भारतीय मानक

IS/IEC 60079 (Part 11) : 2023

*Indian Standard*

# विसफोटी पर्यावरण

## भाग 11 आंतरिक सुरक्षा "i" द्वारा उपकरण सुरक्षा

*( दूसरा पुनरीक्षण )*

# Explosive Atmospheres

## Part 11 Equipment Protection by Intrinsic Safety "i"

*( Second Revision )*

ICS 29.260.20

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भारतीय मानक ब्यूरो
BUREAU OF INDIAN STANDARDS
मानक भवन, 9 बहादुर शाह ज़फर मार्ग, नई दिल्ली - 110002
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI - 110002
www.bis.gov.in www.standardsbis.in

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Electrical Apparatus for Explosive Atmospheres Sectional Committee, ETD 22

NATIONAL FOREWORD

This Indian Standard (Part 11) (Second Revision) which is identical to IEC 60079-11 : 2023 'Explosive atmospheres — Part 11: Equipment protection by intrinsic safety "i"' issued by the International Electrotechnical Commission (IEC) was adopted by the Bureau of Indian Standards on the recommendation of the Electrical Apparatus for Explosive Atmosphere Sectional Committee and approval of the Electrotechnical Division Council.

This revision has been undertaken to align with the latest version of IEC 60079-11 : 2023. This edition supersedes IS/IEC 60079-11 : 2011. This edition constitutes a technical revision.

The text of IEC standard has been approved as suitable for publication as an Indian Standard without deviations. Certain terminologies and conventions are, however, not identical to those used in Indian Standards. Attention is particularly drawn to the following:

a) Wherever the words 'International Standard' appear referring to this standard, they should be read as 'Indian Standard'; and

b) Comma (,) has been used as a decimal marker, while in Indian Standards the currentpractice is to use a point (.) as the decimal marker.

The significance of changes between IS/IEC 60079-11 : 2023 and IS/IEC 60079-11 : 2011 are as listed below:

| | | **Type** | | |
|---|---|---|---|---|
| **Explanation of the Significance of Changes** | **Clause** | **Minor and Editorial Changes** | **Extension** | **Major Technical Changes** |
| A significant number of editorial changes including re-structuring of sections. These are too numerous to list in this table. | All | X | | |
| Protection of catalytic elements for Group IIC or Group IIB + H2 excluded from the scope of the standard. | **1**<br>**7.14.2** | | | C2 |
| Extension, with requirements, of ambient pressure down to 60 kPa. | **1**<br>**6.5.6.1** | | B1 | |
| Modification to Table 1 showing Clause 14 of IEC 60079-0 as 'Applies'. This does not affect the technical requirements. | **1** | X | | |
| Definitions removed as they are now in IEC 60079-0 (references are from IS/IEC 60079-11 : 2011)<br><br>3.2 coating<br>3.3 conformal coating<br>3.7.1 countable fault<br>3.7.3 non-countable fault<br>3.18 recurring peak voltage<br>3.20 encapsulation<br>3.21 casting<br>3.23 galvanic isolation | **3** | X | | |

| Explanation of the Significance of Changes | Clause | Type | | |
|---|---|---|---|---|
| | | **Minor and Editorial Changes** | **Extension** | **Major Technical Changes** |
| Definitions removed as they are no longer considered necessary (references are from IS/IEC 60079-11 : 2011)<br>3.7.2 fault<br>3.10.3 Infallible separation | **3** | X | | |
| Diode safety barriers no longer refers to devices that provide galvanic isolation. | **3.1.7**<br>**7.7.5** | | X | |
| Intrinsic safety parameters and Um can have brief transients above the stated values, and these do not need to be taken into account. | **3.1.12**<br>**7.7.3** | X | | |
| New definition – spark test apparatus. | **3.1.14** | X | | |
| New definition – electrochemical capacitor. | **3.1.15** | | X | |
| New definition – transient rating. | **3.1.16.1** | | X | |
| New definition – transient energy (previously let-through energy). | **3.1.16.2** | X | | |
| New definition – non-hazardous area accessory. | **3.1.17** | X | | |
| Clarification that it is not a requirement of this standard that conformance to industrial standards be verified. | **5.1** | X | | |
| Clarification of conditions for the assessment added. | **5.2.1** | X | | |
| Clarification relating to the application of service temperatures. | **5.2.1 g)** | | | C1 |
| Statements that Level of Protection "ia" and "ib" requirements are always sufficient for level of protection "ic". | **5.2.2** | | X | |
| For level of protection "ic", faults are only considered for spark ignition assessment and the determination of Uo, Io, Li, Ci and Li/Ri. A short circuit fault, and subsequent component faults arising, are now termed non-countable faults. | **5.2.4**<br>**6.5.4.3**<br>**6.5.4.4**<br>**6.5.4.5** | | | C3 |
| For level of protection "ic", the types of components on which intrinsic safety depends are limited. | **5.2.4** | | X | |
| Clarification of the requirements for non-shock hazard equipment or systems (for example, SELV/PELV) for declaration of Um. | **5.2.5**<br>**12.1 c)** | A1 | | |
| Clarification of where spark ignition assessment should and should not be applied. | **5.3.1** | X | | |
| Clarification that spark ignition assessment may be performed on a representative circuit. | **5.3.1**<br>**9.1.1** | X | | |

| Explanation of the Significance of Changes | Clause | Type | | |
|---|---|---|---|---|
| | | Minor and Editorial Changes | Extension | Major Technical Changes |
| Spark ignition assessment at normal ambient is suitable for service temperatures between - 60 °C and 100 °C. | **5.3.1** | | X | |
| Spark ignition testing of mains apparatus is at Um rather than 110 percent of the mains nominal voltage. | **5.3.4.2 d)** | X | | |
| Annex G added as option for spark ignition assessment. | **5.3.4.1**<br>**5.3.4.2**<br>**9.2.6 c)**<br>**Annex G** | | X | |
| Clarification of the requirements for circuits with controlled semiconductor limitation, including need to consider both steady state and transient spark ignition compliance for circuits with controlled semiconductor limitation. | **5.3.6**<br>**Annex D** | | | C4 |
| The exclusion of the IEC 60079-0 10 percent safety margin on voltage for thermal ignition assessment extended to Groups I and II. | **5.4.1** | | X | |
| The 1.3 W limit for T4 for tracks on a printed circuit board now only applies to 40 °C ambient. | **5.4.1** | | | C5 |
| The 5K and 10K margin required for temperature tests from IEC 60079-0 now apply for Level of Protection "ic". | **5.4.2** | | | C6 |
| Corrected the formula for thermal assessment of wires. | **5.4.3** | | | C7 |
| Clarified that only circuit board tracks exposed to the explosive atmosphere require temperature classification. | **5.4.4** | X | | |
| Added a note identifying examples of available data for determining temperature rise in PCB tracks (from IPC- 2221 and IPC-2152). | **5.4.4** | X | | |
| Clarified which dimensions can be reduced by manufacturer's tolerance (track width, board thickness, and conductor thickness). | **5.4.4** | X | | |
| Clarified the use of Table 4 by introducing reduction factors for board thickness, number of layers, copper thickness, track under component, and ambient temperature. | **5.4.4** | | X | |
| Added allowance for linear interpolation of allowed current, track width, track thickness, ambient temperature, and board thickness. | **5.4.4** | | X | |
| Extrapolation of Table 4 is prohibited. | **5.4.4** | | | C1 |

| Explanation of the Significance of Changes | Clause | Type | | |
|---|---|---|---|---|
| | | **Minor and Editorial Changes** | **Extension** | **Major Technical Changes** |
| Reduced the default board thickness for application of Table 4 from 1.6 mm to 1.55 mm to reflect industry standard. | **5.4.4** | | X | |
| Clarified that the track under component reduction factor only applies if the portion of the track underneath the component is greater than 10 mm. | **5.4.4** | | X | |
| Use of the 1.3 W limit for thermal ignition compliance for Group III extended to include Group I. | **5.4.5** | | X | |
| Board thickness, copper thickness and ambient temperature factors extended in use of Table 4. | **5.4.4** | | X | |
| Enclosure requirement for Groups IIIA and IIIB aligned with Group I and Group II. | **6.2.1** | | X | |
| Clarification that the IEC 60079-0 enclosure requirements apply for Group IIIC equipment with separations according to Table 7 (IS/IEC 60079-11 : 2011 Table 5) that are reliant on an enclosure providing IP5X. | **6.2.4 a)1)** | | | C1 |
| Requirement for a specific condition of use added when use of reduced separations is reliant on an enclosure providing IP54. | **6.2.5.1** | | | C8 |
| Plugs and sockets can comply with reduced separation requirements. | **6.3.3** | | X | |
| Use of an enclosure to protect battery charging connections from spark ignition (IS/IEC 60079-11 : 2011 **7.4.9**) extended to include all non-hazardous area connection facilities. | **6.3.5.2** | | X | |
| It is no longer necessary to define Um for the connection from non-hazardous area connection facilities to accessories listed in the certificate provided the accessory is suitably marked and listed in the instructions. | **6.3.5.3**<br>**11.1.5**<br>**12.1 j)** | | X | |
| It is no longer necessary to assess a non-hazardous area accessory in accordance with this standard. | **6.3.5.3** | | X | |
| Clarification that charging of cells and batteries in the non-hazardous area has to be within the limits specified by their manufacturer, and IEC 60079-0. | **6.3.5.3** | X | | |
| Conductors, connectors and PCB tracks have to be suitably rated for their failure to be a countable fault. | **6.4.1** | | | C9 |

| Explanation of the Significance of Changes | Clause | Type<br>Minor and Editorial Changes | <br>Extension | <br>Major Technical Changes |
|---|---|---|---|---|
| It is now a stated requirement that circuits remain intrinsically safe after disconnection of a connector. | **6.4.1** | | | C1 |
| It is now a requirement that infallible connections remain capable of carrying the current following considered fault disconnections. | **6.4.2.2**<br>**6.4.2.3** | | | C10 |
| Infallible PCB connection achieved with two 1 mm wide tracks now have copper thickness requirements. | **6.4.2.4** | | | C11 |
| The options for infallible PCB connections have been extended. | **6.4.2.4** | | B2 | |
| Clarification that connections complying with IEC 60079-7 level of protection "eb" can be considered infallible. | **6.4.2.5** | X | | |
| Clarification that insulation of component packaging cannot be relied upon for separation of conductive parts unless it is specified by the component manufacturer, except for shorts to its solder pads where they are similar to the recommendations of the component manufacturer. | **6.5.1** | X | | |
| Alternate spacing requirements from the previous edition Annex F have been transferred to the main body of this document. | | A2 | | |
| Specific condition of use only required for overvoltage category (OVC) I/II when using Table 8 – Reduced separations. | **6.5.3.2** | | X | |
| Dielectric strength requirements have been clarified in Table 8 – Reduced separations. | **6.5.3.2** | | | C12 |
| Specific condition of use required when OVC II/I is required for mains apparatus when using Table 9 – Reduced separations for Level of Protection "ic". | **6.5.3.3** | | | C13 |
| Table 8 – Reduced separations is derived from IS/IEC 60079-11 : 2011 Table F.1 but with additional requirements. | **6.5.3.2** | | X | |
| Routine tests when using Table 8 – Reduced separations no longer have to be performed at the most onerous ambient condition. | **6.5.3.2** | | X | |
| Table 9 – Reduced separations for level of protection "ic" is derived from IS/IEC 60079-11: 2011 Table F.2 but with additional requirements. | **6.5.3.3** | | X | |

| Explanation of the Significance of Changes | Clause | Type | | |
|---|---|---|---|---|
| | | Minor and Editorial Changes | Extension | Major Technical Changes |
| Additional options for infallible separations when exposing connection facilities. | **6.5.4.2** | | X | |
| Separations tables clarify that the voltages do not need to include non-repetitive transients. | **Table 7**<br>**Table 8**<br>**Table 9** | X | | |
| Determination of type and routine testing required when using reduced separations tables. | **Table 8**<br>**6.5.6.2**<br>**6.5.6.3**<br>**6.5.6.5**<br>**9.7** | | | C14 |
| Additional separation distance options. | **Table 8**<br>**Table 9** | | X | |
| Dielectric strength test is no longer required for all separations through casting compound and solid insulation. | **6.5.6.2**<br>**6.5.6.3** | | X | |
| When comparative tracking index (CTI) Is unknown, a CTI of 100 may be assumed, and some materials are identified as non-tracking. | **6.5.6.4** | | X | |
| Extended and clarified requirements for assessing creepage distances. | **6.5.6.4** | | X | |
| Two coats of conformal coating no longer required when spraying. | **6.5.6.5** | | X | |
| Consideration of composite separations extended to reduced distances tables. | **6.5.7** | | X | |
| Metal parts used for separation no longer have to be earthed. | **6.5.9** | | X | |
| Where metal parts connected to the frame or earth are used to separate two circuits, a specific condition of use is now required. | **6.5.9.1** | | | C15 |
| Clarification that separation by metal parts requires infallible connection. | **6.5.9.1** | | | C1 |
| Relaxation of requirements for non-metallic insulating partitions for level of protection "ic". | **6.5.10** | | X | |
| Added requirements for insulation between internal wiring of separate intrinsically safe circuits. | **6.5.11.3** | | X | |
| Encapsulation requirements have been separated and extended according to the purpose of the encapsulation. | **6.6** | | X | |
| Routine verification of encapsulation added. | **6.6.1**<br>**10.4** | | | C16 |

| Explanation of the Significance of Changes | Clause | Type<br>Minor and Editorial Changes | Extension | Major Technical Changes |
|---|---|---|---|---|
| The specified COT for encapsulation shall not be exceeded in normal operation. Tighter requirements for damage to compound for temperature greater than COT. | **6.6.1 a)** | | | C17 |
| Free space within encapsulation other than within components is now permitted. | **6.6.1**<br>**6.6.7** | | X | |
| Requirements for specification of coating, encapsulation and moulding materials. | **6.7** | | | C18 |
| Components used to protect against polarity reversal have to be rated to 7.1. | **6.8** | | | C1 |
| It is now stated that there are circumstances where 2/3rd rating for all three of voltage, current and power are not applicable for Levels of Protection "ia" and "ib". | **7.1** | X | | |
| Power rating for level of protection "ic" does not require a 1.5 safety factor following the application of faults. | **7.1** | | X | |
| Components for level of protection "ic" are considered to fail if they are not within their manufacturer's rating following the application of faults. | **7.2** | | | C19 |
| Clarification of the application of manufacturing variations added. | **7.3** | X | | |
| Resistors of types not listed (film, wire wound and printed) cannot now be considered to fail as a countable fault, nor to limit their own temperature. | **7.4.2** | | | C20 |
| Clarified that the voltage rating to which the safety factor is applied is that of the resistor series, and not that based on the resistance. | **7.4.2** | X | | |
| Clarification of the power rating of resistors in series with super capacitors. | **7.4.2** | X | | |
| Cold resistance of a fuse, filament of a bulb or infra-red source is assessed at the service temperature rather than the ambient temperature. | **7.4.2** | | | C21 |
| The filament of an infra-red sensor can be used as a resistor for limitation. | **7.4.2** | | X | |
| Clarification that self-heating of capacitors need not be considered. | **7.5.1** | | X | |
| An arrangement of two series blocking capacitors need have only half of the infallible separation across each when using Table 7 and Table 9 (this was already permitted for Table 8). | **7.5.3** | | X | |

| Explanation of the Significance of Changes | Clause | Type: Minor and Editorial Changes | Type: Extension | Type: Major Technical Changes |
|---|---|---|---|---|
| Clarification of the failure modes for inductors and transformers. | **7.6.1**<br>**7.8.1** | X | | |
| References to IEC 60317 updated. | **7.6.3** | X | | |
| Added requirements and tests for common mode chokes which provides allowances to consider only the leakage inductance of common mode chokes, or the inductance of only one coil. | **7.6.5**<br>**9.15** | | X | |
| Clarification that assessment of semiconductors cannot be based on failure rates. | **7.7.1** | | | C1 |
| An enhanced voltage generated by an integrated circuit does not need to be considered as being present on other connected pins. | **7.7.1 c)** | | X | |
| Added an allowance for low complexity semiconductors to avoid being considered to fail so as to dissipate maximum power. | **7.7.1.d) 2)** | | X | |
| Transient rating of semiconductors only applied to transients caused by current limitation. | **7.7.3** | | X | |
| Clarification that a safety factor of 1.0 is required when assessing the transient power rating of a semiconductor on which intrinsic safety depends. | **7.7.3** | X | | |
| For level of protection "ic", transient rating of semiconductors is only necessary for diode safety barriers. | **7.7.3** | | X | |
| Where two diodes are used in a safety shunt for level of protection "ia", the failure of only a single diode has been extended to the failure of a single shunt path. This means that the tracking from the diode to reference voltages (for example, ground) no longer have to be infallible. | **7.7.6** | | X | |
| Controlled semiconductor current limitation is permitted for level of protection "ia". | **7.7.7** | | X | |
| Clarification of the requirements for programmable components. | **7.7.8** | | | C1 |
| Statement that transformers need not be considered to increase the voltage or current beyond that defined by their turns ratio. | **7.8.1** | X | | |
| Table 17 extended with a 10 A column. | **7.8.3** | | X | |
| Foil/screen thickness for 10 A added. | **7.8.3** | | X | |

| Explanation of the Significance of Changes | Clause | Type | | |
|---|---|---|---|---|
| | | Minor and Editorial Changes | Extension | Major Technical Changes |
| Clarification that the requirement for mains transformers includes any transformer that is not galvanically isolated from the mains. | **7.8.4.1** | | | C1 |
| Reduced requirements for transformers that are galvanically isolated from the mains. | **7.8.4.2** | | X | |
| Clarification of requirements for transformers for level of protection "ic". | **7.8.5**<br>**9.17.4** | X | | |
| Requirements for transformers for level of protection "ic" added. | **7.8.5** | | | C22 |
| Clarification of the rating requirements for relays. | **7.9.2** | X | | |
| Countable fault separation between the coil and contacts of a relay is no longer permitted. | **7.9.2 a)** | | | C23 |
| Addition of option for relays depending on reduced separation distances internally to comply with IEC 61810-1. | **7.9.2** | | X | |
| Relays in level of protection "ic" need only comply with the relevant industrial standards. | **7.9.2** | | X | |
| Clarified that IEC 60079-28 does not apply to self-contained optical isolators. | **7.10.1** | X | | |
| Addition of options for non-optical signal isolators. | **7.10.2** | | X | |
| Clarified that a single fuse is sufficient. | **7.11** | X | | |
| Clarification that the cold resistance of a fuse cannot be used to limit the breaking current. | **7.11** | | | C1 |
| A fuse in level of protection "ic" shall be considered an ignition risk if its opening is an expected occurrence. | **7.11** | | | C24 |
| Clarification that the breaking capacity of fuses connected to Um may be less than 1 500 A provided that the maximum prospective current is stated in the instructions. | **7.11**<br>**12.1 j)** | | | C25 |
| Cells which may explode no longer require a statement from the manufacturer of the cell that they are safe for use in any particular apparatus. | **7.12.1** | | X | |
| Clarification that temperature rise and electrolyte leakage should be considered for cells. | **7.12.1** | | | C1 |
| Clarification that short circuit of a single cell is considered a non-countable fault. | **7.12.2** | | | C1 |

| Explanation of the Significance of Changes | Clause | Type: Minor and Editorial Changes | Extension | Major Technical Changes |
|---|---|---|---|---|
| Demonstration of the concentration of hydrogen can come from the manufacturer, rather than the manufacturer of the battery. | **7.12.4** | | X | |
| Containers for sealed cells and batteries no longer need the pressure test of 9.14.4. | **7.12.4** | | X | |
| Clarification of conditions for determining cell voltages | **7.12.5** | X | | |
| Clarified that the requirements only apply to replaceable batteries. | **7.12.8** | X | | |
| Crystal oscillators are excluded from the requirements for piezoelectric devices, and there are extended requirements for level of protection "ic". | **7.13** | | X | |
| Clarified that thermal assessment of catalytic sensors shall take into account heating due to the catalytic reaction. | **7.14.2** | | | C1 |
| Clarification that super capacitors shall be treated as batteries with a limited capacity but without the ability to limit their own voltage. | **7.15**<br>**9.14** | | | C26 |
| Requirements and tests for thermal devices added, including PTCs. | **7.16**<br>**9.12** | | | C27 |
| Clarification that mechanical switches do not require thermal ignition assessment. | **7.17** | X | | |
| Clarification that the protective diodes in diode safety barriers shall be protected by a fuse or resistor(s) and not controlled semiconductor limitation. | **8.1.1** | X | | |
| Additional options for earth facilities for diode safety barriers. | **8.1.2.2** | | X | |
| Requirement for 110 percent of the mains supply voltage when applying the spark test apparatus removed as the conditions for test are specified in **5.2**. | **9.1.1** | | X | |
| Clarified that all circuits (not just capacitive) need to have time to recover where applicable during spark testing. | **9.1.2** | X | | |
| Added allowance for slowing the spark test apparatus down when removing wires is not sufficient to allow rest of the circuit under test. | **9.1.2** | | X | |
| Clarified that the effect of temperature on an inductor's resistance shall be taken into account during spark testing. | **9.1.2** | | | C1 |
| Clarified that the sensitivity of the spark test apparatus may be checked if there is an unexpected failure. | **9.1.2** | X | | |

| Explanation of the Significance of Changes | Clause | Type<br>Minor and Editorial Changes | Extension | Major Technical Changes |
|---|---|---|---|---|
| Minimum ignition current for calibration of the spark test apparatus added. | **9.1.3** | X | | |
| Added formula option for reducing effective capacitance with a resistor. | **9.2.3.3** | | X | |
| Clarification that consideration of the combination of inductance and capacitance is required internal to equipment and not just at connection facilities. | **9.2.6** | X | | |
| An assessment that demonstrates that the safety factor is maintained with a combination of both inductance and capacitance is allowed. | **9.2.6 b)** | | X | |
| Where parameters are specified for combined lumped inductance and capacitance, that shall be stated in the certificate or documentation. | **9.2.6** | X | | |
| 30 N test for casting compound and partitions are not applicable for level of protection "ic". | **9.4.1**<br>**9.4.3** | | X | |
| Test temperature for immersion in water for encapsulated fuses has been lowered by 2 °C for compatibility with other testing. | **9.4.2** | X | | |
| Parameters for loosely specified components shall be determined taking into account the service temperature, not just the ambient temperature. | **9.13** | X | | |
| Clarification and modification of the tests for optical isolators. | **9.10** | | X | |
| Clarified that tests on piezoelectric devices need be performed on only a single sample, unless that sample is damaged during the testing. | **9.11** | X | | |
| Clarified that primary cells shall be unused and limiting devices shall be removed for the electrolyte leakage test. | **9.14.1** | X | | |
| Clarified that the current shall be continuous when discharging during the tests. | **9.14.1** | | | C1 |
| Cells that have essential features that limit their current may be used for level of protection "ia". | **9.14.1** | | X | |
| Cells that explode or catch fire during short circuit test shall not be used for levels of protection "ia" and "ib". | **9.14.1** | X | | |
| Electrolyte leakage and surface temperature test requirements for cells and batteries modified to cover the number of samples | **9.14.1** | | | C28 |

| Explanation of the Significance of Changes | Clause | Type: Minor and Editorial Changes | Type: Extension | Type: Major Technical Changes |
| --- | --- | --- | --- | --- |
| tested, the test temperature, and testing with dust layers. | | | | |
| Added option to conduct short circuit until discharge testing for level of protection "ic" to establish compliance with the electrolyte leakage requirement. | **9.14.2 a)** | | X | |
| Added alternative assessment of damage to encapsulation from leaked electrolyte. | **9.14.2** | | X | |
| Spark ignition of batteries may be carried out following current limitation where separation is maintained. | **9.14.3.2** | | X | |
| Requirement added to consider the spark ignition risk of single lithium cells of less than 4.5 V with high short circuit current. | **9.14.3.2** | | | C29 |
| For single cells, it is sufficient to measure the temperature in the middle of the cell rather than having to locate the highest temperature point. | **9.14.3.3** | | X | |
| For thermal ignition assessment of cells and batteries with level of protection "ib", added an alternative test for lithium-ion rechargeable cells where it is not possible to obtain samples with current limiting devices disabled. | **9.14.3.3 b)**<br>**9.14.2** | | X | |
| There is an assumption that these cells will leak electrolyte so **7.12.3** applies. | | | | |
| Where limiting devices are removed from a cell for testing, it is no longer necessary to also test with 10 samples with the limiting devices still in place. | **9.14.3.3** | | X | |
| Only a single sample need be tested for thermal ignition compliance testing of cells or batteries for level of protection "ic". | **9.14.3.3 c)** | | X | |
| Transient test for diode safety barriers and safety shunts has been extended to include controlled semiconductor current limitation. | **9.16** | | X | |
| Clarify that transformer dielectric strength test is a test at room temperature. | **9.17.1** | X | | |
| Reduced testing requirements for transformers that are galvanically isolated from the mains. | **9.17.3** | | X | |
| Transformer windings requiring galvanic separation between different intrinsically safe circuits are to be tested for a dielectric strength of 2U if that is greater than 500 V. | **10.3.1** | | | C30 |
| Transformers for level of protection "ic" shall be routine tested where there is no applicable | **10.3.2** | | | C31 |

| Explanation of the Significance of Changes | Clause | Type<br>Minor and Editorial Changes | Extension | Major Technical Changes |
|---|---|---|---|---|
| industrial standard, or the applicable industrial standard does not specify a routine test. | | | | |
| Marking of IP rating no longer required as this is now a specific condition of use. | **11** | | X | |
| Flowchart for testing of enclosures added. | Annex I | X | | |
| List of voltage limiting techniques has been deleted. | former **8.7.3** | A3 | | |
| Requirements for handlights and caplights removed as these are covered elsewhere (including in other standards). | former **9.3** | X | | |

NOTE — The technical changes referred to include the significance of technical changes in the revised IEC standard, but they do not form an exhaustive list of all modifications from the previous version.

Explanations:

**A) Definitions**

**Minor and editorial changes**

clarification
decrease of technical requirements
minor technical change
editorial corrections

These are changes which modify requirements in an editorial or a minor technical way. They include changes of the wording to clarify technical requirements without any technical change, or a reduction in level of existing requirement.

**Extension**

addition of technical options

These are changes which add new or modify existing technical requirements, in a way that new options are given, but without increasing requirements for equipment that was fully compliant with the previous standard. Therefore, these will not have to be considered for products in conformity with the preceding edition.

**Major technical changes**

addition of technical requirements increase of technical requirements

These are changes to technical requirements (addition, increase of the level or removal) made in a way that a product in conformity with the preceding edition will not always be able to fulfil the requirements given in the later edition. These changes have to be considered for products in conformity with the preceding edition. For these changes additional information is provided in clause B) below.

NOTE — These changes represent current technological knowledge. However, these changes should not normally have an influence on equipment already placed on the market.

**B) Information about the background of Changes**

A1 $U_m$ is to be applied across galvanic isolations.

A2 The annex for 'alternative separation distances for assembled printed circuit boards and separation of components' in the previous edition is now incorporated in the main text and the alternate spacing tables are now Table 8 and Table 9.

A3 Except for c) batteries for which there is no longer a suggestion that they can be used as voltage limiting shunt devices. Nonetheless, there is no intent to change their use as such.

B1 Apparatus may be used at lower atmospheric pressure than the default 80 kPa specified in IEC 60079-0 with additional requirements such as an increase in clearance for associated apparatus operated at less than 80 kPa.

B2 The values used were based on those in IPC-6012B and tolerances have been taken into account.

C1 It is recognized that the clarified requirements were, in many cases, already applied.
The change is to ensure that they are uniformly and consistently applied.

C2 Catalytic sensors have been demonstrated to auto-ignite hydrogen without electrical stimulus so are not suitable for protection by intrinsic safety.

C3 Failure of separations and subsequent failure of components are considered non-countable faults for "ic". This is expected to be a change in terminology only but is highlighted here as it could change the assessment methodology in some instances.

C4 The steady state maximum voltage and current presents a different spark ignition risk than a transient. A transient is where either of these (voltage or current) is exceeded. Therefore, steady states and transients need to be considered separately. The annex on transients has been revised.

C5 Modified to align with assessment for wires.

C6 Since thermal assessment for level of protection "ic" is substantively under normal operation, the margin is considered a required safety factor.

C7 The formula used for calculating the temperature rise of wiring has been corrected.

C8 Where reduced separation distances rely on an enclosure providing an ingress protection of IP54, and cable glands, thread adapters and blanking elements are necessary to complete the enclosure to maintain the Ingress Protection (IP) rating these also need to comply with IEC 60079-0.

C9 Conductors, connectors and PCB tracks have to be suitably rated for their failure to be a countable fault.

C10 It is now a requirement that infallible connections remain capable of carrying the current following considered fault disconnections.

C11 Infallible PCB connection achieved with two 1 mm wide tracks now have copper thickness requirements.

C12 The safety of reduced separations relies on a suitable dielectric strength for the insulating materials, and these have been added to Table 8.

C13 A specific condition of use is required when over voltage category II/I is required for mains apparatus when using Table 9 – Reduced separations for level of protection "ic".

C14 The previous edition made references to the tests in IEC 60664 -1 and IEC 60664-3, however, it did not state which tests applied. This edition clarifies which tests apply by including them in the text.

C15 This is to be compatible with the specific condition of use already required where insulation between an intrinsically safe circuit and the frame or earth does not meet the dielectric strength requirements.

C16 A routine inspection requirement was added for encapsulated parts to ensure that the application of the encapsulant is acceptable during manufacture.

C17 The Continuous Operating Temperature requirements are a modification of those specified in IEC 60079-0. When temperatures higher than the COT are possible, there must be no damage internally or externally, whereas for IS/IEC 60079-11 : 2011 the requirement was no visible damage.

C18 The specifications required for coating, encapsulation and moulding are a modification of those detailed in IEC 60079-0.

C19 IS/IEC 60079-11 : 2011 did not state how to consider failure of components where the application of failure of separation resulted in them being operated outside of their manufacturer's specification. This is considered necessary, but for spark ignition only.

C20 This is a consequence of the re-organization of the requirements for components.

C21 The cold resistance was previously permitted to be measured at the minimum ambient temperature.

C22 It was recognised that when the requirements for Ex nL were transferred into IEC 60079-11 as Ex ic not all components were addressed. This meant that an Ex ia transformer construction was required for Ex ic equipment.

C23 Countable fault separation between the coil and contacts of a relay is no longer permitted.

C24 A fuse in Level of Protection "ic" shall be considered an ignition risk if its opening is an expected occurrence.

C25 Fuses connected to the mains supply are permitted to have a breaking capacity of less than 1 500 A. However, it is necessary that users and installers are made aware when this is the case and therefore it is a requirement to include the maximum prospective current in the instructions.

C26 Requirements for super capacitors added.

C27 Requirements for the use of thermal devices (PTCs etc) have been added.

C28 Electrolyte leakage, surface temperature test and test under dust requirements for cells, batteries and supercapacitors modified, increasing the number of samples tested and defining the temperature at which the tests are conducted.

C29 Spark ignition has been demonstrated during short circuit of some lithium cells.

C30 Routine tests for transformers with primary and secondary windings in an intrinsically safe circuit changed.

C31 Addition of a specific routine test for transformers used in Ex ic circuits.

In this standard, reference appears to International Standards for which Indian Standards also exists. The corresponding Indian Standards, which are to be substituted, are listed below along with their degree of equivalence for the editions indicated:

| *International Standard* | *Corresponding Indian Standard* | *Degree of Equivalence* |
|---|---|---|
| IEC 60079-0 Explosive atmospheres — Part 0: Equipment — General requirements | IS/IEC 60079-0 : 2017 Explosive Atmospheres: Part 0 Equipment — General Requirements (*third revision*) | Identical |
| IEC 60079-7 Explosive atmospheres — Part 7: Equipment protection by increased safety "e" | IS/IEC 60079-7 : 2017 Explosive atmospheres: Part 7 Equipment protection by increased safety "e" (*second revision*) | Identical |
| IEC 60079-25 Explosive atmospheres – Part 25: Intrinsically safe electrical systems | IS/IEC 60079-25: 2020 Explosive atmospheres: Part 25 Intrinsically safe electrical systems (*second revision*) | Identical |
| IEC 60085 Electrical insulation – Thermal evaluation and designation | IS 1271 : 2012 Electrical insulation — Thermal evaluation and designation (*second revision*) | Identical |
| IEC 60112 Method for the determination of the proof and the comparative tracking indices of solid insulating materials | IS 2824 : 2007/IEC 60112 : 2003 Method for the determination of the proof and the comparative tracking indices of solid insulating materials (*second revision*) | Identical |
| IEC 60127 (all parts)Miniature fuses | IS/IEC 60127 (all parts) Miniature fuses | Identical |
| IEC 60317-0-1 Specifications for particular types of winding wires — Part 0-1: General requirements — Enamelled round copper wire | IS 13730 (Part 0/Sec 1) : 2018/ IEC 60317-0-1 : 2013 Specifications for particular types of winding wires: Part 0 General requirements, Section 1 Enamelled round copper wire (*second revision*) | Identical |
| IEC 60529 Degrees of protection provided by enclosures (IP code) | IS/IEC 60529 : 2001 Degrees of protection provided byenclosures (IP code) | Identical |
| IEC 60664-1 Insulation coordination for equipment within low-voltage supply systems — Part 1: Principles, requirements and tests | IS 15382 (Part 1) : 2022/ IEC 60664-1 : 2020 Insulation coordination for equipment with in low-voltage systems: Part 1 Principles, requirements and tests | Identical |
| IEC 60664-3 Insulation coordination for equipment within low-voltage systems — Part 3: Use of coating, pottingor moulding for protectionagainst pollution | IS 15382 (Part 3) : 2019/ IEC 60664-3 : 2016 Insulation coordination for equipment with in low-voltage systems: Part 3 Use of coating, potting or moulding for protection against pollution (*first revision*) | Identical |
| IEC 60691 Thermal-links — Requirements and application guide | IS/IEC Pub 60691 : 2018 Thermal Links — Requirements and application guide (*first revision*) | Identical |

| *International Standard* | *Corresponding Indian Standard* | *Degree of Equivalence* |
|---|---|---|
| IEC 60851-5 Winding wires — Test methods — Part 5: Electrical properties | IS 13778 (Part 5) : 2012/ IEC 60851-5 : 2008 Winding wires — Test methods: Part 5 Electrical properties (*first revision*) | Identical |
| IEC 61010-1 Safety requirements for electrical equipment for measurement, control, and laboratory use — Part 1: General requirements | IS 17724 (Part 1) : 2023 Safety requirements for electrical equipment for measurement, control, and laboratory use: Part 1 General requirements | Modified/Technically Equivalent |
| IEC 61810-1, Electromechanical elementary relays — Part 1: General and safety requirements | IS 17064 (Part 1) : 2018 Electromechanical elementary relays: Part 1 General and safety requirements | Identical |
| IEC 62133-2 Secondary cells and batteries containing alkaline or other non-acid electrolytes — Safety requirements for portable sealed secondary cells, and for batteries made from them, for use in portable applications — Part 2: Lithium systems | IS 16046 (Part 2) : 2018/ IEC 62133-2 : 2017 Secondary cells and batteries containing alkaline or other non-acid electrolytes — Safety requirements for portable sealed secondary cells and for batteries made from them for use in portable applications: Part 2 Lithium systems (*second revision*) | Identical |
| *ANSI/UL 248* series low-voltage fuses | IS/IEC 60269 series Low-voltage fuses | Identical |

The Committee has reviewed the provisions of the following international standards referred in this adopted standard and decided that they are acceptable for use in conjunctionwith this standard.

| *International Standard* | *Title* |
|---|---|
| IEC 60747-5-5 | Semiconductor devices — Part 5-5: Optoelectronic devices — Photocouplers |
| IEC 60747-17 | Semiconductor devices — Part 17: Magnetic and capacitive coupler for basic and reinforced insulation |
| IEC 61158-2 | Industrial communication networks — Fieldbus specifications — Part 2: Physical layer specification and service definition |
| ANSI/UL 746E | Polymeric materials — Industrial laminates, filament wound tubing, vulcanized fibre, and materials used in printed wiringBoards |
| UL 810A | Standard for electrochemical capacitors |
| DIN VDE V 0884-11 | Semiconductor devices — Part 11: Magnetic and capacitive coupler for basic and reinforced isolation |

Only the English language text has been retained while adopting it in this Indian Standard, and as such, the page numbers given here are not the same as in the IEC publication.

For the purpose of deciding whether a particular requirement of this standard is complied with the final value, observed or calculated expressing the result of a test or analysis shall be rounded off in accordance with IS 2 : 2022 'Rules for rounding of numerical values (*second revision*)'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

# CONTENTS

*Indian Standard*

# EXPLOSIVE ATMOSPHERES

## PART 11 EQUIPMENT PROTECTION BY INTRINSIC SAFETY “i”

( Second Revision )

## 1 Scope

This part of IEC 60079 specifies the construction and testing of intrinsically safe apparatus intended for use in explosive atmospheres, 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 ignition of a surrounding explosive atmosphere. This includes electrical equipment which contains circuits that are intrinsically safe only under certain conditions, for example under battery supply with mains supply removed.

This document 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 assessed for use in such atmospheres by applying this document.

This document applies to sensors connected to intrinsically safe circuits but does not apply to the protection of catalytic elements for Group IIC or Group IIB + $H_2$.

This document does not apply to Ex Equipment cable glands.

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

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

Unless otherwise stated, the requirements in this document are applicable to both intrinsically safe apparatus and associated apparatus, and the generic term "apparatus" is used throughout the standard.

As this document applies only to electrical equipment, the term "equipment" used in the standard always means "electrical equipment".

This document applies to apparatus for use under the atmospheric conditions of IEC 60079-0 with additional requirements for use at extended atmospheric pressures in the range from 60 kPa (0,6 bar), up to 110 kPa (1,1 bar).

**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.6 (2011)** (informative) | **Ed.7 (2017)** (informative) | **Clause / Subclause title** (normative) | **Group I and Group II** | **Group III** | |
| 3 | 3 | Terms and definitions | Applies | Applies | Applies |
| 4 | 4 | Equipment grouping | Applies | Applies | Applies |
| 5 | 5 | Temperatures | | | |
| 5.1 | 5.1 | Environmental influences | Applies | Applies | Applies |
| 5.2 | 5.2 | Service temperature | Applies | Applies | Applies |
| 5.3 | 5.3 | Maximum surface temperature | Applies | Applies | Excluded |
| 6 | 6 | Requirements for all electrical apparatus | | | |
| 6.1 | 6.1 | General | Applies | Applies | Applies |
| 6.2 | 6.2 | Mechanical strength | Excluded except when 6.2.5.1 is applied | Excluded except when 6.2.5.1 is applied | Excluded except when 6.2.5.1 is applied |
| 6.3 | 6.3 | Opening times | Excluded | Excluded | Excluded |
| 6.4 | 6.4 | Circulating currents in enclosures (e.g. of large electric machines) | Excluded | Excluded | Excluded |
| 6.5 | 6.5 | Gasket retention | Excluded except when 6.2.5.1 is applied | Excluded except when 6.2.5.1 is applied | Excluded except when 6.2.5.1 is applied |
| 6.6 | 6.6 | Electromagnetic and ultrasonic energy radiating equipment | | | |
| - | 6.6.1 | General | Applies | Applies | Excluded |
| 6.6.1 | 6.6.2 | Radio frequency sources | Applies | Applies | Excluded |
| 6.6.3 | 6.6.3 | Ultrasonic sources | Applies | Applies | Excluded |
| 6.6.2 | 6.6.4 | Lasers, luminaires and other non-divergent continuous wave optical sources | Modified | Modified | Excluded |
| 7 | 7 | Non-metallic enclosures and non-metallic parts of enclosures | | | |
| 7.1 | 7.1 | General | Excluded except when 6.2.5.1 is applied | Excluded except when 6.2.5.1 is applied | Excluded except when 6.2.5.1 is applied |
| 7.2 | 7.2 | Thermal endurance | Excluded except when 6.2.5.1 is applied | Excluded except when 6.2.5.1 is applied | Excluded except when 6.2.5.1 is applied |
| 7.3 | 7.3 | Resistance to ultraviolet light | Excluded except when 6.2.5.1 is applied | Excluded except when 6.2.5.1 is applied | Excluded except when 6.2.5.1 is applied |
| 7.4 | 7.4 | Electrostatic charges on external non-metallic materials | Applies | Applies | Excluded |

| Clause or subclause of IEC 60079-0 | | | IEC 60079-0 clause application to IEC 60079-11 | | |
|---|---|---|---|---|---|
| | | | Intrinsically safe apparatus | | Associated apparatus |
| **Ed.6 (2011)** (informative) | **Ed.7 (2017)** (informative) | **Clause / Subclause title** (normative) | **Group I and Group II** | **Group III** | |
| 7.5 | 7.5 | Attached external conductive parts | Applies | Applies | Excluded |
| 8 | 8 | Metallic enclosures and metallic parts of enclosures | Applies | Applies | Excluded |
| 9 | 9 | Fasteners | Excluded | Excluded | Excluded |
| 10 | 10 | Interlocking devices | Applies | Applies | Excluded |
| 11 | 11 | Bushings | Excluded | Excluded | Excluded |
| 12 | - | Materials used for cementing | Excluded except when 6.2.5.1 is applied | Excluded except when 6.2.5.1 are applied | Excluded except when 6.2.5.1 is applied |
| - | 12 | (Reserved for future use) | - | - | - |
| 13 | 13 | Ex Components | Applies | Applies | Applies |
| 14 | 14 | Connection facilities | | | |
| 14.1 | 14.1 | General | Applies | Applies | Applies |
| 14.2 | - | Termination compartment | Applies | Applies | Applies |
| 14.3 | 14.2 | Type of Protection | Applies | Applies | Modified |
| 14.4 | 14.3 | Creepage and clearance | Applies | Applies | Applies |
| 15 | 15 | Connection facilities for earthing or bonding conductors | Excluded | Excluded | Excluded |
| 16 | 16 | Entries into enclosures | | | |
| 16.1 | 16.1 | General | Excluded except when 6.2.5.1 is applied | Excluded except when 6.2.5.1 is applied | Excluded except when 6.2.5.1 is applied |
| 16.2 | 16.2 | Identification of entries | Excluded except when 6.2.5.1 is applied | Excluded except when 6.2.5.1 is applied | Excluded except when 6.2.5.1 is applied |
| 16.3 | 16.3 | Cable Glands | Excluded except when 6.2.5.1 is applied | Excluded except when 6.2.5.1 is applied | Excluded except when 6.2.5.1 is applied |
| 16.4 | 16.4 | Blanking elements | Excluded except when 6.2.5.1 is applied | Excluded except when 6.2.5.1 is applied | Excluded except when 6.2.5.1 is applied |
| 16.5 | 16.5 | Thread adapters | Excluded except when 6.2.5.1 is applied | Excluded except when 6.2.5.1 is applied | Excluded except when 6.2.5.1 is applied |
| 16.6 | 16.6 | Temperature at branching point and entry point | Excluded except when 6.2.5.1 is applied | Excluded except when 6.2.5.1 is applied | Excluded except when 6.2.5.1 is applied |
| 16.7 | 16.7 | Electrostatic charges of cable sheaths | 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.6 (2011) (informative) | Ed.7 (2017) (informative) | Clause / Subclause title (normative) | Group I and Group II | Group III | |
| 17 | 17 | Supplementary requirements for electric machines | Excluded | Excluded | Excluded |
| 18 | 18 | Supplementary requirements for switchgear | Excluded | Excluded | Excluded |
| 19 | - | Supplementary requirements for fuses | Excluded | Excluded | Excluded |
| - | 19 | Reserved for future use | - | - | - |
| 20 | 20 | Supplementary requirements for external plugs, socket outlets and connectors for field wiring connection | Excluded | Excluded | Excluded |
| 21 | 21 | Supplementary requirements for luminaires | Excluded | Excluded | Excluded |
| 22 | 22 | Supplementary requirements for caplights and handlights | | | |
| 22.1 | 22.1 | Group I caplights | Applies | Excluded | Excluded |
| 22.2 | 22.2 | Group II and Group III caplights and handlights | Excluded | Excluded | Excluded |
| 23 | 23 | Equipment incorporating cells and batteries | | | |
| 23.1 | 23.1 | General | Applies | Applies | Applies |
| 23.2 | 23.2 | Interconnection of cells to form batteries | Excluded | Excluded | Excluded |
| 23.3 | 23.3 | Cell types | Modified | Modified | Modified |
| 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 | 26 | Type tests | | | |
| 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 |

| Clause or subclause of IEC 60079-0 | | | IEC 60079-0 clause application to IEC 60079-11 | | |
|---|---|---|---|---|---|
| | | | Intrinsically safe apparatus | | Associated apparatus |
| **Ed.6 (2011)** (informative) | **Ed.7 (2017)** (informative) | **Clause / Subclause title** (normative) | **Group I and Group II** | **Group III** | |
| 26.4 | 26.4 | Tests of enclosures | | | |
| 26.4.1 | 26.4.1 | Order of tests | Excluded except when 6.2.5.1 is applied | Excluded except when 6.2.5.1 is applied | Excluded except when 6.2.5.1 is applied |
| 26.4.2 | 26.4.2 | Resistance to impact | Excluded except see [a] | Excluded except see [a] | Excluded except see [a] |
| 26.4.3 | 26.4.3 | Drop test | Applies | Applies | Applies |
| 26.4.4 | 26.4.4 | Acceptance criteria | Applies | Applies | Applies |
| 26.4.5 | 26.4.5 | Degree of protection (IP) by enclosures | Applies | Applies | Applies |
| 26.5 | 26.5 | Thermal tests | | | |
| 26.5.1 | 26.5.1 | Temperature measurement | | | |
| 26.5.1.1 | 26.5.1.1 | General | Applies | Applies | Excluded |
| 26.5.1.2 | 26.5.1.2 | Service temperature | Applies | Applies | Applies |
| 26.5.1.3 | 26.5.1.3 | Maximum surface temperature | Modified | Modified | Excluded |
| 26.5.2 | 26.5.2 | Thermal shock test | Excluded except when 6.2.5.1 is applied | Excluded except when 6.2.5.1 is applied | Excluded except when 6.2.5.1 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 6.2.5.1 is applied | Excluded except when 6.2.5.1 is applied | Excluded except when 6.2.5.1 is applied |
| 26.8 | 26.8 | Thermal endurance to heat | Excluded except when 6.2.5.1 is applied | Excluded except when 6.2.5.1 is applied | Excluded except when 6.2.5.1 is applied |
| 26.9 | 26.9 | Thermal endurance to cold | Excluded except when 6.2.5.1 is applied | Excluded except when 6.2.5.1 is applied | Excluded except when 6.2.5.1 is applied |
| 26.10 | 26.10 | Resistance to UV light | Excluded except when 6.2.5.1 is applied | Excluded except when 6.2.5.1 is applied | Excluded except when 6.2.5.1 is applied |
| 26.11 | 26.11 | Resistance to chemical agents for Group I equipment | Excluded except when 6.2.5.1 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 |
| 26.14 | 26.14 | Measurement of capacitance | Applies | Applies | Excluded |

| Clause or subclause of IEC 60079-0 | | | IEC 60079-0 clause application to IEC 60079-11 | | |
|---|---|---|---|---|---|
| | | | Intrinsically safe apparatus | | Associated apparatus |
| **Ed.6 (2011)** (informative) | **Ed.7 (2017)** (informative) | **Clause / Subclause title** (normative) | **Group I and Group II** | **Group III** | |
| 26.15 | 26.15 | Verification of ratings of ventilating fans | Excluded | Excluded | Excluded |
| 26.16 | 26.16 | Alternative qualification of elastomeric sealing O-rings | Excluded except when 6.2.5.1 is applied | Excluded except when 6.2.5.1 is applied | Excluded except when 6.2.5.1 is applied |
| NR | 26.17 | Transferred charge test | Applies | Excluded | Excluded |
| 27 | 27 | Routine tests | Applies | Applies | Applies |
| 28 | 28 | Manufacturer's responsibility | Applies [b] | Applies [b] | Applies |
| 29 | 29 | Marking | | | |
| 29.1 | 29.1 | Applicability | Applies | Applies | Applies |
| 29.2 | 29.2 | Location | Applies | Applies | Applies |
| 29.3 | 29.3 | General | Applies | Applies | Applies |
| 29.4 | 29.4 | Ex marking for explosive gas atmospheres | Applies | Excluded | Applies |
| 29.5 | 29.5 | Ex marking for explosive dust atmospheres | Excluded | Applies | Applies |
| 29.6 | 29.6 | Combined types (or levels) of protection | Applies | Applies | Applies |
| 29.7 | 29.7 | Multiple types of protection | Applies | Applies | Applies |
| 29.8 | 29.8 | Ga equipment using two independent Gb types (or levels) of protection | Applies | Excluded | Excluded |
| NR | 29.9 | Boundary wall | Applies | Applies | Excluded |
| 29.9 | 29.10 | Ex Components | Applies | Applies | Applies |
| 29.10 | 29.11 | Small Ex Equipment and small Ex Components | Applies | Applies | Applies |
| 29.11 | 29.12 | Extremely small equipment and extremely small Ex Components | Applies | Applies | Applies |
| 29.12 | 29.13 | Warning markings | Applies | Applies | Applies |
| 29.13 | - | Alternate marking of Equipment Protection Levels (EPLs) | Applies | Applies | Applies |
| 29.13.1 | - | Alternate marking of Type of Protection for explosive gas atmospheres | Applies | Excluded | Applies |
| 29.13.2 | - | Alternate marking of Type of Protection for explosive dust atmospheres | Excluded | Applies | Applies |
| 29.14 | 29.14 | Cells and batteries | Applies | Applies | Applies |
| 29.15 | 29.15 | Electrical machines operated with a converter | Excluded | Excluded | Excluded |
| 29.16 | 29.16 | Examples of marking | Examples only | Examples only | Examples only |
| 30 | 30 | Instructions | | | |
| 30.1 | 30.1 | 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.6 (2011)** (informative) | **Ed.7 (2017)** (informative) | **Clause / Subclause title** (normative) | **Group I and Group II** | **Group III** | |
| 30.2 | 30.2 | Cells and batteries | Applies | Applies | Applies |
| 30.3 | 30.3 | Electric machines | Excluded | Excluded | Excluded |
| 30.4 | 30.4 | Ventilating fans | Excluded | Excluded | Excluded |
| - | 30.5 | Cable Glands | Excluded except when 6.2.5.1 is applied | Excluded except when 6.2.5.1 is applied | Excluded except when 6.2.5.1 is applied |
| Annex A | Annex A | Supplementary requirements for cable glands | Excluded except when 6.2.5.1 is applied | Excluded except when 6.2.5.1 is applied | Excluded except when 6.2.5.1 is applied |
| Annex B | Annex B | Requirements for Ex Components | Applies | Applies | Applies |
| Annex C | Annex C | Example of rig for resistance to impact test | Informative Annex | Informative Annex | Informative Annex |
| Annex D | Annex D | Electric machines connected to converters | Informative Annex | Informative Annex | Informative Annex |
| Annex E | Annex E | Temperature evaluation of electric machines | Informative Annex | Informative Annex | Informative Annex |
| Annex F | Annex F | Guideline flowchart for tests of non-metallic enclosures or non-metallic parts of enclosures (26.4) | Informative Annex | Informative Annex | Informative Annex |
| - | Annex G | Guidance flowchart for tests of cable glands | Informative Annex | Informative Annex | Informative Annex |
| - | Annex H | Shaft voltages resulting in motor bearing or shaft brush sparking. Discharge energy calculation | Informative Annex | Informative Annex | Informative Annex |

Applies – This Clause / Subclause of IEC 60079-0 is applied without change.

Excluded – This Clause / Subclause of IEC 60079-0 does not apply.

Modified – This Clause / Subclause of IEC 60079-0 is modified as detailed in this document.

NOTE 1 The applicable Clauses / Subclauses of IEC 60079-0 are identified by the Clause / Subclause title which is normative. This document was written against the specific requirements of IEC 60079-0:2017 (Ed.7). The Clause / Subclause numbers for the 7$^{th}$ and previous edition are shown for information only. This is to enable the general requirements of IEC 60079-0:2011 (Ed.6) to be used where necessary with this part of IEC 60079. Where there were no requirements in the 6$^{th}$ edition but there are for the 7$^{th}$ edition (indicated by NR against the 6$^{th}$ edition only), or where there is a conflict between requirements, the later edition requirements take precedence.

NOTE 2 A shaded row in the above table indicates that this is a Clause heading. In cases where the applicability is the same for all the subclauses the 'Applies' or 'Excluded' is listed in the heading row and the subclauses are not expanded. Where the application of the individual sub-clauses may be different, these are expanded in the above table and the applicability for each is listed.

[a] Excluded except when 6.2.5.1 is applied, or as required by 9.4.1 or 9.11.

[b] Excluded for simple apparatus. See 3.1.5 and 5.5.

## 2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 60317-0-1, *Specifications for particular types of winding wires – Part 0-1: General requirements – Enamelled round copper wire*

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

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

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

IEC 60691, *Thermal-links – Requirements and application guide*

IEC 60747-5-5, *Semiconductor devices – Part 5-5: Optoelectronic devices – Photocouplers*

IEC 60747-17, *Semiconductor devices – Part 17: Magnetic and capacitive coupler for basic and reinforced insulation*

IEC 60851-5, *Winding wires – Test methods – Part 5: Electrical properties*

IEC 61010-1, *Safety requirements for electrical equipment for measurement, control, and laboratory use – Part 1: General requirements*

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

IEC 61810-1, *Electromechanical elementary relays – Part 1: General and safety requirements*

IEC 62133-2, *Secondary cells and batteries containing alkaline or other non-acid electrolytes – Safety requirements for portable sealed secondary cells, and for batteries made from them, for use in portable applications – Part 2: Lithium systems*

ANSI/UL 248 series, *Low-Voltage Fuses*

ANSI/UL 746E, *Polymeric Materials – Industrial Laminates, Filament Wound Tubing, Vulcanized Fibre, and Materials Used In Printed Wiring Boards*

UL 810A, *Standard for Electrochemical Capacitors*

DIN VDE V 0884-11, *Semiconductor devices – Part 11: Magnetic and capacitive coupler for basic and reinforced isolation*

## 3 Terms, definitions and abbreviated terms

### 3.1 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

**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**
**intrinsically safe apparatus**
electrical equipment in which all the circuits are intrinsically safe circuits whilst in the hazardous area

**3.1.3**
**associated apparatus**
electrical apparatus which contains both intrinsically safe and non-intrinsically safe circuits and is constructed so that the non-intrinsically safe circuits cannot adversely affect the intrinsically safe circuits

Note 1 to entry: Associated apparatus is either:

a) additionally protected by a Type of Protection suitable for use in the appropriate explosive atmosphere, or

b) not protected by a Type of Protection suitable for use in the appropriate explosive atmosphere and therefore is not to be used within an explosive atmosphere

[SOURCE: IEC 60050-426:2020, 426-11-03]

**3.1.4**
**intrinsically safe circuit**
circuit, in which any spark or any thermal effect produced under the conditions specified in IEC 60079-11, 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 that is compatible with the intrinsic safety of the circuit in which it is used

**3.1.6**
**control drawing**
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

**3.1.7**
**diode safety barrier**
associated apparatus, which does not provide galvanic isolation, 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

**3.1.8**
**fuse rating**
$I_n$
nominal current rating of a fuse

**3.1.9**
**FISCO**
**Fieldbus Intrinsically Safe Concept**
intrinsically safe system architecture which is bus-powered and designed in accordance with specific requirements

Note 1 to entry: The requirements are specified in IEC 61158-2, *Industrial communication networks – Fieldbus specifications – Part 2: Physical layer specification and service definition*.

