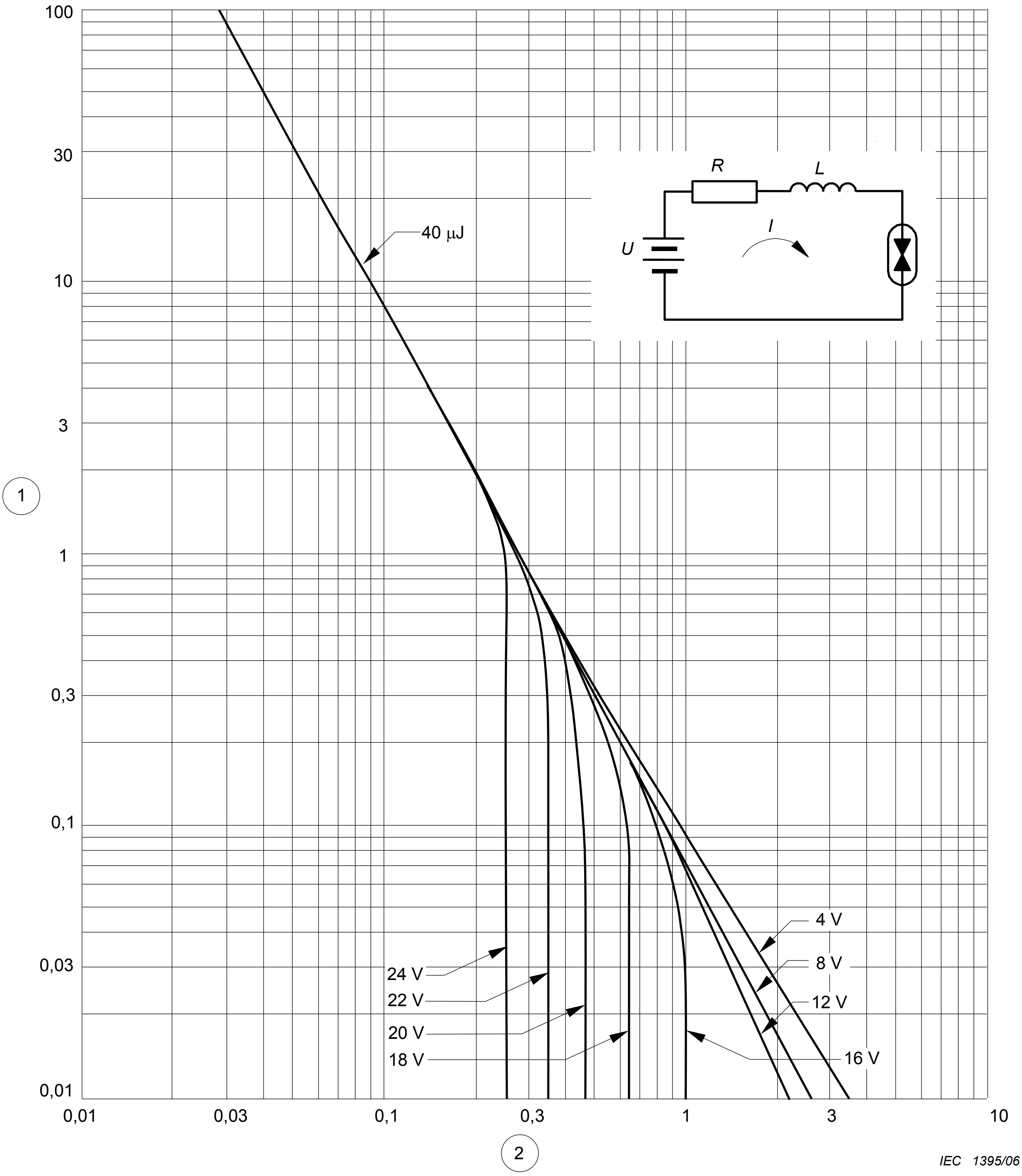
1 Inductance *L* (mH)

2 Minimum igniting current *I* (A)

NOTE 1 The curves correspond to values of circuit voltage *U* as indicated.

NOTE 2 The energy level of 525 μJ refers to the constant energy portion of the curve.

Figure A.5 – Group I inductive circuits



Key

1 Inductance *L* (mH)

2 Minimum igniting current *I* (A)

NOTE 1 The curves correspond to values of circuit voltage *U* as indicated.

NOTE 2 The energy level of 40 μJ refers to the constant energy portion of the curve.

Figure A.6 – Group IIC inductive circuits

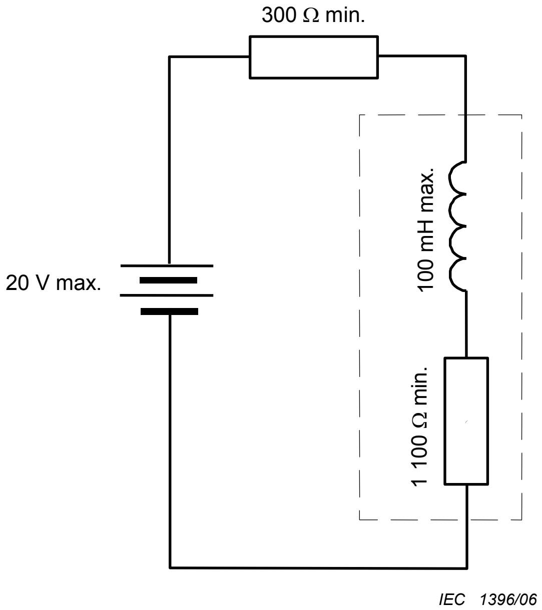


Figure A.7 – Simple inductive circuit

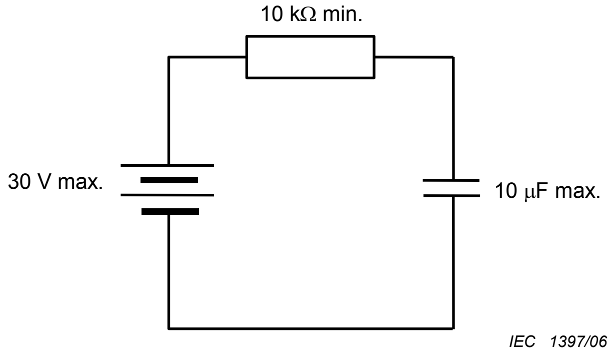


Figure A.8 – Simple capacitive circuit

Table A.1 – Permitted short-circuit current corresponding to the voltage and the Equipment Group

Voltage V	Permitted short-circuit current mA							
	for Group IIC apparatus		for Group IIB apparatus		for Group IIA apparatus		for Group I apparatus	
	with a factor of safety of		with a factor of safety of		with a factor of safety of		with a factor of safety of	
	×1	×1,5	×1	×1,5	×1	×1,5	×1	×1,5
12								
12,1	5 000	3 330						
12,2	4 720	3 150						
12,3	4 460	2 970						
12,4	4 210	2 810						
12,5	3 980	2 650						
12,6	3 770	2 510						
12,7	3 560	2 370						
12,8	3 370	2 250						
12,9	3 190	2 130						
13	3 020	2 020						
13,1	2 870	1 910						
13,2	2 720	1 810						
13,3	2 580	1 720						
13,4	2 450	1 630						
13,5	2 320	1 550	5 000	3 330				
13,6	2 210	1 470	4 860	3 240				
13,7	2 090	1 400	4 720	3 140				
13,8	1 990	1 330	4 580	3 050				
13,9	1 890	1 260	4 450	2 970				
14	1 800	1 200	4 330	2 880				
14,1	1 750	1 160	4 210	2 800				
14,2	1 700	1 130	4 090	2 730				
14,3	1 650	1 100	3 980	2 650				
14,4	1 600	1 070	3 870	2 580				
14,5	1 550	1 040	3 760	2 510				
14,6	1 510	1 010	3 660	2 440				
14,7	1 470	980	3 560	2 380				
14,8	1 430	950	3 470	2 310	5 000	3330		
14,9	1 390	930	3 380	2 250	4 860	3240		
15	1 350	900	3 290	2 190	4 730	3 150		
15,1	1 310	875	3 200	2 140	4 600	3 070		
15,2	1 280	851	3 120	2 080	4 480	2 990		
15,3	1 240	828	3 040	2 030	4 360	2 910		
15,4	1 210	806	2 960	1 980	4 250	2 830		
15,5	1 180	784	2 890	1 920	4 140	2 760		
15,6	1 150	769	2 810	1 880	4 030	2 690		
15,7	1 120	744	2 740	1 830	3 920	2 620		
15,8	1 090	724	2 680	1 780	3 820	2 550		
15,9	1 060	705	2 610	1 740	3 720	2 480		
16	1 030	687	2 550	1 700	3 630	2 420	5 000	3 330
16,1	1 000	669	2 480	1 660	3 540	2 360	4 830	3 220
16,2	980	652	2 420	1 610	3 450	2 300	4 660	3 110
16,3	950	636	2 360	1 570	3 360	2 240	4 490	2 990
16,4	930	620	2 310	1 540	3 280	2 190	4 320	2 880
16,5	910	604	2 250	1 500	3 200	2 130	4 240	2 830
16,6	880	589	2 200	1 470	3 120	2 080	4 160	2 770
16,7	860	575	2 150	1 430	3 040	2 030	4 080	2 720
16,8	840	560	2 100	1 400	2 970	1 980	4 000	2 670
16,9	820	547	2 050	1 370	2 900	1 930	3 740	2 490
17	800	533	2 000	1 340	2 830	1 890	3 480	2 320
17,1	780	523	1 960	1 310	2 760	1 840	3 450	2 300
17,2	770	513	1 930	1 280	2 700	1 800	3 420	2 280
17,3	750	503	1 890	1 260	2 630	1 760	3 390	2 260
17,4	740	493	1 850	1 240	2 570	1 720	3 360	2 240
17,5	730	484	1 820	1 210	2 510	1 680	3 320	2 210
17,6	710	475	1 790	1 190	2 450	1 640	3 300	2 200
17,7	700	466	1 750	1 170	2 400	1 600	3 260	2 170

Table A.1 *(continued)*

Voltage V	Permitted short-circuit current mA							
	for Group IIC apparatus		for Group IIB apparatus		for Group IIA apparatus		for Group I apparatus	
	with a factor of safety of		with a factor of safety of		with a factor of safety of		with a factor of safety of	
	×1	×1,5	×1	×1,5	×1	×1,5	×1	×1,5
17,8	690	457	1720	1150	2340	1560	3230	2150
17,9	670	448	1690	1130	2290	1530	3200	2130
18	660	440	1660	1110	2240	1490	3170	2110
18.1	648	432	1630	1087	2188	1459	3083	2055
18,2	636	424	1601	1068	2139	1426	3000	2000
18,3	625	417	1573	1049	2091	1394	2935	1956
18,4	613	409	1545	1030	2045	1363	2871	1914
18,5	602	402	1518	1012	2000	1333	2807	1871
18,6	592	394	1491	995	1967	1311	2743	1828
18,7	581	387	1466	977	1935	1290	2679	1786
18,8	571	380	1441	960	1903	1269	2615	1743
18,9	561	374	1416	944	1872	1248	2551	1700
19	551	367	1392	928	1842	1228	2487	1658
19,1	541	361	1368	912	1812	1208	2465	1643
19,2	532	355	1345	897	1784	1189	2444	1629
19,3	523	348	1323	882	1755	1170	2423	1615
19,4	514	342	1301	867	1727	1152	2401	1600
19,5	505	337	1279	853	1700	1134	2380	1586
19,6	496	331	1258	839	1673	1116	2359	1572
19,7	484	325	1237	825	1648	1098	2337	1558
19,8	480	320	1217	811	1622	1081	2316	1544
19,9	472	314	1197	798	1597	1065	2295	1530
20	464	309	1177	785	1572	1048	2274	1516
20,1	456	304	1158	772	1549	1032	2219	1479
20,2	448	299	1140	760	1525	1016	2164	1443
20,3	441	294	1122	748	1502	1001	2109	1406
20,4	434	289	1104	736	1479	986	2054	1369
20,5	427	285	1087	724	1457	971	2000	1333
20,6	420	280	1069	713	1435	957	1924	1283
20,7	413	275	1053	702	1414	943	1849	1233
20,8	406	271	1036	691	1393	929	1773	1182
20,9	400	267	1020	680	1373	915	1698	1132
21	394	262	1004	670	1353	902	1623	1082
21,1	387	258	989	659	1333	889	1603	1069
21,2	381	254	974	649	1314	876	1583	1055
21,3	375	250	959	639	1295	863	1564	1043
21,4	369	246	945	630	1276	851	1544	1029
21,5	364	243	930	620	1258	839	1525	1017
21,6	358	239	916	611	1240	827	1505	1003
21,7	353	235	903	602	1222	815	1485	990
21,8	347	231	889	593	1205	804	1466	977,3
21,9	342	228	876	584	1189	792	1446	964
22	337	224	863	575	1172	781	1427	951,3
22,1	332	221	851	567	1156	770	1394	929,3
22,2	327	218	838	559	1140	760	1361	907,3
22,3	322	215	826	551	1124	749	1328	885,3
22,4	317	211	814	543	1109	739	1296	864
22,5	312	208	802	535	1093	729	1281	854
22,6	308	205	791	527	1078	719	1267	844,7
22,7	303	202	779	520	1064	709	1253	835,3
22,8	299	199	768	512	1050	700	1239	826
22,9	294	196	757	505	1036	690	1225	816,7
23	290	193	747	498	1022	681	1211	807,3
23,1	287	191	736	491	1008	672	1185	790
23,2	284	189	726	484	995	663	1160	773,3
23,3	281	187	716	477	982	655	1135	756,7
23,4	278	185	706	471	969	646	1110	740
23,5	275	183	696	464	956	638	1085	723,3
23,6	272	182	687	458	944	629	1079	719,3

Table A.1 *(continued)*

Voltage V	Permitted short-circuit current mA							
	for Group IIC apparatus		for Group IIB apparatus		for Group IIA apparatus		for Group I apparatus	
	with a factor of safety of		with a factor of safety of		with a factor of safety of		with a factor of safety of	
	×1	×1,5	×1	×1,5	×1	×1,5	×1	×1,5
23,7	270	180	677	452	932	621	1 073	715,3
23,8	267	178	668	445	920	613	1 068	712
23,9	264	176	659	439	908	605	1 062	708
24	261	174	650	433	896	597	1 057	704,7
24,1	259	173	644	429	885	590	1 048	698,7
24,2	256	171	637	425	873	582	1 040	693,3
24,3	253	169	631	421	862	575	1 032	688
24,4	251	167	625	416	852	568	1 024	682,7
24,5	248	166	618	412	841	561	1 016	677,3
24,6	246	164	612	408	830	554	1 008	672
24,7	244	163	606	404	820	547	1 000	666,7
24,8	241	161	601	400	810	540	991	660,7
24,9	239	159	595	396	800	533	983	655,3
25	237	158	589	393	790	527	975	650
25,1	234	156	583	389	780	520	964	642,7
25,2	232	155	578	385	771	514	953	635,3
25,3	230	153	572	381	762	508	942	628
25,4	228	152	567	378	752	502	931	620,7
25,5	226	150	561	374	743	496	920	613,3
25,6	223	149	556	371	734	490	916	610,7
25,7	221	148	551	367	726	484	912	608
25,8	219	146	546	364	717	478	908	605,3
25,9	217	145	541	360	708	472	904	602,7
26	215	143	536	357	700	467	900	600
26,1	213	142	531	354	694	463	890	593,3
26,2	211	141	526	350	688	459	881	587,3
26,3	209	139	521	347	683	455	871	580,7
26,4	207	138	516	344	677	451	862	574,7
26,5	205	137	512	341	671	447	853	568,7
26,6	203	136	507	338	666	444	847	564,7
26,7	202	134	502	335	660	440	841	560,7
26,8	200	133	498	332	655	437	835	556,7
26,9	198	132	493	329	649	433	829	552,7
27	196	131	489	326	644	429	824	549,3
27,1	194	130	485	323	639	426	818	545,3
27,2	193	128	480	320	634	422	813	542
27,3	191	127	476	317	629	419	808	538,7
27,4	189	126	472	315	624	416	803	535,3
27,5	188	125	468	312	619	412	798	532
27,6	186	124	464	309	614	409	793	528,7
27,7	184	123	460	306	609	406	788	525,3
27,8	183	122	456	304	604	403	783	522
27,9	181	121	452	301	599	399	778	518,7
28	180	120	448	299	594	396	773	515,3
28,1	178	119	444	296	590	393	768	512
28,2	176	118	440	293	585	390	764	509,3
28,3	175	117	436	291	581	387	760	506,7
28,4	173	116	433	288	576	384	756	504
28,5	172	115	429	286	572	381	752	501,3
28,6	170	114	425	284	567	378	747	498
28,7	169	113	422	281	563	375	743	495,3
28,8	168	112	418	279	559	372	739	492,7
28,9	166	111	415	277	554	370	735	490
29	165	110	411	274	550	367	731	487,3
29,1	163	109	408	272	546	364	728	485,3
29,2	162	108	405	270	542	361	726	484
29,3	161	107	401	268	538	358	724	482,7
29,4	159	106	398	265	534	356	722	481,3
29,5	158	105	395	263	530	353	720	480

