National Standard of the People's Republic of China

GB 3836.4-2000
eqv IEC 60079-11：1999
Superseding GB 3836.4 — 1983

Electrical apparatus for explosive gas atmospheres—

Part 4：Intrinsic Safety "i"

Contents

Foreword

This Standard is mandatory national standard.

This Standard is a revision of National Standard GB 3836.4 -1983 according to the international standard IEC 60079-11: 1999 *Electrical Apparatus for Explosive Gas Atmospheres - Intrinsic Safety "i"*. It is equivalent to IEC 60079-11 in the general factors, technical factors, supplementary factors and other technical content, so as to meet the requirements of international trade, technology and economic exchange. The difference between this standard and 60079-11 is that note is added in Clause 6.6 and supplementary provisions are provided for Group I electrical apparatuses for which ground wire is not allowed to be used as return circuit.

This standard is divided into the following parts under the general title - Electrical Apparatus for Explosive Gas Atmospheres -Intrinsic Safety "i":

GB 3836.1-2000 Electrical Apparatus for Explosive Gas Atmospheres -Part 1: General Requirements (eqv IEC 60079-0:1998)

GB 3836.2-2000 Electrical Apparatus for Explosive Gas Atmospheres -Part 2: Flameproof Type "d" (eqv IEC 60079-1:1990)

GB 3836.4-2000 Electrical Apparatus for Explosive Gas Atmospheres -Part 4: Intrinsic Safe Type "i" (eqv IEC 60079-7:1990)

GB 3836.4-2000 Electrical Apparatus for Explosive Gas Atmospheres -Part 4: Intrinsic Safe Type "i"(eqv IEC 60079-11:1999)

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Compared with National Standard GB 3836.4 -1983, this standard has been changed a lot. The main differences include: 22 necessary definitions, including countable fault and non-countable fault, have been added in the definition; in structure requirements, specific provisions have been added for the temperature of wires and small components; a lot of contents have been added for connecting device for external circuit and space between conductive parts; more detailed provisions have been provided for cell and batteries in the provisions of components related to intrinsic safety; provisions and analysis method about countable fault and non-countable fault have been added for component and connection failure; provisions about connection method of wires and photoelectric coupler have been added in the chapter of reliable components and reliable connection; some test requirements of diode safety barriers have been changed in the chapter of Diode Safety Barriers; in the chapter of Type Verifications and Type Tests provisions of calibration circuit of electrode made with materials other than non cadmium dish have been cancelled, the test method of increasing safety factor with oxygen enriched test gas has been added, and detailed provisions have been added for temperature test, ignition test of small components, cell and batteries test, piezoelectric device test, mechanical test, etc. In addition, this standard also adds appendix for 3 standards. In Appendix A Assessment of Intrinsically Safe Circuits, ignition curves without cadmium, zinc or magnesium have been deleted and corresponding ignition value table has been listed; Appendix B Spark Test Apparatus for Intrinsically Safe Circuits; In Appendix D Encapsulation provisions of encapsulation method and encapsulation components have been provided.

This Standard supersedes National Standard GB 3836.4 - 1983 as from the date when this Standard is enforced.

Appendix A, B and D to this Standard are the normative ones.

Appendix C is the informative one.

This Standard is proposed by the State Bureau of Mechanical Industry.

This Standard is steered by the National Technical Committee for Explosion-proof Electrical Apparatus Standardization.

This Standard is drafted by Nanyang Explosion-proof Electrical Research Institute of the Ministry of Mechanical Industry, Fushun institute and Chongqing Institute under Coal Science Research Institution, etc.

The main drafting persons of this Standard are Yang Baoxiang, Zhang Lianghai, Xing Zizhong, He Chongzhi, Zheng Qi and Zhang Pingyi.

This Standard was issued initially on August 29,1983 and was revised for the first time in October, 2000.

National Technical Committee for Explosion-proof Electrical Apparatus Standardization is entrusted to be responsible for making explanations for this Standard.

Foreword of IEC

1). International Electrotechnic Commission (IEC) is an international standardization organization. It is composed of all the IEC National Committees. The purpose of IEC is to promote the international cooperation in all problems related to standardization in the electro-technical field. For this purpose, IEC also publishes international standards in addition to the other activities. Formulation of standards is entrusted to each technical committee. Any IEC National Committee interested in the subject may take part in the preparations. In formulation of standards, any international organization, government or non-government organization and any other organization related to IEC may also take part in this work. According to the conditions agreed between the two organizations through consultations, IEC cooperates closely with the International Standardization Organization (ISO).

2). All the formal resolutions or agreements of IEC regarding technical problems reflect as possible as they can the internationally uniform opinions, because all IEC National Committees that have special interest in the subject have their representatives in the technical committee.

3). They have forms of recommendation which are generally used internationally, and are published in a form of a standard, a form of a technical report or a guideline and are accepted by all IEC National Committee in this sense.

4). With view to promoting international uniformisation, All IEC National Committees agree to use IEC International Standards to the max. extent in their national standards and regional standards. In case there is any difference between IEC standards and the relevant national standards or regional standards, it shall be clearly described in the test of the relevant national standard respectively.

5). There is no provision for the approval procedure made by IEC. Therefore, when it is stated that some equipment meets some standard of the international standard, IEC shall not bear any responsibility.

6). It is worth noting that some part of this international standard may cover patent rights, and IEC will not bear any responsibility for some equivalence or the equivalence as a whole.

International Standard IEC 60079-11 is formulated by SC31G Sub Technical Committee "Intrinsically Safe Apparatus" of IEC TC 31 Technical Committee.

This fourth edition will cancel and supersede the third edition of IEC 60079-11 published in 1991, and the technical revisions have been made.

Appendix B includes provisions of Spark Test Apparatus and replaces IEC 60079-3:1990.

This international standard should be read together with IEC 60079-0:1998 Electrical Apparatus for Explosive Gas Atmospheres -Part 0: General Requirements.

This Standard is based on the following documents:

FDIS	Report on Voting
31G/65 FDIS	31G/68/RVD

The complete conditions for approval of this Standard by voting can be examined with the reference made to the Report on Voting indicated in the above table.

Appendix A, Appendix B and Appendix D constitute an integral part of this Standard.

Appendix C is only provided as information.

National Standard of the People's Republic of China

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Electrical apparatus for explosive gas atmospheres—

Part 4：Intrinsic Safety "i"

1. Scope

1.1 This standard specifies the construction and testing of intrinsically safe apparatus, intended for use in potentially explosive atmospheres and for associated apparatus, which is intended for connection to intrinsically safe circuits which enter such atmospheres.

1.2 This standard supplements GB 3836.1-2000 Electrical Apparatus for Explosive Gas Atmospheres -Part 1: General Requirements, the requirements of which apply to intrinsically safe apparatus and to associated apparatus except as indicated in the following list.

If associated apparatus is protected by a type of protection listed in GB 3836.1-2000 then the requirements of that method of protection together with the relevant parts of GB 3836.1-2000 also apply to the associated apparatus. The list of exclusions which follows is directly applicable to associated apparatus intended for use in situations where there is no potentially explosive atmosphere and in other circumstances should be used in combination with the requirements of the other methods of protection.

Clause of GB 3836.1-2000	Clause or subclause excluded	
	Intrinsically safe	Associated
3.1 Electrical apparatus	Yes	Yes
4.2.2 Marking of maximum surface temperature	No	Yes
5.1 Maximum surface temperature	No	Yes
5.3 Surface temperature and ignition temperature	No	Yes
6.2 Enclosure opening delay	Yes	Yes
7.1.1 Definition of plastics material	No	Yes
7.1.2 Requirement of plastics material	Yes	Yes
7.1.3 Verification of plastics material compliance	No	Yes
7.2 Thermal endurance	Yes	Yes
7.3 Electrostatic charges on plastics enclosures	No	Yes
7.3.1 Electrical apparatus of Group I	Yes	Yes
7.3.2 Electrical apparatus of Group II	Yes	Yes
7.5 Threaded holes in plastics	Yes	Yes
8.1 Light metal enclosure materials	No	Yes
8.2 Threaded holes in light metals	Yes	Yes

Approved by CSBTS on Oct 17, 2000 Implemented on June 1, 2001

Clause of GB 3836.1-2000	Clause or subclause excluded	
	Intrinsically safe apparatus	Associated apparatus
9 Fasteners	Yes	Yes
10 Interlocking devices	Yes	Yes
11 Bushings	Yes	Yes
12 Materials used for cementing	Yes	Yes
14 Connection facilities and terminal compartments	Yes	Yes
15 Connection facilities for earthing or bonding conductors	Yes	Yes
16 Cable and conduit entries	Yes	Yes
17 to 22 Supplementary requirements for certain electrical apparatus	Yes	Yes
23.4.3.1 Test for resistance to impact	Yes	Yes
23.4.3.2 Drop test (no prior impact test necessary)	No	Yes
23.4.3.3 Required results	No	Yes
23.4.5 Torque test for bushings	Yes	Yes
23.4.6.1 Temperature measurement	No	Yes
23.4.6.2 Thermal shock test	Yes	Yes
23.4.7.1 to 23.4.7.7 Tests on non-metallic enclosures	Yes	Yes
23.4.7.8 Insulation resistance test of parts of enclosures of plastics materials	No	Yes
27.7 Examples of marking	Yes	Yes
Appendix B Ex cable entries	Yes	Yes

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

1.4 This standard is also applicable to electrical apparatus or parts of electrical apparatus located outside the potentially explosive atmosphere or protected by another type of protection listed in GB 3836.1, where the intrinsic safety of the electrical circuits in the potentially explosive atmosphere may depend upon the design and construction of such electrical apparatus or parts of such electrical apparatus. The electrical circuits exposed to the potentially explosive atmosphere are evaluated for use in such an atmosphere by applying this standard.

2 Normative References

The following normative documents contain provisions which, through reference in this text, constitute provisions of this standard. At the time of publication, the editions indicated were valid. All normative documents are subject to revision, and parties to agreements based on this standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below.

GB 9364.1-1997 Miniature fuses-Part 1: Definitions for miniature fuses and general requirement for miniature fuse-links (idt IEC 60127-1:1988)

GB 9364.2-1997 Miniature fuses-Part 2: Cartridge fuse-links (idt IEC 60127-2:1989)

GB 9364.3-1997 Miniature fuses-Part 3: Sub-miniature fuse-links (idt IEC 60127-3:1988)

GB 3836.1-2000 Electrical apparatus for explosive gas atmospheres--Part 1:General requirements (eqv IEC 60079-0:1988)

GB 3836.3-2000 Electrical apparatus for explosive gas atmospheres--Part 3: Increased safety "e" (idt IEC 60079-7:1990)

GB 4208-1993 Degrees of protection provided by enclosure(IP code) (eqv IEC 60529:1989)

GB 4207-1984 Method for determining the comparative and the proof tracking indices of solid insulating materials under moist conditions (eqv IEC 60112:1979)

GB/T 11021-1989 Heat resistance assessment and classification of electrical insulation (eqv IEC 60085:1984)

3 Definitions

For the purpose of this standard, the following definitions apply:

3.1 Intrinsically safe circuit

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

3.2 Electrical apparatus

Assembly of electrical components, electrical circuits or parts of electrical circuits normally contained in a single enclosure.

NOTE 1 – The term "normally" has been introduced to indicate that an apparatus may occasionally be in more than one enclosure, for example, a telephone or a radio transceiver with a hand microphone.

NOTE 2 – This definition is more precise than that contained in GB 3836.1-2000.

3.3 Intrinsically safe apparatus

Electrical apparatus in which all the circuits are intrinsically safe circuits.

3.4 Associated apparatus

Electrical apparatus which contains both intrinsically safe circuits and non-intrinsically safe circuits and is constructed so that the non-intrinsically safe circuits cannot adversely affect the intrinsically safe circuits.

NOTE – Associated apparatus may be either

a) electrical apparatus which has another type of protection listed in GB 3836.1 for use in the appropriate explosive gas atmosphere, or

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

3.5 Normal operation

Operation of intrinsically safe apparatus or associated apparatus such that it conforms electrically and mechanically with the design specification produced by its manufacturer.

3.6 Fault

Any defect of any component, separation, insulation or connection between components, not defined as infallible by this standard, upon which the intrinsic safety of a circuit depends.

3.7 Countable fault

Fault which occurs in parts of electrical apparatus conforming to the constructional requirements of this standard

3.8 Non-countable fault

Fault which occurs in parts of electrical apparatus not conforming to the constructional requirements of this standard

3.9 Infallible component or infallible assembly of components

Component or assembly of components that is considered as not subject to certain fault modes as specified in this standard.

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

3.10 Infallible separation or insulation

Separation or insulation between electrically conductive parts that is considered as not subject to short circuits.

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

3.11 Simple apparatus

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

3.12 Internal wiring

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

3.13 Minimum igniting current (MIC)

Minimum current in resistive or inductive circuits that causes the ignition of the explosive test mixture in the spark-test apparatus according to Appendix B.

3.14 Minimum igniting voltage

minimum voltage of capacitive circuits that causes the ignition of the explosive test mixture in the spark test apparatus described in Appendix B.

3.15 Maximum r.m.s. a.c. or d.c. voltage (Um)

Maximum voltage that can be applied to the non-intrinsically safe connection facilities of associated apparatus without invalidating intrinsic safety,

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

3.16 Maximum input voltage (Ui)

Maximum voltage (peak a.c. or d.c.) that can be applied to the connection facilities for intrinsically safe circuits without invalidating intrinsic safety.

3.17 Maximum output voltage (Uo)

Maximum output voltage (peak a.c. or d.c.) in an intrinsically safe circuit that can appear under open circuit conditions at the connection facilities of the apparatus at any applied voltage up to the maximum voltage, including Um and Ui.

NOTE – Where there is more than one applied voltage, the maximum output voltage is that occurring under the most onerous combination of applied voltages.

3.18 Maximum input current (Ii)

Maximum current (peak a.c. or d.c.) that can be applied to the connection facilities for intrinsically safe circuits without invalidating intrinsic safety.

3.19 Maximum output current (Io)

Maximum current (peak a.c. or d.c.) in an intrinsically safe circuit that can be taken from the connection facilities of the apparatus.

3.20 Maximum input power (Pi)

Maximum input power in an intrinsically safe circuit that can be dissipated within an apparatus when it is connected to an external source without invalidating intrinsic safety.

3.21 Maximum output power (Po)

Maximum electrical power in an intrinsically safe circuit that can be taken from the apparatus,

3.22 Maximum external capacitance (Co)

Maximum capacitance in an intrinsically safe circuit that can be connected to the connection facilities of the apparatus without invalidating intrinsic safety.

3.23 Maximum internal capacitance (Ci)

Total equivalent internal capacitance of the apparatus which is considered as appearing across the connection facilities of the apparatus.

3.24 Maximum external inductance (Lo)

Maximum value of inductance in an intrinsically safe circuit that can be connected to the connection facilities of the apparatus without invalidating intrinsic safety.

3.25 Maximum internal inductance (Li)

Total equivalent internal inductance of the apparatus which is considered as appearing at the connection facilities of the apparatus.

3.26 Maximum external inductance to resistance ratio (Lo/Ro)

Maximum value of ratio of inductance (Lo) to resistance (Ro) of any external circuit that can be connected to the connection facilities of the electrical apparatus without invalidating intrinsic safety.

3.27 Maximum internal inductance to resistance ratio (Li/Ri)

Maximum value of ratio of inductance (Li) to resistance (Ri) which is considered as appearing at the external connection facilities of the electrical apparatus.

3.28 Clearance

Shortest distance in air between two conductive parts.

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

3.29 Distance through casting compound

Shortest distance through a casting compound between two conductive parts.

3.30 Distance through solid insulation

Shortest distance through solid insulation between two conductive parts.

3.31 Creepage distance in air

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

3.32 Creepage distance under coating

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

3.33 Fuse rating (In)

Current rating of a fuse according to GB9346-1997 or to its manufacturer's specification.

3.34 Sealed gas tight cell or battery

Cell or battery which remains closed and does not release either gas or liquid when operated within the limits of charge or temperature specified by the manufacturer.

NOTE – Such cells and batteries may be equipped with a safety device to prevent dangerously high internal pressure. The cell or battery does not require addition to the electrolyte and is designed to operate during its life in its original sealed state.

3.35 Sealed valve-regulated cell or battery

Cell or battery which is closed under normal conditions but which has an arrangement which allows the escape of gas if the internal pressure exceeds a predetermined value. The cell or battery cannot normally receive an addition to the electrolyte.

3.36 Diode safety barrier

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

4 Grouping and Classification of Intrinsically Safe Apparatus and Associated Apparatus

Intrinsically safe apparatus and associated apparatus shall be grouped and classified in accordance with Clauses 4 and 5 of GB 3836.1-2000.

5 Categories of Electrical Apparatus

5.1 General

Intrinsically safe apparatus and intrinsically safe parts of associated apparatus shall be placed in category "ia" or "ib".

The requirements of this standard shall apply to both categories unless otherwise stated. In the determination of category "ia" or "ib", failure of components and connections shall be considered in accordance with 7.6.

NOTE – Apparatus may be specified as both "ia" and "ib", and may have different parameters for each category.

5.2 Category "ia"

With Um and Ui applied, the intrinsically safe circuits in electrical apparatus of category "ia" shall not be capable of causing ignition in each of the following circumstances:

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

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

c) In normal operation and with the application of two countable faults plus those noncountable faults which give the most onerous condition.

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

In testing or assessing the circuits for spark ignition, the following safety factors shall be applied in accordance with 10.4.2:

– for both a) and b) 1.5; and

– for c) 1.0.

The safety factor applied to voltage or current for determination of surface temperature classification shall be 1.0 in all cases.

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

5.3 Category "ib"

With Um and Ui applied, the intrinsically safe circuits in electrical apparatus of category "ib" shall not be capable of causing ignition in each of the following circumstances:

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

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

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

In testing or assessing the circuits for spark ignition, a safety factor of 1,5 shall be applied in accordance with 10.4.2. The safety factor applied to the voltage or current for the determination of surface temperature classification shall be 1,0 in all cases. If no countable fault can occur the requirements of a) are considered to give a category of "ib" if the test requirements for "ib" can be satisfied.

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

5.4 Simple apparatus

The following apparatus shall be considered to be simple apparatus:

a) Passive components, for example switches, junction boxes, resistors and simple semiconductor devices;

b) Sources of stored energy with well-defined parameters, for example capacitors or inductors, whose values shall be considered when determining the overall safety of the system;

c) Sources of generated energy, for example thermocouples and photocells, which do not generate more than 1,5 V, 100 mA and 25 mW. Any inductance or capacitance present in these sources of energy shall be considered as in b).

Simple apparatus shall conform to all relevant requirements of this standard but need not be certified and need not comply with Clause 12. In particular, the following aspects shall always be considered:

1) Simple apparatus shall not achieve safety by the inclusion of voltage and/or currentlimiting and/or suppression devices;

2) Simple apparatus shall not contain any means of increasing the available voltage or current, for example circuits for the generation of ancillary power supplies;

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 6.4.12. Its terminals shall conform to 6.3.1;

4) Non-metallic enclosures and enclosures containing light metals when located in the hazardous area shall conform to 7.3 and 8.1 of GB 3836.1;

5) When simple apparatus is located in the hazardous area, it shall be temperature classified. When used in an intrinsically safe circuit within their normal rating and at a maximum ambient temperature of 40 °C, switches, plugs, sockets and terminals are allocated a T6 temperature classification for Group II applications and considered as having a maximum surface temperature

of 85 °C for Group I applications. Other types of simple apparatus shall be temperature classified in accordance with Clauses 4 and 6 of this standard.

Where simple apparatus forms part of an apparatus containing other electrical circuits, the whole shall be certified.

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

6 Apparatus Construction

NOTE – The requirements given in this clause apply, unless otherwise stated in the relevant subclauses, only to those features of intrinsically safe apparatus and associated apparatus which contribute to this type of protection and they are additional to the general requirements of GB 3836.1 except for those excluded in 1.2.

For example, the requirements for encapsulation with casting compound apply only if encapsulating is required to satisfy 6.4.4 or 6.7.

6.1 Enclosures

In principle, intrinsically safe apparatus and associated apparatus do not require an enclosure as the method of protection is embodied within the circuits themselves. However, where intrinsic safety can be impaired by access to conducting parts, for example if the circuits contain infallible creepage distances in air, an enclosure of at least IP20 in accordance with GB 4208 shall be provided as part of the apparatus under test.

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

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

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

6.2 Wiring and small component temperatures

6.2.1 Dust layers on Group I equipment

For the purposes of this clause where reference is made to T4 and Group I, the Group I equipment shall be equipment in which coal dust cannot form a layer in the location of or on the component being considered.

6.2.2 Wiring within apparatus

The maximum permissible current corresponding to the maximum wire temperature due to selfheating shall either be taken from Table 1 for copper wires or can be calculated from the following equation for metals in general:

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

where

a is the temperature coefficient of resistance of the wire material (0,004265 K–1 for copper);

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

I_f is the current at which the wire melts in an ambient temperature of 40 °C, in amperes;

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

t is the wire temperature due to self-heating and ambient temperature, in degrees Celsius.

Table 1 – Temperature classification of copper wiring
(in a maximum ambient temperature of 40 °C)

Diameter (see Note 4) mm	**Cross-sectional area** (see Note 4) mm^2	**Maximum permissible current for temperature classification**		
		T1 to T4 and Group I A	**T5** A	**T6** A
0.035	0.000 962	0.53	0.48	0.43
0.05	0.001 96	1.04	0.93	0.84
0.1	0.007 85	2.1	1.9	1.7
0.2	0.031 4	3.7	3.3	3.0
0.35	0.096 2	6.4	5.6	5.0
0.5	0.196	7.7	6.9	6.7

NOTE 1 – The value given for maximum permissible current, in amperes, is the r.m.s. a.c. or d.c. value.
NOTE 2 – For stranded conductors, the cross-sectional area is taken as the total area of all strands of the conductor.
NOTE 3 – The table also applies to flexible flat conductors, such as in ribbon cable, but not to printed circuit conductors for which see 6.2.3.
NOTE 4 – Diameter and cross-sectional area are the nominal dimensions specified by the wire manufacturer.
NOTE 5 – Where the maximum input power Pi does not exceed 1.3 W the wiring can be awarded a temperature classification of T4 and is acceptable for Group I.

The maximum current in insulated wiring shall not exceed the rating specified by the manufacturer of the wire.

6.2.3 Printed circuit wiring

On printed circuit boards of at least 0.5 mm thickness, having a conducting track of at least 35 μm thickness on one or both sides, a temperature classification T4 or Group I shall be given to the printed tracks if they have a minimum width of 0.3 mm and the continuous current in the tracks does not exceed 0.518 A. Similarly, for minimum track widths of 0.5 mm, 1.0 mm and 2.0 mm, T4 shall be given for corresponding maximum currents of 0.814 A, 1.388 A and 2.222 A respectively. Track lengths of 10 mm or less shall be disregarded for temperature classification purposes.

For other applications, the temperature classification of copper wiring of printed boards shall be determined from Table 2.