**3.1.9.1**
**infallible connection**
connections, including joints and interconnecting wiring and printed circuit board tracks, that are not considered as becoming open-circuited in service or storage

Note 1 to entry: The specific conditions to be considered are specified in IEC 60079-11, *Explosive atmospheres – Part 11: Equipment protection by intrinsic safety "i"*.

**3.1.10**
**internal wiring**
wiring and electrical connections that are made within the apparatus by its manufacturer

**3.1.11**
**live maintenance**
maintenance activities carried out while the associated apparatus, intrinsically safe apparatus and circuits are energized

**3.1.12**
**intrinsic safety parameters**

Note 1 to entry: Voltage, current and power at connection facilities may have brief transients above the specified parameter value, as permitted by IEC 60079-11.

Note 2 to entry: Apparatus can have multiple sets of intrinsic safety parameters.

**3.1.12.1**
$U_i$
maximum input voltage
maximum (peak) voltage that can be applied to the intrinsically safe connection facilities of the apparatus without invalidating intrinsic safety

**3.1.12.2**
$I_i$
maximum input current
maximum (peak) current for the intrinsically safe connection facilities of the apparatus, that can be taken from external circuits connected to the connection facilities without invalidating intrinsic safety

**3.1.12.3**
$P_i$
maximum input power
maximum power for the intrinsically safe connection facilities of the apparatus, that can be taken from external circuits connected to the connection facilities without invalidating intrinsic safety

**3.1.12.4**
$C_i$
maximum internal capacitance
maximum equivalent internal capacitance of the apparatus, which is considered as appearing at the intrinsically safe connection facilities of the apparatus

**3.1.12.5**
$L_i$
maximum internal inductance
maximum equivalent internal inductance of the apparatus which is considered as appearing at the intrinsically safe connection facilities of the apparatus

**3.1.12.6**
$L_i/R_i$
maximum internal inductance to resistance ratio
maximum value of the ratio of inductance to resistance which is considered as appearing at the intrinsically safe connection facilities of the apparatus

**3.1.12.7**
$U_o$
maximum output voltage
maximum (peak) voltage that can appear at the intrinsically safe connection facilities of the apparatus

**3.1.12.8**
$I_o$
maximum output current
maximum (peak) current that can be taken from the intrinsically safe connection facilities of the apparatus

**3.1.12.9**
$P_o$
maximum output power
maximum electrical power that can be taken from the intrinsically safe connection facilities of the apparatus

**3.1.12.10**
$C_o$
maximum external capacitance
maximum capacitance that can be connected to the intrinsically safe connection facilities of the apparatus without invalidating intrinsic safety

**3.1.12.11**
$L_o$
maximum external inductance
maximum inductance that can be connected to the intrinsically safe connection facilities of the apparatus without invalidating intrinsic safety

**3.1.12.12**
$L_o/R_o$
maximum external inductance to resistance ratio
maximum value of the ratio of inductance to resistance which can be connected to the intrinsically safe connection facilities of the apparatus without invalidating intrinsic safety

**3.1.12.13**
$U_m$
maximum RMS AC or DC voltage
maximum voltage that can be applied to the non-intrinsically safe connection facilities of associated apparatus, or to the connection facilities of intrinsically safe apparatus for use only in the non-hazardous area, without invalidating intrinsic safety

EXAMPLE Examples of connection facilities of intrinsically safe apparatus restricted to use in the non-hazardous area are battery charging contacts and data interfaces.

Note 1 to entry: The value of $U_m$ can be different at different sets of connection facilities, and can be different for AC and DC voltages.

Note 2 to entry: There may be transients above the specified parameter.

**3.1.13**
**moulding**
process of placing an object in a tool with a shaping cavity and introducing plastic material around the inserted component under pressure to either partially or totally encapsulate the inserted component

Note 1 to entry: This process is also referred to as injection moulding, over-moulding or insert moulding.

**3.1.14**
**spark test apparatus**
apparatus used to verify experimentally that the electrical sparks of a circuit are incapable of igniting a specified explosive gas atmosphere

**3.1.15**
**supercapacitor**
electrochemical capacitor
device that stores electrical energy using a double layer in an electrochemical cell

Note 1 to entry: The electrochemical capacitor is not to be confused with electrolytic capacitor.

[SOURCE: IEC 60050-114:2014, 114-03-03]

**3.1.16**
**transients**

**3.1.16.1**
**transient rating**
rating of a component related to transient effects

EXAMPLE An example is $I^2t$ value or peak non-repetitive surge current.

**3.1.16.2**
**transient energy**
energy delivered by a circuit above the steady state condition

**3.1.17**
**non-hazardous area accessory**
<intrinsic safety>
electrical equipment to which intrinsically safe apparatus is temporarily connected by the end user, only while the intrinsically safe apparatus is in a non-hazardous area

EXAMPLE Examples are battery chargers and data readers.

**3.1.18**
**controlled semiconductor**
semiconductor component with an output that can be switched or adjusted using a separate electrical input

EXAMPLE Transistor, thyristor, voltage or current regulator.

Note 1 to entry: The inputs and outputs referred to above may form part of an integrated circuit.

### 3.2 Abbreviated terms

A list of abbreviated terms is given in Table 2.

**Table 2 – List of abbreviated terms used**

| Abbreviation | Full expression | Additional information |
|---|---|---|
| COT | continuous operating temperature | |
| CTI | comparative tracking index | Measured in accordance with IEC 60112 |
| DUT | device under test | |
| ES1 | Electrical energy source class 1 | As defined in IEC 62368-1 |
| FISCO | fieldbus intrinsically safe concept | See 3.1.9 |
| OVC | overvoltage category | Defined in IEC 60664-1 |
| PCB | printed circuit board | |
| PCBA | printed circuit board assembly | |
| PELV | protective extra-low voltage | For example, compliance with IEC 60364-4-41 |
| PDV | partial discharge voltage | |
| PPTC | polymeric positive temperature coefficient | |
| PTC | positive temperature coefficient | Includes PPTC |
| SELV | safety extra-low voltage | For example, compliance with IEC 60364-4-41 |

## 4 Equipment grouping, classification and Levels of Protection of apparatus

Intrinsically safe apparatus and intrinsically safe circuits of associated apparatus shall be grouped in accordance with the equipment grouping requirements of IEC 60079-0.

Intrinsically safe apparatus shall have a maximum surface temperature or temperature class assigned in accordance with the requirements of IEC 60079-0. Temperature classification does not apply to associated apparatus.

NOTE Equipment containing associated apparatus protected by another Type of Protection will be assigned temperature class and equipment group according to the requirements of that Type of Protection. The equipment group for this equipment can be different to the group for intrinsic safety, for example equipment marked Ex db [ia IIC Ga] IIB T4 Gb.

Intrinsically safe apparatus and intrinsically safe circuits of associated apparatus shall be assigned one or more of the following Levels of Protection:

– Level of Protection "ia" (for EPL Ma, Ga, Da);
– Level of Protection "ib" (for EPL Mb, Gb, Db); or
– Level of Protection "ic" (for EPL Gc, Dc).

The requirements of this document apply to all Levels of Protection unless otherwise stated.

Apparatus may be specified with more than one Level of Protection, equipment group, or temperature class, and may have different intrinsic safety parameters for these varied cases.

## 5 Ignition compliance requirements

### 5.1 General

Compliance with this document requires two basic criteria:

1) intrinsically safe circuits shall meet the spark ignition requirements of 5.3; and
2) intrinsically safe apparatus shall meet the thermal ignition requirements of 5.4.

These shall be assessed under the conditions specified in 5.2 for the applicable Level of Protection, equipment group and, for intrinsically safe apparatus only, maximum surface temperature.

Fulfilment of these requirements is achieved by following this document, including consideration of:

– separation between conductive parts in accordance with 6.5;
– external connection facilities in accordance with 6.3 and internal connections in accordance with 6.4; and
– rating of components in accordance with Clause 7.

Intrinsic safety parameters, $U_m$ and, if required by 5.2.5, the maximum rated voltage for apparatus, may be assigned for each of the connection facilities.

NOTE IEC 60079-14 specifies the types of circuits or power supplies which are suitable for associated apparatus with a $U_m$ of less than 250 V.

Where instructions for live maintenance procedures are specified by the manufacturer, the effects of this live maintenance shall not invalidate intrinsic safety. (See 12.1 d) ).

Except for 9.6 a), where it is stated that industrial standards are sufficient to meet the requirements of this document, it is not a requirement of this document that compliance with those industrial standards be verified.

### 5.2 Conditions for assessment

#### 5.2.1 General

Intrinsically safe circuits shall not be capable of causing ignition under the most onerous conditions, except where permitted elsewhere in this document. This shall include, but is not limited to, the following:

a) under the circumstances specified in 5.2.2, 5.2.3 or 5.2.4 as applicable for the Level of Protection;
b) with any voltage up to $U_m$ applied to non-intrinsically safe connection facilities, except as modified by 5.2.5;

c) with any voltage up to $U_i$, current up to $I_i$ or power up to $P_i$, as applicable, applied to intrinsically safe connection facilities;

d) with any value up to the maximum capacitance as defined by $C_o$, as applicable, connected to the intrinsically safe connection facilities;

e) with any value up to either the maximum inductance, as defined by $L_o$, or inductance to resistance ratio, as defined by $L_o/R_o$, as applicable, connected to the intrinsically safe connection facilities;

f) with the connection of the most onerous load to any intrinsically safe connection facilities of the apparatus, including opening, shorting and earthing;

g) at the most onerous temperature within the specified service temperature range for the applicable parts of the apparatus. For rating of components according to Clause 7, and thermal ignition compliance for Levels of Protection "ia" and "ib", the effects of mounting conditions of the component and the service temperature local to the component shall be taken into account. Heating from other components from related faults might need to be considered.

EXAMPLES:

– Heating from closely located series or parallel components that carry or share the same fault current, normally need to be considered.

– Heating above service temperature from independent faults in other parts of the apparatus do not normally need to be considered.

NOTE Rating of a component is assessed without faults applied to the component, whereas its thermal ignition compliance is assessed with the most onerous faults according to Clause 7 applied to the component;

and

h) with the most onerous values of any relevant parameters applied within the manufacturing tolerances of the apparatus (see 7.3).

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. Within a single fault scenario, all countable and non-countable faults shall be considered static. For example, once a short circuit component fault is applied, this failure mode shall be maintained throughout the entire fault scenario.

For determination of the maximum surface temperature, a safety factor of 1,0 shall be applied to voltage and power.

### 5.2.2 Level of Protection "ia"

Intrinsically safe circuits in Level of Protection "ia" shall be assessed in each of the following circumstances:

a) under the most onerous condition with no faults applied;

b) with the application of those non-countable faults which result in the most onerous condition;

c) with the application of one countable fault plus those non-countable faults which result in the most onerous condition; and

d) with the application of two countable faults plus those non-countable faults which result in the most onerous condition.

The faults applied can differ in each of the above circumstances.

In assessing the circuits for spark ignition, the following safety factors shall be applied in accordance with 5.3.4:

– for a), b), and c) 1,5

– for d) 1,0

If only one countable fault can occur, the requirements of d) need not be considered.

If no countable fault can occur, the requirements of c) and d) need not be considered.

Designs which conform to the requirements for Level of Protection "ia" are also suitable for Levels of Protection "ib" and "ic".

### 5.2.3 Level of Protection "ib"

Intrinsically safe circuits in Level of Protection "ib" shall be assessed in each of the following circumstances:

a) under the most onerous condition with no faults applied;
b) with the application of those non-countable faults which result in the most onerous condition; and
c) with the application of one countable fault plus the application of those non-countable faults which result in the most onerous condition.

The faults applied can differ in each of the above circumstances.

In assessing the circuits for spark ignition, a safety factor of 1,5 shall be applied in accordance with 5.3.4.

If no countable fault can occur, the requirements of c) need not be considered.

Designs which conform to the requirements for Level of Protection "ib" are suitable for Level of Protection "ic".

### 5.2.4 Level of Protection "ic"

Intrinsically safe circuits in Level of Protection "ic" shall be assessed in each of the following circumstances:

a) under the most onerous condition with no faults applied; and
b) for spark ignition compliance in accordance with 5.3 and in the determination of $U_o$, $I_o$, $L_i$, $C_i$ and $L_i/R_i$ as applicable: with the application of those non-countable faults which result in the most onerous condition.

NOTE No faults are applied for thermal ignition compliance in accordance with 5.4.

Countable faults are not applied.

Only components which:

– define voltage or current for the purposes of spark ignition compliance, including components used to protect other components on which intrinsic safety depends,
– define $U_o$ or $I_o$, or
– provide protection against polarity reversal in accordance with 6.8.

are required to conform to 7.1.

If applicable, $P_o$ and $P_i$ shall be determined under the most onerous normal operating conditions.

In assessing the circuits for spark ignition, a safety factor of 1,0 shall be applied in accordance with 5.3.4.

### 5.2.5 Non-shock hazard equipment or systems

Equipment or systems that are limited to extra low voltage and are designed according to other standards or regulations to prevent the risk of electric shock that might be hazardous to human health may be considered non-shock hazard equipment or systems.

EXAMPLE 1 Such other standards include SELV, PELV, ES1.

Where this document requires the application of $U_m$ between connection facilities that are not galvanically isolated from each other, it is permitted to only consider application of the manufacturer's maximum rated voltage, providing the following requirements are met:

NOTE 1 The manufacturer's rated voltage is typically referred to as differential mode.

a) the connection facilities shall only be connected to non-shock hazard equipment or systems.

b) Where this document requires the application of $U_m$ between connection facilities for circuits that employ galvanic isolation between the non-intrinsically safe circuit and other circuits, the applied voltage shall be the higher of:

   – $U_m$; or

   – a voltage derived from the rated voltage or $U_m$, for example where the circuit has components that enhance the voltage to greater than $U_m$ under normal operation.

   NOTE 2 In this case the voltage across the galvanic isolation is typically referred to as common mode.

   NOTE 3 Requirements for non-hazardous area accessories are detailed in 6.3.5.

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 which apply to equipment or systems to be connected to the connection facilities, for example, they shall be SELV, PELV, ES1, or equivalent; and

   – state the permitted maximum voltage that may be applied between the non-intrinsically safe connection facilities that form a circuit within the apparatus.

     NOTE 4 It is not a requirement of this document that a type or model for the supply be specified.

EXAMPLE 2 A serial data port is declared to have a $U_m$ of 250 V $AC_{RMS}$, but with a maximum voltage between any two pins of the data port of 6 V. The circuit is assessed with 6 V differential mode applied between any two data port pins, but with 250 V $AC_{RMS}$ common mode applied between the data port and galvanically isolated circuits (such as earth or the intrinsically safe circuits). The Specific Conditions of Use would state that the voltage applied to the serial data port connections is a maximum of 6 V and that only equipment complying with IEC 62368-1 may be used. Any galvanic isolation between the circuit of the data port and the intrinsically safe circuit would require separations for $U_m$ (so in this example, 250 V $AC_{RMS}$).

## 5.3 Spark ignition compliance

### 5.3.1 General

Intrinsically safe circuits shall be assessed to ensure that at each point where an interruption or interconnection exposed to the explosive atmosphere is considered to occur, the available spark energy is incapable of causing ignition of the explosive atmosphere for the specified equipment group under the conditions and safety factors specified in 5.2 for the Level of Protection of the circuit.

NOTE The term "spark" is used throughout this document to refer to a make or break of the circuit under test. It is not necessary for such a make or break to produce a visible spark.

Spark ignition shall be assessed, except where stated otherwise in this document, as follows:

a) across normally opening and closing contacts; and

EXAMPLE 1 Examples of normally opening and closing contacts are plugs and sockets, switches, pushbuttons and potentiometers that are user accessible without the use of a tool and are manually operated.

b) at the connection facilities of intrinsically safe circuits, including connection of the applicable $C_o$, $L_o$ and $L_o/R_o$ specified for the connection facility. Unless stated otherwise in the instructions, $C_o$ and $L_o$ are applied separately when assessing the connection facility.

Spark ignition does not need to be considered:

1) across infallible separations complying with 6.5.4.2;
2) in series with infallible connections complying with 6.4.2;
3) within encapsulation meeting the requirements for protection against spark ignition specified in 6.6.1 and 6.6.2.1;
4) within associated apparatus other than at its intrinsically safe circuit connection facilities; or
5) between terminals of separate circuits conforming to 6.3.1.

For Group III circuits, the energy limits of Group IIB shall be applied.

Spark ignition assessment may use representative circuits that are at least as onerous for spark ignition in place of the actual circuit under assessment.

EXAMPLE 2

– spark ignition from a capacitor limited by a resistor complying with 7.4.2 can be considered as a resistive circuit with a fixed voltage;
– all the capacitors in a part of a circuit can be represented by a single capacitor equivalent to the sum of capacitance.

Spark ignition testing conducted according to 9.1 at normal ambient temperatures, and the ignition data in Annex A and Annex G, may be used, where the service temperature is between −60 °C and 100 °C. No additional safety factors or consideration of heating due to faults within the apparatus are required. Equipment designed for use in service temperatures outside this range shall be subject to special investigation.

### 5.3.2 Levels of Protection "ia" and "ib"

For Levels of Protection "ia" and "ib", spark ignition assessment shall be applied to the following, except where stated otherwise in this document:

a) at any interruption or interconnection (including failure of separation) of a circuit that is considered a countable or non-countable fault; and
b) at any earth fault that is considered a countable or non-countable fault.

Spark ignition assessment (for example, application of the spark test apparatus) shall be carried out after the application of faults as specified in 5.2.2 and 5.2.3 and shall not add further to the fault count.

### 5.3.3 Level of Protection "ic"

For Level of Protection "ic", spark ignition assessment shall be applied to the following, except where stated otherwise in this document:

a) across any separation of conductive parts whose failure is considered a non-countable fault according to 6.5.4; and
b) in place of all or any part of components that are operated in excess of their manufacturer's specification under normal operating conditions.

Transients resulting from the application of $U_m$, which do not occur in normal operation (for example, as a result of a failure in the power supply), shall not be considered for the purposes of spark ignition compliance.

### 5.3.4 Application of safety factors

#### 5.3.4.1 Safety factor 1,0

Where a safety factor of 1,0 is required by 5.2 for spark ignition assessment, it shall be obtained by one of the following methods:

a) using the columns for safety factor of 1,0 in the tables in Annex A;

b) using the curves in Annex A;

c) using Annex G without removing the 1,5 safety factor; or

d) testing according to 9.1 using test mixtures according to 9.1.3.1.

#### 5.3.4.2 Safety factor 1,5

Where a safety factor of 1,5 is required by 5.2 for spark ignition assessment, it shall be obtained by one of the following methods:

a) using the columns for safety factor of 1,5 in the tables in Annex A.

b) using the curves in Annex A or the columns for safety factor 1,0 in the tables in Annex A where, prior to the application of the curves or tables:
   1) for inductive circuits the current is increased by a factor of 1,5;
   2) for capacitive circuits the voltage is increased by a factor of 1,5; or
   3) for resistive circuits, the current is increased by a factor of 1,5, or, as a conservative alternative, the voltage may instead be increased by a factor of 1,5.

c) using Annex G (the limit curves of which already include a safety factor of 1,5);

d) testing according to 9.1 applying one of the following:
   1) starting with the current and voltage under the conditions specified in 5.2 and testing using the test mixtures specified in 9.1.3.1:
      – for inductive and resistive circuits, so far as practical the current is increased to 1,5 times the assessed current by decreasing the values of limiting resistance; where it is not practical to obtain the 1,5 safety factor in this way, the voltage is increased until the required current is obtained; or
      – for capacitive circuits, the voltage is increased by a factor of 1,5.
   2) where 5.3.4.2 d) 1) is not practical, the use of more ignitable test mixtures according to 9.1.3.2;

e) using Annex F (which applies the safety factor to the gas mixture).

NOTE The purpose of the application of a safety factor is to ensure either that a type test or theoretical 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 safety factor, but the methods stated in this document provide acceptable alternatives.

### 5.3.5 Circuits without controlled semiconductor limitation

Circuits for which intrinsic safety does not depend on controlled semiconductor limitation shall be assessed using one of the following:

a) with the spark ignition test specified in 9.1;

b) at the connection facilities of FISCO equipment: complying with the intrinsic safety parameter limits specified in Annex E;

c) by assessment as specified in 9.2;

EXAMPLE For a trapezoidal output characteristic consisting of a voltage source followed by a resistor followed by a Zener diode, 9.2 can be used by assessing with the Zener diode removed from the circuit leaving a linear characteristic.

d) for linear output characteristic, using Annex G for linear sources of power; or

e) for trapezoidal output characteristic, using Annex G for rectangular sources of power.

NOTE A circuit assessed using the reference curves and tables of Annex A might cause ignition when tested using the spark test apparatus. Nevertheless, the tables can still be used for assessment because the sensitivity of the spark test apparatus varies, and the curves and tables are derived from a large number of such tests.

#### 5.3.6 Circuits with controlled semiconductor limitation

Circuits for which intrinsic safety depends on the operation of controlled semiconductor limitation shall be assessed to ensure spark ignition compliance both in the steady state condition where limitation is not activated and for the transient response when the limitation is activated.

In both of these cases the assessment shall consider the worst-case load that the application is expected to encounter under the conditions specified in 5.2 both for the limiting circuit and the load. This load might be a resistance, a fixed voltage load (such as a Zener) or a constant current source load, in combination with the inductance and capacitance that may be present under these conditions.

Where the transient response of the limitation is tested using the spark test apparatus (either using 9.1 or Annex F), the circuit shall be arranged to ensure that it fully resets during the test between each main break and following make of the spark test apparatus. Make and break caused by bouncing of the tungsten wire on the cadmium disk need not be considered. The test may be carried out on a representative circuit where the reset time has been reduced from that of a production circuit.

Where connection facility parameters are limited by circuits with controllable semiconductor limitation, $U_o$ and $I_o$ shall be calculated from the steady state limits, and not the peak of the transient response.

Assessment may involve one or more of the following, as applicable, to demonstrate steady state and transient response compliance.

a) compliance with the spark ignition test specified in 9.1;
b) at the connection facilities of FISCO equipment: complying with the intrinsic safety parameter limits specified in Annex E;
c) where it is not practical to apply the safety factor to the voltage or current, compliance with Annex F;
d) for linear output characteristic assessed as specified in 9.2;
e) steady state compliance may be demonstrated where the steady state output characteristic is fully contained within a linear characteristic that meets Table A.1; transient state compliance may also be demonstrated where transient state characteristics are fully contained within a linear characteristic that meets Table A.1.
f) where there is no more than one controlled semiconductor current limitation supply directly connected to the circuit, steady state compliance may be demonstrated using Annex G for non-linear sources of power; and
g) transient compliance may be assessed according to Annex D.

Different methods may be used for steady state and transient response. Switching controlled semiconductor limitation shall not trigger or trip during any test used to demonstrate steady state compliance.

### 5.4 Thermal ignition compliance

#### 5.4.1 General

All surfaces of intrinsically safe apparatus that come into contact with explosive atmospheres shall be assessed to ensure that, under the conditions specified in 5.2, the apparatus complies with the maximum surface temperature requirements of IEC 60079-0 as modified by:

a) 5.4.2, 5.4.3, 5.4.4 for Groups I and II; and

b) 5.4.5 for Group I, and for Group III.

The assessment shall be made without any additional factor required by IEC 60079-0 on the input voltage, current or power other than those required by this document.

Temperature classification may be assessed using thermal models based on knowledge of components' thermal behaviour or with reference to comparable apparatus. Tests, when required, shall be in accordance with 9.3.

Where the maximum power dissipation in tracks or wiring does not exceed 1,3 W, they shall be considered acceptable for a temperature classification of T4, or for Group I at a maximum ambient temperature of 40 °C. Where dust is excluded and the maximum power dissipation in the track or wiring does not exceed 3,3 W, they shall be considered suitable for Group I at a maximum ambient temperature of 40 °C. When using this assessment at ambient temperatures greater than 40 °C, these power limits shall be derated as specified in IEC 60079-0 for assessment of temperature classification for component surface area ≥ 20 $mm^2$.

#### 5.4.2 Temperature of small components for Group I and Group II

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

The 5 K and 10 K margin required by IEC 60079-0 in the type tests for determining maximum surface temperature applies to surface temperature requirements for 7.16.2.4b) and for Level of Protection "ic".

The 5 K and 10 K margin required by IEC 60079-0 does not apply for surface temperature requirements for Levels of Protection "ia" or "ib" when the table for assessment of temperature classification according to component size for small components in IEC 60079-0 is used, otherwise, the margin applies.

#### 5.4.3 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 3 for copper wires or can be calculated from the following equation for metals in general.

$$I = I_{\mathrm{f}} \sqrt{\frac{(t - T_{\mathrm{a}})(1 + \alpha(T - T_{\mathrm{a}}))}{(T - T_{\mathrm{a}})(1 + \alpha(t - T_{\mathrm{a}}))}}$$

where

$\alpha$ is the temperature coefficient of resistance of the wire material at $T_{\mathrm{a}}$ in $K^{-1}$;

$I$ is the maximum permissible current RMS, in amperes;

$I_{\mathrm{f}}$ is the current, in amperes, at which the wire melts in an ambient temperature $T_{\mathrm{a}}$;

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

$T_a$ is the maximum ambient temperature in °C; and

$t$ is the threshold temperature, in °C, for thermal ignition compliance. This is also the resultant wire temperature due to self-heating and ambient temperature.

Where the temperature coefficient of resistance of the material is specified at an ambient other than $T_a$, $\alpha_a$ at $T_a$ can be determined as follows:

$$\alpha_a = \frac{1}{\left(\frac{1}{\alpha_r} + (T_a - T_r)\right)}$$

$T_r$ is the known reference ambient temperature in °C (for example, 20 °C).

$\alpha_r$ is the coefficient of resistance at $T_r$ in $K^{-1}$ (for example, 0,004 27 $K^{-1}$ for copper, 0,004 201 $K^{-1}$ for gold at 20 °C)[1].

Where the melting current of the wire is available at a different ambient temperature to $T_a$ (for example, where the manufacturer of the wire specifies the melting current in the wire in an ambient of 20 °C),

$$I_f = I_r \sqrt{\frac{(T - T_a)}{(T - T_r)}}$$

where:

$I_r$ is the current, in amperes, at which the wire melts in an ambient temperature $T_r$

then $I_f$ may be determined as follows:

EXAMPLE fine copper wire with a surface area less than 20 mm$^2$ (Temperature class = T4)

α = 0,004 27 $K^{-1}$

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

$T$ = 1 083 °C

$T_a$ = 40 °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.)

1 Temperature coefficient of resistance of copper" by D.H Dellinger, Bulletin of the Bureau of Standards Vol 7 No 1 page 89, November 1910.

**Table 3 – Temperature classification of copper wiring for ambient temperature ≤ 40 °C**

| Diameter [a]<br><br>mm | Cross-sectional area [a]<br><br>$mm^2$ | Maximum permissible current for temperature classification<br><br>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 |

[a] Diameter and cross-sectional area are the nominal dimensions specified by the wire manufacturer.

The value given for maximum permissible current, in amperes, is the RMS AC or DC value.

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

The table also applies to flexible circuit boards and flexible flat conductors, such as a ribbon cable, but not to rigid circuit conductors.

### 5.4.4 PCB tracks for Group I and Group II

The temperature classification of PCB tracks exposed to the explosive atmosphere shall be determined using available analytical techniques and data or by testing. In all cases, the maximum continuous current shall be used to determine the temperature classification of a track. Tracks with lengths of 10 mm or less shall be disregarded for temperature classification purposes. Manufacturing tolerances shall not reduce the track width, board thickness or conductor thickness values determined in accordance with these requirements by more than 10 % or 1 mm, whichever is the smaller.

NOTE IPC-2221 and IPC-2152 are examples of available data.

Where the tracks are made of copper, the temperature classification may be determined using Table 4. The values found in the table shall be adjusted depending on the actual board thickness, number of track layers, copper conductor thickness, ambient temperature, and whether the track passes under components dissipating more than 0,25 W. When applying Table 4 and the associated adjustment factors, linear interpolation between current, track width, track thickness, ambient temperature, and board thickness values is allowed. No extrapolation of any values or adjustment factors is allowed. The maximum permissible current $I_P$ is calculated as shown below:

$$I_P = I \times \lambda_B \times \lambda_L \times \lambda_T \times \lambda_C \times \lambda_A$$

where

$I$ is the maximum permissible current for temperature classification found in Table 4;

$\lambda_B$ is the board thickness factor;

$\lambda_L$ is the number of layers factor;

$\lambda_T$ is the copper thickness factor;

$\lambda_C$ is the under component factor;

$\lambda_A$ is the ambient temperature factor.

EXAMPLE

To find the maximum permissible current for a T5 ($T_{amb}$ = 60 °C) rating of a 1 mm wide track that is greater than 10 mm in length on a two-layer circuit board with board thickness of 1,55 mm and copper conductor thickness of 18 µm that does not pass under power dissipating components.

Table 4 maximum permissible current for T5 ($T_{amb}$ = 40 °C) of a 1 mm wide track $I$ = 4,8 A

$\lambda_B$ = 1,00; $\lambda_L$ = 0,67; $\lambda_T$ = 0,67; $\lambda_C$ = 1,00; $\lambda_A$ = 0,83

$I_P$ = 4,8 A × 1,00 × 0,67 × 0,67 × 1,00 × 0,83 = 1,79 A

## Table 4 – Temperature classification of tracks on PCBs

| Minimum track width | Maximum permissible current for temperature classification (for a maximum ambient temperature of 40 °C) | | |
|---|---|---|---|
| | 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 |

The value given for maximum permissible current, in amperes, is the RMS AC or DC value.

This table applies to PCBs 1,55 mm or thicker with a single layer of copper of 33 µm thickness. The values found in the table shall be adjusted by multiplying the maximum permissible current found above by each of the factors below.

| Board thickness (mm) | Factor ($\lambda_B$) |
|---|---|
| 1,55 | 1,00 |
| 1,00 | 0,91 |
| 0,75 | 0,87 |
| 0,50 | 0,83 |

| Number of track layers | Factor ($\lambda_L$) |
|---|---|
| 1 | 1,00 |
| 2 | 0,67 |
| > 2 | 0,50 |

| Cu thickness (µm) | Factor ($\lambda_T$) |
|---|---|
| 70 | 1,30 |
| 51 | 1,20 |
| 33 | 1,00 |
| 18 | 0,67 |

| Under component [a] | Factor ($\lambda_C$) |
|---|---|
| No | 1,00 |
| Yes | 0,67 |

| Ambient temperature | Factor ($\lambda_A$) | | |
|---|---|---|---|
| (°C) | T4 | T5 | T6 |
| 40 | 1,00 | 1,00 | 1,00 |
| 60 | 0,83 | 0,83 | 0,83 |
| 80 | 0,77 | 0,64 | 0,40 |
| 100 | 0,66 | - | - |

[a] Applies to tracks passing under components dissipating 0,25 W or more, either normally or under fault conditions, where the section of track passing under the component exceeds a length of 10 mm.

### 5.4.5 Intrinsically safe apparatus and component temperature for dusts

The temperature considered for thermal ignition compliance shall be that of the surface of the intrinsically safe apparatus that is in contact with the dust.

EXAMPLE 1 For intrinsically safe apparatus protected by an enclosure providing a degree of protection of at least IP5X, the surface temperature of the enclosure is measured regardless of whether the enclosure requirements of IEC 60079-0 identified in Table 1 have been applied.

EXAMPLE 2 For EPL Da, or EPL Db with a specified layer of dust, with an enclosure that does not meet 6.2.4 a), the test of 9.14.3.3 is performed with the enclosure filled with dust and the balance of the 200 mm external to the enclosure. The temperature is measured on the surface of the cell.

As an alternative to assessment of the surface temperature, for the purpose of thermal ignition compliance for Groups I or III, intrinsically safe apparatus shall be considered suitable for total immersion, or an uncontrolled dust layer thickness, if the maximum power dissipation in any component under the conditions specified in 5.2 is in accordance with Table 5, and the continuous short circuit current is less than 250 mA. In this case, for Group III, the intrinsically safe apparatus shall be marked for a maximum surface temperature of 135 °C for an uncontrolled dust layer thickness.

NOTE The 250 mA level is to address the risk of thermal ignition from wires or tracks.

**Table 5 – Maximum permitted power dissipation within a component immersed in dust**

| **Maximum ambient temperature** | **°C** | 40 | 70 | 100 |
|---|---|---|---|---|
| **Permitted power** | **mW** | 750 | 650 | 550 |
| Linear interpolation between these values is permitted. | | | | |

### 5.5 Simple apparatus

The following may 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; and

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 document with the exception of Clause 11 and the manufacturer's responsibility requirement of IEC 60079-0. The manufacturer or intrinsically safe system designer shall demonstrate compliance, including material data sheets and test reports, if applicable.

The following aspects shall always be considered:

1) Simple apparatus shall not achieve safety by the inclusion of:
   - voltage limiting
   - current-limiting, or
   - suppression devices.

2) Simple apparatus shall not contain any means of increasing the available voltage or current, for example DC/DC converters.

3) Where it is necessary that the simple apparatus maintains the integrity of the isolation from earth of the intrinsically safe circuit, it shall be capable of withstanding the test voltage to earth in accordance with 6.9. Its terminals shall conform to 6.3.1.

4) Non-metallic enclosures shall conform to the requirements for electrostatic charges on external non-metallic materials specified in IEC 60079-0.
5) Metallic enclosures and metallic parts of enclosures shall conform to the applicable requirements of IEC 60079-0.
6) When used in an intrinsically safe circuit within their normal rating, switches, plugs, sockets and terminals may be assumed to have a temperature rise of less than 40 K. For other types of simple apparatus, the maximum temperature shall be assessed in accordance with 5.4.

Where simple apparatus forms part of an apparatus containing other electrical circuits, the whole shall be assessed according to the requirements of this document, including apparatus that complies with 5.5 c).

NOTE 1 Sensors which utilize catalytic reaction or other electro-chemical mechanisms are not normally simple apparatus.

NOTE 2 It is not a requirement of this document that the simple apparatus manufacturer's specifications, such as electrical and thermal rating, be verified.

## 6 Apparatus construction

### 6.1 General

The requirements given in this clause apply, unless otherwise stated in the relevant subclauses, only to those features of apparatus on which intrinsic safety depends.

EXAMPLE The requirements for encapsulation with casting compound apply only if it is required to satisfy 6.5.6.2 or 6.6.

### 6.2 Enclosures

#### 6.2.1 General

Where intrinsic safety can be invalidated by ingress of moisture or dust or by access to conductive parts, for example where parts of apparatus rely on separation requirements, an enclosure suitable for the intended use and environmental conditions shall be used.

The degree of protection required will vary according to the intended use; for example, an enclosure providing a degree of protection of at least IP54 in accordance with IEC 60529 might be required for Group I and Group III apparatus.

NOTE It is not a requirement of this document that the suitability for the intended use and environmental conditions be verified.

The enclosure for protection against contact with live parts may be physically different from that for ingress protection.

The designation of the surfaces of the enclosure relevant to intrinsic safety shall be recorded in the documentation according to the documentation requirements of IEC 60079-0 and in the user instructions (See 12.1 f)).

Any specific requirements for entries into enclosures, for example for IP rating, shall be provided in the manufacturer's instructions.

Enclosures for intrinsically safe apparatus for Group I, Group II, Group IIIA, and Group IIIB, which rely on the separation requirements in Table 7 or the reduced separation distances of Table 8 or Table 9, shall meet the requirements of 6.2.2 or 6.2.3 as applicable. See Annex I for additional information.

Enclosures for intrinsically safe apparatus for Group IIIC shall meet the requirements of 6.2.4.

Enclosures for associated apparatus (or parts thereof) for all equipment groups which rely on the separation requirements in Table 7 or the reduced separation distances of Table 8 or Table 9 shall meet the requirements of 6.2.2 or 6.2.3 as applicable.

### 6.2.2 Apparatus complying with Table 7

Parts of apparatus relying on the separation requirements of Table 7 shall be provided with an enclosure providing a degree of ingress protection of at least IP2X in accordance with IEC 60529.

The enclosure does not need to be subjected to the tests for enclosures in IEC 60079-0, except that for portable or personal equipment, the drop test of IEC 60079-0 still applies.

### 6.2.3 Apparatus complying with Table 8 or Table 9

Parts of apparatus relying on the reduced separation requirements of Table 8 or Table 9 shall be provided with protection for the separations on which intrinsic safety depends by one of the following:

a) The enclosure shall provide a degree of ingress protection of at least IP54 according to IEC 60529 and meet the requirements of 6.2.5.1.

b) The separations shall be protected according to 6.2.5.2.

c) For fixed installations, an enclosure providing a degree of protection of at least IP2X according to IEC 60529 and restricted to installation and use in environments providing pollution degree 2 or 1 according to IEC 60664-1. The enclosure does not need to be subjected to the tests for enclosures in IEC 60079-0. 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 restricted installation conditions.

   EXAMPLE "Equipment shall only be used in controlled environments which achieve pollution degree 2 as defined in IEC 60664-1." (Only non-conductive pollution occurs except that occasionally a temporary conductivity caused by condensation is to be expected).

### 6.2.4 Enclosures for Group IIIC intrinsically safe apparatus

Parts of apparatus relying on the separation requirements of Table 7, Table 8 or Table 9, shall be provided with protection for the separations on which intrinsic safety depends by one of the following:

a) The enclosure shall provide at least the degree of protection given in 1) or 2) below and meet the requirements of 6.2.5.1;

   1) Where separation is accomplished by meeting the requirements for clearance or creepage distances of Table 7, at least IP5X according to IEC 60529.

   2) Where the separation is accomplished by meeting the requirements for clearance or creepage distances of Table 8 or Table 9, at least IP54 according to IEC 60529.

b) The separations shall be protected according to 6.2.5.2.

### 6.2.5 Protection of separations

#### 6.2.5.1 Protection by enclosure

Separations may be protected to satisfy 6.2.3 a) or 6.2.4 a) by the use of an enclosure providing the specified IP rating, after the requirements according to IEC 60079-0 as identified in Table 1 have been applied.

Where the enclosure integrity relies on the sealing of openings that can be used for wiring, 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 that only cable glands, thread adapters and blanking elements conforming to the requirements of IEC 60079-0 may be used with the apparatus.

#### 6.2.5.2 Protection by other means

Separations may be protected to satisfy 6.2.3 b) or 6.2.4 b) by the use of an enclosure providing a degree of protection of at least IP2X according to IEC 60529, provided that separations are:

a) protected by a coating conforming to 6.5.6.5;
b) protected by encapsulation or casting compound conforming to 6.5.6.2;
c) through solid insulation conforming to 6.5.6.3; or
d) located on the inner layers of a multi-layer PCB.

The enclosure does not need to be subjected to the tests for enclosures in IEC 60079-0, except that for portable and personal equipment, the drop test of IEC 60079-0 still applies.

## 6.3 Connection facilities for external circuits

### 6.3.1 Terminals

In addition to satisfying the requirements of 6.5.1, 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) as follows:

a) The clearance between bare conductive parts of intrinsically safe terminals and bare conductive parts of non-intrinsically safe terminals shall be at least 50 mm.

   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.

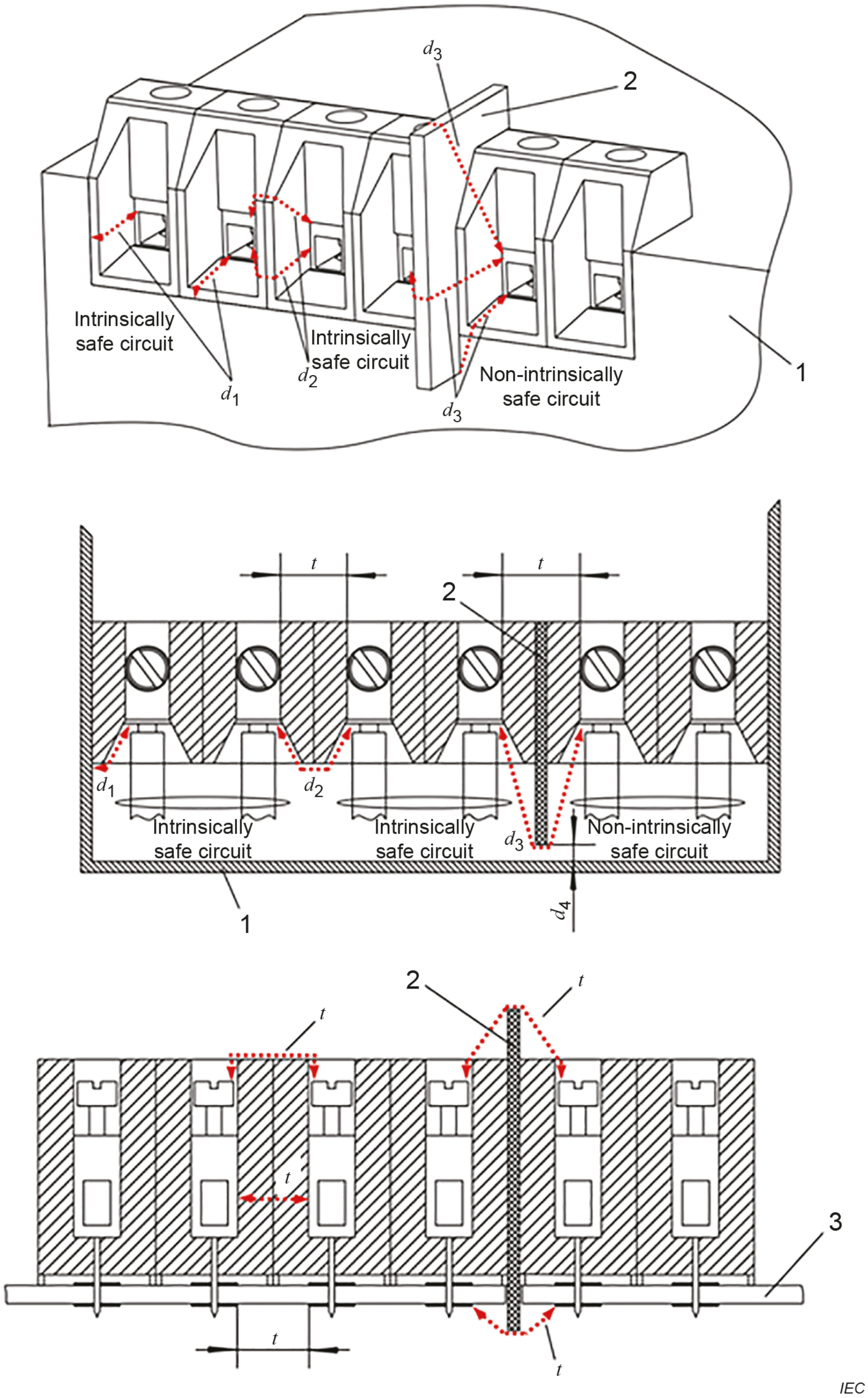
b) When separation is accomplished by locating terminals for intrinsically safe and non-intrinsically safe circuits in separate enclosures or by use of either an insulating partition or an earthed metal partition between terminals with a common cover, the following applies:
   1) partitions used to separate 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 conductive 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 9.4.3 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; and
   3) non-metallic insulating partitions 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 9.4.3 if of lesser thickness.

In addition to satisfying the requirements of 6.5.1, the clearance and creepage distances between bare conductive parts of connection facilities intended to receive connections for external circuits (see d1 and d2 in Figure 1) shall meet the following:

– at least 6 mm between separate intrinsically safe circuits; and
– at least 3 mm between intrinsically safe circuits and earthed parts where connection to earth would invalidate intrinsic safety.

The above methods of separation shall also be applied where intrinsic safety can be invalidated by external wiring which, if disconnected from the terminal, can come into contact with conductors or components which are not protected by an enclosure providing a degree of protection of at least IP2X according to IEC 60529.

Movement of metallic parts that are not rigidly fixed shall be taken into account. Figure 1 shows the distances to be considered at terminals.




**Key**

1 Cover / enclosure

2 Partition in accordance with 6.3.1; in this example, it shall be homogeneous with the base or cemented to it

3 PCB

*t* Distances for separations in accordance with 6.5.1

$d_1$ ≥ 3 mm, when cover / enclosure is conductive and earthed

$d_2$ ≥ 6 mm

$d_3$ ≥ 50 mm or $d_4$ ≤ 1,5 mm

**Figure 1 – Separation at terminals**

### 6.3.2 Earth Terminals

Where earthing is required to maintain intrinsic safety, the following applies:

a) terminals used for this purpose shall be fixed in their mountings without possibility of self-loosening and shall be constructed in such a way that the conductors are prevented from slipping out from their intended location;
b) 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;
c) the contact made by a terminal shall not be appreciably impaired by temperature changes in normal service;
d) terminals which are intended for clamping stranded cores shall include a resilient intermediate part; and
e) terminals designed for conductors of maximum cross-sections up to 4 $mm^2$ shall be of a type designed to accommodate conductors having a smaller cross-section than their maximum.

Terminals which conform to the requirements for electrical connections of IEC 60079-7 are considered to comply with these requirements.

The following shall not be used:

– terminals with sharp edges which could cause breakage of the conductors;
– terminals which may turn, be twisted or permanently deformed by normal tightening; or
– insulating materials which transmit contact pressure in terminals.

### 6.3.3 Plugs and sockets

Where apparatus is fitted with more than one plug or socket for external connections and interchange could adversely affect intrinsic safety, the following requirements apply.

a) Plugs and sockets used for connection of external intrinsically safe circuits shall be separate from, and non-interchangeable with, those for connection of non-intrinsically safe circuits.
b) Plugs and sockets used for connection of separate intrinsically safe circuits, or separate non-intrinsically safe circuits, shall either:
    1) be arranged, for example by keying, so that interchange is not possible; or;
    2) have mating plugs and sockets that are 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 6.3.1. If prefabricated, or 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 comply with Table 7, Table 8 or Table 9 under the conditions of 6.2.2, 6.2.3 or 6.2.4 as applicable.

Where a connector carries earthed circuits and intrinsic safety depends on the earth connection then the connector shall be constructed in accordance with 6.4.4.

### 6.3.4 Permanently connected cable

Apparatus which is constructed with an integral cable for external connections shall be subjected to the pull test in 9.4.4 on the cable if breakage of the terminations inside the apparatus could result in intrinsic safety being invalidated, for example where there is more than one intrinsically safe circuit in the cable and breakage could lead to an unsafe interconnection.

#### 6.3.5 Connections and accessories for intrinsically safe apparatus for use in non-hazardous area

##### 6.3.5.1 General

Intrinsically safe apparatus may be provided with connection facilities that are restricted to connection to a non-hazardous area accessory, for example data downloading or battery charging connections. These connections shall conform to 6.3.5.2 and 6.3.5.3.

The requirements of 6.3.5 do not apply to:

– connection facilities used for manufacturing, test, repair or overhaul; or

– connections that are not accessible by the end user.

NOTE Repair and overhaul are covered under IEC 60079-19.

##### 6.3.5.2 Protection against spark ignition while in the hazardous area

These connections shall be protected against causing spark ignition when the apparatus is in the hazardous area by either of the following:

– The outputs shall be limited in accordance with this document; or

– for Group II intrinsically safe apparatus, a degree of protection by enclosure of at least IP3X for the connection facilities to be used in the non-hazardous area. The apparatus shall be marked with a warning label as specified in 11.2 d) and the separation distances between the contacts shall conform to 6.5.1 considering the open circuit voltage of the internal circuitry, for example that of the battery.

##### 6.3.5.3 Protection of components on which intrinsic safety depends

For Levels of Protection "ia" and "ib", connection facilities shall be provided with protection to ensure the rating of components on which intrinsic safety depends within the intrinsically safe apparatus conform to 7.1 while it is connected in the non-hazardous area, including connection implemented through galvanic isolation.

EXAMPLE Wireless charging implementing galvanic isolation of the connection.

Dependent on the location of the protective circuitry and components in either the intrinsically safe apparatus or the non-hazardous area accessory, one of the following applies:

a) Where the intrinsically safe apparatus connection facilities are not restricted to the use of a non-hazardous area accessory listed in the certificate, the maximum voltage $U_m$, which can be applied to these connections, shall be stated in the certificate and marked on the apparatus; or

b) Where any part of the protection circuit is located in the non-hazardous area accessory, the accessory shall be listed in the certificate. The maximum rated input voltage $U_m$, which can be applied to the connection facilities of the non-hazardous area accessory that connect to non-intrinsically safe equipment, shall be stated in the certificate and the marking of the accessory shall conform to 11.1.5.

   NOTE 1 It is not a requirement of this document to specify parameters for the connection between the accessory and the intrinsically safe apparatus.

   Countable fault analysis of 5.2, separation distances, thermal or spark ignition considerations are not required for the non-hazardous area accessory, although protection components shall conform to the requirements of 7.1 after the application of non-countable faults to components.

   EXAMPLE A fuse and a single Zener diode conforming to 7.1 fulfil this requirement.

NOTE 2 IEC 60079-14 specifies the types of circuits or power supplies which are suitable for associated apparatus with a $U_m$ of less than 250 V.

Charging of secondary cells and batteries shall only be done within the limits specified by the cell or battery manufacturer and as defined in the secondary cells table of IEC 60079-0.

## 6.4 Internal connections and connectors

### 6.4.1 General

For Levels of Protection "ia" and "ib", if not complying with 6.4.2, failure to open circuit of any conductor, connector or PCB track, including its connections, shall be considered:

– a countable fault if rated for the maximum current using available data; or;

– a non-countable fault.

NOTE 1 It is not a requirement of this document that the conformity of the equipment manufacturer's specification of the current rating of the conductors, connector or PCB tracks needs to be verified.

NOTE 2 IPC-2221 and IPC-2152 are examples of available data.

If, after failure to open circuit, the connection is free to move, a short circuit fault to any part of the circuit within the range of movement shall be considered a countable fault in addition to the fault resulting in disconnection.

For Level of Protection "ic", the connection shall be suitable for the maximum current under normal operating conditions including 5.2.1 f), and shall not be subjected to open circuit faults.

For all Levels of Protection, where complete disconnection of a connector can occur, the circuits shall remain intrinsically safe.

### 6.4.2 Infallible connections

#### 6.4.2.1 General

Connections made via connectors, wires, PCBs or other means complying with 6.4.2.2, 6.4.2.3, 6.4.2.4 and 6.4.2.5 as applicable, and that are protected by an enclosure of at least IP2X, including when exposing connection facilities, shall be considered infallible against failure to open circuit.

#### 6.4.2.2 Connectors

Connectors shall be considered infallible if the connection comprises at least three independent connecting elements for Level of Protection "ia" circuits and at least two for Level of Protection "ib" circuits (see Figure 2). 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.

Either:

– each connecting element shall be rated to carry the complete current under the conditions specified in 5.2; or

– if more than one conductor is needed to carry the complete current, then under the conditions specified in 5.2, the remaining conductors shall be capable of carrying the complete current.

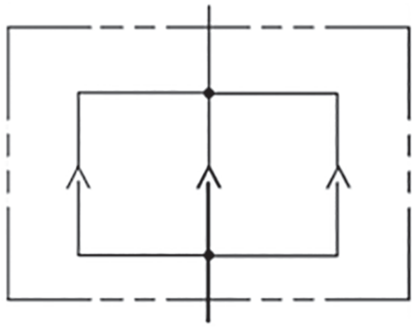



**Figure 2a) – Example of three independent connecting elements**

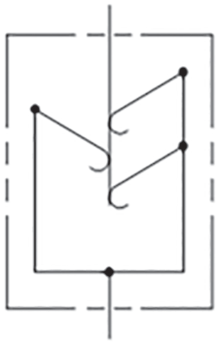



**Figure 2b) – Example of three connecting elements which are not independent**

**Figure 2 – Examples of independent and non-independent connecting elements**

#### 6.4.2.3 Wiring

Wiring is considered to make an infallible connection:

a) where two wires are in parallel and individually rated to carry the complete current under the conditions specified in 5.2 using available data, in which case only one of the wires shall be considered to disconnect;

NOTE Reconnection of the disconnected wire is considered in accordance with 6.4.1.

b) where a single wire has a conductor 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

c) where a single wire is of stranded or flexible ribbon type construction, has a conductor 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.

#### 6.4.2.4 Printed circuit boards

The following PCB tracks and vias are considered to make an infallible connection:

a) copper tracks and vias conforming to Table 6;

b) single tracks and vias that have a minimum track width or via circumference of 1 mm and either:

1) conform to the test requirements of 9.5; or
2) can be shown using available data to be adequately sized to carry the maximum current.

**Table 6 – Requirements for infallible circuit board tracks and vias**

| Level of Protection | Minimum Number of Tracks or Vias | Minimum Conductor Thickness (μm) | Minimum Track Width or Via Circumference (mm) |
|---|---|---|---|
| "ia" | 1 | 30 (outer layers)<br>24 (inner layers) | 2 |
| | 2 | 30 (outer layers)<br>24 (inner layers) | 1 |
| | 3 | Adequately sized | Adequately sized |
| "ib" | 1 | 30 (outer layers)<br>24 (inner layers) | 2 |
| | 2 | Adequately sized | Adequately sized |

EXAMPLE IPC-2221 and IPC-2152 are examples of available data for demonstrating adequate sizing.

#### 6.4.2.5 Other connections

Other connections shall be considered infallible where:

a) there are two connections in parallel individually rated to carry the complete current under the conditions specified in 5.2;

b) there is a single soldered joint in which the wire passes through the board (including through-plated holes) and:
   - is soldered at or adjacent to the hole; or
   - has a crimped connection; or
   - is brazed or welded;

c) there is a soldered joint of a surface mount component mounted in accordance with the component manufacturer's recommendations or applicable industrial standard; or

   NOTE IEC 61191-2, IPC-A-610 are examples of applicable industrial standards.

d) there is a single connection which conforms to IEC 60079-7 Level of Protection "eb".