Table A.1 *(continued)*

Voltage V	Permitted short-circuit current mA							
	for Group IIC apparatus		for Group IIB apparatus		for Group IIA apparatus		for Group I apparatus	
	with a factor of safety of		with a factor of safety of		with a factor of safety of		with a factor of safety of	
	×1	×1,5	×1	×1,5	×1	×1,5	×1	×1,5
29,6	157	105	392	261	526	351	718	478,7
29,7	155	104	388	259	522	348	716	477,3
29,8	154	103	385	257	518	345	714	476
29,9	153	102	382	255	514	343	712	474,7
30	152	101	379	253	510	340	710	473,3
30,2	149	99,5	373	249	503	335	690	460
30,4	147	97,9	367	245	496	330	671	447,3
30,6	145	96,3	362	241	489	326	652	434,7
30,8	142	94,8	356	237	482	321	636	424
31	140	93,3	350	233	475	317	621	414
31,2	138	92,2	345	230	468	312	614	409,3
31,4	137	91	339	226	462	308	607	404,7
31,6	135	89,9	334	223	455	303	600	400
31,8	133	88,8	329	219	449	299	592	394,7
32	132	87,8	324	216	442	295	584	389,3
32,2	130	86,7	319	213	436	291	572	381,3
32,4	129	85,7	315	210	431	287	560	373,3
32,6	127	84,7	310	207	425	283	548	365,3
32,8	126	83,7	305	204	419	279	536	357,3
33	124	82,7	301	201	414	276	525	350
33,2	123	81,7	297	198	408	272	520	346,7
33,4	121	80,8	292	195	403	268	515	343,3
33,6	120	79,8	288	192	398	265	510	340
33,8	118	78,9	284	189	393	262	505	336,7
34	117	78	280	187	389	259	500	333,3
34,2	116	77,2	277	185	384	256	491	327,3
34,4	114	76,3	274	183	380	253	482	321,3
34,6	113	75,4	271	181	376	251	473	315,3
34,8	112	74,6	269	179	372	248	464	309,3
35	111	73,8	266	177	368	245	455	303,3
35,2	109	73	263	175	364	242	450	300
35,4	108	72,2	260	174	360	240	446	297,3
35,6	107	71,4	258	172	356	237	442	294,7
35,8	106	70,6	255	170	352	235	438	292
36	105	69,9	253	168	348	232	434	289,3
36,2	104	69,1	250	167	345	230	431	287,3
36,4	103	68,4	248	165	341	227	429	286
36,6	102	67,7	245	164	337	225	426	284
36,8	100	66,9	243	162	334	223	424	282,7
37	99,4	66,2	241	160	330	220	422	281,3
37,2	98,3	65,6	238	159	327	218	419	279,3
37,4	97,3	64,9	236	157	324	216	417	278
37,6	96,3	64,2	234	156	320	214	414	276
37,8	95,3	63,6	231	154	317	211	412	274,7
38	94,4	62,9	229	153	314	209	410	273,3
38,2	93,4	62,3	227	151	311	207	408	272
38,4	92,5	61,6	225	150	308	205	407	271,3
38,6	91,5	61	223	149	304	203	405	270
38,8	90,6	60,4	221	147	301	201	404	269,3
39	89,7	59,8	219	146	298	199	403	268,7
39,2	88,8	59,2	217	145	296	197	399	266
39,4	88	58,6	215	143	293	195	395	263,3
39,6	87,1	58,1	213	142	290	193	391	260,7
39,8	86,3	57,5	211	141	287	191	387	258
40	85,4	57	209	139	284	190	383	255,3
40,5	83,4	55,6	205	136	278	185	362	241,3
41	81,4	54,3	200	133	271	181	342	228
41,5	79,6	53	196	131	265	177	336	224
42	77,7	51,8	192	128	259	173	331	220,7
42,5	76	50,6	188	125	253	169	321	214

Table A.1 *(continued)*

Voltage V	**Permitted short-circuit current** mA							
	for Group IIC apparatus		**for Group IIB apparatus**		**for Group IIA apparatus**		**for Group I apparatus**	
	with a factor of safety of		**with a factor of safety of**		**with a factor of safety of**		**with a factor of safety of**	
	×1	**×1,5**	**×1**	**×1,5**	**×1**	**×1,5**	**×1**	**×1,5**
43	74,3	49,5	184	122	247	165	312	208
43,5	72,6	48,4	180	120	242	161	307	204,7
44	71	47,4	176	117	237	158	303	202
44,5	69,5	46,3	173	115	231	154	294	196
45	68	45,3	169	113	227	151	286	190,7

Table A.2 – Permitted capacitance corresponding to the voltage and the Equipment Group

Voltage V	Permitted capacitance µF							
	for Group IIC apparatus		for Group IIB apparatus		for Group IIA apparatus		for Group I apparatus	
	with a factor of safety of		with a factor of safety of		with a factor of safety of		with a factor of safety of	
	×1	×1,5	×1	×1,5	×1	×1,5	×1	×1,5
5,0		100						
5,1		88						
5,2		79						
5,3		71						
5,4		65						
5,5		58						
5,6	1 000	54						
5,7	860	50						
5,8	750	46						
5,9	670	43						
6,0	600	40		1 000				
6,1	535	37		880				
6,2	475	34		790				
6,3	420	31		720				
6,4	370	28		650				
6,5	325	25		570				
6,6	285	22		500				
6,7	250	19,6		430				
6,8	220	17,9		380				
6,9	200	16,8		335				
7,0	175	15,7		300				
7,1	155	14,6		268				
7,2	136	13,5		240				
7,3	120	12,7		216				
7,4	110	11,9		195				
7,5	100	11,1		174				
7,6	92	10,4		160				
7,7	85	9,8		145				
7,8	79	9,3		130				
7,9	74	8,8		115				
8,0	69	8,4		100				
8,1	65	8,0		90				
8,2	61	7,6		81				
8,3	56	7,2		73				
8,4	54	6,8		66				
8,5	51	6,5		60				
8,6	49	6,2		55				
8,7	47	5,9		50		1 000		
8,8	45	5,5		46		730		
8,9	42	5,2		43		590		
9,0	40	4,9	1 000	40		500		
9,1	38	4,6	920	37		446		
9,2	36	4,3	850	34		390		
9,3	34	4,1	790	31		345		
9,4	32	3,9	750	29		300		
9,5	30	3,7	700	27		255		1 000
9,6	28	3,6	650	26		210		500
9,7	26	3,5	600	24		170		320
9,8	24	3,3	550	23		135		268
9,9	22	3,2	500	22		115		190
10,0	20,0	3,0	450	20,0		100		180
10,1	18,7	2,87	410	19,4		93		160
10,2	17,8	2,75	380	18,7		88		140
10,3	17,1	2,63	350	18,0		83		120
10,4	16,4	2,52	325	17,4		79		110
10,5	15,7	2,41	300	16,8		75		95
10,6	15,0	2,32	280	16,2		72		90
10,7	14,2	2,23	260	15,6		69		85
10,8	13,5	2,14	240	15,0		66		80
10,9	13,0	2,05	225	14,4		63		70
11,0	12,5	1,97	210	13,8		60		67,5
11,1	11,9	1,90	195	13,2		57,0		60

Table A.2 *(continued)*

Voltage V	Permitted capacitance µF							
	for Group IIC apparatus		for Group IIB apparatus		for Group IIA apparatus		for Group I apparatus	
	with a factor of safety of		with a factor of safety of		with a factor of safety of		with a factor of safety of	
	×1	×1,5	×1	×1,5	×1	×1,5	×1	×1,5
11,2	11,4	1,84	180	12,6		54,0		58
11,3	10,9	1,79	170	12,1		51,0		54
11,4	10,4	1,71	160	11,7		48,0		52
11,5	10,0	1,64	150	11,2		46,0		48
11,6	9,6	1,59	140	10,8		43,0		46
11,7	9,3	1,54	130	10,3		41,0		42
11,8	9,0	1,50	120	9,9		39,0		40
11,9	8,7	1,45	110	9,4		37,0		38,6
12,0	8,4	1,41	100	9,0		36,0		38
12,1	8,1	1,37	93	8,7		34,0		36,6
12,2	7,9	1,32	87	8,4		33,0		36
12,3	7,6	1,28	81	8,1		31,0		34,3
12,4	7,2	1,24	75	7,9		30,0		34
12,5	7,0	1,2	70	7,7		28,0		32,3
12,6	6,8	1,15	66	7,4		27,0		32
12,7	6,6	1,10	62	7,1		25,4		30,5
12,8	6,4	1,06	58	6,8		24,2		30
12,9	6,2	1,03	55	6,5		23,2		29
13,0	6,0	1,0	52	6,2	1 000	22,5		28,5
13,1	5,7	0,97	49	6,0	850	21,7		27,5
13,2	5,4	0,94	46	5,8	730	21,0		27
13,3	5,3	0,91	44	5,6	630	20,2		26
13,4	5,1	0,88	42	5,5	560	19,5		25,6
13,5	4,9	0,85	40	5,3	500	19,0		24,8
13,6	4,6	0,82	38	5,2	450	18,6		24,4
13,7	4,4	0,79	36	5,0	420	18,1		23,5
13,8	4,2	0,76	34	4,9	390	17,7		23
13,9	4,1	0,74	32	4,7	360	17,3		22
14,0	4,0	0,73	30	4,60	330	17,0		21,5
14,1	3,9	0,71	29	4,49	300	16,7		20,5
14,2	3,8	0,70	28	4,39	270	16,4	1 000	20
14,3	3,7	0,68	27	4,28	240	16,1	800	19,64
14,4	3,6	0,67	26	4,18	210	15,8	500	19,48
14,5	3,5	0,65	25	4,07	185	15,5	360	19,16
14,6	3,4	0,64	24	3,97	160	15,2	320	19
14,7	3,3	0,62	23	3,86	135	14,9	268	18,6
14,8	3,2	0,61	22	3,76	120	14,6	220	18,4
14,9	3,1	0,59	21	3,65	110	14,3	190	18
15,0	3,0	0,58	20,2	3,55	100	14,0	180	17,8
15,1	2,9	0,57	19,7	3,46	95	13,7	170	17,48
15,2	2,82	0,55	19,2	3,37	91	13,4	160	17,32
15,3	2,76	0,53	18,7	3,28	88	13,1	140	17
15,4	2,68	0,521	18,2	3,19	85	12,8	130	16,8
15,5	2,60	0,508	17,8	3,11	82	12,5	120	16,48
15,6	2,52	0,497	17,4	3,03	79	12,2	110	16,32
15,7	2,45	0,487	17,0	2,95	77	11,9	100	16
15,8	2,38	0,478	16,6	2,88	74	11,6	95	15,8
15,9	2,32	0,469	16,2	2,81	72	11,3	90	15,4
16,0	2,26	0,460	15,8	2,75	70	11,0	87,5	15,2
16,1	2,20	0,451	15,4	2,69	68	10,7	85	14,8
16,2	2,14	0,442	15,0	2,63	66	10,5	80	14,64
16,3	2,08	0,433	14,6	2,57	64	10,2	75	14,32
16,4	2,02	0,424	14,2	2,51	62	10,0	70	14,16
16,5	1,97	0,415	13,8	2,45	60	9,8	67,5	13,8
16,6	1,92	0,406	13,4	2,40	58	9,6	65	13,64
16,7	1,88	0,398	13,0	2,34	56	9,4	60	13,32
16,8	1,84	0,390	12,6	2,29	54	9,3	58	13,16
16,9	1,80	0,382	12,3	2,24	52	9,1	56	12,8
17,0	1,76	0,375	12,0	2,20	50	9,0	54	12,64
17,1	1,71	0,367	11,7	2,15	48	8,8	52	12,32
17,2	1,66	0,360	11,4	2,11	47	8,7	50	12,16
17,3	1,62	0,353	11,1	2,06	45	8,5	48	11,8
17,4	1,59	0,346	10,8	2,02	44	8,4	46	11,6

Table A.2 *(continued)*

Voltage V	Permitted capacitance µF for Group IIC apparatus with a factor of safety of ×1	for Group IIC ×1,5	for Group IIB apparatus with a factor of safety of ×1	for Group IIB ×1,5	for Group IIA apparatus with a factor of safety of ×1	for Group IIA ×1,5	for Group I apparatus with a factor of safety of ×1	for Group I ×1,5
17,5	1,56	0,339	10,5	1,97	42	8,2	44	11,2
17,6	1,53	0,333	10,2	1,93	40	8,1	42	11
17,7	1,50	0,327	9,9	1,88	39	8,0	40	10,64
17,8	1,47	0,321	9,6	1,84	38	7,9	39,2	10,48
17,9	1,44	0,315	9,3	1,80	37	7,7	38,6	10,16
18,0	1,41	0,309	9,0	1,78	36	7,6	38	10
18,1	1,38	0,303	8,8	1,75	35	7,45	37,3	9,86
18,2	1,35	0,297	8,6	1,72	34	7,31	36,6	9,8
18,3	1,32	0,291	8,4	1,70	33	7,15	36	9,68
18,4	1,29	0,285	8,2	1,69	32	7,0	34,6	9,62
18,5	1,27	0,280	8,0	1,67	31	6,85	34,3	9,5
18,6	1,24	0,275	7,9	1,66	30	6,70	34	9,42
18,7	1,21	0,270	7,8	1,64	29	6,59	32,6	9,28
18,8	1,18	0,266	7,6	1,62	28	6,48	32,3	9,21
18,9	1,15	0,262	7,4	1,60	27	6,39	32	9,07
19,0	1,12	0,258	7,2	1,58	26	6,3	31,2	9
19,1	1,09	0,252	7,0	1,56	25,0	6,21	30,5	8,86
19,2	1,06	0,251	6,8	1,55	24,2	6,12	30	8,8
19,3	1,04	0,248	6,6	1,52	23,6	6,03	29,5	8,68
19,4	1,02	0,244	6,4	1,51	23,0	5,95	29	8,62
19,5	1,00	0,240	6,2	1,49	22,5	5,87	28,5	8,5
19,6	0,98	0,235	6,0	1,47	22,0	5,8	28	8,42
19,7	0,96	0,231	5,9	1,45	21,5	5,72	27,5	8,28
19,8	0,94	0,227	5,8	1,44	21,0	5,65	27	8,21
19,9	0,92	0,223	5,7	1,42	20,5	5,57	26,5	8,07
20,0	0,90	0,220	5,6	1,41	20,0	5,5	26	8
20,1	0,88	0,217	5,5	1,39	19,5	5,42	25,6	7,87
20,2	0,86	0,213	5,4	1,38	19,2	5,35	25,2	7,8
20,3	0,84	0,209	5,3	1,36	18,9	5,27	24,8	7,75
20,4	0,82	0,206	5,2	1,35	18,6	5,2	24,4	7,62
20,5	0,8	0,203	5,1	1,33	18,3	5,12	24	7,5
20,6	0,78	0,200	5,0	1,32	18,0	5,05	23,5	7,42
20,7	0,76	0,197	4,9	1,31	17,7	4,97	23	7,33
20,8	0,75	0,194	4,8	1,30	17,4	4,9	22,5	7,16
20,9	0,74	0,191	4,7	1,28	17,2	4,84	22	7
21,0	0,73	0,188	4,6	1,27	17,0	4,78	21,5	6,93
21,1	0,72	0,185	4,52	1,25	16,8	4,73	21	6,87
21,2	0,71	0,183	4,45	1,24	16,6	4,68	20,5	6,75
21,3	0,7	0,181	4,39	1,23	16,4	4,62	20	6,62
21,4	0,69	0,179	4,32	1,22	16,2	4,56	19,8	6,56
21,5	0,68	0,176	4,25	1,20	16,0	4,5	19,64	6,5
21,6	0,67	0,174	4,18	1,19	15,8	4,44	19,48	6,37
21,7	0,66	0,172	4,11	1,17	15,6	4,38	19,32	6,25
21,8	0,65	0,169	4,04	1,16	15,4	4,32	19,16	6,18
21,9	0,64	0,167	3,97	1,15	15,2	4,26	19	6,12
22,0	0,63	0,165	3,90	1,14	15,0	4,20	18,8	6
22,1	0,62	0,163	3,83	1,12	14,8	4,14	18,6	5,95
22,2	0,61	0,160	3,76	1,11	14,6	4,08	18,4	5,92
22,3	0,6	0,158	3,69	1,10	14,4	4,03	18,2	5,9
22,4	0,59	0,156	3,62	1,09	14,2	3,98	18	5,85
22,5	0,58	0,154	3,55	1,08	14,0	3,93	17,8	5,8
22,6	0,57	0,152	3,49	1,07	13,8	3,88	17,64	5,77
22,7	0,56	0,149	3,43	1,06	13,6	3,83	17,48	5,75
22,8	0,55	0,147	3,37	1,05	13,4	3,79	17,32	5,7
22,9	0,54	0,145	3,31	1,04	13,2	3,75	17,16	5,65
23,0	0,53	0,143	3,25	1,03	13,0	3,71	17	5,62
23,1	0,521	0,140	3,19	1,02	12,8	3,67	16,8	5,6
23,2	0,513	0,138	3,13	1,01	12,6	3,64	16,54	5,55
23,3	0,505	0,136	3,08	1,0	12,4	3,60	16,48	5,5
23,4	0,497	0,134	3,03	0,99	12,2	3,57	16,32	5,47
23,5	0,49	0,132	2,98	0,98	12,0	3,53	16,16	5,45