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

Where the maximum input power Pi does not exceed 1.3 W, the printed wiring shall be given a temperature classification of T4 or Group I.

Table 2 – Temperature classification of printed board wiring
(in a maximum ambient temperature of 40 °C)

Minimum track width mm	**Maximum permissible current for temperature classification**		
	T1 to T4 and Group I A	**T5** A	**T6** A
0.15	1.2	1.0	0.9
0.2	1.8	1.45	1.3
0.3	2.8	2.25	1.95
0.4	3.6	2.9	2.5
0.5	4.4	3.5	3.0
0.7	5.7	4.6	4.1
1.0	7.5	6.05	5.4
1.5	9.8	8.1	6.9
2.0	12.0	9.7	8.4
2.5	13.5	11.5	9.6
3.0	16.1	13.1	11.5
4.0	19.5	16.1	14.3
5.0	22.7	18.9	16.6
6.0	25.8	21.8	18.9

Minimum track width mm	**Maximum permissible current for temperature classification**		
	T1 to T4 and Group I A	**T5** A	**T6** A
NOTE 1 – The value given for maximum permissible current, in amperes is the r.m.s. a.c. or d.c. value. NOTE 2 – This table applies to printed boards 1.6 mm or thicker with a single layer of copper of 35μm thickness. NOTE 3 – For boards with a thickness between 0.5 mm and 1.6 mm, divide the maximum current specified by 1.2. NOTE 4 – For boards with conducting tracks on both sides, divide the maximum current specified by 1.5. NOTE 5 – For multilayer boards, for the track layer under consideration, divide the maximum current specified by 2. NOTE 6 – For 18μm copper thickness, divide the maximum current by 1.5. NOTE 7 – For 70μm copper thickness, multiply the maximum current by 1.3. NOTE 8 – For tracks passing under components dissipating 0.25 W or more either normally or under fault conditions, divide the maximum current specified by 1.5. NOTE 9 – At terminations of components dissipating 0.25 W or more either normally or under fault conditions, and for 1.00 mm along the conductor, either multiply the track width by 3 or divide the maximum current specified by 2. If the track goes under the component apply the factor specified in Note 8 in addition.			

6.2.4 Small components

Small components, for example transistors or resistors, whose temperature exceeds that permitted for the temperature classification, shall be acceptable providing that they conform to one of the following:

a) When tested in accordance with 10.7, small components shall not cause ignition of the flammable mixture and any deformation or deterioration caused by the higher temperature shall not impair the type of protection;

b) For T4 and Group I classification, small components shall conform to Table 3;

c) For T5 classification, the surface temperature of a component with a surface area smaller than 10 cm^2 (excluding lead wires) shall not exceed 150 °C.

Table 3 – Assessment for T4 classification according to component size and ambient temperature

Total surface area excluding lead wires	Requirement for T4 and Group I classification
<20 mm^2	Surface temperature ≤275 °C
≥20 mm^2	Power dissipation≤1.3 W*
≥20 mm^2 <10 cm^2	Surface temperature ≤200 °C
* Reduced to 1.2 W with 60 °C ambient temperature or 1.0 W with 80 °C ambient temperature.	

For potentiometers, the surface to be considered shall be that of the resistance element and not the external surface of the component. The mounting arrangement, and heatsinking and cooling effect of the overall potentiometer construction shall be taken into consideration during the test. Temperature shall be measured on the track with that current which flows under conditions of "ib" or "ia", as appropriate. If this results in a resistance value of less than 10 % of the track resistance value, the measurement shall be carried out at 10 % of the track resistance value.

6.3 Facilities for connection of external circuits

6.3.1 Terminals

In addition to satisfying the requirements of Table 4, terminals for intrinsically safe circuits shall be separated from terminals for non-intrinsically safe circuits by one or more of the methods given in a) or b).

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

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

a) When separation is accomplished by distance then the clearance between terminals shall be at least 50 mm. Care shall 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 nonintrinsically 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 terminals when measured in any direction around the partition;

2) Metal partitions shall be earthed and shall have sufficient strength and rigidity to ensure that they are not likely to be damaged during field wiring. Such partitions shall be at least 0.45 mm thick or shall conform to 10.10.2 if of lesser thickness. In addition, metal partitions shall have sufficient current-carrying capacity to prevent burn-through or loss of earth connection under fault conditions;

3) Non-metallic insulating partitions shall have sufficient thickness and shall be so supported that they cannot readily be deformed in a manner that would defeat their purpose. Such partitions shall be at least 0.9 mm thick, or shall conform to 10.10.2 if of lesser thickness.

The clearances between bare conducting parts of terminals of separate intrinsically safe circuits shall be equal to or exceed the values given in Table 4. In addition, the clearances between terminals shall be such that the clearances between the bare conducting parts of connected external conductors are at least 6 mm when measured in accordance with Figure 1.

Any possible movement of metallic parts which are not rigidly fixed shall be taken into account.

The minimum clearance between the bare conducting parts of external conductors connected to terminals and earthed metal or other conducting parts shall be 3 mm, unless the possible interconnection has been taken into account in the safety analysis.

6.3.2 Plugs and sockets

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

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

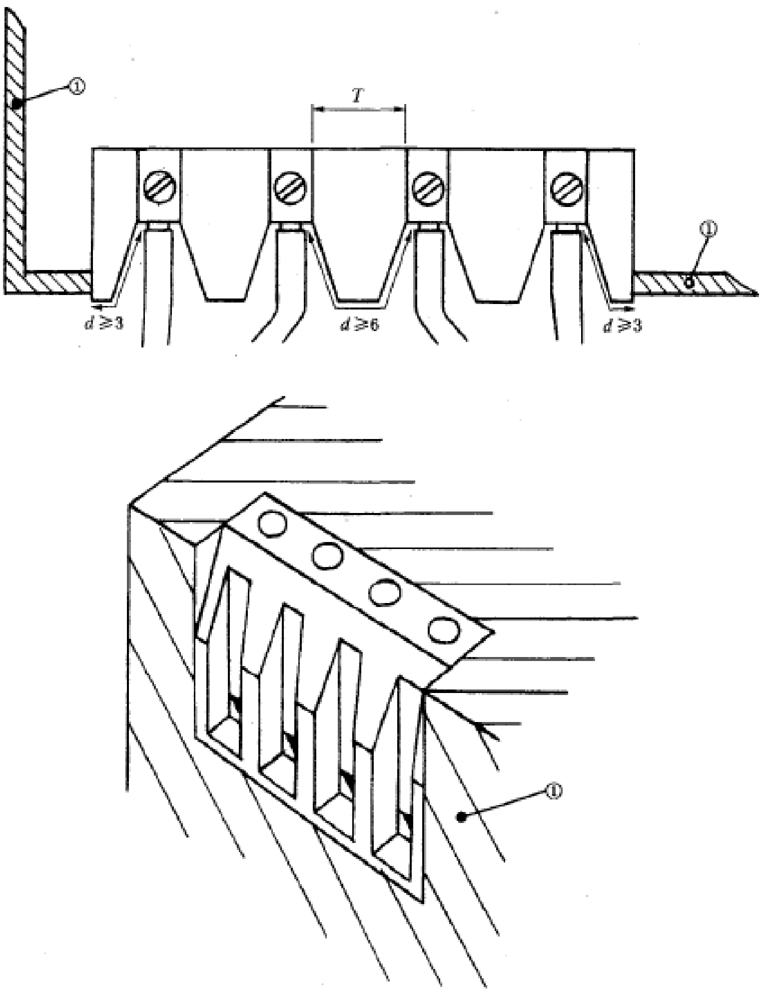
Where a plug or a socket is not prefabricated with its wires, the connecting facilities shall conform to 6.3.1. If, however, the connections require the use of a special tool, for example by crimping, such that there is no possibility of a strand of wire becoming free, then the connection facilities need only conform to Table 4.

Where a connector carries earthed circuits and the type of protection depends on the earth connection, then the connector shall be constructed in accordance with 6.6.

Table 4 – Clearances, creepage distances and separations

1 Voltage (peak value) V	10	30	60	60	190	375	550	750	1 000	1 300	1 575	3.3 k	4.7 k	9.5 k	15.6 k
2 Clearance mm	1.5	2.0	3.0	4.0	5.0	6.0	7.0	8.0	10.0	14.0	16.0				
3 Separation distance through casting compound mm	0.5	0.7	1.0	1.3	1.3	2.0	2.4	2.7	3.3	4.6	5.3	9.0	12.0	20.0	33.0
4 Separation distance through solid insulation mm	0.5	0.5	0.5	0.7	0.8	1.0	1.2	1.4	1.7	2.3	2.7	4.5	6.0	10.0	16.5
5 Creepage	1.5	2.0	3.0	4.0	8.0	10.0	15.0	18.0	25.0	36.0	49.0				

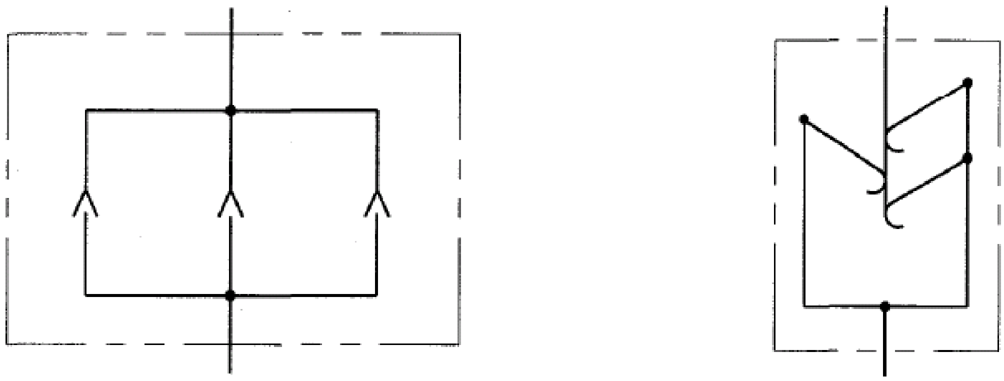
distance in air mm																
6 Creepage distance under coating mm		0.5	0.7	1.0	1.3	2.6	3.3	5.0	6.0	8.3	12.0	13.3				
7 Comparative tracking index (CTI)	I_a		100	100	100	175	175	275	275	275	275	275				
	I_b		100	100	100	175	175	175	175	175	175	175				
NOTE 1 – Except for separation distances, no values for voltages higher than 1 575 V are proposed at present. NOTE 2 – At voltages up to 10 V, the CTI of insulating materials is not required to be specified.																



①- Conductive cover; T-Clearance and creepage distances in accordance with Table 4; d-Clearance and creepage distances in accordance with 6.3.1

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

Figure 1 – Clearance and creepage distance requirements for terminals carrying separate intrinsically safe circuits



a) Example of three independent connecting elements

b) Example of three connecting elements which are not Independent

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

6.3.3 Determination of maximum external inductance to resistance ratio (Lo/Ro) for resistance limited power source

The maximum external inductance to resistance ratio (Lo/Ro) which may be connected to a resistance limited power source shall be calculated using the following formula. This formula takes account of a 1.5 factor of safety on current and shall not be used where Ci for the output terminals of the apparatus exceeds 1 % of Co.

$$L_o/R_o = \frac{8eR_i + (64e^2R_i^2 - 72U_o^2)^{\frac{1}{2}}}{4.5U_o^2} \quad \mathrm{H/\Omega}$$

Where:

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

– Group I apparatus: 525μJ

– Group IIA apparatus: 320μJ

– Group IIB apparatus: 160μJ

– Group IIC apparatus: 40μJ

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

Uo is the maximum open circuit voltage, in volts;

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

If Li = 0, then

$$L_o/R_o = \frac{32\,eR_i}{9U_o^2} \quad \mathrm{H/\Omega}$$

Where a safety factor of 1 is required, this value for Lo/Ro shall be multiplied by 2.25.

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

6.3.4 Permanently connected cable

Apparatus constructed with a permanently connected cable shall conform to 10.13.

6.4 Separation distances

6.4.1 Separation of conductive parts

Separation of conductive parts between

a) Intrinsically safe and non-intrinsically safe circuits;

b) Different intrinsically safe circuits; or

c) A circuit and earthed or isolated metal parts, shall conform to the following if the type of protection depends on the separation.

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

If the separation conforms to Table 4, it shall be considered as not subject to failure to a lower insulation resistance.

Smaller separation distances, which exceed one-third of the values specified in Table 4, shall be considered as subject to countable short-circuit faults.

If separation distances are less than one-third of the values specified in Table 4, they shall be considered as subject to non-countable short-circuit faults if this impairs intrinsic safety.

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

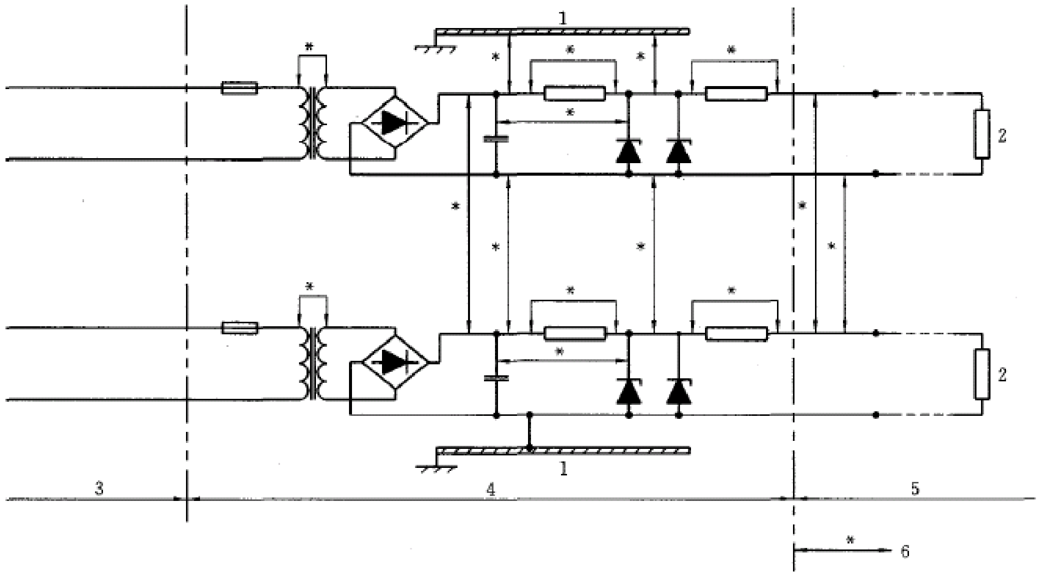
NOTE 1 – For example, the type of protection does depend on the separation to earthed or isolated metallic parts if a current-limiting resistor can be bypassed by short circuits between the circuit and the earthed or isolated metallic part.

An earthed metal partition shall have strength and rigidity so that it is unlikely to be damaged and shall be of sufficient thickness and of sufficient current-carrying capacity to prevent burnthrough or loss of earth under fault conditions. A partition either shall be at least 0.45 mm thick and attached to a rigid, earthed metal portion of the device, or shall conform to 10.10.2 if of lesser thickness.

Where a non-metallic insulating partition having an appropriate CTI is placed between the conductive parts, the clearances, creepage distances and other separation distances either shall be measured around the partition provided that the partition has a thickness of at least 0,9 mm, or shall conform to 10.10.2 if of lesser thickness.

NOTE 2 – Methods of assessment are given in Appendix C.

6.4.2 Voltage between conductive parts



1-Chassis; 2-Load; 3-Non-intrinsically safe circuit defined by Um;
4-Part of intrinsically safe circuit not in itself intrinsically safe; 5-Intrinsically safe circuit;
6-←*→Dimensions to which Table 4 is applicable

Figure 3 – Separation of conducting parts

The voltage which is taken into account when using Table 4 shall be the voltage between any two conductive parts for which the separation has an effect on the type of protection of the circuit under consideration, that is for example (see Figure 3) the voltage between an intrinsically safe circuit and

a) Part of the same circuit which is not intrinsically safe;

b) Non-intrinsically safe circuits; or

c)Other intrinsically safe circuits.

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

a) For circuits which are galvanically separated within the apparatus, the value of voltage to be considered between the circuits, shall be the highest voltage that can appear across the separation when the two circuits are connected together at any one point, derived from –

The rated voltages of the circuits;

The maximum voltages specified by the manufacturer which may safely be supplied tothe circuits; or

Any voltages generated within the same apparatus.

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

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

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

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

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

6.4.3 Clearance

In measuring or assessing clearances between conductive parts, insulating partitions of less than 0.9 mm thickness, or which do not conform to 10.10.2, shall be ignored. Other insulating parts shall conform to Line 4 of Table 4. For voltages higher than 1 575 V peak, an interposing insulating partition or earthed metal partition shall be used. In either case, the partition shall conform to 6.4.

6.4.4 Separation distances through and requirements of casting compound

The casting compound shall conform to the following:

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

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

b) Have at its free surface a CTI value of at least that specified in Table 4 if any bare conductive parts protrude from the casting compound;

Only hard material, for example epoxy resin, shall have its free surface exposed and unprotected, thus forming part of the enclosure (see Figure D.1). It shall conform to 10.10.1.

c) Be adherent to all conductive parts, components and substrates except when they are totally enclosed by the casting compound;

d) Be specified by its generic name and type designation given by the manufacturer of the casting compound;

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

If circuits connected to the encapsulated conductive parts and/or components and/or bare parts protruding from the casting compound are not intrinsically safe, they shall be protected by another type of protection listed in GB 3836.1.

The minimum separation distance between encapsulated conductive parts and components, and the free surface of the casting compound shall be at least half the values shown in Line 3 of Table 4, with a minimum separation distance of 1 mm. When the casting compound is in direct contact with an enclosure of insulating material conforming to Line 4 of Table 4, no other separation is required (see Figure D.1).

The insulation of the encapsulated circuit shall conform to 6.4.12.

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

Further requirements are given in Appendix D.

6.4.5 Separation distances through solid insulation

Solid insulation is insulation which is extruded or moulded but not poured. It shall have an electrical strength which conforms to 6.4.12 when the separation distance is in accordance with Table 4.

NOTES

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

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

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

6.4.6 Composite separations

Where separations are composite, for example through a combination of air and insulation, the total separation shall be calculated on the basis of referring all separations to one line of Table 4. For example at 60 V:

Clearance (Line 2) = 6×separation through solid insulation (Line 4);

Clearance (Line 2) = 3×separation through casting compound (Line 3);

Equivalent clearance = actual clearance + (3×any additional separation through encapsulant) + (6×any additional separation through solid insulation).

To be infallible, the above result shall be not less than the clearance value specified in Table 4.

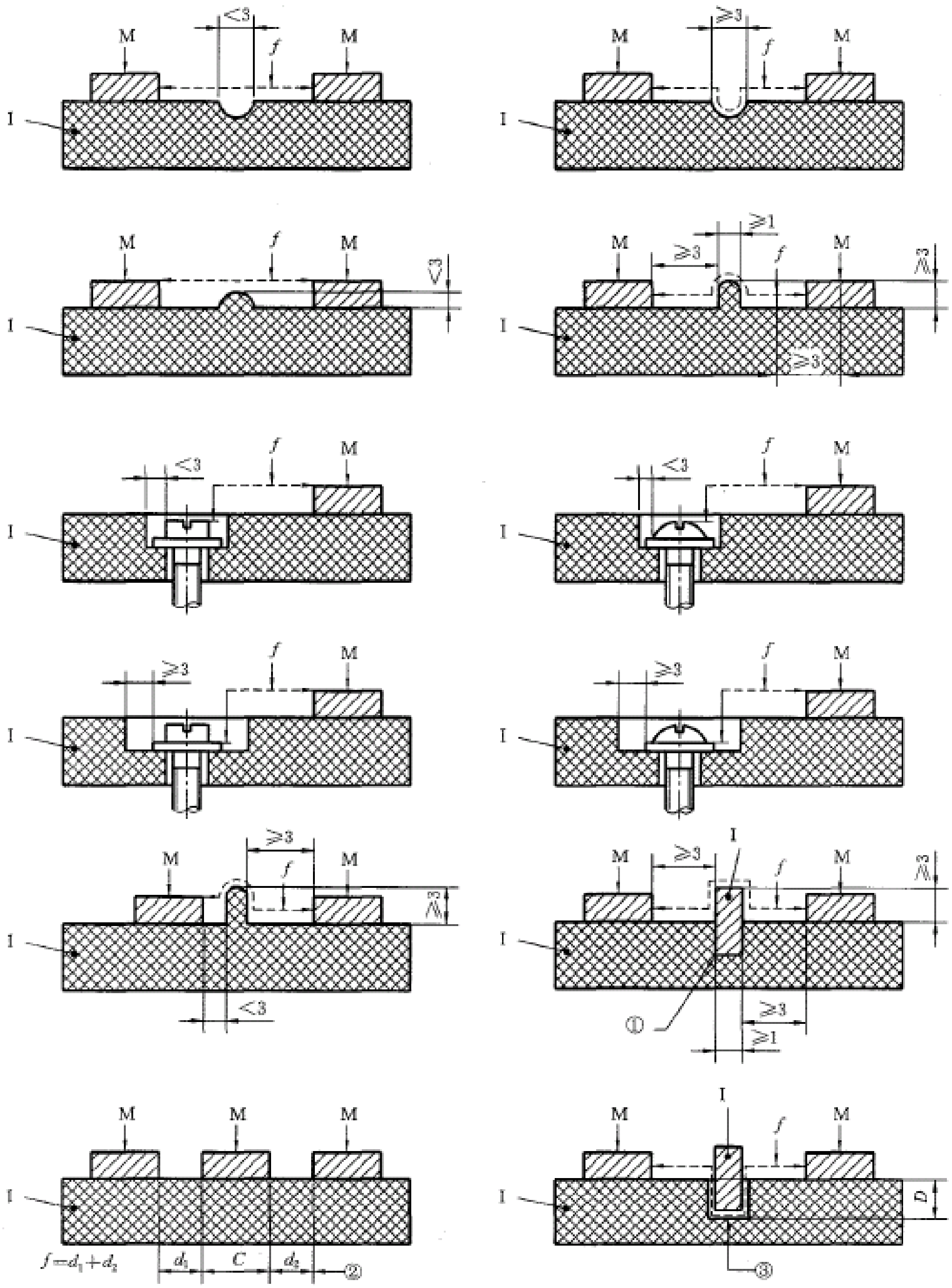
Any clearance or separation which is below one-third of the relevant value specified in Table 4 shall be ignored for the purpose of calculation.

6.4.7 Creepage distance in air

For the creepage distances in air specified in Line 5 of Table 4, the insulating material shall conform to Line 7 of Table 4 which specifies the minimum comparative tracking index (CTI) measured in accordance with GB 4207. The method of measuring or assessing these distances shall be in accordance with Figure 4.