### 6.4.3 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 within the same apparatus is not possible unless intrinsic safety is not invalidated, or the connectors are identified in such a manner that incorrect connection is obvious. For Level of Protection "ic", this is only applicable when the circuitry is to be accessed as part of normal operation.

For Levels of Protections "ia" and "ib", if the connection provided by a connector is required to maintain intrinsic safety, the requirements of 6.4.2.2 apply.

### 6.4.4 Earth conductors and connections

Where earthing is required to maintain intrinsic safety, any conductor, connector, and PCB track used for this purpose shall meet the requirements of 6.4.2 under the conditions specified in 5.2.

NOTE Earthing of enclosures, conductors, metal screens, tracks on a PCB, separation contacts of plug-in connectors and diode safety barriers might be required to maintain intrinsic safety.

## 6.5 Separation of conductive parts

### 6.5.1 Separations on which intrinsic safety depends

Where intrinsic safety depends on the separation between conductive parts of:

– intrinsically safe and non-intrinsically safe circuits,
– different intrinsically safe circuits,
– different parts of an intrinsically safe circuit, for example, across current limiting components, or
– a circuit and earthed or isolated metal parts,

separation shall be maintained as necessary, in accordance with 6.5.2 and 6.5.3, following the fault analysis of 6.5.4.

For Levels of Protection "ia" and "ib", this requirement applies to internal separations within components unless stated otherwise in this document.

For Level of Protection "ic", this requirement does not apply to internal separations within components unless stated otherwise in this document.

NOTE 1 Separations are additionally required by IEC 60079-0 to meet applicable safety requirements of relevant industrial standards.

NOTE 2 Details about the different types of separation are given in 6.5.6.

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 below the minimum requirement by more than 10 % or 1 mm, whichever is the smaller.

NOTE 3 Methods of assessment are given in Annex C.

For Levels of Protection "ia" and "ib", where a separation distance to bodies of prefabricated electronic components is required for intrinsic safety, no allowance shall be taken of the component insulation to achieve separation unless the thickness of this insulation is specified by the manufacturer of the component.

EXAMPLE 1 Where a component is mounted over or adjacent to tracks on the PCBs, the separation between the conductive part inside the component and the track.

EXAMPLE 2 Between an insulated resistor and a neighbouring component or a conductive part.

Short circuits between any internal conducting parts of a component and its solder pads do not need to be considered where the solder footprint is of similar design to the recommendation of the manufacturer of the component.

### 6.5.2 Separation distances according to Table 7

Separation distances according to Table 7 represent standard separation distances under the conditions of 6.2.2 or the applicable requirements of 6.2.4.

NOTE The requirements for separation distances specified in Table 7 are similar to those specified in IEC 60664-1 for pollution degree 3 and OVC III.

### 6.5.3 Reduced separation distances

#### 6.5.3.1 General

Table 8 or Table 9, under the conditions of 6.2.3 or 6.2.4, provide reduced separation requirements with respect to Table 7 for:

– assembled PCBs;
– insulation materials, except where only Table 7 is permitted by this document; and
– galvanically isolating components, such as relays and signal isolators with the exception of transformers.

NOTE Table 8 and Table 9 take advantage of a reduced pollution degree and defined OVC to apply reduced separation distances derived from IEC 60664-1.

#### 6.5.3.2 Reduced separation distances according to Table 8

Apparatus meeting the separation requirements of Table 8 shall comply with the following:

For mains powered associated apparatus, the mains supply shall be assumed to be OVC III as defined in IEC 60664-1 unless restricted by the apparatus manufacturer. Where the OVC is restricted to OVC I or II, 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.

Circuits that are either not connected to the mains supply or receive reduced transient overvoltages as specified for OVC I or II due to suitable protection internal to the apparatus, shall use the OVC I or II columns in Table 8 circuits from the point of limitation.

#### 6.5.3.3 Reduced separation distances for Level of Protection "ic"

Table 9 may be used for Level of Protection "ic" up to 250 V $AC_{RMS}$ / DC or 375 $V_{peak}$ provided that the following requirements are met:

a) Circuits that are either not connected to the mains supply or receive reduced transient overvoltages as specified for OVC I or II due to suitable protection internal to the apparatus, shall be considered to be OVC I or II circuit from the point of limitation.
b) For mains powered associated apparatus without suitable internal protection, the mains supply shall be limited to OVC I or II 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.
c) If the rated voltage of the apparatus or the nominal voltage of any part of the apparatus being considered does not exceed 60 V $AC_{RMS}$ or 85 V DC, no separation distance requirements additional to the general industrial standards are required.

### 6.5.4 Failure of separations

#### 6.5.4.1 General

Failure of separations within an enclosure complying with 6.2 shall be considered according to 6.5.4.2, 6.5.4.3, 6.5.4.4 or 6.5.4.5.

Separations shall only be considered to fail to a short circuit.

#### 6.5.4.2 Infallible separations

Separation distances complying with the values of Table 7, Table 8 or Table 9, under the applicable conditions of 6.2.2, 6.2.3 or 6.2.4 shall not be considered to fail.

Where connection facilities are accessible by the end user, separation distances are only considered infallible against failure where the separation is:

a) provided by solid insulation, including location of tracks on the inner layers of a multi-layer PCB;
b) encapsulated;
c) covered by a coating in accordance with this document; or
d) protected by an enclosure providing a degree of protection of at least IP2X according to IEC 60529.

#### 6.5.4.3 Distances according to Table 7

For Levels of Protection "ia" and "ib", separation distances less than the values specified in Table 7 but greater than or equal to one-third of that value, shall be subject to countable faults.

For Level of Protection "ia", where the total distance value of Table 7 consists of two sections combined in accordance with 6.5.7 a countable fault shall be applied to either section but not both, in the assessment of the overall separation.

For Levels of Protection "ia" and "ib", separation distances less than one-third of the values specified in Table 7 shall be subject to a non-countable fault.

For Level of Protection "ic", except as permitted by 6.5.7, separation distances less than the values specified in Table 7 shall be subject to a non-countable fault.

#### 6.5.4.4 Distances according to Table 8

For Levels of Protection "ia" and "ib", except where used to comply with 6.5.7, separation distances less than the values specified in Table 8 but greater than or equal to one-half of that value, shall be subject to a countable fault. The dielectric test voltages shall be those specified in 9.7 and 9.8 as applicable.

For Level of Protection "ia" where the total distance value of Table 8 consists of two sections combined in accordance with 6.5.7, a countable fault shall be applied to either section, but not both, in the assessment of the overall separation.

For Levels of Protection "ia" and "ib", separation distances less than one-half of the values specified in Table 8 shall be subject to a non-countable fault.

For Level of Protection "ic", the distances of Table 8 may be applied and separation distances less than the values specified in Table 8 shall be subject to a non-countable fault.

EXAMPLE: Table 9 cannot be applied to an OVC III Level of Protection “ic” circuit, but Table 7 and Table 8 can be.

#### 6.5.4.5 Distances according to Table 9

For Level of Protection "ic", except as permitted by 6.5.7, separation distances less than the values specified in Table 9 shall be considered as subject to a non-countable fault.

**Table 7 – Clearances, creepage distances and separations**

| 1 | 2 | | 3 | | 4 | | 5 | | 6 | | 7 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Voltage (peak value)** [a]<br>V | **Clearance**<br>mm | | **Separation distance through casting compound**<br>mm | | **Separation distance through solid insulation**<br>mm | | **Creepage distance**<br>mm | | **Separation distance protected by coating**<br>mm | | **CTI** [b] | |
| **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 |
| 3 300 | - | 18,0 | 9,0 | - | 4,5 | - | - | 32,0 | - | - | - | - |
| 4 700 | - | 22,0 | 12,0 | - | 6,0 | - | - | 50,0 | - | - | - | - |
| 9 500 | - | 45,0 | 20,0 | - | 10,0 | - | - | 100,0 | - | - | - | - |
| 15 600 | - | 70,0 | 33,0 | - | 16,5 | - | - | 150,0 | - | - | - | - |

[a] Including recurring peak voltage, but transients may be ignored

[b] See 6.5.6.4. At voltages up to 10 V, the CTI of insulating materials is not required to be specified.

## Table 8 – Reduced separations

| 1 | 2 | | 3 | | | | 4 | | 5 | | 6 | 7 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rated insulation voltage $AC_{RMS}$ or DC [a] | Clearance | | Creepage | | | | Separation distance under type 1 protection [c] | | Separation distance under type 2 protection [c] or separation distance through casting compound | | Solid insulation | Dielectric test voltages for type 1 and type 2 protection, solid insulation and casting compound | |
| | | | | Material Group [b] | | | | | | | | | |
| | OVC III | OVC I or II | PCB [d] | I (CTI ≥ 600) | II (CTI ≥ 400) | III (CTI ≥ 100) | OVC III | OVC I or II | OVC III | OVC I or II | | OVC III | OVC I or II |
| V | mm | mm | mm | mm | mm | mm | mm | mm | mm | mm | mm | | |
| 10 | 0,50 | 0,20 | 0,20 | 0,20 | 0,20 | 0,20 | 0,50 | 0,20 | 0,20 | 0,20 | 0,20 | 840 V $AC_{RMS}$ | 620 V $AC_{RMS}$ |
| 32 | 0,50 | 0,20 | 0,20 | 0,20 | 0,20 | 0,20 | 0,50 | 0,20 | 0,20 | 0,20 | 0,20 | 840 V $AC_{RMS}$ | 620 V $AC_{RMS}$ |
| 50 | 0,50 | 0,20 | 0,20 | 0,20 | 0,20 | 0,20 | 0,50 | 0,20 | 0,20 | 0,20 | 0,20 | 840 V $AC_{RMS}$ | 620 V $AC_{RMS}$ |
| 63 | 1,50 | 0,32 | 0,32 | 1,26 [h] | 1,80 [h] | 2,50 [h] | 0,75 | 0,32 | 0,45<br>0,20 [f] | 0,20 | 0,20 | 1 390 V $AC_{RMS}$ | 840 V $AC_{RMS}$ |
| 100 | 1,50 | 0,32 | 0,32 | 1,42 [h] | 2,00 [h] | 2,80 [h] | 0,75 | 0,32 | 0,45<br>0,20 [f] | 0,20 | 0,20 | 2 600 V $AC_{RMS}$ | 2 600 V $AC_{RMS}$ |
| 150 | 3,00 | 1,50<br>1,30 [e] | 1,50<br>1,30 [e] | 1,57 [h] | 2,17 [h] | 3,14 [h] | 1,50 | 0,65 | 1,20<br>0,20 [f] | 0,45<br>0,20 [f] | 0,20 [g] | 2 830 V $AC_{RMS}$<br>PDV: 849 $V_{peak}$ | 2 700 V $AC_{RMS}$<br>PDV: 849 $V_{peak}$ |
| 300 | 5,50 | 3,00 | 3,00 | 3,00 [h] | 4,13 [h] | 6,00 [h] | 2,75 | 1,50 | 1,50<br>0,20 [f] | 1,20<br>0,20 [f] | 0,20 [g] | 4 240 V $AC_{RMS}$<br>PDV:1 167 $V_{peak}$ | 3 000 V $AC_{RMS}$<br>PDV: 1 167 $V_{peak}$ |
| 600 | 8,00 | 5,50 | 6,10 | 6,10 [h] | 8,60 [h] | 12,00 [h] | 4,00 | 3,20 | 3,00<br>0,20 [f] | 1,50<br>0,20 [f] | 0,20 [g] | 5 660 V $AC_{RMS}$<br>PDV:1 803 $V_{peak}$ | 4 240 V $AC_{RMS}$<br>PDV:1 803 $V_{peak}$ |

[a] Including recurring peak voltage, but transients may be ignored.

[b] Material groups according to IEC 60664-1. See 6.5.6.4

[c] Type according to IEC 60664-3, see also 6.5.6.5.

[d] CTI for PCB shall be: ≥ 100 for voltages from 10 V to 100 V; ≥ 175 for voltages from 150 V to 400 V and ≥ 275 for voltages greater than 400 V.

[e] The lower value is permitted when the type test for dielectric strength is applied with $U$ = 2 065 V $AC_{RMS}$.

[f] Requires the routine test for dielectric strength requirements according to 10.1.

[g] Requires a type test according to 9.7 (see 6.5.6.3).

[h] Applied only for components and parts that provide or are located across galvanic isolation. Where there is no galvanic isolation the PCB column may be used.

[l] The dielectric requirements are to verify the suitability of the casting compound material for the application. Care should be taken that test results are not influenced by any electrical path in parallel to the isolation.

**Table 9 – Reduced separations for Level of Protection "ic"**

| 1 | | 2 | 3 | | | 4 | | | 5 | 6 |
|---|---|---|---|---|---|---|---|---|---|---|
| Voltage [a] $AC_{RMS}$ or DC | Voltage peak | Clearance | Creepage<br>Material Group [b]<br>I (CTI ≥ 600) | II (CTI ≥ 400) | III (CTI ≥ 100) | Separation distance protected by coating<br>Conformal coating | Type 1 protection | Type 2 protection | Separation distance through solid insulation and casting compound | Dielectric test voltages for type 1 and type 2 protection |
| V | V | mm | mm | mm | mm | mm | mm | mm | mm | V $AC_{RMS}$ |
| 60 [f] | 85 | - | - | - | - | - | - | - | - | - |
| 63 [c] | - | 0,40 | 0,63 | 0,90 | 1,25 | 0,30 | 0,20 | 0,10 | 0,15 | 780 |
| - | 90 [d] | 0,40 | - | - | 1,25 | 0,30 | - | - | 0,15 | - |
| 80 [c] | - | 0,40 | 0,67 | 0,95 | 1,30 | 0,40 | 0,22 | 0,10 | 0,30 | 780 |
| 100 [c] | - | 0,50 | 0,71 | 1,00 | 1,40 | 0,40 | 0,25 | 0,10 | 0,30 | 1 300 |
| 125 [c] | - | 0,50 | 0,75 | 1,05 | 1,50 | 0,40 | 0,28 | 0,20 | 0,30 | 1 325 |
| - | 190 [d] | 0,50 | - | - | 1,50 [e] | 0,40 | - | - | 0,30 | - |
| 160 [c] | - | 1,25 | 0,80 | 1,10 | 1,60 | 0,85 | 0,63 | 0,20 | 0,30 | 1 360 |
| 200 [c] | - | 1,25 | 1,50 | 1,50 | 2,00 | 0,85 | 0,63 | 0,45 | 0,30 | 1 768 |
| 250 [c] | - | 1,25 | 1,50 | 1,80 | 2,50 | 0,85 | 0,63 | 0,45 | 0,30 | 1 768 |
| | 375 [d] | 1,25 | - | - | 2,50 [e] | 0,85 | - | - | 0,30 | - |

[a] Including recurring peak voltage, but transients may be ignored.

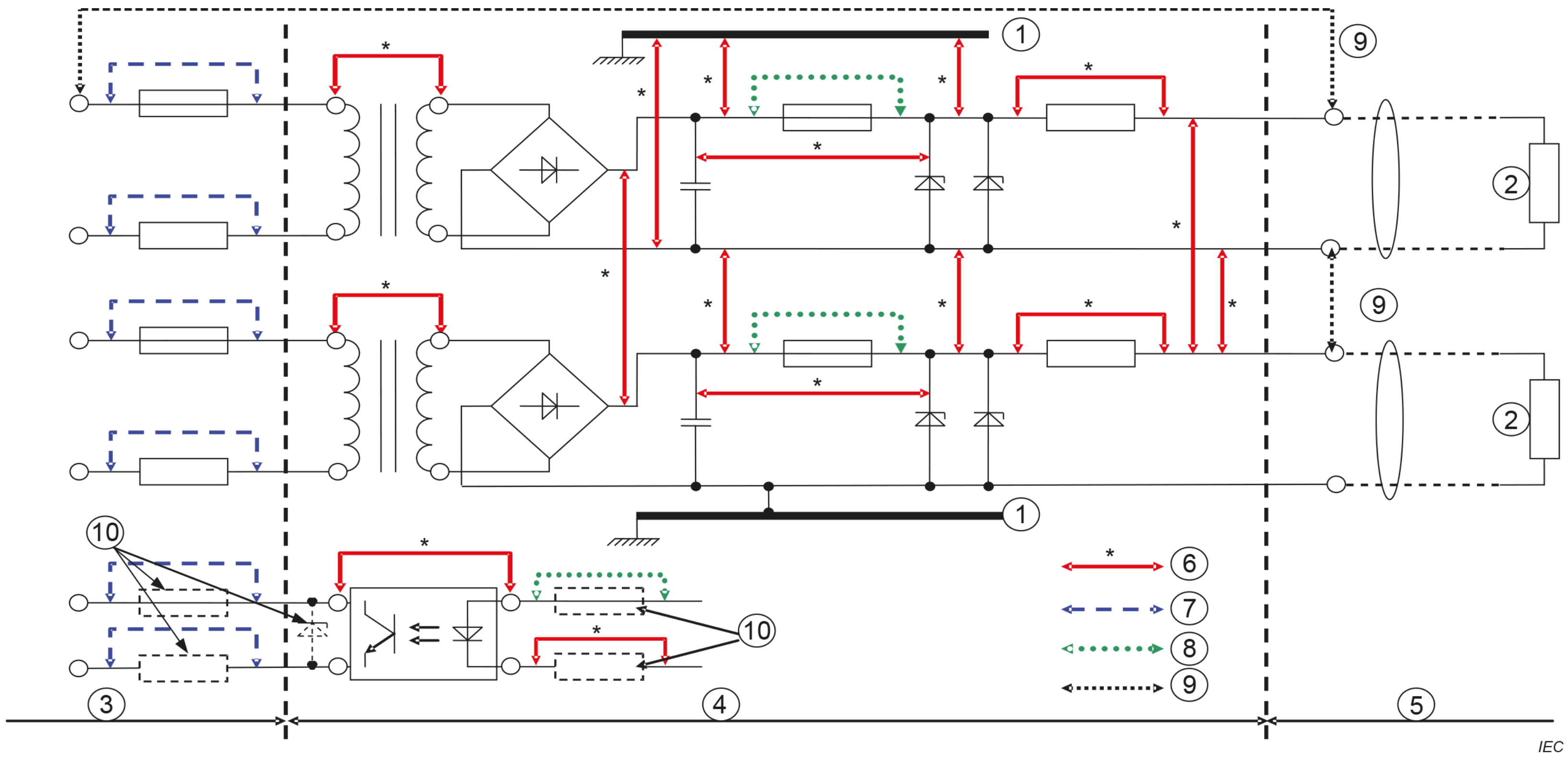
[b] Material groups according to IEC 60664-1. See 6.5.6.4.

[c] For bare PCBs and between different components on the PCB, the minimum creepage distance may be reduced to the values of clearance. This does not apply along components. CTI for PCB shall be: ≥ 100 for voltages from 10 V up to and including 100 V; ≥ 175 for voltages above 100 V to the maximum voltage in the table.

[d] Provided for compatibility with the previous edition of IEC 60079-11.

[e] CTI ≥ 175, at least material group IIIa.

[f] No separation distances additional to the general industrial standards are required.




**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 7, Table 8 or Table 9 are applicable
7 Dimensions to which general industrial standards are applicable
8 Dimensions to 7.11
9 Dimensions to 6.3.1 for output terminals between separate Intrinsically safe circuits and between Intrinsically safe to non-intrinsically safe circuits
10 Protective components as applicable for example, in accordance with 7.8.4.2 or 7.10.2.

**Figure 3 – Example of separation of conductive parts**

### 6.5.5 Voltage between conductive parts

When using Table 7, Table 8, or Table 9, the value of voltage to be considered between any two conductive parts shall be either of the following, as applicable:

a) for circuits which are galvanically isolated within the apparatus: the highest voltage that can appear across the separation when the two circuits are connected together at any one point, derived from:
   - the maximum voltage of 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

   $\sqrt{2}$ × RMS value of the rated voltage.

b) between parts of a circuit: the maximum peak value of the voltage that can occur between the two conductive parts. This is normally the maximum voltage in that circuit but could be the sum of the voltages of different sources connected to that circuit. Where it is the sum of the voltages, one of them shall be ignored if it is less than 20 % of the other.

In all cases, the conditions specified in 5.2 shall be applied to derive the maximum voltage.

Any external voltage shall be assumed to have the value $U_m$, or the rated voltage when applying 5.2.5, or $U_i$ declared for the connection facilities through which it enters, or the maximum voltage as defined by the protection components of a specified non-hazardous area accessory.

An example of separation of conductive parts is given in Figure 3.

### 6.5.6 Types of separation

#### 6.5.6.1 Clearance

Clearance distances are given in column 2 of Table 7, Table 8 or Table 9 and are applicable for:

- intrinsically safe apparatus when used at atmospheric pressure between 60 kPa and 110 kPa; and
- associated apparatus when used at atmospheric pressure between 80 kPa and 110 kPa.

For associated apparatus intended to be used at atmospheric pressure between 60 kPa and 80 kPa, multiply the clearance found in column 2 by the atmospheric pressure correction factor of 1,34 for the critical separations in non-intrinsically safe circuits and the separations between intrinsically safe circuits and non-intrinsically safe circuits.

NOTE It is possible to specify different input voltages or overvoltage categories for different pressures. For example, $U_m$ = 250 V for use between 80 kPa and 110 kPa and $U_m$ = 125 V for use between 60 kPa and 110 kPa.

The marking for associated apparatus designed for use in the ambient pressure range 60 kPa to 80 kPa shall include either the symbol $P_a$ or $P_{amb}$ together with both the upper and lower ambient pressures or, if this is impracticable, 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 limitations.

Where an insulating partition is used to extend clearance, it shall meet the requirements of 6.5.10. Other insulating parts shall comply with column 4 of Table 7, or column 6 of Table 8 or column 5 in Table 9 as applicable.

#### 6.5.6.2 Separation distances through casting compound

Where the casting compound meets the requirements of 6.6.1 and 6.6.5, separation distances which meet column 3 of Table 7, or column 5 of Table 8 or Table 9 apply. These separations may also be applied at the boundary between casting compound and solid insulation provided that the casting compound adheres to both the conductive parts and to the solid insulation (for example, tracks on a PCB).

Casting compound according to Table 8 shall comply with the dielectric requirements of column 7. Specifications provided by the manufacturer of the material may be used to demonstrate compliance with this requirement, otherwise testing shall be according to 9.7.

NOTE The exclusion of creepage distance requirements through the casting compound is due to the removal of the likelihood of contamination.

#### 6.5.6.3 Separation distances through solid insulation

Separation distance through solid insulation shall comply respectively with:

– column 4 of Table 7,
– column 6 of Table 8, or
– column 5 of Table 9.

Solid insulation according to Table 8 shall comply with the dielectric requirements of column 7. Specifications provided by the manufacturer of the material may be used to demonstrate compliance with this requirement, otherwise testing shall be according to 9.7.

Where type testing for reduced solid insulation distances is explicitly required by Table 8, the type test shall be in accordance with 9.7 applying the test voltage as applicable according to column 7 of Table 8. A partial discharge test is only required where a PDV is specified in column 7 of Table 8.

If the insulator is fabricated from two or more pieces of electrical insulating material, then the composite may be considered as solid.

For the purpose of this document, solid insulation should either be prefabricated (for example sheet or sleeving or elastomeric insulation on wiring) or moulded.

Varnish and similar coatings shall not be considered solid insulation.

Separation between adjacent tracks on intermediate layers of PCBs may be considered separation distances through solid insulation.

#### 6.5.6.4 Creepage distance

For the creepage distances specified in column 5 of Table 7, the insulating material shall comply with column 7 of Table 7.

For creepage distances specified in column 3 of Table 8 or Table 9, the insulating material shall comply with the respective material groups or CTI value.

Specification of CTI provided by the manufacturer of the material may be used to demonstrate compliance with the requirements.

For insulation materials where the CTI value is not known, a CTI of 100 is assumed. For glass, ceramics or other inorganic insulating materials which do not track, there are no requirements for creepage distances.

In Table 8, the creepage distance specified for material groups shall be applied to components across galvanic isolation, and parts across galvanic isolation, for voltages above 50 $V_{RMS}$. Otherwise, the distance specified in PCB column applies also to components and parts.

Where a joint is cemented and the cement has insulation properties at least as good as the adjacent material, clearance or a creepage path through the joint need not be considered.

The method of measuring or assessing these distances shall be in accordance with Figure 4. The values of the distance $X$, applicable for Table 7, Table 8 or Table 9 and the Level of Protection are shown in Table 10. The following shall apply for assessment of the creepage path:

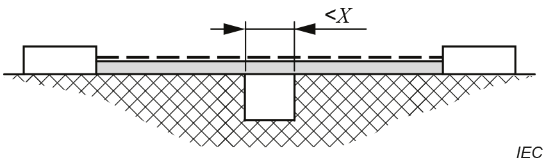
– where the distance is equal to or larger than the specified value of $X$, the creepage distance shall be measured along the contours; and
– any distance less than the specified value of $X$ shall be assumed to be bridged with an insulating link placed in the most unfavourable position. See Figure 4 Examples 1 and 3.

**Table 10 – Creepage distance and clearance $X$ in Figure 4**

| Level of Protection | Table 7<br>mm | Table 8<br>mm | Table 9<br>mm |
|---|---|---|---|
| "ia" and "ib" | 3,0 | 2,0 | n/a |
| "ic" | 1,5 | 1,0 | 1,0 |

Where the creepage distance is made up from the addition of shorter distances, for example where a conductive part is interposed, the distance shall be accomplished by their sums in accordance with 6.5.7.

**Example 1**



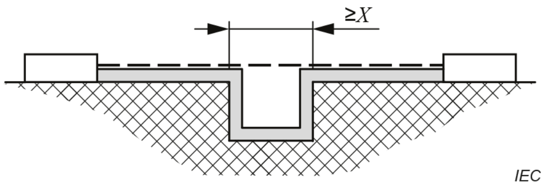

Condition: Path under consideration includes a parallel- or converging-sided groove of any depth with a width less than $X$ mm.

Rule: Creepage distance and clearance are measured directly across the groove as shown.

clearance    creepage distance

**Figure 4** *(1 of 5)*

**Example 2**

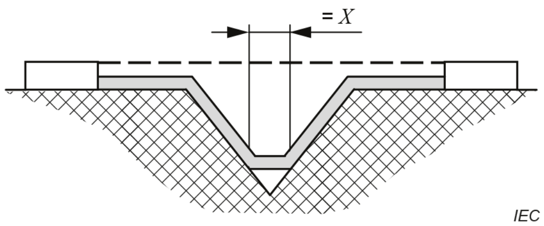



Condition: Path under consideration includes a parallel-sided groove of any depth $d$ equal to or more than $X$ mm.

Rule: Clearance is the 'line of sight' distance. Creepage path follows the contour of the groove.

clearance creepage distance

**Example 3**

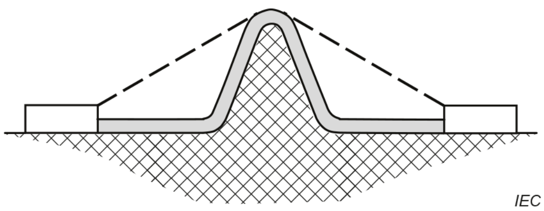



Condition: Path under consideration includes a V-shaped groove with a width greater than $X$ mm.

Rule: Clearance is the 'line of sight' distance. Creepage path follows the contour of the groove but 'short circuits' the bottom of the groove by $X$ mm link.

clearance creepage distance

**Example 4**



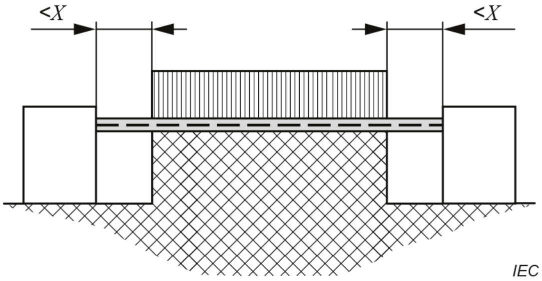

Condition: Path under consideration includes a rib.

Rule: Clearance is the shortest direct air path over the top of the rib. Creepage path follows the contour of the rib.

clearance creepage distance

**Figure 4** *(2 of 5)*

**Example 5**

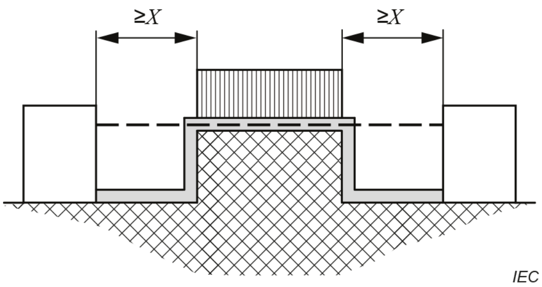



Condition: Path under consideration includes an uncemented joint with groove less than $X$ mm wide on each side.

Rule: Creepage and clearance path is the 'line of sight' distance shown.

clearance creepage distance

**Example 6**

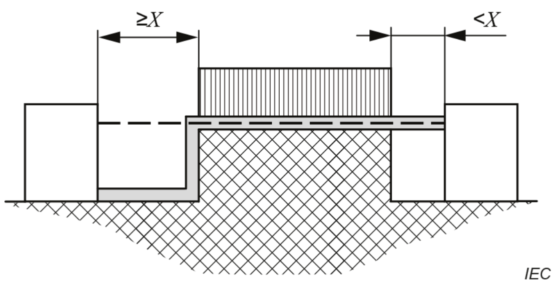



Condition: Path under consideration includes an uncemented joint with grooves equal to or more than $X$ mm wide on each side.

Rule: Clearance is the 'line of sight' distance. Creepage path follows the contour of the grooves.

clearance creepage distance

**Example 7**



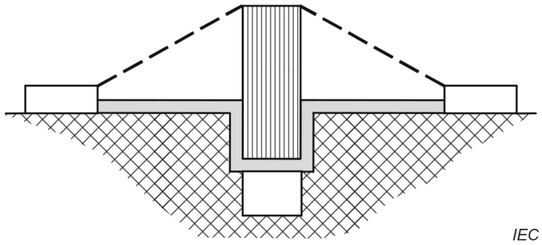

Condition: Path under consideration includes an uncemented joint with a groove on one side less than $X$ mm wide and the groove on the other side equal to or more than $X$ mm wide.

Rule: Clearance and creepage paths are as shown.

clearance creepage distance

**Figure 4** *(3 of 5)*

**Example 8**

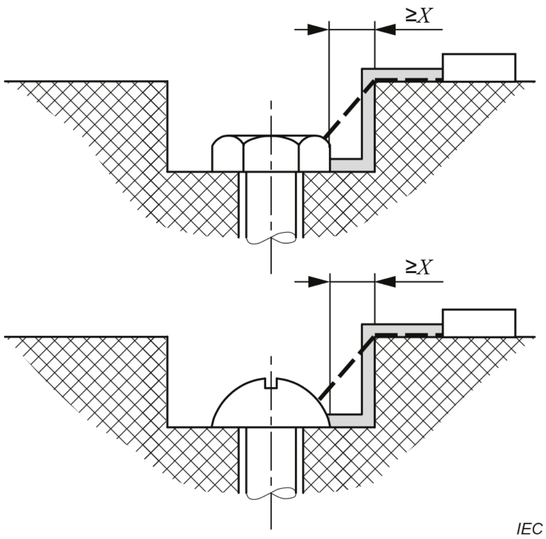



Condition: Creepage distance through uncemented joint is less than creepage distance over partition.

Rule: Clearance is the shortest direct air path over the top of the partition.

clearance creepage distance

**Example 9**

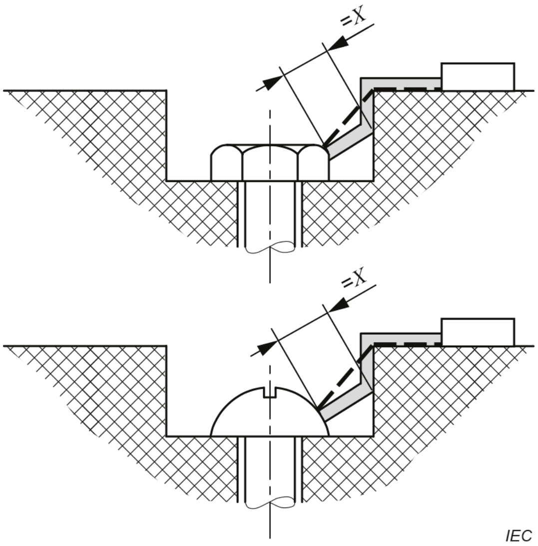



Gap between head of screw and wall of recess wide enough to be taken into account.

clearance creepage distance

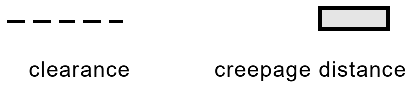
**Figure 4** *(4 of 5)*

**Example 10**

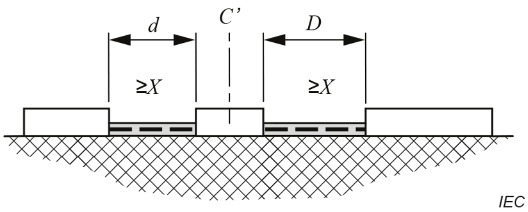



Gap between head of screw and wall of recess too narrow to be taken into account.

Measurement of creepage distance is from screw to wall when the distance is equal to $X$ mm.




**Example 11**




Clearance is the distance $d + D$

Creepage distance is also $d + D$

C' conductive part interposed in the insulating path between the conductors


**Figure 4** *(5 of 5)*

**Figure 4 – Determination of creepage distances and clearance**

### 6.5.6.5 Separations distances protected by coating

Separations protected by coating shall comply with column 6 of Table 7, or columns 4 or 5 of Table 8, or column 4 of Table 9, as applicable.

A coating shall seal the path between the conductors which require protection against the ingress of moisture and pollution and shall give an effective, lasting, unbroken seal. It shall adhere to both the conductive parts and to the insulating material.

The application of the coating together with a subsequent inspection according to 10.4, shall ensure that the coating is complete and homogeneous.

The COT rating of the coating as specified by the manufacturer of the coating shall be at least equal to the maximum and minimum service temperature of any conformally coated component or part.

Any recommendations of the coating manufacturer should be followed to achieve a homogeneous reliable coating and to introduce a suitable inspection method where necessary.

EXAMPLE An example of an inspection method is described in IPC-A-610.

Coating used to achieve type 1 or type 2 protection shall be subjected to the type testing specified in 9.8.

For separation distances on a PCB, a solder mask that meets the requirements of type 1 or type 2 protection in accordance with IEC 60664-3 may be considered as conformal coating provided that no damage occurs during soldering.

Coatings according to IEC 61010-1 or ANSI/UL 746E may be used to achieve type 1 protection without testing according to IEC 60664-3 as specified above, noting that there are application limitations that those standards require to be considered.

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

The method used for coating and the measures for inspection, if applicable, 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 type examination.

Where bare conductors or conductive parts emerge from the coating, the CTI of the coating shall comply with column 7 of Table 7 or comply with the respective material group or CTI value of Table 8 or Table 9.

#### 6.5.7 Composite separations

Where separations consist of a combination of different types of separation, for example through a combination of clearance and solid insulation, sections of the identical type of separation, or a creepage path on a PCB interrupted by conductive material, the equivalent total separation shall be calculated as follows.

Separations shall be converted to a percentage of the minimum required separation for the appropriate table column.

The equivalent total separation is the sum of all calculated percentages.

For separations in accordance with Table 7:

– for Levels of Protection "ia" and "ib", any separation less than 33,3 % shall be ignored; for the overall separation to be infallible, the sum shall be at least 100 %; and
– for Level of Protection "ic", the sum shall be at least 100 %.

For separations in accordance with Table 8 or Table 9:

– for Levels of Protection "ia" and "ib", any separation less than 0,2 mm or less than 50 % shall be ignored; for the overall separation to be infallible, the sum shall be at least 100 %;
– for Level of Protection "ic", the sum shall be at least 100 %; and

– voltages defined in column 7 of Table 8 and column 6 of Table 9 shall be applied across the composite separation.

NOTE Further guidance is given in Annex C.

Where an ambient pressure correction factor is applied in accordance with 6.5.6.1 for associated apparatus, the correction factor shall be applied only to the clearance values when considering whether the composite separation sums up to 100 % of the required value. The correction factor is not used in determining whether a clearance is large enough to be counted in the composite separation.

### 6.5.8 Printed circuit board assemblies

Creepage and clearance distances for PCBAs shall comply with the following (see Figure 5):

a) When a PCBA is covered by a conformal coating according to 6.5.6.5, the requirements for creepage and clearance distances shall apply only to conductive parts which lie outside the coating, including, for example;
   - tracks which emerge from the coating;
   - the free surface of a PCBA which is coated on one side only; or
   - bare parts of components able to protrude through the coating.

b) The requirements of 6.5.6.5 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.

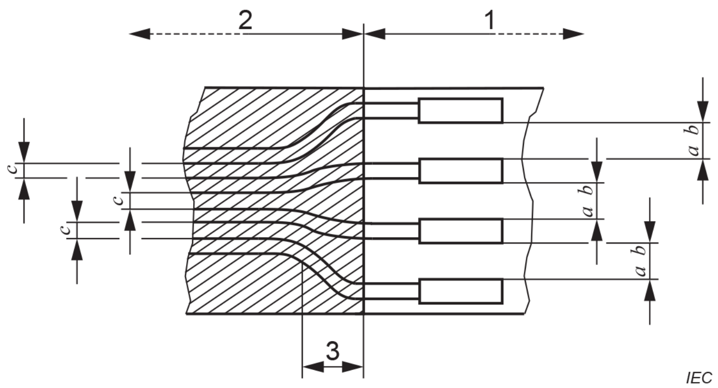



**Figure 5a – PCBA partially coated board**

**Figure 5** *(1 of 2)*

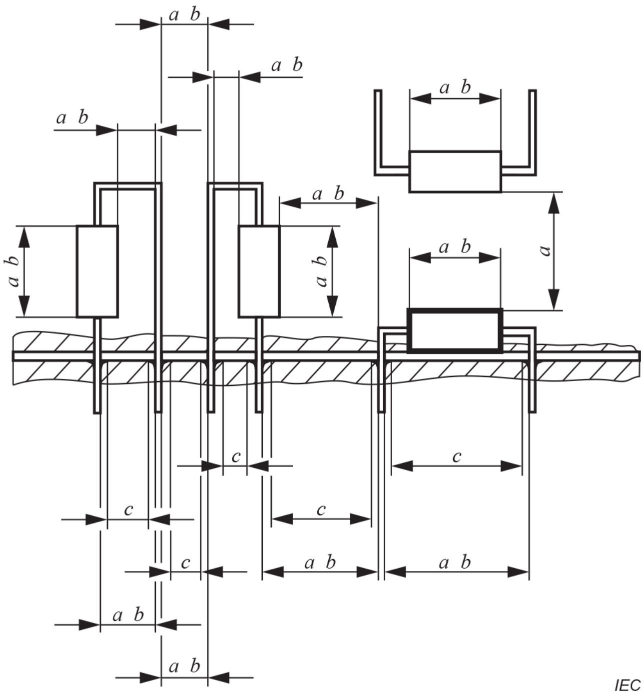



**Figure 5b – PCBA with soldered leads protruding**

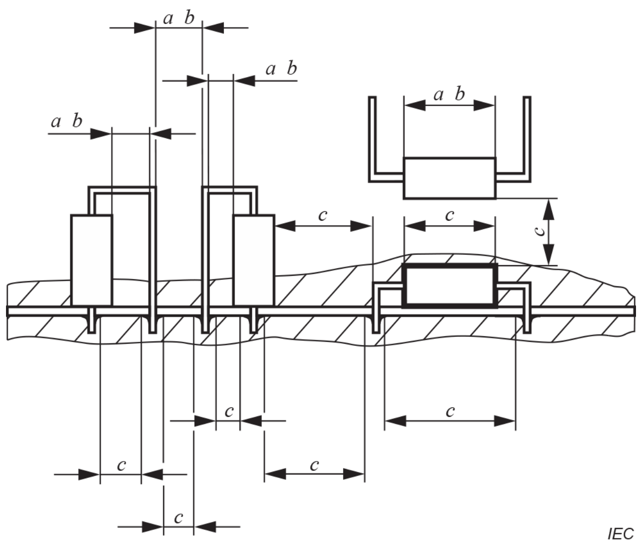



**Figure 5c – PCBA with soldered leads folded or cropped, completely covered by coating**

**Figure 5** *(2 of 2)*

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

**Key**

*a* Clearance requirements of 6.5.6.1 apply

*b* Creepage distance requirements of 6.5.6.4 apply

*c* Distance under coating requirements of 6.5.6.5 apply

*1* Uncoated area

*2* Coated area

*3* Transition area, composite separations for *a*, *b*, *c* apply

## Figure 5 – Creepage distances and clearances on PCBAs

#### 6.5.9 Separation by metal parts

##### 6.5.9.1 General

Separation by metal parts shall only be used when breakdown to the metal part results in conduction to a potential (for example, earth or the terminal of a battery) which does not invalidate intrinsic safety. In this case, separation requirements to the metal part do not apply.

Where the connection to the metal part results in losing the isolation between an intrinsically safe circuit and the frame or earth and this might invalidate intrinsic safety, 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 limitations as required by 6.9.

EXAMPLE Intrinsic safety depends on the separation to earthed metal parts if a current-limiting resistor can be bypassed by short circuits between the circuit and the earthed metal part.

Creepage distance requirements do not apply where interposing PCB tracks (for example, an earthed track) separate the conductive tracks under consideration, however, clearance requirements shall still be applied. Clearance requirements shall not apply where a metal partition of sufficient dimensions does not allow a discharge between components requiring separation.

A metal part used for separation 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 connection under the conditions specified in 5.2.

##### 6.5.9.2 Levels of Protection "ia" and "ib"

For Levels of Protection "ia" and ib":

a) Where a metal part, for example a track of a PCB, a screen or a partition, separates an intrinsically safe circuit from other circuits, the metal part, as well as any connection to it, shall conform to 6.4.2.
b) Where the connection is made through a connector, the connector shall be constructed in accordance with 6.4.2.2.
c) Where intrinsic safety depends on a metal partition, it shall either be at least 0,45 mm thick, or shall conform to 9.4.3 if of lesser thickness.

##### 6.5.9.3 Level of Protection "ic"

For Level of Protection "ic", where separation distances to a metal part connected to a controlled potential do not comply with the required separation distances, the metal part shall be capable of carrying the maximum current to which it could be continuously subjected.

#### 6.5.10 Separation by non-metallic insulating partitions

For Levels of Protection "ia" and "ib", a non-metallic insulating partition used to maintain separation shall comply with applicable separation requirements and shall:

a) have a thickness of at least 0,9 mm; or
b) conform to 9.4.3.

For Level of Protection "ic" non-metallic insulating partitions, there is no minimum thickness other than the applicable separation requirements and 9.4.3 does not apply.

#### 6.5.11 Insulation of internal wiring

##### 6.5.11.1 General

Except for varnish and similar coatings, insulation covering the conductors of internal wiring may be considered as solid insulation (see 6.5.6.3).

The separation of conductors of insulated wires shall be determined by adding together the radial thicknesses of extruded insulation on wires which could come into contact either as separate wires, or in a cable form, or in a cable.

The maximum current in the insulated wiring shall not cause the temperature rating specified by the manufacturer of the wire to be exceeded.

Insulation on wires that comply with the distance through solid insulation are not considered to fail or reduce the insulation thickness should breakage of the conductor occur.

##### 6.5.11.2 Insulation between intrinsically safe and non-intrinsically safe circuits

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 7 taking into account the requirements of 6.5.7 except when one of the following applies:

– the cores of either the intrinsically safe or the non-intrinsically safe circuit are enclosed in an earthed screen complying with 6.4.4; or
– in Levels of Protection "ib" and "ic" apparatus with a maximum voltage of 375 V (peak value) between the conductors, the insulation of the intrinsically safe cores is capable of withstanding the test in accordance with 9.6 applying a test voltage of 2 000 $V_{RMS}$.

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

##### 6.5.11.3 Insulation between separate intrinsically safe circuits

The distance between the conductors of any core of separate intrinsically safe circuits shall be in accordance with column 4 of Table 7 taking into account the requirements of 6.5.7, except when one of the following applies:

– the cores of either intrinsically safe circuits are enclosed in an earthed screen; or
– the insulation between separate intrinsically safe circuits with a maximum voltage of 90 V (peak value) between the conductors is capable of withstanding the test in accordance with 9.6 applying a test voltage of 1 000 $V_{RMS}$ (or 500 $V_{RMS}$ core to insulation).

### 6.6 Encapsulation

#### 6.6.1 General

Encapsulation may be used for, but is not limited to, one or a combination of the following:

– exclusion of explosive atmospheres:
  - protection against spark ignition (see 6.6.2.1);
  - protection against thermal ignition (see 6.6.2.2);
– provision of mechanical protection to avoid access to conductive parts (see 6.6.3);
– protection of fuses as required by 7.11 (see 6.6.4);
– application of separation distances according to 6.5.6.2 (see 6.6.5);
– establishing the rating of protective components (see 6.6.6).

Encapsulation may be applied by casting, pouring or moulding. Where encapsulation is used, the method of verification in accordance with the routine verification requirements of 10.4 shall be stated in the documentation.

Failure of separations and components within the compound shall be assessed under the conditions specified in 5.2.

For intrinsically safe apparatus, all circuits connected to the encapsulated conductive parts, and components or bare conductive parts protruding from the compound, shall be either intrinsically safe or protected by another Type of Protection listed in IEC 60079-0. The possibility of spark ignition inside the encapsulation need not be considered if the encapsulation complies with 6.6.2.1.

The following requirements apply to the encapsulating compound and, where applicable, any potting box or part of an enclosure:

a) The COT of the compound as specified by the manufacturer of the compound shall be at least equal to the maximum and minimum temperature at the interface between the compound and any encapsulated component or part under normal operating conditions. Temperatures higher than the compound's COT rating are permitted if under the conditions specified in 5.2, there is no damage to the compound both internally and externally that could invalidate intrinsic safety.

   EXAMPLE Damage that could invalidate intrinsic safety includes cracks in the compound, exposure of encapsulated parts, flaking, impermissible shrinkage, swelling, decomposition, softening or evidence of overheating.

b) The compound shall have at its free surface a CTI value of at least that specified in Table 7 or Table 8 or Table 9 as applicable if any bare conductive parts protrude from the compound.
c) Only materials passing the test in 9.4.1 shall have its free surface exposed and unprotected, thus forming part of the enclosure.
d) The compound shall be adherent to all conductive parts, components and substrates except when they are totally enclosed by the compound. A seal shall be maintained where any part of the circuit, for example a bare or insulated conductor or component or the substrate of a PCB, emerges from the encapsulation and therefore the compound shall be adherent at these interfaces.
e) Measures to prevent voids in the compound during the encapsulation process shall be defined in the documentation according to the documentation requirements of IEC 60079-0.

Free space is permitted within encapsulation provided it complies with 6.6.7.

### 6.6.2 Encapsulation used for the exclusion of explosive atmospheres

#### 6.6.2.1 Protection against spark ignition

Where casting or pouring is used to exclude an explosive atmosphere from components and conductive parts, the minimum thickness to the free surface of the encapsulating compound shall be at least half the values specified in column 3 of Table 7, or column 5 of Table 8 and Table 9, with a minimum of 1 mm (see Figure 6).

When the encapsulating compound is in direct contact with and adheres to an enclosure of solid insulation material conforming to column 4 of Table 7, no other separation is required (see Figure 7, Figure 8 and Figure 9).

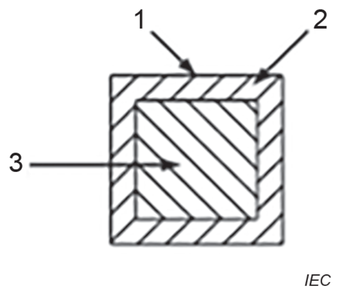
Where the encapsulating compound is in direct contact with and adheres to a metallic enclosure:

a) there is no minimum thickness required for the encapsulation provided that there is no free space (see 6.6.7) and failure of separation to the metallic enclosure does not invalidate intrinsic safety;

b) there is no minimum thickness required for the metallic enclosure; and

c) If this enclosure also forms the external enclosure of the apparatus, it shall also conform to 6.2 (See Figure 9).

NOTE The requirements of 6.2 and 6.9 remain applicable.



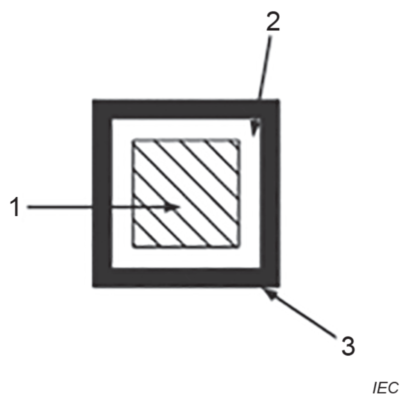

**Key**

1 Free surface, external wall

2 Compound

3 Component – compound need not enter the component

**Figure 6 – Encapsulation used without a separate external enclosure**



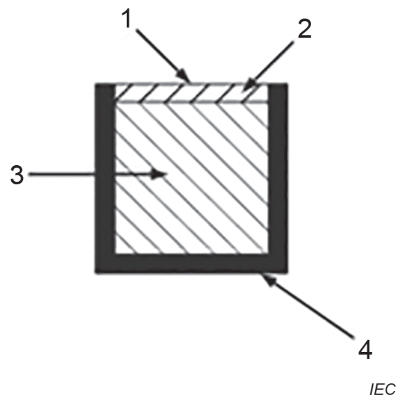

**Key**

1 Component – compound need not enter the component

2 Compound – no specified thickness

3 Metal or insulating enclosure

**Figure 7 – Complete enclosure with no user removable covers or openings**




**Key**

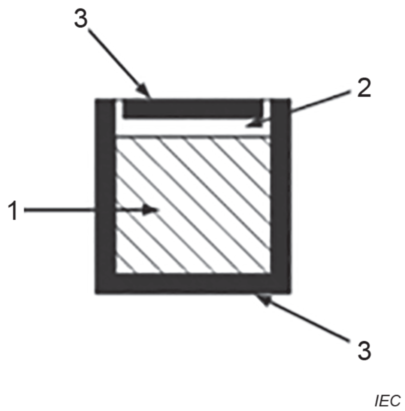
1 Free surface, external wall

2 Compound

3 Component – compound need not enter the component

4 Metal or insulating enclosure

**Figure 8 – Enclosure where the compound forms one of the external walls**




**Key**

1 Component – compound need not enter the component

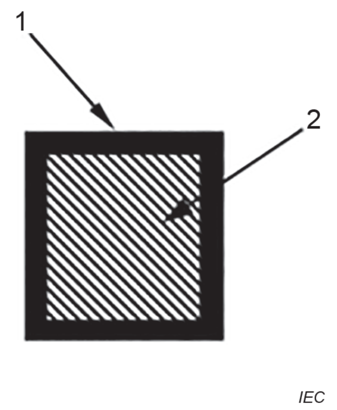
2 Compound

3 Metal or insulating enclosure

**Figure 9 – Enclosure with cover**

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 7, with a minimum thickness of 0,5 mm (see Figure 10 and Figure 11). When the plastic is in direct contact with and adheres to a solid insulation material conforming to column 4 of Table 7, with a minimum thickness of 0,5 mm, no other separation is required.

Figure 10 shows moulding over an unmounted component.



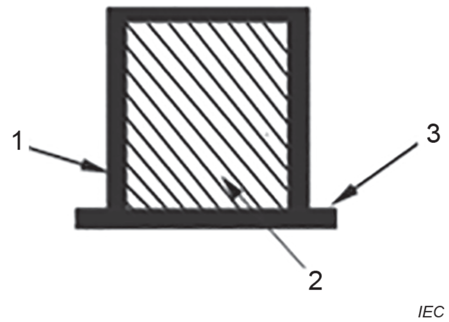

**Key**

1 Moulding

2 Components

**Figure 10 – Moulding over un-mounted components**

Figure 11 is intended to show components that are first mounted onto a PCB (item 3) before being moulded under pressure. This is sometimes referred to as insert moulding.




**Key**

1 Moulding

2 Components

3 PCB with a minimum thickness of 0,5 mm

**Figure 11 – Moulding over components mounted on a PCB**

EXAMPLE Examples of the application of moulding over components are fuses, piezoelectric devices with their suppression components and energy storage devices with their suppression components.

### 6.6.2.2 Additional requirements for protection against thermal ignition

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 ensure compliance with 5.4.

### 6.6.3 Mechanical protection to avoid access to parts

When encapsulation is used to prevent access to parts, the minimum thickness to the free surface shall be at least half the value given in column 3 of Table 7 with a minimum of 1 mm.

### 6.6.4 Encapsulation used for protection of a fuse

The minimum thickness to the free surface when the compound is cast or poured shall be at least half the value given in column 3 of Table 7 with a minimum of 1 mm. The minimum thickness to the free surface when moulded shall be at least the value given in column 4 of Table 7 with a minimum of 0,5 mm. The compound shall not enter any free space within the body of the fuse.

### 6.6.5 Encapsulation used to provide separation

For those parts that require encapsulation to provide separation complying with 6.5.6.2, the minimum separation distance between the free surface of the encapsulating compound and encapsulated conductive parts or components shall be at least half the values specified in column 3 of Table 7, or column 5 of Table 8 or Table 9 as appropriate, with a minimum of 1 mm. When the encapsulating compound is in direct contact with and adheres to an enclosure of solid insulation material conforming to column 4 of Table 7 or column 6 of Table 8 or column 5 of Table 9 as appropriate, no other separation is required.

### 6.6.6 Encapsulation used to enhance the rating of protective components

Encapsulation may be used to enhance the rating of protective components, for example Zener diodes, using an increased thermal conductivity provided that the arrangement can be demonstrated to be suitably effective under the conditions specified in 5.2.

### 6.6.7 Free space within the encapsulation

#### 6.6.7.1 General

Where encapsulation is used for the exclusion of explosive atmospheres, the free space within the encapsulation shall conform to 6.6.7.2 and 6.6.7.3, as applicable except that free space within components (for example, transistors, relays, fuses) does not need to be considered when the component volume is less than 1 $cm^3$.

Free space shall not be used within encapsulation to protect the compound from damage from components within it.

#### 6.6.7.2 Volume of free space

For Group I and Group II, individual free space shall comply with the volume and compound thickness values shown in Table 11, and the sum of the individual free spaces within a single encapsulated volume shall not exceed:

a) 100 $cm^3$ for Levels of Protection "ib" and "ic"; or

b) 10 $cm^3$ for Level of Protection "ia".

For Group III the sum of the free spaces is not limited, but the volume of each individual free space shall comply with the volume and compound thickness values shown in Table 12.