Table A.2 *(continued)*

Voltage V	Permitted capacitance µF							
	for Group IIC apparatus		for Group IIB apparatus		for Group IIA apparatus		for Group I apparatus	
	with a factor of safety of		with a factor of safety of		with a factor of safety of		with a factor of safety of	
	×1	×1,5	×1	×1,5	×1	×1,5	×1	×1,5
23,6	0,484	0,130	2,93	0,97	11,8	3,50	16	5,4
23,7	0,478	0,128	2,88	0,96	11,6	3,46	15,8	5,35
23,8	0,472	0,127	2,83	0,95	11,4	3,42	15,6	5,32
23,9	0,466	0,126	2,78	0,94	11,2	3,38	15,4	5,3
24,0	0,46	0,125	2,75	0,93	11,0	3,35	15,2	5,25
24,1	0,454	0,124	2,71	0,92	10,8	3,31	15	5,2
24,2	0,448	0,122	2,67	0,91	10,7	3,27	14,8	5,17
24,3	0,442	0,120	2,63	0,90	10,5	3,23	14,64	5,15
24,4	0,436	0,119	2,59	0,89	10,3	3,20	14,48	5,1
24,5	0,43	0,118	2,55	0,88	10,2	3,16	14,32	5,05
24,6	0,424	0,116	2,51	0,87	10,0	3,12	14,16	5,02
24,7	0,418	0,115	2,49	0,87	9,9	3,08	14	5,0
24,8	0,412	0,113	2,44	0,86	9,8	3,05	13,8	4,95
24,9	0,406	0,112	2,4	0,85	9,6	3,01	13,64	4,9
25,0	0,4	0,110	2,36	0,84	9,5	2,97	13,48	4,87
25,1	0,395	0,108	2,32	0,83	9,4	2,93	13,32	4,85
25,2	0,390	0,107	2,29	0,82	9,3	2,90	13,16	4,8
25,3	0,385	0,106	2,26	0,82	9,2	2,86	13	4,75
25,4	0,380	0,105	2,23	0,81	9,1	2,82	12,8	4,72
25,5	0,375	0,104	2,20	0,80	9,0	2,78	12,64	4,7
25,6	0,37	0,103	2,17	0,80	8,9	2,75	12,48	4,65
25,7	0,365	0,102	2,14	0,79	8,8	2,71	12,32	4,6
25,8	0,36	0,101	2,11	0,78	8,7	2,67	12,16	4,57
25,9	0,355	0,100	2,08	0,77	8,6	2,63	12	4,55
26,0	0,35	0,099	2,05	0,77	8,5	2,60	11,8	4,5
26,1	0,345	0,098	2,02	0,76	8,4	2,57	11,6	4,45
26,2	0,341	0,097	1,99	0,75	8,3	2,54	11,4	4,42
26,3	0,337	0,097	1,96	0,74	8,2	2,51	11,2	4,4
26,4	0,333	0,096	1,93	0,74	8,1	2,48	11	4,35
26,5	0,329	0,095	1,90	0,73	8,0	2,45	10,8	4,3
26,6	0,325	0,094	1,87	0,73	8,0	2,42	10,64	4,27
26,7	0,321	0,093	1,84	0,72	7,9	2,39	10,48	4,25
26,8	0,317	0,092	1,82	0,72	7,8	2,37	10,32	4,2
26,9	0,313	0,091	1,80	0,71	7,7	2,35	10,16	4,15
27,0	0,309	0,090	1,78	0,705	7,6	2,33	10	4,12
27,1	0,305	0,089	1,76	0,697	7,5	2,31	9,93	4,1
27,2	0,301	0,089	1,74	0,690	7,42	2,30	9,86	4,05
27,3	0,297	0,088	1,72	0,683	7,31	2,28	9,8	4,0
27,4	0,293	0,087	1,71	0,677	7,21	2,26	9,74	3,97
27,5	0,289	0,086	1,70	0,672	7,10	2,24	9,68	3,95
27,6	0,285	0,086	1,69	0,668	7,00	2,22	9,62	3,9
27,7	0,281	0,085	1,68	0,663	6,90	2,20	9,56	3,85
27,8	0,278	0,084	1,67	0,659	6,80	2,18	9,5	3,82
27,9	0,275	0,084	1,66	0,654	6,70	2,16	9,42	3,8
28,0	0,272	0,083	1,65	0,650	6,60	2,15	9,35	3,76
28,1	0,269	0,082	1,63	0,645	6,54	2,13	9,28	3,72
28,2	0,266	0,081	1,62	0,641	6,48	2,11	9,21	3,70
28,3	0,263	0,08	1,60	0,636	6,42	2,09	9,14	3,68
28,4	0,26	0,079	1,59	0,632	6,36	2,07	9,07	3,64
28,5	0,257	0,078	1,58	0,627	6,30	2,05	9	3,6
28,6	0,255	0,077	1,57	0,623	6,24	2,03	8,93	3,57
28,7	0,253	0,077	1,56	0,618	6,18	2,01	8,86	3,55
28,8	0,251	0,076	1,55	0,614	6,12	2,00	8,8	3,5
28,9	0,249	0,075	1,54	0,609	6,06	1,98	8,74	3,45
29,0	0,247	0,074	1,53	0,605	6,00	1,97	8,68	3,42
29,1	0,244	0,074	1,51	0,600	5,95	1,95	8,62	3,4
29,2	0,241	0,073	1,49	0,596	5,90	1,94	8,56	3,35
29,3	0,238	0,072	1,48	0,591	5,85	1,92	8,5	3,3
29,4	0,235	0,071	1,47	0,587	5,80	1,91	8,42	3,27
29,5	0,232	0,071	1,46	0,582	5,75	1,89	8,35	3,25

Table A.2 *(continued)*

Voltage V	Permitted capacitance µF							
	for Group IIC apparatus		for Group IIB apparatus		for Group IIA apparatus		for Group I apparatus	
	with a factor of safety of		with a factor of safety of		with a factor of safety of		with a factor of safety of	
	×1	×1,5	×1	×1,5	×1	×1,5	×1	×1,5
29,6	0,229	0,070	1,45	0,578	5,70	1,88	8,28	3,2
29,7	0,226	0,069	1,44	0,573	5,65	1,86	8,21	3,15
29,8	0,224	0,068	1,43	0,569	5,60	1,85	8,14	3,12
29,9	0,222	0,067	1,42	0,564	5,55	1,83	8,07	3,1
30,0	0,220	0,066	1,41	0,560	5,50	1,82	8	3,05
30,2	0,215	0,065	1,39	0,551	5,40	1,79	7,87	2,99
30,4	0,210	0,064	1,37	0,542	5,30	1,76	7,75	2,96
30,6	0,206	0,0626	1,35	0,533	5,20	1,73	7,62	2,93
30,8	0,202	0,0616	1,33	0,524	5,10	1,70	7,5	2,90
31,0	0,198	0,0605	1,32	0,515	5,00	1,67	7,33	2,87
31,2	0,194	0,0596	1,30	0,506	4,90	1,65	7,16	2,84
31,4	0,190	0,0587	1,28	0,497	4,82	1,62	7	2,81
31,6	0,186	0,0578	1,26	0,489	4,74	1,60	6,87	2,78
31,8	0,183	0,0569	1,24	0,482	4,68	1,58	6,75	2,75
32,0	0,180	0,0560	1,23	0,475	4,60	1,56	6,62	2,72
32,2	0,177	0,0551	1,21	0,467	4,52	1,54	6,5	2,69
32,4	0,174	0,0542	1,19	0,460	4,44	1,52	6,37	2,66
32,6	0,171	0,0533	1,17	0,452	4,36	1,50	6,25	2,63
32,8	0,168	0,0524	1,15	0,444	4,28	1,48	6,12	2,6
33,0	0,165	0,0515	1,14	0,437	4,20	1,46	6	2,54
33,2	0,162	0,0506	1,12	0,430	4,12	1,44	5,95	2,49
33,4	0,159	0,0498	1,10	0,424	4,05	1,42	5,9	2,45
33,6	0,156	0,0492	1,09	0,418	3,98	1,41	5,85	2,44
33,8	0,153	0,0486	1,08	0,412	3,91	1,39	5,8	2,42
34,0	0,150	0,048	1,07	0,406	3,85	1,37	5,75	2,4
34,2	0,147	0,0474	1,05	0,401	3,79	1,35	5,7	2,33
34,4	0,144	0,0468	1,04	0,397	3,74	1,33	5,65	2,28
34,6	0,141	0,0462	1,02	0,393	3,69	1,31	5,6	2,26
34,8	0,138	0,0456	1,01	0,390	3,64	1,30	5,55	2,22
35,0	0,135	0,045	1,00	0,387	3,60	1,28	5,5	2,2
35,2	0,133	0,0444	0,99	0,383	3,55	1,26	5,45	2,2
35,4	0,131	0,0438	0,97	0,380	3,50	1,24	5,4	2,2
35,6	0,129	0,0432	0,95	0,376	3,45	1,23	5,35	2,2
35,8	0,127	0,0426	0,94	0,373	3,40	1,21	5,3	2,17
36,0	0,125	0,042	0,93	0,370	3,35	1,20	5,25	2,15
36,2	0,123	0,0414	0,91	0,366	3,30	1,18	5,2	2,15
36,4	0,121	0,0408	0,90	0,363	3,25	1,17	5,15	2,1
36,6	0,119	0,0402	0,89	0,359	3,20	1,150	5,1	2
36,8	0,117	0,0396	0,88	0,356	3,15	1,130	5,05	1,99
37,0	0,115	0,039	0,87	0,353	3,10	1,120	5	1,98
37,2	0,113	0,0384	0,86	0,347	3,05	1,100	4,95	1,96
37,4	0,111	0,0379	0,85	0,344	3,00	1,090	4,9	1,95
37,6	0,109	0,0374	0,84	0,340	2,95	1,080	4,85	1,94
37,8	0,107	0,0369	0,83	0,339	2,90	1,070	4,8	1,93
38,0	0,105	0,0364	0,82	0,336	2,85	1,060	4,75	1,92
38,2	0,103	0,0359	0,81	0,332	2,80	1,040	4,7	1,91
38,4	0,102	0,0354	0,80	0,329	2,75	1,030	4,65	1,9
38,6	0,101	0,0350	0,79	0,326	2,70	1,020	4,6	1,87
38,8	0,100	0,0346	0,78	0,323	2,65	1,010	4,55	1,86
39,0	0,099	0,0342	0,77	0,320	2,60	1,000	4,5	1,85
39,2	0,098	0,0338	0,76	0,317	2,56	0,980	4,45	1,83
39,4	0,097	0,0334	0,75	0,314	2,52	0,970	4,4	1,82
39,6	0,096	0,0331	0,75	0,311	2,48	0,960	4,35	1,8
39,8	0,095	0,0328	0,74	0,308	2,44	0,950	4,3	1,79
40,0	0,094	0,0325	0,73	0,305	2,40	0,940	4,25	1,78
40,2	0,092	0,0322	0,72	0,302	2,37	0,930	4,2	1,76
40,4	0,091	0,0319	0,71	0,299	2,35	0,920	4,15	1,75
40,6	0,090	0,0316	0,70	0,296	2,32	0,910	4,1	1,74
40,8	0,089	0,0313	0,69	0,293	2,30	0,900	4,05	1,73
41,0	0,088	0,0310	0,68	0,290	2,27	0,890	4	1,72
41,2	0,087	0,0307	0,674	0,287	2,25	0,882	3,95	1,7
41,4	0,086	0,0304	0,668	0,284	2,22	0,874	3,9	1,68

Table A.2 *(continued)*

Voltage V	Permitted capacitance µF							
	for Group IIC apparatus		for Group IIB apparatus		for Group IIA apparatus		for Group I apparatus	
	with a factor of safety of		with a factor of safety of		with a factor of safety of		with a factor of safety of	
	×1	×1,5	×1	×1,5	×1	×1,5	×1	×1,5
41,6	0,085	0,0301	0,662	0,281	2,20	0,866	3,85	1,67
41,8	0,084	0,0299	0,656	0,278	2,17	0,858	3,8	1,66
42,0	0,083	0,0297	0,650	0,275	2,15	0,850	3,75	1,65
42,2	0,082	0,0294	0,644	0,272	2,12	0,842	3,72	1,62
42,4	0,081	0,0292	0,638	0,269	2,10	0,834	3,68	1,61
42,6	0,079	0,0289	0,632	0,266	2,07	0,826	3,64	1,6
42,8	0,078	0,0286	0,626	0,264	2,05	0,818	3,6	1,59
43,0	0,077	0,0284	0,620	0,262	2,02	0,810	3,55	1,58
43,2	0,076	0,0281	0,614	0,259	2,00	0,802	3,5	1,56
43,4	0,075	0,0279	0,608	0,257	1,98	0,794	3,45	1,55
43,6	0,074	0,0276	0,602	0,254	1,96	0,786	3,4	1,54
43,8	0,073	0,0273	0,596	0,252	1,94	0,778	3,35	1,53
44,0	0,072	0,0271	0,590	0,25	1,92	0,770	3,3	1,52
44,2	0,071	0,0268	0,584	0,248	1,90	0,762	3,25	1,5
44,4	0,070	0,0266	0,578	0,246	1,88	0,754	3,2	1,48
44,6	0,069	0,0263	0,572	0,244	1,86	0,746	3,15	1,47
44,8	0,068	0,0261	0,566	0,242	1,84	0,738	3,1	1,46
45,0	0,067	0,0259	0,560	0,240	1,82	0,730	3,05	1,45
45,2	0,066	0,0257	0,554	0,238	1,80	0,722	3	1,42
45,4	0,065	0,0254	0,548	0,236	1,78	0,714	2,98	1,41
45,6	0,064	0,0251	0,542	0,234	1,76	0,706	2,96	1,4
45,8	0,063	0,0249	0,536	0,232	1,74	0,698	2,94	1,39
46,0	0,0623	0,0247	0,530	0,230	1,72	0,690	2,92	1,38
46,2	0,0616	0,0244	0,524	0,228	1,70	0,682	2,9	1,36
46,4	0,0609	0,0242	0,518	0,226	1,68	0,674	2,88	1,35
46,6	0,0602	0,0239	0,512	0,224	1,67	0,666	2,86	1,34
46,8	0,0596	0,0237	0,506	0,222	1,65	0,658	2,84	1,33
47,0	0,0590	0,0235	0,500	0,220	1,63	0,650	2,82	1,32
47,2	0,0584	0,0232	0,495	0,218	1,61	0,644	2,8	1,3
47,4	0,0578	0,0229	0,490	0,216	1,60	0,638	2,78	1,28
47,6	0,0572	0,0227	0,485	0,214	1,59	0,632	2,76	1,27
47,8	0,0566	0,0225	0,480	0,212	1,57	0,626	2,74	1,26
48,0	0,0560	0,0223	0,475	0,210	1,56	0,620	2,72	1,25
48,2	0,0554	0,0220	0,470	0,208	1,54	0,614	2,7	1,22
48,4	0,0548	0,0218	0,465	0,206	1,53	0,609	2,68	1,21
48,6	0,0542	0,0215	0,460	0,205	1,52	0,604	2,66	1,2
48,8	0,0536	0,0213	0,455	0,203	1,50	0,599	2,64	1,19
49,0	0,0530	0,0211	0,450	0,201	1,49	0,594	2,62	1,18
49,2	0,0524	0,0208	0,445	0,198	1,48	0,589	2,6	1,16
49,4	0,0518	0,0206	0,440	0,197	1,46	0,584	2,56	1,15
49,6	0,0512	0,0204	0,435	0,196	1,45	0,579	2,52	1,14
49,8	0,0506	0,0202	0,430	0,194	1,44	0,574	2,46	1,13
50,0	0,0500	0,0200	0,425	0,193	1,43	0,570	2,46	1,12
50,5	0,0490	0,0194	0,420	0,190	1,40	0,558	2,43	1,1
51,0	0,0480	0,0190	0,415	0,187	1,37	0,547	2,4	1,08
51,5	0,0470	0,0186	0,407	0,184	1,34	0,535	2,3	1,02
52,0	0,0460	0,0183	0,400	0,181	1,31	0,524	2,25	1
52,5	0,0450	0,0178	0,392	0,178	1,28	0,512	2,2	0,99
53,0	0,0440	0,0174	0,385	0,175	1,25	0,501	2,2	0,97
53,5	0,0430	0,0170	0,380	0,172	1,22	0,490	2,2	0,96
54,0	0,0420	0,0168	0,375	0,170	1,20	0,479	2,15	0,95
54,5	0,0410	0,0166	0,367	0,168	1,18	0,468	2,15	0,94
55,0	0,0400	0,0165	0,360	0,166	1,16	0,457	2	0,94

A.4 Permitted reduction of effective capacitance when protected by a series resistance

When a resistance is used in series with a capacitance to limit the energy that may discharge from the combination of both (energy between nodes A and B in the Figure A.9 below), the assessment of the effective capacitance between these two nodes may be simplified by using Table A.3. Alternatively, if the table is not applied, the circuit may be tested.