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

Where the creepage distance is made up from the addition of shorter distances, for example where a conductive part is interposed, distances of less than one-third the relevant value in Line 5 of Table 4 shall not be taken into account. For voltages higher than 1 575 V peak, an interposing insulating partition or earthed metallic partition shall be used. In either case, the partition shall conform to 6.4.1.



f-Creepage distance ; ①-Cemented joint;

M-Metal; ②-The central metal is not electrically connected

I-Insulating material; ③-Uncemented joint. Exposed height of partition > D

Figure 4 – Determination of creepage distances (in air)

6.4.8 Creepage distance under coating

A conformal coating shall seal the creepage path between the conductors in question against the ingress of moisture and pollution, and shall give an effective lasting unbroken seal. It shall adhere to the conductive parts and to the insulating material. If the coating is applied by spraying, two separate coats shall be applied. Other methods of application require only one coat, for example dip coating, brushing, vacuum impregnating. A solder mask alone can be accepted as one of the two coats, provided the solder mask is not damaged during soldering.

The method used for coating the board shall be specified in the certification documentation.

Where the coating is considered adequate to prevent conductive parts, for example soldered joints and component leads, from protruding through the coating, this shall be stated in the documentation and confirmed by examination.

Where bare conductors or conductive parts emerge from the coating the comparative tracking index (CTI) in Line 7 of Table 4 shall apply to both insulation and coating.

NOTE – The concept of creepage distance under coating was developed for flat surfaces, for example non-flexible printed circuit boards. Radical differences from this format require special consideration.

6.4.9 Requirements for assembled printed circuit boards

Where creepage and clearance distances affect the intrinsic safety of the apparatus, the printed circuit shall conform to the following (see Figure 5):

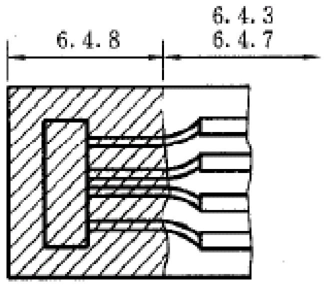
a) When a printed circuit is covered by a conformal coating according to 6.4.8, the requirements of 6.4.3 and 6.4.7 shall apply only to any conductive parts which lie outside the coating, including, for example

1) Tracks which emerge from the coating,

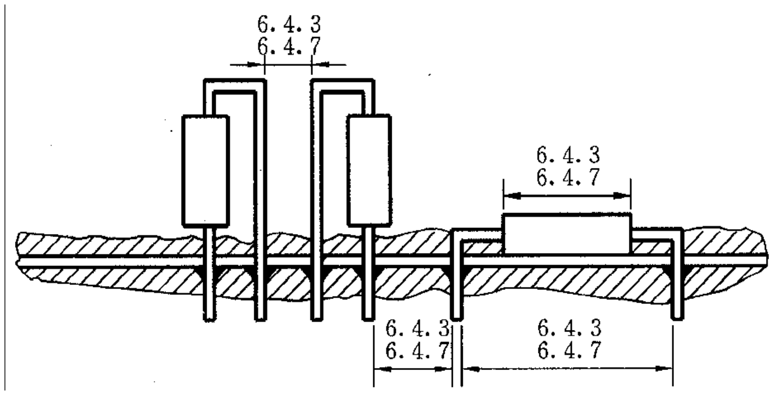
2) The free surface of a printed circuit which is coated on one side only,

3) Bare parts of components able to protrude through the coating;

b) The requirements of 6.4.8 shall apply to circuits or parts of circuits and their fixed components when the coating covers the connecting pins, solder joints and the conductive parts of any components.

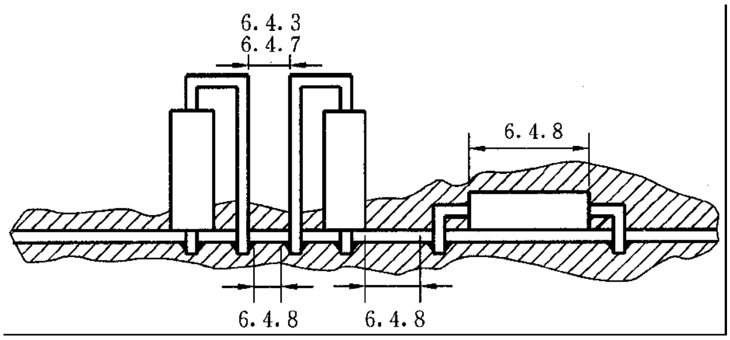


a) Partially coated board



Resistor leads not sealed within coating, therefore 6.4.3 and 6.4.7 apply to all marked Dimensions.

b) Board with soldered leads protruding



c) Board with soldered leads folded or cropped

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

Figure 5 – Creepage distances and clearances on printed circuit boards

6.4.10 Separation by earth screens

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

Where the connection is made through a connector, the connector shall be constructed in accordance with 6.6.

6.4.11 Internal wiring

Insulation, except for varnish and similar coatings, covering the conductors of internal wiring shall be considered as solid insulation (see 6.4.5).

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

The distance between the conductors of any core of an intrinsically safe circuit and that of any core of a non-intrinsically safe circuit shall be in accordance with Line 4 of Table 4, taking into account the requirements of 6.4.6 except when one of the following apply:

– the cores of either the intrinsically safe or the non-intrinsically safe circuit are enclosed in an earth screen, or

– in category "ib" electrical apparatus, the insulation of the intrinsically safe cores is capable of withstanding an r.m.s. a.c. test voltage of 2 000 V.

NOTES

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

2 Intrinsically safe wires and non-intrinsically safe wires shall be arranged separately[1].

6.4.12 Electric strength tests

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

Either the current flowing during the test shall not increase above that which is expected from the design of the circuit and shall not exceed 5 mA r.m.s. at any time, or where the circuit does not satisfy this requirement the apparatus shall be marked with the symbol X.

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

the non-intrinsically safe circuit.
Where breakdown between separate intrinsically safe circuits could produce an unsafe condition, the insulation between these circuits shall be capable of withstanding an r.m.s. test voltage of 2U, with a minimum of 500 V, where U is the sum of the r.m.s. values of the voltages of the circuits under consideration.
The test method used in the above tests shall be in accordance with 10.6.

6.4.13 Relays

Where the coil of a relay is connected to an intrinsically safe circuit, the contacts in normal operation shall not exceed their manufacturer's rating and shall not switch more than 5 A r.m.s.
or 250 V r.m.s. or 100 VA. When the values switched by the contacts exceed these values but do not exceed 10 A or 500 VA, the values for creepage distance and clearance from Table 4 for the relevant voltage shall be doubled.
For higher values, intrinsically safe circuits and non-intrinsically safe circuits shall be connected to the same relay only if they are separated by an earthed metal barrier or an insulating barrier conforming to 6.4.1. The dimensions of such an insulating barrier shall take into account the ionization arising from operation of the relay which would generally require creepage distances and clearances greater than those given in Table 4.
Where a relay has contacts in intrinsically safe circuits and other contacts in non-intrinsically safe circuits, the intrinsically safe and non-intrinsically safe contacts shall be separated by an insulating or earthed metal barrier conforming to 6.4.1 in addition to Table 4. 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.

6.5 Protection against polarity reversal

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

6.6 Earth conductors, connections and terminals

Where earthing, for example of enclosures, conductors, metal screens, printed wiring board conductors, segregation contacts of plug-in connectors and diode safety barriers, is required to maintain the type of protection, the cross-sectional area of any conductors, connectors and terminals used for this purpose shall be such that they are rated to carry the maximum possible current to which they could be continuously subjected under the conditions specified in Clause 5. Components shall also conform to Clause 7.
Notes used:
1] In IEC 60079-11 this note doesn't exist.
NOTE: Intrinsically safe circuit of Group I apparatus is generally not allowed to be used as return circuit, except those requiring ground protection.[1]
Where a connector carrier's earthed circuits and the type of protection depends on the earthed circuit, the connector shall comprise at least three independent connecting elements for "ia" circuits and at least two for "ib" circuits (see Figure 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.
Terminals shall be fixed in their mountings without possibility of self-loosening and shall be

constructed so that the conductors cannot slip out from their intended location. Proper contact shall be assured without deterioration of the conductors, even if multi-stranded cores are used in terminals which are intended for direct clamping of the cores. The contact made by a terminal shall not be appreciably impaired by temperature changes in normal service. Terminals which are intended for clamping stranded cores shall include resilient intermediate part. Terminals for conductors of cross-sections up to 4 mm^2 shall also be suitable for the effective connection of conductors having a smaller cross-section. Terminals which comply with the requirements of GB 3836.3 are considered to conform to these requirements.

The following shall not be used:

a) Terminals with sharp edges which could damage the conductors;

b) Terminals which may turn, be twisted or permanently deformed by normal tightening;

c) Insulating materials which transmit contact pressure in terminals.

6.7 Encapsulation used for the exclusion of a potentially explosive atmosphere

Where a casting compound is used to exclude a potentially explosive atmosphere from components and intrinsically safe circuits, for example fuses, piezo-electric devices with their suppression components and energy storage devices with their suppression components, it shall conform to 6.4.4.

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

7 Components on which Intrinsic Safety Depends

7.1 Rating of components

In both normal operation and after application of the fault conditions given in Clause 5, any remaining components on which the type of protection depends, except such devices as transformers, fuses, thermal trips, relays and switches, shall not operate at more than two-thirds of their maximum current, voltage and power related to the rating of the device, the mounting conditions and the temperature range specified. These maximum rated values shall be the normal commercial ratings specified by the manufacturer of the component.

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

Detailed testing or analysis of components and assemblies of components to determine the parameters, for example voltage and current, to which the safety factors are applied shall not be performed, since the factors of safety of 5.2 and 5.3 obviate the need for detailed testing or analysis. For example a Zener diode stated by its manufacturer to be 10 (1+ 10 %) V at 40 °C shall be taken to be 11 V maximum without the need to take into account effects such as voltage elevation due to rise in temperature.

Account shall also be taken of the effects of the mounting conditions and ambient temperature range specified by the manufacturer of the apparatus and by 5.2 of GB 3836.1-2000. For example, in the case of a semiconductor the power dissipation shall not exceed two-thirds of that which will cause the maximum junction temperature to be reached under the particular mounting conditions.

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

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

incorrect connection is obvious.
Where the type of protection depends on a connection, the failure to a high resistance or open circuit of a connection shall be a countable fault in accordance with Clause 5.
If a connector carries earthed circuits and the type of protection depends on the earth connection, then the connector shall be constructed in accordance with 6.6.

7.3 Fuses

Where fuses are used to protect other components, 1.7 I_n shall be assumed to flow continuously.
The fuse time-current characteristics shall ensure that the transient ratings of protected components are not exceeded. Where the fuse time-current characteristic is not available from the manufacturer's data, a type test shall be carried out in accordance with 10.12 on at least 10 samples.
Notes used:
1] In IEC 60079-11 this note doesn't exist.
This test shows the capability of the sample to withstand 1.5 times any transient which can occur when Um is applied through a fuse. Fuses located in the explosive atmospheres shall be protected in accordance with 6.7.
Where fuses are encapsulated, the casting compound shall not enter the fuse interior. This requirement shall be satisfied by testing samples or by a declaration from the fuse manufacturer confirming acceptability of the fuse for encapsulation.
Alternatively, the fuse shall be sealed prior to encapsulation.
Fuses used to protect components shall be replaceable only by opening the apparatus enclosure. The type designation and the fuse rating I_n, or the characteristics important to intrinsic safety shall be marked adjacent to the fuses.
Fuses shall have a rated voltage of at least Um (or Ui in intrinsically safe apparatus and circuits) although they do not have to conform to Table 4. General industrial standards for the construction of fuses and fuseholders shall be applied and their method of mounting shall not reduce the clearances, creepage distances and separations afforded by the fuse and its holder.

NOTE 1 – Microfuses conforming to GB 9346 are acceptable.

A fuse shall be capable of interrupting the maximum prospective current of the circuit in which it is installed. For mains electricity supply systems not exceeding 250 V a.c., the prospective current shall normally be considered to be 1 500 A a.c. The breaking capacity of the fuse is determined according to GB 9346 or an equivalent standard.

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

If a current-limiting device is necessary to limit the prospective current to a value not greater than the rated breaking capacity of the fuse, this device shall be infallible in accordance with Clause 7 and the rated values shall be at least:
– Current rating: 1.5×1.7×In;
– Voltage rating: Um or Ui;
– Power rating: 1.5 $\times(1.7\times In)^2\times$resistance of limiting device.

7.4 Cell(primary and secondary cells) and batteries

7.4.1 General

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

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

7.4.2 Electrolyte leakage

Either cells and batteries shall be of a type from which there can be no spillage of electrolyte or they shall be enclosed to prevent damage by the electrolyte to the component upon which safety depends. Cells and batteries declared as sealed (gas tight) or sealed (valve regulated) by their manufacturer (see 7.4.9) shall be deemed to satisfy this requirement. Other cells and batteries shall be tested in accordance with 10.9.2, or written confirmation shall be obtained from the cell/battery manufacturer that the product conforms to 10.9.2. If cells and batteries which leak electrolyte are encapsulated in accordance with 6.7, they shall be tested in accordance with 10.9.2 after encapsulation. Compartments containing cells or batteries which are charged within them shall be ventilated directly to the outside of the equipment.

7.4.3 Cell and battery voltages

For the purpose of evaluation and test, the cell/battery voltage shall be considered to be the maximum open circuit voltage attainable from either a new primary cell/battery or a secondary cell/battery just after a full charge as specified in Table 5. When the cell or battery is not covered by Table 5, it shall be tested in accordance with 10.9 to determine the maximum open circuit voltage, and the nominal voltage shall be that specified by the cell or battery manufacturer.

Table 5 – Cell voltages

IEC type	**Cell type**	**Peak open-circuit voltage for spark ignition hazard** V	**Nominal voltage for component surface temperature assessment** V
K	Nickel-cadmium Lead-acid (dry) Lead-acid (wet)	1.5 2.35 2.67	1.3 2.2 2.2
L M N	Alkaline-manganese Mercury-zinc Mercury-manganese dioxide-zinc Silver-zinc	1.65 1.37 1.6 1.63	1.5 1.35 1.4 1.55
S A C	Zinc-air Lith ium-manganese dioxide Zinc-manganese dioxide (zinc-carbon Leclanché) Nickel-hydride	1.55 3.7 1.725 1.6	1.4 3.0 1.5 1.3

7.4.4 Internal resistance of cell and batteries

The internal resistance of a battery or cell shall be determined in accordance with 10.9.3.

7.4.5 Current-limiting devices for batteries in associated apparatus

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

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

7.4.6 Current-limiting devices for batteries to be 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 a hazardous atmosphere, it shall form a completely replaceable unit with its current-limiting devices. The unit shall be encapsulated or enclosed so that only the intrinsically safe output terminals and suitably protected intrinsically safe terminals for charging purposes (if provided) are exposed.

7.4.7 Current-limiting devices for batteries to be used but not replaced in explosive atmospheres

If the cell or battery requiring current-limiting devices to ensure the safety of the battery itself is not intended to be replaced in the hazardous area, it shall either be protected in accordance with 7.4.6 or alternatively it may be housed in a compartment with special fasteners, for example those specified by GB 3836.1. It shall also conform to the following:

a) The cell or battery housing or means of attachment shall be arranged so that the cell or battery can be installed and replaced without reducing the intrinsic safety of the apparatus;

b) Handheld electrical apparatus or electrical apparatus carried on the person, ready for use, such as radio receivers and transceivers shall be subjected to the drop test in accordance with 23.4.3.2 of GB 3836.1-2000 except that the prior impact test shall be omitted. The construction of the apparatus shall be considered adequate if the test does not result in the ejection or separation of the cells from the apparatus in such a way as to invalidate the intrinsic safety of the apparatus or battery;

c) The apparatus shall have a warning label against changing the battery in the potentially explosive atmosphere, for example "DO NOT REMOVE BATTERY IN A POTENTIALLY EXPLOSIVE ATMOSPHERE".

7.4.8 External contacts for charging batteries

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

a) Blocking diodes or an infallible series resistor shall be placed in the charging circuits. For category "ib" two diodes and for category "ia" three diodes shall be used. Either the battery charger shall be associated apparatus or the diodes or resistor shall be protected by an appropriately rated fuse. The fuse shall either be encapsulated or shall not carry any current when situated in a potentially explosive atmosphere and the circuit is assessed as required by Clause 5;

b) for Group II electrical apparatus, a degree of protection by enclosure of at least IP20 for the suitably protected charging circuit and a label warning against charging in the potentially explosive atmosphere shall be provided.

The maximum input voltage Um which can be applied to these connection facilities without invalidating the intrinsic safety of the apparatus U_m shall be marked on the apparatus and stated in the certification documentation.

7.4.9 Battery construction

The spark ignition capability and surface temperature of cells and batteries shall be tested or assessed in accordance with 10.9.3. The cell or battery construction shall be one of the following types:

a) sealed (gas-tight) cells or batteries;

b) sealed (valve-regulated) cells or batteries;

c) cells or batteries which are intended to be sealed in a similar manner to items a) and b) apart from a pressure relief device. Such cells or batteries shall not require addition of electrolyte during their life and shall have a sealed metallic or plastics enclosure conforming to the following:

1) without seams or joints, for example solid-drawn, spun or moulded, joined by fusion, eutectic methods, welding or adhesives sealed with elastomeric or plastics sealing devices retained by the structure of the enclosure and held permanently in compression, for example washers and "o" rings,

2) 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 casting compound specified by the manufacturer of the casting compound as being suitable for use with the electrolyte concerned and conforming to 6.7.

A declaration of conformance to a) or b) shall be obtained from the manufacturer of the cell or battery and this shall not be checked by the testing station. Conformance to c) or d) shall be determined by physical examination of the cell or battery and where necessary its constructional drawings.

7.5 Semiconductors

7.5.1 Transient effects

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

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

7.5.2 Shunt voltage limiters

Semiconductors may be used as shunt voltage limiting devices provided that they conform to the following requirements and provided that relevant transient conditions are taken into account.

Semiconductors shall be capable of carrying, without open-circuiting, 1.5 times the current which would flow at their place of installation if they failed in the short-circuit mode. In the following cases, this shall be confirmed from their manufacturer's data by:

a) diodes, diode connected transistors, thyristors and equivalent semiconductor devices having a forward current rating of at least 1.5 times the maximum possible short-circuit current;

b) Zener diodes being rated:

1) In the Zener direction at 1.5 times the power that would be dissipated in the Zener mode, and

2) In the forward direction at 1.5 times the maximum current that would flow if they were short-circuited.

For category "ia", the application of controllable semiconductor components as shunt voltage limiting devices, for example transistors, thyristors, voltage/current regulators, etc., is permitted if both the input and output circuits are intrinsically safe circuits or where it can be shown that they cannot be subjected to transients from the power supply network. In circuits complying with the above, two devices are considered to be an infallible assembly. For category "ia", three thyristors may be used in associated apparatus provided the transient conditions of 7.5.1 are met. Circuits using shunt thyristors shall also be tested in accordance with 10.4.3.3.

7.5.3 Series current limiters

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

NOTE – The use of semiconductors and controllable semiconductor devices as current-limiting devices is not permitted for category "ia" apparatus because of their probable future use in areas in which a continuous or frequent presence of an explosive atmosphere may coincide with the possibility of a brief transient which could cause ignition.

7.6 Failure of components and connections

The application of 5.2 and 5.3 shall include the following:

a) Where a component is not rated in accordance with 7.1, its failure shall be a non-countable fault. Where a component is rated in accordance with 7.1, its failure shall be a countable fault;

b) Where a fault can lead to a subsequent fault or faults, then the primary and subsequent faults shall be considered to be a single fault;

c) the failure of resistors to any value of resistance between open circuit and short circuit shall be taken into account (but see 8.4);

d) Semiconductor devices shall be considered to fail to short circuit or to open circuit and to the state to which they can be driven by failure of other components. For surface temperature classification, failure of any semiconductor device to a condition where it dissipates maximum power shall be taken into account. Integrated circuits can fail so that any combination of short and open circuits can exist between their external connections. Although any combination can be assumed, once that fault has been applied it cannot be changed, for example by application of a second fault. Under this fault situation any capacitance and inductance connected to the device shall be considered in their most onerous connection as a result of the applied fault;

e) connections shall be considered to fail to open circuit and, if free to move, may connect to any part of the circuit within the range of movement. The initial break is one countable fault and the reconnection is a second countable fault (but see 8.7);

f) clearances, creepage and separation distances shall be taken into account in accordance with 6.4;

g) failure of capacitors to open-circuit, short circuit and any value less than the maximum specified value shall be taken into account (but see 8.5);

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

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

Insertion of the spark test apparatus to effect an interruption, short circuit or earth fault shall not be considered as a countable fault but as a test in normal operation. Infallible connections and separations in accordance with Clause 8 shall not be considered as producing a fault and the spark test apparatus shall not be inserted in series with such connections or across such separations. However, where infallible connections and separations are not encapsulated or covered by a coating in accordance with Clause 6 or do not maintain an enclosure integrity of at least IP20 when exposing connection facilities, the spark test apparatus shall be inserted in series with such connections or across such separations.

7.7 Piezo-electric devices

Piezo-electric devices shall be tested in accordance with 10.11.

8 Infallible Components, Infallible Assemblies of Components and Infallible Connections

8.1 Mains transformers

8.1.1 Winding faults

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

8.1.2 Protective measures

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

If the input and output windings are separated by an earthed metal screen (see type 2b) construction in 8.1.3), each non-earthed input line shall be protected by a fuse or circuit breaker.

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

Fuses, fuseholders, circuit-breakers and thermal devices shall conform to an appropriate recognized standard. Conformance with the recognized standard shall not be verified by the certification body.

8.1.3 Transformer construction

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

For type 1 construction, the windings shall be placed either

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

b) On different legs of the core.

The windings shall be separated in accordance with Table 4.

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

a) Solid insulation in accordance with Table 4 between the windings, or

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

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

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

Rating of the fuse A	0.1	0.5	1	2	3	5
Minimum thickness of the foil screen mm	0.05	0.05	0.075	0.15	0.25	0.3
Minimum diameter of the wire of the screen	0.2	0.45	0.63	0.9	1.12	1.4

mm						

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

The foil screen shall be provided with two mechanically separate leads to the earth connection, each of which is rated to carry the maximum continuous current which could flow before the fuse or circuit-breaker operates, for example 1.7 I_n for a fuse.

A wire screen shall consist of at least two electrically independent layers of wire, each of which is provided with an earth connection rated to carry the maximum continuous current which could flow before the fuse or circuit-breaker operates. The only requirement of the insulation between the layers is that it shall be capable of withstanding a 500 V test in accordance with 10.6.

The cores of all mains supply transformers shall be provided with an earth connection, except where earthing is not required for the type of protection, for example when transformers with insulated cores are used.

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

8.1.4 Transformer type tests

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

Where a series resistor is either incorporated within the transformer, or encapsulated with the transformer so that there is no bare live part between the transformer and the resistor, or mounted so as to provide creepage distances and clearances conforming to Table 4, and if the resistor remains in circuit after the application of Clause 5, then the output winding shall not be considered as subject to short circuit except through the resistor.