#### 6.6.7.3 Protection of free space

The assembly containing free spaces shall be protected against access to these free spaces by the encapsulation or by an enclosure which forms a non-recoverable unit and forms a single entity.

With the exception of free spaces within components as addressed in 6.6.7.2, the thickness of compound required to protect free spaces shall be as specified in Table 11 for Group I and Group II, and in Table 12 for Group III.

**Table 11 – Minimum thickness of compound adjacent to individual free space for Group I and Group II**

| Level of protection | Minimum thickness of compound adjacent to free space to: | Free space ≤ 1 $cm^3$ | Free space > 1 $cm^3$ ≤ 10 $cm^3$ | Free space > 10 $cm^3$ |
|---|---|---|---|---|
| "ia" | Free space or free surface | 3 mm | Not permitted | Not permitted |
| | Non-metallic or metal enclosure with adhesion | 3 mm including enclosure wall [a] | Not permitted | Not permitted |
| | Non-metallic or metal enclosure without adhesion | 3 mm without enclosure wall | Not permitted | Not permitted |
| "ib" | Free space or free surface | 1 mm | 3 mm | Not permitted |
| | Non-metallic or metal enclosure with adhesion | 1 mm including enclosure wall [a] | 3 mm including enclosure wall [a] | Not permitted |
| | Non-metallic or metal enclosure without adhesion | 1 mm without enclosure wall | 3 mm | Not permitted |
| "ic" | Free space or free surface | 1 mm | 3 mm | Not permitted |
| | Non-metallic or metal enclosure with adhesion | 1 mm including enclosure wall [b] | 3 mm including enclosure wall [b] | Not permitted |
| | Non-metallic or metal enclosure without adhesion | 1 mm | 3 mm | Not permitted |

[a] Provided that the wall thickness of the enclosure ≥ 1 mm the compound only needs to be thick enough to retain adhesion.

[b] There is no minimum wall thickness requirement for Level of Protection "ic".

The thickness of the materials quoted in this table does not imply compliance with other mechanical tests required by IEC 60079-0.

**Table 12 – Minimum thickness of compound adjacent to individual free space for Group III**

| Level of Protection | Minimum thickness of compound adjacent to free space to: | Free space ≤ 1 $cm^3$ | Free space > 1 $cm^3$ ≤ 100 $cm^3$ | Free space > 100 $cm^3$ |
|---|---|---|---|---|
| "ia" | Free space or free surface | 3 mm | 3 mm | Not permitted |
| | Non-metallic or metal enclosure with adhesion | 3 mm including enclosure wall [a] | 3 mm including enclosure wall [a] | Not permitted |
| | Non-metallic or metal enclosure without adhesion | 3 mm | 3 mm | Not permitted |
| "ib" | Free space or free surface | 1 mm | 3 mm | Not permitted |
| | Non-metallic or metal enclosure with adhesion | 1 mm including enclosure [a] | 3 mm including enclosure wall [a] | Not permitted |
| | Non-metallic or metal enclosure without adhesion | 1 mm | 3 mm | Not permitted |
| "ic" | Free space or free surface | 1 mm | 1 mm | Not permitted |
| | Non-metallic or metal enclosure with adhesion | 1 mm including enclosure wall [b] | 1 mm including enclosure wall [b] | Not permitted |
| | Non-metallic or metal enclosure without adhesion | 1 mm | 1 mm | Not permitted |

[a] Provided that the wall thickness of the enclosure ≥ 1 mm the compound only needs to be thick enough to retain adhesion.

[b] There is no minimum wall thickness requirement for Level of Protection "ic".

The thickness of the materials quoted in this table does not imply compliance with other mechanical tests required by IEC 60079-0.

### 6.7 Specification of coating, encapsulation materials

The documents according to the documentation clause in IEC 60079-0 shall specify the materials used for conformal coating and encapsulation when applied to achieve intrinsic safety. This shall include the following material parameters:

a) the COT;

b) if applicable, the CTI value;

c) for coating materials when applying Table 8 or Table 9: their coating classification as type 1 or type 2 protection;

d) for coating materials: if applicable, the required surface treatments, such as cleaning, temperature conditioning, etc.;

e) for materials used for encapsulation where applicable to obtain correct adhesion of the compound to a component: any requirement for pre-treating of the component, for example cleaning, etching.

When the material is relied upon for compliance with type testing then the following shall also be controlled:

1) the name or registered trademark of the coating material manufacturer;

2) the identification of the material, including its type designation and colour.

The source of the data for material characteristics shall be identified.

NOTE 1 Variations in type and percentage of fillers, flame retardants, ultra-violet light stabilizers, and the like can have a significant effect on the properties of the material.

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

### 6.8 Protection against polarity reversal

Protection shall be provided within intrinsically safe apparatus to prevent invalidation of intrinsic safety as a result of reversal of the polarity, where this could occur, of:

– supplies to that intrinsically safe apparatus; or

– at connections between cells of a battery or supercapacitor.

For this purpose, a single diode rated in accordance with 7.1 shall be acceptable.

### 6.9 Dielectric strength requirement

Where it is required to maintain intrinsic safety, the insulation between an intrinsically safe circuit and the frame of the apparatus or parts which may be earthed shall be capable of complying with the test described in 9.6 at a test voltage of at least twice the voltage of the intrinsically safe circuit or 500 V $AC_{RMS}$, whichever is the greater. Where the circuit does not satisfy this requirement, 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 necessary information regarding the correct installation.

The insulation between an intrinsically safe circuit and a non-intrinsically safe circuit that it is galvanically isolated from shall be capable of withstanding a test voltage of at least $2\ U$ + 1 000 V, with a minimum of 1 500 V $AC_{RMS}$, where $U$ is the voltage applicable according to 6.5.5.

Where breakdown between separate intrinsically safe circuits could produce an unsafe condition, the insulation between these circuits shall be capable of withstanding a test voltage of at least $2\ U$, with a minimum of 500 V $AC_{RMS}$, where $U$ is the voltage applicable according to 6.5.5.

Compliance with this requirement may be demonstrated by a component or material manufacturer's specification.

## 7 Characteristics and failure of components and assemblies

### 7.1 Rating of components on which intrinsic safety depends

For Levels of Protection "ia" and "ib", under the conditions specified in 5.2.2 and 5.2.3, components on which intrinsic safety depends shall not operate at more than two-thirds of their manufacturer's maximum current, voltage and power rating, as applicable unless otherwise permitted by this document.

For Level of Protection "ic", unless otherwise stated in this document, under the conditions specified in 5.2.4, components on which intrinsic safety depends shall not operate at more than their manufacturer's maximum current and voltage rating and, for power rating:

a) at the manufacturer's maximum power rating with the application of non-countable faults; and
b) at no more than two thirds of their power rating under normal operation.

For all Levels of Protection 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 need not be performed where parameters are supplied by the manufacturer of the component since the factors of safety of 5.2 obviate the need for testing or analysis.

EXAMPLE 1 The safety factor is applicable to the power rating of a Zener diode, but not to the Zener voltage as the Zener diode limits its own voltage, but cannot limit its own power.

EXAMPLE 2 For a PCB mounted semiconductor, the maximum permitted power dissipation is two-thirds of the power required to reach the maximum permitted junction temperature, taking into account the specific mounting and environmental conditions of the semiconductor.

EXAMPLE 3 A Zener diode stated by its manufacturer to be 10 V + 10 % is 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 Failure of components

For Levels of Protection "ia" and "ib", where a component is rated in accordance with 7.1, its failure shall be a countable fault unless the component is considered to be infallible against that failure mode. The failure of a component that is not rated according to 7.1 shall be a non-countable fault unless otherwise stated in this document.

For Level of Protection "ic", if, under the conditions specified in 5.2.4, a component does not operate within its manufacturer's rating, then its failure to short or open circuit shall be a non-countable fault unless otherwise stated in this document. For all other conditions and failure modes, the failure of components need not be considered.

### 7.3 Manufacturing variation

For Levels of Protection "ia" and "ib" and for spark ignition assessment for Level of Protection "ic", in the assessment of the application of the conditions of 5.2, the most onerous values resulting from the manufacturing process shall be taken into account. These might be different in each case considered.

For components, the tolerance on values may be those specified by the manufacturer of the component. Alternatively, the manufacturer of the equipment may specify absolute maxima or minima (as applicable) which are assured by the manufacturing process.

EXAMPLE 1 For the purposes of assessment, the manufacturer uses an absolute minimum value of resistance for a resistor on which intrinsic safety depends. Then in production there can be variation in the nominal value of resistor used without further assessment provided that the nominal value less the tolerance is at least the absolute minimum used for the assessment.

EXAMPLE 2 Components are selected in production based on routine measurement of their value.

For Level of Protection "ic", thermal ignition compliance may be assessed using a representative sample of the equipment, which is considered to be worst-case in practice, without having to take into account the worst-case tolerance of every component.

## 7.4 Resistors

### 7.4.1 General

For Levels of Protection "ia" and "ib", if not complying with 7.4.2 the failure of resistors to open circuit, short circuit and any value of resistance between open circuit and short circuit shall be considered a non-countable fault.

For Level of Protection "ic", resistors that do not conform to 7.4.2 shall be considered to fail as specified in 7.2.

### 7.4.2 Resistors on which intrinsic safety depends

Resistors rated in accordance with the requirements of 7.1 and complying with the following shall be considered as capable of failing according to Table 13.

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; or

c) printed resistors as used in hybrid and similar circuits covered by a coating conforming to 6.5.6.5 or encapsulated in accordance with 6.6.

**Table 13 – Rating and failure modes of resistors**

| Level of Protection | Safety factor applied to the rating [a] | | | Failure mode | | | Normal operation value |
|---|---|---|---|---|---|---|---|
| | $U$ [b] | $I$ [c] | $P$ | Open circuit | Short circuit | < (R – Tol) or > (R + Tol) | |
| "ia" and "ib" | 1,5 | 1,5 | 1,5 | Countable fault | Not applied | Not applied | R ± Tol |
| "ic" | 1,0 | 1,0 | 1,5 [d]<br>1,0 [d] | Not applied | Not applied | Not applied | R ± Tol |

[a] Safety factor of 1,0 on rating for thermal ignition compliance in accordance with 5.4.

[b] The voltage rating shall be the specified constant value for the resistor series and not the reduced voltage due to the resistance.

[c] Current rating is not normally specified but may exist for low resistance value resistors.

[d] Refer to 7.1.

The external connections of a resistor shall conform to 6.5.1 except where a resistor only ensures its own thermal ignition compliance. Separation requirements shall not be applied to the interior of a resistor. Faults between turns of a correctly rated wire wound resistor with windings coated by the resistor manufacturer need not be taken into account. The insulating surface of a resistor shall be assumed to comply with the required CTI value in column 7 of Table 7 or footnote d) in Table 8 at the voltage rating defined by the resistor manufacturer. When applying Table 9 the insulating surface of a resistor shall be assumed to have material group IIIa if not specified otherwise by the manufacturer of the resistor.

Where a resistor and capacitor or supercapacitor are connected in series to limit the charge or discharge of the capacitor or supercapacitor, the power rating of the resistor shall be based on the lesser of the power calculated using the voltage across the capacitance (as if the capacitor were a battery), or a total available power in watts equivalent to $CU^2$ where $C$ is the maximum capacitance and $U$ is the maximum voltage.

Other than for the power rating of series resistors during the charge or discharge of capacitors or supercapacitors, resistors meeting the requirements of 7.4.2 shall be considered to be capable of withstanding any transient to be expected.

The internal resistance of a battery or supercapacitor may be used for limitation in the assessment of intrinsic safety, in which case its minimum resistance value shall be specified by the cell manufacturer or determined according to 9.14.5.

The resistance of:

– a fuse;
– the filament of a bulb in handlights or caplights; or
– infra-red sources in gas detectors

may be used for limitation provided that these components are used within their normal operating rating. The resistance shall be the cold resistance at the minimum service temperature, determined either in accordance with 9.8 or as specified by the manufacturer of the component.

NOTE The bulb might need to be protected by a Type of Protection other than intrinsic safety.

### 7.5 Capacitors

#### 7.5.1 General

For Levels of Protection "ia" and "ib", if not complying with 7.5.2, 7.5.3 or 7.5.4 the failure of capacitors to open circuit, short circuit and any value less than the maximum specified capacitance shall be considered a non-countable fault. The capacitance is not considered to increase from the maximum rated value.

For Level of Protection "ic", capacitors that do not conform to 7.5.2 shall be considered to fail as specified in 7.2.

Capacitors shall be considered as energy storing components.

Self-heating of capacitors need not be considered.

NOTE Requirements for supercapacitors are addressed in 7.15.

#### 7.5.2 Capacitors on which intrinsic safety depends

Capacitors rated in accordance with the requirements of 7.1 and complying with the following shall be considered as capable of failing according to Table 14.

**Table 14 – Rating and failure modes of capacitors**

| Level of Protection | Safety factor applied to the rating | | | Failure mode | | | Normal operation value |
|---|---|---|---|---|---|---|---|
| | *U* | *I* | *P* | Open circuit | Short circuit | C < ($C_{nom}$ – Tol) | |
| "ia" and "ib" | 1,5 | N/A | N/A | Countable fault | Countable fault [a] | Countable fault | $C_{nom}$ ± Tol |
| "ic" | 1,0 | N/A | N/A | Not applied | Not applied | Not applied | $C_{nom}$ ± Tol |

[a] Capacitors with internal and external separations complying with 6.5.4.2 shall not be considered to fail to short circuit.

External connections of capacitors shall conform to 6.5.1. Where the failure of the capacitor to short circuit is a countable fault, and for Level of Protection "ic", the separation requirements shall not be applied to the interior of capacitors.

Where capacitors are located between circuits requiring galvanic isolation for intrinsic safety the insulation of each capacitor shall comply with the dielectric strength requirements of 6.9 applied between its electrodes and also between each electrode and external conductive parts of the capacitor.

### 7.5.3 Blocking capacitors

Electrolytic capacitors, including tantalum, shall not be used where intrinsic safety depends on the blocking of DC current.

The effect of capacitive coupling shall be considered. Current caused by the highest nominal operating frequency in that part of the circuit (as specified by the manufacturer) shall be taken into account. Transient energy from a non-intrinsically safe circuit to an intrinsically safe circuit (for example as a result of the application of the peak of $U_m$) shall be in accordance with the permissible ignition energy of 9.11.

For Level of Protection "ia", DC blocking may be achieved with two series capacitors provided that the capacitors:

– conform to 7.5.2;
– are of a solid dielectric type; and
– each comply with the dielectric strength requirement of 6.9.

Either of the two capacitors shall be considered as being capable of failing to short or open circuit as a countable fault. However, a second countable fault shall not be applied to the capacitor assembly if the total distance across the assembly complies with 6.5.4.2 and the distance across each capacitor is at least half the value required for an infallible separation.

NOTE Only one capacitor is required where its internal and external separations meet 6.5.4.2.

### 7.5.4 Infallible filter capacitors

Capacitors connected between the frame of the apparatus and an intrinsically safe circuit shall conform to 6.9. Where their failure to short circuit would bypass a component on which the intrinsic safety of the circuit depends, they shall also either:

a) maintain infallible separation requirements of 6.5.4.2 both externally and internally; or
b) conform to the requirements for blocking capacitors in 7.5.3.

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

## 7.6 Inductors and windings

### 7.6.1 General

Inductors and windings shall conform to 7.6 except for the windings of transformers described in 7.8.

NOTE Values for $R$ or $L/R$ for transformer windings can be determined using 7.6. Transformer windings might benefit from an assessment described in 7.6.3.

For Levels of Protection "ia" and "ib", if not complying with 7.6.2, 7.6.3, 7.6.4 or 7.6.5.2 the failure of inductors to any value of resistance between open circuit and short circuit shall be considered a non-countable fault in accordance with 7.2. Only inductance to resistance ratios less than or equal to that derived from the inductor specifications shall be considered. The inductance is not considered to increase from its maximum rated value.

The inductance of a common mode choke shall be assessed according to 7.6.5.

For Level of Protection "ic", inductors that do not conform to 7.6.2 or 7.6.4 shall be considered to fail as specified in 7.2.

Inductors shall be considered as energy storing components.

NOTE For the purpose of 7.6 windings are considered to be inductors.

### 7.6.2 Inductors on which intrinsic safety depends

Inductors rated in accordance with the requirements of 7.1 and complying with the following shall be considered as capable of failing according to Table 15.

**Table 15 – Rating and failure modes of inductors**

| Level of Protection | Safety factor applied to the rating | | | Failure mode | | | | | Normal operation value |
|---|---|---|---|---|---|---|---|---|---|
| | $U$ | $I$ | $P$ | Open circuit | Short circuit | R < ($R_{nom}$ – Tol) | L < ($L_{nom}$ – Tol) | L/R > max | |
| "ia" and "ib" | N/A | 1,5 | N/A | Countable fault | Countable fault [a] | Countable fault [a] | Countable fault | Not applied | $L_{nom}$ ± Tol<br>$R_{nom}$ ± Tol |
| "ic" | N/A | 1,0 | N/A | Not applied | Not applied | Not applied | Not applied | Not applied | $L_{nom}$ ± Tol<br>$R_{nom}$ ± Tol |

[a] Inductors complying with 7.6.3 are not considered to fail to a lower resistance than their rated value.

The external connections of inductors shall conform to 6.5.1 but the separation requirements shall not be applied to the interior of the inductor.

### 7.6.3 Infallibly insulated inductors

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

a) the inductor shall conform to 7.6.2;

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

c) 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 either:
   1) Grade 1 enamelled round wire that complies with the minimum dielectric breakdown requirements for grade 2 according to IEC 60317-0-1, and has no more than 6 faults per 30 m of wire irrespective of diameter when tested according to the continuity of insulation test of IEC 60851-5; or
   2) Grade 2 enamelled round wire according to IEC 60317-0-1.

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

d) windings shall be consolidated with a suitable substance for example by dipping, trickling or vacuum impregnation, taking into account the following:
   1) consolidation shall take place after any fastening or wrapping, and after drying to remove moisture;
   2) the consolidation shall be carried out in compliance with the specific instructions of the manufacturer of the relevant type of consolidating substance;
   3) the consolidation shall ensure that the spaces between the conductors are filled as completely as possible and that good cohesion between the conductors is achieved;
   4) if consolidating substances containing solvents are used, the consolidation and drying process shall be carried out at least twice; and
   5) coating by painting or spraying shall not be considered as consolidation.

#### 7.6.4 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.

#### 7.6.5 Common mode choke coils (EMI suppression filters)

##### 7.6.5.1 General

If the recoverable energy stored within a common mode choke, in addition to transient energies provided by the circuit, does not exceed the energy limits specified in Table D.1 when tested according to 9.15, then the common mode choke is considered to have an inductance corresponding to the leakage inductance. If the above is not satisfied, then the following shall apply:

a) For Levels of Protection "ia" or "ib" if the common mode choke does not comply with 7.6.5.2, the inductance of the common mode choke shall be that of one winding with the other open circuit.
b) For Level of Protection "ic", where the return path can only be through the choke, common mode chokes are considered to have an inductance corresponding to the leakage inductance. Otherwise, the inductance shall be that of one winding with the other open circuit.

NOTE Common mode chokes are usually operated in differential mode to reduce electromagnetic interference.

##### 7.6.5.2 Infallible common mode chokes

Common mode chokes for Level of Protection "ia" and "ib" may be considered to have an inductance value equal to the leakage inductance if they are in compliance with the following:

a) the inductors shall be rated in accordance with the requirements of 7.6.2; and
b) the current return path shall only be through the common mode choke; and
c) either:

1) they shall comply with the requirements of 7.6.3; and
2) they shall meet the dielectric strength requirements in accordance with 6.9; and
3) the separation between the inputs and the outputs shall comply with 6.5.4.2 but the separation requirements shall not be applied to the interior;

or:

4) the construction shall ensure the windings and their connections are separated according 6.5.4.2.

### 7.7 Semiconductors

#### 7.7.1 Failure of semiconductors

Analysis of integrated circuits based on failure rates of particular failure modes other than stated is not permitted by this document.

Software may be used during the manufacture and test of apparatus.

EXAMPLE Analysis according to IEC 61508 is not sufficient to demonstrate intrinsic safety.

For Levels of Protection "ia" or "ib", semiconductors shall be considered to fail as follows:

a) if not complying with 7.7.2 and 7.7.3 the failure to open circuit or short circuit shall be considered a non-countable fault.
b) Integrated circuits shall be considered to 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.
c) 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 flash memory), 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 such as capacitors or inductors are used for the conversion. If the enhanced voltage is available at any external pin of an integrated circuit under normal operating conditions, then the enhanced voltage shall only be considered to be present on that pin and any pins of the same package that are not internally connected to the integrated circuit (for example, not connected pins).

   NOTE It is not a requirement of this document that the manufacturer's specification for the semiconductor needs to be verified.
d) For thermal ignition assessment for Levels of Protection "ia" and "ib", the semiconductor shall be considered to fail as a non-countable fault to a state where it dissipates the maximum power available at its place of installation under the conditions specified in 5.2, unless one of the following is applied:
   1) Diodes (including LEDs and Zener diodes) operated within the requirements of 7.7.2 shall only be considered for the power they can dissipate in the forward conducting mode, or Zener mode, if applicable.
   2) Controlled semiconductors of low complexity, such as transistors, thyristors and triacs operating within the requirements of 7.7.2 shall be considered to fail to short or open circuit. Additionally, thermal ignition assessment of the controlled semiconductor shall include its operation without failing in any intended conducting or triggered state as well as in any state to which it can be driven by the failure of other components in the circuit in which it is installed. For example, a fault in the circuit driving the gate of a field-effect transistor might cause heating due to a high on resistance.

For Level of Protection "ic", semiconductors that do not comply with 7.7.2 shall be considered to fail as specified in 7.2.

### 7.7.2 Semiconductors on which intrinsic safety depends

Semiconductors rated in accordance with the requirements of 7.1 and complying with the following shall be considered as capable of failing according to Table 16.

**Table 16 – Rating and failure modes of semiconductors**

| Level of Protection | Safety factor applied to the rating | | | Failure mode | | |
|---|---|---|---|---|---|---|
| | U [b] | I [b] | P [b] | Open circuit | Short circuit | Other faults [a] |
| "ia" and "ib" | 1,5 | 1,5 | 1,5 | Countable fault | Countable fault | Countable fault |
| "ic" | 1,0 | 1,0 | 1,5 [c]<br>1,0 [c] | Not applied | Not applied | Not applied |

[a] Faults according to 7.7.1.

[b] Safety factor is not applicable to the rating of semiconductors, including integrated circuits, that provide internal limitation corresponding to that parameter, for example the conducting voltage rating of diodes and current rating of current limit integrated circuits.

[c] Refer to 7.1.

The external connections of a semiconductor shall comply with 6.5.1, as applicable, but the separation requirements shall not be applied to the interior of a sealed semiconductor.

### 7.7.3 Transient effects on semiconductors on which intrinsic safety depends

Semiconductors on which intrinsic safety depends that are protected by a fuse or controlled semiconductor current limitation shall be rated with a safety factor of 1,0 for the maximum transient current pulse that results during switching of the limitation (such as opening of the fuse or response time of the controlled semiconductor limitation). This shall be demonstrated in accordance with 9.16.

Semiconductors on which intrinsic safety depends that are protected by controlled semiconductor voltage limitation (such as a crowbar) shall be rated, with a safety factor of 1,0, for the maximum voltage to which they are subjected during switching of the limitation. A suitably protected single transient limiting shunt device such as a Zener diode may be used to reduce the maximum voltage during this transient.

Any other transients, including overvoltage transients on $U_m$ and $U_i$, do not need to be considered for the transient rating of semiconductors.

EXAMPLE Transients generated by switched mode supplies do not need to be considered when rating semiconductors.

For Level of Protection "ic", the above requirements only apply to diode safety barriers.

### 7.7.4 Semiconductors in shunt voltage limiters

Semiconductors may be used as shunt voltage limiting devices provided that they conform to 7.7.2 and 7.7.3 with the applicable safety factor for the following:

a) for diodes, diode connected transistors, thyristors and equivalent semiconductor devices: a forward current rating greater than or equal to the short circuit current that would flow at their place of installation; and

b) for Zener diodes:

   1) rated for the power that would be dissipated in the Zener mode, and

   2) having a forward current rating greater than or equal to the short circuit current that would flow at their place of installation.

NOTE The maximum current in the forward direction is necessary to ensure the overall construction of the Zener diode is adequate to carry any fault current.

Shunt limiting devices may conduct in normal operation.

#### 7.7.5 Shunt assembly on which intrinsic safety depends

A circuit or assembly of components including a controlled shunt semiconductor may be used for shunt limitation provided that the following requirements are met:

a) all components shall be rated in accordance with 7.7.2, 7.7.3, and 7.7.4;

b) where there are multiple independent shunt paths, the voltage of the assembly shall be that of the highest voltage shunt path; and

c) where a shunt assembly which does not provide galvanic isolation is manufactured as an individual apparatus rather than as part of a larger apparatus, the construction of the assembly shall be in accordance with 8.1.2.

NOTE When a shunt component is used to prevent spark ignition of a component, for example, an inductor, encapsulation in accordance with 6.6.2 may be required.

#### 7.7.6 Safety assemblies infallible against failure to limit voltage

The following shunt assembly constructions shall be considered infallible for Level of Protection "ia" against failure to limit the output voltage where they comply with 7.7.5:

a) two parallel paths of diodes or Zener diodes or diode chains; the failure of only a single diode or Zener diode to either open circuit or short circuit shall be considered a single countable fault;

b) an assembly of bridge connected diodes;

c) two independent controlled semiconductor voltage limitation circuits if both the input and output circuits are intrinsically safe circuits or where it can be shown that they cannot be subjected to any transient voltage; or

d) for associated apparatus, three independent controlled semiconductor voltage limitation circuits where these can be subjected to transient voltage.

#### 7.7.7 Semiconductor current limiters

Controlled and non-controlled semiconductors may be used for the purposes of blocking or limiting current provided that they comply with 7.7.2 and 7.7.3.

#### 7.7.8 Use of programmable components

Programmable components considered in this clause are microcontrollers, microprocessors, programmable logic and components providing volatile and non-volatile memory as their main function. Higher integrated components containing microcontrollers, microprocessors or programmable logic as sub-function are considered as programmable components as well.

NOTE Microcontrollers and microprocessors are intended to run software code while programmable logic components can be configured by a hardware description language.

For all Levels of Protection for the determination of service temperatures, it shall be assumed that programmable components operate normally.

For Levels of Protection "ia" and "ib", the failure of a programmable component shall be a non-countable fault.

For Level of Protection "ic", programmable components:

a) may be relied upon to set levels for hardware control of circuits (for example for control of voltage, current, temperature) where intrinsic safety depends on the controlled level;

b) may form part of the control loop for control of circuits for the purposes of thermal ignition compliance and rating of components;

c) shall not be relied upon to respond to changes in conditions that present a spark ignition risk.

EXAMPLES For Level of Protection "ic",

– where a crowbar is relied upon for spark ignition compliance, programmable components can be used to control the threshold of a hardware trigger for the crowbar, but programmable components cannot be used to trigger the crowbar;

– programmable components cannot be used within the control loop of a voltage regulator that defined $U_o$ if this is relied upon to prevent an ignition capable spark, but programmable components may be used to set the set-point of the voltage regulator;

– programmable components cannot be used within the control loop of an output that limits $I_o$ if this is relied upon to keep $I_o$ within short circuit spark ignition limits, but programmable components may be used to set the set-point of the current regulator.

## 7.8 Transformers

### 7.8.1 General

The combination of faults within a transformer which would result in an increased output voltage or current shall not be considered.

Transformers shall be considered as energy storing components.

Transformers which do not comply with 7.8.2 shall be assessed as follows:

a) short circuit of the galvanic isolation between windings of a transformer shall be considered a non-countable fault.

b) For Levels of Protection "ia" and "ib", the failure of windings to any value of resistance between open circuit and short circuit shall be considered a non-countable fault except where the winding complies with 7.6.2 or 7.6.3.

c) For Level of Protection "ic", short circuits within windings and open circuits of windings shall be considered to occur, except where the transformer is constructed in accordance with the relevant industrial standard for the equipment type.

### 7.8.2 Transformers on which intrinsic safety depends

For Levels of Protection "ia" and "ib", transformers used within their normal rating and meeting the requirements of 7.8.3 and 7.8.4 as applicable, shall be considered as providing infallible galvanic isolation between applicable windings.

For Levels of Protection "ia" and "ib" transformers on which intrinsic safety depends shall be type tested according to 9.17.2 or 9.17.3 as applicable.

For Level of Protection "ic", transformers rated for the normal operating voltage, current and power in the circuit, and meeting the requirements of 7.8.5 as applicable, shall be considered as providing infallible galvanic isolation between applicable windings.

Transformers on which intrinsic safety depends shall be routine tested in accordance with 10.3.

### 7.8.3 Construction of transformers on which intrinsic safety depends

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

NOTE 1 Use of impregnation to consolidate the windings might not meet the requirements for separation.

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:

Type 1a) side by side; or

Type 1b) on different legs of the core.

The windings shall be separated in accordance with Table 7.

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

Type 2a) solid insulation in accordance with Table 7 between the windings; or

Type 2b) a copper foil screen complying with 6.5.9 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 17.

NOTE 2 This ensures that, for Type 2b) 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 17 by more than 10 % or 0,1 mm, whichever is the smaller.

**Table 17 – Minimum foil thickness or minimum wire diameter of the screen**

| **Rating of the fuse** | A | **0,1** | **0,5** | **1** | **2** | **3** | **5** | **10** |
|---|---|---|---|---|---|---|---|---|
| **Maximum current** | A | **0,17** | **0,85** | **1,7** | **3,4** | **5,1** | **8,5** | **17** |
| **Minimum thickness of the foil screen** | mm | 0,05 | 0,05 | 0,075 | 0,15 | 0,25 | 0,3 | 0,5 |
| **Minimum diameter of the wire of the screen** | mm | 0,2 | 0,45 | 0,63 | 0,9 | 1,12 | 1,4 | 1,8 |

The foil screen shall be provided with two mechanically separate leads to a reference potential, for example earth or the negative terminal of a battery, each of which is rated to carry the maximum continuous current which could flow.

EXAMPLE Examples of maximum continuous current are the current before a circuit-breaker operates, or 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 a connection rated to carry the maximum continuous current which could flow. The only requirement of the insulation between the layers is that it shall be capable of withstanding a 500 $V_{RMS}$ test to all adjacent layers in accordance with 9.6.

For transformers using ferrite cores, there is no requirement for grounding the core, but the ferrite shall be considered as conductive for separation purposes, unless adequate information is available to demonstrate that the core material is insulating.

### 7.8.4 Protective measures for transformers on which intrinsic safety depends for Levels of Protection "ia" and "ib"

#### 7.8.4.1 Mains transformers

The cores of all mains supply transformers, including all transformers where at least one winding is not galvanically isolated from the mains supply, shall be provided with an earth connection, except where earthing is not required for intrinsic safety, for example when transformers with insulated cores are used.

The input circuit of mains transformers intended for supplying intrinsically safe circuits shall be protected either by a fuse conforming to 7.11 or by a suitably rated circuit-breaker.

If the input and output windings are separated by an earthed metal screen (type 2b construction), 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 device complying with 7.16.2.1 and 7.16.2.3 is used for protection against overheating of the transformer, a single device is considered sufficient.

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

Mains frequency transformers shall be tested according to 9.17.2.1, and other transformers shall be tested according to 9.17.2.2.

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

#### 7.8.4.2 Transformers galvanically isolated from the mains supply

As transformers that are galvanically isolated from the mains supply are not directly connected to mains voltage, the reduced test requirements according to 9.17.3 apply.

NOTE Transformers not directly connected to mains supply are considered connected to secondary circuits with a reduced OVC. These transformers can be coupling transformers such as those used in signal circuits or switched mode power supplies.

When such transformers are connected to non-intrinsically safe circuits derived from mains voltages, then either protective measures in accordance with 7.8.4.1 shall be applied or a single shunt Zener diode protected to a safety factor of 1,0 by a suitably rated fuse according to 7.11 shall be included at the supply connection so that unspecified power shall not impair the infallibility of the galvanic isolation provided by the transformer. The rated input voltage of 9.17.3 shall be that of the Zener diode.

When such transformers are only 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 conditions specified in 5.2.

### 7.8.5 Requirements for transformers for Level of Protection "ic"

For Level of Protection "ic", transformers on which intrinsic safety depends shall have a rated input voltage equivalent to $U_m$ or $U_i$ and shall comply with the applicable safety requirements of the relevant industrial standards providing basic insulation. The requirements of Table 7 or Table 9 as applicable shall apply for the external connections of the transformers but shall not apply to the internal separations between the windings.

For Level of Protection "ic" transformers shall be type tested according to 9.17.4.

## 7.9 Relays

### 7.9.1 General

The coil of a relay shall be considered an energy storage component. Only inductance to resistance ratios less than or equal to that derived from the inductor specifications shall be considered. The inductance is not considered to increase from its maximum rated value.

If not complying with 7.9.2, relays shall be assessed as follows:

- short circuit of the isolation of relays from coil to contact and between contacts shall be a non-countable fault;
- for Levels of Protection "ia" and "ib", the failure of the coil to any value of resistance between open circuit and short circuit shall be considered a non-countable fault;
- for Level of Protection "ic", the failure of the coil to open circuit and short circuit shall be considered a non-countable fault.

### 7.9.2 Relays on which intrinsic safety depends

Relays on which intrinsic safety depends shall comply with the dielectric strength requirements of 6.9.

For Levels of Protection "ia" and "ib", relays on which intrinsic safety depends that are operated within their specification under normal operation and that comply with all the following as applicable shall be considered to provide infallible galvanic isolation between the coil and the contacts or between different contacts:

a) Separation between the coil and the contacts shall comply with 6.5.4.2.

b) The coil shall be capable of dissipating the maximum power to which it can be subjected under the conditions specified in 5.2.

c) Where the coil is connected to an intrinsically safe circuit, the contacts in normal operation shall not exceed their manufacturer's rating.

d) Where the nominal contact current is between 5 $A_{RMS}$ and 10 $A_{RMS}$, or the apparent power is between 100 VA and 500 VA or the voltage is greater than 250 V $AC_{RMS}$, one of the following is applied:

   1) the required creepage distance and clearance within the relay shall be doubled, or

   2) when reduced separation distances according to 6.5.3 are used for relays, relays that meet IEC 61810-1 are acceptable provided that:

      - the relay conforms to reinforced insulation according to IEC 61810-1 with a rated insulation voltage of at least the voltage required by 6.5.5,
      - the assessment of the relay according to IEC 61810-1 for the rated insulation voltage is done at least for the same OVC as the relay is used in the context this document,
      - the assessment of the relay according to IEC 61810-1 for the rated insulation voltage is done at least for pollution degree 2, and
      - the contacts in normal operation are used within the ratings of the IEC 61810-1 assessment for this relay.

   The separation requirements and dielectric strength requirements according to this document still apply for such relays, except that a partial discharge test is not required for such relays.

e) For values of current or power higher than specified in d), intrinsically safe circuits and non-intrinsically safe circuits shall be connected to the same relay only if one of the following is applied:

   1) they are separated by a metal partition conforming to 6.5.9 or an insulating partition conforming to 6.5.10. The dimensions of such an insulating partition 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 6.5.4.2, or

   2) when reduced separation distances according to 6.5.3 are used for relays, relays that meet IEC 61810-1 are acceptable, provided that:

      - the relay conforms to reinforced insulation according to IEC 61810-1 with a rated insulation voltage of at least the voltage required by 6.5.5,
      - the assessment of the relay according to IEC 61810-1 for the rated insulation voltage is done at least for the same OVC as the relay is used in the context this document,

– the assessment of the relay according to IEC 61810-1 for the rated insulation voltage is done at least for pollution degree 3, and

NOTE Although the relay is used in pollution degree 2, the inner distances of the relay are rated for pollution degree 3, to take into account the ionization arising from operation of the relay.

– the contacts in normal operation are used within the ratings of the IEC 61810-1 assessment for this relay.

The separation requirements and dielectric strength requirements according to this document still apply for such relays, except that a partial discharge test is not required for such relays.

f) 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 partition conforming to 6.5.10 or a metal partition conforming to 6.5.9 in addition to Table 7. 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.

g) If the insulating or earthed metal partition is embedded in a closed relay enclosure then 9.4.3 shall be applied to the closed relay enclosure and not to the insulating or earthed metal partition itself.

For Level of Protection "ic" where the relay is constructed in accordance with the relevant industrial standard for the apparatus, other than dielectric and separation distances, no additional enhanced constructional requirements are required.

### 7.10 Signal isolators

#### 7.10.1 General

The requirements of 7.10 apply to signal isolators using optical, magnetic, capacitive coupling and galvanically separating components, other than transformers (See 7.8), relays (See 7.9), or single capacitors (See 7.5).

For Levels of Protection "ia" and "ib", if not complying with 7.10.2 and either 7.10.3 or 7.10.4 the failure of signal isolators to a short circuit across the galvanic isolation and to any resistance value shall be considered a non-countable fault.

For Level of Protection "ic", signal isolators that do not comply with 7.10.2 and either 7.10.3 or 7.10.4 shall be considered to fail as specified in 7.2, including across their galvanic isolation.

The requirements of IEC 60079-28 need not be applied to self-contained optical isolators for compliance with this document.

#### 7.10.2 Signal isolators on which intrinsic safety depends

Signal isolators rated in accordance with the requirements of 7.1 and complying with the following shall be considered as capable of failing according to Table 18.

**Table 18 – Rating and failure modes of signal isolators**

| Level of Protection | Safety factor applied to the rating | | | Failure mode | |
|---|---|---|---|---|---|
| | U | I | P | Short circuit across the galvanic isolation | Other faults |
| "ia" and "ib" | 1,0 | 1,0 | 1,0 | Countable fault [a] | Countable fault |
| "ic" | 1,0 | 1,0 | 1,0 | Not applied | Not applied |

[a] Signal isolators complying with 7.10.3 or 7.10.4 shall not be considered to fail to short circuit across the isolation.

Where external protective components are required to fulfil the rating of the signal isolator, countable faults shall not be applied to the protective components and the rating of the protective component shall have a safety factor of 1,0. For example, a single shunt Zener diode protected to a safety factor of 1,0 by a suitably rated fuse according to 7.11 shall be considered as sufficient protection. Separations according to general industrial standards shall be applied for such components (see Figure 3).

The external connections across the isolation of a signal isolator shall comply with 6.5.1 but the separation requirements shall not be applied to the interior of encapsulated or sealed signal isolators except where required by 7.10.3.

Signal isolators shall comply with the dielectric strength requirements in accordance with 6.9 across the galvanic isolation. The manufacturer's insulation voltage rating for the infallible separation of the component shall be not less than the test voltage required by 6.9.

Non-optical signal isolators, and optical isolators with intentional power transfer, shall comply with a differential leakage current transfer limit of 50 µA, under the most onerous conditions of data rate for the application under consideration, either as measured by 9.9 or obtained from the manufacturer of the signal isolator. Current transfer of the signal isolator need not be considered for the assessment of the equipment.

NOTE Optical signal isolators are excluded from evaluation of transferred current based on the assumption that the energy transferred optically with known architectures is not capable of violating the current transfer limit.

#### 7.10.3 Signal isolators between intrinsically safe and non-intrinsically safe circuits

Signal isolators are considered to provide infallible separation between intrinsically safe and non-intrinsically safe circuits if complying with one or more of the following:

a) Optical signal isolators that meet the construction, material and test requirements for reinforced insulation according to IEC 60747-5-5 with an insulation rating of at least the voltage required by 6.5.5. The signal isolator shall additionally comply with 7.10.2.
b) Non optical signal isolators that meet the construction, material and test requirements for reinforced insulation according to DIN VDE V 0884-11 or IEC 60747-17 with an insulation rating of at least the voltage required by 6.5.5 of this document. The signal isolator shall additionally comply with 7.10.2.
c) Signal isolators that comply with 7.10.2, and in addition comply with the separation requirements of 6.5.4.2 applied to the interior of the device except that inside sealed devices columns 5, 6 and 7 of Table 7, or columns 3 and 4 of Table 8 and Table 9 shall not apply.
d) Optical signal isolators that comply with the requirements of 6.9 across the galvanic isolation and for Levels of Protection "ia" and "ib" the tests of 9.10. The rating of the optical signal isolator need not comply with 7.1 or 7.10.2, except that the separation requirements of 6.5.4.2 shall be applied to the external connections across the isolation and to the interior of the optical signal isolator. Inside sealed devices columns 5, 6, and 7 of Table 7, or columns 3, 4 and 5 of Table 8, and columns 3 and 4 of Table 9 shall not apply.

NOTE It is not a requirement of this document that the conformity of the signal isolator manufacturer's specification needs to be verified against IEC 60747-5-5, DIN VDE V 0884-11 or IEC 60747-17.

#### 7.10.4 Signal isolators between separate intrinsically safe circuits

Signal isolators shall be considered to provide infallible separation of separate intrinsically safe circuits if complying with 7.10.2, or 7.10.3 d). Protective techniques (such as those indicated in 7.10.2) may be necessary to avoid exceeding the rating of the isolating component.

### 7.11 Fuses

Where intrinsic safety depends on the opening of a fuse, for the purposes of assessment the fuse shall be considered capable of carrying a current of 1,7 $I_n$ continuously. A single suitably rated fuse is sufficient to provide protection.

For intrinsically safe apparatus of Levels of Protection "ia" and "ib", fuses which can carry current when located in explosive atmospheres shall be encapsulated in accordance with 6.6.

For Level of Protection "ic", the opening of a fuse shall only be considered an ignition risk where such opening is an expected occurrence, for example where shorting or overloading at the connection facilities would cause the fuse to open.

Where fuses are encapsulated or coated, the compound or coating shall not enter the fuse interior. This shall be demonstrated by one of the following:

a) testing samples in accordance with 9.4.2;

b) a declaration from the fuse manufacturer confirming acceptability of the fuse for encapsulation or coating; or

c) the sealing of the fuse prior to encapsulation or coating.

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 voltage rating of at least the maximum voltage that they might be subjected to under the conditions specified in 5.2 while open circuit, although they do not need to conform to 6.5.4.2. General industrial standards for the construction of fuses and fuse holders shall be applied and their method of mounting including the connecting wiring shall not reduce the clearances, creepage distances and other separations afforded by the fuse and its holder. Where required for intrinsic safety, the distances to other parts of the circuit shall comply with 6.5.1.

For Levels of Protection "ia" and "ib", the opening of fuses shall be considered and is not a countable fault.

A fuse shall have a breaking capacity (AC or DC as applicable) not less than the maximum prospective current of the circuit in which it is installed. For mains electricity supply systems not exceeding 250 V $AC_{RMS}$, the prospective current shall normally be considered to be 1 500 A AC. The breaking capacity of the fuse is determined according to the IEC 60127 series or ANSI/UL 248 series and shall be stated by the manufacturer of the fuses. The cold resistance shall not be used for the purpose of complying with the breaking capacity of the fuse.

NOTE This does not exclude the use of the cold resistance to limit current in the rest of the circuit or to protect other components. See 7.4.2.

For connection facilities with a specified $U_m$ the breaking capacity of the fuse may be below 1 500 A. In this case the manufacturer shall specify the maximum prospective current allowed for the circuit in their instructions.

If a current-limiting component or device is necessary to limit the prospective current to a value not greater than the rated breaking capacity of the fuse, this component or device shall be a component on which intrinsic safety depends, and the rated values shall be at least:

– current rating $1{,}7 \times I_n$, with applicable safety factors applied;

– voltage rating with the application of a 1,0 safety factor, for example $U_m$ or $U_i$; and

– power rating $(1{,}7 \times I_n)^2 \times$ maximum resistance of limiting device with applicable safety factors applied.

Separation across the resistor shall be determined using the voltage of $1{,}7 \times I_n \times$ maximum resistance of the resistor.

### 7.12 Primary and secondary cells and batteries

#### 7.12.1 General

Contrary to the cells and 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 invalidated. For example, 5.3, 5.4.4, 7.12.3, and 9.14.3.3 are considered under the conditions of short circuiting of one or more of the parallel cells or supercapacitors.

NOTE The parallel battery requirement of IEC 60079-0 applies to cells and batteries in associated apparatus that are protected by another Type of Protection listed in IEC 60079-0.

Some types of cells and batteries, for example some lithium types, might explode if short-circuited or subjected to reverse charging. These types of cells shall conform to the applicable safety requirements of the relevant industrial standards, for example, IEC 62133 or UL 1642.

The instructions and, if practicable, the marking for the apparatus shall draw attention to any safety precautions for cells and batteries to be observed by the user.

Where batteries are intended to be replaced by the user (for example where 7.12.7 or 7.12.8 are applicable), the apparatus shall be marked with a warning label as specified in item a) of 11.2.

Where secondary batteries are used but cannot be charged in a hazardous area, the apparatus shall be marked with a warning label as specified in item c) of 11.2.

If the cells or batteries are charged in hazardous areas, the charging circuits shall be fully specified and assessed as part of the assessment of the apparatus. The charging system shall be such that, under the conditions specified in 5.2, the charger voltage and current do not exceed the limits specified by the cell or battery manufacturer.

For intrinsically safe apparatus with cells or batteries for EPL Da, or EPL Db where the cells are charged in hazardous areas, the temperature rise and electrolyte leakage tests of the cells specified in 9.14 shall also be considered under the conditions of charging.

#### 7.12.2 Construction of cells and batteries used in intrinsically safe apparatus

The spark ignition capability and surface temperature of cells and batteries used in intrinsically safe apparatus shall be tested or assessed in accordance with 9.14.3. The cell or battery construction shall be one of the following types:

a) sealed cells;
b) 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 battery container 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 plastic 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 A manufacturer's datasheet specifying compliance with the applicable standards for sealed cells or valve regulated cells is considered a declaration of conformance. It is not a requirement of this document that the conformity of the cell or battery manufacturer's specification needs to be verified.

If a battery comprises several discrete cells or smaller batteries combined in a well-defined construction conforming to the separation and other requirements of this document, then each type of discrete cell or smaller battery shall be subjected to the tests specified in 9.14.3. For batteries constructed with internal separations complying with 6.5.4.2 short circuits between cells need not be considered. However, the failure to short circuit of a single cell shall be considered as a non-countable fault except that the surface temperature test considers only a single cell failing to short circuit.

In less well-defined circumstances, the battery shall be considered to have a short circuit failure between its external terminals.

### 7.12.3 Electrolyte leakage

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 components upon which intrinsic safety depends. Cells and batteries which are not enclosed to prevent damage to the intrinsically safe circuit by the electrolyte shall be tested in accordance with 9.14.2, or written confirmation shall be obtained from the cell/battery manufacturer that the product conforms to 9.14.2. If cells and batteries which leak electrolyte are encapsulated in accordance with 6.6, they shall be tested in accordance with 9.14.2 after encapsulation.

### 7.12.4 Ventilation

Where the intrinsically safe apparatus contains cells or batteries that are charged within them, the manufacturer shall demonstrate that the concentration of hydrogen cannot exceed 2 % by volume in any free volume of the apparatus containing electrical or electronic components or connections. Alternatively, where the apparatus meets the requirements for Levels of Protection "ia" or "ib" and Group IIC, the requirement of degassing apertures or limitation of hydrogen concentration does not apply.

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

Battery containers for primary and secondary valve regulated cells or batteries within intrinsically safe apparatus that are sealed (no visible vents such as holes, leaks or slots) shall be tested in accordance with 9.14.4, and the pressure above atmospheric inside the battery container shall not exceed 30 kPa (0,3 bar).

Sealed cells that clearly do not vent during the tests found in 9.14 and battery containers that enclose such cells do not need to be tested in accordance with 9.14.4.

NOTE 2 Higher pressures might occur in sealed and valve regulated cells. Valve regulated cells limit the pressure to a value that can be contained by the cell, as specified by the manufacturer.

### 7.12.5 Cell voltages

For the purpose of evaluation and test, the cell voltage shall be that specified in the primary cells 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 9.13 to determine the maximum open circuit voltage at a temperature of (23 ± 5) °C and after charging using the method specified by the apparatus manufacturer. The nominal voltage shall be that specified by the cell manufacturer.

#### 7.12.6 Batteries in equipment protected by different Types of Protection

EXAMPLE This subclause can be used for equipment that is protected by a different Type of Protection (for example a flameproof enclosure) but contains a battery and associated circuits that require intrinsic safety protection when the external power supply is removed and the enclosure is opened in the explosive atmosphere.

These requirements supplement those of the other Types of Protection.

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

Where a resistor is used to limit the current that can be supplied by the battery, it shall be rated in accordance with 7.4.2.

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 may be achieved by use of a single Zener diode rated in accordance with 7.7.2.

Current-limiting devices necessary to ensure the safety of the battery are not required to be an integral part of the battery.

#### 7.12.7 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, or suitably protected intrinsically safe terminals for charging purposes, 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 or current-limiting device in such a way as to invalidate the intrinsic safety of the unit.

#### 7.12.8 Replaceable batteries used but not replaced in explosive atmospheres

If the cell or battery requires current-limiting devices to ensure the safety of the battery itself, and is not intended to be replaced in the explosive atmosphere, it shall either be protected in accordance with 7.12.7 or alternatively it may be housed in a compartment that can only be opened with the use of a tool, or an interlocking device according to IEC 60079-0. The apparatus shall also conform to the following:

a) the battery compartment or means of attachment shall be arranged so that the cell or battery can be installed and replaced without invalidating the intrinsic safety of the apparatus;
b) handheld apparatus, 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; and
c) the apparatus shall be marked with a warning label as specified in 11.2 b).

#### 7.12.9 External contacts for charging batteries

External charging contacts of batteries shall meet the requirements according to 6.3.5.

### 7.13 Piezoelectric devices

Other than crystal-oscillators (for example, clock oscillators), piezoelectric devices shall be tested in accordance with 9.11.

For Level of Protection "ic", the test in 9.11 only applies where the piezoelectric circuit can be directly shorted, for example, due to non-compliant spacings or directly connected sparking contacts. The voltage used to determine the separation distances shall be one of the following as applicable:

a) the normal operating voltage of the circuit when the piezoelectric element is not subjected to shock during normal operation; or
b) the maximum voltage generated by the test in 9.11 when the piezoelectric element is subjected to shock in normal operation.

### 7.14 Cells for the detection of gases

#### 7.14.1 Electrochemical

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

#### 7.14.2 Catalytic

Catalytic sensors are only permitted for intrinsically safe apparatus for Groups I, IIA, IIB and III.

The temperature rise due to catalytic reaction heating shall be taken into account for thermal ignition compliance according to 5.4. This may be by application of the small component ignition test given in IEC 60079-0.

### 7.15 Supercapacitors

Supercapacitors are permitted to be connected in parallel in intrinsically safe apparatus provided that intrinsic safety is not invalidated.

The voltage applied to the supercapacitor shall not exceed the limit specified by the manufacturer, even when faults in accordance with 5.2 are applied. The service temperature of the supercapacitors shall not exceed the allowable limits defined by the supercapacitor manufacturer.

When considering the influence of a supercapacitor on the power rating of components on which intrinsic safety depends and on thermal ignition hazards, it may be assumed to have stored energy limited by the specified capacitance.

For Levels of Protection "ia" and "ib":

a) the failure of supercapacitors to short circuit shall be a non-countable fault;
b) where reverse polarity could be applied to the supercapacitors, protection rated in accordance with 7.7.2, shall be provided; and
c) supercapacitors shall be subjected to the electrolyte leakage test of 9.14.2 or meet the construction and performance requirements according to UL 810A. Additionally, supercapacitors shall be subjected to the spark ignition and surface temperature tests found in 9.14.

NOTE It is not a requirement of this document that the conformity of the supercapacitor manufacturer's specification needs to be verified against UL 810A.

For Level of Protection "ic", supercapacitors shall be considered to fail as specified in 7.2.

### 7.16 Thermal devices

#### 7.16.1 General

For Levels of Protection "ia" and "ib", if not complying with 7.16.2 or 7.16.3, the failure of thermal devices to any value of resistance between open circuit and short circuit shall be a non-countable fault.

For Level of Protection "ic", resistive thermal devices that do not comply with 7.16.2 or 7.16.3 shall be considered to fail as specified in 7.2.

Resistors covered by 7.4 or fuses covered by 7.11 are exempt from 7.16.

#### 7.16.2 Thermal devices used to limit temperature

##### 7.16.2.1 General

Thermal devices, including temperature sensors, may be used to limit temperature for the purposes of intrinsic safety providing that they comply with 7.16.2.2 or 7.16.2.3 or 7.16.2.4 and the following:

a) that they are rated in accordance with the requirements of 7.1;
b) there shall be sufficient thermal coupling between the thermal device and the protected parts which shall be verified according to 9.3; and
c) the external connections of thermal devices shall comply with 6.5.1 but separation requirements shall not be applied to the interior of the thermal device.

##### 7.16.2.2 Temperature sensors

Temperature sensors shall comply with the following:

a) they shall be used within a control circuit (for example used in conjunction with controlled semiconductor limitation); and
b) they shall be considered as capable of failing according to Table 19.

**Table 19 – Rating and failure modes of temperature sensors**

| Level of Protection | Safety factor applied to the rating | | | Failure mode | | |
|---|---|---|---|---|---|---|
| | $U$ | $I$ [a] | $P$ [a] | Open circuit | Short circuit | $0 < R_T$ [c] $< \infty$ |
| "ia" and "ib" | 1,0 | 1,5 | 1,5 | Countable fault | Countable fault | Countable fault |
| "ic" | 1,0 | 1,0 | 1,5 [b]<br>1,0 [b] | Not applied | Not applied | Not applied |

[a] Where specified.

[b] Refer to 7.1.

[c] Most onerous resistance, or equivalent (for example, thermocouple voltage), at the required maximum temperature.

##### 7.16.2.3 Switching thermal devices

Non-resettable thermal fuses, and resettable thermal switches or thermal trips, shall be considered as capable of failing according to Table 20.

**Table 20 – Rating and failure modes of switching thermal devices**

| Level of Protection | Safety factor applied to the rating | | | Failure mode | |
|---|---|---|---|---|---|
| | U | I | P | Failure to open [a] | 0 < R < ∞ |
| "ia" and "ib" | 1,0 | 1,0 | N/A | Countable fault [b c] | Not applied |
| "ic" | 1,0 | 1,0 | N/A | Not applied | Not applied |

[a] At the maximum opening temperature

[b] A device complying with IEC 60691 is not considered to fail to open.

[c] Except where a single device is permitted by 7.8.4.1 or 7.10.2 where failure to open need not be considered.