The resistor shall be in accordance with 7.1, and the node X shall be segregated from all other conductive parts according to 6.3.

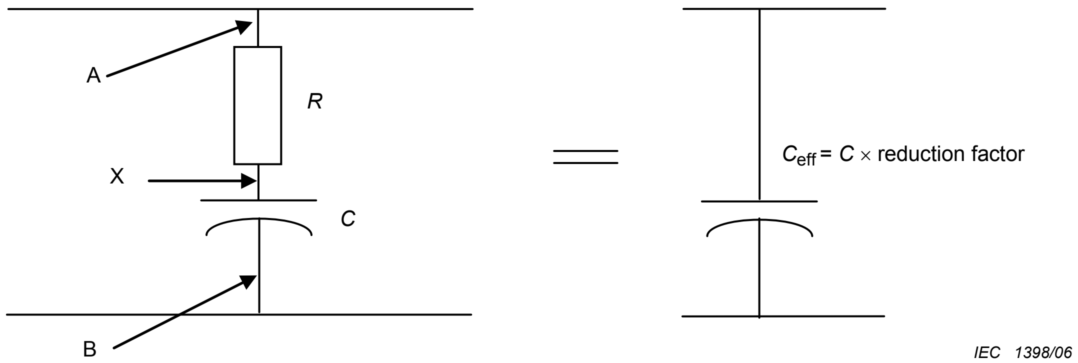


Figure A.9 – Equivalent capacitance

Table A.3 – Permitted reduction of effective capacitance when protected by a series resistance

Resistance R Ω	Reduction factor
0	1,00
1	0,97
2	0,94
3	0,91
4	0,87
5	0,85
6	0,83
7	0,80
8	0,79
9	0,77
10	0,74
12	0,70
14	0,66
16	0,63
18	0,61
20	0,57
25	0,54
30	0,49
40	0,41

NOTE The reductions specified in the above table are conservative and further reductions may be achieved by testing.

Annex B
(normative)

Spark test apparatus for intrinsically safe circuits

B.1 Test methods for spark ignition

B.1.1 Principle

The circuit to be tested is connected to the contacts of the spark test apparatus, which are in an explosion chamber that is filled with an explosive test mixture.

The parameters of the circuit are adjusted to achieve the prescribed safety factor and a test is made to determine whether or not ignition of the explosive test mixture takes place within a defined number of operations of the contact system.

Except where otherwise specified, the tolerance on mechanical dimensions of the machined parts is ±2 % (tungsten wire length ±10 %) and that of voltages and current is ±1 %.

B.1.2 Apparatus

The apparatus shall consist of a contact arrangement in an explosion chamber having a volume of at least 250 cm^3. It is arranged to produce make-sparks and break-sparks in the prescribed explosive test mixture.

NOTE 1 An example of a practical design of the test apparatus is shown in Figure B.4. (For the contact arrangement, see Figures B.1, B.2 and B.3.)

One of the two contact electrodes shall consist of a rotating cadmium contact disc with two slots as in Figure B.2.

NOTE 2 Cadmium as supplied for electroplating may be used for casting cadmium contact discs.

The other contact electrode consists of four tungsten contact wires with a diameter of 0,2 ± 0,02 mm clamped on a circle of 50 mm diameter to an electrode holder (made of brass or other suitable material as in Figure B.3).

NOTE 3 It is advantageous to round off the corners of the electrode holder slightly at the points where the wires are clamped to avoid premature breakage of the wires at the sharp edge.

The contact arrangement shall be mounted as shown in Figure B.1. The electrode holder rotates so that the tungsten contact wires slide over the slotted cadmium disc. The distance between the electrode holder and the cadmium disc is 10 mm. The free length of the contact wires is 11 mm. The contact wires are straight and fitted so as to be normal to the surface of the cadmium disc when not in contact with it.

The axes of the shafts driving the cadmium disc and the electrode holder are 31 mm apart and are electrically insulated from each other and from the baseplate of the apparatus. The current is led in and out through sliding contacts on the shafts which are geared together by non-conductive gears with a ratio of 50:12.

The electrode holder shall rotate at 80 r/min by an electric motor, with suitable reduction gearing if necessary. The cadmium disc is turned more slowly in the opposite direction.

NOTE 4 Gas-tight bearing bushes in the baseplate are necessary unless a gas flow system is used.

Either a counting device is provided to record the number of revolutions of the motor-driven shaft of the electrode holder or a timing device may be used to determine the test duration, from which the number of revolutions of the shaft of the electrode holder can be calculated.

NOTE 5 It is advantageous to stop the driving motor, or at least the counting device, automatically after an ignition of the explosive mixture, for example by means of a photocell or a pressure switch.

The explosion chamber shall be capable of withstanding an explosion pressure of at least 1 500 kPa (15 bars) except where provision is made to release the explosion pressure.

At the terminals of the contact arrangement, the self-capacitance of the test apparatus shall not exceed 30 pF with the contacts open. The resistance shall not exceed 0,15 Ω at a current of 1 A d.c. and the self-inductance shall not exceed 3 µH with the contacts closed.

B.1.3 Calibration of spark test apparatus

The sensitivity of the spark test apparatus shall be checked before and after each series of tests in accordance with 10.1.3.

When the sensitivity is not as specified, the following procedure shall be followed until the required sensitivity is achieved:

a) check the parameters of the calibration circuit;
b) check the composition of the explosive test mixture;
c) clean the tungsten wires;
d) replace the tungsten wires;
e) connect the terminals to a 95 mH/24 V/100 mA circuit as specified in 10.1.3 and run the test apparatus with the contacts in air for a minimum of 20 000 revolutions of the electrode holder;
f) replace the cadmium disc and calibrate the apparatus in accordance with 10.1.3.

B.1.4 Preparation and cleaning of tungsten wires

Tungsten is a very brittle material and tungsten wires often tend to split at the ends after a relatively short period of operation.

To resolve this difficulty, one of the following procedures shall be followed.

a) Fuse the ends of the tungsten wires in a simple device as shown in Figure B.5. This forms a small sphere on each wire which shall be removed, for example by slight pressure by tweezers.

   When prepared in this way, it is found that, on average, one of the four contact wires has to be changed only after about 50 000 sparks.
b) Cut the tungsten wires with a shearing action, for example using heavy duty scissors in good condition.

The wires are then mounted in the electrode holder and manually cleaned by rubbing the surface, including the end of the wire, with grade 0 emery cloth or similar.

NOTE 1 It is advantageous to remove the electrode holder from the test apparatus when cleaning the wires.

NOTE 2 The specification for grade 0 emery cloth grains determined by sieving is as follows.

Requirements	Sieve aperture size (µm)
All grains to pass	106
Not more than 24 % to be retained	75
At least 40 % to be retained	53

Not more than 10 % to pass	45

Experience has shown that, in order to stabilize the sensitivity during use, it is advantageous to clean and straighten the wires at regular intervals. The interval chosen depends on the rate at which deposits form on the wires. This rate depends on the circuit being tested. A wire shall be replaced if the end of the wire is split or if the wire cannot be straightened.

B.1.5 Conditioning a new cadmium disc

The following procedure is recommended for conditioning a new cadmium disc to stabilize the sensitivity of the spark test apparatus:

a) fit the new disc into the spark test apparatus;

b) connect the terminals to a 95 mH/24 V/100 mA circuit as specified in 10.1.3 and run the test apparatus with the contacts in air for a minimum of 20 000 revolutions of the electrode holder;

c) fit new tungsten wires prepared and cleaned in accordance with B.1.4 and connect the test apparatus to a 2 μF non-electrolytic capacitor charged through a 2 kΩ resistor;

d) using the Group IIA (or Group I) explosive test mixture conforming to 10.1.3.1, apply 70 V (or 95 V for Group I) to the capacitive circuit and operate the spark test apparatus for a minimum of 400 revolutions of the electrode holder or until ignition occurs. If no ignition takes place, check the gas mixture, replace wires, or check the spark test apparatus. When ignition occurs, reduce the voltage in steps of 5 V and repeat. Repeat until no ignition takes place;

e) the voltage at which ignition shall be obtained to be 45 V for Group IIA (55 V for Group I) and the voltage at which no ignition takes place shall be 40 V for Group IIA (50 V for Group I).

B.1.6 Limitations of the apparatus

The spark test apparatus is designed for testing intrinsically safe circuits within the following limits:

a) a test current not exceeding 3 A;

b) resistive or capacitive circuits where the operating voltage does not exceed 300 V;

c) inductive circuits where the inductance does not exceed 1 H;

d) for circuits up to 1,5 MHz.

NOTE 1 The apparatus can be successfully applied to circuits exceeding these limits but variations in sensitivity may occur.

NOTE 2 If the test current exceeds 3 A, the temperature rise of the tungsten wires may lead to additional ignition effects invalidating the test result.

NOTE 3 With inductive circuits, care should be exercised that self-inductance and circuit time constants do not adversely affect the results.

NOTE 4 Capacitive and inductive circuits with large time constants may be tested, for example by reducing the speed at which the spark test apparatus is driven. Capacitive circuits may be tested by removing two or three of the tungsten wires. Attention is drawn to the fact that reducing the speed of the spark test apparatus may alter its sensitivity.

The spark test apparatus might not be suitable for the testing of circuits, which shut off the current or reduce the electrical values as a result of making or breaking contact in the spark apparatus during the required number of revolutions. Such circuits shall under test deliver the worst case output conditions throughout the test.

NOTE 5 For the test of such circuits Annex E and Annex H provide further information.

B.1.7 Modifications of test apparatus for use at higher currents

Test currents of 3 A to 10 A may be tested in the test apparatus when it is modified as follows.

The tungsten wires are replaced by wires with diameter increased from 0,2 mm to 0,4 ± 0,03 mm and the free length reduced to 10,5 mm.

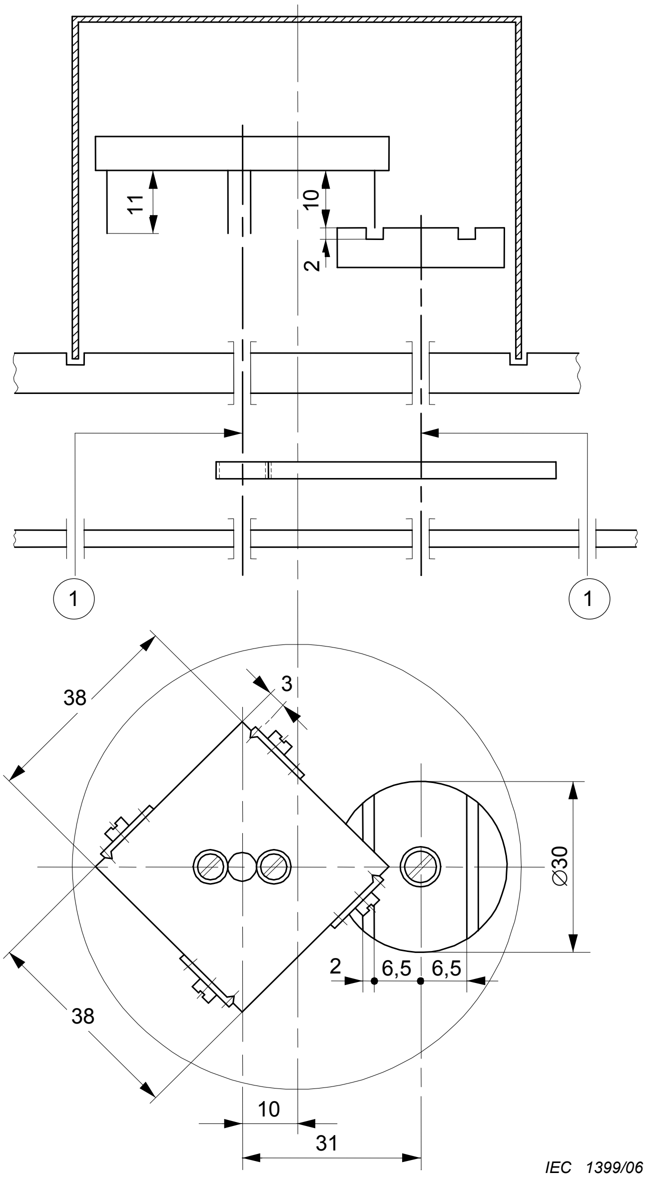
NOTE 1 The reduction in free length reduces the wear on the cadmium disc.

The total resistance of the apparatus including the commutation contact resistance shall be reduced to less than 100 mΩ or the circuit under test shall be modified to compensate for the internal resistance of the spark test apparatus.

NOTE 2 Brushes of the type used in the automobile industry combined with brass sleeves on the apparatus shafts so as to increase the contact area have been found to be one practical solution to reduce the contact resistance.

The total inductance of the test apparatus and the inductance of the interconnection to the circuit under test must be minimized. A maximum value of 1 μH must be achieved.

The apparatus can be used for higher currents but special care in interpreting the results is necessary.