The requirement for safe electrical isolation is satisfied if the transformer passes the type test described below and subsequently withstands a test voltage (see 10.6) of 2 Un + 1 000 V or 1 500 V, whichever is the greater, between any winding(s) used to supply intrinsically safe circuits and all other windings, Un being the highest rated voltage of any winding under test.

The input current shall be adjusted to 1.7 I_n or to the maximum continuous current which the circuit-breaker will carry without operating. During the test this current shall be maintained within ±10 % of this value. The current shall be adjusted by varying the input voltage up to the rated voltage of the transformer. Where this limit is reached, the test shall proceed using the rated input voltage.

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

For type 1 and type 2a) transformers, the transformer winding temperature shall not exceed the permissible value for the class of insulation given in GB/T 11021. The winding temperature shall be measured in accordance with 10.5.

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

8.1.5 Routine test of mains transformers

Each mains transformer shall be tested in accordance with 11.2.

8.2 Transformers other than mains transformers

The infallibility and failure modes of these transformers shall conform to 8.1.

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

The construction and testing of these transformers shall conform to 8.1 except that they shall be tested at their maximum load.

Where it is not practicable to operate the transformer under alternating current conditions, each winding shall be subjected to a direct current of 1.7 In in the type test of 8.1.4. However, the routine test in accordance with 11.2 shall use a reduced voltage between the input and output windings of 2 Un + 1 000 V r.m.s. or 1 500 V, whichever is the greater.

When such transformers are connected to non-intrinsically safe circuits derived from mains voltages, then either protective measures in accordance with 8.1.2 or a fuse and Zener diode shall be included at the supply connection in accordance with 8.8 so that unspecified power shall not impair the infallibility of the transformer creepage distances and clearances. The rated input voltage of 8.1.4 shall be that of the Zener diode.

8.3 Damping windings

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

8.4 Current-limiting resistors

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

a) film type;

b) wire wound type with protection to prevent unwinding of the wire in the event of breakage;

c) printed resistors as used in hybrid and similar circuits covered by a coating conforming to 6.4.8 or encapsulated in accordance with 6.4.4.

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

A current-limiting resistor shall be rated in accordance with the requirements of 7.1, to withstand at least 1.5 times the maximum voltage and to dissipate at least 1.5 times the maximum power that can arise in normal operation and under the fault conditions defined in Clause 5. Faults between turns of correctly rated wire wound resistors with coated windings shall not be taken into account. The coating of the winding shall be assumed to comply with the required CTI value in accordance with Table 4 at its manufacturer's voltage rating.

8.5 Blocking capacitors

Either of the two series capacitors in an infallible arrangement of blocking capacitors shall be considered as being capable of failing to short or open circuit. The capacitance of the assembly shall be taken as the most onerous value of either capacitor and a safety factor of 1.5 shall be used in all applications of the assembly.

Blocking capacitors shall be of a high reliability solid dielectric type. Electrolytic or tantalum capacitors shall not be used. The external connections of the assembly shall comply with 6.4 but these separation requirements shall not be applied to the interior of the blocking capacitors.

The insulation of each capacitor shall conform to the electrical strength test of 6.4.12. Where blocking capacitors are used between intrinsically safe circuits and non-intrinsically safe circuits, all possible transients shall be taken into account.

Where such an assembly also conforms to 8.8, it shall be considered as providing infallible galvanic separation for direct current.

Capacitors connected between the frame of the apparatus and an intrinsically safe circuit shall conform to 6.4.12. Where their failure by-passes a component on which the intrinsic safety of the circuit depends, they shall also conform to the requirements for blocking capacitors.

NOTE – The normal purpose of these capacitors is the rejection of high frequencies.

8.6 Shunt safety assemblies

8.6.1 General

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

Where diodes or Zener diodes are used as the shunt components in an infallible shunt safety assembly, they shall form at least two parallel paths of diodes. Diodes shall be rated to carry the current which would flow at their place of installation if they failed in the short-circuit mode.

The connections of the shunt components shall either be in accordance with 8.7 or be arranged so that, if either of the shunt paths becomes disconnected, the circuit or component being protected becomes disconnected at the same time.

NOTE 1 – To prevent spark ignition when a connection breaks, encapsulation in accordance with 6.4.4 may be required.

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

Where shunt safety assemblies are subjected to power faults specified only by a value of Um, the components of which they are formed shall be rated in accordance with 7.1. Where the components are protected by a fuse, the fuse shall be in accordance with 7.3 and the components shall be assumed to carry a continuous current of 1.7 In of the fuse. The ability of the shunt components to withstand transients shall either be tested in accordance with 10.12 or be determined by comparison of the fuse-current time characteristic of the fuse and the performance characteristics of the device.

Where a shunt safety assembly is manufactured as an individual apparatus rather than as part of a larger apparatus, then the construction of the assembly shall be in accordance with 9.2.

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

a) either of the two shunt paths in the assembly shall be considered as failing to an open circuit condition;

b) the voltage of the assembly shall be that of the highest voltage shunt path;

c) the failure of either shunt path to short circuit shall be considered as one fault;

d) a safety factor of 1.5 shall be used in the application of all the fault counts of 5.2 and 5.3;

e) circuits using shunt thyristors shall be tested in accordance with 10.4.3.3.

8.6.2 Safety shunts

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

Safety shunts shall be subjected to the required analysis of transients when they are connected to power supplies defined only by Um in accordance with 8.6.1, except when used as follows:

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

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

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

8.6.3 Shunt voltage limiters

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

Shunt voltage limiters shall be subjected to the required analysis of transients required when they are connected to power supplies defined only by Um in accordance with 8.6.1, except when the assembly is fed from one of the following:

a) An infallible transformer in accordance with 8.1;

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

c) A battery in accordance with 7.4;

d) An infallible shunt safety assembly in accordance with 8.6.

8.7 Wiring and connections

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

a) for wires:

1) Where two wires are in parallel, or

2) Where a single wire has a diameter of at least 0.5 mm and has an unsupported length of less than 50 mm or is mechanically secured adjacent to its point of connection, or

3) Where a single wire is of stranded or flexible ribbon type construction, has a cross-sectional area of at least 0.125 mm2 (0.4 mm diameter), is not flexed in service and is either less than 50 mm long or is secured adjacent to its point of connection;

b) For printed board tracks:

1) Where two tracks of minimum width 1 mm are in parallel, or

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

3) Where each track is formed from copper cladding having a nominal thickness of not less than 35 m;

c) For connections (excluding plugs, sockets and terminals):

1) Where there are two connections in parallel, or

2) Where there is a single soldered joint in which the wire passes through the board (including through-plated holes) and is either bent over before soldering or, if not bent over, machine soldered or has a crimped connection or is brazed or welded, or

3) Where there is a single connection which is screwed or bolted and conforms to 6.6.

8.8 Galvanically separating components

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

Isolating components other than transformers and relays, for example optocouplers, shall be considered to provide infallible separation of separate intrinsically safe circuits if the following conditions are satisfied:

a) the rating of the component shall be according to 7.1;

b) before application of Um and Ui the component shall withstand an electric strength test as

described in 6.4.12.
The manufacturer's rated isolation voltage for the infallible separation of the component under test shall be not less than the test voltage required by 6.4.12.
Where separation is between intrinsically safe and non-intrinsically safe circuits, the requirements of Table 4 shall also apply to the isolating component except that, inside sealed devices, for example optocouplers, Lines 5, 6 and 7 shall not apply. The non-intrinsically safe circuit terminals shall be provided with protection to ensure that the ratings of the components in accordance with 7.1 Are not exceeded unless it can be shown that the circuits connected to these terminals cannot invalidate intrinsic safety of the components. Typically the inclusion of a single shunt Zener diode protected by a suitably rated fuse capable of interrupting the prospective peak current of the supply shall be considered as sufficient protection. For this purpose, Table 4 shall not be applied to the fuse and Zener diode. The Zener diode power rating shall be at least 1.7 In times the diode maximum Zener voltage. General industrial standards of construction shall be considered adequate for fuses and the method of mounting, for example in a fuse holder, shall not reduce the clearances and creepage distances afforded by the fuse itself.
Where the external protective devices of the optocoupler comply with Clauses 5, 6 and 7 of this standard, there is no requirement for the internal distance between the conductive parts of the emitter and receiver of the optocoupler, provided that the internal components of the optocoupler, when operating normally or with faults applied to the intrinsically safe circuits and non-intrinsically safe circuits, do not operate at more than two-thirds of the maximum permissible power specified by the manufacturer.
Galvanically separating relays shall conform to 6.4.13 and any winding shall be capable of dissipating the maximum power to which it is connected.
NOTE – Derating of the relay winding in accordance with 7.1 is not required.

9 Diode Safety Barriers

9.1 General

The diodes within a diode safety barrier limit the voltage applied to an intrinsically safe circuit and a following infallible current-limiting resistor limits the current which can flow into the circuit. These assemblies are intended for use as interfaces between intrinsically safe circuits and non-intrinsically safe circuits, and shall be subject to the routine test of 11.1.
The ability of the safety barrier to withstand transient faults shall be tested in accordance with 10.12.
Safety barriers containing only two diodes or diode chains and used for category "ia" shall be acceptable as infallible assemblies in accordance with 8.6, provided the diodes have been subjected to the routine tests specified in 11.1.2.
In category "ia" two-diode barriers, only the failure of one diode shall be taken into account in the application of Clause 5.

9.2 Construction

9.2.1 Mounting

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

9.2.2 Facilities for connection to earth

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

9.2.3 Protection of components

The assembly shall be protected against access, in order to prevent repair or replacement of any components on which safety depends either by encapsulation in accordance with 6.4.4 or by an enclosure which forms a non-recoverable unit. The entire assembly shall form a single entity.

10 Type Verifications and Type Tests

10.1 Spark ignition test

10.1.1 General

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

Normal and fault conditions shall be simulated during the tests. Safety factors shall be taken into account as described in Appendix A.

The spark test apparatus shall be inserted in the circuit under test at each point where it is considered that an interruption, short circuit, or earth fault may occur. The spark test apparatus shall be operated in a chamber filled with the most readily ignited mixture of the test gas with air, within the limits specified in 10.2, as determined by calibration in accordance with 10.3.

A circuit may be exempted from a type test with the spark-test apparatus if its structure and its electrical parameters are sufficiently well defined for its safety to be deduced from the reference curves, Figures A.1 to A.6 or Tables A.1 and A.2, by the methods described in Appendix A.

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

NOTE – A circuit assessed using the reference curves and tables may cause ignition when tested using the spark test apparatus. The sensitivity of the spark test apparatus varies, and the curves and tables are derived from a large number of such tests. The assessment using the curves and tables is more consistent and takes precedence over the experimental results.

10.1.2 Spark test apparatus

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

The use of the spark test apparatus to produce short circuits, interruptions and earth faults shall be a test of normal operation and is a non-countable fault:

a) At connection facilities,

b) At internal connections or across internal creepage distances, clearances, distances through casting compound and distances through solid insulation not conforming to Table 4.

The spark test apparatus shall not be used:

a) Across infallible separations, or in series with infallible connections,

b) Across creepage distances, clearances, distances through casting compound and distances through solid insulation conforming to table 4,

c) Within associated apparatus other than at its intrinsically safe circuit terminals,

d) Between terminals of separate circuits conforming to 6.3.1, apart from the exceptions described in 7.6i).

10.2 Explosive test mixtures

The following explosive test mixtures shall be used according to the stated apparatus group which is being tested:

Group I 8.0 % to 8.6 % methane in air

Group IIA 5.0 % to 5.5 % propane in air

Group IIB 7.3 % to 8.3 % ethylene in air

Group IIC 19 % to 23 % hydrogen in air

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.

Where a more severe test mixture is used to achieve a factor of safety, its composition shall be as given in 10.4.2.

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

10.3 Calibration of the spark test apparatus

The sensitivity of the spark test apparatus shall be checked before each test series carried out in accordance with 10.4. For this purpose, the test apparatus shall be operated in a 24 V d.c. circuit containing a 0.09 H to 0.1 H air-cored coil. The current in this circuit shall be set at the value given in table 7 for the appropriate group, or to this value divided by the factor of safety when a more easily ignited test gas is used.

Table 7 – Current in the calibration circuit

Apparatus group	**Current** mA
I	110 – 111
IIA	100 – 101
IIB	65 – 66
IIC	30 – 30,5

The spark test apparatus shall be run at not less than 400 and not more than 440 revolutions of the contact holder with the wire holder at positive polarity. The sensitivity shall be considered to be satisfactory if at least one ignition of the explosive test mixture occurs.

10.4 Tests with the spark test apparatus

10.4.1 Circuit test

The circuit to be tested shall be based on the most incendive circuit that can arise, toleranced in accordance with Clause 7 and taking into account a 10 % variation in the mains supply voltage.

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

Each circuit shall be tested for the following number of revolutions, with a tolerance of 0%~+10 % of the wire holder in the spark test apparatus:

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

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

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

After each test in accordance with a), b) or c) calibration of the spark test apparatus shall be repeated. If the calibration does not conform to 10.3, the ignition test on the circuit under investigation shall be considered invalid.

10.4.2 Safety factors

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

The safety factor of 1.5 shall be obtained by one of the following methods:

a) increase the mains (electrical supply system) voltage to 110 % of the nominal value to allow for mains variations, or set other voltages, for example batteries, power supplies and voltage limiting devices at the maximum value in accordance with Clause 7, then:

1) for inductive and resistive circuits, increase the current to 1.5 times the fault current by decreasing the values of limiting resistance, if the 1.5 factor cannot be obtained, further increase the voltage;

2) for capacitive circuits, increase the voltage to obtain 1.5 times the fault voltage. Alternatively when an infallible current-limiting resistor is used with a capacitor, consider the capacitor as a battery and the circuit as resistive.

NOTE-When using the curves in Figures A.1 to A.6 or Tables A.1 and A.2 for assessment, this same method shall be used.

b) Use the more easily ignited explosive test mixtures in accordance with Table 8. These mixtures shall be measured to confirm that they are within ±0.5 of the quoted values.

Table 8 – Compositions of explosive test mixtures equivalent to 1.5 safety factor

Gaz group	**Compositions of explosive test mixtures** Volume %				
	Oxygen-hydrogen-air mixture			**Oxygen-hydrogen mixture**	
	Hydrogen	**Air**	**Oxygen**	**Hydrogen**	**Oxygen**
I	52	48	–	85	15
IIA	48	52	–	81	19
IIB	38	62	–	75	25
IIC	30	17	53	60	40

10.4.3 Testing considerations

10.4.3.1 General

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

10.4.3.2 Circuits with both inductance and capacitance

Where a circuit contains energy stored in both capacitance and inductance, it may be difficult to assess such a circuit from the curves in Figures A.1 to A.6, for example where the capacitive stored energy may reinforce the power source feeding an inductor. The circuit shall be tested with the combination of capacitance and inductance.

10.4.3.3 Circuits using shunt short-circuit (crowbar) protection

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

– Group IIC apparatus: 20μJ

– Group IIB apparatus: 80μJ

– Group IIA apparatus: 160μJ

– Group I apparatus: 260 μJ

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

10.4.4 Results of spark tests

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

10.5 Temperature tests

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

Temperatures shall be measured by any convenient means. The measuring element shall not substantially lower the measured temperature. An acceptable method of determining the rise in temperature of a winding is as follows:

– measure the winding resistance with the winding at a recorded ambient temperature;

– apply the test current or currents and measure the maximum resistance of the winding, and record the ambient temperature at the time of measurement;

– calculate the rise in temperature from the following equation:

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

where

t is the temperature rise, in kelvins;

r is the resistance of the winding at the ambient temperature t1, in ohms;

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

t_1 is the ambient temperature, in degrees Celsius, when r is measured;
t_2 is the ambient temperature, in degrees Celsius, when R is measured;
k is the inverse of the temperature coefficient of resistance of the winding at 0 °C and has the value of 234.5 K for copper.

10.6 Voltage tests

Voltage tests shall be in accordance with the appropriate IEC standard. Where there is no such standard, the following test method shall be used. The test shall be performed either with an alternating voltage of substantially sinusoidal waveform at a power frequency between 48 Hz and 62 Hz or with a d.c. voltage having no more than 3 % peak-topeak ripple at a level 1.4 times the specified a.c. voltage.

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

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

The applied voltage shall remain constant during the test and the current shall not exceed an r.m.s. value of 5 mA.

10.7 Small component ignition test

A small component tested to demonstrate that it shall not cause temperature ignition of a flammable mixture in accordance with 6.2.4a) shall be tested as described below. The appearance of a cool flame shall be considered as an ignition. Detection of ignition shall either be visual or by measurement of temperature, for example by a thermocouple.

The component shall be tested under normal operation or in the fault conditions in accordance with Clause 5 which produce the highest value of surface temperature. The test shall be continued either until thermal equilibrium of the component and the surrounding parts is attained or until the component temperature drops. Where the component failure causes the temperature to fall, the test shall be repeated five times using five additional samples of the component. Where in normal operation or in the fault conditions in accordance with Clause 5, the temperature of more than one component exceeds the temperature class of the apparatus, the test shall be carried out with all such components at their maximum temperature.

The component under test may either be mounted in the apparatus as intended and precautions shall be taken to ensure that the test mixture is in contact with the component.

Alternatively, the test shall be carried out on a model which ensures representative results.

Such a simulation shall take into account the effect of other parts of the apparatus in the vicinity of the component being tested which affect the temperature of the mixture and the flow of the mixture around the component as a result of ventilation and thermal effects.

The safety factor required in 5.3 of GB 3836.1-2000 shall be achieved either by raising the ambient temperature at which the test is carried out or, where this is possible, by raising the temperature of the component under test and other relevant adjacent surfaces by the required margin.

For T4 temperature classification, the mixture shall be either:

a) a homogeneous mixture of between 22.5 % and 23.5 % in volume diethyl ether and air, or

b) a mixture of diethyl ether and air obtained by allowing a small quantity of diethyl ether to evaporate within a test chamber while the ignition test is being carried out.

For other temperature classifications, the choice of suitable test mixtures shall be at the discretion of the testing station.

If no ignition occurs during a test, the presence of the flammable mixture shall be verified by igniting the mixture by some other means.

10.8 Determination of parameters of loosely specified components

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

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

10.9 Tests for cells and batteries

10.9.1 General

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

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

10.9.2 Electrolyte leakage test for cells and batteries

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

a) Short circuit until discharged;

b) Application of input or charging currents within the manufacturer's recommendations;

c) Charging a battery within the manufacturer's recommendations with one cell fully discharged or suffering from polarity reversal.

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

There shall be no visible sign of electrolyte on the blotting paper or on the external surfaces of the test samples when they have cooled. Where casting compound has been applied to achieve conformance to 7.4.9, examination of the cell at the end of the test shall show no damage which would invalidate conformance with 7.4.9.

10.9.3 Spark ignition and surface temperature of cells and batteries

If a battery comprises a number of discrete cells or smaller batteries combined in a well-defined construction conforming to the segregation and other requirements of this standard, then each discrete element shall be considered as an individual component for the purpose of testing.

Except for specially constructed cells where it can be shown that short circuits between cells cannot occur, the failure of each element shall be considered as a single fault.

In less well-defined circumstances, the battery shall be considered to have a short-circuit failure between its external terminals. Cells and batteries which conform to 7.4.9 shall be tested or assessed as follows.

a) Spark ignition assessment or testing shall be carried out at the cell or battery external terminals, except where a current-limiting device is included and the junction of this device and the cell or battery conforms to 6.7. The test or assessment shall then include the current-limiting device.

When the internal resistance of a cell or battery is to be included in the assessment of intrinsic safety, its minimum resistance value shall be made available to the testing station.

If the cell/battery manufacturer is unable to confirm the minimum value of internal resistance, the testing station shall use the most onerous value of short-circuit current from a test of 10 samples of the cell/battery together with the peak open circuit voltage in accordance with 7.4.3 of the cell/battery to determine the internal resistance.

b) The maximum surface temperature shall be determined as follows. All current-limiting devices external to the cell or battery shall be short-circuited for the test. Any external sheath (of paper or metal, etc.) not forming part of the actual cell enclosure shall be removed for the test. The temperature shall be determined on the outer enclosure of each cell or battery and the maximum figure taken. The test shall be carried out both with internal current-limiting devices in circuit and with the devices short-circuited using 10 cells in each case.

The 10 samples having the internal current-limiting devices short-circuited shall be obtained from the cell/battery manufacturer together with any special instructions or precautions necessary for safe use and testing of the samples.

NOTE – When determining the surface temperature of most batteries, the effect of built-in protective devices, for example fuses or PTC resistors, is not taken into account because this is an assessment of a possible internal fault, for example failure of a separator.

10.10 Mechanical tests

10.10.1 Casting compound

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

Where a free surface of casting compound occurs, in order to ensure that the compound is rigid but not brittle, one of the following impact tests shall be carried out on the surface of the casting compound at (20 ± 10) °C using the test apparatus described in Appendix G of GB 3836.1-2000:

a) For Group I applications where casting compound forms part of the external enclosure and is used to exclude a potentially explosive atmosphere, a minimum impact energy of 20 J shall be used;

b) for all other applications a minimum impact energy of 2 J shall be used.

The casting compound shall remain intact and no permanent deformation shall occur. Minor surface cracks shall be ignored.

10.10.2 Partitions

Partitions shall withstand a minimum force of 30 N applied by a 6 mm diameter solid test rod.

The force shall be applied to the approximate centre of the partition for at least 10 s. There shall be no deformation of the partition that would make it unsuitable for its purpose.

10.11 Tests for apparatus containing piezoelectric devices

Measure both the capacitance of the device and also the voltage appearing across it when any part of the apparatus which is accessible in service is impact tested in accordance with the "high" column of Table 4 in GB 3836.1-2000 carried out at (20 ± 10) °C using the test apparatus in Appendix D of GB 3836.1-2000. For the value of voltage, the higher figure of the two tests on the same sample shall be used. When the 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 apparatus mounted as intended by the manufacturer.

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

– for Group I apparatus: 1 500μJ

– for Group IIA apparatus: 950μJ

– for Group IIB apparatus: 250μJ

– for Group IIC apparatus: 50μJ

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

Where it is necessary to protect the apparatus from external physical impact in order to prevent the impact energy exceeding the specified values, details of the requirements shall be specified as special conditions for safe use and the apparatus shall be marked with the symbol X.

10.12 Type tests for diode safety barriers and safety shunts

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

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

The diodes shall be shown to be capable of withstanding the peak Um divided by the value (at 20 °C) of the fuse resistance and any infallible resistance in series with the fuse, either by the diode manufacturer's specification or by the following test.

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

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

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

10.13 Cable pull test

Apparatus which is constructed with an integral cable for external connections shall be subjected to a pull test 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. The test shall be carried out as follows:

– apply a tensile force of minimum value 30 N on the cable in the direction of the cable entrance into the apparatus for the duration of at least 1 h;

– although the cable sheath may be displaced, no visible displacement of the cable terminations shall be observed;

– this test shall not be applied to individual conductors which are permanently connected and do not form part of a cable.

11 Routine Verifications and Tests

11.1 Routine tests for diode safety barriers

11.1.1 Completed barriers

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

11.1.2 Diodes for 2-diode "ia" barriers

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

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

b) subject each diode to the pulse current test in accordance with 10.12.