#### 7.16.2.4 PTC devices used to limit temperature

PTC devices, including PPTC devices, may be used to limit temperature without the use of additional control circuits provided that:

a) they satisfy the tests in 9.12;

b) the temperature margins required by IEC 60079-0 maximum surface temperature tests apply;

c) account is made of the impact of switching speed on the components being protected; and

d) they are considered as capable of failing according to Table 21.

**Table 21 – Rating and failure modes of PTC devices used to limit temperature**

| Level of Protection | Safety factor applied to the rating | | | Failure mode | | |
|---|---|---|---|---|---|---|
| | U | I | P | Open circuit | Short circuit | 0 < R < ∞ |
| "ia" and "ib" | 1,5 | N/A | N/A | Countable fault | Countable fault | Countable fault |
| "ic" | 1,0 | N/A | N/A | Not applied | Not applied | Not applied |

### 7.16.3 PPTC devices used to limit current

PPTC devices rated in accordance with the requirements of 7.1, may use self-heating to limit current for the purposes of thermal ignition compliance, power rating of components, and the determination of $P_o$ provided they comply with all the following:

a) Thermal assessment takes into account the maximum power available to the device, and shall not be based on the trip temperature;

b) The external connections of PPTC devices comply with 6.5.1 but separation requirements shall not be applied to the interior; and

c) They are considered capable of failing according to Table 22.

**Table 22 – Rating and failure modes of PPTC devices used to limit current**

| Level of Protection | Safety factor applied to the rating | | | Failure mode | | |
|---|---|---|---|---|---|---|
| | $U$ | $I_{TRIP}$ [a] | $I_{MAX}$ [b] | Open circuit | Short circuit | 0 < $R$ < ∞ |
| "ia" and "ib" | 1,5 | 1,0 | 1,5 | Countable fault | Countable fault | Countable fault |
| "ic" | 1,0 | 1,0 | 1,0 | Not applied | Not applied | Not applied |

[a] The maximum current at which the device will trip into a high impedance mode whilst at the minimum ambient temperature.

[b] The maximum current the device can withstand without damage. This shall be compared to the maximum transient current available under the conditions specified in 5.2 with all related PPTC devices short circuited.

### 7.17 Mechanical switches

Mechanical switches, forming part of the apparatus, operated within their manufacturer's specification under the conditions specified in 5.2 need only be considered as open or closed.

## 8 Supplementary requirements for specific apparatus

### 8.1 Diode safety barriers

#### 8.1.1 General

The diodes within a diode safety barrier limit the voltage applied to an intrinsically safe circuit and a following resistor limits the current which can flow into the circuit. The diodes shall be protected by a fuse or resistor(s). These assemblies are intended for use as interfaces between intrinsically safe circuits and non-intrinsically safe circuits and shall be subject to the routine tests of 10.2.

The ability of the diode safety barrier to withstand transients shall be tested in accordance with 9.16.

Diode 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 7.7.6, provided the diodes have been subjected to the routine tests specified in 10.2.2. In this case, the failure of only one diode shall be taken into account in the application of 5.2.

For Level of Protection "ic", diode safety barriers shall have as a minimum a single diode and a current limiting resistor operated in accordance with 7.1.

#### 8.1.2 Construction

##### 8.1.2.1 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.

##### 8.1.2.2 Facilities for connection to earth

In addition to any circuit connection facility which may be at earth potential, the barrier shall be fitted with at least one of the following for connection to earth:

– a connection facility according to 6.3.2,
– two separate insulated wires each rated to carry the maximum current which can continuously flow, each with a minimum cross-section of 1,5 $mm^2$ copper,
– an insulated wire with a minimum cross-section of 4 $mm^2$ copper.

##### 8.1.2.3 Protection of components

The assembly shall be protected against access in order to prevent repair or replacement of any components on which intrinsic 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.

### 8.2 FISCO apparatus

Apparatus that is to be used within a FISCO system shall comply with Annex E, and shall be marked according to 11.1.3.

# 9 Type verifications and type tests

## 9.1 Spark ignition test

### 9.1.1 General

The spark ignition test shall use a representative circuit that is at least as incendive as the most onerous circuit under consideration. Where it is impractical to use components on the limit of their manufacturing tolerance (for example Zener diodes), the most onerous component from a sample set of 10 shall be used.

Safety factors shall be taken into account as described in 5.3.4.1 d) or 5.3.4.2 d) as applicable.

No ignition shall occur during the test described in 9.1.2 applied to the representative circuit.

### 9.1.2 Spark test apparatus and its use

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 documentation.

The sensitivity of the spark test apparatus shall be checked in accordance with 9.1.3 before each test series is carried out. For this purpose, the test apparatus shall be operated in a (24 ± 0,24) V DC circuit containing a (95 ± 5) mH air-cored coil. The current in this circuit shall be set at the value given in Table 23 or Table 24 as applicable, using the 'ignition' column, according to the appropriate equipment group and the safety factor of the test mixture. 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. When sensitivity is not satisfactory, refer to B.3 for guidance.

Each circuit shall be tested for the following number of revolutions of the wire holder in the spark test apparatus, with no ignition allowed to take place:

a) for DC and capacitive circuits, $400\ ^{+40}_{\ 0}$ revolutions (5 min), $200\ ^{+20}_{\ 0}$ revolutions at each polarity;

b) for AC circuits, $1\ 000\ ^{+100}_{\ 0}$ revolutions (12,5 min).

Care shall be taken to ensure that the circuit has sufficient time to reset (at least three-time constants for capacitive circuits) between each discharge or trip. The normal time for reset of the circuit shall be less than 20 ms using the normal speed of the spark test apparatus and using 4 wires.

Where this is inadequate for resetting the circuit, then the duration between the opening and subsequent shorting of the wire and disc shall be increased by removing one or more of the wires and the number of revolutions shall be increased accordingly. Where sufficient reset time cannot be obtained by removing all but one wire, then the speed of rotation of the spark test apparatus may be reduced, but for capacitive circuits to not lower than that needed to achieve four time constants, while ensuring adequate sensitivity of the spark test apparatus.

After each test in accordance with a) or b), sensitivity of the spark test apparatus shall be verified. If the sensitivity does not conform to 9.1.3, the ignition test on the circuit under investigation shall be considered invalid and shall be repeated.

When testing inductors, the effects of service temperature on coil resistance shall be taken into account to ensure that the worst-case current is flowing through the inductor. Self-heating effects during the test shall be ignored.

When there is a doubt that the apparatus is over-sensitive (for example, if a test has resulted in an ignition which was unexpected), the sensitivity may be checked by applying at least the 'no-ignition' column of Table 23 or Table 24, as applicable. If an ignition occurs within 400 revolutions, then investigation of the source of the over sensitivity shall take place and the ignition test on the circuit under investigation shall be considered invalid and shall be repeated.

NOTE Bent, frayed, or cadmium coated tungsten wires of the spark test apparatus can change its sensitivity. This might cause invalid test results.

### 9.1.3 Test gas mixtures and spark test apparatus calibration current

#### 9.1.3.1 Explosive test mixtures and calibration currents for safety factor 1,0

The explosive test mixtures as given in Table 23 shall be used, according to the stated equipment group which is being tested.

**Table 23 – Compositions of explosive test mixtures adequate for 1,0 safety factor**

| Equipment Group | Compositions of explosive test mixtures<br>Vol. % in air | Calibration current for ignition<br>mA | Minimum calibration current for no ignition<br>mA |
|---|---|---|---|
| I | (8,3 ± 0,3) % methane | 110 to 111 | 87 |
| IIA | (5,25 ± 0,25) % propane | 100 to 101 | 79 |
| IIB | (7,8 ± 0,5) % ethylene | 65 to 66 | 51 |
| IIC | (21 ± 2) % hydrogen | 30 to 30,5 | 23 |

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.

Flammable gasses and vapours of purity less than 95 % shall not be used.

NOTE The purity of commercially available gases and vapours is normally adequate for these tests. 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.

#### 9.1.3.2 Explosive test mixtures and calibration currents for safety factor 1,5

When conducting the test of 9.1.2, the preferred test mixtures are those specified in 9.1.3.1 with a safety factor applied by an increase of voltage or current as applicable according to 5.3.4.2 d)1). Where this is not practical and a more ignitable 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 document when the composition is as given in Table 24.

**Table 24 – Compositions of explosive test mixtures adequate for 1,5 safety factor**

| Equipment Group | Compositions of explosive test mixtures Volume % | | | | | Calibration current for ignition | Minimum calibration current for no ignition |
|---|---|---|---|---|---|---|---|
| | Oxygen-hydrogen-air mixture | | | Oxygen-hydrogen mixture | | | |
| | Hydrogen | Air | Oxygen | Hydrogen | Oxygen | mA | mA |
| I | 52 ± 0,5 | 48 ± 0,5 | – | 85 ± 0,5 | 15 ± 0,5 | 73 to 74 | 57 |
| IIA | 48 ± 0,5 | 52 ± 0,5 | – | 81 ± 0,5 | 19 ± 0,5 | 66 to 67 | 51 |
| IIB | 38 ± 0,5 | 62 ± 0,5 | – | 75 ± 0,5 | 25 ± 0,5 | 43 to 44 | 33 |
| IIC | 30 ± 0,5 | 53 ± 0,5 | 17 ± 0,5 | 60 ± 0,5 | 40 ± 0,5 | 20 to 21 | 16 |

### 9.2 Spark ignition assessment using reference curves and tables

#### 9.2.1 General

Where the circuit to be assessed for ignition compliance approximates to the simple circuit from which the curve is derived, Figure A.1 to Figure A.6 or Table A.1 and Table A.2 may be used in the assessment.

The following procedure shall be applied:

- determine the most onerous circuit configuration considering component tolerances, supply voltage variations, separation faults and component faults under the conditions specified in 5.2;
- apply the safety factors specified in 5.2, using the methods specified in 5.3.4; and

verify that the relevant parameters of the resulting circuit are within the limits of the applicable reference curves in Figure A.1 to Figure A.6 or values found in Table A.1 and Table A.2.

NOTE The figures and Tables in Annex A are based on the probability of ignition rather than binary ignition / no ignition. It is therefore possible that circuits that comply with Annex A will cause an ignition when tested using the spark test apparatus, and that circuits that pass the spark ignition test of 9.1 do not comply with Annex A. The sensitivity of the spark test apparatus varies, and the curves and tables are derived from a large number of such tests.

#### 9.2.2 Assessment of simple resistive circuit

##### 9.2.2.1 General

A simple resistive circuit is shown in Figure 12. It consists of a voltage source limited by a fixed resistance and does not include capacitive or inductive energy storage components. Spark ignition assessment of such circuits may be done using the values found in Figure A.1 or Table A.1.

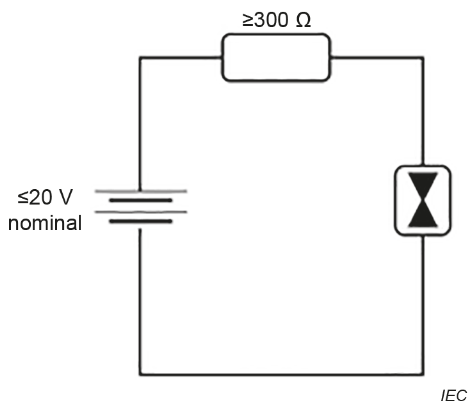



**Figure 12 – Example of a simple resistive circuit**

##### 9.2.2.2 Example simple resistive circuit assessment

A schematic diagram of a simple resistive circuit is shown in Figure 12. Spark ignition assessment of this circuit is conducted as follows:

a) Determine resistor value – The resistor conforms to 7.4.2 and its value is specified as 300 Ω minimum so no tolerance need be applied.

b) Determine the maximum voltage – Determine the maximum open circuit voltage of the battery in accordance with 7.12.5. For this example, assume the maximum battery voltage for spark ignition evaluation is 23,5 V.

c) Determine the maximum short circuit current – The maximum short circuit current is calculated by dividing the maximum voltage by the minimum resistance: 23,5 V / 300 Ω = 78,3 mA. Since the circuit is resistive, the requirements of 5.2 and 5.3.4 are applied resulting in a short circuit current, including safety factor, of 1,5 × 78,3 mA = 117,5 mA.

d) Verify spark ignition compliance – From Table A.1 for Group IIC, the minimum igniting current for a resistive circuit at 23,5 V is 275 mA. The circuit can therefore be assessed as intrinsically safe regarding spark ignition.

### 9.2.3 Assessment of simple capacitive circuits

#### 9.2.3.1 General

A simple capacitive circuit is shown in Figure 13. If the combination of voltage and resistance limits the short circuit current appropriately to the equipment group and safety factor when assessed in accordance with 9.2.2, the reference curves in Figure A.2 and Figure A.3 or the values found in Table A.2 may be applied.

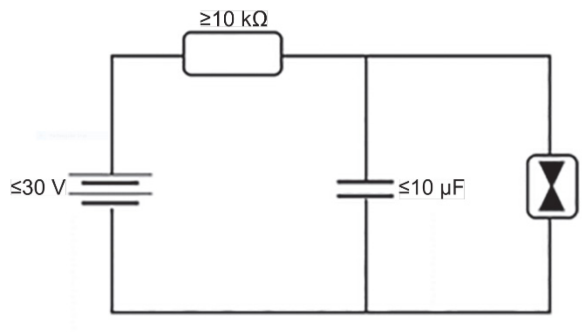



**Figure 13 – Example of simple capacitive circuit**

NOTE Due to the voltage source decoupling provided by an already intrinsically safe resistive circuit and the large safety factors involved in generating the ignition data found in Figure A.2 and Figure A.3 and Table A.2, it is not necessary to consider the influence of resistive limited energy during capacitive ignition assessment under the conditions stated.

#### 9.2.3.2 Example of simple capacitive circuit assessment

Consider the circuit of Figure 13 which is intended for Group I application. It consists of a 30 V battery connected to a 10 µF capacitor through a 10 kΩ resistor. For this example, the values of 30 V and 10 µF are taken as maximum values, and 10 kΩ as a minimum value.

Spark ignition assessment of this circuit is conducted as follows:

a) Complete resistive ignition assessment in accordance with 9.2.2.

b) Determine the maximum voltage – In this example, the specified maximum battery voltage is 30 V. No faults are applied since the 10 kΩ resistor is rated to 7.4.2 and either short circuit or open circuit failure of the capacitor results in a simple resistive circuit as addressed in 9.2.2. Where a safety factor of 1,5 is required, either use the 1,5 safety factor column from Table A.2 at 30 V, or use Figure A.2 or using the 1,0 safety factor column at 30 V × 1,5 = 45 V.

c) Determine the maximum capacitance – This example specifies the maximum value of the capacitance as 10 µF. If the specified capacitance were the nominal value, the tolerance would be added.

d) Verify spark ignition compliance – Figure A.2 for Group I shows that at 45 V a maximum capacitance of 3 µF is allowed. The example circuit contains a maximum capacitance of 10 µF and therefore cannot be assessed as intrinsically safe.

NOTE To modify the circuit so that it can be assessed as being intrinsically safe, there are several possibilities. The circuit voltage or capacitance values could be reduced, or a resistor complying with 7.4.2 could be inserted in series with the 10 µF capacitor in accordance with 9.2.3.3, or encapsulation according to 6.6.2 could be used.

#### 9.2.3.3 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 Figure 14), the assessment of the effective capacitance between these two nodes may be simplified by excluding the resistance and multiplying the capacitance by a reduction factor. The reduction factor is determined by using Table 25 and where the resistance value exceeds 40 ohms, the following formula may be used:

$$\beta = \frac{1}{\left(1 + \frac{R}{28}\right)}$$

where

$\beta$ is the Reduction Factor;

$R$ is the Resistance.

Alternatively, the circuit may be tested or, for Group I, Figure A.2 may be used to determine the effective capacitance with resistors of the values given in that figure.

The resistor shall be in accordance with 7.4.2, and the node X shall be separated from all other conductive parts according to 6.5.4.2.

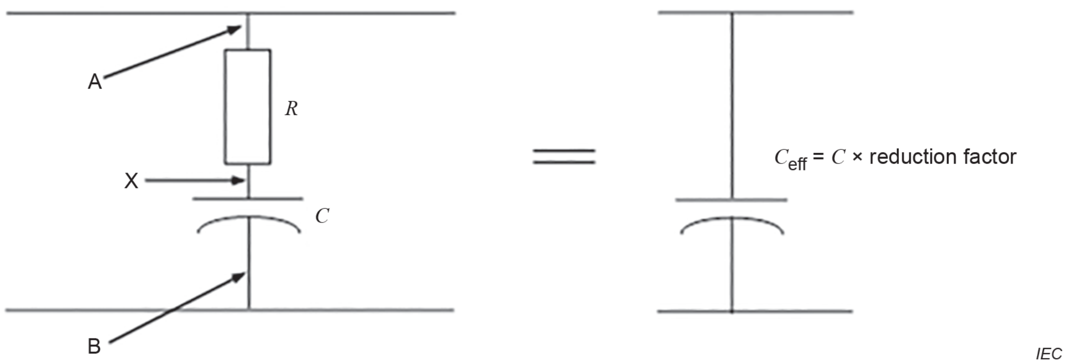



**Figure 14 – Effective capacitance**

**Table 25 – Permitted reduction of effective capacitance when protected by a series resistance**

| Resistance *R*<br>Ω | Reduction factor<br>β |
|---|---|
| 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 |

### 9.2.4 Assessment of Simple Inductive Circuits

#### 9.2.4.1 General

Figure 15 shows an example of a simple inductive circuit. Such simple inductive circuits may be assessed for spark ignition by applying Figure A.4, Figure A.5, or Figure A.6 as appropriate.

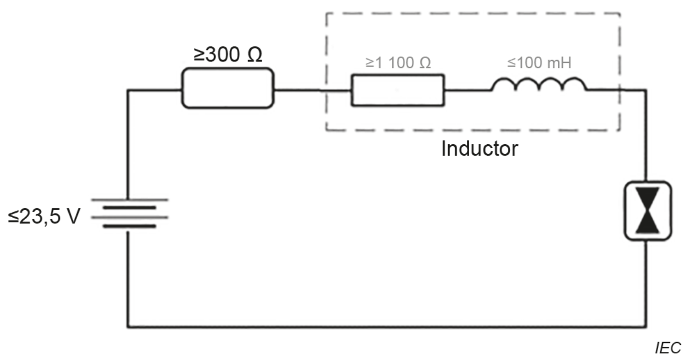



**Figure 15 – Example of simple inductive circuit**

#### 9.2.4.2 Example of simple inductive circuit assessment

Consider a circuit for a Group IIC explosive atmosphere requiring a safety factor of 1,5, consisting of a power supply comprising a 23,5 V battery with a suitably mounted 300 Ω current-limiting resistor feeding into a 1 100 Ω, 100 mH inductor as shown in Figure 15. For the purpose of this example, the 300 Ω and 1 100 Ω values are specified as minimum values and 100 mH is a maximum value.

Spark ignition assessment of this circuit is conducted as follows:

a) Determine the maximum voltage – Determine the maximum value for the battery voltage in accordance with 7.12.5. For this example, assume the maximum battery voltage for spark ignition evaluation is 23,5 V.
b) Complete resistive ignition assessment in accordance with 9.2.2. This example circuit is assessed as intrinsically safe as the maximum short circuit current, including safety factor, is 118 mA and the limiting value found in Table A.1 is 275 mA.
c) Determine the maximum current flowing through the inductor – Since the 300 Ω and 1 100 Ω values are specified as minimums, the maximum possible current in the load is 23,5 V / (300 Ω + 1 100 Ω) = 16,8 mA. No faults need to be applied since the 300 Ω resistor is rated to 7.4.2 and short circuit failure of the inductor leads to the circuit considered in b) above. Application of the requirements of 5.2 requires that, for a safety factor of 1,5, the current in the circuit be increased to 1,5 ×16,8mA = 25,2 mA.
d) Verify spark ignition compliance – 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 28,3 mA. The circuit can therefore be assessed as intrinsically safe regarding spark ignition for Group IIC.

NOTE Figure A.4, Figure A.5 and Figure A.6 have been derived using air-cored inductors. Normally these limits can be used for non-air-cored inductors, though it is sometimes necessary to use the spark test of 9.1 instead.

### 9.2.5 Determination of $L_o/R_o$ for resistance limited power source

For linear circuits the maximum external inductance to resistance ratio ($L_o/R_o$) which may be connected to a resistance limited power source may be calculated using the following formula.

NOTE 1 It is not a requirement of this document to specify $L_o/R_o$.

This formula takes account of a 1,5 factor of safety on current and shall not be used where the maximum capacitance present at the power source output exceeds 1 % of $C_o$.

$$\frac{L_O}{R_O} = \frac{8eR_S + \sqrt{(64e^2R_S^2 - 72U_O^2eL_S)}}{4,5U_O^2} \text{ H/}\Omega$$

where

$e$ is the minimum 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 Henrys.

If $L_s = 0$

then $$\frac{L_O}{R_O} = \frac{32eR_S}{9U_O^2} \text{ H/}\Omega$$

Where a safety factor of 1,0 is required, this value for $L_o/R_o$ shall be multiplied by 2,25.

NOTE 2 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.

Alternatively, $L_o/R_o$ 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 test apparatus and the spark tests in 9.1. 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 failing the spark test.

### 9.2.6 Circuits with both inductance and capacitance

For circuits containing both inductance and capacitance where the capacitive stored energy can reinforce the power source feeding an inductor or vice versa, the circuit shall be assessed for compliance using one of the following methods:

a) tested in accordance 9.1 or Annex F with the combination of capacitance and inductance;

b) assessment that the combination of capacitance and inductance maintains the required safety factor when connected to the power supply;

   EXAMPLE Where a capacitor shunts energy from an inductor under all the conditions specified in 5.2.

c) using Annex G; or

d) where linear (resistive current limiting) circuits are being considered, 1) or 2) may be applied:

   1) the values of inductance and capacitance determined according to 9.2.3 and 9.2.4 are allowed when:

      – all inductance and capacitance are distributed, for example as in a cable; or

      – the total inductance of the circuit (excluding the cable) is < 1 % of the allowed value of inductance; or

      – the total capacitance of the circuit (excluding the cable) is < 1 % of the allowed value of capacitance;

   2) where both the total inductance and capacitance of the circuit (excluding the cable) is greater than or equal to 1 % of the allowed values of inductance and capacitance determined according to 9.2.3 and 9.2.4, the allowed values shall be halved.

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

The values of allowed inductance and capacitance determined by these methods shall not be exceeded by the sum of all the lumped and distributed inductances and the sum of all lumped and distributed capacitances in the circuit, respectively.

As an alternative to assessment using the allowed value of inductance, the inductance to resistance ratio may be used.

Where the application of the above leads to reduced values of $L_o$ and $C_o$ for use with lumped inductance and capacitance, this shall be indicated in the manufacturer's instructions or certificate so that both lumped inductance and capacitance may be connected without further reduction.

### 9.3 Temperature tests

Except for cells, batteries and supercapacitors tested according to 9.14, for Levels of Protection "ia" and "ib" where the thermal characteristic of the component is non-linear, tests shall be carried out at the maximum ambient temperature or, where sufficient information is known about the thermal characteristic of the component, extrapolated from the test temperature.

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; and
– calculate the rise in temperature from the following equation:

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

where

$\Delta T$ 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; and

$k$ 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.

### 9.4 Mechanical tests

#### 9.4.1 Casting compound

For Level of Protection "ia" and "ib", a force of at least 30 N shall be applied perpendicular to the exposed surface of casting compound with a (6 ± 0,2) mm diameter flat ended metal rod for at least 10 s. No damage to or permanent deformation of the encapsulation or movement greater than 1 mm shall occur.

For all Levels of Protection, where a free surface of casting compound occurs and forms part of the enclosure required for intrinsic safety, the resistance to impact tests shall be carried out on the surface of the casting compound in accordance with IEC 60079-0 using the drop height $h$ for enclosures and external accessible parts of enclosures (other than light-transmitting parts) in the tests for resistance to impact table of IEC 60079-0.

NOTE A requirement for the resistance to impact test does not imply the inclusion of other requirements in IEC 60079-0, such as thermal endurance to heat or cold.

#### 9.4.2 Acceptability of encapsulated or coated fuses

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

With the test samples at an initial temperature of (23 ± 5) °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, encapsulated or coated as defined in the documentation, are examined after application of the encapsulation or coating to ensure that the material has not entered the interior.

#### 9.4.3 Partitions

For Levels of Protection "ia" and "ib", partitions in their place of installation 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.

No test is required for partitions in Level of Protection "ic".

#### 9.4.4 Cable pull test

The cable pull test shall be carried out by the application of a tensile force of minimum value 30 N on the cable in the direction of the cable entrance into the apparatus. The test duration shall be 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.

### 9.5 Current carrying capacity of infallible printed circuit board connections

For Levels of Protection "ia" and "ib", the current carrying capacity of the connection shall be tested for at least 1 h at the maximum service temperature with a current of 1,5 times the maximum continuous current which can flow in the connection under the conditions specified in 5.2. The application of this test current shall not cause the connection to fail to open circuit or to be separated from its substrate at any point.

### 9.6 Dielectric strength tests

Where a dielectric strength test is required, it shall be conducted either:

a) in accordance with the relevant industrial standard; or

b) with an alternating voltage of substantially sinusoidal waveform at a power frequency between 48 Hz and 62 Hz; or

c) with a DC voltage having no more than 3 % peak-to-peak ripple at a level 1,4 times the specified AC voltage.

For b) and c) 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 and the current flowing during the test shall not exceed 5 $mA_{RMS}$ at any time.

### 9.7 Qualification of solid insulation and distance through casting compound for application of reduced separations

#### 9.7.1 General

These type tests qualify solid insulation and distance through casting compound for reduced separation distances.

This type test consists of the following parts:

a) preconditioning according to 9.7.2;

b) AC power frequency voltage test according to 9.7.3; and

c) partial discharge test according to 9.7.4.

During the tests, the samples are unpowered.

### 9.7.2 Preconditioning

#### 9.7.2.1 Dry heat preconditioning

Six samples shall be conditioned in an air oven for at least 48 h at a temperature of between 10 K and 15 K above the maximum service temperature, but at not less than 80 °C.

NOTE This procedure is in accordance with test in IEC 60068-2-2.

#### 9.7.2.2 Dry heat cycle preconditioning

This procedure is only required if the partial discharge test is applicable.

After dry heat preconditioning of 9.7.2.1, the same six samples shall be subjected to temperature cycling as follows:

| | |
|---|---|
| Minimum temperature: | the minimum service temperature reduced by between 5 K and 10 K |
| Maximum temperature: | as specified in 9.7.2.1 for dry heat preconditioning |
| Duration of cycle: | 24 h with at least 10 h at each temperature |
| Rate of change: | within 2 h |
| Number of cycles: | 3 |

NOTE This procedure is in accordance with test in IEC 60068-2-2.

#### 9.7.2.3 Rapid change of temperature preconditioning

This procedure is only required if the partial discharge test is applicable.

After dry heat cycle of 9.7.2.2, the same six samples shall be subjected to rapid change of temperature as follows:

| | |
|---|---|
| Minimum temperature: | the minimum service temperature reduced by between 5 K and 10 K |
| Maximum temperature: | as specified in 9.7.2.1 for the dry heat preconditioning |
| Duration of cycle: | 60 min. (30 ± 2) min at each temperature |
| Rate of change: | within 30 s |
| Number of cycles: | 50 |

NOTE This procedure is in accordance with test Na in IEC 60068-2-14.

#### 9.7.2.4 Humidity preconditioning

The six samples from test before shall be subjected to the following humidity preconditioning before the AC power frequency voltage test of 9.7.3.

The humidity test is carried out in a chamber containing air with a humidity of (93 ± 3) % RH. The temperature of the air in the chamber is maintained at (40 ± 2) °C.

Before applying humidity, the sample is brought to a temperature of (42 ± 2) °C, maintaining it at this temperature for at least 4 h before the humidity conditioning. The air in the chamber is stirred and the chamber is designed so that condensation will not precipitate on the sample.

The sample remains exposed to humidity for at least 96 h.

NOTE This procedure is in accordance with test Cab in IEC 60068-2-78.

### 9.7.3 AC power frequency voltage test

The AC power frequency voltage test is performed and completed within 1 h of the end of humidity conditioning as specified in 9.7.2.4.

The test shall be performed at a frequency between 48 Hz and 62 Hz. Testing with a DC voltage is not permitted for this test.

The waveform of the test voltage shall be substantially sinusoidal. This requirement is fulfilled if the ratio of the peak value to the RMS value is $\sqrt{2}$ ± 3 %. The test voltage is specified in Table 8 column 7.

The supply shall have sufficient volt-ampere capacity to maintain the test voltage, taking into account any leakage current which may occur. The applied voltage shall remain constant during the test. The current flowing during the test shall not exceed 100 $mA_{RMS}$ at any time.

The voltage shall be increased steadily from 0 V to the specified value within 5 s and then maintained for at least 60 s.

No breakdown shall occur during the test.

### 9.7.4 Partial discharge test

The following test shall be carried out following the AC power frequency voltage test specified in 9.7.3.

The waveform of the sinusoidal power frequency test voltage shall be substantially sinusoidal. This requirement is fulfilled if the ratio of the peak value to the RMS value is $\sqrt{2}$ ± 3 %.

The test shall be performed at a frequency between 48 Hz and 62 Hz.

The peak value of $U_t$ is the specified value PDV in Table 8.

NOTE Where Table 8 does not specify a PDV value, the Partial discharge test is not required according to this document.

Partial discharge test methods shall be those described in IEC 60664-1.

According to the partial discharge hysteresis an initial value of 1,25 times the test voltage $U_t$ shall be applied.

The voltage shall be raised uniformly from 0 V up to the initial test voltage 1,25 times $U_t$. It shall then be kept constant for a specified time $t_1$ of 5 s. If no partial discharges have occurred, the test voltage shall be reduced to zero after $t_1$. If a partial discharge has occurred, the voltage shall be decreased to the test voltage $U_t$, which shall be kept constant for a specified time $t_2$ of 15 s until the partial discharge magnitude is measured. (See Figure 16)

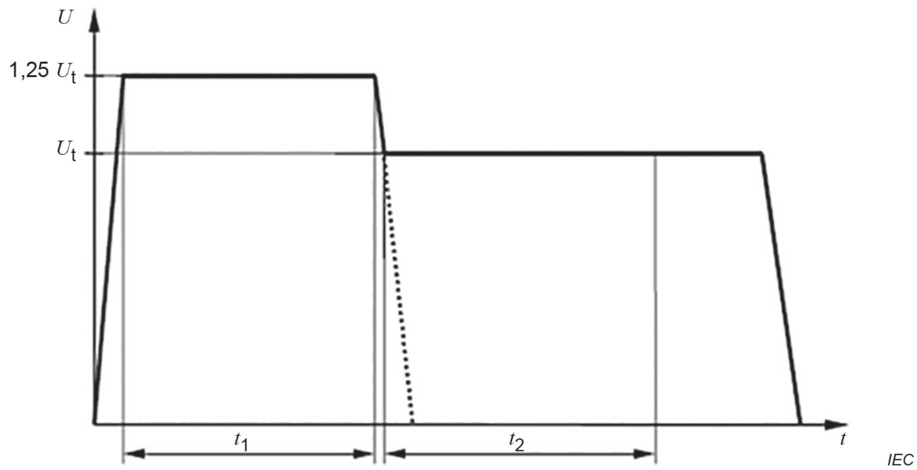



**Figure 16 – Test voltages**

The insulation complies if:

– no insulation breakdown has occurred; and
– during the application of the test voltage, partial discharges have not occurred, or after $t_2$ the magnitude of the discharge is not higher than 5 pC.

The noise level shall not be subtracted from the reading of the partial discharge meter.

## 9.8 Type tests for PCB coatings

Coatings used to achieve type 1 or type 2 protection shall be subjected to the type testing specified in test sequence 1 of IEC 60664-3 Annex A Table A.1.

Type tests shall be carried out applying the following:

– The minimum service temperature shall be reduced by at least 5 K as minimum temperature for cold conditioning and for rapid change of temperature;
– For type 1 protection, the test voltage for the impulse voltage test shall be the AC voltage value specified in column 7 of Table 8 or column 6 of Table 9, as applicable, multiplied by $\sqrt{2}$. A partial discharge test is not required for type 1 protection; and
– For type 2 protection, the test voltage for the AC power frequency voltage test (see 9.7.3) and $U_t$ for the partial discharge test (see 9.7.4) shall be those specified in column 7 of Table 8 or column 6 of Table 9, as applicable. A partial discharge test is only required where a PDV is specified in these tables.

## 9.9 Differential Leakage current tests for signal isolators

Three samples of a signal isolator that has power and ground terminals on the signal output side shall be subjected to a differential leakage test. The signal input side of the signal isolator shall be operated at the nominal operating voltage for the application. Input signals of logic high, logic low and toggling at the maximum data rate of the application or higher, and at 50 % duty factor shall be applied to all inputs on the powered side of the signal isolator. The voltage generated on the output side for each test condition shall remain less than 0,5 V into a 10 kΩ 1 % load installed between the component power and ground terminals as shown in Figure 17.

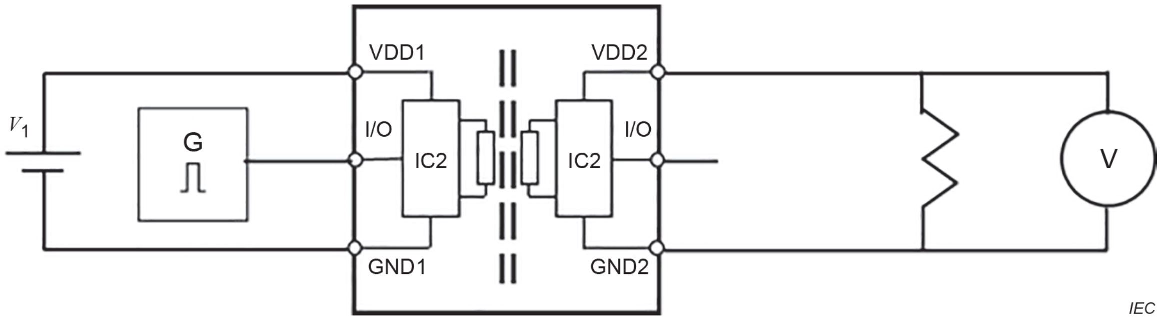



**Figure 17 – Recommended bias circuit for Differential Leakage measurement**

NOTE The values for output side resistive load and voltage threshold are chosen for ease of measurement and do not have other significance.

### 9.10 Isolator tests

#### 9.10.1 General

For Levels of Protection "ia" and "ib", the following tests shall be performed for optical isolators used to provide isolation between intrinsically safe circuits and non-intrinsically safe circuits.

The samples shall successfully comply with both the tests specified in 9.10.2 and 9.10.3.

#### 9.10.2 Thermal conditioning and dielectric test

##### 9.10.2.1 General

The maximum temperature for thermal conditioning shall be determined by the overload tests using 5 samples each for the receiver side test and for the transmitter side test. All 10 samples shall then be subjected to thermal conditioning and dielectric strength tests.

##### 9.10.2.2 Overload test at the receiver side

The transmitter side of the isolator shall be operated with the rated load values (for example, $I_f = I_N$).

The receiver side shall be operated with a specific power (for example, 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 either:

a) the receiver semiconductor is damaged. This will terminate or drastically reduce the power dissipation; or
b) the power at the receiver semiconductor reaches the point to which it is limited by protective components or assemblies that form part of the circuit.

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

##### 9.10.2.3 Overload test at the transmitter side

The receiver side of the isolator shall be connected to a source voltage $U$ with a series resistor $R$ where:

$$U = 4 \times \frac{P_{max}}{I_{max}}$$

$$R = \frac{U}{I_{max}}$$

Where:

$P_{max}$ maximum permitted power in the receiver

$I_{max}$ maximum permitted current in the receiver

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 either:

a) the transmitter semiconductor is damaged. This will terminate or drastically reduce the power dissipation; or
b) the power at the transmitter semiconductor reaches the point to which it is limited by protective components or assemblies that form part of the circuit.

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

#### 9.10.2.4 Thermal conditioning and dielectric strength test

All samples used in 9.10.2.2 and 9.10.2.3 shall be placed in an oven for $6^{+0,2}_{0}$ h at the maximum surface temperature recorded from 9.10.2.2 or 9.10.2.3 and increased by at least 10 K but at most 15 K.

After the isolators have cooled down to (23 ± 5) °C they shall be subjected to dielectric strength test with a voltage of 1 500 V (AC 48 Hz to 62 Hz) applied between intrinsically safe and non-intrinsically safe terminals and within 10 s increased to $3^{+0,15}_{0}$ 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 $mA_{RMS}$.

### 9.10.3 Dielectric and short circuit test

#### 9.10.3.1 General

Three new samples, not used in the tests of 9.10.2, shall be used for this test.

Optical isolators shall be subjected to a pre-test dielectric strength test (9.10.3.2), followed by a short circuit current test (9.10.3.3) followed by a dielectric strength test (9.10.3.4).

#### 9.10.3.2 Pre-test dielectric

Prior to the short circuit current tests, the samples shall be capable of withstanding without breakdown a dielectric strength test in accordance with 9.6 b) of $4^{+0,2}_{0}$ $kV_{RMS}$ applied between the intrinsically safe side and the non-intrinsically safe side. The leakage current measured in 9.6 b), shall not exceed 1 $mA_{RMS}$ during the dielectric strength test.

#### 9.10.3.3 Short circuit current test

All samples shall be subjected to a short circuit current test. The open circuit voltage of the test circuit shall be the maximum voltage available to the optical isolator under the conditions specified in 5.2 (for example, the peak of $U_m$). 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. The optical isolators shall not burst or catch fire throughout the short circuit current tests.

#### 9.10.3.4 Dielectric strength test

Each sample shall withstand without breakdown a dielectric strength test in accordance with 9.6 b) of 2 $U$ + 1 000 $V_{RMS}$ or 1 500 $V_{RMS}$, whichever is greater, applied between the intrinsically safe side and the non-intrinsically safe side. The leakage current measured in 9.6 b) shall not exceed 1 $mA_{RMS}$ during the dielectric strength test.

### 9.11 Tests for intrinsically safe apparatus containing piezoelectric devices

The following shall be measured on one sample:

– the capacitance of the device; and
– the voltage appearing across the device when any part of the intrinsically safe apparatus which is accessible in service is impact tested in accordance with the "high" column of the table for tests for resistance to impact in IEC 60079-0. This test shall be carried out at (20 ± 10) °C using the test apparatus in IEC 60079-0. For the value of voltage, the higher figure of two tests shall be used. The tests should be completed on the same sample; however, it might suffer damage during the test and a second sample may be required.

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 device 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 and Group III 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 intrinsic safety 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, 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.

### 9.12 Tests for PTC devices

At least 10 samples for Level of Protection "ia" and "ib, and at least one sample for Level of Protection "ic" shall be tested for their ability to control the components and apparatus being protected, with the surface temperature of the PTC being taken into account. The thermal coupling shall be taken to be the worst-case identified from the testing of these samples.

### 9.13 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. Except when determining thermal characteristics, tests shall normally be carried out at, or referred to, the most onerous service temperature, but where necessary, temperature-sensitive components shall be tested at lower temperatures to obtain their most onerous conditions.

The most onerous value for the parameter, obtained on any of the 10 samples shall be taken as representative of the component and the parameters shall be documented as required by IEC 60079-0.

### 9.14 Tests for cells, batteries and supercapacitors

#### 9.14.1 Conditions for testing

##### 9.14.1.1 General

Secondary cells or batteries, or supercapacitors, 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, battery or supercapacitor shall be confirmed as being within its manufacturer's specification to ensure that tests are carried out on a fully charged sample which is within its manufacturer's specification.

The primary cells for the following tests shall be new and previously unused.

Except where otherwise permitted by 9.14.3.3 b), 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 voltage. The short circuit shall be applied as close to the cell, battery or supercapacitor terminals as practicable.

The current and voltage shall be continuous during the discharge. There shall be no sudden drop of current or voltage to zero.

NOTE Voltage and current are expected to decrease following a natural curve for a cell or supercapacitor with no discontinuities.

The short circuit tests for electrolyte leakage in 9.14.2 and surface temperature in 9.14.3 shall be carried out with all current-limiting devices, internal or external to the cell container or battery case removed, bypassed or otherwise deactivated. Samples having internal current-limiting devices removed, bypassed or otherwise deactivated should be obtained from the cell/battery manufacturer together with any special instructions or precautions necessary for safe use and testing of the samples. Features of a cell or supercapacitor that provide essential functions, such as a separator with shutdown function or the ohmic resistance of electrolyte, are not considered current limiting devices in the sense of this clause and need not be removed, bypassed or deactivated and such cells or supercapacitors can be considered for Level of Protection "ia" or "ib".

Where a short circuit test results in explosion or fire of the cell or battery, it shall not be used for Levels of Protection "ia" or "ib".

##### 9.14.1.2 Tests without dust layers

For EPLs Ma, Mb, Ga, Gb and Db where no dust layer is specified, the tests found in 9.14.2 and 9.14.3.3 shall be conducted as follows;

a) on 3 test samples at the higher of the minimum service temperature or -20 °C, with a tolerance of ± 2 °C;
b) on 3 test samples at the maximum service temperature ± 2 °C; and
c) on 3 test samples at (23 ± 5) °C.

#### 9.14.1.3 Tests with dust layers

For EPL Db where the cell or supercapacitor might become in direct contact with dust and for EPL Da, 9.14.3.3 shall be carried out with the applicable dust layer depth specified in IEC 60079-0, either:

1) 3 test samples at the maximum service temperature ± 2 °C and 3 test samples at (23 ± 5) °C; or
2) where there is no possibility of thermal runaway occurring, 3 test samples at (23 ± 5) °C. In this case the maximum temperature rise achieved in air is added to the maximum temperature reached under dust. For testing cells or supercapacitors in air, 9.14.2 and 9.14.3.3 shall be conducted as follows:
   i) on 3 test samples at the higher of the minimum service temperature or -20 °C, with a tolerance of ± 2 °C; and
   ii) on 3 test samples at the maximum service temperature ± 2 °C; and
   iii) on 3 test samples at (23 ± 5) °C.

For EPL Da or EPL Db the tests in 9.14.2 and 9.14.3.3 shall be conducted under the applicable dust layer either inside or outside the apparatus enclosure.

#### 9.14.1.4 Additional tests

Following the tests in 9.14.1.2 and 9.14.1.3, a further 7 test samples shall be tested at the temperature from a), b) or c) above which results in the maximum temperature of the cell or supercapacitor surface.

### 9.14.2 Electrolyte leakage test for cells, batteries and supercapacitors

Secondary lithium ion cells that are tested using the alternative short circuit link resistance value in 9.14.3.3 b) are assumed to leak electrolyte and the requirements of 7.12.3 shall apply, otherwise the test samples specified in 9.14.1 shall be subjected to the most onerous of the following:

a) for Levels of Protection "ia" and "ib", short circuit until discharged. For Level of Protection "ic", this test is not required but is nonetheless sufficient to establish compliance with 9.14.2 for the cell, battery or supercapacitor;
b) application of input or charging currents within the manufacturer's recommendations; or
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. They shall not include the use of an external charging circuit which exceeds the charging rates recommended by the manufacturer of the cell, battery or supercapacitor.

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 7.12.2, examination of the compound at the end of the test shall show no damage which would invalidate intrinsic safety. Alternatively, the compatibility of electrolyte with the encapsulation may be tested by applying the electrolyte directly to a sample of encapsulant. The sample thickness shall be representative of the application. After at least 12 hours, there shall be no observable damage to the encapsulant which would invalidate conformance with 7.12.2.

For EPL Da and Db where the cell might come into direct contact with dust the electrolyte leakage test may be conducted without a layer of dust, but at the maximum temperature obtained in 9.14.1.

NOTE The cell manufacturer may need be approached to determine the suitably of the cells for this test.

#### 9.14.3 Spark ignition and surface temperature of cells, batteries or supercapacitors

##### 9.14.3.1 General

For the purposes of 9.14.3, the term cell shall also refer to supercapacitors.

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

NOTE 2 Some cells, batteries or supercapacitors can catch fire or explode during the short circuit test.

Cells and batteries shall be tested or assessed in accordance with 9.14.3.2 and 9.14.3.3 taking into account the requirements of 9.14.1.

##### 9.14.3.2 Spark ignition assessment

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:

– maintains infallible separation, including between conductive parts of different polarities on the cell enclosure itself; or
– is encapsulated according to 6.6,

in which case the test or assessment may then include the current-limiting device.

Where the apparatus contains one or more 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 except for supercapacitors and lithium-ion cells and batteries with a high short circuit current where spark ignition risk should be considered.

NOTE 1 The allowance for excluding single cells with peak open circuit voltage less than 4,5 V from spark ignition testing is based on the presence of negligible inductance between the cell terminals resulting in a purely resistive circuit with a voltage below that needed to cause spark breakdown between electrodes in air. This rationale does not apply to spark ignition testing in any other case covered by this document, as any interconnecting conductors will introduce some inductance into the circuit.

NOTE 2 For lithium-ion cells, inductance between the cell terminals cannot be ignored as some cells can provide extremely high short circuit current and spark ignition from cells with open circuit voltage below 4,5 V has been experimentally demonstrated. Work on more specific proposals to address this issue is ongoing.

NOTE 3 One method of achieving the necessary safety factors for the spark ignition testing of individual cells or supercapacitors is to use an assembly of cells, either two in series for voltage or two in parallel for current as appropriate.

##### 9.14.3.3 Thermal ignition assessment

The specified number of cells or batteries shall be short-circuited in accordance with 9.14.1 and the measured temperature values obtained shall be used in the thermal ignition assessment.

NOTE The 5 K or 10 K temperature margin required by IEC 60079-0 for maximum surface temperature measurement for Group II still applies.

The cells or batteries 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 or battery that may be exposed to the explosive atmosphere. In case of testing single cells, it is sufficient to measure the temperature in the middle of the cell with respect to its longitudinal axis. 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:

a) For Levels of Protection "ia" and "ib", if leakage of electrolyte occurs during the maximum surface temperature test, then the requirements of 7.12.3 should also be considered.

   While determining the maximum surface temperature of a battery comprising more than one cell in series connection, provided that the cells are adequately separated from each other, only one cell should be shorted at a time.

   NOTE This is based on the extremely low likelihood of more than one cell shorting at the same time.

b) For Level of Protection "ib", if:
   - the short circuit test conducted with a short circuit link resistance according to 9.14.1 fails due to interruption or sudden drop of the current and voltage; and
   - the short circuit link resistance test according to 9.14.1 did not result in explosion or fire of the cell or battery; and
   - no samples with internal current-limiting devices removed, bypassed, or otherwise deactivated can be obtained

   then secondary lithium-ion cells may be alternatively tested with a short circuit link resistance of (80 ± 20) mΩ according to the short circuit test described in IEC 62133-2 under otherwise identical conditions as described in 9.14.1. This alternative short circuit test shall not be used to show compliance with 9.14.2.

c) For Level of Protection "ic", the maximum surface temperature shall be determined by testing a single sample in normal operating conditions with all protection devices in place.

#### 9.14.4 Battery container pressure tests

Five samples of the battery container shall be subjected to a pressure test to determine the pressure at which venting occurs. Pressure shall be applied to the inside of the container. The pressure is to be gradually increased until venting occurs. The maximum 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.

Where separation distances within the battery container are based on Table 7, the pressure test may be carried out on a sample that has not been submitted to the thermal endurance tests of IEC 60079-0. Where separation distances within the battery container are based on Table 8 or Table 9, 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.

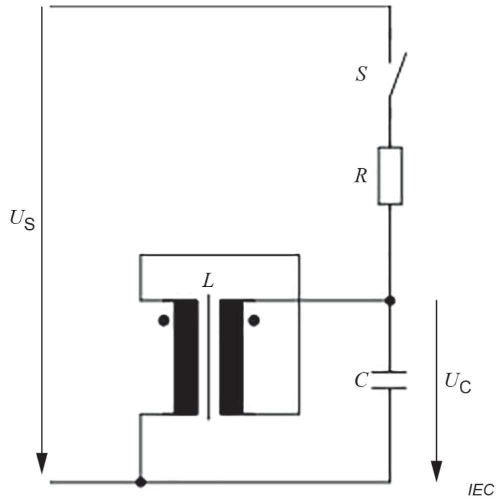
#### 9.14.5 Battery resistance

The short circuit current shall be determined from tests of 10 samples of the cell or battery.

The minimum internal resistance shall be calculated using the peak open circuit voltage according to 7.12.5 and the highest measured value of short circuit current.

### 9.15 Determination of storable energy in common mode chokes

Measurement of the maximum energy that can be stored in a common mode choke shall use the setup of Figure 18.




**Key**

$L$ is the common mode choke under test, with the windings connected in series

$U_S$ is the maximum voltage available in the circuit being assessed

$R$ is a resistor which, in conjunction with $U_S$, determines the test current.

S is a bounce-free mechanical contact or a transistor switch. Where a transistor is used, its internal capacitance shall be added to $C$ when calculating the result.

$C$ is a capacitor used to measure the energy returned from the choke.

**Figure 18 – Inductor test circuit**

$C$ shall be a polymer or foil type capacitor. To minimize measurement errors a switch with an effective capacitance of less than 10 % of the capacitance value of $C$ shall be used. The capacitance shall be such that, with the switch closed, the energy stored in the capacitor is less than 1 % of the energy stored in the choke,

$$E = \frac{0{,}5 L U_S^2}{\left(R + R_{CHOKE}\right)^2}$$

$R_{CHOKE}$ is the resistance of the choke under test.

$U_C$ shall be monitored with an oscilloscope.

The test shall be performed by closing and then re-opening S and measuring $\hat{U}_C$, the peak voltage achieved in the first half cycle of oscillation, as shown in Figure 19. The switch S may be opened and closed repeatedly; in which case the duty cycle shall ensure that the heating of the common mode choke is negligible.

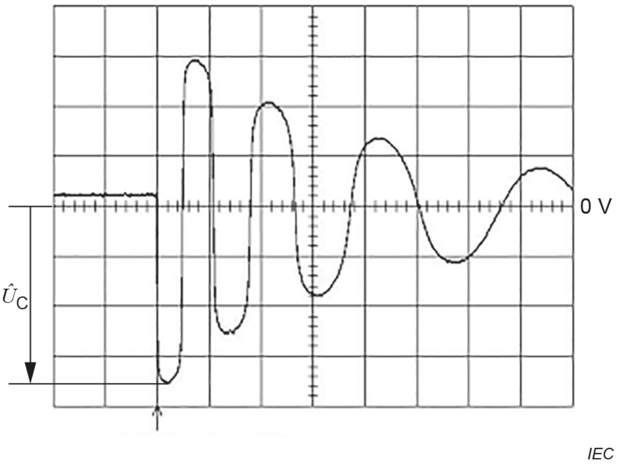



**Figure 19 – Measured oscillation**

The energy stored in the common mode choke shall be calculated as:

$$E = \frac{1}{2} C \hat{U}_C^{\,2}$$

The test shall be repeated on one sample at different temperatures over the service temperature range for the choke, in order to determine the most onerous case (the highest value of $\hat{U}_C$). The test need not be performed above the Curie temperature for the ferrite material.

For Levels of Protection "ia" and "ib", the measurement shall be made at the most onerous temperature on a further 9 samples of the common mode choke.

### 9.16 Type tests for components protected by time dependent current limitation

Where a semiconductor component on which intrinsic safety depends is protected by a fuse or by controlled semiconductor current limitation, its ability to withstand the transients during the operating time of the current limitation shall be demonstrated as follows.

When suitable data is available from the manufacturers of the devices, the transient rating of the protected device may be shown to be greater than or equal to the transient rating of the limiting device, for example where the $I^2t$ rating of a fuse is less than the $I^2t$ rating of a protected thyristor.

Otherwise, the size of the transient shall be compared with the ability of the protected device to withstand the transient. The size of the transient shall be determined as follows:

a) The maximum transient current under the conditions specified in 5.2 shall be determined.

EXAMPLE 1 Examples of maximum current are:

1) The peak of $U_m$, $U_i$ or the voltage of a battery divided by a series resistance plus the cold resistance of a fuse.
2) The transient current from the secondary side of a transformer measured under worst-case condition of the supply circuit.
3) $I_i$ at power input connection facilities.

b) The operating time of the current limitation shall be determined by one of the following:

1) From the data of the manufacturer of the current limiting device. For example, if the $I^2t$ rating of a fuse is used then the operating time is the rating divided by the square of the current determined in a).

2) For a fuse, the greater of 50 μs or the maximum fuse opening time as specified by the manufacturer of the fuse at the current as determined in a). Where this time is not specified, 10 fuses shall be subjected to this current and the maximum fuse opening time measured.
3) For semiconductor limitation, the pulse length where the current exceeds the maximum continuous current which can flow without the limitation being applied, under most onerous conditions (including component values, voltage, current, timing and temperature). This time shall either be:
   i) calculated from component data (for example using circuit simulation), or
   ii) measured on a circuit representative of the worst-case, and with a 1,5 safety factor added to the measured time.

The ability of the protected device to withstand the transient shall be determined by either of the following:

c) By comparison with the transient rating of the protected component, as specified by the manufacturer of the component, or;
d) By testing as follows;
   1) The primary value(s) of the protected component for carrying out its protective function is measured.

   EXAMPLE 2 Examples of primary values are:
   – the forward voltage for a diode;
   – the Zener voltage for a Zener diode;
   – the saturation voltage for a thyristor or bipolar junction transistor;
   - the on and off resistance for a FET.

   2) Each protected component is subjected to at least five rectangular current pulses of the maximum transient current derived from 9.16 a) with a pulse length of the time equal to the operating time determined in 9.16 b), applied with approximately 20 ms intervals. For resettable current limiting circuits, the number of pulses should be greater than the designed maximum demand.
   3) The primary value(s) of the protected component is re-measured at the same current as 9.16 d) 1) and the values shall not differ with those taken before the component was subjected to the pulse currents by more than 5 % (including the uncertainties of the test apparatus), nor take the component outside of the component manufacturer's specification. After testing, the component shall be checked for conformity to the component manufacturer's specification for its principal function.

From a generic range manufactured by a particular manufacturer, a worst-case may be used to demonstrate the acceptability of less onerous cases in the generic range.

EXAMPLE 3 Testing a 12 V Zener diode for a fuse current is considered to demonstrate the suitability of a 5,2 V Zener diode of the same type at the same fuse current.

### 9.17 Transformer tests

#### 9.17.1 General

The requirement for safe electrical isolation is satisfied if the transformer passes the type test described below and, after the transformer has cooled down to (23 ± 5) °C, withstands the dielectric strength test according to 9.6 with the applicable voltage according to 6.9.

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 infallible separation in accordance with 6.5.4.2, and if the resistor remains in circuit after the application of 5.2 then the output winding shall not be considered as subject to short circuit except through the resistor.