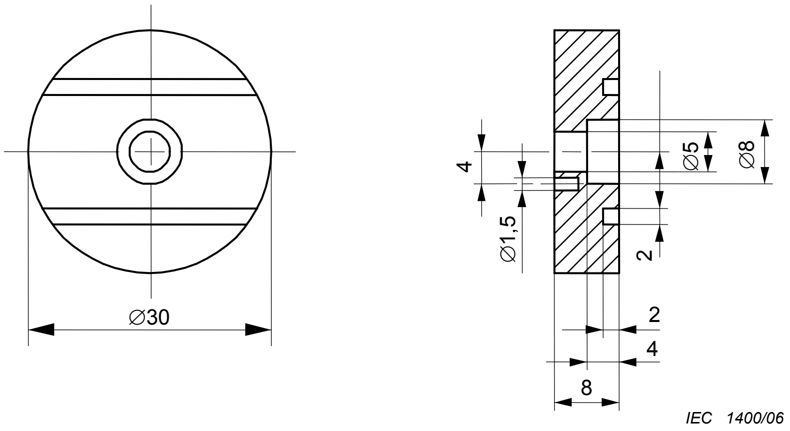


Key

1 Connection for circuit under test

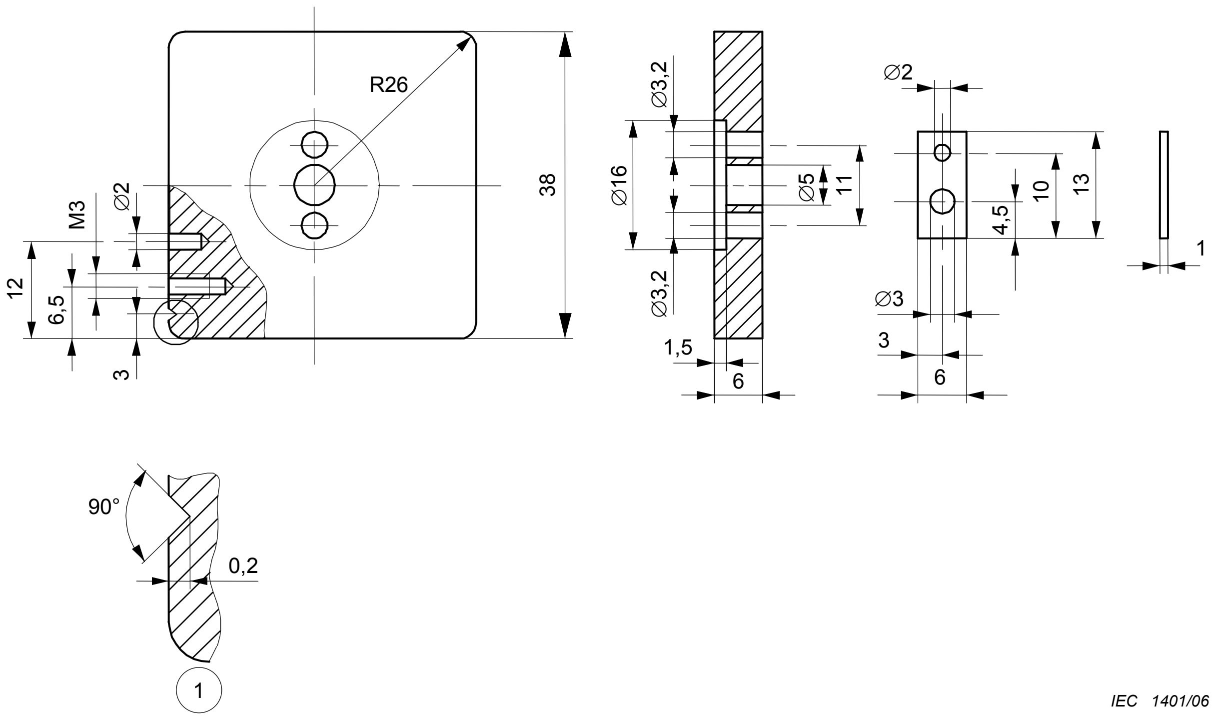
Dimensions in millimetres

Figure B.1 – Spark test apparatus for intrinsically safe circuits



Dimensions in millimetres

Figure B.2 – Cadmium contact disc

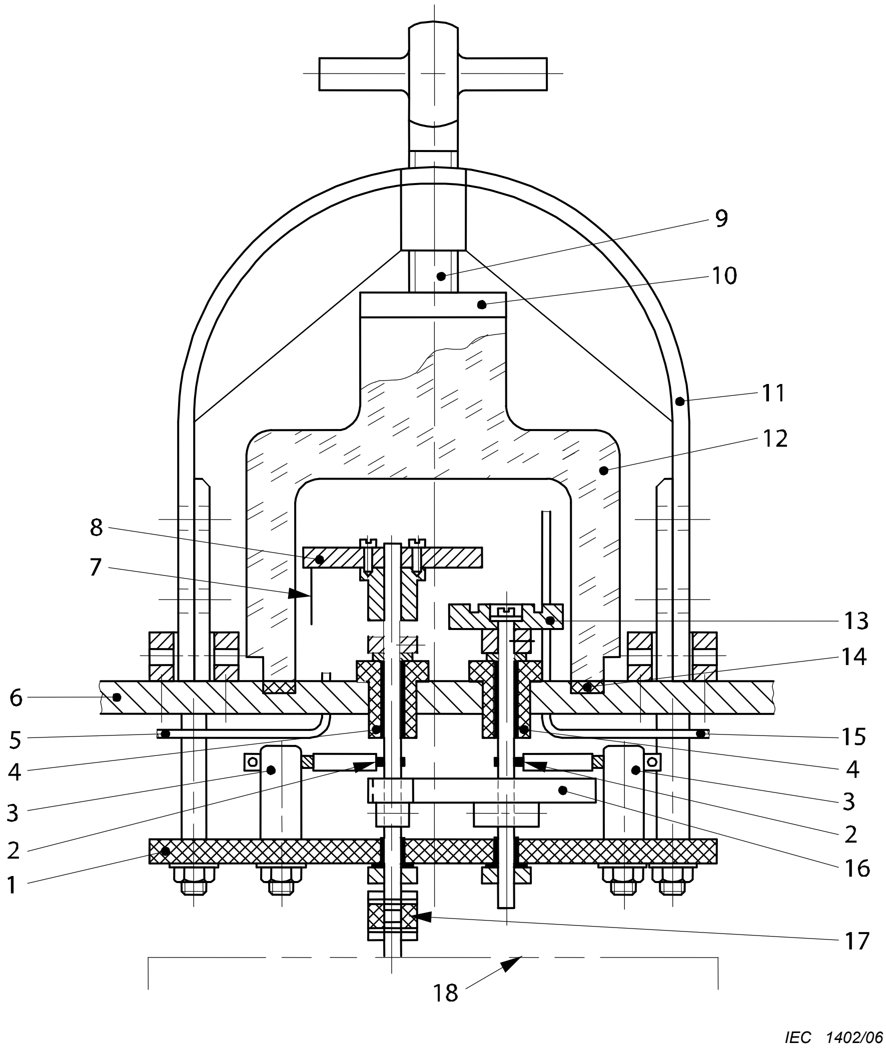


Key

1 Detail X, scale 10:1

Dimensions in millimetres

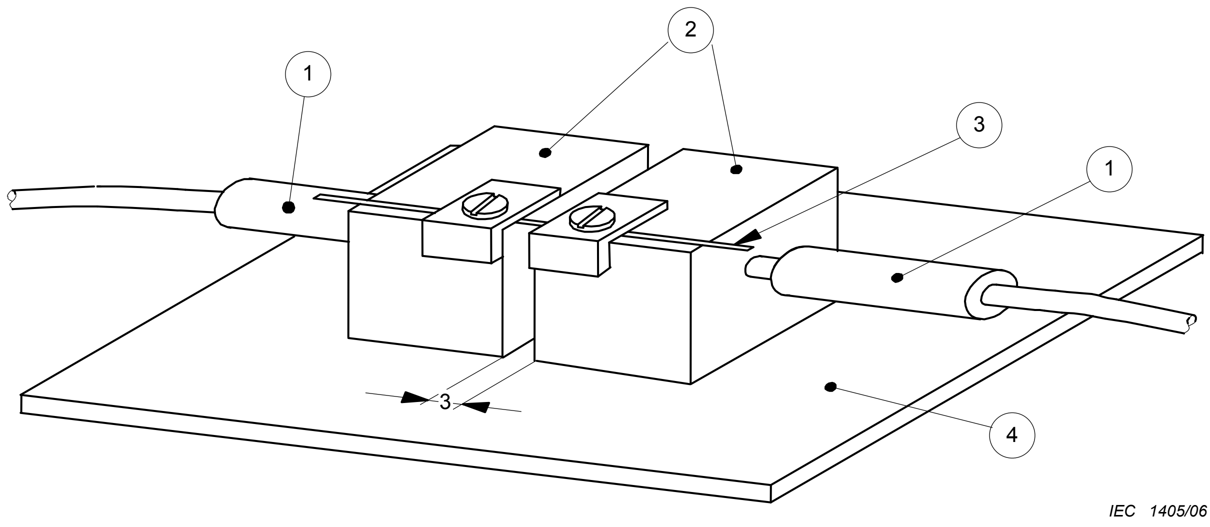
Figure B.3 – Wire holder



Key

1 Insulating plate	10 Pressure plate
2 Current connection	11 Clamp
3 Insulated bolt	12 Chamber
4 Insulated bearing	13 Cadmium contact disc
5 Gas outlet	14 Rubber seal
6 Base plate	15 Gas inlets
7 Contact wire	16 Gear wheel drive 50:12
8 Wire holder	17 Insulated coupling
9 Clamping screw	18 Drive motor with reduction gears 80 r/min

Figure B.4 – Example of a practical design of spark test apparatus



Key

1 Current feed

2 Copper block

3 Tungsten wire

4 Insulating plate

NOTE Remove melted droplets with tweezers.

Figure B.5 – Arrangement for fusing tungsten wires

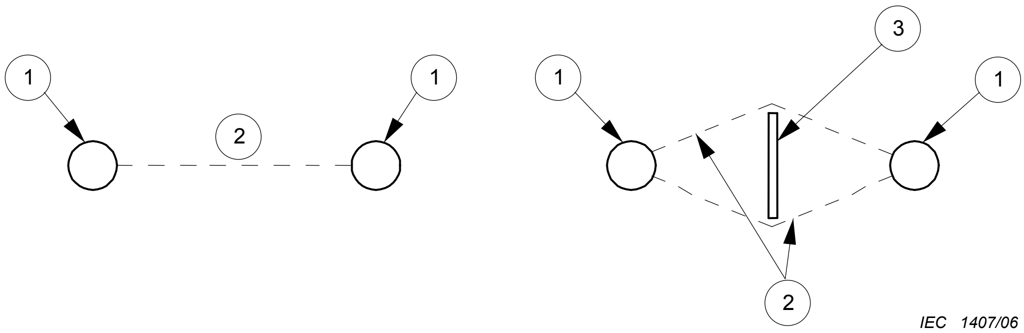
Annex C
(informative)

Measurement of creepage distances, clearances and separation distances through casting compound and through solid insulation

C.1 Clearances and separation distances through casting compound and through solid insulation

The voltage to be used should be determined in accordance with 6.3.3.

The clearance is taken as the shortest distance in air between two conductive parts and, where there is an insulating part, for example a barrier, between the conductive parts, the distance is measured along the path which will be taken by a stretched piece of string as can be seen in Figure C.1.



Key

1 Conductor

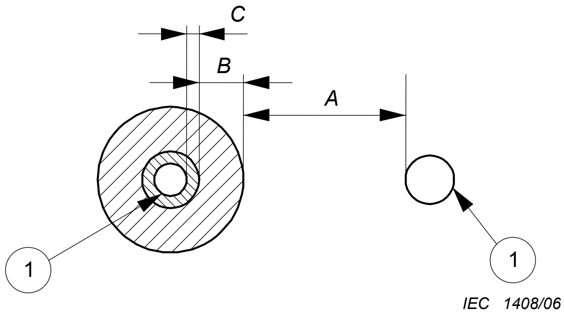
2 Clearance

3 Barrier

Figure C.1 – Measurement of clearance

Where the distance between the conductive parts is partly clearance and partly separation distance through casting compound and/or solid insulation, the equivalent clearance or separation distance through casting compound can be calculated in the following manner. The value can then be compared with the value in the relevant column of Table 5.

In Figure C.2 let *A* be the clearance, *B* be the separation distance through casting compound and *C* be the separation distance through solid insulation.



Key

1 Conductor

Figure C.2 – Measurement of composite distances

If *A* is less than the applicable value of Table 5, one of the following tabulations can be used. Any clearance or separation which is below one-third of the relevant value specified in Table 5 should be ignored for the purpose of these calculations.

The results of these calculations should be added and compared with the appropriate value in Table 5.

To use column 2 of Table 5, multiply the measured values by the following factors:

Voltage difference	$U < 10$ V	10 V $\leq U <$ 30 V	$U \geq 30$ V
A	1	1	1
B	3	3	3
C	3	4	6

To use column 3 of Table 5, multiply the measured values by the following factors:

Voltage difference	$U < 10$ V	10 V $\leq U <$ 30 V	$U \geq 30$ V
A	0,33	0,33	0,33
B	1	1	1
C	1	1,33	2

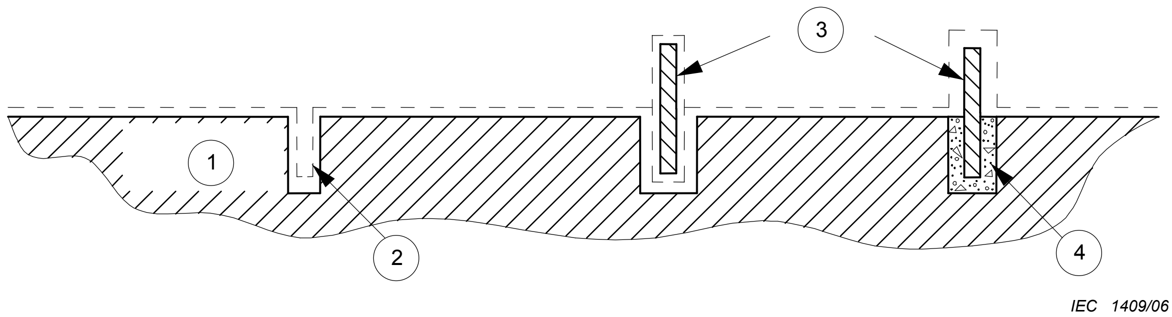
To use column 4 of Table 5, multiply the measured values by the following factors:

Voltage difference	$U < 10$ V	10 V $\leq U <$ 30 V	$U \geq 30$ V
A	0,33	0,25	0,17
B	1	0,75	0,5
C	1	1	1

C.2 Creepage distances

The voltage to be used should be determined in accordance with 6.3.3.

Creepage distances have to be measured along the surface of insulation and, therefore, are measured as shown in the following sketch.



Key

1 Substrate
3 Barrier
2 Groove
4 Cement

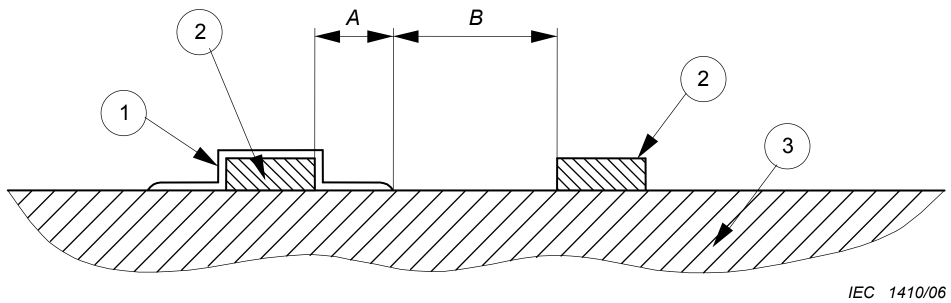
Figure C.3 – Measurement of creepage

The following measurements should be made as shown in Figure C.3:

a) the creepage distance should be measured around any intentional groove in the surface, providing that the groove is at least 3 mm wide;

b) where an insulating partition or barrier conforming to 6.3.2 is inserted but not cemented in, the creepage distance should be measured either over or under the partition, whichever gives the smaller value;

c) if the partition described in b) is cemented in, then the creepage distance should always be measured over the partition.



Key

1 Varnish
2 Conductor
3 Substrate

Figure C.4 – Measurement of composite creepage

When varnish is used to reduce the required creepage distances, and only part of the creepage distance is varnished as shown in Figure C.4, the total effective creepage distance is compared to either column 5 or column 6 of Table 5 by the following calculation: to compare to column 5 of Table 5, multiply *B* by 1 and *A* by 3; to compare to column 6 of Table 5, multiply *B* by 0,33 and *A* by 1. Then add the results together.

Annex D
(normative)

Encapsulation

D.1 Adherence

A seal shall be maintained where any part of the circuit emerges from the encapsulation and therefore the compound shall adhere at these interfaces.

The exclusion of components encapsulated with casting compound from the creepage distance requirements is based upon the removal of the likelihood of contamination. The measurement of CTI is, in effect, a measurement of the degree of contamination needed to cause breakdown in a separation between conductive parts. The following assumptions emerge from this basic consideration:

- if all electrical parts and substrates are totally enclosed, that is if nothing emerges from the encapsulation, then there is no risk of contamination and hence breakdown from contamination cannot occur;
- if any part of the circuit, for example a bare or insulated conductor or component or the substrate of a printed circuit board, emerges from the encapsulation, then, unless the compound adheres at the interface, contamination can enter at that interface and cause breakdown.

D.2 Temperature

The casting compound shall have a temperature rating conforming to 6.6.

NOTE 1 All casting compounds have a maximum temperature above which they may lose or change their specified properties. Such changes may cause cracking or decomposition which could result in surfaces hotter than the outside surface of the casting compound being exposed to an explosive atmosphere.

NOTE 2 It should be noted that components which are encapsulated may be hotter or colder than they would be in free air, depending on the thermal conductivity of the casting compound.