11.2 Routine tests for mains transformers

In routine tests, the voltages applied to mains transformers shall conform to the values given in Table 9, where Un is the highest rated voltage of any winding under test.

Table 9 – Routine test voltages for mains transformers

Where applied	**RMS test voltage**
Between input and output windings	4 Un or 2 500 V, whichever is the greater
Between all the windings and the core or screen	2 Un or 1 000 V, whichever is the greater
Between each winding which supplies an intrinsically safe circuit and any other output winding	2 Un + 1 000 V or 1 500 V, whichever is the greater

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

12 Marking

12.1 General

Intrinsically safe apparatus and associated apparatus shall carry at least the minimum marking specified in GB 3836.1. The marking of the serial number may be achieved by using a date or batch number code which is sufficient to ensure traceability for quality control purposes.

NOTE – The serial number marking may be separate from the other marking.

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

All relevant parameters should be marked, for example Um, Li, Ci, Lo, Co wherever practicable.

NOTE– Standard symbols for marking and documentation are given in Clause 3.

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 Uo.

12.2 Marking of connection facilities

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

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 forthe 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.

The following are examples of marking.

a) Self-contained intrinsically safe apparatus

Name of Manufacturer TYPE XX PAGING RECEIVER Ex ia IIC T4 –25 °C≤Ta ≤+50 °C ACB No. and Explosion-proof Certificate No. Serial No.:

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

Name of Manufacturer TYPEXX TRANSDUCTEUR Ex ib IIB T4 ACB No. and Explosion-proof Certificate No. Li: 10μH Ci: 1 200 pF Ui: 28 V Ii: 250 mA Pi: 1.3 W Serial No.:

c) Associated apparatus

Name of Manufacturer TYPE XX SORGUNG [Ex ib] I ACB No. and Explosion-proof Certificate No. Um: 250 V Po: 0.9 W Io: 150 mA Uo: 24 V Lo: 20 mH Co: 5.5μF Serial No.:

d) Associated apparatus protected by a flameproof enclosure

Name of Manufacturer Model and Name of Product Ex d [ia] IIB T6

ACB No. and Explosion-proof Certificate No. Um: 250 V Po: 0.9 W Uo: 36 V Io: 100 mA Co: 0.31μF Lo: 15 mH Serial No.:

13 Documentation

The descriptive documentation required by 23.2 of GB 3836.1-2000 shall include the following information:

a) electrical parameters for the apparatus:

1) power sources: output data such as Uo, Io, Po and, if applicable, Co, Lo and/or the permissible Lo/Ro ratio;

2) power receivers: input data such as Ui, Ii, Pi, Ci, Li and the Li/Ri ratio;

b) any special requirements for installation and use;

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

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

e) conformance or non-conformance with 6.4.12;

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

Appendix A

(Normative Appendix)

Assessment of Intrinsically Safe Circuits

A.1 Basic criteria

An intrinsically safe circuit shall satisfy three basic criteria:

a) the circuit shall be adequately separated from other circuits;

b) the temperature classification of intrinsically safe apparatus shall be carried out in accordance with 6.2 and Clause 5 of GB 3836.1-2000 so as to ensure that ignition is not caused by hot surfaces. Temperature classification shall not apply to associated apparatus;

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

NOTE 1 – Criterion a) may be satisfied by the provision of adequate creepage distances and clearances, and by the use of components conforming to Clause 8, for example transformers and current-limiting resistors.

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

NOTE 3 – Criterion c) may be satisfied by assessment. Information relating to voltage, current and circuit parameters such as capacitance and inductance at the boundary for ignition is necessary. The circuit can then be assessed as intrinsically safe in regard to spark ignition.

A.2 Assessment using reference curves and tables

Where the circuit to be assessed for ignition capability approximates to the simple circuit from which the curve is derived, Figures A.1 to A.6 or Tables A.1 and A.2 shall be used in the assessment. The fault conditions in accordance with Clause 5 and the safety factors in accordance with 10.4.2 shall also be taken into account.

Generally the following procedure shall be applied:

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

– then apply the appropriate safety factors, which depend on the type of circuit (see 10.4.2) as well as on the category of the electrical apparatus (see Clause 5), in order to derive a circuit to be subjected to assessment;

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

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

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

A.3 Examples of simple circuits

a) Simple inductive circuit

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

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

1) Power supply

The steps in the assessment are the following.

i) The value of the current-limiting resistor is quoted as 300Ω minimum and this represents the worst situation as far as the resistor is concerned. If this resistor does not conform to the requirements for infallibility (see 8.4), application of a single fault (see Clause 5) would produce a modified circuit in which the resistor would be assumed to be short-circuited. With such a fault, the power supply would not be intrinsically safe.

It is also necessary to determine a maximum value for the battery voltage in accordance with 7.4.3. Assume the maximum battery voltage derived is 22 V.

ii) The maximum short-circuit current is 22/300 = 73.3 mA.

Since the circuit is resistive, application of the requirements of clause 5 and 10.4.2 give rise to a modified circuit in which the short-circuit current is increased to 1.5×73.3 = 110 mA.

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

2) Connection of load

The steps in the assessment are as follows.

i) The maximum battery voltage is 22 V. Since 300Ω and 1 100Ω are minimum values, the maximum possible current in the load is 22/(300 + 1 100) = 15.7 mA. No faults need to be applied since the 300Ω resistor is infallible and short-circuit failure of the inductor leads to the circuit considered above.

ii) Application of the requirements of Clause 5 and 10.4.2 requires that, for a safety factor of 1,5, the current in the circuit be increased to 1.5×15.7 = 23,6 mA.

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

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

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

b) Simple capacitive circuit

Consider now the circuit of Figure A.8 which is intended for Group I application. It consists of a 30 V battery connected to a 10μF capacitor through a suitably mounted infallible 10 kΩ resistor. For the purpose of this example, the values of 30 V and 10μF are taken as maximum values, and 10 kΩ as a minimum value. Two separate assessments are made: one to ensure that the power supply itself is intrinsically safe and the other to take account of the presence of the capacitor.

1) Power supply

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

2) Capacitor

The steps in the assessment are as follows.

i) The maximum battery voltage is 30 V, and 10μF is the maximum capacitance value.

No faults are applied since the 10 kΩ resistor is infallible and either short-circuit or open-circuit failure of the capacitor gives rise to the circuit considered in a) 1).

ii) Application of the requirements of Clause 5 and 10.4.2 requires that, for a safety factor of 1,5, the voltage be increased to 1.5×30 V = 45 V.

iii) Reference to Figure A.2 for Group I shows that at 45 V the minimum value of capacitance to give ignition is only 3 μF and at 30 V only 8μF, so that the circuit cannot be assessed as intrinsically safe.

NOTE – To modify the circuit so that it may be assessed as being intrinsically safe, there are several possibilities. The circuit voltage or capacitance values could be reduced, or an infallible resistor could be inserted in series with the 10μF capacitor. Reference to figure A.2 shows that the minimum igniting voltage for 10 μF is 26 V, so that the battery voltage would have to be reduced to 26/1.5 = 17.3 V if the value of 10 μF were to be maintained. Alternatively, the capacitance value could be reduced to 8μF, or, since 10 μF + 5.6 Ω gives a minimum igniting voltage of 48 V, insertion of an infallible resistor having a minimum value of 5.6Ω in series with the capacitor would also produce a circuit which could be assessed as intrinsically safe as regards spark ignition for Group I.

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

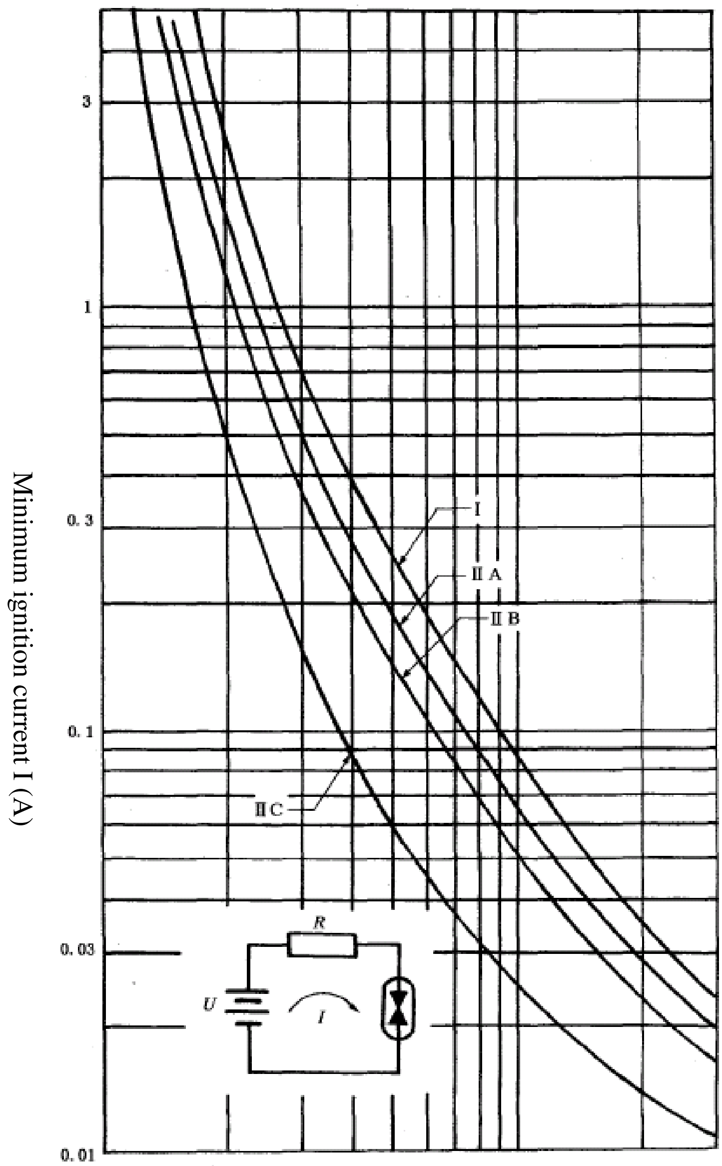
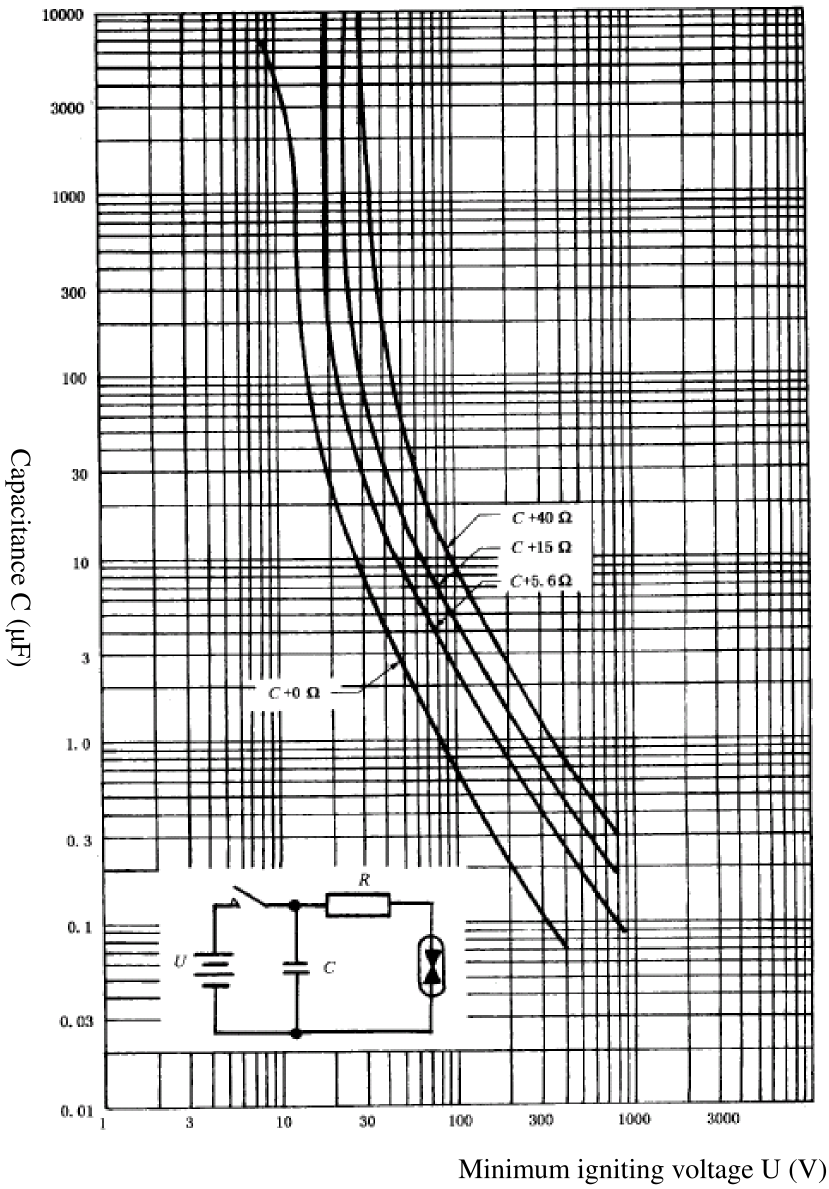


Figure A.1 – Resistive circuits



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

Figure A.2 – Group I capacitive circuits

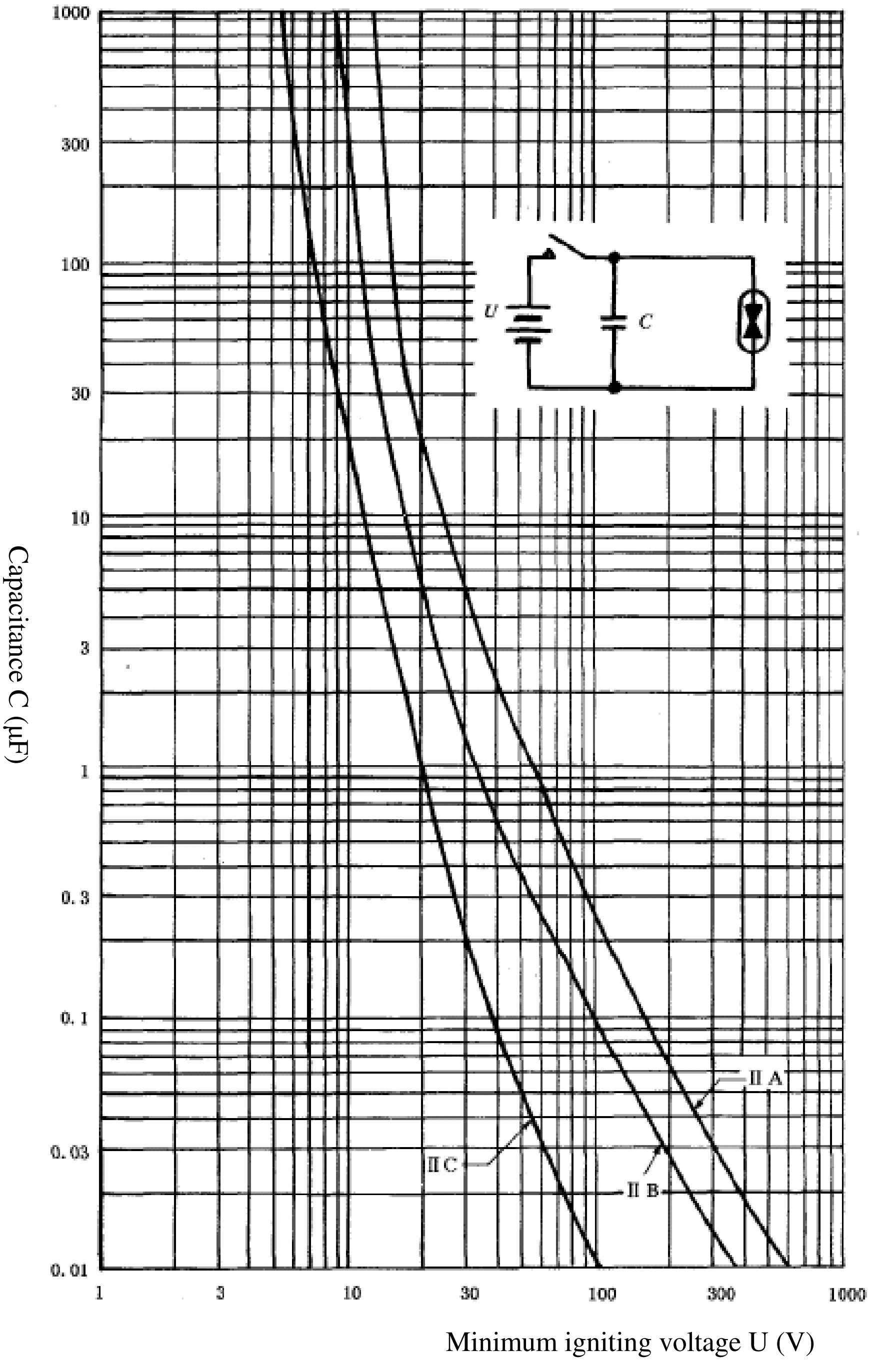
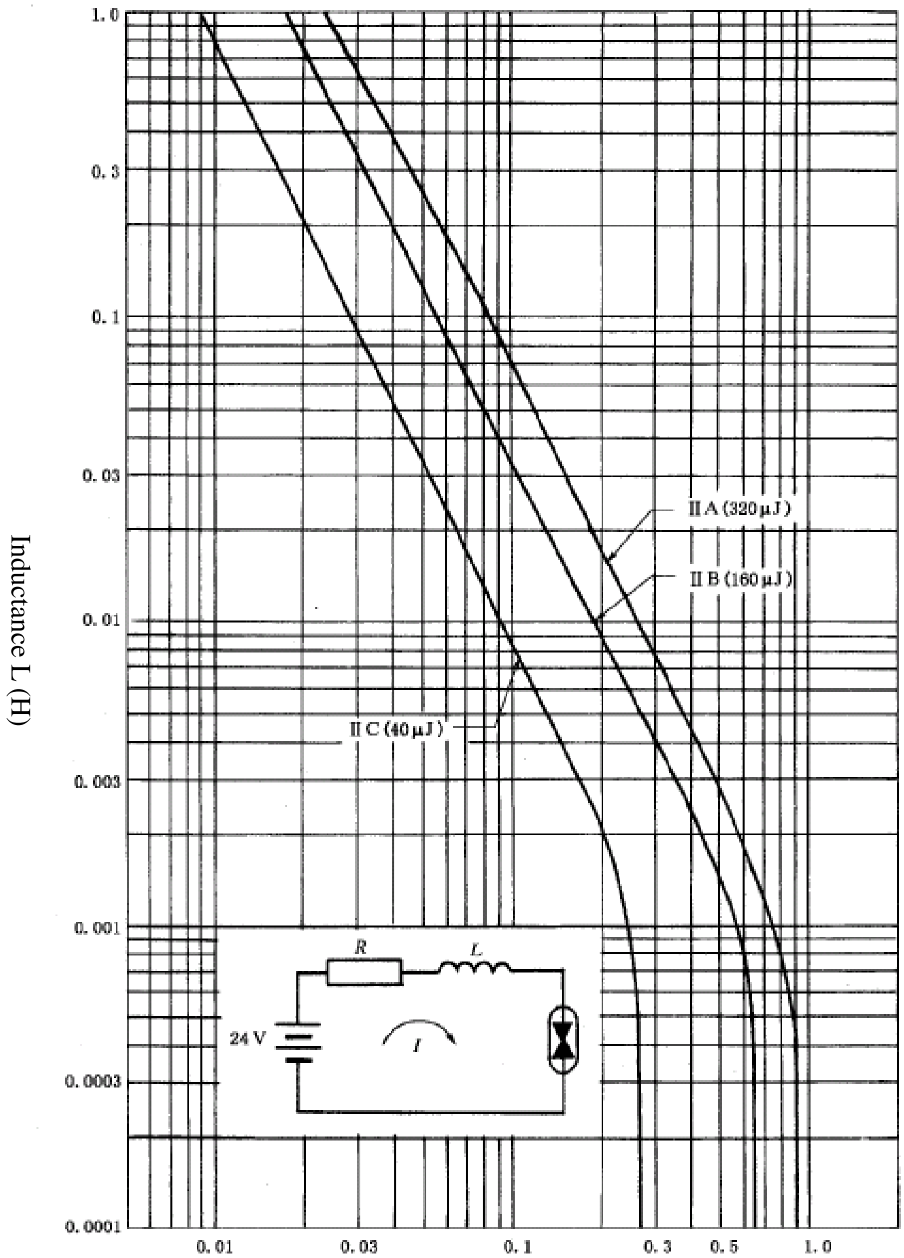


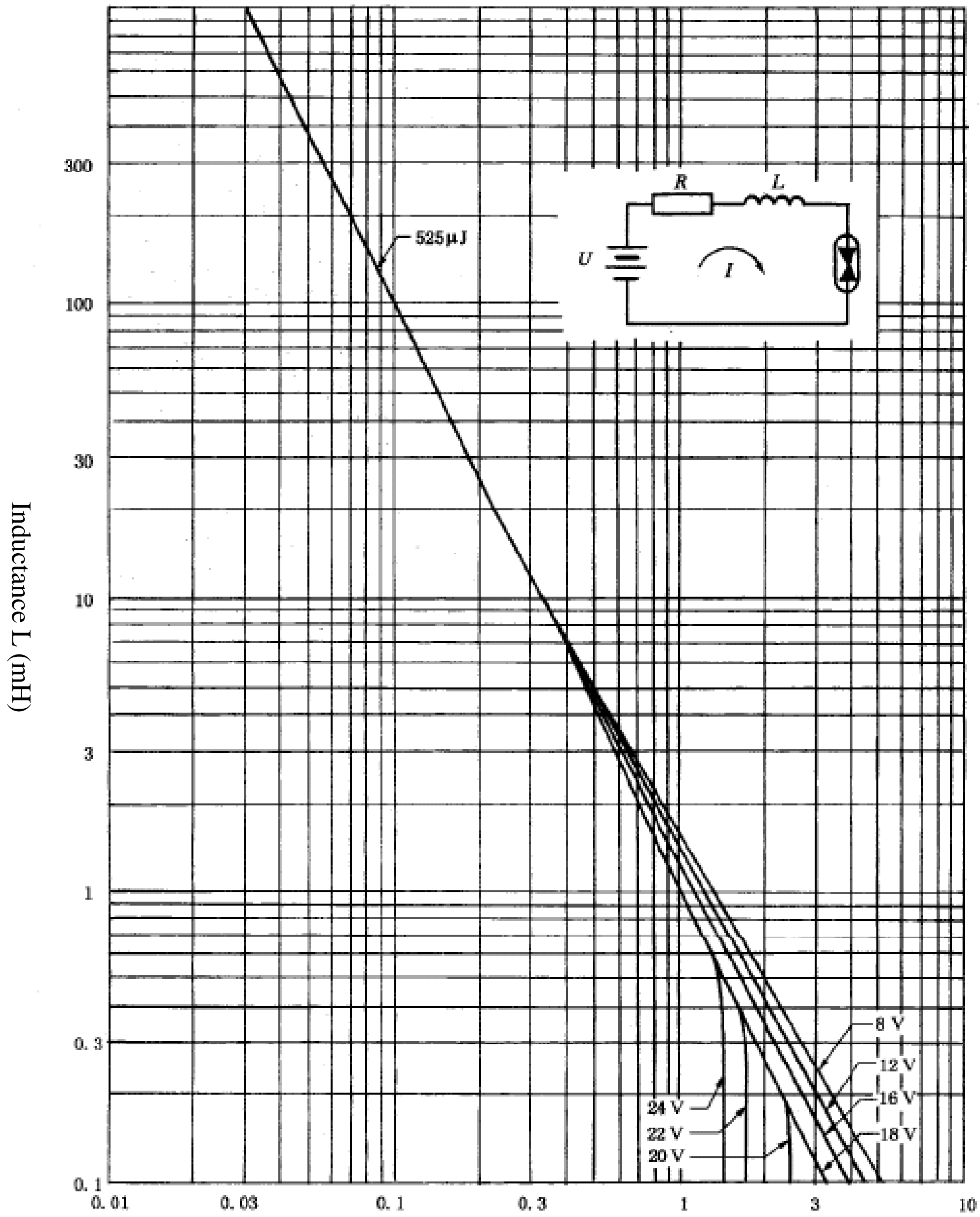
Figure A.3 – Group II capacitive circuits