### 9.17.2 Mains transformers for Level of Protection "ia" and "ib"

#### 9.17.2.1 Mains transformers operated at mains frequency

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.

The input voltage is set to the rated voltage of the transformer. The input current shall be adjusted to between 1,70 $I_n$ and 1,87 $I_n$ 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.

Where a self-resetting thermal trip is used, the test shall continue for at least 12 h, otherwise the test shall continue for at least 6 h or until a non-resetting thermal trip operates.

#### 9.17.2.2 Mains transformers operated at non-mains frequency

Transformers that are not galvanically isolated from the mains supply and which do not operate at mains frequency shall be tested in a functional circuit that represents conditions specified in 5.2 including where practicable, possible variations in frequency range, input voltage range and load.

The input current shall be adjusted to its maximum value to between 1,70 $I_n$ and 1,87 $I_n$ of the fuse, or to the maximum continuous current which the circuit breaker will carry without operating, by adjusting the input voltage, frequency and load within the ranges that apply to the DC/DC converter circuit in which the transformer is used.

Where a self-resetting thermal trip is used, the test shall continue for at least 12 h, otherwise the test shall continue for at least 6 h or until a non-resetting thermal trip operates.

#### 9.17.2.3 Acceptance criteria

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 or the COT of the insulating materials. The winding temperature shall be measured in accordance with 9.3.

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 produce flames.

### 9.17.3 Transformers galvanically isolated from the mains supply for Levels of Protection "ia" and "ib"

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 when subjected to the load that gives maximum power dissipation in the transformer without open circuiting the windings, to ensure that the insulation is rated correctly.

Transformers shall be tested in a functional circuit that is able to represent the worst-case operating conditions, taking into account the requirements of 5.2.

The worst-case conditions include the possible variations in frequency range, input voltage range and load.

The input current shall be adjusted to its maximum value by adjusting the input voltage, frequency or load within the ranges that apply to the circuit in which the transformer is used. For fuse limitation the current shall be up to between 1,70 $I_n$ and 1,87 $I_n$, for a circuit breaker the current shall be the maximum continuous current which the circuit breaker will carry without operating. Where it is not practicable to operate the transformer under alternating current conditions, each winding shall be subjected to a direct current of between 1,7 $I_n$ and 1,87 $I_n$ considering the current transfer ratios if this increases the current.

Where a self-resetting thermal trip is used, the test shall continue for at least 12 h, otherwise the test shall continue for at least 6 h or until a non-resetting thermal trip operates.

The acceptance criteria shall be as specified in 9.17.2.3.

#### 9.17.4 Transformers for Level of Protection "ic"

Except where insulation from earth is not required for intrinsic safety for type 2b transformers, transformers shall be subject to the conditions specified in 5.2.4 and the transformer winding temperature shall not exceed the permissible value for the class of insulation given in IEC 60085 or the COT of the insulating materials. The temperature of the windings shall be determined according to 9.3.

## 10 Routine verifications and tests

### 10.1 Alternative reduced spacings

Where the alternative spacings of Table 8 column 5 indicate the requirement for a routine dielectric strength test, the test in 9.6 shall be conducted as the routine test at the voltage required by 6.9.

As routine tests can only be performed with galvanically separated circuits, representative test conductors may be included in the design of the printed circuit board for verification that the intended manufacturing procedure (coating, potting) was successful.

### 10.2 Routine tests for diode safety barriers

#### 10.2.1 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.

NOTE Removable links are not generally needed for Level of Protection "ic" safety barriers.

#### 10.2.2 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; and
b) subject each diode to the pulse current test in accordance with 9.16.

### 10.3 Routine tests for transformers

#### 10.3.1 Levels of Protection "ia" and "ib"

For routine tests, the voltages applied to transformers shall conform to the values given in Table 26, where $U$ is the voltage determined according to 6.5.5 a). 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 $mA_{RMS}$ 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 26 – Routine test voltages for transformers**

| Where applied | $AC_{RMS}$ test voltage [a] | |
|---|---|---|
| | **Mains transformer** | **Non-mains transformer** |
| Between non-intrinsically safe primary and secondary windings | 4 $U$ or 2 500 V, whichever is the greater | 2 $U$ + 1 000 V or 1 500 V, whichever is the greater |
| 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 |
| Between each winding which supplies an intrinsically safe circuit and any other winding | 2 $U$ + 1 000 V or 1 500 V, whichever is the greater | 2 $U$ or 500 V, whichever is the greater |
| Between each intrinsically safe circuit winding | 2 $U$ or 500 V, whichever is the greater | 2 $U$ or 500 V, whichever is the greater |

[a] DC voltages of 1,4 times the above $AC_{RMS}$ voltages may be used.

### 10.3.2 Level of Protection "ic"

For Level of Protection "ic", where there is a routine dielectric strength test in the relevant industrial standard for the equipment type, this test is acceptable. Where the relevant industrial standard does not require a routine test, no routine test according to this document is required. Where no relevant industrial standard exists, the routine tests specified for Levels of Protection "ia" and "ib" transformers shall be used.

## 10.4 Routine verification of conformal coating and encapsulation

Apparatus that uses conformal coating or encapsulation as part of the intrinsic safety protection shall be subjected to a routine verification.

No damage shall be evident to the conformal coating or encapsulation, this includes but is not limited to;

- Cracks;
- non-homogeneous covering of the encapsulated or coated parts;
- inadmissible shrinkage;
- swelling;
- decomposition;
- failure of adhesion (separation of any adhered parts) or flaking; and
- softening.

Routine verification may be replaced by batch verification where there is confidence in the manufacturing process, in which case the following criteria based on ISO 2859-1 shall apply:

- For a production batch up to 100, a sampling of 8 shall be inspected with no failures
- For a production batch from 101 to 1 000, a sampling of 32 shall be inspected with no failure

– For a production batch from 1 001 up to 10 000, a sampling of 80 shall be inspected with no failures
– Batches above 10 000 shall be subdivided into smaller batches

If there are any non-compliant inspection results, 100 % of all remaining samples in the batch shall be inspected. Future batches shall be routinely inspected until confidence is established to reconsider batch verification.

In cases where destructive testing is used to verify the encapsulation process, verification on fewer test samples is permitted. If it is not stated in the schedule drawings, this destructive testing shall take place at least at the beginning and at the end of each production batch. Representative samples for this verification are permitted.

NOTE Upon non-compliant inspections, reconsideration of this batch testing approach is at the discretion of the party issuing the involved certificate.

## 11 Marking

### 11.1 Intrinsically safe apparatus and associated apparatus

#### 11.1.1 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.

Where required by 6.5.6.1, the marking shall include the pressure range.

NOTE Examples of marking are given in Annex H.

#### 11.1.2 Intrinsic safety parameters

Where practicable, all parameters relevant for intrinsic safety should be marked. Where $L_o$ and $L_o/R_o$ are both marked, the $L_o/R_o$ ratio should be shown as an alternative to the use of $L_o$, for example, with an interposing "or".

NOTE Standard symbols for marking and documentation are given in Clause 3 of this document 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 "$U_o$".

#### 11.1.3 FISCO

For apparatus complying with the requirements of Annex E, each piece of apparatus shall additionally be marked with the word "FISCO" followed by an indication of its function, such as '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.

### 11.1.4 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.

### 11.1.5 Non-hazardous area accessory

Where required by 6.3.5.3, non-hazardous area accessories shall carry at least the following marking:

a) the name of the manufacturer or their registered trademark;
b) the manufacturer's type identification; and
c) the maximum rated input voltage.

The non-hazardous area accessory shall not include any Ex marking, certificate number or output parameters $U_o$, $I_o$, $C_o$, $L_o$, $P_o$.

NOTE The intent is to make clear it is not associated apparatus.

## 11.2 Warning markings

Where any of the following warning markings are required on the apparatus, the text as described in Table 27, following the word "WARNING," may be replaced by technically equivalent text. Multiple warnings may be combined into one equivalent warning.

**Table 27 – Text of warning markings**

| Item | Reference | WARNING Marking |
|---|---|---|
| a) | 7.12.1 | WARNING – USE ONLY *YYYYY* BATTERIES (where Y is the cell manufacturers name and the type number of the cell or battery). |
| b) | 7.12.8 | WARNING – DO NOT REPLACE BATTERY WHEN AN EXPLOSIVE ATMOSPHERE IS PRESENT |
| c) | 7.12.1 | WARNING – DO NOT CHARGE THE BATTERY IN THE HAZARDOUS AREA |
| d) | 6.3.5.2 | WARNING – DO NOT OPEN WHEN AN EXPLOSIVE ATMOSPHERE IS PRESENT |

## 12 Instructions

### 12.1 General

In addition to the requirements of IEC 60079-0 the instructions shall include the following information as applicable:

a) intrinsic safety parameters:
   1) power sources: output data such as $U_o$, $I_o$, $P_o$, $C_o$, $L_o$ and the permissible $L_o/R_o$ ratio; and
   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) the value of $U_m$ which may be applied to non-intrinsically safe circuits connection facilities;

c) the maximum rated voltage if required by 5.2.5;

d) 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.

e) any conditions which are assumed in determining intrinsic safety, for example that the voltage is to be supplied from a protective transformer, galvanically isolated power supply or through a diode safety barrier;

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 separation distances rely upon the enclosure, as in 6.2.3 a) and 6.2.4 a), the IP rating and the measures necessary to maintain the integrity of the enclosure and entries into enclosures;

i) permitted non-hazardous area accessories; and

j) For connection facilities with a specified $U_m$, the maximum prospective current allowed for the circuit, if less than 1 500 A.

These instructions form part of the documentation requirement of IEC 60079-0.

### 12.2 Specific Conditions of Use

This document permits the use of Specific Conditions of Use as a method of addressing a specific requirement at the time of installation. In these cases, the certificate number shall include the suffix "X" in accordance with the marking requirements of IEC 60079-0 and the Specific Conditions of Use listed on the certificate shall detail how to address the concern. Multiple Specific Conditions of Use may be combined. The areas of concern that may be mitigated by using Specific Conditions of Use are shown in Table 28 and are in addition to those permitted by IEC 60079-0.

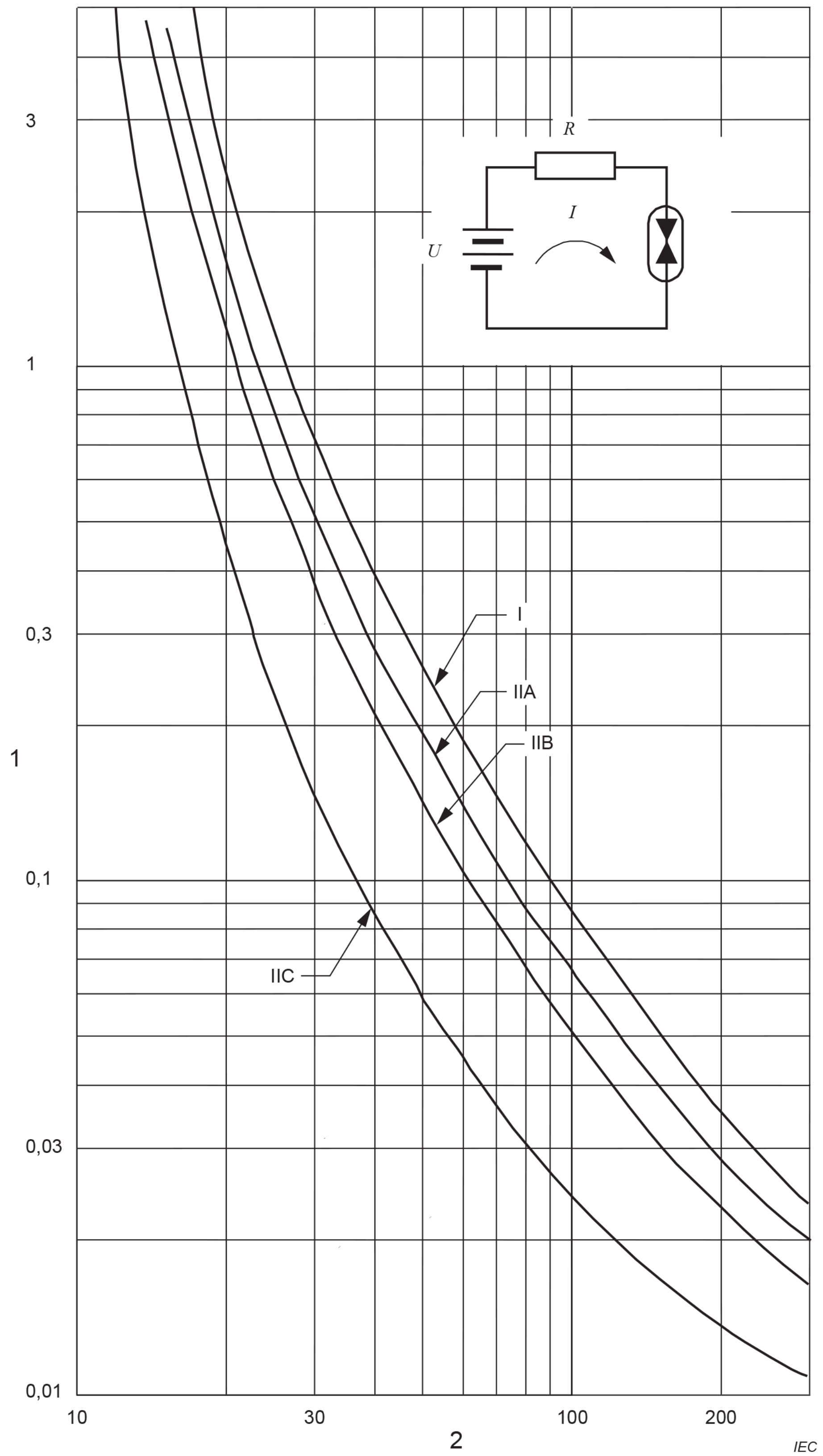
**Table 28 – Concerns addressed by Specific Conditions of Use**

| Item | Reference | Concern that can be addressed with Specific Conditions of Use |
|---|---|---|
| a) | 5.2.5 c) | The requirements which apply to equipment or systems to be connected to the connection facilities and the maximum voltage that may be applied between the non-intrinsically safe connection facilities. |
| b) | 6.2.3 c) | The restricted installation conditions. |
| c) | 6.5.3.2 | The restricted installation conditions. |
| d) | 6.2.5.1 | Only cable glands, thread adapters, and blanking elements conforming to IEC 60079-0 shall be used with the apparatus. |
| e) | 6.5.3.3 | The restricted installation conditions. |
| f) | 6.5.6.1 | The permitted ambient pressure range. |
| g) | 6.5.9.1<br>6.9 | The necessary information regarding the correct installation. |
| h) | 9.11 | The installation requirements. |

# Annex A
(normative)

## Spark ignition reference curves

The curves and tables found in this annex are derived from ignition testing of simple linear circuits. They may be applied in accordance with 9.2 when the circuit being assessed approximates the simple circuits depicted in Figure A.1 through Figure A.6 as applicable. Circuits that do not approximate the simple linear circuits shown in these figures require an alternative assessment: refer to 5.3 for additional requirements. The curves shown in Figure A.1 through Figure A.6 represent a 1,0 safety factor.

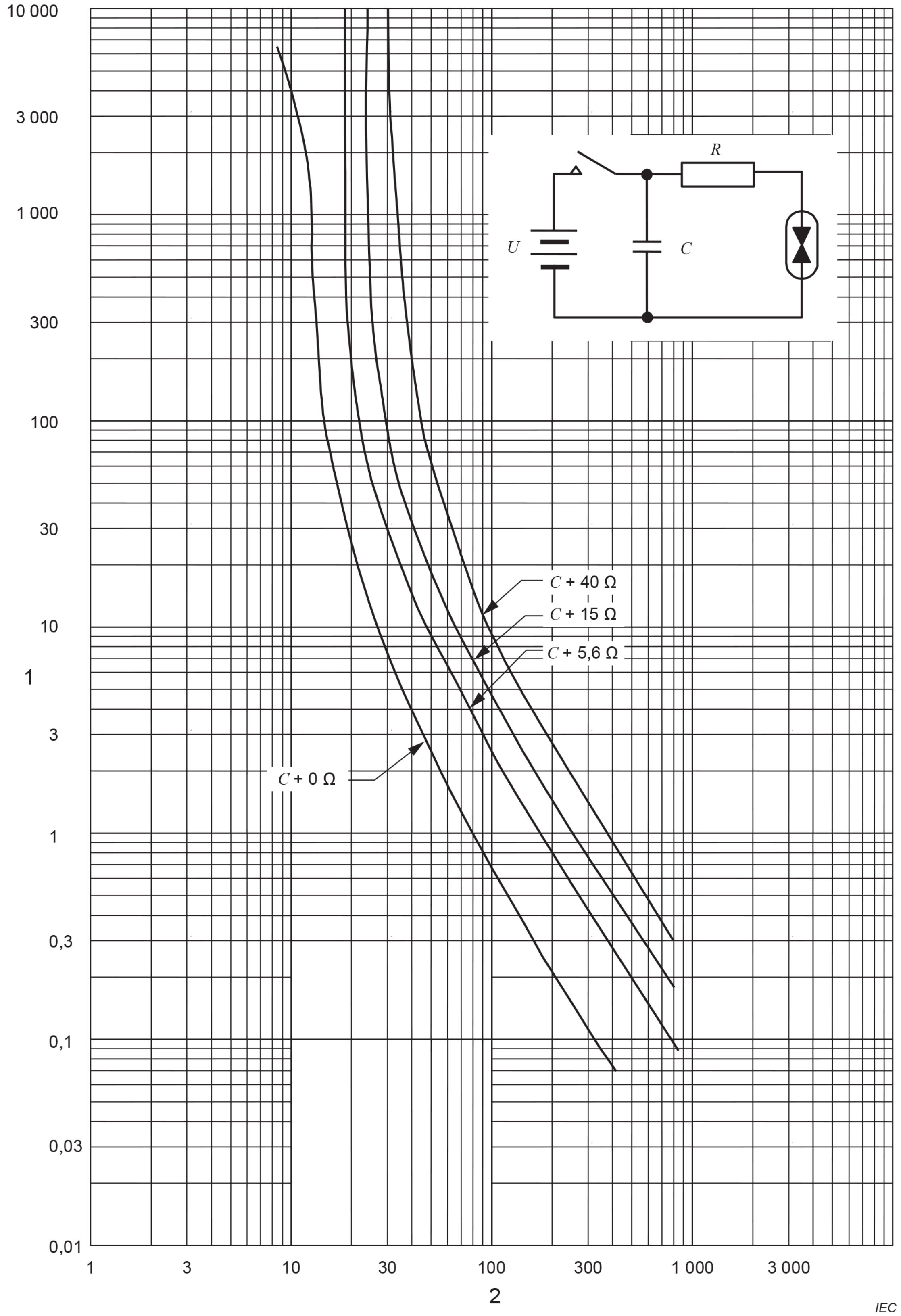



**Key**

1 Minimum ignition current $I$ (A)

2 Source voltage $U$ (V)

**Figure A.1 – Resistive circuits**



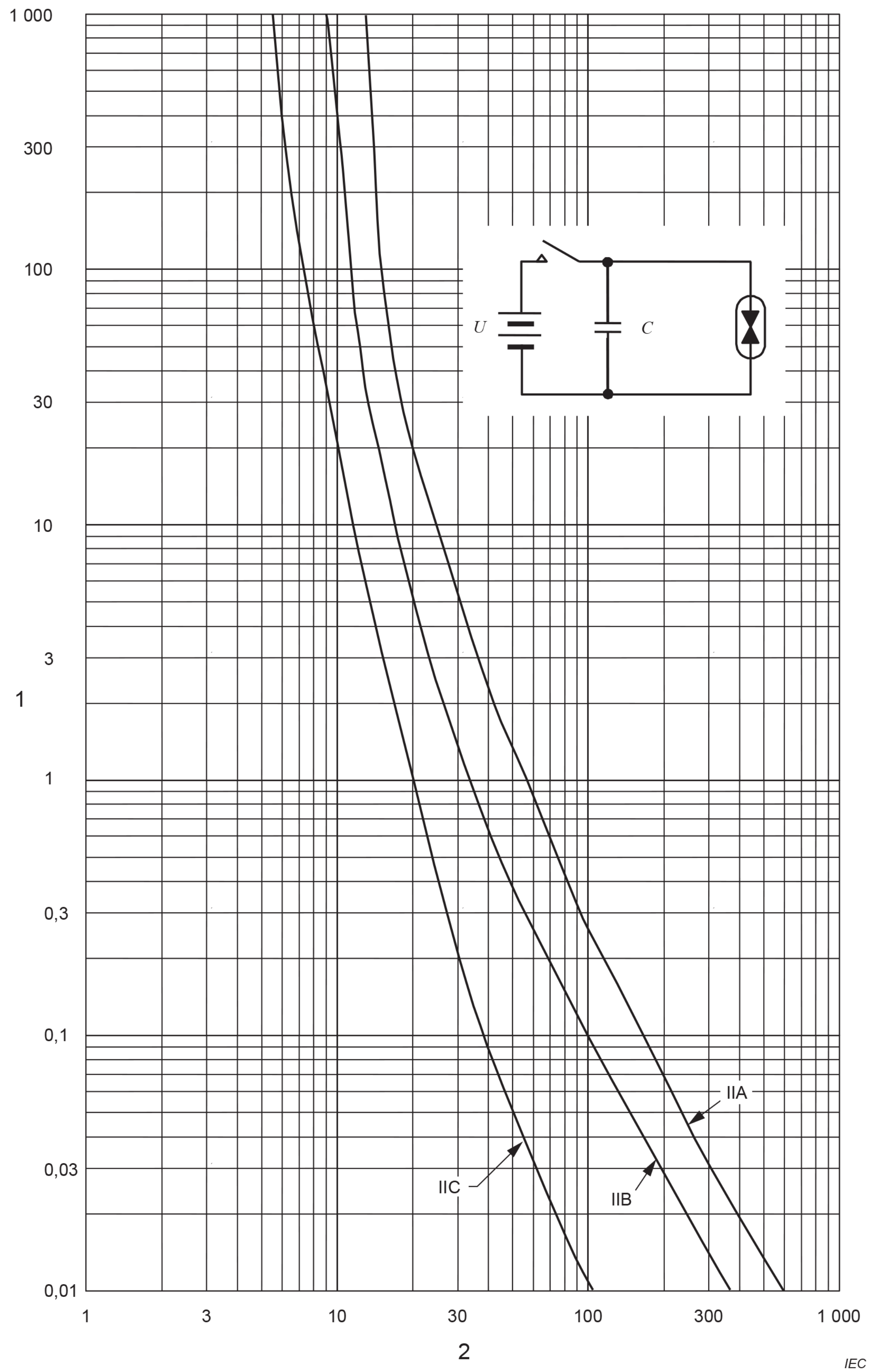

**Key**

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**

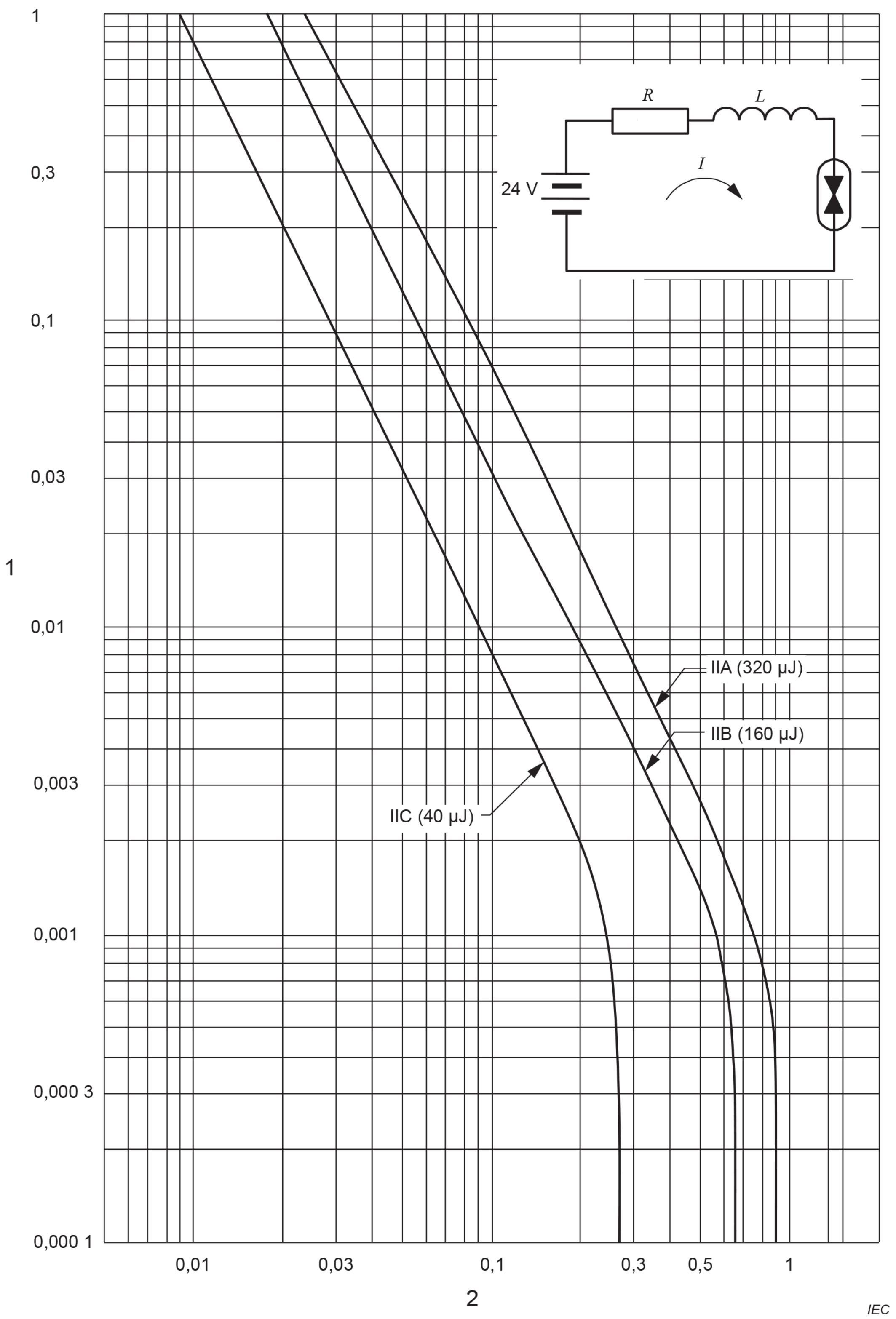



**Key**

1 Capacitance $C$ (µF)

2 Minimum igniting voltage $U$ (V)

**Figure A.3 – Group II capacitive circuits**




**Key**

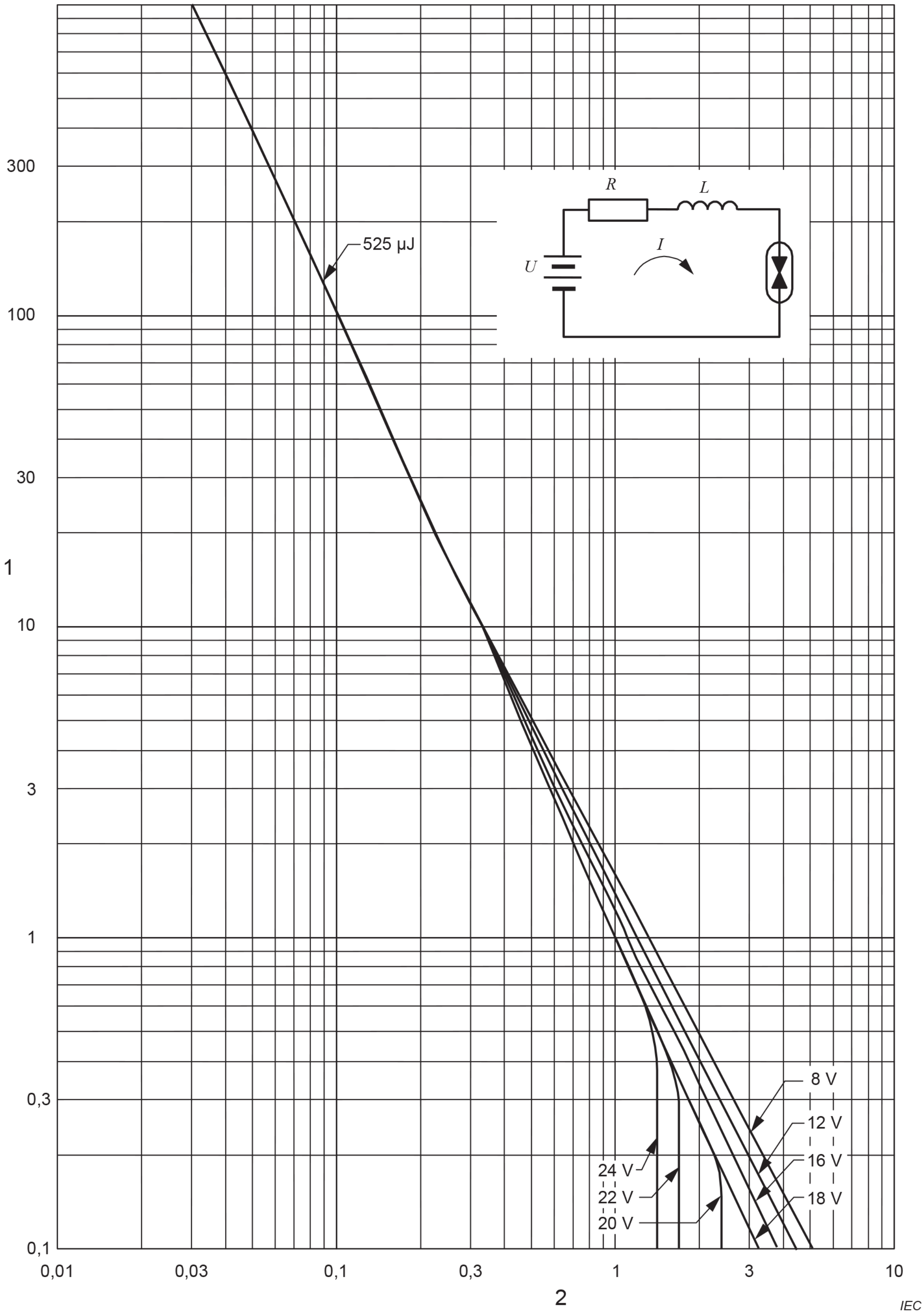
1 Inductance $L$ (H)

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**

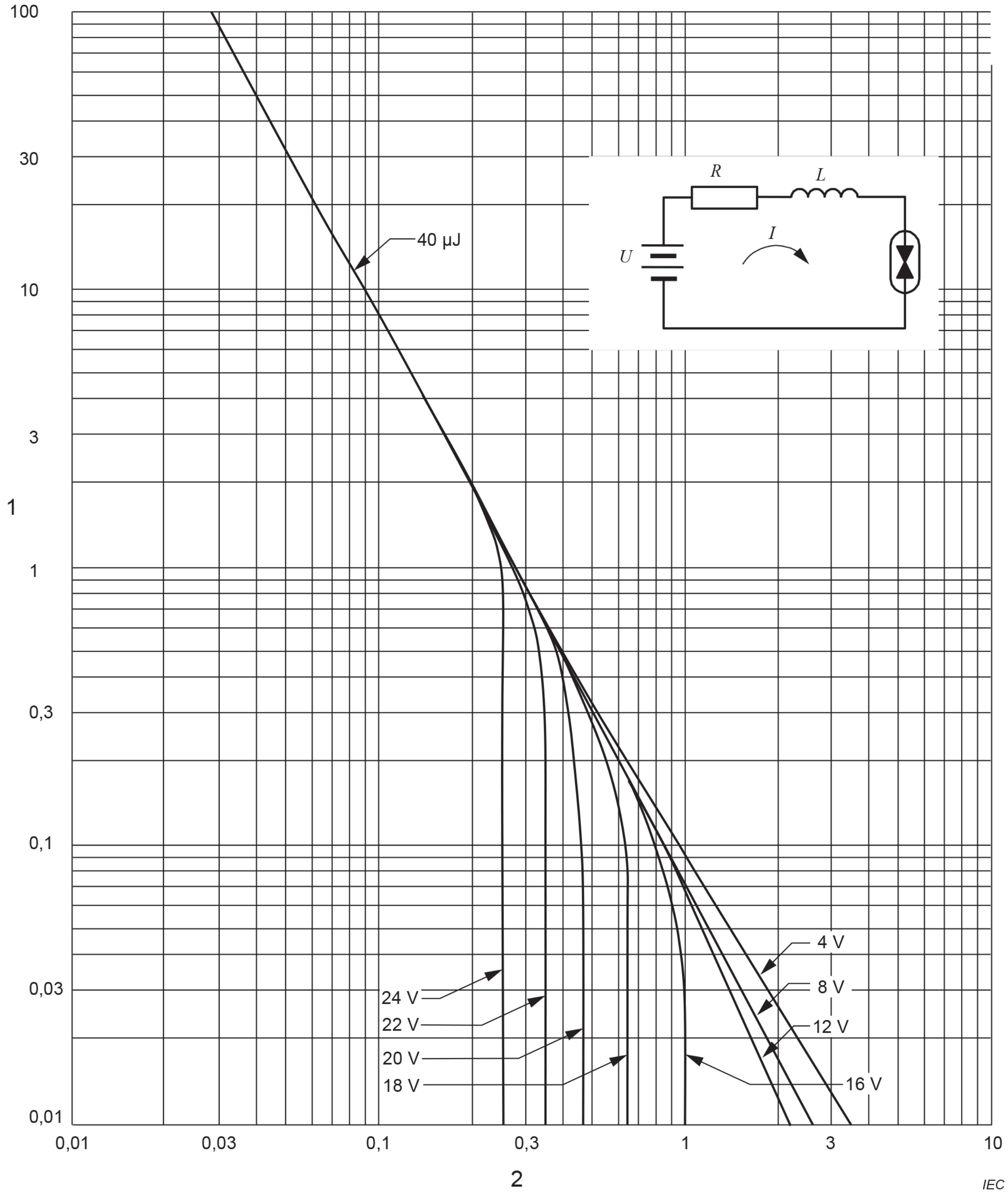
1 Inductance $L$ (mH)

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**

**Table A.1 – Permitted short circuit current corresponding to the voltage and the equipment group**

| Voltage V | Table A.1 - 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 |
| 12,0 | | | | | | | | |
| 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 | | | | | | |
| 13,0 | 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 | | | | |
| 14,0 | 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 | 3 330 | | |
| 14,9 | 1 390 | 930 | 3 380 | 2 250 | 4 860 | 3 240 | | |
| 15,0 | 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 | | |

| Voltage V | Table A.1 - 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 |
| 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 | | |
| 16,0 | 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 |
| 17,0 | 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 |
| 17,8 | 690 | 457 | 1 720 | 1 150 | 2 340 | 1 560 | 3 230 | 2 150 |
| 17,9 | 670 | 448 | 1 690 | 1 130 | 2 290 | 1 530 | 3 200 | 2 130 |
| 18,0 | 660 | 440 | 1 660 | 1 110 | 2 240 | 1 490 | 3170 | 2 110 |
| 18.1 | 648 | 432 | 1 630 | 1 087 | 2 188 | 1 459 | 3 083 | 2 055 |
| 18,2 | 636 | 424 | 1 601 | 1 068 | 2 139 | 1 426 | 3 000 | 2 000 |
| 18,3 | 625 | 417 | 1 573 | 1 049 | 2 091 | 1 394 | 2 935 | 1 956 |
| 18,4 | 613 | 409 | 1 545 | 1 030 | 2 045 | 1 363 | 2 871 | 1 914 |
| 18,5 | 602 | 402 | 1 518 | 1 012 | 2 000 | 1 333 | 2 807 | 1 871 |
| 18,6 | 592 | 394 | 1 491 | 995 | 1 967 | 1 311 | 2 743 | 1 828 |
| 18,7 | 581 | 387 | 1 466 | 977 | 1 935 | 1 290 | 2 679 | 1 786 |
| 18,8 | 571 | 380 | 1 441 | 960 | 1 903 | 1 269 | 2 615 | 1 743 |
| 18,9 | 561 | 374 | 1 416 | 944 | 1 872 | 1 248 | 2 551 | 1 700 |
| 19,0 | 551 | 367 | 1 392 | 928 | 1 842 | 1 228 | 2 487 | 1 658 |
| 19,1 | 541 | 361 | 1 368 | 912 | 1 812 | 1 208 | 2 465 | 1 643 |
| 19,2 | 532 | 355 | 1 345 | 897 | 1 784 | 1 189 | 2 444 | 1 629 |
| 19,3 | 523 | 348 | 1 323 | 882 | 1 755 | 1 170 | 2 423 | 1 615 |
| 19,4 | 514 | 342 | 1 301 | 867 | 1 727 | 1 152 | 2 401 | 1 600 |
| 19,5 | 505 | 337 | 1 279 | 853 | 1 700 | 1 134 | 2 380 | 1 586 |

| Voltage V | Table A.1 - 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 |
| 19,6 | 496 | 331 | 1 258 | 839 | 1 673 | 1 116 | 2 359 | 1 572 |
| 19,7 | 484 | 325 | 1 237 | 825 | 1 648 | 1 098 | 2 337 | 1 558 |
| 19,8 | 480 | 320 | 1 217 | 811 | 1 622 | 1 081 | 2 316 | 1 544 |
| 19,9 | 472 | 314 | 1 197 | 798 | 1 597 | 1 065 | 2 295 | 1 530 |
| 20,0 | 464 | 309 | 1 177 | 785 | 1 572 | 1 048 | 2 274 | 1 516 |
| 20,1 | 456 | 304 | 1 158 | 772 | 1 549 | 1 032 | 2 219 | 1 479 |
| 20,2 | 448 | 299 | 1 140 | 760 | 1 525 | 1 016 | 2 164 | 1 443 |
| 20,3 | 441 | 294 | 1 122 | 748 | 1 502 | 1 001 | 2 109 | 1 406 |
| 20,4 | 434 | 289 | 1 104 | 736 | 1 479 | 986 | 2 054 | 1 369 |
| 20,5 | 427 | 285 | 1 087 | 724 | 1 457 | 971 | 2 000 | 1 333 |
| 20,6 | 420 | 280 | 1 069 | 713 | 1 435 | 957 | 1 924 | 1 283 |
| 20,7 | 413 | 275 | 1 053 | 702 | 1 414 | 943 | 1 849 | 1 233 |
| 20,8 | 406 | 271 | 1 036 | 691 | 1 393 | 929 | 1 773 | 1 182 |
| 20,9 | 400 | 267 | 1 020 | 680 | 1 373 | 915 | 1 698 | 1 132 |
| 21,0 | 394 | 262 | 1 004 | 670 | 1 353 | 902 | 1 623 | 1 082 |
| 21,1 | 387 | 258 | 989 | 659 | 1 333 | 889 | 1 603 | 1 069 |
| 21,2 | 381 | 254 | 974 | 649 | 1 314 | 876 | 1 583 | 1 055 |
| 21,3 | 375 | 250 | 959 | 639 | 1 295 | 863 | 1 564 | 1 043 |
| 21,4 | 369 | 246 | 945 | 630 | 1 276 | 851 | 1 544 | 1 029 |
| 21,5 | 364 | 243 | 930 | 620 | 1 258 | 839 | 1 525 | 1 017 |
| 21,6 | 358 | 239 | 916 | 611 | 1 240 | 827 | 1 505 | 1 003 |
| 21,7 | 353 | 235 | 903 | 602 | 1 222 | 815 | 1 485 | 990 |
| 21,8 | 347 | 231 | 889 | 593 | 1 205 | 804 | 1 466 | 977,3 |
| 21,9 | 342 | 228 | 876 | 584 | 1 189 | 792 | 1 446 | 964 |
| 22,0 | 337 | 224 | 863 | 575 | 1 172 | 781 | 1 427 | 951,3 |
| 22,1 | 332 | 221 | 851 | 567 | 1 156 | 770 | 1 394 | 929,3 |
| 22,2 | 327 | 218 | 838 | 559 | 1 140 | 760 | 1 361 | 907,3 |
| 22,3 | 322 | 215 | 826 | 551 | 1 124 | 749 | 1 328 | 885,3 |
| 22,4 | 317 | 211 | 814 | 543 | 1 109 | 739 | 1 296 | 864 |
| 22,5 | 312 | 208 | 802 | 535 | 1 093 | 729 | 1 281 | 854 |
| 22,6 | 308 | 205 | 791 | 527 | 1 078 | 719 | 1 267 | 844,7 |
| 22,7 | 303 | 202 | 779 | 520 | 1 064 | 709 | 1 253 | 835,3 |
| 22,8 | 299 | 199 | 768 | 512 | 1 050 | 700 | 1 239 | 826 |
| 22,9 | 294 | 196 | 757 | 505 | 1 036 | 690 | 1 225 | 816,7 |
| 23,0 | 290 | 193 | 747 | 498 | 1 022 | 681 | 1 211 | 807,3 |
| 23,1 | 287 | 191 | 736 | 491 | 1 008 | 672 | 1 185 | 790 |
| 23,2 | 284 | 189 | 726 | 484 | 995 | 663 | 1 160 | 773,3 |
| 23,3 | 281 | 187 | 716 | 477 | 982 | 655 | 1 135 | 756,7 |
| 23,4 | 278 | 185 | 706 | 471 | 969 | 646 | 1 110 | 740 |

| Voltage<br>V | Table A.1 - Permitted short circuit current<br>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 |
| 23,5 | 275 | 183 | 696 | 464 | 956 | 638 | 1 085 | 723,3 |
| 23,6 | 272 | 182 | 687 | 458 | 944 | 629 | 1079 | 719,3 |
| 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 |
| 24,0 | 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 |
| 25,0 | 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 |
| 26,0 | 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 |
| 27,0 | 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 |

| Voltage V | Table A.1 - 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 |
| 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 |
| 28,0 | 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 |
| 29,0 | 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 |
| 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 |
| 30,0 | 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 |
| 31,0 | 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 |
| 32,0 | 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 |

| Voltage V | Table A.1 - 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 |
| 32,6 | 127 | 84,7 | 310 | 207 | 425 | 283 | 548 | 365,3 |
| 32,8 | 126 | 83,7 | 305 | 204 | 419 | 279 | 536 | 357,3 |
| 33,0 | 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 |
| 34,0 | 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 |
| 35,0 | 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 |
| 36,0 | 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 |
| 37,0 | 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 |
| 38,0 | 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 |
| 39,0 | 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 |
| 40,0 | 85,4 | 57 | 209 | 139 | 284 | 190 | 383 | 255,3 |
| 40,5 | 83,4 | 55,6 | 205 | 136 | 278 | 185 | 362 | 241,3 |

| Voltage<br>V | Table A.1 - Permitted short circuit current<br>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 |
| 41,0 | 81,4 | 54,3 | 200 | 133 | 271 | 181 | 342 | 228 |
| 41,5 | 79,6 | 53 | 196 | 131 | 265 | 177 | 336 | 224 |
| 42,0 | 77,7 | 51,8 | 192 | 128 | 259 | 173 | 331 | 220,7 |
| 42,5 | 76 | 50,6 | 188 | 125 | 253 | 169 | 321 | 214 |
| 43,0 | 74,3 | 49,5 | 184 | 122 | 247 | 165 | 312 | 208 |
| 43,5 | 72,6 | 48,4 | 180 | 120 | 242 | 161 | 307 | 204,7 |
| 44,0 | 71 | 47,4 | 176 | 117 | 237 | 158 | 303 | 202 |
| 44,5 | 69,5 | 46,3 | 173 | 115 | 231 | 154 | 294 | 196 |
| 45,0 | 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 | Table A.2 - 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 | | | | |

| Voltage V | Table A.2 - 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 |
| 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 |
| 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 |

| Voltage<br>V | Table A.2 - Permitted capacitance<br>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** |
| 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 |

| Voltage V | Table A.2 - 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 |
| 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 |
| 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 |

| Voltage<br>V | Table A.2 - Permitted capacitance<br>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 |
| 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 |
| 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 |

| Voltage V | Table A.2 - 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 |
| 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 |

| Voltage V | Table A.2 - 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 |
| 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 |
| 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 |

| Voltage V | Table A.2 - 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 |
| 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 |
| 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 |

| Voltage V | Table A.2 - 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 |
| 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 |

| Voltage<br>V | Table A.2 - Permitted capacitance<br>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 |
| 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 |

# Annex B
(normative)

# Spark test apparatus for intrinsically safe circuits

## B.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 % and that of voltages and current is ±1 %.

## B.2 Spark test apparatus

The spark test 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 spark test apparatus is shown in Figure B.4. (For the contact arrangement, see Figure B.1, Figure B.2 and Figure B.3.)

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

The spark test apparatus described in B.2 refers to the 3 A test current limited apparatus, and B.7 describes the 10 A test current limited apparatus.

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 2 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 spark test 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 between 78 r/min and 82 r/min by an electric motor, with suitable reduction gearing if necessary. The cadmium disc is turned more slowly in the opposite direction.

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

Either a counting or a timing device shall be used to determine the number of revolutions of the shaft of the electrode holder.

NOTE 3 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 bar) except where provision is made to release the explosion pressure.

At the terminals of the contact arrangement, the self-capacitance of the spark 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 DC and the self-inductance shall not exceed 3 μH with the contacts closed.

## B.3 Spark test apparatus sensitivity

When the sensitivity is not as specified, one or more of the following may be conducted 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 9.1.3 and run the spark test apparatus with the contacts in air for 20 000 revolutions of the electrode holder;
f) replace the cadmium disc and calibrate the spark test apparatus in accordance with 9.1.3.

## B.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.

   NOTE 1 When prepared in this way, it is found that, on average, the contact wires have to be changed after about 12 500 revolutions.

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 2 It is advantageous to remove the electrode holder from the spark test apparatus when cleaning the wires.

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.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 9.1.3 and operate the test apparatus with air in the chamber and the contacts mounted in accordance with Figure B.1 for a minimum of 20 000 revolutions of the electrode holder;

c) fit new tungsten wires prepared and cleaned in accordance with B.4 and connect the spark 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 9.1.3.1, 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.6 Limitations of the spark test apparatus

Except as permitted by B.7, the use of the spark test apparatus shall be limited to the testing of intrinsically safe circuits with the following parameters:

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

The spark test apparatus may be successfully applied to circuits exceeding these limits but variations in sensitivity might occur.

If the test current exceeds 3 A, the temperature rise and cadmium coating of the tungsten wires might lead to additional ignition effects invalidating the test result.

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

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 test apparatus during the required number of revolutions. Such circuits shall be modified for the test to deliver the worst-case output conditions throughout the test.

NOTE For the test of such circuits Annex D and Annex F provide further information.

## B.7 Modification of spark test apparatus for use at higher currents

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

The tungsten wires shall be 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.

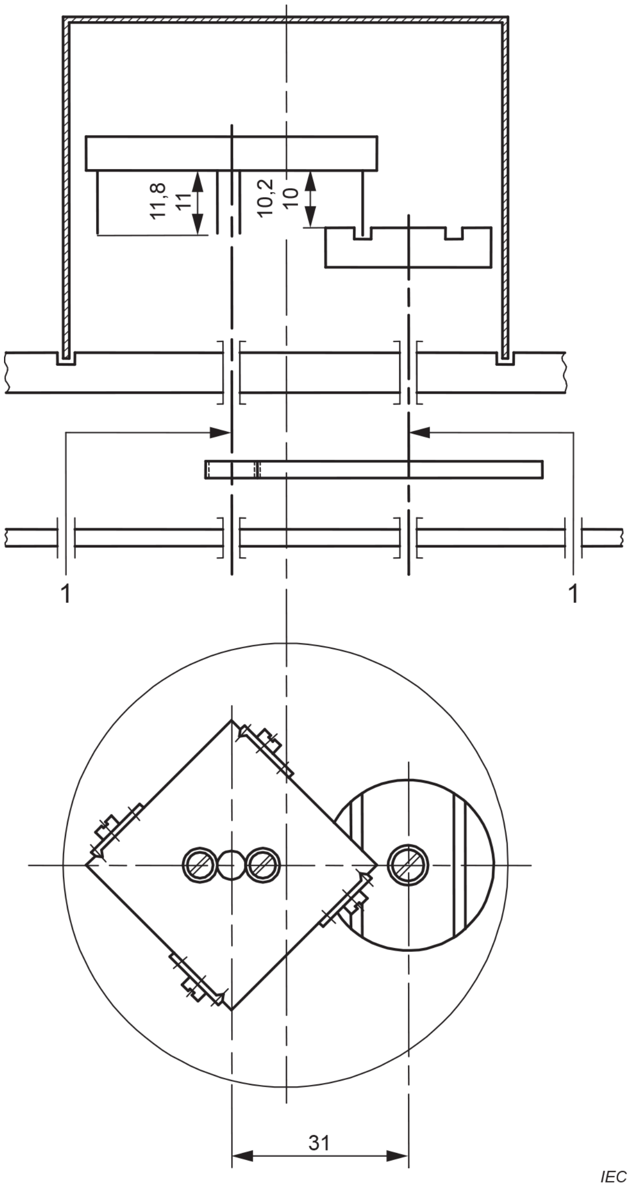
The total resistance of the spark test apparatus including the commutation contact resistance shall be reduced to less than 100 mΩ or the circuit under test shall be modified to compensate for the internal resistance of the spark test apparatus.

NOTE 2 Brushes of the type used in the automobile industry combined with brass sleeves on the spark test 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 spark test apparatus and the inductance of the interconnection to the circuit under test shall be minimized. A maximum value of 1 μH shall be achieved.