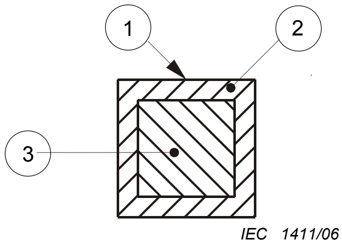


Figure D.1a – No enclosure

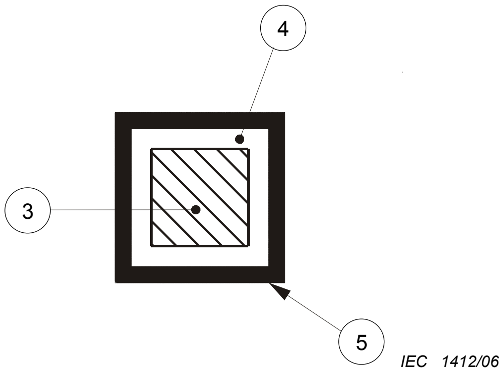


Figure D.1b – Complete enclosure

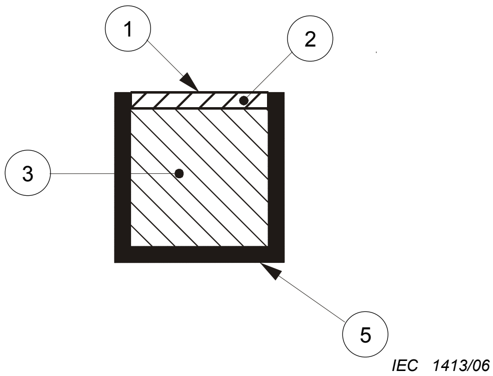


Figure D.1c – Open enclosure

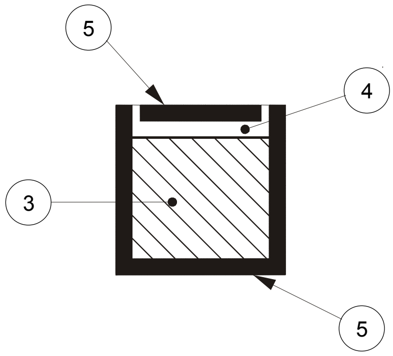


Figure D.1d – Enclosure with cover

Key

1 Free surface

2 Encapsulant – ½ of column 3 of Table 5 with a minimum of 1,00 mm

3 Component – encapsulant need not penetrate

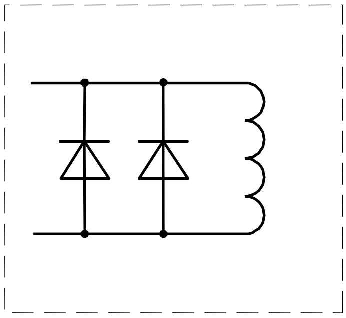
4 Encapsulant – no specified thickness

5 Metal or insulating enclosure

– no specified thickness for metallic enclosure, but see 6.1

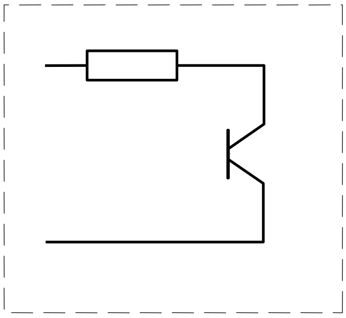
– Insulation thickness shall conform to column 4 of Table 5

Figure D.1 – Examples of encapsulated assemblies conforming to 6.3.5 and 6.6



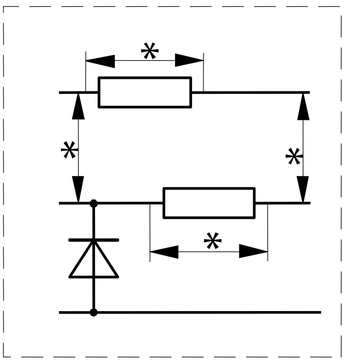
The minimum thickness to the free surface is at least ½ the value given in column 3 of Table 5 with a minimum of 1 mm.

Figure D.2a – Mechanical



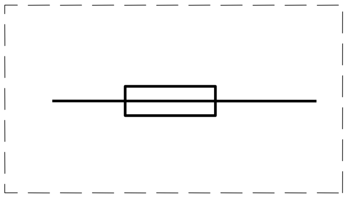
The minimum thickness is determined by external surface temperature.

Figure D.2b – Temperature



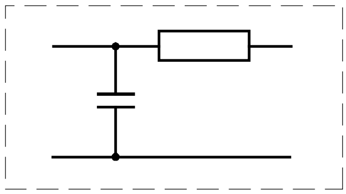
The marked separation distances comply with column 3 of Table 5, Table F.1 or Table F.2. The minimum thickness to the free surface is at least 1 mm.

Figure D.2c – Separation of circuits



The minimum thickness to the free surface is at least ½ the value given in column 3 of Table 5 with a minimum of 1 mm.

Figure D.2d – Protection of fuses in an intrinsically safe circuit



The minimum thickness to the free surface is at least ½ the value given in column 3 of Table 5 with a minimum of 1 mm.

Figure D.2e – Exclusion of gas

Figure D.2 – Applications of encapsulation using casting compound without an enclosure

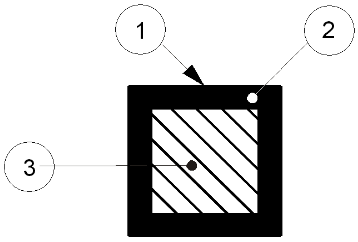


Figure D.3a – Moulding over un-mounted components

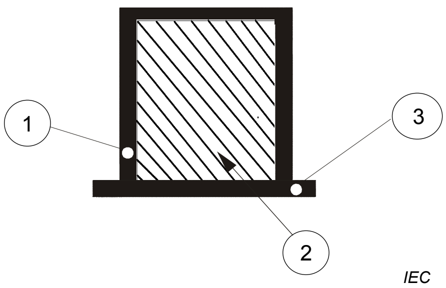


Figure D.3b – Moulding over components mounted on a printed circuit board

Key

1 Moulding – The moulding shall have a minimum thickness to free surface of at least Table 5, column 4, with a minimum thickness of 0,5mm

2 Component (e.g. fuse).

3 Printed circuit board with a minimum thickness of 0,5mm

Figure D.3 – Examples of assemblies using moulding conforming to 6.6

NOTE Figures D.1, D.2 and D.3 for simplicity do not show connections into and out of the assemblies. These illustrate by example parts that are important to the type of protection.

Figure D.1 illustrates some examples of assemblies using encapsulation by casting compound. These show the essential differences between clearance distances to the surface for poured casting compound and metal or solid insulation potting boxes.

Figure D.1a shows no enclosure.

Figure D.1b shows a complete enclosure.

Figure D.1c shows an open enclosure with no cover.

Figure D.1d shows an enclosure with a cover.

Figure D.2 shows some further examples of encapsulation using casting compound without an enclosure.

Figure D.2a shows mechanical protection of an inductor and its suppression components.

Figure D.2b shows the application of casting compound to reduce surface temperature.

Figure D.2c shows the separation of intrinsically safe circuits.

Figure D.2d shows the protection of fuses by casting compound in an intrinsically safe circuit.

Figure D.2e shows the application of casting compound for the exclusion of gas.

Figure D.3 illustrates some examples of assemblies using encapsulating solid insulation. These show essential requirements with respect to construction and clearance distances to the surface. The technique of encapsulating solid insulation is to mould the assembly as a single unit.

Figure D.3a shows encapsulating solid insulation over an un-mounted component such as a fuse.

The intention of Figure D.3a is to show a device such as a fuse that is moulded under pressure on all six sides all at the same time.

Figure D.3b shows encapsulating solid insulation over a component such as a fuse mounted on a printed circuit board.

Figure D.3b is intended to show that although it is similar to Figure D.3a component such as a fuse is first mounted onto a printed circuit board (item 3) before being moulded under pressure. This sometimes referred to as insert moulding.

Annex E
(informative)

Transient energy test

E.1 Principle

Where the circuit may deliver a transient voltage and current, then a voltage and current higher than the values provided in Annex A may be allowable, provided it can be shown that the transient energy is limited to the values specified in 10.1.5.3. An example is when a power supply that uses a series semiconductor current-limiting switch detects a high current and shuts down, but allows a brief transient to be transferred to the load. Another example is where a voltage-detecting circuit triggers a thyristor connected in shunt across the load, but where the high voltage may be briefly present across the load before the thyristor fires.

The circuit under test should be tested with those faults applicable under 5.1 that give the most onerous energy under the conditions described in this clause.

NOTE The worst case situation may not occur at the maximum voltage. Lower voltages should also be assessed.

The principle of this test is to measure the energy for the period when the voltage and current exceed the values given in Annex A or the values known to be non-incendive when tested using the spark test apparatus as given in 10.1.

E.2 Test

The energy that may be released to the explosive atmosphere is measured by the integral of the power and time, during the period at which the voltage and current exceed the values given in Annex A or the values known to be non-ignition capable when tested with the spark test apparatus.

The circuit is tested assuming the worst possible load under the faults applicable under 5.1. Where the circuit provides power to external apparatus (for example, where a power supply with a series semiconductor current-limiting switch delivers power at its output terminals to other apparatus located in the explosive atmosphere) then the worst load may be any load between the limits of open-circuit and short-circuit.

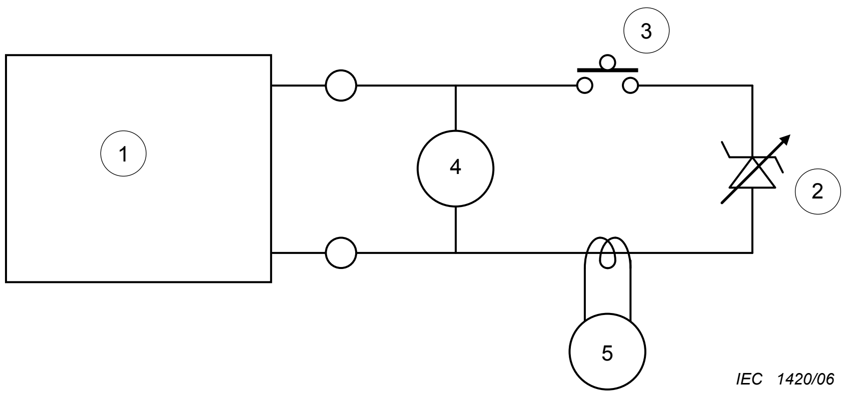
As an example, if a power supply delivers 15 V under open-circuit, and has a series current limiting switch that operates when the current exceeds 1 A, it is expected that the circuit, if connected to the worst case load of a Zener at approximately 14,5 V, would give a brief transient with current greater than 1 A before causing the current switch to operate. Zeners at voltages lower than this should also be considered for the test.

For Group IIB, the maximum allowable current at 14,5 V is 3,76 A (using Table A.1). Therefore, the test measures the product of voltage and current during the time when the current exceeds 3,76 A. The test set-up and expected voltage and current logged with a digital oscilloscope should be of the form shown in Figures E.1 and E.2.

In this case, the transient energy will need to be calculated by measuring the current to the Zener (using a current measuring clamp) and the voltage across the Zener. A set of current versus time for each value of Zener can then be measured, and the area under the plot of voltage × current versus time can be obtained. The area under the curve before the current drops to a value below which it is known as non-ignition capable can thus be obtained, with this being the transient energy test.

In other cases, the most onerous load may be a variable resistor. In this case, a set of current versus time can then be plotted for each resistive load from practically short-circuit to a resistance just less than U_o/I_o, and the integral of the power and time delivered to the resistor, can then be used to calculate the transient power delivered. This load may also be a capacitor, or inductor, depending on the output parameters specified.

Care should be taken that the voltage and current are measured by a high speed storage oscilloscope, capable of providing a time base speed of less than 1 µs per division. The test equipment and its connection to the circuit under test should minimize any variation of the measurands due to introduction of the test equipment. Current clamp probes and high impedance voltage measurement channels are recommended. A mercury contact tilt switch is recommended as it provides a bilateral low contact resistance mechanism, but other equivalent switches may be used.



Key

1 Circuit under test

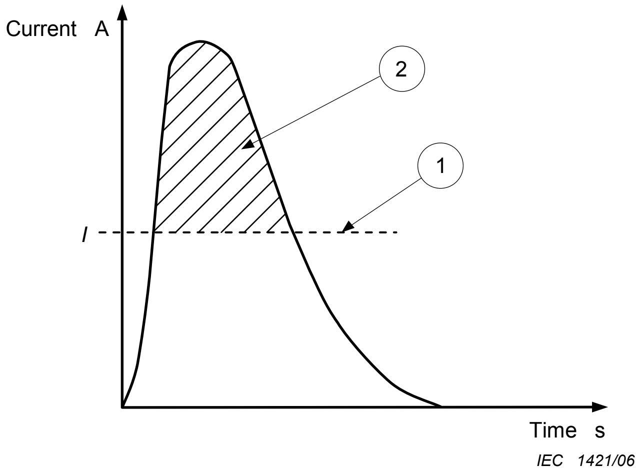
2 Load

3 Mercury switch

4 High impedance voltmeter

5 Current clamp probe

Figure E.1 – Example of test circuit



Key

1 *I* is equal to the maximum permitted current by spark test or Annex A

2 Transmitted energy (in Joules) = V (in volts) × hatched area of the curve (in A·s)

Figure E.2 – Example of output waveform

Annex F
(normative)

Alternative separation distances for assembled printed circuit boards and separation of components

F.1 General

Compliance with this annex yields reduced separation distances of conductive parts with respect to Table 5. It is applicable when a maximum pollution degree 2 affects electrical segregations under concern for:

- assembled printed circuit boards, and
- separation components, with the exception of transformers, complying with Table F.1 or F.2 depending on the level of protection.

NOTE The general requirements for separation distances of conductive parts are given in 6.3 of this standard. These are based widely on pollution degree 3 (IEC 60664-1). Conceptually, a double or reinforced insulation based on IEC 60664-1 is considered to comply with safety separation requirements of intrinsic safety level “ia” and “ib” also.

With printed circuit boards and relays and opto-couplers where either the pollution degree 2 is applicable due to installation conditions or by housing or coating with protection from ingress of dust and moisture, the requirements of this annex may offer less onerous construction requirements.

The application takes advantage of "Insulation coordination for equipment within low voltage systems" (IEC 60664-1).

Data stated in Table F.1 are valid for overvoltage category I/II/III (non-mains/mains circuits), and pollution degree 2 (no condensation when in service); they are derived from IEC 60664-1. This alternative method widely makes use of insulation coordination.

F.2 Control of pollution access

Where the pollution level to the printed circuit board assemblies or the separation components is limited to pollution degree 2 or better, reduced separation distances apply for;

- Levels of Protection ”ia” and “ib” stated in Table F.1;
- Level of Protection “ic” stated in Table F.2.

Reduction of pollution degree 2 is achieved by:

- an ingress protection rating of the enclosure protecting the printed circuit board assemblies or the separation components suitable for the required installation, with a minimum of IP54 according to IEC 60529.

  The enclosure shall be subjected to all the applicable requirements for enclosures as provided in IEC 60079-0 with an ingress protection rating of at minimum IP54; or
- application of conformal coating type 1 or type 2 according to IEC 60664-3, where effective ;or
- installation in a controlled environment with suitably reduced pollution; in such case the required condition of installation shall be added to the documentation provided by the manufacturer, and the symbol ”X” shall be added to the marking given in IEC 60079-0.

F.3 Distances for printed circuit boards and separation of components

F.3.1 Levels of protection "ia" and "ib"

For Levels of Protection "ia" and "ib", segregation distances according to Table F.1 may be used in the cases stated in Clause F.1, provided that the circuits are limited to overvoltage category I/II/III (non mains/mains circuits) as defined in IEC 60664-1. This shall be included in the documentation provided by the manufacturer as a condition of installation. The certificate number shall include the "X" suffix in accordance with the marking requirements of IEC 60079-0 and the specific conditions of use listed on the certificate shall detail the installation requirements.

Separation distances that comply with Table F.1 shall be considered infallible and shall not be subject to failure to a lower resistance. However, where redundancy of components is required (for example two capacitors in series), separation distance of less than the full value but greater or equal to half the value according to Table F.1 shall be considered as a single countable fault; no further faults to be considered.

Distance under coating, distance through casting compound and distance through solid insulation shall be subjected to type and routine testing as required in IEC 60664-1 and IEC 60664-3, while clearance and creepage distances do not need type or routine testing. As routine tests can only be performed with galvanically separated circuits, it is considered suitable to include special test conductors in the design of the printed circuit board for conclusion that the intended manufacturing procedure (coating, potting) was successful.

Type tests shall be carried out taking into account the most onerous ambient conditions claimed for the apparatus, for example the maximum and minimum temperatures.

Composite separations as provided in 6.3.7 shall not be applied when using Table F.1.

F.3.2 Level of protection "ic"

For Level of Protection "ic", reduced segregation distances according to Table F.2 may be used, provided that the following conditions apply.

– If the rated voltage of the apparatus or the nominal voltage of any part of the apparatus being considered does not exceed 60 V peak value no separation distance requirements additional to the general industrial standards are required. Apparatus with a rated voltage of over 60 V peak up to 375 V peak shall comply with the creepage and clearance requirements in Table F.2.
– Provision shall be made, either in the apparatus or external to the apparatus, to provide that the circuits are limited to overvoltage category II as defined in IEC 60664-1.