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

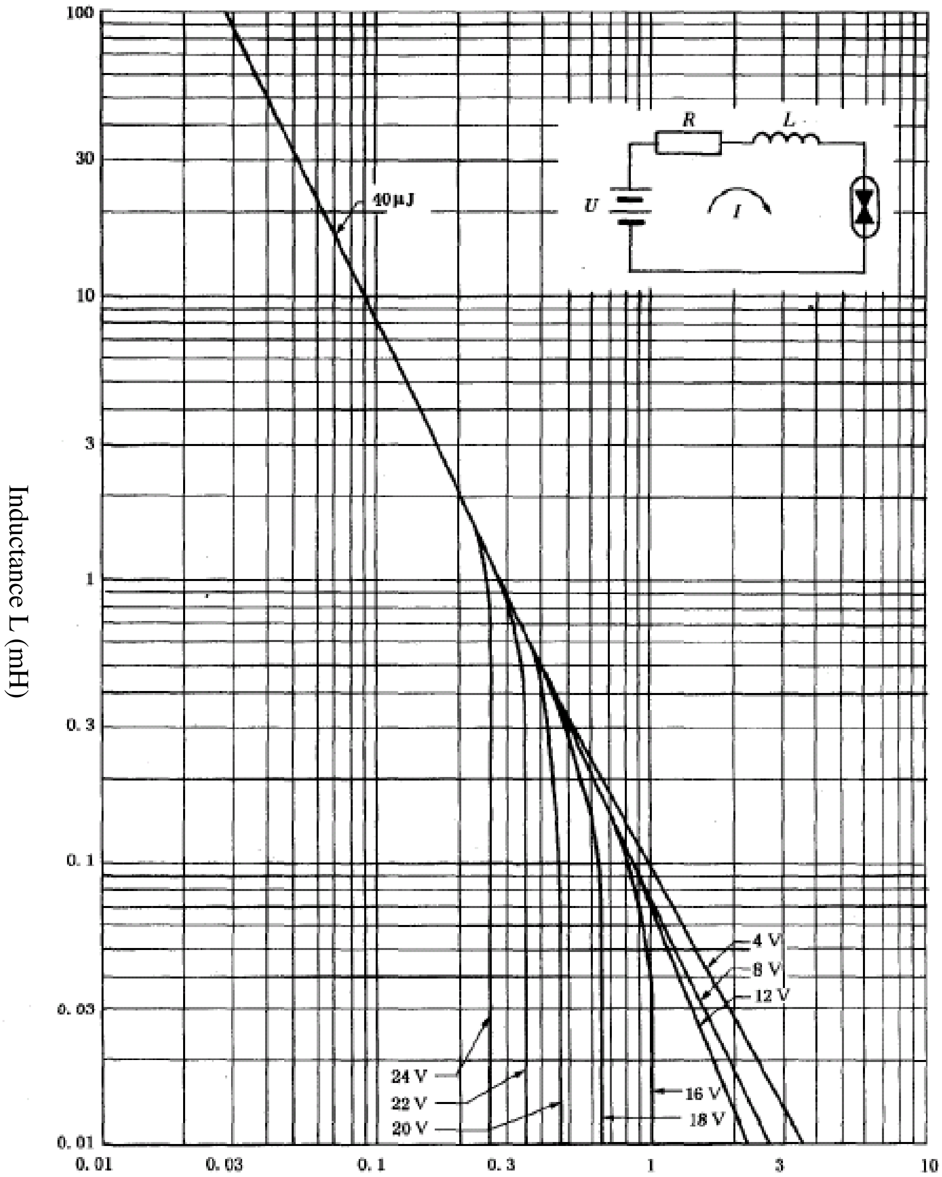


Minimum igniting current I (A)

NOTE 1 – The curves correspond to values of circuit voltage Uo as indicated.

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

Figure A.5 – Group I inductive circuits



Minimum igniting current I (A)

NOTE 1 – The curves correspond to values of circuit voltage Uo as indicated.

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

Figure A.6 – Group II inductive circuits

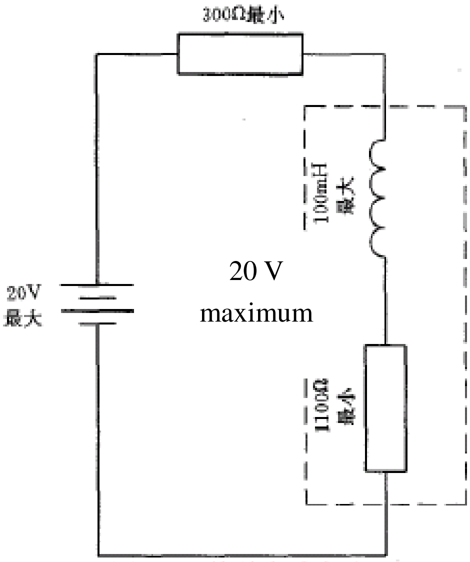


Figure A.7 – Circuit inductif simple

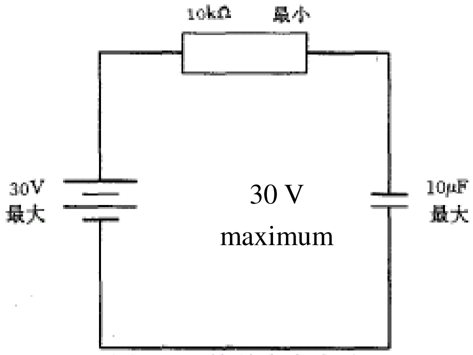


Figure A.8 – Circuit capacitive simple

Table A.1 – Permitted short-circuit current corresponding to the voltage and the apparatus group

Voltage V	Permitted short-circuit current					
	for Group IIC apparatus		for Group IIB apparatus		for Group IIA apparatus	
	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
	A	A	A	A	A	A
12.0						
12.1	5.00	3.33				
12.2	4.72	3.15				
12.3	4.46	2.97				
12.4	4.21	2.81				
12.5	3.98	2.65				
12.6	3.77	2.51				
12.7	3.56	2.37				

Table A.1 (continued)

Voltage V	Permitted short-circuit current					
	for Group IIC apparatus		for Group IIB apparatus		for Group IIA apparatus	
	with a factor of safety of		with a factor of safety of		with a factor of safety of	
	×1 A	×1.5 A	×1 A	×1.5 A	×1 A	×1.5 A
12.8	3.37	2.25				
12.9	3.19	2.13				
13.0	3.02	2.02				
13.1	2.87	1.91				
13.2	2.72	1.81				
13.3	2.58	1.72				
13.4	2.45	1.63				
13.5	2.32	1.55	5.00	3.33		
13.6	2.21	1.47	4.86	3.24		
13.7	2.09	1.40	4.72	3.14		
13.8	1.99	1.33	4.58	3.05		
13.9	1.89	1.26	4.45	2.97		
14.0	1.80	1.20	4.33	2.88		
14.1	1.75	1.16	4.21	2.80		
14.2	1.70	1.13	4.09	2.73		
14.3	1.65	1.10	3.98	2.65		
14.4	1.60	1.07	3.87	2.58		
14.5	1.55	1.04	3.76	2.51		
14.6	1.51	1.01	3.66	2.44		
14.7	1.47	0.98	3.56	2.38		
14.8	1.43	0.95	3.47	2.31	5.00	3.33
14.9	1.39	0.93	3.38	2.25	4.86	3.24
15.0	1.35	0.900	3.29	2.19	4.73	3.15
15.1	1.31	0.875	3.20	2.14	4.60	3.07
15.2	1.28	0.851	3.12	2.08	4.48	2.99
15.3	1.24	0.828	3.04	2.03	4.36	2.91
15.4	1.21	0.806	2.96	1.98	4.25	2.83
15.5	1.18	0.784	2.89	1.92	4.14	2.76
15.6	1.15	0.769	2.81	1.88	4.03	2.69
15.7	1.12	0.744	2.74	1.83	3.92	2.62
15.8	1.09	0.724	2.68	1.78	3.82	2.55

Table A.1 (continued)

Voltage V	Permitted short-circuit current					
	for Group IIC apparatus		for Group IIB apparatus		for Group IIA apparatus	
	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
	A	A	A	A	A	A
15.9	1.06	0.705	2.61	1.74	3.72	2.48
16.0	1.03	0.687	2.55	1.70	3.63	2.42
16.1	1.00	0.669	2.48	1.66	3.54	2.36
16.2	0.98	0.652	2.42	1.61	3.45	2.30
16.3	0.95	0.636	2.36	1.57	3.36	2.24
16.4	0.93	0.620	2.31	1.54	3.28	2.19
16.5	0.91	0.604	2.25	1.50	3.20	2.13
16.6	0.88	0.589	2.20	1.47	3.12	2.08
16.7	0.86	0.575	2.15	1.43	3.04	2.03
16.8	0.84	0.560	2.10	1.40	2.97	1.98
16.9	0.82	0.547	2.05	1.37	2.90	1.93
17.0	0.80	0.533	2.00	1.34	2.83	1.89
17.1	0.78	0.523	1.96	1.31	2.76	1.84
17.2	0.77	0.513	1.93	1.28	2.70	1.80
17.3	0.75	0.503	1.89	1.26	2.63	1.76
17.4	0.74	0.493	1.85	1.24	2.57	1.72
17.5	0.73	0.484	1.82	1.21	2.51	1.68
17.6	0.71	0.475	1.79	1.19	2.45	1.64
17.7	0.70	0.466	1.75	1.17	2.40	1.60
17.8	0.69	0.457	1.72	1.15	2.34	1.56
17.9	0.67	0.448	1.69	1.13	2.29	1.53
18.0	0.66	0.440	1.66	1.11	2.24	1.49
	mA	mA	mA	mA	mA	mA
18.1	648	432	1 630	1 087	2 188	1 459
18.2	636	424	1 601	1 068	2 139	1 426
18.3	625	417	1 573	1 049	2 091	1 394
18.4	613	409	1 545	10 30	2 045	1 363
18.5	602	402	1 518	1 012	2 000	1333
18.6	592	394	1 491	995	1 967	1 311
18.7	581	387	1 466	977	1 935	1 290
18.8	571	380	1 441	960	1 903	1 269

Table A.1 (continued)

Voltage V	Permitted short-circuit current					
	for Group IIC apparatus		for Group IIB apparatus		for Group IIA apparatus	
	with a factor of safety of		with a factor of safety of		with a factor of safety of	
	mA	mA	mA	mA	mA	mA
18.9	561	374	1 416	944	1 872	1 248
19.0	551	367	1 392	928	1 842	1 228
19.1	541	361	1 368	912	1 812	1 208
19.2	532	355	1 345	897	1 784	1 189
19.3	523	348	1 323	882	1 755	1 170
19.4	514	342	1 301	867	1 727	1 152
19.5	505	337	1 279	853	1 700	1 134
19.6	496	331	1 258	839	1 673	1 116
19.7	448	325	1 237	825	1 648	1 098
19.8	480	320	1 217	811	1 622	1 081
19.9	472	314	1 197	798	1 597	1 065
20.0	464	309	1 177	785	1 572	1 048
20.1	456	304	1 158	772	1 549	1 032
20.2	448	299	1 140	760	1 525	1 016
20.3	441	294	1 122	748	1 502	1 001
20.4	434	289	1 104	736	1 479	986
20.5	427	285	1 087	724	1 457	971
20.6	420	280	1 069	713	1 435	957
20.7	413	275	1 053	702	1 414	943
20.8	406	271	1 036	691	1 393	929
20.9	400	267	1 020	680	1 373	915
21.0	394	262	1 004	670	1 353	902
21.1	387	258	989	659	1 333	889
21.2	381	254	974	649	1 314	876
21.3	375	250	959	639	1 295	863
21.4	369	246	945	630	1 276	851
21.5	364	243	930	620	1 258	839
21.6	358	239	916	611	1 240	827
21.7	353	235	903	602	1 222	815
21.8	347	231	889	593	1 205	804
21.9	342	228	876	584	1 189	792

Table A.1 (continued)

Voltage V	Permitted short-circuit current					
	for Group IIC apparatus		for Group IIB apparatus		for Group IIA apparatus	
	with a factor of safety of		with a factor of safety of		with a factor of safety of	
	mA	mA	mA	mA	mA	mA
22.0	337	224	863	575	1 172	781
22.1	332	221	851	567	1 156	770
22.2	327	218	838	559	1 140	760
22.3	322	215	826	551	1 124	749
22.4	317	211	814	543	1 109	739
22.5	312	208	802	535	1 093	729
22.6	308	205	791	527	1 078	719
22.7	303	202	779	520	1 064	709
22.8	299	199	768	512	1 050	700
22.9	294	196	757	505	1 036	690
23.0	290	193	747	498	1 022	681
23.1	287	191	736	491	1 008	672
23.2	284	189	726	484	995	663
23.3	281	187	716	477	982	655
23.4	278	185	706	471	969	646
23.5	275	183	696	464	956	638
23.6	272	182	687	458	944	629
23.7	270	180	677	452	932	621
23.8	267	178	668	445	920	613
23.9	264	176	659	439	908	605
24.0	261	174	650	433	896	597
24.1	259	173	644	429	885	590
24.2	256	171	637	425	873	582
24.3	253	169	631	421	862	575
24.4	251	167	625	416	852	568
24.5	248	166	618	412	841	561
24.6	246	164	612	408	830	554
24.7	244	163	606	404	820	547
24.8	241	161	601	400	810	540
24.9	239	159	595	396	800	533
25.0	237	158	589	393	790	527

Table A.1 (continued)

Voltage V	Permitted short-circuit current					
	for Group IIC apparatus		for Group IIB apparatus		for Group IIA apparatus	
	with a factor of safety of		with a factor of safety of		with a factor of safety of	
	mA	mA	mA	mA	mA	mA
25.1	234	156	583	389	780	520
25.2	232	155	578	385	771	514
25.3	230	153	572	381	762	508
25.4	228	152	567	378	752	502
25.5	226	150	561	374	743	496
25.6	223	149	556	371	734	490
25.7	221	148	551	367	726	484
25.8	219	146	546	364	717	478
25.9	217	145	541	360	708	472
26.0	215	143	536	357	700	467
26.1	213	142	531	354	694	463
26.2	211	141	526	350	688	459
26.3	209	139	521	347	683	455
26.4	207	138	516	344	677	451
26.5	205	137	512	341	671	447
26.6	203	136	507	338	666	444
26.7	202	134	502	335	660	440
26.8	200	133	498	332	655	437
26.9	198	132	493	329	649	433
27.0	196	131	489	326	644	429
27.1	194	130	485	323	639	426
27.2	193	128	480	320	364	422
27.3	191	127	476	317	629	419
27.4	189	126	472	315	624	416
27.5	188	125	468	312	619	412
27.6	186	124	464	309	614	409
27.7	184	123	460	306	609	406
27.8	183	122	456	304	604	403
27.9	181	121	452	301	599	399
28.0	180	120	448	299	594	396
28.1	178	119	444	296	590	393

Table A.1 (continued)

Voltage V	Permitted short-circuit current					
	for Group IIC apparatus		for Group IIB apparatus		for Group IIA apparatus	
	with a factor of safety of		with a factor of safety of		with a factor of safety of	
	mA	mA	mA	mA	mA	mA
28.2	176	118	440	293	585	390
28.3	175	117	436	291	581	387
28.4	173	116	433	288	576	384
28.5	172	115	429	286	572	381
28.6	170	114	425	284	567	378
28.7	169	113	422	281	563	375
28.8	168	112	418	279	559	372
28.9	166	111	415	277	554	370
29.0	165	110	411	274	550	367
29.1	163	109	408	272	546	364
29.2	162	108	405	270	542	361
29.3	161	107	401	268	538	358
29.4	159	106	398	265	534	356
29.5	158	105	395	263	530	353
29.6	157	105	392	261	526	351
29.7	155	104	388	259	522	348
29.8	154	103	385	257	518	345
29.9	153	102	382	255	514	343
30.0	152	101	379	253	510	340
30.2	149	99.5	373	249	503	335
30.4	147	97.9	367	245	496	330
30.6	145	96.3	362	241	489	326
30.8	142	94.8	356	237	482	321
31.0	140	93.3	350	233	475	317
31.2	138	92.2	345	230	468	312
31.4	137	91.0	339	226	462	308
31.6	135	89.9	334	223	455	303
31.8	133	88.8	329	219	449	299
32.0	132	87.8	324	216	442	295
32.2	130	86.7	319	213	436	291
32.4	129	85.7	315	210	431	287

Table A.1 (continued)

Voltage V	Permitted short-circuit current					
	for Group IIC apparatus		for Group IIB apparatus		for Group IIA apparatus	
	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
	mA	mA	mA	mA	mA	mA
32. 6	127	84. 7	310	207	425	283
32. 8	126	83. 7	305	204	419	279
33. 0	124	82. 7	301	201	414	276
33. 2	123	81. 7	297	198	408	272
33. 4	121	80. 8	292	195	403	268
33. 6	120	79. 8	288	192	398	265
38. 8	118	78. 9	284	189	393	262
34. 0	117	78. 0	280	187	389	259
34. 2	116	77. 2	277	185	384	256
34. 4	114	76. 3	274	183	380	253
34. 6	113	75. 4	271	181	376	251
34. 8	112	74. 6	269	179	372	248
35. 0	111	73. 8	266	177	368	245
35. 2	109	73. 0	263	175	364	242
35. 4	108	72. 2	260	174	360	240
35. 6	107	71. 4	258	172	356	237
35. 8	106	70. 6	255	170	352	235
36. 0	105	69. 9	253	168	348	232
36. 2	104	69. 1	250	167	345	230
36. 4	103	68. 4	248	165	341	227
36. 6	102	67. 7	245	164	337	225
36. 8	100	66. 9	243	162	334	223
37. 0	99. 4	66. 2	241	160	330	220
37. 2	98. 3	65. 6	238	159	327	218
37. 4	97. 3	64. 9	236	157	324	216
37. 6	96. 3	64. 2	234	156	320	214
37. 8	95. 3	63. 6	231	154	317	211
38. 0	94. 4	62. 9	229	153	314	209
38. 2	93. 4	62. 3	227	151	311	207
38. 4	92. 5	61. 6	225	150	308	205
38. 6	91. 5	61. 0	223	149	304	203

Table A.1(end)

Voltage V	Permitted short-circuit current					
	for Group IIC apparatus with a factor of safety of		for Group IIB apparatus with a factor of safety of		for Group IIA apparatus with a factor of safety of	
	×1 mA	×1.5 mA	×1 mA	×1.5 mA	×1 mA	×1.5 mA
38.8	90.6	60.4	221	147	301	201
39.0	89.7	59.8	219	146	298	199
39.2	88.8	59.2	217	145	296	197
39.4	88.0	58.6	215	143	293	195
39.6	87.1	58.1	213	142	290	193
39.8	86.3	57.5	211	141	287	191
40.0	85.4	57.0	209	139	284	190
40.5	83.4	55.6	205	136	278	185
41.0	81.4	54.3	200	133	271	181
41.5	79.6	53.0	196	131	265	177
42.0	77.7	51.8	192	128	259	173
42.5	76.0	50.6	188	125	253	169
43.0	74.3	49.5	184	122	247	165
43.5	72.6	48.4	180	120	242	161
44.0	71.0	47.4	176	117	237	158
44.5	69.5	46.3	173	115	231	154
45.0	68.0	45.3	169	113	227	151

Table A.2 – Permitted capacitance corresponding to the voltage and the apparatus group

Voltage V	Permitted capacitance					
	for Group IIC apparatus		for Group IIB apparatus		for Group IIA apparatus	
	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
	μF	μF	μF	μF	μF	μF
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				

Table A.2 (continued)

Voltage V	Permitted capacitance					
	for Group IIC apparatus		for Group IIB apparatus		for Group IIA apparatus	
	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
	μF	μF	μF	μF	μF	μF
5.8	750	46				
5.9	670	43				
6.0	600	40		1 000		
6.1	535	37		880		
6.2	475	34		790		
6.3	420	31		720		
6.4	370	28		650		
6.5	325	25		570		
6.6	285	22		500		
6.7	250	19.6		430		
6.8	220	17.9		380		
6.9	200	16.8		335		
7.0	175	15.7		300		
7.1	155	14.6		268		
7.2	136	13.5		240		
7.3	120	12.7		216		
7.4	110	11.9		195		
7.5	100	11.1		174		
7.6	92	10.4		160		
7.7	85	9.8		145		
7.8	79	9.3		130		
7.9	74	8.8		115		
8.0	69	8.4		100		
8.1	65	8.0		90		
8.2	61	7.6		81		
8.3	56	7.2		73		
8.4	54	6.8		66		
8.5	51	6.5		60		
8.6	49	6.2		55		
8.7	47	5.9		50		1 000
8.8	45	5.5		46		730

Table A.2 (continued)

Voltage V	Permitted capacitance					
	for Group IIC apparatus		for Group IIB apparatus		for Group IIA apparatus	
	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
	μF	μF	μF	μF	μF	μF
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
9.6	28	3.6	650	26		210
9.7	26	3.5	600	24		170
9.8	24	3.3	550	23		135
9.9	22	3.2	500	22		115
10.0	20.0	3.0	450	20.0		100
10.1	18.7	2.87	410	19.4		93
10.2	17.8	2.75	380	18.7		88
10.3	17.1	2.63	350	18.0		83
10.4	16.4	2.52	325	17.4		79
10.5	15.7	2.41	300	16.8		75
10.6	15.0	2.32	280	16.2		72
10.7	14.2	2.23	260	15.6		69
10.8	13.5	2.14	240	15.0		66
10.9	13.0	2.05	225	14.4		63
11.0	12.5	1.97	210	13.8		60
11.1	11.9	1.90	195	13.2		57.0
11.2	11.4	1.84	180	12.6		54.0
11.3	10.9	1.79	170	12.1		51.0
11.4	10.4	1.71	160	11.7		48.0
11.5	10.0	1.64	150	11.2		46.0
11.6	9.6	1.59	140	10.8		43.0
11.7	9.3	1.54	130	10.3		41.0
11.8	9.0	1.50	120	9.9		39.0
11.9	8.7	1.45	110	9.4		37.0