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

Dimensions in millimetres




**Key**

1 Connection for circuit under test

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

Dimensions in millimetres

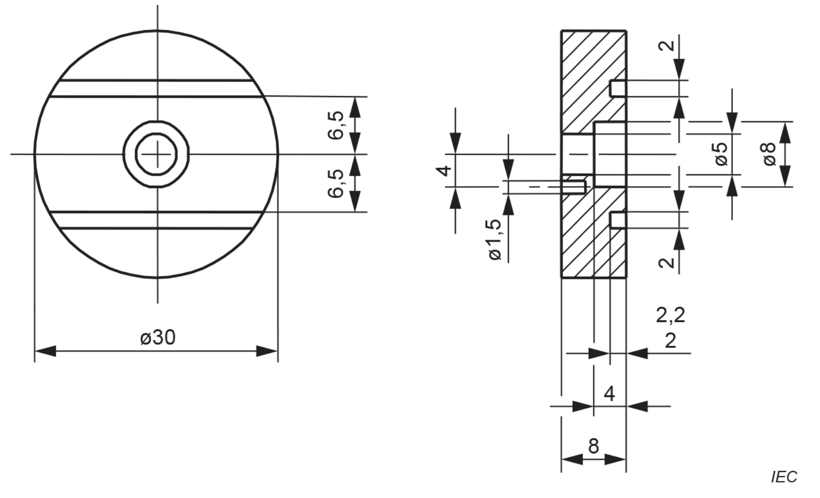



**Figure B.2 – Cadmium contact disc**

Dimensions in millimetres

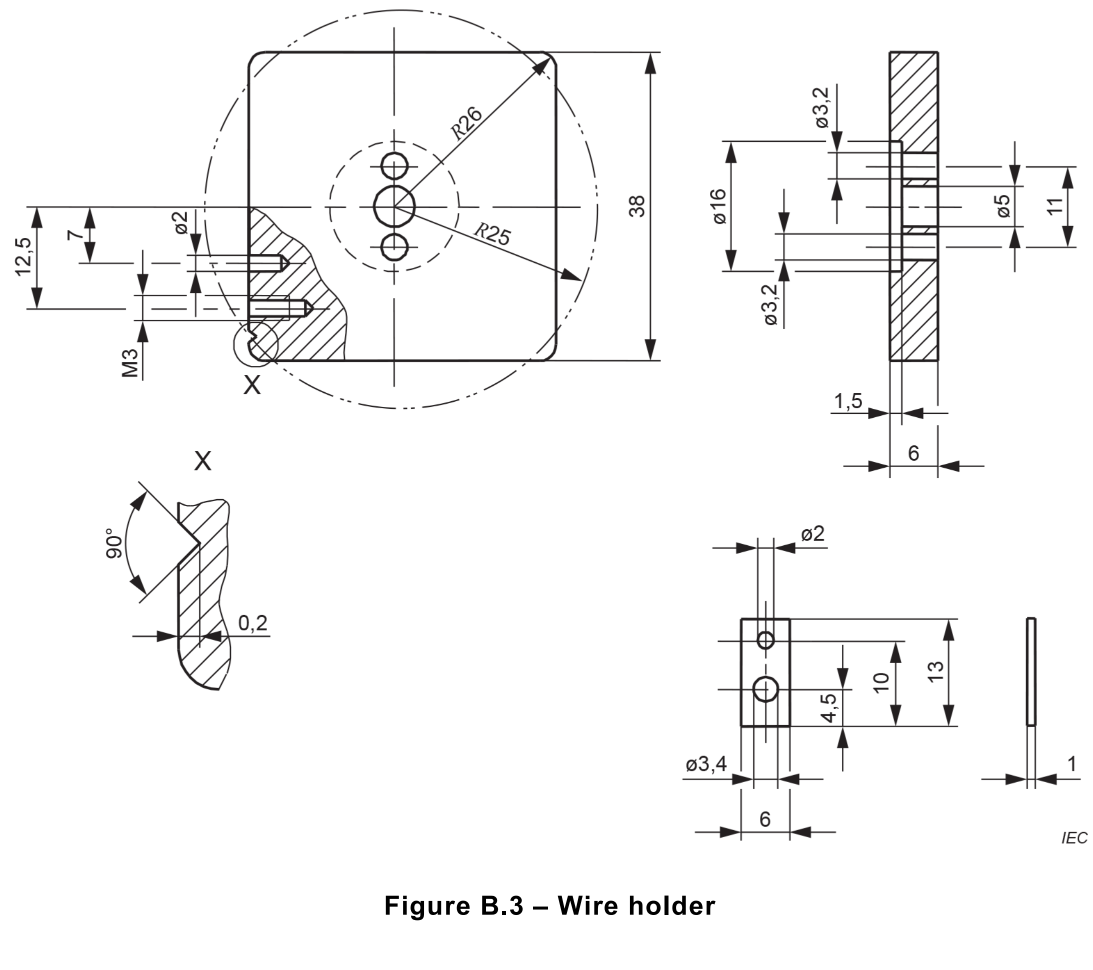
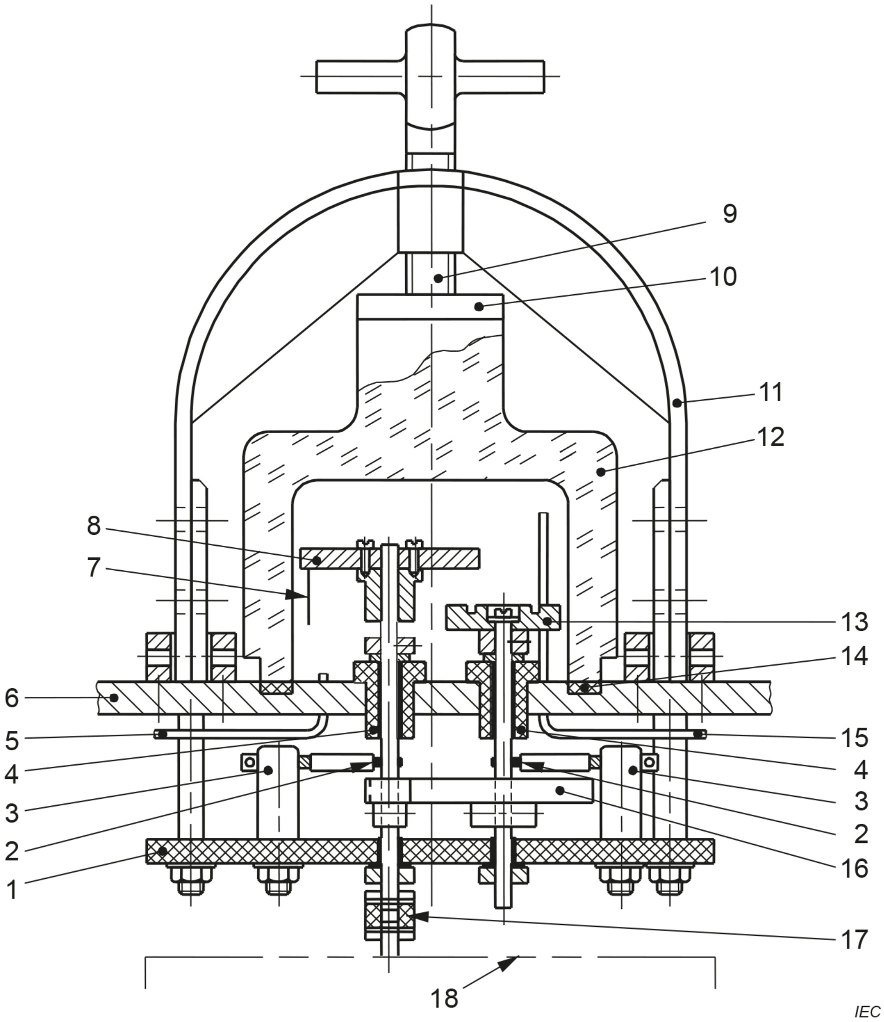



**Figure B.3 – Wire holder**

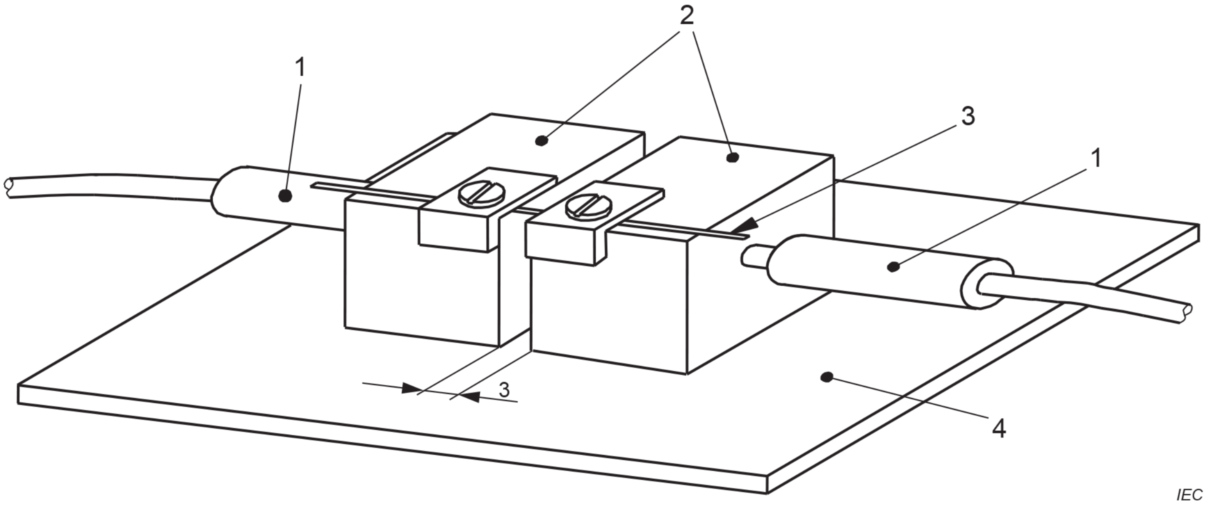



**Key**

| | |
|---|---|
| 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**

Dimensions in millimetres




**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**

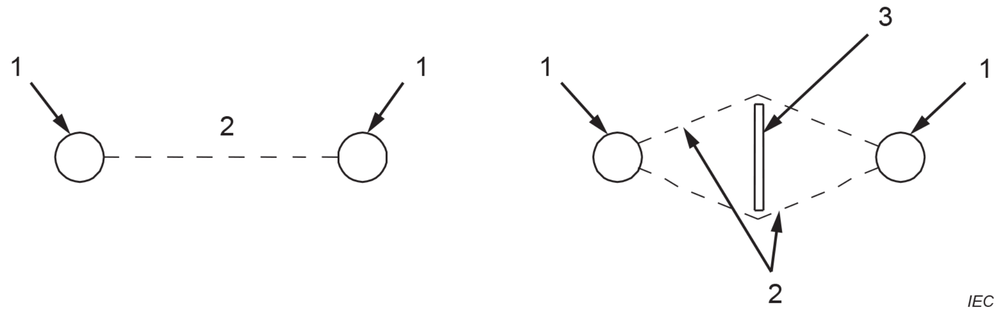
# Annex C
(informative)

# 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 6.5.5.

The clearance is taken as the shortest distance in air between two conductive parts. Where there is an insulating part according to this standard, for example an insulating partition conforming to 6.5.10, 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**

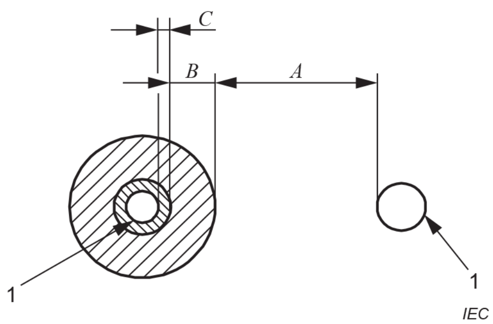
1 Conductor

2 Clearance

3 Insulating partition

**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 7, Table 8 or Table 9 as applicable.




**Key**

1 Conductor

*A* Clearance

*B* separation distance through casting compound

*C* Separation through solid insulation

**Figure C.2 – Measurement of composite distances**

In Figure C.2, if A is less than the applicable value of Table 7, the distances that make up the composite separation should be converted to a percentage of their appropriate figure in Table 7. Any percentage less than 33,3 % should be ignored, the rest added. If the result is 100 % or more then the separation is infallible.

For Levels of Protection "ia" and "ib", If the result is between 33,3 % and 100 % then failure of the separation is a countable fault. For Level of Protection "ic", if the result is less than 100 % then the separation is not permitted to be used to maintain intrinsic safety.

For example, if the separation voltage is 25 V, and distances are A = 1,0 mm, B = 0,25 mm and C = 0,2 mm then the calculation is as follows:

| | | | |
|---|---|---|---|
| A | = (1,0 mm / 2,0 mm) × 100 % | = | 50,0 % |
| B | = (0,25 mm / 0,7 mm) × 100 % | = | 35,7 % |
| C | = (0,2 mm / 0,5 mm) × 100 % | = | 40,0 % |
| Total | | = | 125,7 % |

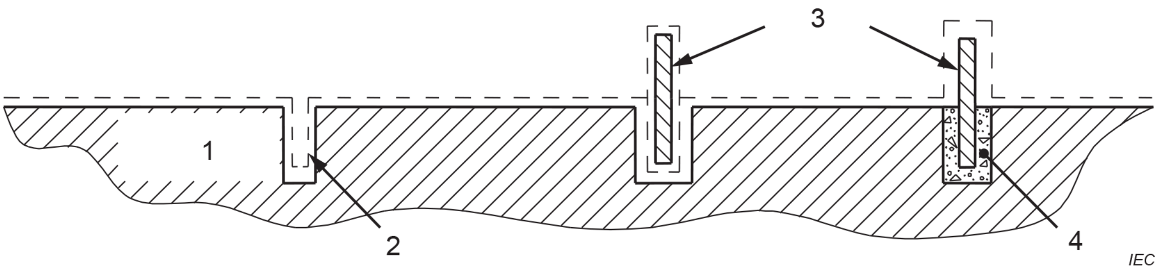
As this is greater than 100 %, the separation is infallible.

A similar consideration can be used for Table 8 and Table 9 but applying the requirements from 6.5.7 for Table 8 and Table 9 instead of the requirements for Table 7.

## C.2 Creepage distances

The voltage to be used is determined in accordance with 6.5.5.

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




**Key**

1 Substrate

2 Groove

3 Insulating partition

4 Cement

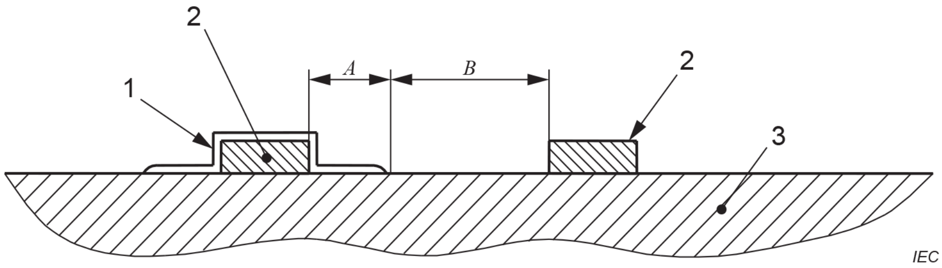
**Figure C.3 – Measurement of creepage**

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 width of the groove is at least the applicable value for $X$ in accordance with 6.5.6.4;

b) where an insulating partition conforming to 6.5.10 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 Conformal coating

2 Conductor

3 Substrate

A Distance under conformal coating

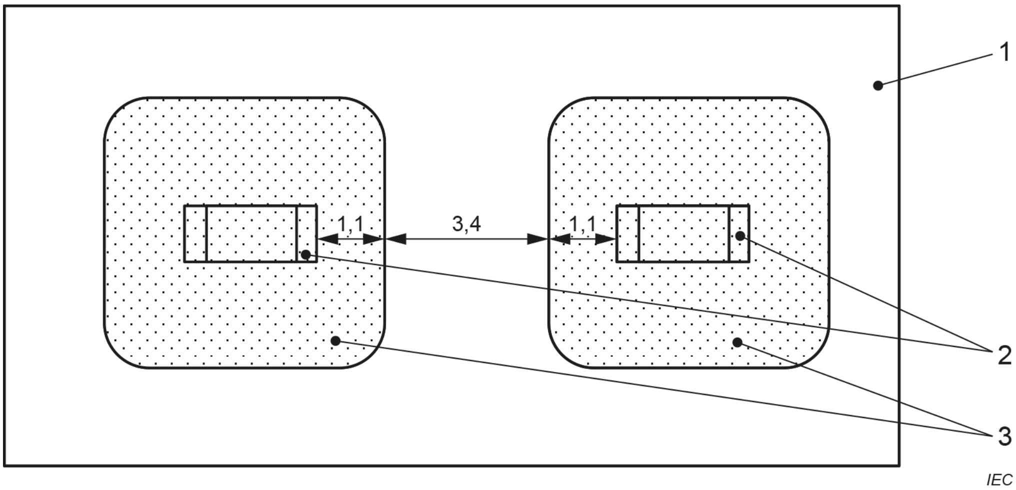
B Distance with no coating

**Figure C.4 – Composite separation including creepage**

When conformal coating is used to reduce the required creepage distances, and only part of the separation distance is coated as shown in Figure C.4, the total effective separation is calculated by calculating the percentage of distance *A* of the appropriate value in column 6 of Table 7 (or column 4 or 5 of Table 8, or column 4 Table 9), calculating the percentage of distance *B* of the appropriate value in column 5 (or column 3 of Table 8 or Table 9), and adding the two percentages together.

## C.3 Examples for the application of an ambient pressure correction factor

Dimensions in millimetres




**Key**

1 PCB

2 Electrical component

3 Coating

**Figure C.5 – PCB with two coated components designed for ambient pressure 60 kPa to 110 kPa**

The following assumes an ambient pressure range of 60 kPa to 110 kPa, a voltage of 375 V between the two components, and Level of Protection "ia" or "ib.

Distances with reference to Table 7:

| | |
|---|---|
| Clearance for 80 kPa to 110 kPa | 6,0 mm |
| Clearance for 60 kPa to 110 kPa = 6,0 mm × 1,34 | 8,0 mm |
| Creepage distance | 10,0 mm |
| Distance under coating | 3,3 mm |

For Figure C.5:

Distance under coating consists of two distances of 1,1 mm, which are both ≥ ⅓ of 3,3 mm so can be used as composite separation.

The 3,4 mm is both composite clearance and creepage. Since the allowed creepage distance is greater than the allowed clearance, the 3,4 mm need only be considered as a clearance.

Clearance of 3,4 mm is ≥ ⅓ of 8,0 mm so can be used as composite separation.

So overall composite separation with 3.4 mm as clearance is:

distance under coating / 3,3 mm + clearance / 8,0 mm

= (1,1 + 1,1) / 3,3 + 3,4 / 8,0 = 109,1 %.

Creepage of 3,4 mm is ≥ ⅓ of 10,0 mm so can be used as composite separation.

So overall composite separation with 3.4 mm as creepage is:

distance under coating / 3,3 mm + creepage / 10,0 mm

= (1,1 + 1,1) / 3,3 + 3,4 / 10,0 = 100,6 %.

Hence this passes the assessment.

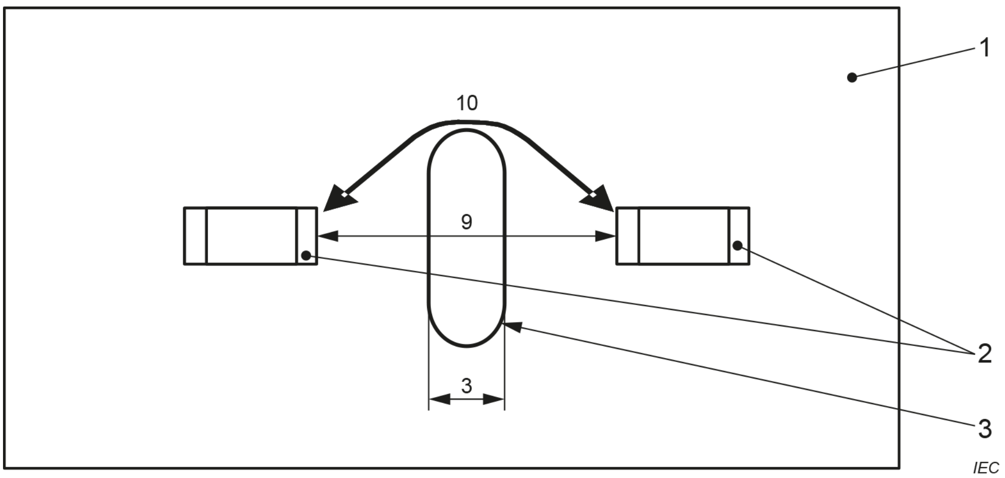
For Figure C.6:

Clearance of 9,0 mm is greater than the allowed 8,0 mm.

Creepage distance 10,0 mm is equal to the allowed distance.

Hence this passes the assessment.

Dimensions in millimetres




**Key**

1 PCB

2 Electrical component

3 Slot

NOTE The two electrical components belong to different electrical circuits to be separated for voltages up to 375 $V_{peak}$.

**Figure C.6 – PCB with 3 mm slot designed for ambient pressure 60 kPa to 110 kPa**

EXAMPLE

Creepage in accordance with Table 7 or Table 8: 10 mm

Clearance in accordance with Table 7 or Table 8: 6 mm × 1,34 = 8,04 mm (with 1,34 factor for associated apparatus in pressure range 60 kPa to 110 kPa)

# Annex D
(normative)

# Excess transient energy test

## D.1 Overview

Annex D defines the analysis and measurements required to establish that, during the time that controlled semiconductor current or voltage limitation takes to respond to changes in the supply or load, the energy released in the spark is sufficiently unlikely to cause an ignition, considering the applicable EPL, output characteristics, equipment group and safety factor.

Measurement of transient output energy should follow the guidance in this annex as closely as is practical, taking into account that it provides generic recommendations which may not be suitable in all cases. The search for the maximum transient energy can take a large number of tests with different load and source combinations. This testing should be kept to a practical limit taking into consideration the margin of safety found and the Level of Protection required. The maximum transient output energy under the conditions specified in 5.2 can be affected by variations in manufacturing tolerances, voltage, current, response time, thresholds, timing of semiconductors, applied faults and loads, and temperature. The representative circuit and the test setup should take reasonable measures to apply the most incendive values within these tolerances.

The measurement is of the transient energy out from a power supply into an intrinsically safe load. It does not include energy that might be available from the load, hence the position of the current probe in Figure D.1. For example, a short circuit of the output of the supply might include energy from both the supply and the load, but only the energy from the supply is considered in the analysis and measurement.

Although the tests require repeating with different sources and loads, there is no requirement to repeat these tests on more than one circuit.

Consideration should be given to the transient response to two types of changes that can cause the controlled semiconductor limitation to activate: a change in the supply to the circuit (upstream), and a change to the load (downstream). Normally a change to the supply is required for controlled semiconductor voltage limitation, and a change to the load is required for controlled semiconductor current limitation. However, both should be considered for all circuits as, for example, an open-circuit fault in the load can cause a voltage regulator in the circuit under test to overshoot and exceed the steady state voltage limit.

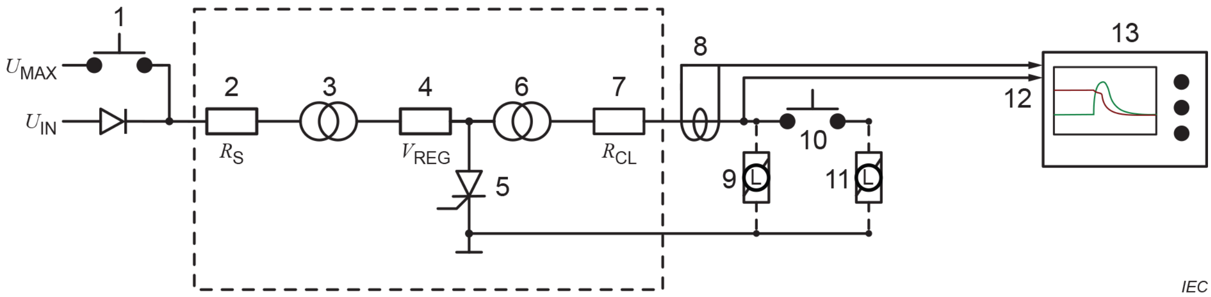
Table D.1 provides the energy limits considered as sufficiently unlikely to cause an ignition for the particular equipment group.

**Table D.1 – Energy limits by equipment group**

| Equipment Group | Transient energy |
|---|---|
| Group I | 260 μJ |
| Group IIA | 160 μJ |
| Group IIB | 80 μJ |
| Group IIC | 20 μJ |
| Group III | 80 μJ |

## D.2 Circuit configuration

Figure D.1 provides a combined representation of possible circuit configurations and test setup for both supply change test (D.6) using switch (1) and load change test (D.7) using switch (10). Where a circuit does not correlate to this configuration, a suitable alternative test setup should be used.




**Key**

1 supply change test switch

2 $R_S$, supply source resistance (if any)

3 semiconductor controlled series or shunt current limit for intrinsic safety (may have redundancy)

4 voltage regulator which may be for functional purposes or intrinsic safety

5 shunt voltage limitation, either controlled semiconductor, or diode clamp

6 semiconductor controlled current limit for intrinsic safety (may have redundancy)

7 $R_{CL}$, output resistor at the lowest resistance defined by the scheduled drawings

8 current probe

9 permanent load (which may include $L$ and $C$ as applicable)

10 load change test switch

11 switched load (which may include $L$ and $C$ as applicable)

12 voltage probe

13 oscilloscope

Items within the dotted line that are not present in the circuit under test or need to be omitted under fault conditions should not be included.

**Figure D.1 – Example circuit configuration**

Additional parameters referenced in this annex are as follows:

$U_{MAX}$ is the maximum voltage that the supply to the circuit under test could be subjected to under the conditions specified in 5.2.

$U_{IN}$ is the nominal voltage for the test prior to the application of a change to the supply. During tests, lower values of $U_{IN}$ might be required to establish the worst-case energy measurement.

$U_{LIM}$ is the maximum controlled or uncontrolled voltage limitation provided at (5) used for the steady state assessment of 5.3.6. At connection facilities, $U_o = U_{LIM}$

$I_{LIM}$ is the maximum controlled or uncontrolled current limitation provided at (3) or (6) used for the steady state assessment of 5.3.6. At connection facilities, $I_o = I_{LIM}$

$P_{LIM}$ is the peak power of the permitted steady state output characteristic of the circuit taking into account the required safety factor

A controlled semiconductor limitation circuit may be designed to have lower voltage or current trip points than the voltage or current limits used for the steady state assessment of 5.3.6.

EXAMPLE Where $U_{LIM}$ is determined as 12 V for a voltage triggered crowbar, in production the crowbar can be designed to trigger at a maximum of 11 V and hence there is 1 V margin before the $U_{LIM}$ is exceeded. This can provide stability of the circuit in the field.

Where controlled semiconductor limitation circuits use redundancy to comply with the countable fault requirements of 5.2, and where interaction between redundant circuits might invalidate the tests, they should be repeated with the redundant circuits both enabled and disabled. Other than this consideration of redundant circuits, it is not necessary to apply more countable faults than required by 5.2 when considering faults in both the supply and load.

Components that are present for functional reasons and on which intrinsic safety does not depend should be either left in or removed from the circuit depending on which produces the most onerous result of the test. For example, the voltage regulator at (4) might be considered a short circuit under the conditions specified in 5.2, and hence should be replaced with a short circuit for the test. $U_{IN}$ would then be set accordingly to provide the range of voltage outputs possible from the regulator.

## D.3 Test equipment

The tests require the capability to measure the current and voltage at a frequency of at least 100 MHz. A digital storage oscilloscope (13) with a bandwidth of at least 100 MHz. The oscilloscope is typically capable of producing a trace of the product of two channels and of integration between user defined points in time. If these functions are not available, then they may be calculated by other means.

The output current should be measured using a galvanically isolated oscilloscope current probe or clamp (8) of suitable bandwidth and the output voltage measured using a voltage probe (12) with an impedance of at least 1 MΩ.

NOTE The suitability of the bandwidth of the current probe can be determined by comparison with the rise time of the measured current signal.

The oscilloscope should be set to trigger from a suitable point on either the current or voltage channel as applicable for the test. The oscilloscope should be set to record sufficient pre-trigger time to ensure that the whole of the excess transient energy is included in the assessment of the result.

Switching of source voltage (1) or load (10) should be made with a non-bouncing switching device such as a MOSFET or mercury switch which has a sufficient switching speed. This should be verified from the switching profile once the test has been run.

EXAMPLE A switching device that switches within 5% of the time that would be required for the transient operation of the circuit is suitable for this test.

The voltage across the switching device when in the on state should be limited to avoid interference with the result of the test. This can be achieved either by a low on-state resistance or low saturation voltage to ensure that the switching device voltage is less than 5 % of the applied voltage, or for supply change tests, by increasing $U_{MAX}$ to compensate for the switch voltage.

## D.4 Test load

Test loads for connection at the output of the circuit under test (9) and (11) should be selected to produce the maximum energy in the output transient during the test, and this normally requires experimentation. The type and size of the loads will vary depending on the circuit and its input conditions. For example, this could be any combination of:

a) a Zener diode with an avalanche voltage of the next available voltage below $U_{LIM}$;

b) a resistor;

c) the capacitance or inductance for the circuit (for example, including $C_o$ and $L_o$ at connection facilities);

d) constant current loads.

Steady state loads (9) should not cause activation of any voltage or current limitation prior to the closing of the fault simulating switch (1) or (10).

## D.5 Supply voltage

The steady state supply voltage ($U_{IN}$) should be representative of the supply under the conditions specified in 5.2, including the source resistance ($R_S$) and any inductance or capacitance. This may be based on a bench top power supply. The voltage should be varied during the test from 0 V to the highest voltage available to the circuit, or the highest voltage that does not cause a voltage limiter under test (5) to operate, whichever is lower.

For the supply change test, the fault voltage ($U_{MAX}$) can be supplied from a benchtop power supply and should be varied during the test as the maximum transient energy might occur with $U_{MAX}$ set anywhere between $U_{IN}$ and the maximum supply voltage to the circuit under the conditions specified in 5.2.

EXAMPLES

– for associated apparatus $U_{MAX}$ might be voltages up to $U_m$

– the most onerous condition might be a short circuit of a voltage regulator at (4)

– the most onerous condition might be due to the failure of a control circuit operating where the output is from the secondary side of a transformer, and the control signal varies the drive of the primary.

## D.6 Supply change tests

For a test of the response to a change in the supply, the fault voltage ($U_{MAX}$) should be switched into the circuit using the non-bouncing switching device (1) and the voltage across the load and current through the load recorded over time by the oscilloscope.

Variation of combinations of both steady state and fault voltages ($U_{IN}$, $U_{MAX}$) as well as the load (9) should be considered.

For Levels of Protection "ia" and "ib", test conditions should include measuring the transient output energy during both power up and power down of the equipment. This requires de-energising the steady state voltage ($U_{IN}$).

## D.7 Load change tests

For a test of the response to a change in the load, the steady state load at (9) should be modified by switching the modifying load (11) into or out of the circuit using the load switch (10). The voltage across the load and total current in the combined loads (9) and (11) should be recorded over time by the oscilloscope.

Different combinations of various steady state voltages ($U_{IN}$ up to $U_{LIM}$), and steady state loads (9) should be considered with the transient load (11).

## D.8 Transient energy calculation

Figure D.2 provides examples of output waveforms measured during a load change test of a controlled semiconductor current limitation circuit.

a) For series-controlled semiconductor current limitation in Levels of Protection "ia", the energy determined during the time $t$ when $U_{LIM}$ or $I_{LIM}$ are exceeded should be within the values in Table D.1 (see Figure D.2a).

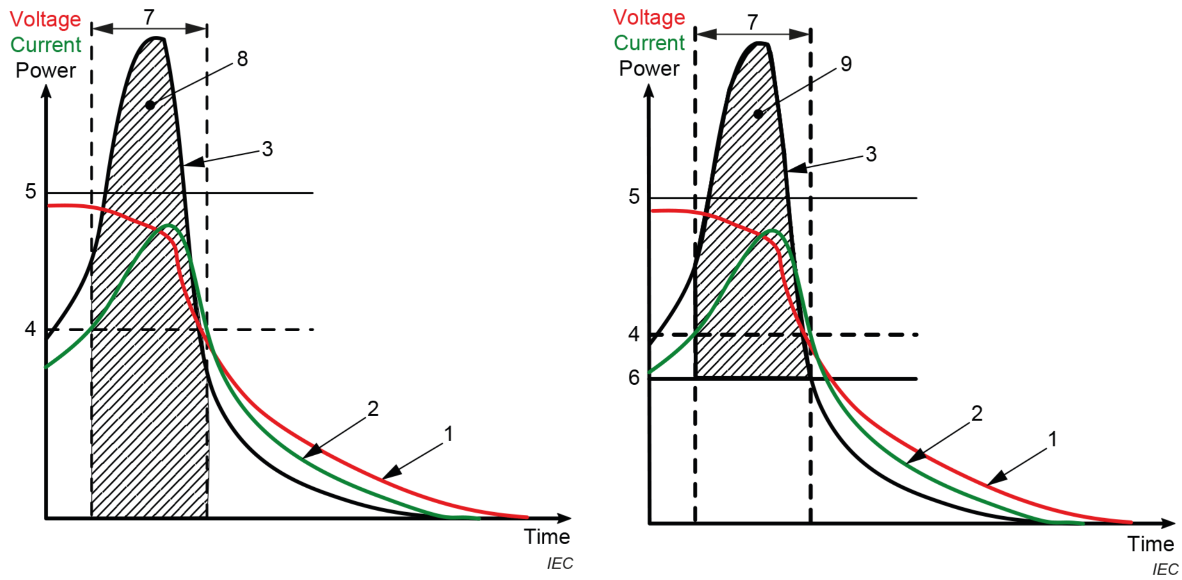
   Where it can be demonstrated that intrinsic safety is maintained, higher energy limits may be used.

   EXAMPLE The transfer of an assessment of an equivalent circuit verified by means of the spark test apparatus.

b) For circuits other than a), the energy in excess of that derived from $P_{LIM}$ (see Figure D.2b) determined during the time $t$ when $U_{LIM}$ or $I_{LIM}$ are exceeded should be within the values in Table D.1.

   NOTE As there is limited information on the spark ignition risk presented by a transient during controlled semiconductor limitation, ongoing work might result in future editions in energy limits that are not related to the steady state power, hence result in less permitted transient energy.

Where there is ringing, the time $t$ can comprise more than one section.




a – Example total transient output energy

b – Example excess transient energy output

**Key**

1 Measured output voltage

2 Measured load current

3 Measured output power (Voltage x Current on oscilloscope

4 $I_{LIM}$

5 $U_{LIM}$

6 $P_{LIM}$

7 Time $t$

8 Transient output energy is given by this area.

9 Excess transient output energy is given by this area.

**Figure D.2 – Example output voltage, current, power and energy measured during a load transient**

# Annex E
(normative)

# FISCO – Apparatus requirements

## E.1 Overview

Annex E contains the details of the construction of apparatus for use with the 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 document 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. 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 E.1.

## E.2 Apparatus requirements

### E.2.1 General

Apparatus shall be constructed in accordance with this document 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.

### E.2.2 FISCO power supplies

#### E.2.2.1 General

The power supply shall either be resistive limited or have a trapezoidal or rectangular output characteristic. The maximum output voltage $U_o$ shall be in the range 14 V to 17,5 V under the conditions specified in this document 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.

#### E.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 document but shall not exceed 380 mA. For rectangular supplies, Table E.1 may be used for assessment.

**Table E.1 – Assessment of maximum output current for use with "ia" and "ib" FISCO rectangular supplies**

| $U_o$<br>V | Permissible current, for IIC (includes 1,5 safety factor)<br>mA | Permissible current, for IIB (includes 1,5 safety factor)<br>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.

### E.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 document. For "ic" FISCO rectangular supplies Table E.2 may be used for assessment.

**Table E.2 – Assessment of maximum output current for use with "ic" FISCO rectangular supplies**

| $U_o$<br>V | Permissible current, for IIC<br>mA | Permissible current, for IIB<br>mA |
|---|---|---|
| 14 | 274 | 570 |
| 15 | 199 | 531 |
| 16 | 154 | 432 |
| 17 | 121 | 360 |
| 17,5 | 112 | 319 |
| NOTE The maximum output power $P_o$ from "ic" FISCO power supplies is not restricted. | | |

## E.3 FISCO field devices

### E.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 document;
c) the bus terminals of separately powered field devices shall be galvanically isolated from other sources of power in accordance with this document, 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 document 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 Group I, IIC or III or any combination of these groups; and

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.

#### E.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; and

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

#### E.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.

#### E.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.

The terminator shall;

a) be allocated a Level of Protection;

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

   i) Group IIC terminators intended to be installed within the hazardous area shall be temperature classified;

   ii) Group III terminators intended to be installed in the hazardous area shall be allocated a maximum surface temperature;

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

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

e) be isolated from earth in accordance with this document; and

f) have a maximum unprotected internal inductance $L_i$ not greater than 10 µH.

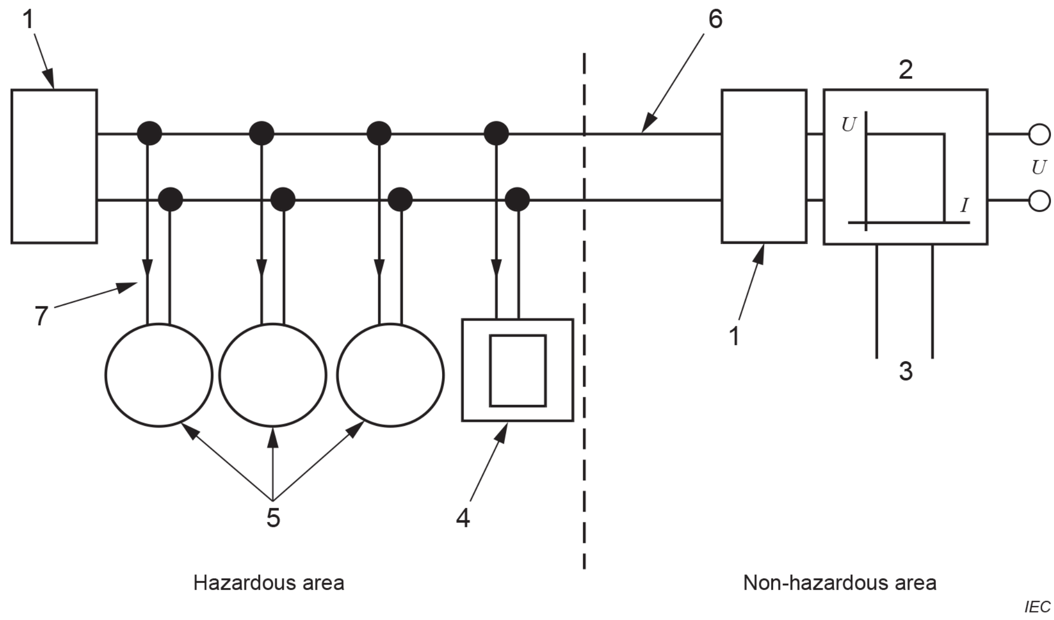
NOTE 2 The terminators may be incorporated within field devices or power supplies.

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.

#### E.3.5 Simple apparatus

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

NOTE For a Levels of Protection "ia" or "ib" the maximum power available can be as high as 5,32 W, which could invalidate the assumption about temperature rise in 5.5 6).




**Key**

1 FISCO Terminator

2 FISCO Power supply

3 Data

4 FISCO Handheld terminal (HHT)

5 FISCO Field devices

6 Trunk

7 Spur

**Figure E.1 – Typical FISCO system**

# Annex F
(normative)

# Ignition testing of semiconductor limiting power supply circuits

## F.1 Overview

For the purposes of this annex, the probability of ignition shall be considered to be the number of ignitions divided by the number of sparks during a test sequence. No account is taken of the resulting margin of error.

This annex provides a test procedure for spark ignition testing of the intrinsically safe outputs of power supplies with controlled semiconductor limitation. It is based on using the spark test apparatus of Annex B with at least three gas mixtures with increased safety factors to determine a probability of ignition with the target gas of less than $1,16 \times 10^{-6}$. It is not intended for use where the safety factor is applied to the voltage or current.

For the purposes of this annex, the term 'power supply' is a generic term for all circuits that provide power. This includes dedicated power supply equipment, internal current regulators or voltage enhancement circuits, and circuits for which providing power is not the primary function.

This annex is suitable for both semiconductor current and voltage limited power supplies that limit or shut off the current when the current or voltage limit is exceeded but recover to normal operation sufficiently rapidly between each break of contact of the spark test apparatus and the following make. This annex is not suitable for supplies for which the recovery time cannot be sufficiently reduced for the purpose of the test.

## F.2 Initial test

There shall be an initial test of 400 revolutions of the power supply under test using test gas mixture providing a safety factor of 1,5 as specified in 9.1.3.2 where there shall be no ignitions observed.

## F.3 Subsequent tests

There shall be at least three tests of the power supply under test using the sequence described in Table F.2. Further such tests may be performed using gas mixtures with additional safety factors if required.

Table F.3 provides examples of suitable gas mixtures, together with the corresponding calibrating currents using the standard 24 V, 95 mH calibrating circuit.

Table F.1 provides definitions of terms to apply when using Table F.2:

**Table F.1 – Terms used in Annex F**

| Term | Definition |
|---|---|
| DUT | The power supply under test modified as necessary to meet the requirements of 5.2, and with the recovery time reduced as necessary to ensure full recovery between each break and the following make during the tests. |
| Simple reference circuit | A circuit consisting of a laboratory power supply and a low-inductance series resistor.<br>The laboratory power supply has its voltage set to the maximum output voltage of the DUT under the conditions specified in 5.2 (for example, $U_o$).<br>The resistor sets the short circuit current to be equal to the maximum continuous current that can be supplied by the DUT (for example, $I_o$). |

## F.4 Examples of pass and fail

Table F.4 is an example of a circuit that passes the test sequence of Table F.2. The plot of this circuit is provided in Figure F.1, labelled 'Pr – Table F.4 – PASS'. When the plot of this circuit is compared with the plot for a simple reference circuit, labelled 'Pr – Simple Reference 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 reference circuit, and therefore has an acceptably low figure as the safety factor would drop to unity.

Table F.5 is an example of a circuit that does not pass the test sequence of Table F.2. The plot of this circuit is provided in Figure F.1, labelled 'Pr – Table F.5 – FAIL'. When the plot of this circuit is compared with the plot for a simple reference circuit, labelled 'Pr – Simple Reference 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 reference circuit, and therefore it does not slope to an acceptably low figure as the safety factor would drop to unity.

**Table F.2 – Sequence of tests**

| Step | Description | Column 'x' | Column 'y' | Column 'z' |
|---|---|---|---|---|
| 1 | Target safety factor for test | 1,5 | 1,67 to 2,0 | 2,0 to 2,5 |
| 2 | Calculate target calibration current for 24 V 95 mH calibration circuit | $\frac{\text{(Calibration current from Table 23)}}{\text{(Step 1 target safety factor)}}$ | $\frac{\text{(Calibration current from Table 23)}}{\text{(Step 1 target safety factor)}}$ | $\frac{\text{(Calibration current from Table 23)}}{\text{(Step 1 target safety factor)}}$ |
| 3 | Record test gas used | Use Table F.3 if useful | Use Table F.3 if useful | Use Table F.3 if useful |
| 4 | Measure calibration current achieved using 24 V 95 mH calibration circuit | Measure using 24V 95 mH calibration circuit | Measure using 24V 95 mH calibration circuit | Measure using 24V 95 mH calibration circuit |
| 5 | Calculate safety factor achieved (should be within range specified in Step 1) | $SFx = \frac{\text{(Calibration current from Table 23)}}{\text{(Current achieved at step 4)}}$ | $SFy = \frac{\text{(Calibration current from Table 23)}}{\text{(Current achieved at step 4)}}$ | $SFz = \frac{\text{(Calibration current from Table 23)}}{\text{(Current achieved at step 4)}}$ |
| 6 | Number of revolutions to apply for test | 4 000 | 400 | 40 |
| 7 | Number of sparks assumed for number of revolutions in step 6 | 16 000 | 1 600 | 160 |
| 8 | Measure number of ignitions when DUT tested for number of revolutions in step 6 | *Nx* | *Ny* | *Nz* |
| 9 | Calculate number of ignitions per spark obtained for DUT | $Px = \frac{Nx}{16\,000}$ | $Py = \frac{Ny}{1\,600}$ | $Pz = \frac{Nz}{160}$ |
| 10 | Review 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 | Measure number of ignition when simple reference circuit tested for number of revolutions in step 6. | *Na* | *Nb* | *Nc* |
| 12 | Calculate number of ignitions per spark obtained for the simple reference circuit | $Pa = \frac{Na}{16\,000}$ | $Pb = \frac{Nb}{1\,600}$ | $Pc = \frac{Nc}{160}$ |
| 13 | Review compliance result | The DUT has passed if all three of the following conditions are met:<br>1) $(\log Px) \leq (\log Pa)$, or $Px \leq Pa$<br>2) $(\log Py - \log Px) \geq (\log Pb - \log Pa)$, or $\frac{Py}{Px} \geq \frac{Pb}{Pa}$<br>3) $\frac{(\log Py - \log Px)}{(\log SFy - \log SFx)} \geq \frac{(\log Pz - \log Py)}{(\log SFz - \log SFy)}$, or $\left(\frac{Py}{Px}\right)^{\log\frac{SFz}{SFy}} \geq \left(\frac{Pz}{Py}\right)^{\log\frac{SFy}{SFx}}$ | | |

**Table F.3 – Safety factor provided by several explosive test mixtures that may be used for the tests in Table F.2**

| | **Compositions of explosive test mixtures,** % by volume in the air | **Current in the calibration circuit,** mA | **Safety factor for equipment group and subgroup** | | | |
|---|---|---|---|---|---|---|
| | | | **I** | **IIA** | **IIB** | **IIC** |
| | (8,3 ± 0,3) % methane | 110 to 111 | 1,00 | | | |
| | (5,25 ± 0,25) % propane | 100 to 101 | 1,089 to 1,11 | 1,00 | | |
| | (52 ± 0,5) % hydrogen | 73 to 74 | 1,49 to 1,52 | 1,35 to 1,38 | | |
| | (48 ± 0,5) % hydrogen | 66 to 67 | 1,64 to 1,68 | 1,49 to 1,53 | | |
| | (7,8 ± 0,5) % ethylene | 65 to 66 | 1,67 to 1,70 | 1,52 to 1,55 | 1,00 | |
| | (38 ± 0,5) % hydrogen | 43 to 44 | 2,05 to 2,58 | 2,27 to 2,35 | 1,47 to 1,53 | |
| | (21 ± 2) % hydrogen | 30,0 to 30,5 | 3,60 to 3,70 | 3,27 to 3,36 | 2,13 to 2,20 | 1,00 |
| | (60 ± 0,5) % hydrogen/ (40 ± 0,5) % oxygen | 20,0 to 21,0 | 5,23 to 5,55 | 4,76 to 5,05 | 3,09 to 3,30 | 1,42 to 1,53 |
| | (70 ± 0,5) % hydrogen/ (30 ± 0,5) % oxygen under the pressure of 0,22 MPa | 15,0 to 15,3 | - | - | - | 1,96 to 2,03 |

**Table F.4 – Example of a Group I circuit with characteristics described by 'Pr – Table F.4 – PASS' of Figure F.1**

| Step | Description | Column 'x' | Column 'y' | Column 'z' |
|---|---|---|---|---|
| 1 | Target safety factor for test | 1,5 | 1,67 to 2,0 | 2,0 to 2,5 |
| 2 | Calculate target calibration current for 24 V 95 mH calibration circuit | $\frac{110\ \text{mA}}{1,5} = 73\ \text{mA}$ | $\frac{110\ \text{mA}}{1,67\ \text{to}\ 2,0} = 55\ \text{to}\ 66\ \text{mA}$ | $\frac{110\ \text{mA}}{2,0\ \text{to}\ 2,5} = 44\ \text{to}\ 55\ \text{mA}$ |
| 3 | Record test gas used | 52 % $H_2$, 48 % air | 48 % $H_2$, 52 % air | 38 % $H_2$, 62 % air |
| 4 | Measure calibration current achieved using 24 V 95 mH calibration circuit | 73 mA | 66 mA | 44 mA |
| 5 | Calculate safety factor achieved (should be within range specified in Step 1) | $SFx = \frac{110\ \text{mA}}{73\ \text{mA}} = 1,5$ Okay<br>Log $SFx$ = 0,176 | $SFy = \frac{110\ \text{mA}}{66\ \text{mA}} = 1,67$ Okay<br>Log $SFy$ = 0,223 | $SFz = \frac{110\ \text{mA}}{44\ \text{mA}} = 2,5$ Okay<br>Log $SFz$ = 0,398 |
| 6 | Number of revolutions to apply for test | 4 000 | 400 | 40 |
| 7 | Number of sparks assumed for number of revolutions in step 6 | 16 000 | 1 600 | 160 |
| 8 | Measure number of ignitions when DUT tested for number of revolutions in step 6 | $Nx$ = 1 ignition | $Ny$ = 9 ignitions | $Nz$ = 80 ignitions |
| 9 | Calculate number of ignitions per spark obtained for DUT | $Px = \frac{1}{16\,000} = 6,25 \times 10^{-5}$<br>Log $Px$ = -4,204 | $Py = \frac{9}{1\,600} = 5,6 \times 10^{-3}$<br>Log $Py$ = -2,252 | $Pz = \frac{80}{160} = 5,0 \times 10^{-1}$<br>Log $Pz$ = -0,301 |
| 10 | Review possible compliance result | $Px \neq 0$, $Py \neq 0$ and $Pz \neq 0$, therefore continue to step 11 | | |
| 11 | Measure number of ignition when simple reference circuit tested for number of revolutions in step 6. | $Na$ = 10 ignitions | $Nb$ = 3 ignitions | $Nc$ = 32 ignitions |
| 12 | Calculate number of ignitions per spark obtained for the simple reference circuit | $Pa = \frac{10}{16\,000} = 6,25 \times 10^{-4}$<br>Log $Pa$ = -3,204 | $Pb = \frac{3}{1\,600} = 1,88 \times 10^{-3}$<br>Log $Pb$ = -2,726 | $Pc = \frac{32}{160} = 2,0 \times 10^{-1}$<br>Log $Pc$ = -0,699 |
| 13 | Review compliance result | The DUT has passed because:<br>1) (log $Px$) ≤ (log $Pa$)? Yes as -4,204 < -3,204<br>2) (log $Py$ – log $Px$) ≥ (log $Pb$ – log $Pa$) ? Yes as (-2,252 + 4,204 = 1,952) > (-2,726 + 3,204 = 0,478)<br>3) $\frac{(\log Py - \log Px)}{(\log SFy - \log SFx)} \geq \frac{(\log Pz - \log Py)}{(\log SFz - \log SFy)}$ ? Yes as $\left(\frac{(-2,252 + 4,204)}{(0,223 - 0,176)} = 41,868\right) \geq \left(\frac{(-0,301 + 2,252)}{(0,398 - 0,223)} = 11,133\right)$ | | |

NOTE This passes the test sequence of Table F.2

**Table F.5 – Example of a Group I circuit with characteristics described by 'Pr – Table F.5 – FAIL' of Figure F.1**

| Step | Description | Column 'x' | Column 'y' | Column 'z' |
|---|---|---|---|---|
| 1 | Target safety factor for test | 1,5 | 1,67 to 2,0 | 2,0 to 2,5 |
| 2 | Calculate target calibration current for 24 V 95 mH calibration circuit | $\frac{110\text{ mA}}{1,5} = 73\text{ mA}$ | $\frac{110\text{ mA}}{1,67\text{ to }2,0} = 55\text{ to }66\text{ mA}$ | $\frac{110\text{ mA}}{2,0\text{ to }2,5} = 44\text{ to }55\text{ mA}$ |
| 3 | Record test gas used | 52 % $H_2$, 48 % air | 48 % $H_2$, 52 % air | 38 % $H_2$, 62 % air |
| 4 | Measure calibration current achieved using 24 V 95 mH calibration circuit | 73 mA | 66 mA | 44 mA |
| 5 | Calculate safety factor achieved (should be within range specified in Step 1) | $SFx = \frac{110\text{ mA}}{73\text{ mA}} = 1,5$ Okay<br>Log $SFx$ = 0,176 | $SFy = \frac{110\text{ mA}}{66\text{ mA}} = 1,67$ Okay<br>Log $SFy$ = 0,223 | $SFz = \frac{110\text{ mA}}{44\text{ mA}} = 2,5$ Okay<br>Log $SFz$ = 0,398 |
| 6 | Number of revolutions to apply for test | 4 000 | 400 | 40 |
| 7 | Number of sparks assumed for number of revolutions in step 6 | 16 000 | 1 600 | 160 |
| 8 | Measure number of ignitions when DUT tested for number of revolutions in step 6 | $Nx$ = 6 ignitions | $Ny$ = 1 ignition | $Nz$ = 1 ignition |
| 9 | Calculate number of ignitions per spark obtained for DUT | $Px = \frac{6}{16\,000} = 3,75 \times 10^{-4}$<br>Log $Px$ = -3,426 | $Py = \frac{1}{1\,600} = 6,25 \times 10^{-4}$<br>Log $Py$ = -3,204 | $Pz = \frac{1}{160} = 6,25 \times 10^{-3}$<br>Log $Pz$ = -2,204 |
| 10 | Review possible compliance result | $Px \neq 0$, $Py \neq 0$ and $Pz \neq 0$, therefore continue to step 11 | | |
| 11 | Measure number of ignition when simple reference circuit tested for number of revolutions in step 6. | $Na$ = 10 ignitions | $Nb$ = 3 ignitions | $Nc$ = 32 ignitions |
| 12 | Calculate number of ignitions per spark obtained for the simple reference circuit | $Pa = \frac{10}{16\,000} = 6,25 \times 10^{-4}$<br>Log $Pa$ = -3,204 | $Pb = \frac{3}{1\,600} = 1,88 \times 10^{-3}$<br>Log $Pb$ = -2,726 | $Pc = \frac{32}{160} = 2,0 \times 10^{-1}$<br>Log $Pc$ = -0,699 |
| 13 | Review compliance result | The DUT has not passed because:<br>1) (log $Px$) ≤ (log $Pa$) ? Yes as -3,426 < -3,204<br>2) (log $Py$ – log $Px$) ≥ (log $Pb$ – log $Pa$) ? No as (-3,204 + 3,426 = 0,222) is not greater than (-2,726 + 3,204 = 0,478)<br>3) $\frac{(\log Py - \log Px)}{(\log SFy - \log SFx)} \geq \frac{(\log Pz - \log Py)}{(\log SFz - \log SFy)}$ ? No as $\left(\frac{(-3,204 + 3,426)}{(0,223 - 0,176)} = 4,758\right)$ is not greater than $\left(\frac{(-2,204 + 3,204)}{(0,398 - 0,223)} = 5,707\right)$ | | |
| NOTE This does not pass the test sequence of Table F.2 | | | | |

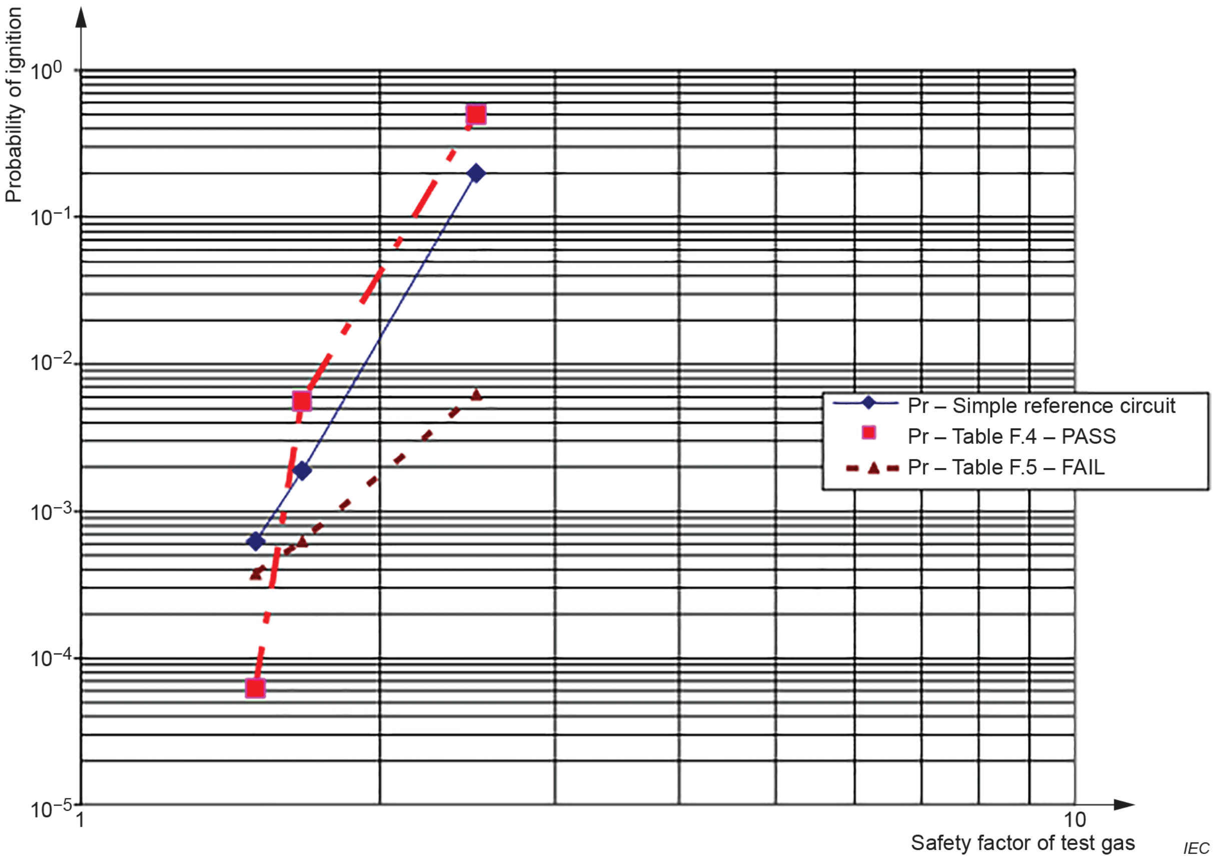



**Figure F.1 – Safety factor vs ignition probability**

# Annex G
(normative)

# Universal output characteristics

## G.1 Overview

Annex G describes a curve based method to replace spark testing as part of spark ignition assessment of intrinsically safe sources of power.

Curves are provided for Groups IIB and IIC. Groups I, IIA and III may use the curves for Group IIB as a conservative demonstration of intrinsic safety. The curves in Figure G.1, Figure G.2 and Figure G.3 represent a 1,5 safety factor.

NOTE The curves in this annex are identical to those in IEC 60079-25. However, they are used in this document for a different purpose. The restriction of their use in IEC 60079-25 to Level of Protection "ib" does not apply to the use of these curves in this document.

## G.2 Linear source

The successful application of this annex for linear sources of power shall have their maximum voltage within the limit curve for linear source from the applicable diagram from Figure G.2 or Figure G.3.

## G.3 Non-linear source

The successful application of this annex for non-linear sources of power (for example, rectangular or trapezoidal output characteristic) requires three assessments:

a) The output characteristic curve shall be fully within the limit curve for rectangular source from the applicable diagram from Figure G.2 or Figure G.3. The solid blue line of Figure G.1 provides an example of an output characteristic for Group IIC.
b) The point on the applicable diagram representing the maximum voltage and maximum current shall be within the limit curve for linear source from the applicable diagram from Figure G.2 or Figure G.3. The dashed blue line of Figure G.1 provides an example of this point relating to the solid blue output characteristic.
c) The maximum short circuit current, capacitance and inductance shall be the smaller of the values derived from the above or from Annex A.