Table F.1 – Clearances, creepage distances and separations for Level of Protection "ia" and "ib" when ingress protected, and special conditions of material and installation are fulfilled

1	2		3	4	5		6	7
Rated insulation voltage AC rms or DC Note 1 and Note 5 V	**Clearance and creepage distance Note 2** mm		**Separation distance through casting compound** mm	**Separation distance through solid insulation** mm	**Distance under coating Coating type 1 Note 4** mm		**Distance under coating Coating type 2 Note 4** mm	**Minimum Comparative tracking index (CTI)**
Overvoltage category Note 3	**III**	**I / II**	**I / II / III**	**I / II / III**	**III**	**I / II**	**I / II / III**	
10	0,5	0,2	0,2	0,2	0,5	0,2	0,2	-
50	0,5	0,2	0,2	0,2	0,5	0,2	0,2	100
100	1,5	0,32	0,2	0,2	0,75	0,32	0,2	100
150	3,0	1,3	0,2	0,2	1,5	0,65	0,2	175
300	5,5	3,2	0,2	0,2	2,75	1,6	0,2	175
600	8,0	6,4	0,2	0,2	4,0	3,2	0,2	275

NOTE 1 Voltage steps are based on the R10 series. The actual working voltage may exceed the value given in the table by up to 10 %.

NOTE 2 Including components and parts on the PCB.

NOTE 3 Overvoltage category according to IEC 60664-1.

NOTE 4 Coating type according to IEC 60664-3.

NOTE 5 Including any recurring peak voltage for example with DC-DC converters but transients may be neglected.

Table F.2 – Clearances, creepage distances and separations for Level of Protection "ic" when ingress is protected by an enclosure or by special conditions of installation

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)
90	0,4	0,15	0,15	1,25	0,3	100
190	0,5	0,3	0,3	1,5	0,4	175
375	1,25	0,3	0,3	2,5	0,85	175
>375	*	*	*	*	*	*

NOTE 1 For distances marked '*', no values are available presently.

NOTE 2 Evidence of compliance with the CTI requirements of insulating materials should be provided by the manufacturer.

Annex G
(normative)

Fieldbus intrinsically safe concept (FISCO) – Apparatus requirements

G.1 Overview

This annex contains the details of the construction of apparatus for use with the Fieldbus Intrinsically Safe Concept (FISCO). It is based on the concepts of Manchester encoded, bus powered systems designed in accordance with IEC 61158-2 which is the physical layer standard for Fieldbus installations.

The constructional requirements of FISCO apparatus are determined by this standard except as modified by this annex. Part of a Fieldbus device may be protected by any of the methods of explosion protection listed in IEC 60079-0, appropriate to the EPL or Zone of intended use. In these circumstances, the requirements of this annex apply only to that part of the apparatus directly connected to the intrinsically safe trunk or spurs.

NOTE 1 Certification to the FISCO requirements does not prevent apparatus also being certified and marked in the conventional manner so that they may be used in other systems.

NOTE 2 A typical system illustrating the types of FISCO apparatus is shown in Figure G.1.

G.2 Apparatus requirements

G.2.1 General

Apparatus shall be constructed in accordance with this standard except as modified by this annex.

The apparatus documentation shall confirm that each apparatus is suitable for use in a FISCO system in accordance with IEC 60079-25.

G.2.2 FISCO power supplies

G.2.2.1 General

The power supply shall either be resistive limited or have a trapezoidal or rectangular output characteristic. The maximum output voltage U_0 shall be in the range 14 V to 17,5 V under the conditions specified in this standard for the respective level of protection.

The maximum unprotected internal capacitance C_i and inductance L_i shall be not greater than 5 nF and 10 μH, respectively.

The output circuit from the power supply may be connected to earth.

G.2.2.2 Additional requirements of 'ia' and 'ib' FISCO power supplies

The maximum output current I_O for any 'ia' or 'ib 'FISCO power supply shall be determined in accordance with this standard but shall not exceed 380 mA. For rectangular supplies, Table G.1 may be used for assessment.

Table G.1 – Assessment of maximum output current for use with 'ia' and 'ib' FISCO rectangular supplies

U_o V	Permissible current, for IIC (includes 1,5 safety factor) *mA*	Permissible current, for IIB (includes 1,5 safety factor) *mA*
14	183	380
15	133	354
16	103	288
17	81	240
17,5	75	213
NOTE The two largest current values for IIB are derived from 5,32 W		

The maximum output power P_O shall not exceed 5,32 W.

G.2.2.3 Additional requirements of 'ic' FISCO power supplies

The maximum output current I_O for an 'ic' FISCO power supply shall be determined in accordance with this standard. For 'ic' FISCO rectangular supplies Table G.2 may be used for assessment.

Table G.2 – Assessment of maximum output current for use with 'ic' FISCO rectangular supplies

U_o V	Permissible current, for IIC *mA*	Permissible current, for IIB *mA*
14	274	570
15	199	531
16	154	432
17	121	360
17,5	112	319
NOTE The maximum output power *Po* from 'ic' FISCO power supplies is not restricted		

G.3 FISCO field devices

G.3.1 General

These requirements apply to apparatus other than the power supply, terminators and simple apparatus connected to the intrinsically safe bus whether installed inside or outside the hazardous area.

The requirements are as follows:

a) field devices shall have minimum input voltage parameter of U_i: 17,5 V;
b) the bus terminals shall be isolated from earth in accordance with this standard;
c) the bus terminals of separately powered field devices shall be galvanically isolated from other sources of power in accordance with this standard, so as to ensure that these terminals remain passive and multiple earthing of the bus is avoided;
d) the maximum unprotected internal capacitance C_i of each field device shall not be greater than 5 nF. No specification of the input and internal parameters is required on the certificate or label;

e) under normal or fault conditions as specified in this standard the bus terminals shall remain passive, that is the terminals shall not be a source of energy to the system except for a leakage current not greater than 50 μA;

f) field devices shall be allocated a level of protection and be suitable for Equipment Group I, IIC or III or any combination of these groups;

g) Group IIC field devices intended to be installed within the hazardous area shall be temperature classified. Group III devices intended to be installed in the hazardous area shall be allocated a maximum surface temperature.

G.3.2 Additional requirements of 'ia' and 'ib' FISCO field devices

The additional requirements of 'ia' and 'ib' FISCO field devices are as follows:

a) field devices shall have minimum input parameters of I_i:380 mA and P_i: 5,32 W;

b) field devices shall have a internal inductance L_i not greater than 10 μH.

G.3.3 Additional requirement of 'ic' FISCO field devices

The additional requirement of 'ic' FISCO field devices is that they shall have an internal inductance L_i not greater than 20 μH.

G.3.4 Terminator

The line terminators required by the system shall comprise a resistor-capacitor combination, which presents at its terminals a circuit equivalent to a resistor of minimum value 90 Ω in series with a capacitor of maximum value 2,2 μF (including tolerances).

NOTE 1 IEC 61158-2 specifies the component values necessary for operational reasons.

a) The terminator shall;

b) be allocated a level of protection

c) be suitable for Equipment Group I, II or III or any combination of these groups;

   1) Group IIC field devices intended to be installed within the hazardous area shall be temperature classified.

   2) Group III field devices intended to be installed in the hazardous area shall be allocated a maximum surface temperature.

d) If the capacitive component(s) are considered to be able to fail to create a short circuit then the required power rating of the resistors is 5,1 W;

e) have an input voltage parameter U_i not less than 17,5 V;

f) be isolated from earth in accordance with this standard; and,

g) have a maximum unprotected internal inductance L_i not greater than 10 μH;

NOTE 2 The terminators may be incorporated within field devices or power supplies.

NOTE 3 For safety assessment purposes, the effective capacitance, C_i, of the terminator is considered not to affect the intrinsic safety of the system.

G.3.5 Simple apparatus

The requirement of simple apparatus used in an intrinsically safe system is that the apparatus shall comply with this standard. Additionally the total inductance and capacitance of each simple apparatus connected to a FISCO system shall not be greater than 10μH and 5nF respectively.

NOTE Care should be taken in temperature classifying or allocating a maximum surface temperature to simple apparatus within an 'ia' or 'ib' system since the maximum power available may be as high as 5,32 W. Temperature classification of an 'ic' system is done in normal operation.

G.4 Marking

Each piece of apparatus shall be marked with the word "FISCO" followed by an indication of its function, i.e. power supply, field device or terminator. In addition, each piece of apparatus shall be marked in accordance with IEC 60079-11, except where modified by this annex. For example, the manufacturer's name and address shall still be marked.

Where apparatus is dual marked so that it can be used in both a FISCO system and a conventional intrinsically safe system, care shall be taken to differentiate between the FISCO marking and the marking for the conventional intrinsically safe system.

For FISCO power supplies, output parameters U_o, I_o, C_o, L_o, P_o and L_o/R_o need not be marked. For FISCO field devices or terminators, input and internal parameters U_i, I_i, C_i, L_i, P_i and L_i/R_i need not be marked.

G.4.1 Examples of marking

a) Power supply

FISCO power supply

U_m: 250 V

[Ex ia] IIC

John Jones Ltd

SW99 2AJ UK

Type: DRG OOI

- 20 °C ≤ Ta ≤ +50 °C

PTB Nr 01A 2341

Serial No. 014321

b) Field device

FISCO field device

Ex ia IIC T4

Paul McGregor plc

GL99 1JA UK

Type: RWS 001

-20 °C ≤ Ta ≤ +60 °C

c) Terminator

FISCO terminator

Ex ia IIC T4

James Bond plc

MK45 6BY UK

Type MI5 007

BAS 01 A 4321

Serial No. 012345

d) Dual marked field device

A McTavish plc

GL 98 1BA UK

Type RWS 002

-20 °C ≤ Ta ≤ +60 °C

INERIS 02 A 2345

Serial No. 060128

- - - - - - - - - - - - - - -

FISCO Field device

Ex ia IIC T4

- - - - - - - - - - - - - - - -

Ex ia IIC T6

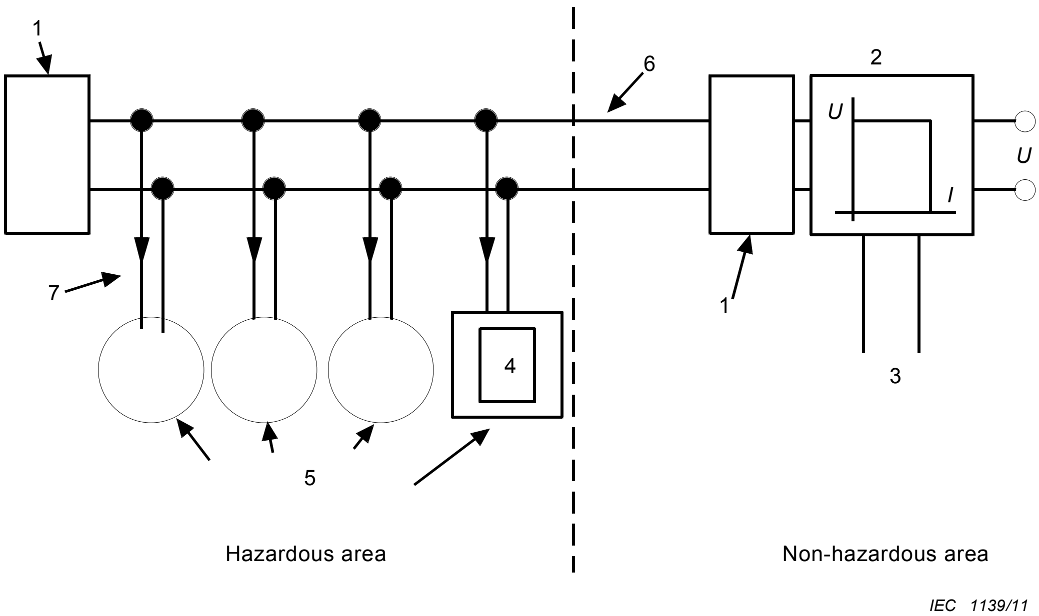
U_i: 28 V

C_i: 3 nF

I_i: 200 mA

L_i: 10 µH

P_i: 1,2 W



Key

1 Terminator	5 Field devices
2 Power supply	6 Trunk
3 Data	7 Spur
4 Hand held terminal	

Figure G.1 – Typical system

Annex H
(informative)

Ignition testing of semiconductor limiting power supply circuits

H.1 Overview

Power supplies are an essential item in any electrical circuit. Where the power is supplied to intrinsically safe circuits located in hazardous areas, the output of the power supply should be intrinsically safe.

NOTE 1 For the purposes of this annex, the term 'power supply' is a generic term. It may be dedicated equipment that provides intrinsically safe power, and it also may be a current regulator or a voltage enhancement circuit within equipment.

NOTE 2 This annex refers only to the intrinsically safe output of the power supply.

The earliest intrinsically safe power supplies consisted of an infallible transformer, rectifier, smoothing capacitor, followed by a current limiting resistor to limit the maximum output current. The output voltage was the voltage on the smoothing capacitor under no load conditions, or the voltage across the shunt connected Zener diodes that limit the maximum output voltage.

The curves and tables in Annex A are based on the voltages, currents, capacitances and inductances tested on the spark test apparatus using such simple power supply circuits, with no ignitions permitted for 400 revolutions of the spark test apparatus using 4 tungsten wires with cadmium disk. Mathematically, assuming that 1 600 sparks have occurred, it means that the probability of ignition (based on number of ignitions obtained) on an opening or closing of the output connections of the power supply is less than $6{,}25 \times 10^{-04}$. Actually, due to the bouncing of the tungsten wire on the cadmium disk, and due to the slots on the cadmium disk, the number of sparks is much higher. Therefore, the actual probability of ignition is lower.

Based on empirical data, it has been seen that a plot of logarithmic of probability of ignition versus the logarithmic of current in the circuit shows a linear relationship (see Figure H.1). Based on the requirements of this standard, power supplies (for "ia" and "ib") are considered in compliance with the standard only if they are spark tested using 1,5 times the current that they would normally provide, with the test gas being that specified for the particular group.

Based on the relationship of probability and current described above, such a power supply would have, at normal current, a probability of ignition lesser than $1{,}16 \times 10^{-06}$.

In summary, only such power supplies are considered satisfactory that provide a probability of ignition on an opening or closing of the output connections of the power supply at normal current and voltage of less than $1{,}16 \times 10^{-06}$.

Later developments in the design of power supplies introduced complex circuits that provide intrinsic safety not only by the limitation of current, voltage, inductance and capacitance, but also by the use of artificial limitation of discharge duration or limitation of voltage changing at switch contacts. Conventional tests using the spark test apparatus became unsatisfactory due to several reasons:

- it is not easily possible to increase the current or voltage in the power supply to provide the necessary 1,5 safety factor, as the circuits in most cases cannot be easily altered,
- the supply cannot deliver the increased current or voltage due to limitations in the rating of its components,
- changes made to the power supply to provide an increase in the current or voltage alters its timing circuits and hence changes its circuit performance

In such cases, it was generally considered satisfactory to provide the safety factor by increasing the sensitivity of the test gas mixture, using the mixtures specified as 'safety factor 1,5'. The intention was that the power supply would be tested with the increased safety factor of the test gas mixture to show that no ignition took place in the 400 revolutions of the spark test apparatus, hence proving that the ignition probability was less than $6,25 \times 10^{-04}$. It was hence assumed that under normal conditions, the ignition probability would be less than $1,16 \times 10^{-06}$.

However, it has been found that in some cases, that although the power supply has been tested for the ignition probability of less than $6,25 \times 10^{-04}$ with the gas mixture of safety factor 1,5, it did not provide the ignition probability of $1,16 \times 10^{-06}$ at normal conditions because the power supply did not follow the linear relationship of logarithmic of ignition probability with logarithmic of current. This has caused concern, and such power supplies are not considered as providing an 'acceptably low probability of ignition' at normal current.

This annex provides the test methods for testing such complex power supplies; a test gas mixture with increased sensitivity is used to achieve the safety factor (see 10.1.3.2).

It requires testing using a test gas with safety factor of 1,5, and ensuring that no ignition takes place in 400 revolutions. This test is done to ensure that the normative requirements of this Standard, as specified in 10.1.4, are followed.

It then requires further tests to ensure that the circuit exhibits a relationship between probability of ignition and safety factor of the test gas to ensure that at normal current and unity safety factor gas, the acceptably low ignition of $1,16 \times 10^{-06}$ is achieved. This is done by testing the power supply with gas mixtures with safety factors of SFx = 1,5, SFy = 2,0, SFz = 2,5. The plot of probability of ignition and safety factor on a log-log scale is taken. It is tested that either no ignition has taken place at these safety factors, or if ignitions have taken place, the slope of the semiconductor limited power supply is greater than that for simple circuits. Also, that the slope of the semiconductor limited supply continues to increase as the safety factor is reduced, hence ensuring that at normal current and unity safety factor, the ignition probability is less than that for a simple circuit, that is, less than $1,16 \times 10^{-06}$.

This annex is suitable for semiconductor current or voltage limited power supplies that limit or shut the current when the current or voltage limit is exceeded, but recover sufficiently rapidly between the successive strikes or opening of the wire and disc of the spark test apparatus so that they regain normal operation before the next strike or opening of the wire. This annex is not suitable for supplies that switch off for extended periods when the current or voltage is exceeded. In such cases, Annex E may be applicable.