Table A.2 (continued)

Voltage V	Permitted capacitance					
	for Group IIC apparatus		for Group IIB apparatus		for Group IIA apparatus	
	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
	μF	μF	μF	μF	μF	μF
12.0	8.4	1.41	100	9.0		36.0
12.1	8.1	1.37	93	8.7		34.0
12.2	7.9	1.32	87	8.4		33.0
12.3	7.6	1.28	81	8.1		31.0
12.4	7.2	1.24	75	7.9		30.0
12.5	7.0	1.20	70	7.7		28.0
12.6	6.8	1.15	66	7.4		27.0
12.7	6.6	1.10	62	7.1		25.4
12.8	6.4	1.06	58	6.8		24.2
12.9	6.2	1.03	55	6.5		23.2
13.0	6.0	1.00	52	6.2	1 000	22.5
13.1	5.7	0.97	49	6.0	850	21.7
13.2	5.4	0.94	46	5.8	730	21.0
13.3	5.3	0.91	44	5.6	630	20.2
13.4	5.1	0.88	42	5.5	560	19.5
13.5	4.9	0.85	40	5.3	500	19.0
13.6	4.6	0.82	38	5.2	450	18.6
13.7	4.4	0.79	36	5.0	420	18.1
13.8	4.2	0.76	34	4.9	390	17.7
13.9	4.1	0.74	32	4.7	360	17.3
14.0	4.0	0.73	30	4.60	330	17.0
14.1	3.9	0.71	29	4.49	300	16.7
14.2	3.8	0.70	28	4.39	270	16.4
14.3	3.7	0.68	27	4.28	240	16.1
14.4	3.6	0.67	26	4.18	210	15.8
14.5	3.5	0.65	25	4.07	185	15.5
14.6	3.4	0.64	24	3.97	160	15.2
14.7	3.3	0.62	23	3.86	135	14.9
14.8	3.2	0.61	22	3.76	120	14.6
14.9	3.1	0.59	21	3.65	110	14.3
15.0	3.0	0.58	20.2	3.55	100	14.0

Table A.2 (continued)

Voltage V	Permitted capacitance					
	for Group IIC apparatus		for Group IIB apparatus		for Group IIA apparatus	
	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
	μF	μF	μF	μF	μF	μF
15.1	2.90	0.57	19.7	3.46	95	13.7
15.2	2.82	0.55	19.2	3.37	91	13.4
15.3	2.76	0.53	18.7	3.28	88	13.1
15.4	2.68	0.521	18.2	3.19	85	12.8
15.5	2.60	0.508	17.8	3.11	82	12.5
15.6	2.52	0.497	17.4	3.03	79	12.2
15.7	2.45	0.487	17.0	2.95	77	11.9
15.8	2.38	0.478	16.6	2.88	74	11.6
15.9	2.32	0.469	16.2	2.81	72	11.3
16.0	2.26	0.460	15.8	2.75	70	11.0
16.1	2.20	0.451	15.4	2.69	68	10.7
16.2	2.14	0.442	15.0	2.63	66	10.5
16.3	2.08	0.433	14.6	2.57	64	10.2
16.4	2.02	0.424	14.2	2.51	62	10.0
16.5	1.97	0.415	13.8	2.45	60	9.8
16.6	1.92	0.406	13.4	2.40	58	9.6
16.7	1.88	0.398	13.0	2.34	56	9.4
16.8	1.84	0.390	12.6	2.29	54	9.3
16.9	1.80	0.382	12.3	2.24	52	9.1
17.0	1.76	0.375	12.0	2.20	50	9.0
17.1	1.71	0.367	11.7	2.15	48	8.8
17.2	1.66	0.360	11.4	2.11	47	8.7
17.3	1.62	0.353	11.1	2.06	45	8.5
17.4	1.59	0.346	10.8	2.02	44	8.4
17.5	1.56	0.339	10.5	1.97	42	8.2
17.6	1.53	0.333	10.2	1.93	40	8.1
17.7	1.50	0.327	9.9	1.88	39	8.0
17.8	1.47	0.321	9.6	1.84	38	7.9
17.9	1.44	0.315	9.3	1.80	37	7.7
18.0	1.41	0.309	9.0	1.78	36	7.6
18.1	1.38	0.303	8.8	1.75	35	7.45

Table A.2 (continued)

Voltage V	Permitted capacitance					
	for Group IIC apparatus		for Group IIB apparatus		for Group IIA apparatus	
	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
	μF	nF	μF	μF	μF	μF
18.2	1.35	297	8.6	1.72	34	7.31
18.3	1.32	291	8.4	1.70	33	7.15
18.4	1.29	285	8.2	1.69	32	7.00
18.5	1.27	280	8.0	1.67	31	6.85
18.6	1.24	275	7.9	1.66	30	6.70
18.7	1.21	270	7.8	1.64	29	6.59
18.8	1.18	266	7.6	1.62	28	6.48
18.9	1.15	262	7.4	1.60	27	6.39
19.0	1.12	258	7.2	1.58	26	6.30
19.1	1.09	252	7.0	1.56	25.0	6.21
19.2	1.06	251	6.8	1.55	24.2	6.12
19.3	1.04	248	6.6	1.52	23.6	6.03
19.4	1.02	244	6.4	1.51	23.0	5.95
19.5	1.00	240	6.2	1.49	22.5	5.87
19.6	0.98	235	6.0	1.47	22.0	5.80
19.7	0.96	231	5.9	1.45	21.5	5.72
19.8	0.94	227	5.8	1.44	21.0	5.65
19.9	0.92	223	5.7	1.42	20.5	5.57
20.0	0.90	220	5.6	1.41	20.0	5.50
20.1	0.88	217	5.5	1.39	19.5	5.42
20.2	0.86	213	5.4	1.38	19.2	5.35
20.3	0.84	209	5.3	1.36	18.9	5.27
20.4	0.82	206	5.2	1.35	18.6	5.20
20.5	0.80	203	5.1	1.33	18.3	5.12
20.6	0.78	200	5.0	1.32	18.0	5.05
20.7	0.76	197	4.9	1.31	17.7	4.97
20.8	0.75	194	4.8	1.30	17.4	4.90
20.9	0.74	191	4.7	1.28	17.2	4.84
21.0	0.73	188	4.6	1.27	17.0	4.78
21.1	0.72	185	4.52	1.25	16.8	4.73
21.2	0.71	183	4.45	1.24	16.6	4.68

Table A.2 (continued)

Voltage V	Permitted capacitance					
	for Group IIC apparatus		for Group IIB apparatus		for Group IIA apparatus	
	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
	μF	nF	μF	μF	μF	μF
21.3	0.70	181	4.39	1.23	16.4	4.62
21.4	0.69	179	4.32	1.22	16.2	4.56
21.5	0.68	176	4.25	1.20	16.0	4.50
21.6	0.67	174	4.18	1.19	15.8	4.44
21.7	0.66	172	4.11	1.17	15.6	4.38
21.8	0.65	169	4.04	1.16	15.4	4.32
21.9	0.640	167	3.97	1.15	15.2	4.26
22.0	0.630	165	3.90	1.14	15.0	4.20
22.1	0.620	163	3.83	1.12	14.8	4.14
22.2	0.610	160	3.76	1.11	14.6	4.08
22.3	0.600	158	3.69	1.10	14.4	4.03
22.4	0.590	156	3.62	1.09	14.2	3.98
22.5	0.580	154	3.55	1.08	14.0	3.93
22.6	0.570	152	3.49	1.07	13.8	3.88
22.7	0.560	149	3.43	1.06	13.6	3.83
22.8	0.550	147	3.37	1.05	13.4	3.79
22.9	0.540	145	3.31	1.04	13.2	3.75
23.0	0.530	143	3.25	1.03	13.0	3.71
23.1	0.521	140	3.19	1.02	12.8	3.67
23.2	0.513	138	3.13	1.01	12.6	3.64
23.3	0.505	136	3.08	1.00	12.4	3.60
23.4	0.497	134	3.03	0.99	12.2	3.57
23.5	0.490	132	2.98	0.98	12.0	3.53
23.6	0.484	130	2.93	0.97	11.8	3.50
23.7	0.478	128	2.88	0.96	11.6	3.46
23.8	0.472	127	2.83	0.95	11.4	3.42
23.9	0.466	126	2.78	0.94	11.2	3.38
24.0	0.460	125	2.75	0.93	11.0	3.35
24.1	0.454	124	2.71	0.92	10.8	3.31
24.2	0.448	122	2.67	0.91	10.7	3.27
24.3	0.442	120	2.63	0.90	10.5	3.23

Table A.2 (continued)

Voltage V	Permitted capacitance					
	for Group IIC apparatus		for Group IIB apparatus		for Group IIA apparatus	
	with a factor of safety of		with a factor of safety of		with a factor of safety of	
v	×1	×1.5	×1	×1.5	×1	×1.5
	nF	nF	μF	μF	μF	μF
24.4	436	119	2.59	0.89	10.3	3.20
24.5	430	118	2.55	0.88	10.2	3.16
24.6	424	116	2.51	0.87	10.0	3.12
24.7	418	115	2.49	0.87	9.9	3.08
24.8	412	113	2.44	0.86	9.8	3.05
24.9	406	112	2.40	0.85	9.6	3.01
25.0	400	110	2.36	0.84	9.5	2.97
25.1	395	108	2.32	0.83	9.4	2.93
25.2	390	107	2.29	0.82	9.3	2.90
25.3	385	106	2.26	0.82	9.2	2.86
25.4	380	105	2.23	0.81	9.1	2.82
25.5	375	104	2.20	0.80	9.0	2.78
25.6	370	103	2.17	0.80	8.9	2.75
25.7	365	102	2.14	0.79	8.8	2.71
25.8	360	101	2.11	0.78	8.7	2.67
25.9	355	100	2.08	0.77	8.6	2.63
26.0	350	99	2.05	0.77	8.5	2.60
26.1	345	98	2.02	0.76	8.4	2.57
26.2	341	97	1.99	0.75	8.3	2.54
26.3	337	97	1.96	0.74	8.2	2.51
26.4	333	96	1.93	0.74	8.1	2.48
26.5	329	95	1.90	0.73	8.0	2.45
26.6	325	94	1.87	0.73	8.0	2.42
26.7	321	93	1.84	0.72	7.9	2.39
26.8	317	92	1.82	0.72	7.8	2.37
26.9	313	91	1.80	0.71	7.7	2.35
27.0	309	90	1.78	0.705	7.60	2.33
27.1	305	89	1.76	0.697	7.50	2.31
27.2	301	89	1.74	0.690	7.42	2.30
27.3	297	88	1.72	0.683	7.31	2.28
27.4	293	87	1.71	0.677	7.21	2.26

Table A.2 (continued)

Voltage V	Permitted capacitance					
	for Group IIC apparatus		for Group IIB apparatus		for Group IIA apparatus	
	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
	nF	nF	μF	nF	μF	μF
27.5	289	86	1.70	672	7.10	2.24
27.6	285	86	1.69	668	7.00	2.22
27.7	281	85	1.68	663	6.90	2.20
27.8	278	84	1.67	659	6.80	2.18
27.9	275	84	1.66	654	6.70	2.16
28.0	272	83	1.65	650	6.60	2.15
28.1	269	82	1.63	645	6.54	2.13
28.2	266	81	1.62	641	6.48	2.11
28.3	263	80	1.60	636	6.42	2.09
28.4	260	79	1.59	632	6.36	2.07
28.5	257	78	1.58	627	6.30	2.05
28.6	255	77	1.57	623	6.24	2.03
28.7	253	77	1.56	618	6.18	2.01
28.8	251	76	1.55	614	6.12	2.00
28.9	249	75	1.54	609	6.06	1.98
29.0	247	74	1.53	605	6.00	1.97
29.1	244	74	1.51	600	5.95	1.95
29.2	241	73	1.49	596	5.90	1.94
29.3	238	72	1.48	591	5.85	1.92
29.4	235	71	1.47	587	5.80	1.91
29.5	232	71	1.46	582	5.75	1.89
29.6	229	70	1.45	578	5.70	1.88
29.7	226	69	1.44	573	5.65	1.86
29.8	224	68	1.43	569	5.60	1.85
29.9	222	67	1.42	564	5.55	1.83
30.0	220	66	1.41	560	5.50	1.82
30.2	215	65	1.39	551	5.40	1.79
30.4	210	64	1.37	542	5.30	1.76
30.6	206	62.6	1.35	533	5.20	1.73
30.8	202	61.6	1.33	524	5.10	1.70
31.0	198	60.5	1.32	515	5.00	1.67

Table A.2 (continued)

Voltage V	Permitted capacitance					
	for Group IIC apparatus		for Group IIB apparatus		for Group IIA apparatus	
	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
	nF	nF	μF	nF	μF	μF
31.2	194	59.6	1.30	506	4.90	1.65
31.4	190	58.7	1.28	497	4.82	1.62
31.6	186	57.8	1.26	489	4.74	1.60
31.8	183	56.9	1.24	482	4.68	1.58
32.0	180	56.0	1.23	475	4.60	1.56
32.2	177	55.1	1.21	467	4.52	1.54
32.4	174	54.2	1.19	460	4.44	1.52
32.6	171	53.3	1.17	452	4.36	1.50
32.8	168	52.4	1.15	444	4.28	1.48
33.0	165	51.5	1.14	437	4.20	1.46
33.2	162	50.6	1.12	430	4.12	1.44
33.4	159	49.8	1.10	424	4.05	1.42
33.6	156	49.2	1.09	418	3.98	1.41
33.8	153	48.6	1.08	412	3.91	1.39
34.0	150	48.0	1.07	406	3.85	1.37
34.2	147	47.4	1.05	401	3.79	1.35
34.4	144	46.8	1.04	397	3.74	1.33
34.6	141	46.2	1.02	393	3.69	1.31
34.8	138	45.6	1.01	390	3.64	1.30
35.0	135	45.0	1.00	387	3.60	1.28
35.2	133	44.4	0.99	383	3.55	1.26
35.4	131	43.8	0.97	380	3.50	1.24
35.6	129	43.2	0.95	376	3.45	1.23
35.8	127	42.6	0.94	373	3.40	1.21
36.0	125	42.0	0.93	370	3.35	1.20
36.2	123	41.4	0.91	366	3.30	1.18
36.4	121	40.8	0.90	363	3.25	1.17
	nF	nF	nF	nF	μF	nF
36.6	119	40.2	890	359	3.20	1 150
36.8	117	39.6	880	356	3.15	1 130
37.0	115	39.0	870	353	3.10	1 120

Table A.2 (continued)

Voltage V	Permitted capacitance					
	for Group IIC apparatus		for Group IIB apparatus		for Group IIA apparatus	
	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
	nF	nF	nF	nF	μF	nF
37.2	113	38.4	860	347	3.05	1 100
37.4	111	37.9	850	344	3.00	1 090
37.6	109	37.4	840	340	2.95	1 080
37.8	107	36.9	830	339	2.90	1 070
38.0	105	36.4	820	336	2.85	1 060
38.2	103	35.9	810	332	2.80	1 040
38.4	102	35.4	800	329	2.75	1 030
38.6	101	35.0	790	326	2.70	1 020
38.8	100	34.6	780	323	2.65	1 010
39.0	99	34.2	770	320	2.60	1 000
39.2	98	33.8	760	317	2.56	980
39.4	97	33.4	750	314	2.52	970
39.6	96	33.1	750	311	2.48	960
39.8	95	32.8	740	308	2.44	950
40.0	94	32.5	730	305	2.40	940
40.2	92	32.2	720	302	2.37	930
40.4	91	31.9	710	299	2.35	920
40.6	90	31.6	700	296	2.32	910
40.8	89	31.3	690	293	2.30	900
41.0	88	31.0	680	290	2.27	890
41.2	87	30.7	674	287	2.25	882
41.4	86	30.4	668	284	2.22	874
41.6	85	30.1	662	281	2.20	866
41.8	84	29.9	656	278	2.17	858
42.0	83	29.7	650	275	2.15	850
42.2	82	29.4	644	272	2.12	842
42.4	81	29.2	638	269	2.10	834
42.6	79	28.9	632	266	2.07	826
42.8	78	28.6	626	264	2.05	818
43.0	77	28.4	620	262	2.02	810
43.2	76	28.1	614	259	2.00	802

Table A.2 (continued)

Voltage V	Permitted capacitance					
	for Group IIC apparatus		for Group IIB apparatus		for Group IIA apparatus	
	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
	nF	nF	nF	nF	μF	nF
43.4	75	27.9	608	257	1.98	794
43.6	74	27.6	602	254	1.96	786
43.8	73	27.3	596	252	1.94	778
44.0	72	27.1	590	250	1.92	770
44.2	71	26.8	584	248	1.90	762
44.4	70	26.6	578	246	1.88	754
44.6	69	26.3	572	244	1.86	746
44.8	68	26.1	566	242	1.84	738
45.0	67	25.9	560	240	1.82	730
45.2	66	25.7	554	238	1.80	722
45.4	65	25.4	548	236	1.78	714
45.6	64	25.1	542	234	1.76	706
45.8	63	24.9	536	232	1.74	698
46.0	62.3	24.7	530	230	1.72	690
46.2	61.6	24.4	524	228	1.70	682
46.4	60.9	24.2	518	226	1.68	674
46.6	60.2	23.9	512	224	1.67	666
46.8	59.6	23.7	506	222	1.65	658
47.0	59.0	23.5	500	220	1.63	650
47.2	58.4	23.2	495	218	1.61	644
47.4	57.8	22.9	490	216	1.60	638
47.6	57.2	22.7	485	214	1.59	632
47.8	56.6	22.5	480	212	1.57	626
48.0	56.0	22.3	475	210	1.56	620
48.2	55.4	22.0	470	208	1.54	614
48.4	54.8	21.8	465	206	1.53	609
48.6	54.2	21.5	460	205	1.52	604
48.8	53.6	21.3	455	203	1.50	599
49.0	53.0	21.1	450	201	1.49	594
49.2	52.4	20.8	445	198	1.48	589
49.4	51.8	20.6	440	197	1.46	584

Table A.2 (end)

Voltage V	Permitted capacitance					
	for Group IIC apparatus		for Group IIB apparatus		for Group IIA apparatus	
	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
	nF	nF	nF	nF	μF	nF
49.6	51.2	20.4	435	196	1.45	579
49.8	50.6	20.2	430	194	1.44	574
50.0	50.0	20.0	425	193	1.43	570
50.5	49.0	19.4	420	190	1.40	558
51.0	48.0	19.0	415	187	1.37	547
51.5	47.0	18.6	407	184	1.34	535
52.0	46.0	18.3	400	181	1.31	524
52.5	45.0	17.8	392	178	1.28	512
53.0	44.0	17.4	385	175	1.25	501
53.5	43.0	17.0	380	172	1.22	490
54.0	42.0	16.8	375	170	1.20	479
54.5	41	16.6	367	168	1.18	468
55.0	40	16.5	360	166	1.16	457

Appendix B
(Normative Appendix)
Spark Test Apparatus for Intrinsically Safe Circuits

B.1 Test methods for spark ignition

B.1.1 Principle

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

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

Except where otherwise specified, the tolerance on mechanical dimensions is ±0,5 % and that of voltages and current is ±1 %.

B.1.2 Apparatus

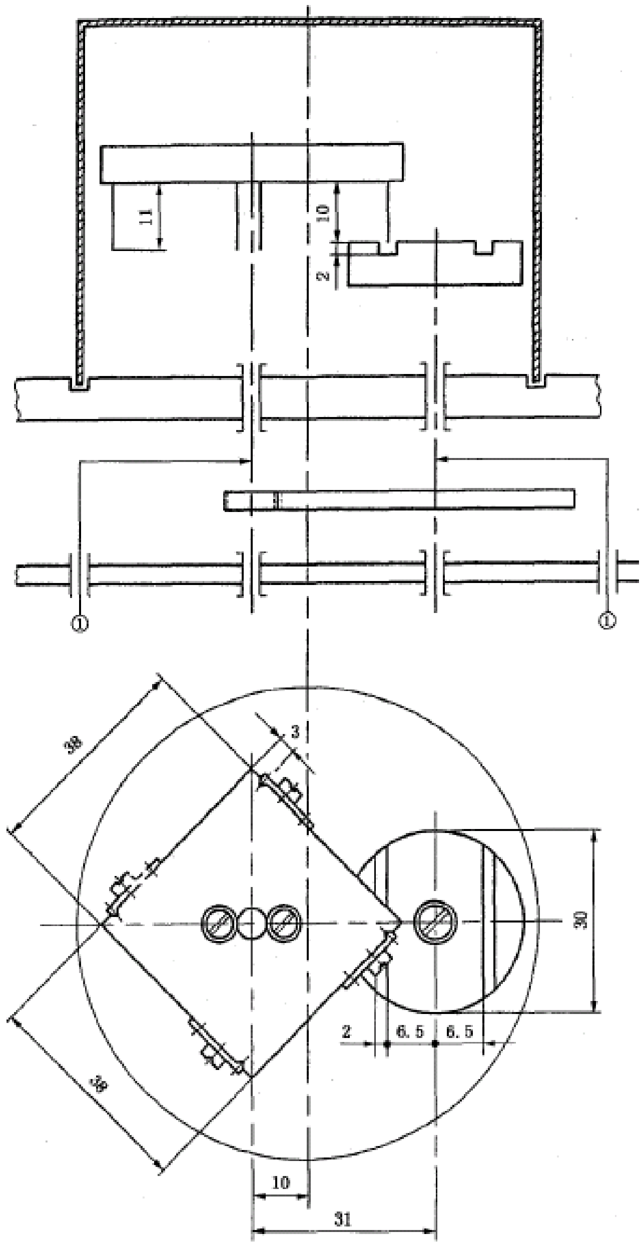
The apparatus consists of a contact arrangement in an explosion chamber having a volume of at least 250 cm^3. It is arranged to produce make-sparks and break-sparks in the prescribed explosive test mixture.

NOTE 1 – An example of a practical design of the test apparatus is shown in figure B.4. (For the contact arrangement, see Figures B.1 and B.3.) One of the two contact electrodes consists of a rotating cadmium contact disc with two slots.

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

The other contact electrode consists of four tungsten contact wires with a diameter of 0.2 mm clamped on a circle of 50 mm diameter to an electrode holder (made of brass or other suitable material as in Figure B.3).