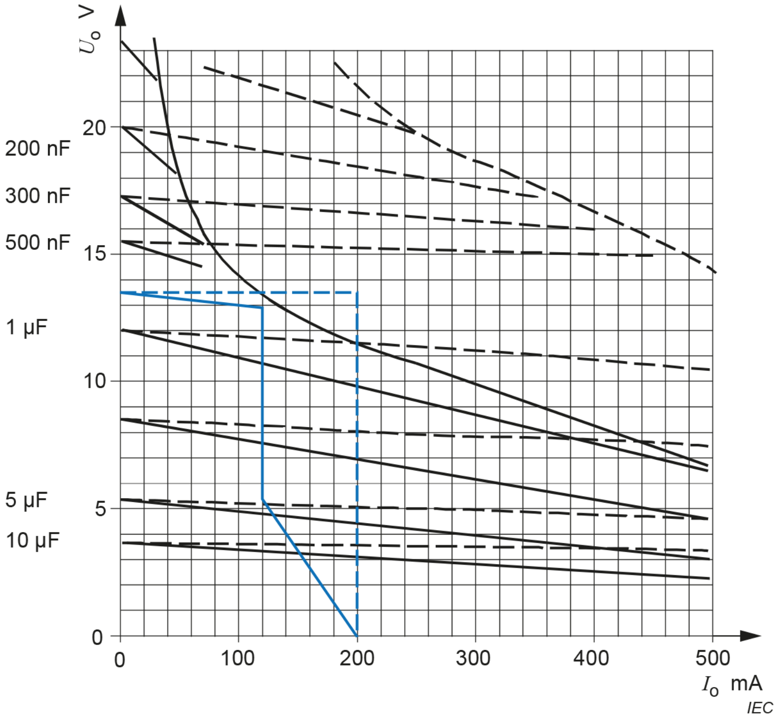
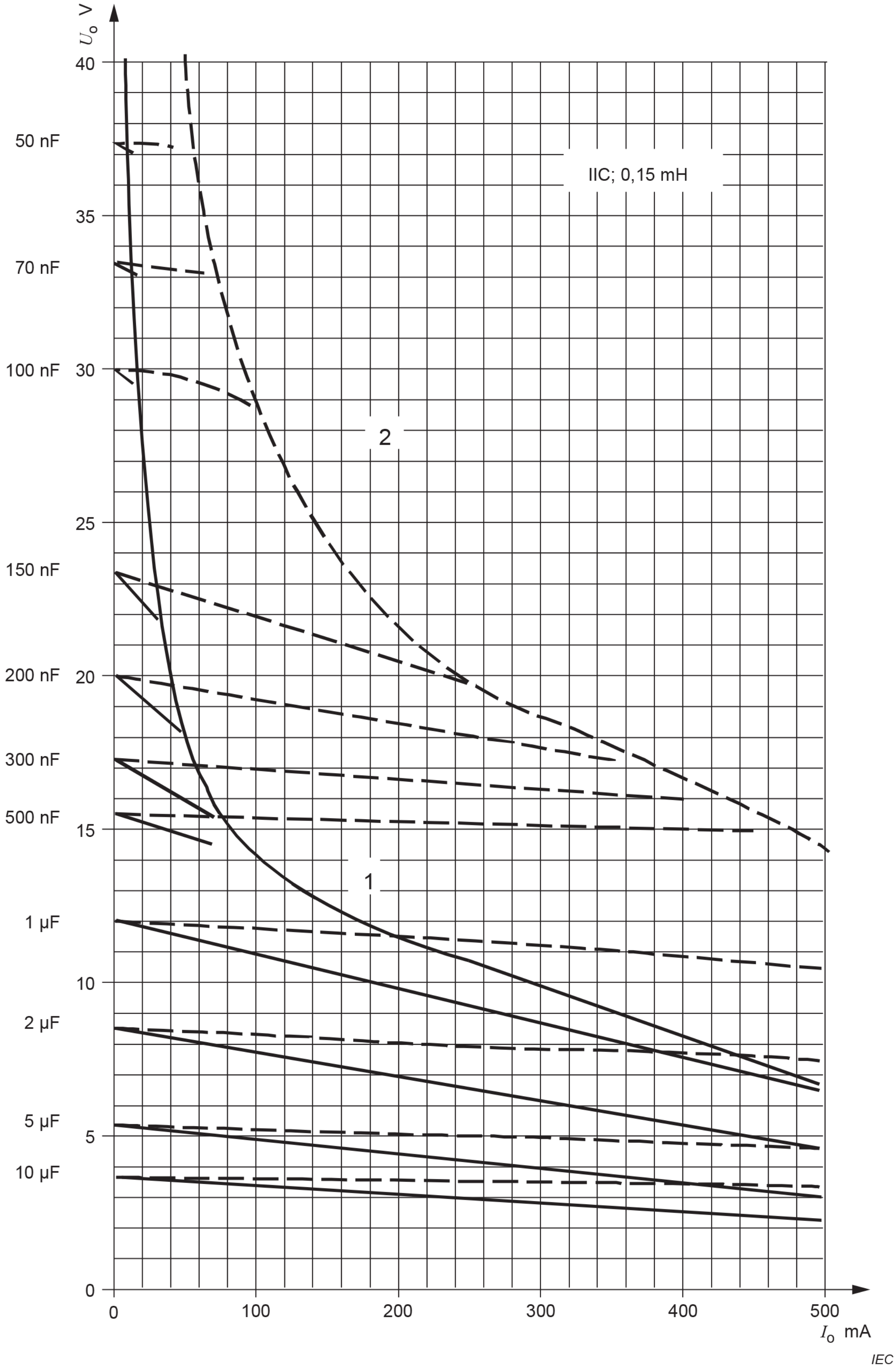



**Figure G.1 – Example of an output characteristic for Group IIC**

## G.4 Curves

The following pages contain the limit curve diagrams Figure G.2 and Figure G.3.

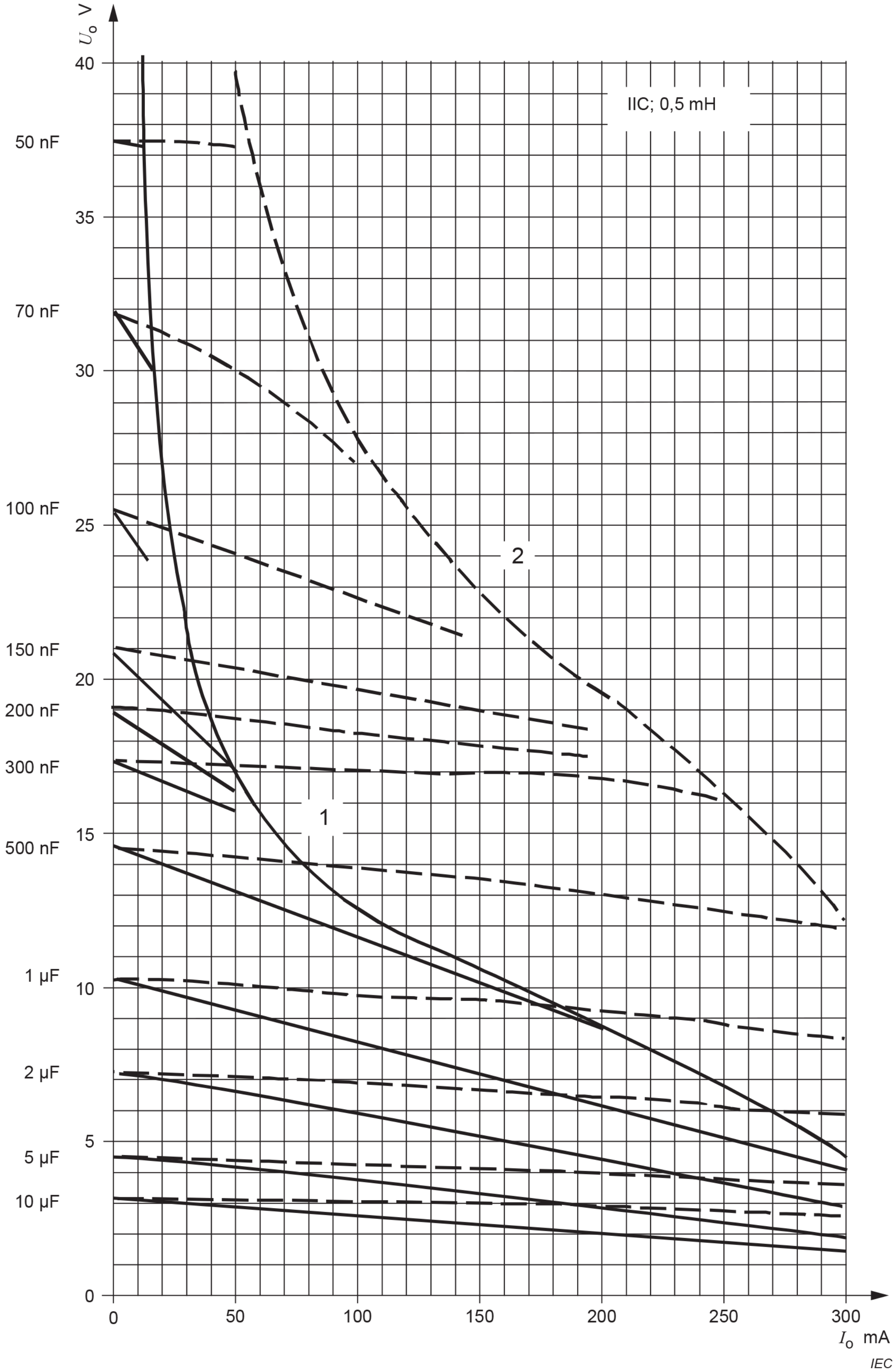



**Key**

1 inductive limit for rectangular source

2 inductive limit for linear source

**Figure G.2a) – Diagram for 0,15 mH**

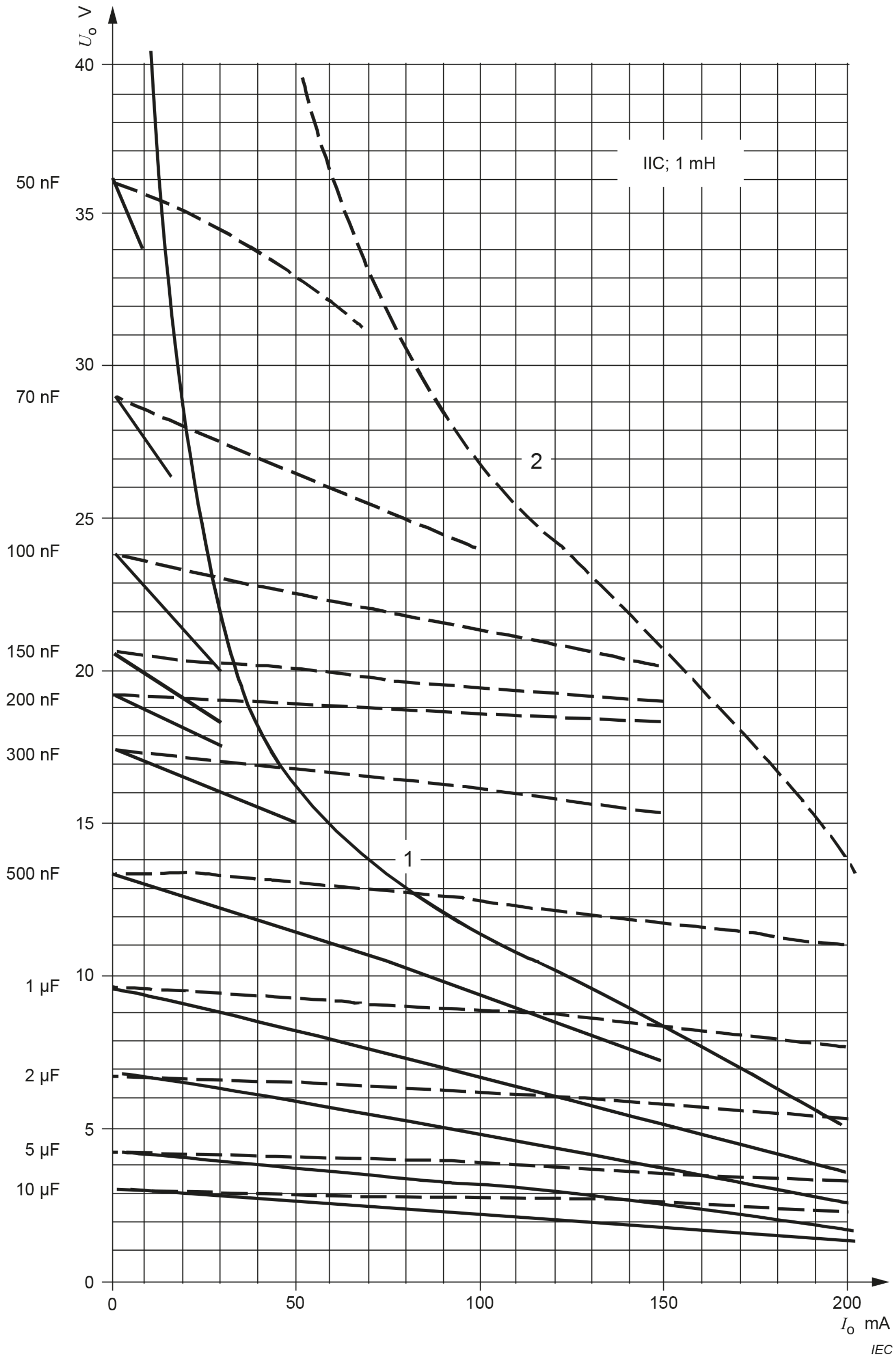



**Key**

1 inductive limit for rectangular source

2 inductive limit for linear source

**Figure G.2b) – Diagram for 0,5 mH**

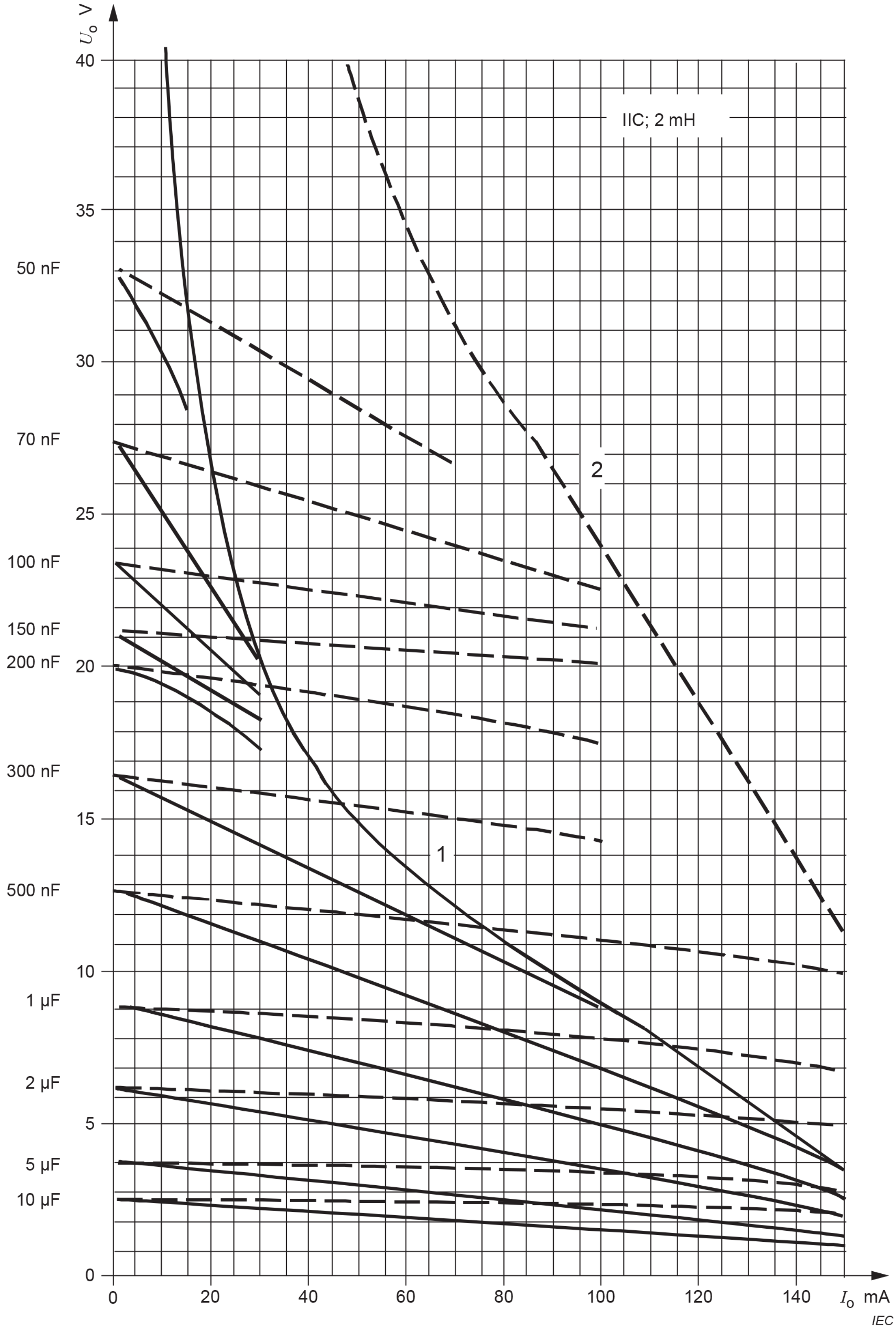



**Key**

1 inductive limit for rectangular source

2 inductive limit for linear source

**Figure G.2c) – Diagram for 1 mH**

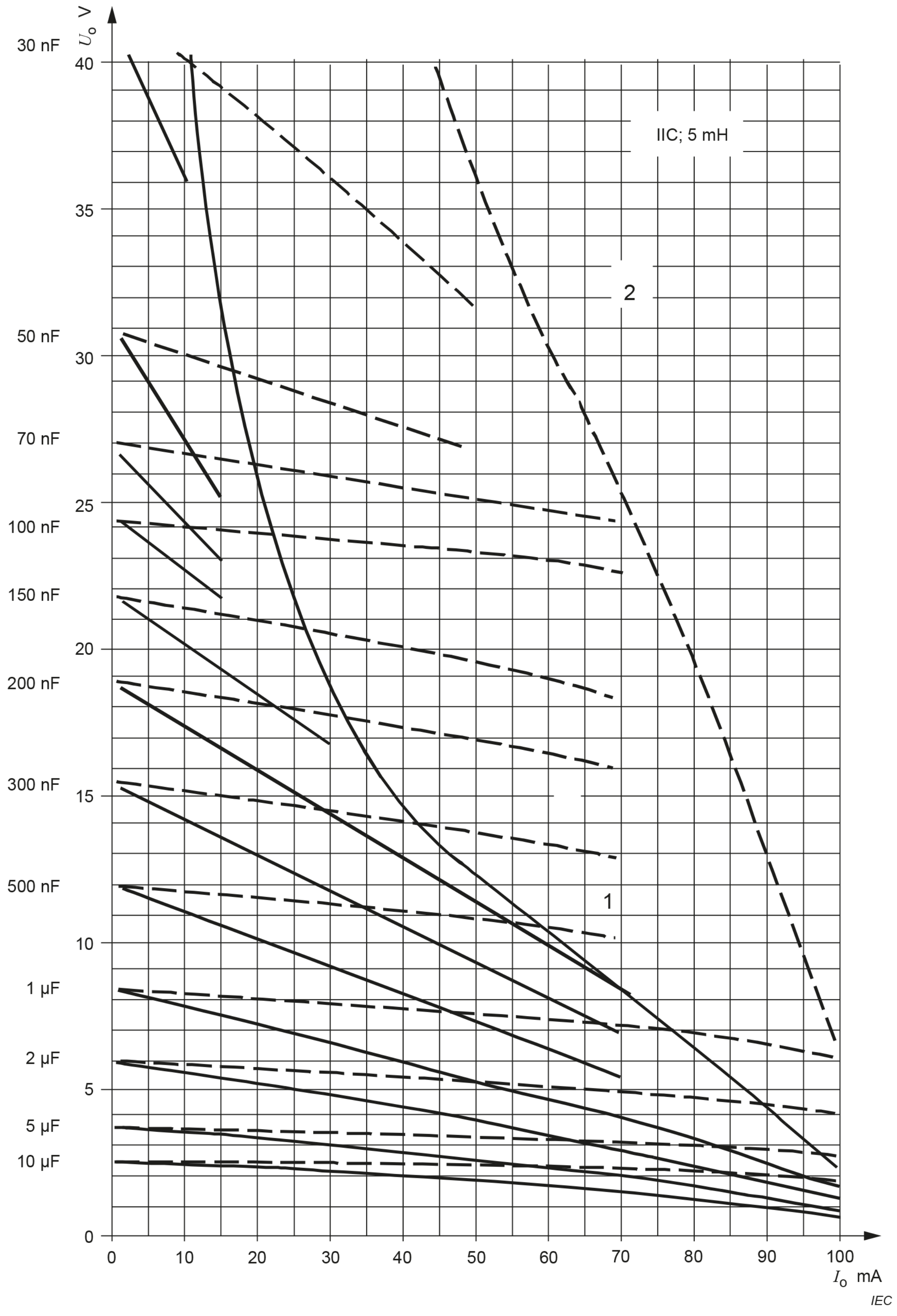



**Key**

1 inductive limit for rectangular source

2 inductive limit for linear source

**Figure G.2d) – Diagram for 2 mH**



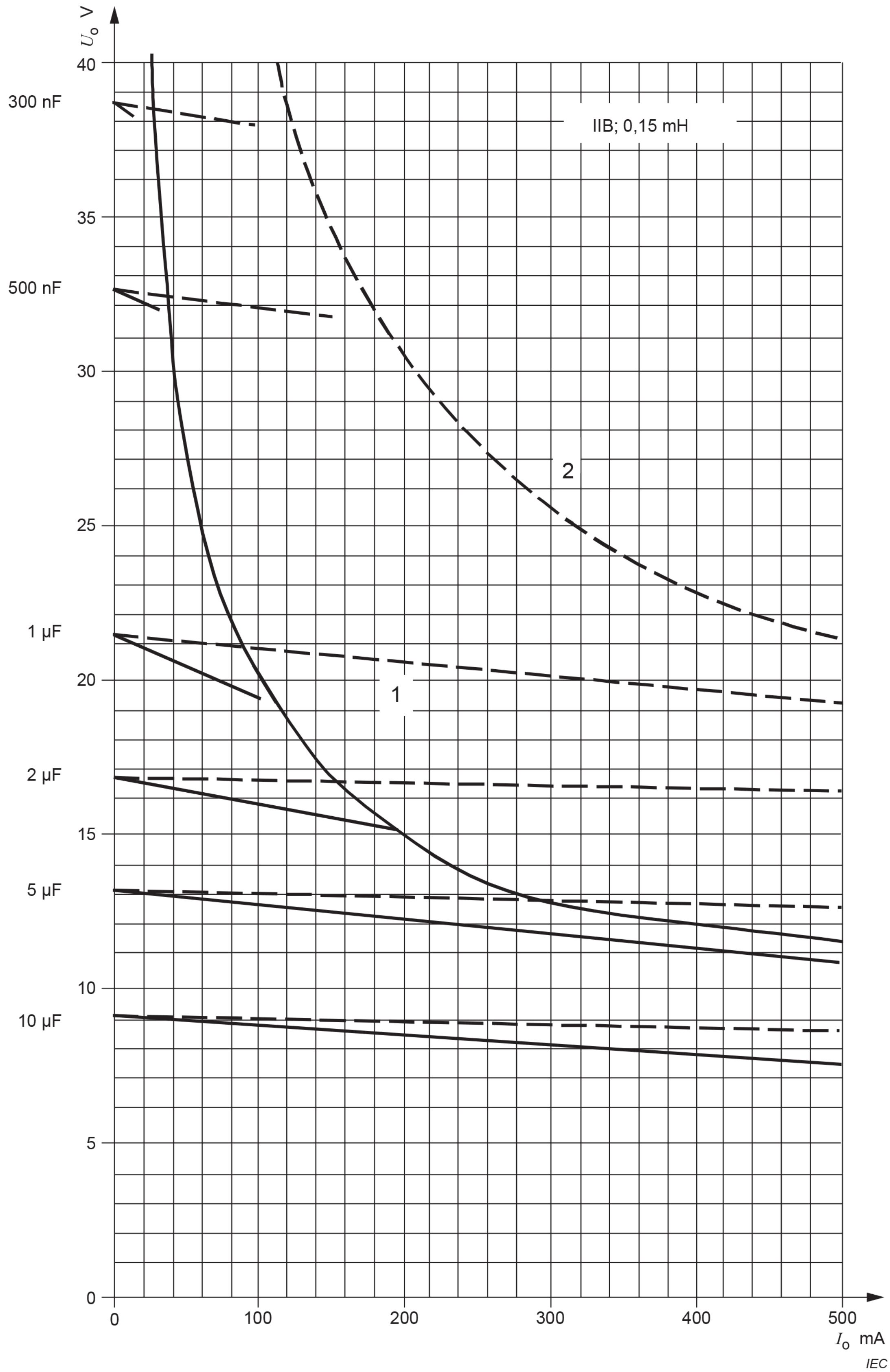

**Key**

1 inductive limit for rectangular source

2 inductive limit for linear source

**Figure G.2e) – Diagram for 5 mH**

**Figure G.2 – Limit curve diagram for universal source characteristic − Group IIC**

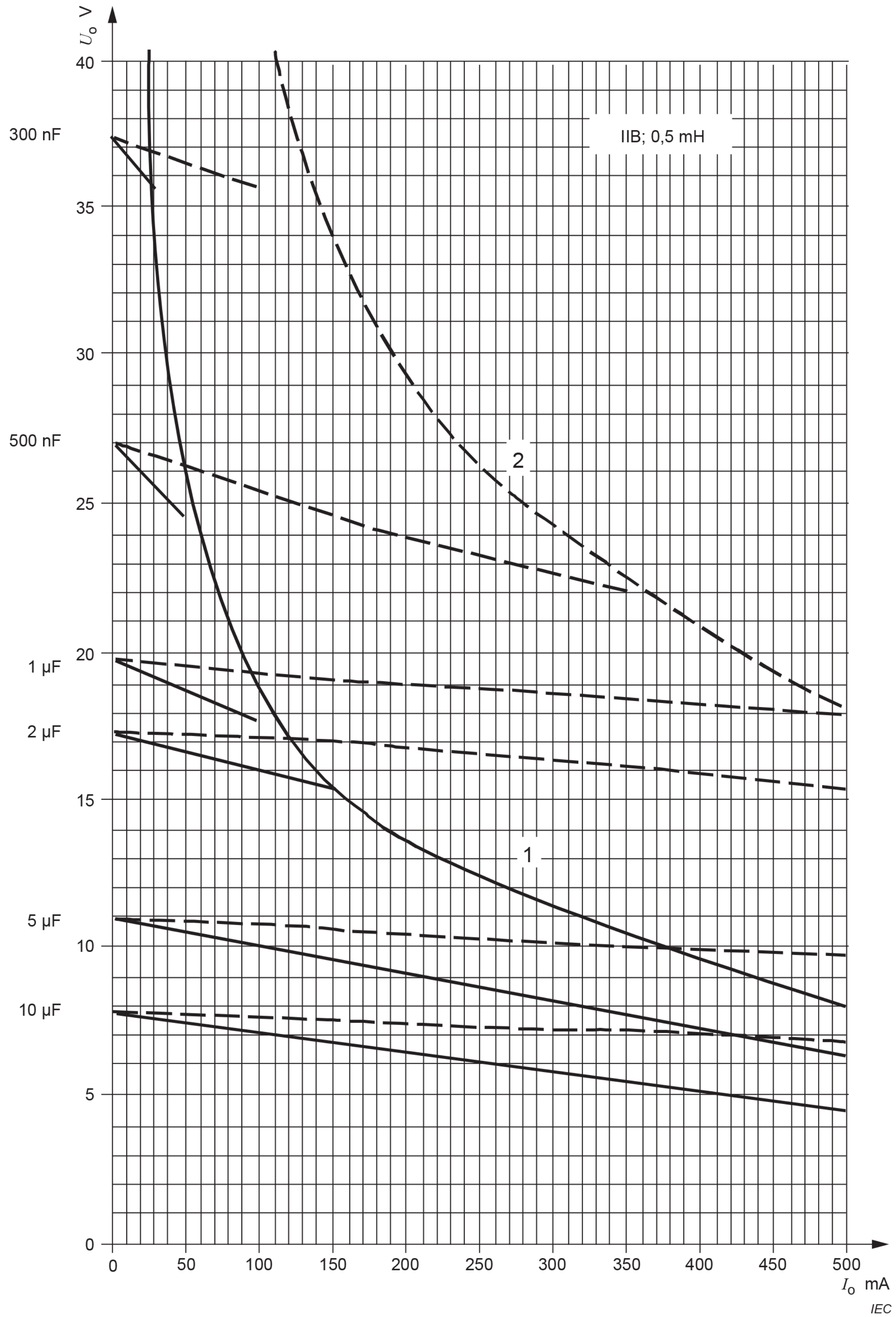



**Key**

1 inductive limit for rectangular source

2 inductive limit for linear source

**Figure G.3a) – Diagram for 0,15 mH**

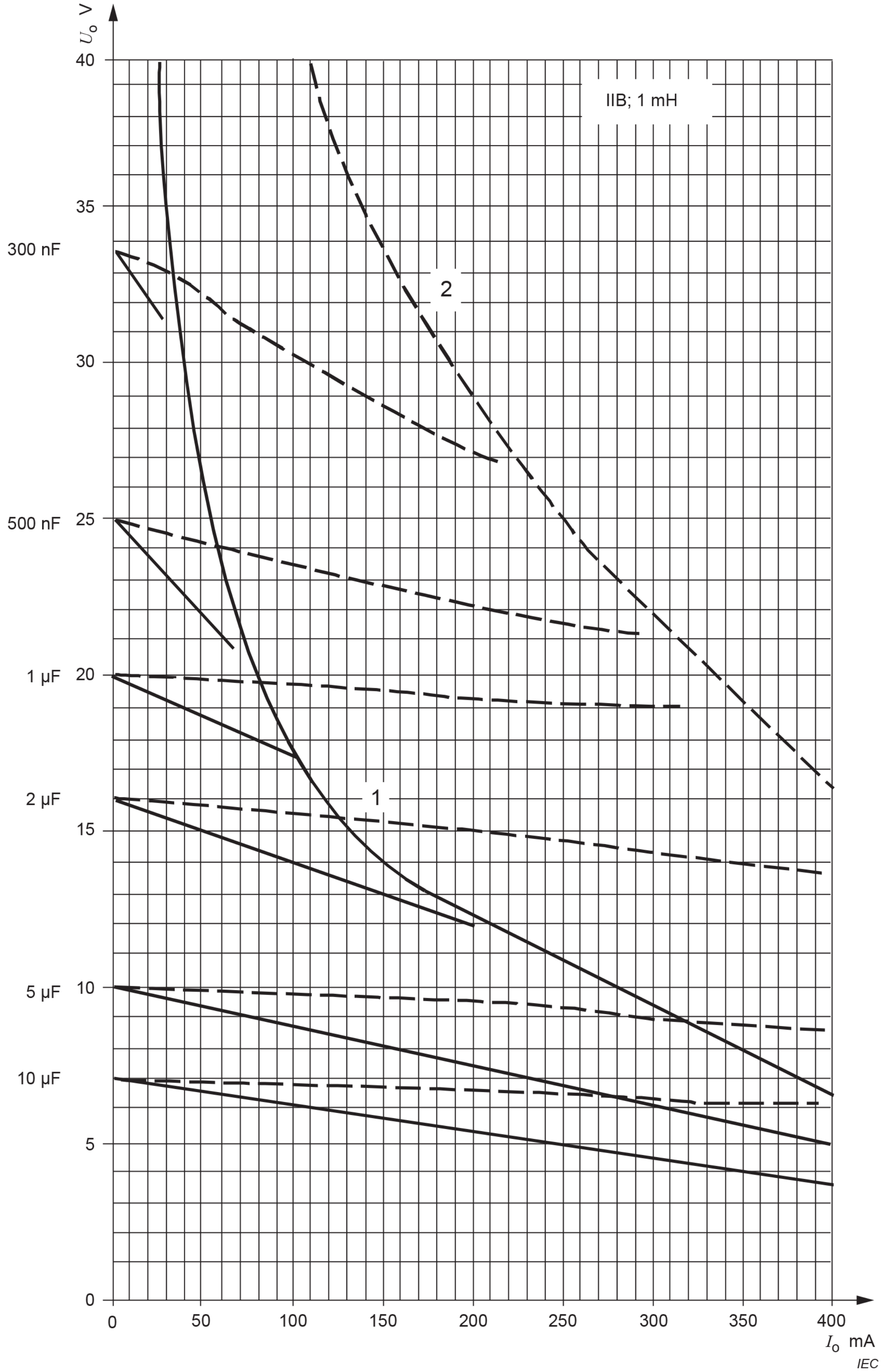



**Key**

1 inductive limit for rectangular source

2 inductive limit for linear source

**Figure G.3b) – Diagram for 0,5 mH**

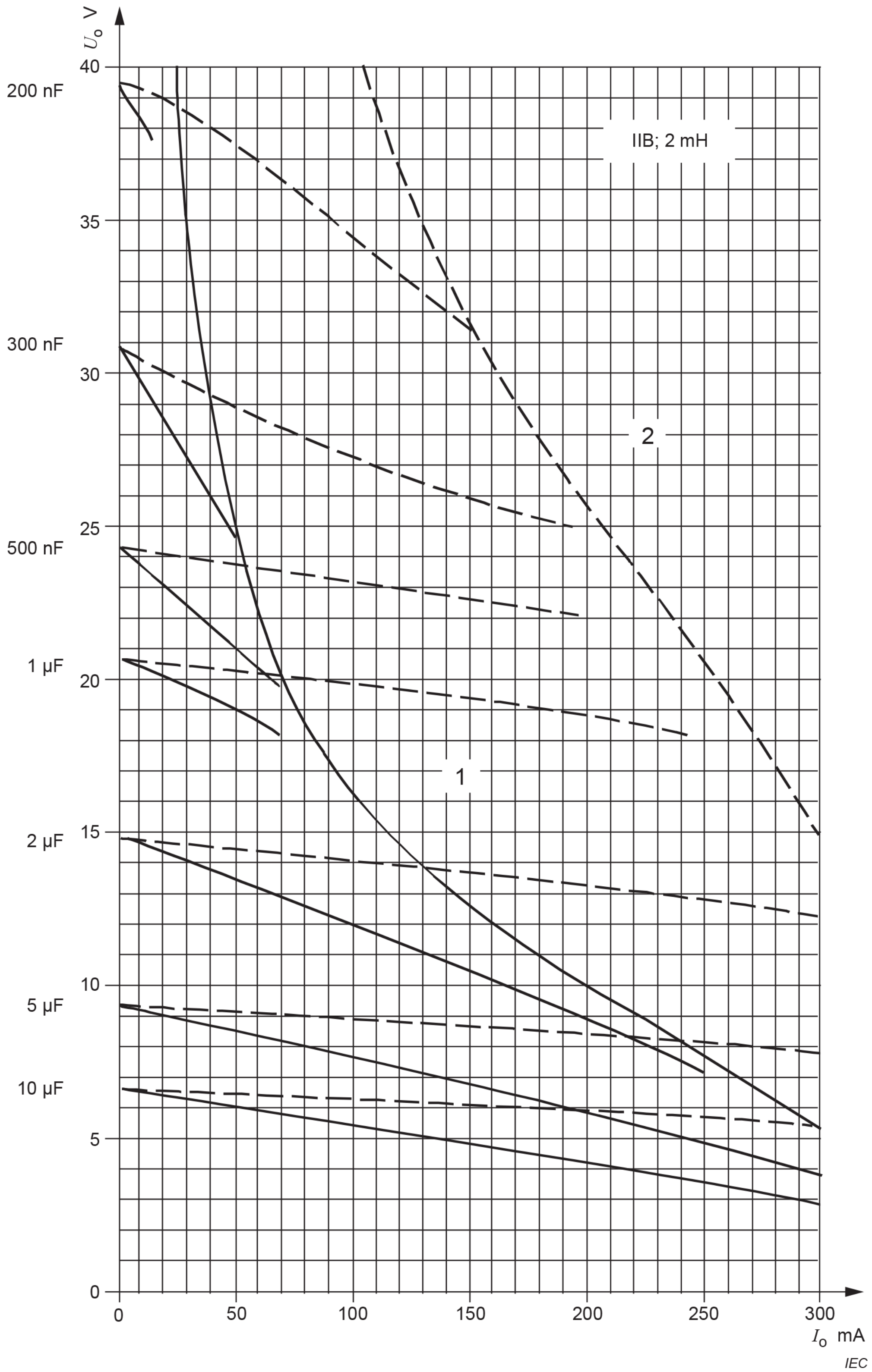



**Key**

1 inductive limit for rectangular source

2 inductive limit for linear source

**Figure G.3c) – Diagram for 1 mH**

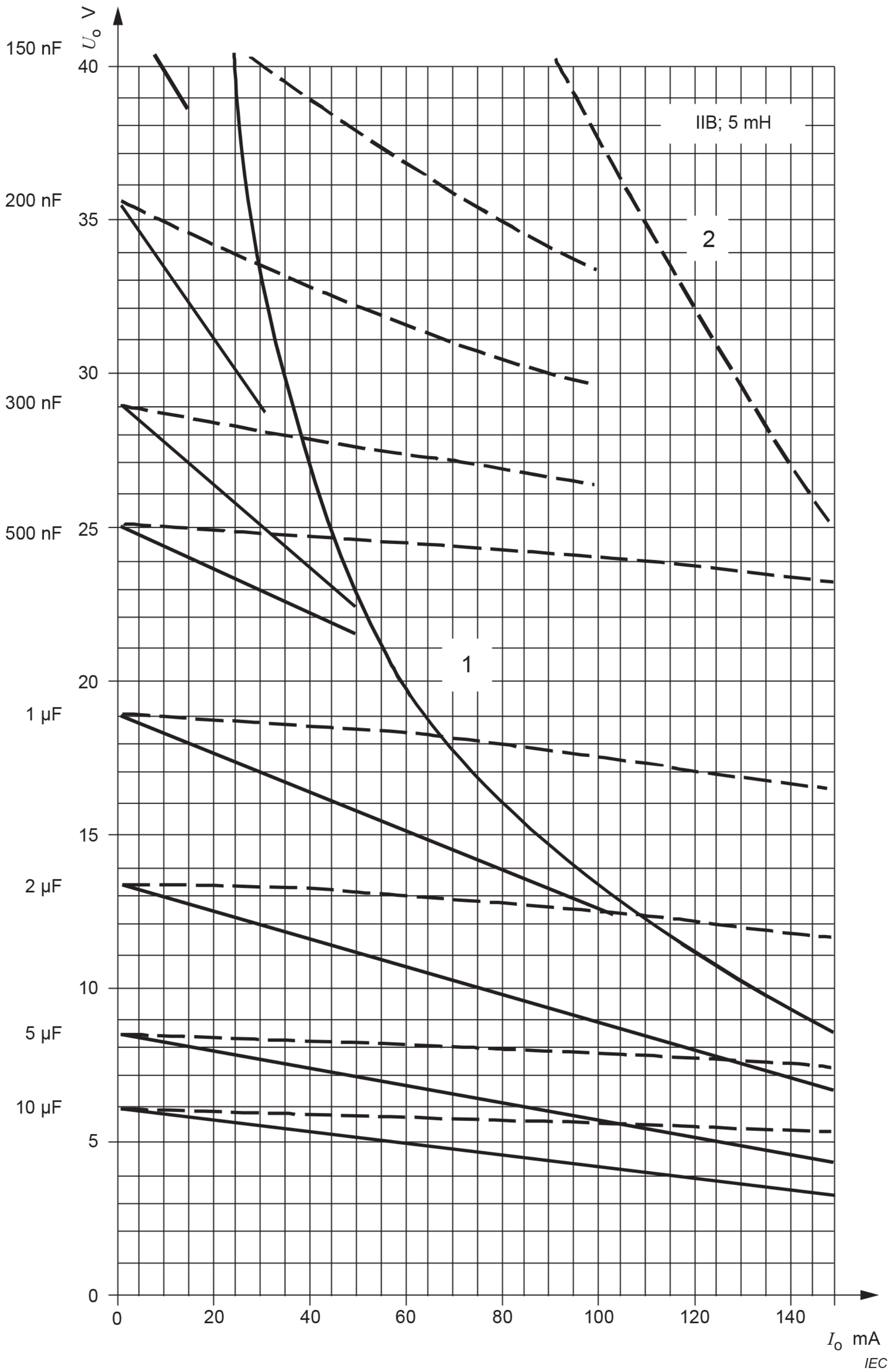



**Key**

1 inductive limit for rectangular source

2 inductive limit for linear source

**Figure G.3d) – Diagram for 2 mH**




**Key**

1 inductive limit for rectangular source

2 inductive limit for linear source

**Figure G.3e) – Diagram for 5 mH**

**Figure G.3 – Limit curve diagram for universal source characteristic – Group IIB**

# Annex H
(informative)

# Examples of marking

## H.1 General

The following are examples of marking.

Where ABC represents the conformity assessment scheme and DEF the initials of the certifying body, as applicable.

This information is given for the convenience of users of this document and does not constitute an endorsement by the IEC of the product named. Any resemblance to actual product is entirely coincidental.

## H.2 Self-contained intrinsically safe apparatus

| |
|---|
| C TOME LTD |
| PAGING RECEIVER TYPE 3 |
| Serial No. 12345 |
| Ex ia IIC T4 Ga |
| –25 °C ≤ Ta ≤ +50 °C |
| ABC DEF 12.1234 |

## H.3 Intrinsically safe apparatus supplied by other intrinsically safe circuits

| | |
|---|---|
| M HULOT | |
| TRANSDUCTEUR TYPE 12 | |
| Serial No. 12345 | |
| Ex ib IIB T4 Gb | |
| Ex ib IIIC T135°C Db | |
| ABC DEF 12.1234 | |
| $L_i$: 10 µH | $C_i$: 1 200 pF |
| $U_i$: 28 V | $I_i$: 250 mA |
| $P_i$: 1,3 W | |

## H.4 Associated apparatus

| | |
|---|---|
| J SCHMIDT A.G. | |
| STROMVERSORGUNG TYP 4 | |
| Serial No. 12345 | |
| [Ex ib Mb] I | |
| ABC DEF 12.1234 | |
| $U_m$: 250 V | $P_o$: 0,9 W |
| $I_o$: 150 mA | $U_o$: 24 V |
| $L_o$: 20 mH or $L_o/R_o$: 50 µH/Ω | $C_o$: 4,6 µF |
| 60 kPa ≤ $P_{amb}$ ≤ 110 kPa | |

## H.5 Associated apparatus protected by a flameproof enclosure

| | |
|---|---|
| PIZZA ELECT. SpA | |
| Type 6789 | |
| Serial No. 12345 | |
| Ex db [ia Ga] IIB T6 Gb | |
| ABC DEF 12.1234 | |
| $U_m$: 250 V | $P_o$: 0,9 W |
| $U_o$: 36 V | $I_o$: 100 mA |
| $C_o$: 0,31 µF | $L_o$: 15 mH |

## H.6 Intrinsically safe apparatus Level of Protection "ic"

| | |
|---|---|
| M HULOT | |
| TRANSDUCTEUR TYPE 12A | |
| Serial No. 12345 | |
| Ex ic IIB T4 Gc | |
| ABC DEF 12.1234 | |
| $U_i$: 28 V | $C_i$ = 0 |

## H.7 Intrinsically safe apparatus Level of Protection "ib" with "ia"' outputs

| | |
|---|---|
| PRAHA ELECT | |
| Type f transmitter with separate sensing element | |
| Serial No. 12345 | |
| Ex ib [ia IIC Ga] IIB T6 Gb | |
| ABC DEF 12.1234 | |
| $U_i$: 30 V | $U$o: 5.6V |
| $I_i$: 93 mA | $P_o$: 0.014 W |
| $L_i$: 0.01 mH | $I_o$: 10 mA |
| $C_i$: 0.031 µF | $L_o$: 0.15 mH |
| | $C_o$: 35 uF |

## H.8 FISCO

### H.8.1 Power supply

| |
|---|
| FISCO power supply |
| $U_m$: 250 V |
| [Ex ia Ga] IIC |
| John Jones Ltd |
| SW99 2AJ UK |
| Type: DRG OOI |
| – 20 °C ≤ Ta ≤ +50 °C |
| ABC DEF 12.1234 |
| Serial No. 014321 |

### H.8.2 Field device

| |
|---|
| FISCO field device |
| Ex ia IIC T4 Ga |
| Paul McGregor plc |
| GL99 1JA UK |
| Type: RWS 001 |
| -20 °C ≤ Ta ≤ +60 °C |
| ABC DEF 12.1234 |
| Serial No. 78745A |

### H.8.3 Terminator

| |
|---|
| FISCO terminator |
| Ex ia IIC T4 Ga |
| James Bond plc |
| MK45 6BY UK |
| Type MI5 007 |
| ABC DEF 12.1234 |
| Serial No. 012345 |

### H.8.4 Dual marked field device

| | |
|---|---|
| A McTavish plc GL 98 1BA UK<br>Type RWS 002<br>-20 °C ≤ Ta ≤ +60 °C<br>ABC DEF 12.1234<br>Serial No. 060128 | |
| FISCO Field device<br>Ex ia IIC T4 Ga | |
| Ex ia IIC T6<br>$U_i$: 28 V<br>$C_i$: 3 nF | $I_i$: 200 mA<br>$L_i$: 10 µH<br>$P_i$: 1,2 W |

# Annex I
(informative)

## Overview of tests on enclosures or parts of enclosures

Figure I.1 shows an overview for the tests required on enclosures and parts of enclosures for intrinsically safe apparatus when the spacing requirements comply with Table 7.

Figure I.2 shows an overview for the tests required on enclosures and parts of enclosures for intrinsically safe apparatus and associated apparatus when the spacing requirements comply with Table 8 and Table 9.

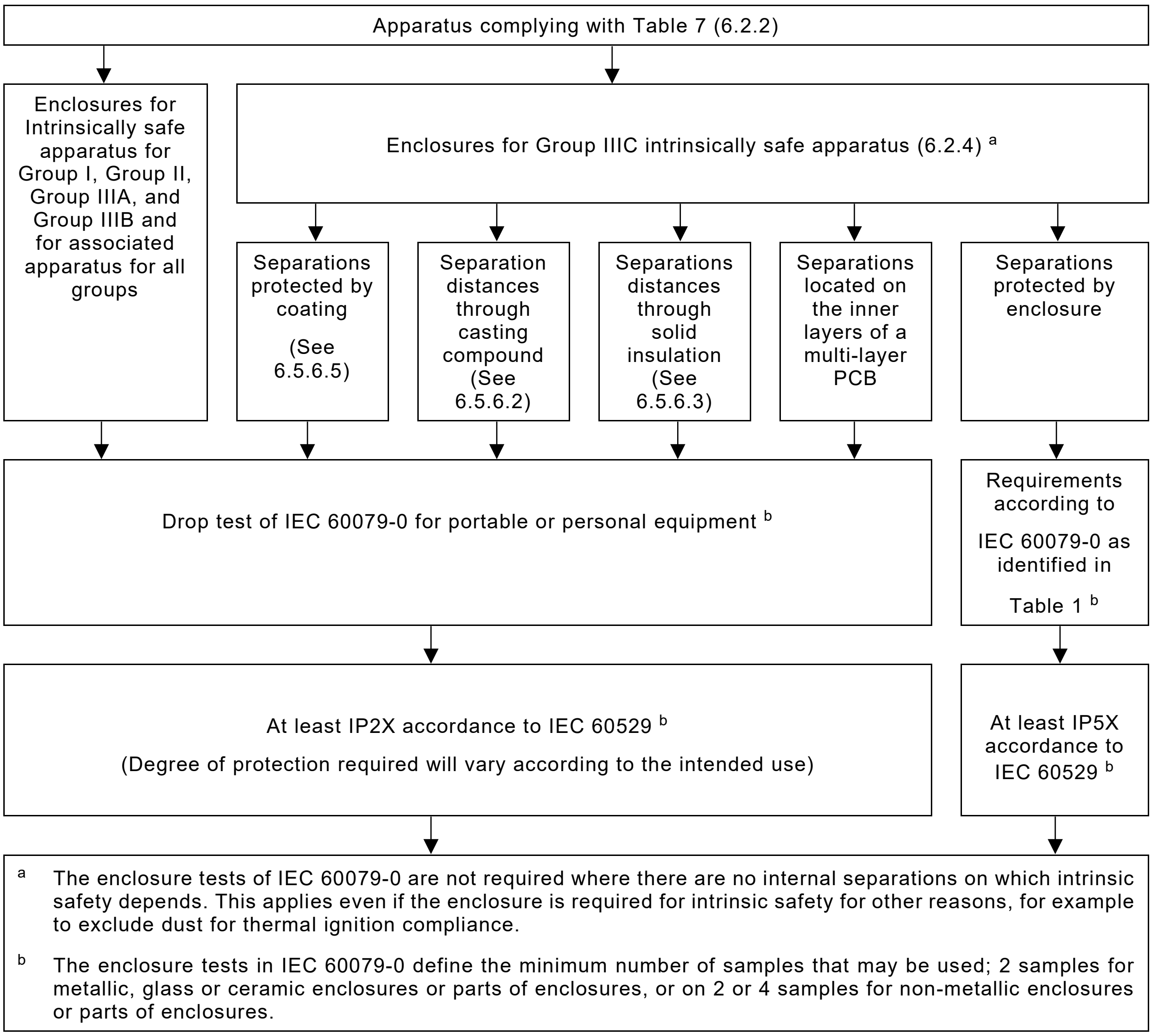
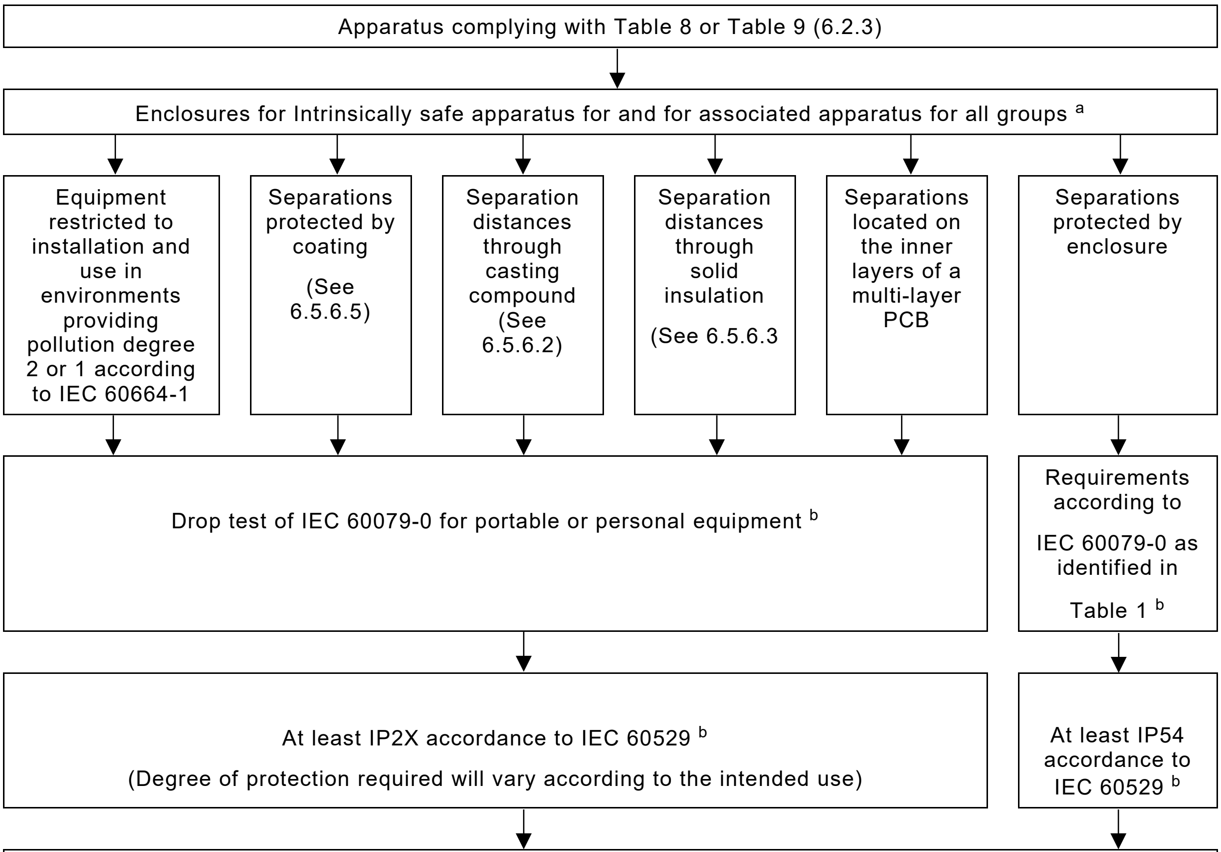



**Figure I.1 – Tests for enclosures or parts of enclosures for separation distances complying with Table 7**




[a] The enclosure tests of IEC 60079-0 are not required where there are no internal separations on which intrinsic safety depends. This applies even if the enclosure is required for intrinsic safety for other reasons, for example to exclude dust for thermal ignition compliance.

[b] The enclosure tests in IEC 60079-0 define the minimum number of samples that may be used; 2 samples for metallic, glass or ceramic enclosures or parts of enclosures, or on 2 or 4 samples for non-metallic enclosures or parts of enclosures.

**Figure I.2 – Tests for enclosures or parts of enclosures for separation distances complying with Table 8 or Table 9**

# Bibliography


IEC 60050-114, *International Electrotechnical Vocabulary (IEV) – Part 114: Electrochemistry*

IEC 60050-426, *International Electrotechnical Vocabulary (IEV) – Part 426: Explosive atmospheres*

IEC 60068-2-14, *Environmental testing – Part 2-14: Tests – Test N: Change of temperature*

IEC 60068-2-78, *Environmental testing – Part 2-78: Tests – Test Cab: Damp heat, steady state*

IEC 60079-14, *Explosive atmospheres – Part 14: Electrical installations design, selection and erection*

IEC 60079-18, *Explosive atmospheres – Part 18: Equipment protection by encapsulation "m"*

IEC 60079-19, *Explosive atmospheres – Part 19: Equipment repair, overhaul and reclamation*

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IPC-2221, *Generic Standard on Printed Board Design*

IPC-6012B, *Qualification and Performance Specification for Rigid Printed Boards*

IPC-A-610, *Acceptability of electronic assemblies*

UL 1642, *Standard for Lithium Batteries*

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