H.2 Test

The power supply should be tested using the spark test apparatus for the following cases:

- 400 revolutions using test gas mixture providing a safety factor of 1,5, with no ignitions observed; and
- further tests as provided in Table H.1, to ensure that the probability of ignition at unity safety factor would be acceptable and lower than that for a simple circuit.

Some of the gas mixtures suitable for the above tests, and the corresponding calibrating currents using the standard 24V 95 mH calibrating circuit are provided in Table H.2.

Reference to DUT in the test sequence of Table H.1 refers to device under test. It is the power source within the equipment, with faults applied as per the level of protection, and the voltage and current set at the maximum values within the tolerances of the circuit components. Safety factors are not applied to the current or voltage, because these are applied to the test gases.

Where the test sequence described in Table H.1 requires the use of a simple circuit, it will be made up of a laboratory power supply with a voltage set at the Uo of the DUT, and short circuit current limited to Io of the DUT by use of a series low-inductance current limiting resistor.

Table H.3 is an example of a circuit that passes the test sequence of Table H.1. The plot of this circuit is provided in Figure H.1, labelled 'Pr – Table H.3 – PASS'. When the plot of this circuit is compared with the plot for a simple circuit, labelled 'Pr – Simple Circuit', it shows that while there are more ignitions when the safety factor is higher, at 1,67 and 2,5, but as the safety factor is reduced, the probability reduces faster than for a simple circuit, and therefore has an acceptably low figure as the safety factor would drop to unity.

Table H.4 is an example of a circuit that does not pass the test sequence of Table H.1. The plot of this circuit is provided in Figure H.1, labelled 'Pr – Table H.4 – FAIL'. When the plot of this circuit is compared with the plot for a simple circuit, labelled 'Pr – Simple Circuit', it shows that while there are less ignitions when the safety factor is higher, at 1,67 and 2,5, but as the safety factor is reduced, the probability does not reduce faster than for a simple circuit, and therefore it does not slope to an acceptably low figure as the safety factor would drop to unity.

Table H.1 – Sequence of tests

Step #	Description	Column 'x'	Column 'y'	Column 'z'
1	Target safety factor	1,5	1,67 to 2,0	2,0 to 2,5
2	Determination of target calibration current for 24 V 95 mH calibration circuit	$\frac{(calibration\_current\_provided\_in\_Table7)}{(Target\_Safety\_Factor)}$	$\frac{(calibration\_current\_provided\_in\_Table7)}{(Target\_Safety\_Factor)}$	$\frac{(calibration\_current\_provided\_in\_Table7)}{(Target\_Safety\_Factor)}$
3	Test gas used	Use Table H.2 if useful	Use Table H.2 if useful	Use Table H.2 if useful
4	Calibration current achieved	Measure using 24V 95mH calibration circuit	Measure using 24V 95mH calibration circuit	Measure using 24V 95mH calibration circuit
5	Safety factor achieved (should be within range specified in Step 1)	$SFx = \frac{(Calibration\_current\_provided\_in\_Table7)}{(Calibration\_Current\_Achieved)}$	$SFy = \frac{(Calibration\_current\_provided\_in\_Table7)}{(Calibration\_Current\_Achieved)}$	$SFz = \frac{(Calibration\_current\_provided\_in\_Table7)}{(Calibration\_Current\_Achieved)}$
6	Number of revolutions for DUT (Device Under Test)	4000	400	40
7	Number of sparks assumed for above number of revolutions	16 000	1 600	160
8	DUT tested for number of revolutions at Step 6 and number of ignitions obtained	Nx	Ny	Nz
9	Probability based on number of ignitions per spark obtained	$Px = \frac{Nx}{16000}$	$Py = \frac{Ny}{1600}$	$Pz = \frac{Nz}{160}$
10	Possible compliance result	If either Px = 0, or Py = 0, or Pz = 0, the DUT has passed. If all are not 0, then continue to Step 11		
11	Simple circuit (made up of laboratory power supply and current limiting resistor) tested as provided in Step 8 above, and number of ignitions obtained	Na	Nb	Nc
12	Probability based on number of ignitions per spark obtained for the simple circuit	$Pa = \frac{Na}{16000}$	$Pb = \frac{Nb}{1600}$	$Pc = \frac{Nc}{160}$
13	Compliance calculation	The DUT has passed if the following conditions are met: (log Px) ≤ (log Pa), or $Px \le Pa$		

Step #	Description	Column 'x'	Column 'y'	Column 'z'
		(log Py – log Px) ≥ (log Pb – log Pa), or $\frac{Py}{Px} \geq \frac{Pb}{Pa}$ $\frac{(\log Py - \log Px)}{(\log SFy - \log SFx)} \geq \frac{(\log Pz - \log Py)}{(\log SFz - \log SFy)}$, or $\left(\frac{Py}{Px}\right)^{\log\frac{SFz}{SFy}} \geq \left(\frac{Pz}{Py}\right)^{\log\frac{SFy}{SFx}}$		

Table H.2 – Safety factor provided by several explosive test mixtures that may be used for the tests in Table H.1

	Compositions of explosive test mixtures, % by volume in the air	Current in the calibration circuit, mA	Safety factor for group and subgroup of electrical equipment			
			I	IIA	IIB	IIC
	(8,3 ± 0,3) % methane	110-111	1			
	(5,25 ± 0,25)% propane	100-101	1,089-1,11	1		
	(52 ± 0,5) % hydrogen	73-74	1,49-1,52	1,35-1,38		
	(48 ± 0,5) % hydrogen	66-67	1,64-1,68	1,49-1,53		
	(7,8 ± 0,5) % ethylene	65-66	1,67-1,7	1,52-1,55	1	
	(38 ± 0,5) % hydrogen	43-44	2,5-2,58	2,27-2,35	1,47-1,53	
	(21 ± 2) % hydrogen	30-30,5	3,6-3,7	3,27-3,36	2,13-2,2	1
	(60 ± 0,5)% hydrogen/ (40 ± 0,5)% oxygen	20-21	5,23-5,55	4,76-5,05	3,09-3,3	1,42-1,53
	(70 ± 0,5)% hydrogen/ (30 ± 0,5)% oxygen under the pressure of 0,22 MPa	15-15,3	-	-	-	1,96-2,03

Table H.3 – Example of a Group I circuit with characteristics described by Curve II of Figure H.1 – This passes the test sequence of Table H.1

Step #	Description	Column 'x'	Column 'y'	Column 'z'
1	Target safety factor	1,5	1,67 to 2,0	2,0 to 2,5
2	Determination of target calibration current for 24 V 95 mH calibration circuit	$\frac{110\_mA}{(1.5)}$ = 73 mA	$\frac{110\_mA}{(1.67\_to\_2.0)}$ = 66 to 55 mA	$\frac{110\_mA}{(2.0\_to\_2.5)}$ = 55 to 44 mA
3	Test gas used	52 % H_2: 48 % air	48 % H_2: 52 % air	38 % H_2: 62 % air
4	Calibration current achieved	73 mA	66 mA	44 mA
5	Safety factor achieved (should be within range specified in Step 1)	$SFx = \frac{(110\_mA)}{(73\_mA)}$ = 1,5 Okay Log SFx = 0,17609	$SFy = \frac{(110\_mA)}{(66\_mA)}$ = 1,67 Okay Log SFy = 0,22272	$SFz = \frac{(110\_mA)}{(44\_mA)}$ = 2,5 Okay Log SFz = 0,39794
6	Number of revolutions for DUT (Device under test)	4 000	400	40
7	Number of sparks assumed for above number of revolutions	16 000	1 600	160
8	DUT tested for number of revolutions at Step 6 and number of ignitions obtained	Nx = 1 ignition	Ny = 9 ignition	Nz = 80 ignition
9	Probability based on number of ignitions per spark obtained	$Px = \frac{1}{16000} = 6,25 \times 10^{-5}$ Log Px = -4,20412	$Py = \frac{9}{1600} = 5,6 \times 10^{-3}$ Log Py = -2,25181	$Pz = \frac{80}{160} = 5,0 \times 10^{-1}$ Log Pz = -0,30103
10	Possible compliance result	$Px \neq 0$, $Py \neq 0$, $Pz \neq 0$, therefore continue to Step 11		
11	Simple circuit (made up of laboratory power supply and current limiting resistor) tested as provided in Step 8 above, and number of ignitions obtained	Na = 10 ignitions	Nb = 3 ignitions	Nc = 32 ignitions
12	Probability based on number of ignitions per spark obtained for the Simple circuit	$Pa = \frac{10}{16000} = 6,25 \times 10^{-4}$ Log Pa = -3,20412	$Pb = \frac{3}{1600} = 1,88 \times 10^{-3}$ Log Pb = -2,72584	$Pc = \frac{32}{160} = 2,0 \times 10^{-1}$ Log Pc = -0,69897
13	Compliance calculation	The DUT has passed because: (log Px) ≤ (log Pa)? Yes, because -4,20412 < -3,20412		

Step #	Description	Column 'x'	Column 'y'	Column 'z'
		(log *Py* – log *Px*) ≥ (log *Pb* – log *Pa*)? Yes, because (-2,25181 + 4,20412 = +1,95231) > (-2,72584 + 3,20412 = +0,47828) $\frac{(\log Py - \log Px)}{(\log SFy - \log SFx)} \geq \frac{(\log Pz - \log Py)}{(\log SFz - \log SFy)}$? Yes, because $\left\{\frac{(-2{,}25181+4{,}20412)}{(0{,}22272-0{,}17609)} = 41{,}868\right\} \geq \left\{\frac{(-0{,}30103+2{,}25181)}{(0{,}39794-0{,}22272)} = 11{,}1333\right\}$		

Table H.4 – Example of a Group I circuit with characteristics described by Curve III of Figure H.1 – This does not pass the test sequence of Table H.1

Step #	Description	Column 'x'	Column 'y'	Column 'z'
1	Target_safety_factor	1,5	1,67 to 2,0	2,0 to 2,5
2	Determination of target calibration current for 24 V 95 mH calibration circuit	$\frac{110\_mA}{(1{,}5)}$ = 73 mA	$\frac{110\_mA}{(1{,}67\_to\_2{,}0)}$ = 66 to 55 mA	$\frac{110\_mA}{(2{,}0\_to\_2{,}5)}$ = 55 to 44 mA
3	Test_gas_used	52 % H_2: 48 % air	48 % H_2: 52 % air	38 % H_2: 62 % air
4	Calibration_current_achieved	73 *mA*	66 *mA*	44 *mA*
5	Safety factor achieved (should be within range specified in Step 1)	$SFx = \frac{(110\_mA)}{(73\_mA)}$ = 1,5 Okay Log *SFx* = 0,17609	$SFy = \frac{(110\_mA)}{(66\_mA)}$ = 1,67 Okay Log *SFy* = 0,22272	$SFz = \frac{(110\_mA)}{(44\_mA)}$ = 2,5 Okay Log *SFz* = 0,39794
6	Number of revolutions for DUT (Device under test)	4 000	400	40
7	Number of sparks assumed for above number of revolutions	16 000	1 600	160
8	DUT tested for number of revolutions at Step 6 and number of ignitions obtained	*Nx* = 6 ignition	*Ny* = 1 ignition	*Nz* = 1 ignition
9	Probability based on number of ignitions per spark obtained	$Px = \frac{(6)}{16000} = 3{,}75 \times 10^{-4}$ Log *Px* = -3,42597	$Py = \frac{1}{1600} = 6{,}25 \times 10^{-4}$ Log *Py* = -3,20412	$Pz = \frac{1}{160} = 6{,}25 \times 10^{-3}$ Log *Pz* = -2,20412
10	Possible compliance result	$Px \neq 0$, $Py \neq 0$, $Pz \neq 0$, therefore continue to Step 11		
11	Simple circuit (made up of laboratory power supply and current limiting resistor) tested as provided in Step 8 above, and number of ignitions obtained	*Na* = 10 ignitions	*Nb* = 3 ignitions	*Nc* = 32 ignitions
12	Probability based on number of ignitions per spark obtained for the simple circuit	$Pa = \frac{10}{16000} = 6{,}25 \times 10^{-4}$ Log *Pa* = -3,20412	$Pb = \frac{3}{1600} = 1{,}88 \times 10^{-3}$ Log *Pb* = -2,72584	$Pc = \frac{32}{160} = 2{,}0 \times 10^{-1}$ Log *Pc* = -0,69897
13	Compliance calculation	The DUT has not passed because: (log *Px*) ≤ (log *Py*)? Yes, because -3,42597< -3,20412		

Step #	Description	Column 'x'	Column 'y'	Column 'z'
		(log *Py* – log *Px*) ≥ (log *Pb* – log *Pa*)? NO, because (-3,20412+3,42597 = +0,22185) not greater than (-2,72584+3,20412 = +0,47828) $\frac{(\log Py - \log Px)}{(\log SFy - \log SFx)} \geq \frac{(\log Pz - \log Py)}{(\log SFz - \log SFy)}$? NO, because $\left\{ \frac{(-3{,}20412 + 3{,}42597)}{(0{,}22272 - 0{,}17609)} = 4{,}75766 \right\}$ not greater than $\left\{ \frac{(-2{,}20412 + 3{,}20412)}{(0{,}39794 - 0{,}22272)} = 5{,}70711 \right\}$		

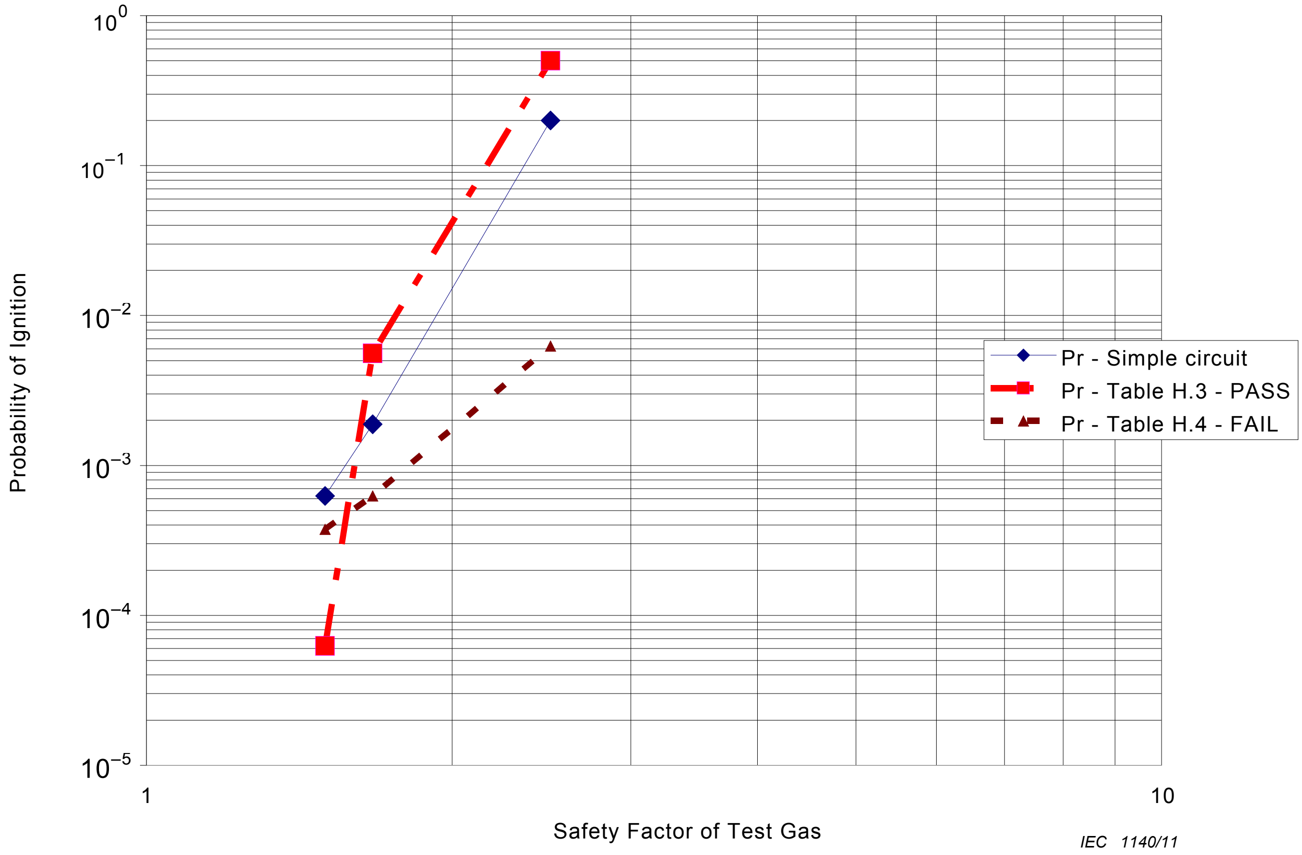


Figure H.1 – Safety factor vs ignition probablity

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