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



1 Connection for circuit under test

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

The contact arrangement is mounted as shown in Figure B.1. The electrode holder rotates so that the tungsten contact wires slide over the slotted cadmium disc. The distance between the electrode holder and the cadmium disc is 10 mm. The free length of the contact wires is 11 mm. The contact wires are straight and fitted so as to be normal to the surface of the cadmium disc when not in contact with it. The axes of the shafts driving the cadmium disc and the electrode holder are 31 mm apart and are electrically insulated from each other and from the baseplate of the apparatus. The current is led in and out through sliding contacts on the shafts which are geared together by non-conductive gears with a ratio of 50:12.

The electrode holder is rotated at 80 r/min by an electric motor, with suitable reduction gearing if necessary. The cadmium disc is turned more slowly in the opposite direction. Gas-tight bearing bushes in the baseplate are necessary unless a gas flow system is used. Either a counting device is provided to record the number of revolutions of the motor-driven shaft of the electrode holder or a timing device may be used to determine the test duration, from which the number of revolutions of the shaft of the electrode holder can be calculated.

NOTE 4 – 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 (see Figures B.5 and B.6).

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

At the terminals of the contact arrangement, the self-capacitance of the test apparatus shall not exceed 30 pF with the contacts open. The resistance shall not exceed 0.15 Ω at a current of 1 A d.c. and the self-inductance should not exceed 3 μH with the contacts closed.

B.1.3 Calibration of spark test apparatus

The sensitivity of the spark test apparatus shall be checked before and after each series of tests in accordance with 10.3.

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

a) check the parameters of the calibration circuit;

b) check the composition of the explosive test mixture;

c) clean the tungsten wires;

d) replace the tungsten wires;

e) connect the terminals to a 95 mH/24 V/100 mA circuit as specified in 10.3 and run the test apparatus with the contacts in air for a minimum of 20 000 revolutions of the electrode holder;

f) replace the cadmium disc and calibrate the apparatus in accordance with 10.3.

B.1.4 Preparation and cleaning of tungsten wires

Tungsten is a very brittle material and tungsten wires often tend to split at the ends after a relatively short period of operation. To resolve this difficulty, one of the following procedures should be followed.

a) Fuse the ends of the tungsten wires in a simple device as shown in figure B.7. This forms a small sphere on each wire which should be removed by slight pressure by tweezers. When prepared in this way, it is found that, on average, one of the four contact wires has to be changed only after about 50 000 sparks.

b) Cut the tungsten wires with a shearing action, for example using heavy duty scissors in good condition.

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

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

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

Requirements	Sieve aperture size (μm)
All grains to pass	106
Not more than 24 % to be retained	75
At least 40 % to be retained	53
Not more than 10 % to pass	45

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

B.1.5 Conditioning a new cadmium disc

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

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

b) connect the terminals to a 95 mH/24 V/100 mA circuit as specified in 10.3 and run the test apparatus with the contacts in air for a minimum of 20 000 revolutions of the electrode holder;

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

d) using the Group IIA (or Group I) explosive test mixture conforming to 10.2 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, reduce the voltage by 5 % and repeat until no ignition occurs in a minimum of 400 revolutions;

e) repeat the procedure given in d) but starting at 60 V (80 V for Group I); if no ignition occurs at 50 V (70 V) repeat d);

f) repeat the procedure given in e) but starting at 50 V (70 V for Group I); if no ignition occurs at 40 V (55 V) repeat d).

B.1.6 Limitations of the apparatus

The spark test apparatus should normally be used for testing intrinsically safe circuits within the following limits:

a) the test current does not exceed 3 A;

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

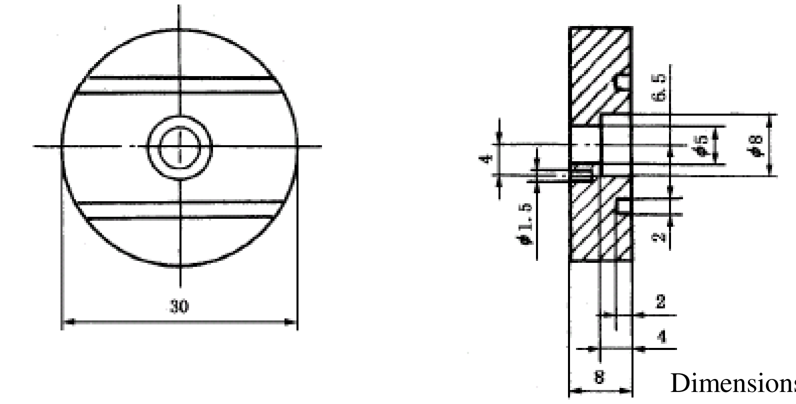
c) for inductive circuits the inductance should not exceed 1 H;

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

NOTE 1 – If the test current exceeds 3 A, the temperature rise of the tungsten wires may lead to additional ignition effects invalidating the test result.

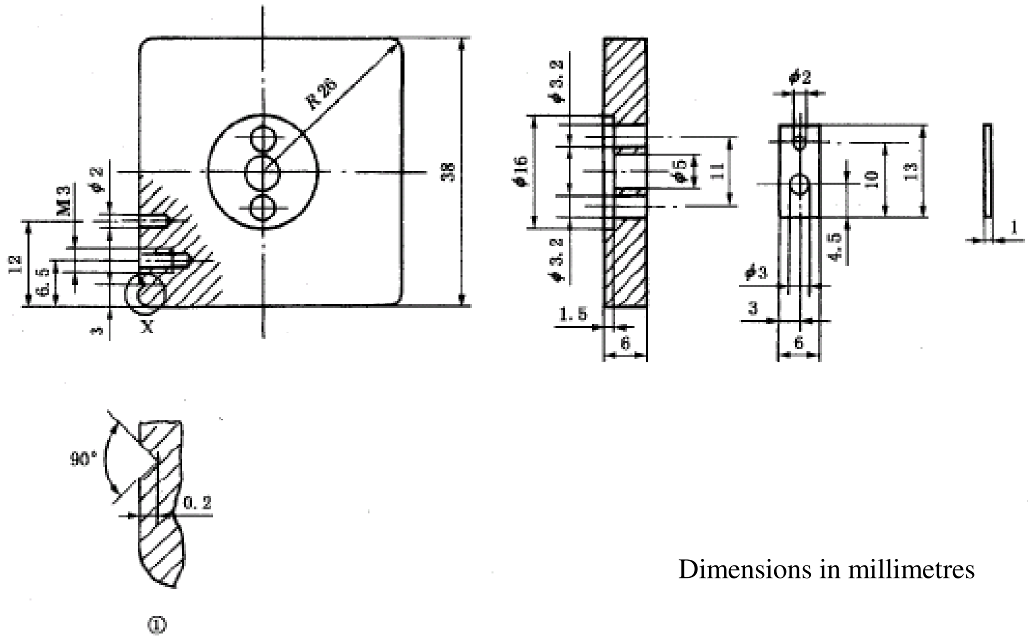
NOTE 2 – With inductive circuits, care should be exercised that self-inductance and circuit time constants do not adversely affect the results.

NOTE 3 – 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.



Dimensions in millimetres

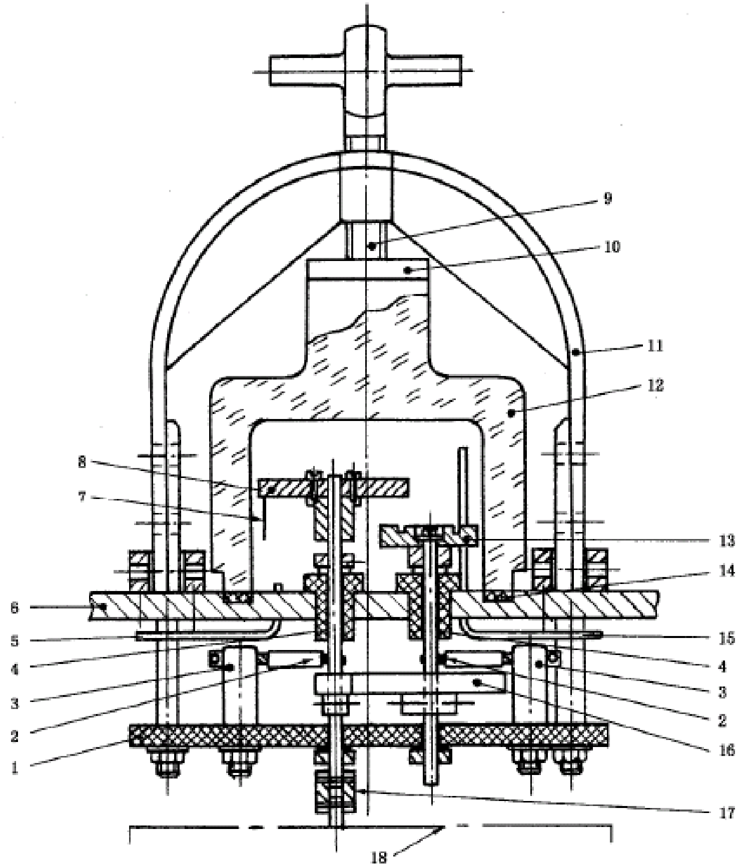
Figure B.2 – Cadmium contact disc



Dimensions in millimetres

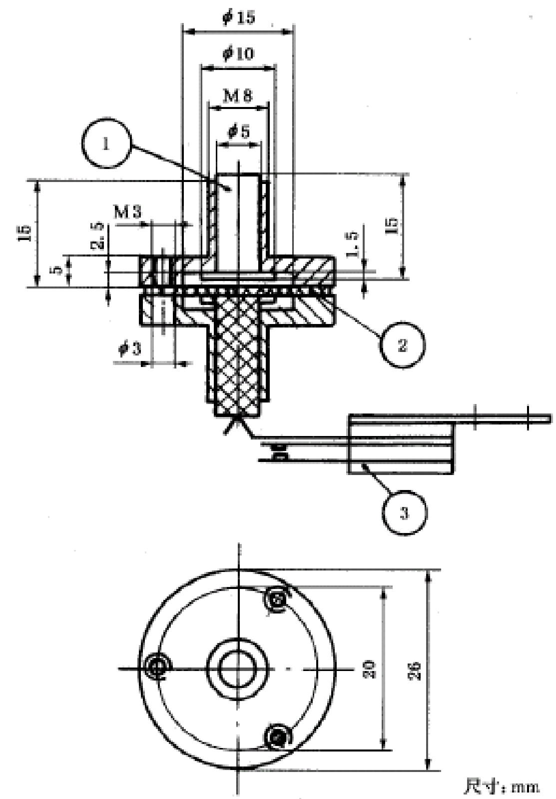
①- Detail X, scale 10:1

Figure B.3 – Contact holder



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 inlet
7-Contact wire	16-Gear wheel drive 50:12
8-Contact holder	17-Insulated coupling
9-Clamping screw	18-Drive motor with reduction gears 80 r/min

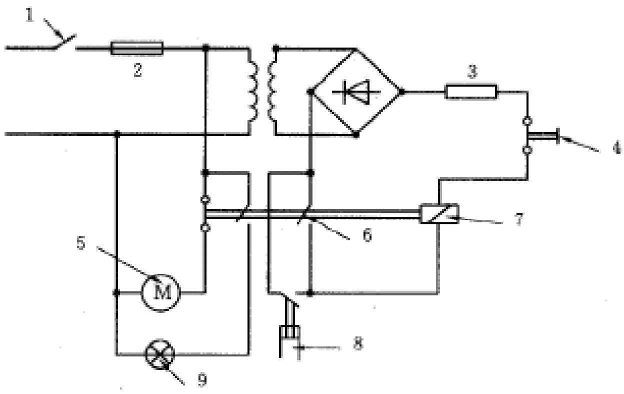
Figure B.4 – Example of a practical design of spark test apparatus



Dimensions in millimetres

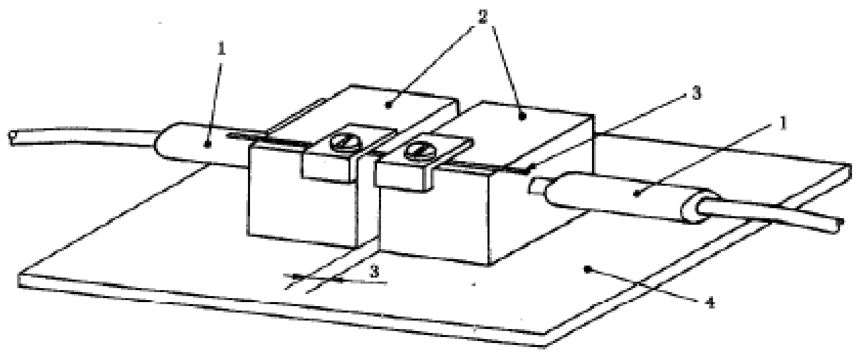
①-Metal piston; ②-Rubber diaphragm; ③-Spring contact

Figure B.5 – Example of an explosion pressure switch



1-Main switch	6-Hold-in contact
2-Circuit breaker	7-Relay
3-Resistor	8-Explosion pressure switch
4-Reset button	9-Signal lamp
5-Drive motor	

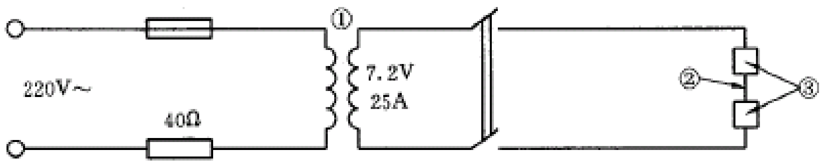
Figure B.6 – Example of automatic stopping by means of an explosion pressure switch



NOTE – Remove melted droplets with tweezers. (diameter of tungsten wire is 0.2mm)

1-Current feed; 2-Copper block; 3-Tungsten wire (diameter 0,2 mm); 4-Insulating plate

Figure B.7 – Arrangement for fusing tungsten wires



①-Cross-section of core 19 cm2; ②-Tungsten wire; ③-Copper block

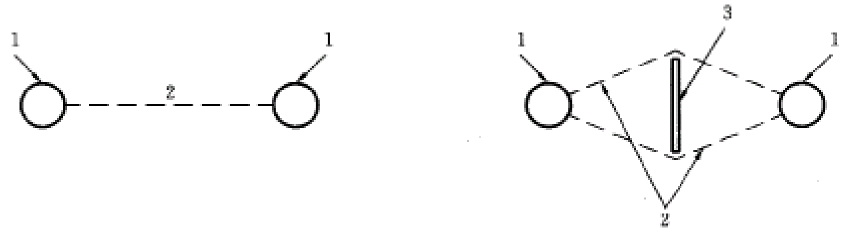
Figure B.8 – Circuit diagram for fusing tungsten wires

Appendix C
(Informative Appendix)
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 shall be determined in accordance with 6.4.2.

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

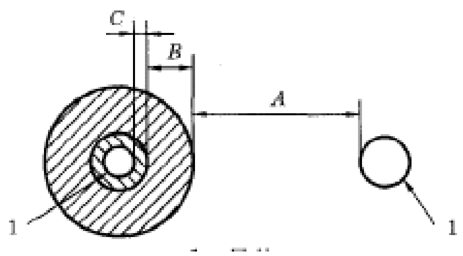


1-Conductor; 2-Clearance; 3-Barrier

Figure C.1 – Measurement of clearance

Where the distance between the conductive parts is partly clearance and partly separation distance through casting compound and/or solid insulation, the equivalent clearance or separation distance through casting compound can be calculated in the following manner. The value can then be compared with the value in the relevant line of Table 4.

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



1 Conductor

Figure C.2 – Measurement of composite distances

If A is less than the applicable value of Table 4, one of the following tabulations can be used. Any clearance or separation which is below one-third of the relevant value specified in Table 4 shall be ignored for the purpose of these calculations.

The results of these calculations should be added and compared with the appropriate value in Table 4.

To use Line 2 of Table 4, multiply the measured values by the following factors:

Voltage difference	**U < 10 V**	**10 V≤U＜30 V**	**U＞30 V**
A	1	1	1
B	3	3	3
C	3	4	6

To use Line 3 of Table 4, multiply the measured values by the following factors:

Voltage difference	U < 10 V	10 V≤U<30 V	U>30 V
A	0.33	0.33	0.33
B	1	1	1
C	1	1.33	2

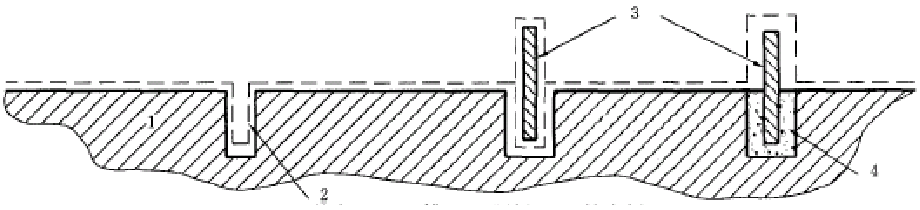
To use Line 4 of Table 4, multiply the measured values by the following factors:

Voltage difference	U < 10 V	10 V≤U<30 V	U>30 V
A	0.33	0.33	0.33
B	1	0.75	0.55
C	1	1	1

C.2 Creepage distances

The voltage to be used shall be determined in accordance with 6.4.2.

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



1-Substrate; 2-Groove; 3-Barrier; 4-Cement

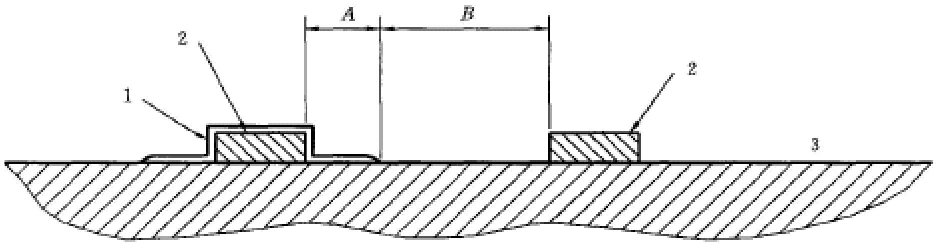
Figure C.3 – Measurement of creepage

The following points shown in Figure C.3 should be taken into account:

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

b) where an insulating partition or barrier conforming to 6.4.1 is inserted but not cemented in, the creepage distance is 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 is always measured over the partition.



1-Varnish; 2-Conductor; 3-Substrate

Figure C.4 – Measurement of composite creepage

When varnish is used to reduce the required creepage distances, and only part of the creepage distance is varnished as shown in the sketch, the total effective creepage distance is referred to either Line 5 or Line 6 of table 4 by the following calculation: to refer to Line 5 of Table 4, multiply B by 1 and A by 3; to refer to Line 6 of Table 4, multiply B by 0.33 and A by 1. Then add the results together.

NOTE – Varnish may or may not cover the conductor.

Appendix D

(Normative Appendix)

Encapsulation

NOTE – Figure D.1 illustrates some applications of encapsulation by casting compound. Figure D.2 shows some further application of encapsulation where no enclosure is used.

D.1 Adherence

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

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

– if all electrical parts and substrates are totally enclosed, that is if nothing emerges from the encapsulation, then there is no risk of contamination and hence breakdown from contamination cannot occur.

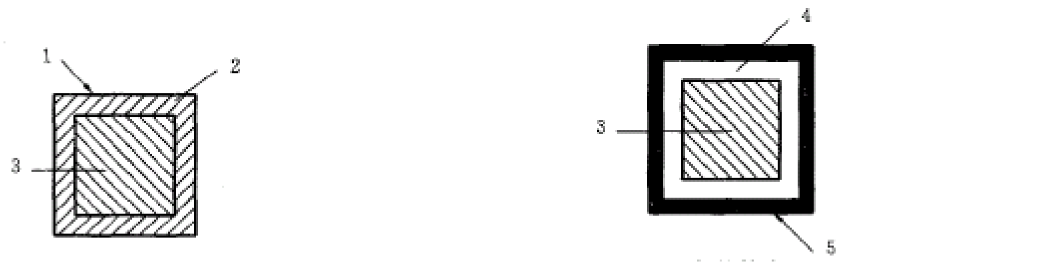
– if any part of the circuit, for example a bare or insulated conductor or component or the substrate of a printed wiring board, emerges from the encapsulation, then, unless the casting compound adheres at the interface, contamination can enter at that interface and cause breakdown.

D.2 Temperature

The casting compound shall have a temperature rating conforming to 6.4.4.

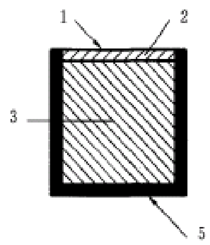
NOTE – All casting compounds have a maximum temperature above which they may lose or change their specified properties. Such changes may cause cracking or decomposition which could result in surfaces hotter than the outside surface of the casting compound being exposed to a potentially explosive atmosphere.

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

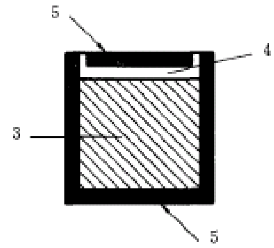


a) No enclosure **b) Complete enclosure**

Figure D.1 – Examples of encapsulated assemblies conforming to 6.4.4 and 6.7



c) Open enclosure



d) Enclosure with cover

1-Free surface;

2-Encapsulant – ½ of line 3 of table 4 with a minimum of 1,00 mm

3-Component – encapsulant need not penetrate

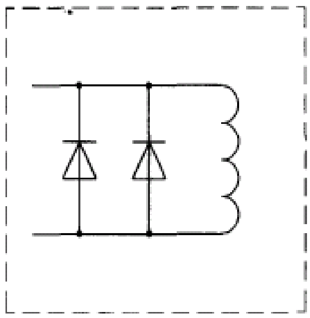
4-Encapsulant – no specified thickness

5-Metal or insulating enclosure

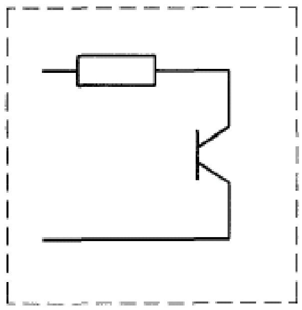
– no specified thickness for metallic enclosure, but see 6.4

– Insulation thickness shall conform to Line 4 of Table 4

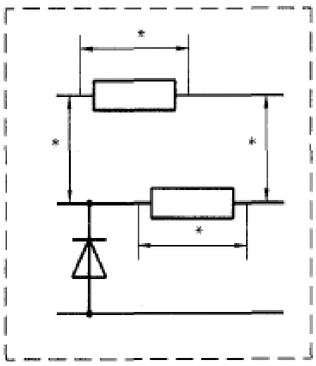
Figure D.1



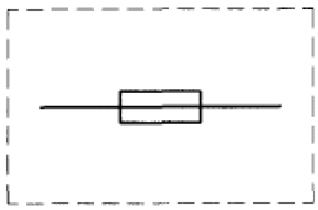
a) Mechanical



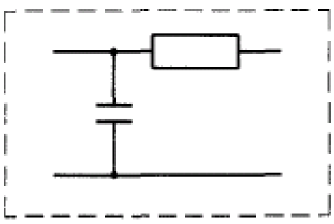
b) Temperature



c) Separation of circuits



d) Protection of fuses in an intrinsically safe circuit



e) Exclusion of gas

Figure D.2 – Applications of encapsulation without enclosure