BRITISH STANDARD

BS 5345-1: 1989

Incorporating Amendment Nos. 1, 2 and 3

Code of practice for

Selection, installation and maintenance of electrical apparatus for use in potentially explosive atmospheres (other than mining applications or explosives processing and manufacture) —

Part 1: General recommendations

UDC 696.6:621.3 – 7:614.83

Committees responsible for this British Standard

The preparation of this British Standard was entrusted by the General Electrotechnical Engineering Standards Policy Committee (GEL/-) to Technical Committee GEL/114, upon which the following bodies were represented:

Association of British Mining Equipment Companies
Association of Consulting Engineers
BEAMA Ltd
British Coal Corporation
British Electrical Systems Association (BEAMA Ltd)
British Gas plc
British Industrial Truck Association
Chief and Assistant Chief Fire Officers' Association
Civil Aviation Authority (Airworthiness Division)
Council for Electrical Equipment for Flammable Atmospheres (BEAMA)
Department of Transport — Marine Directorate
ERA Technology Ltd
Energy Industries Council
Engineering Equipment and Materials Users' Association
Fire Offices Committee
GAMBICA (BEAMA Ltd)
Gland Manufacturers' Technical Committee
Health and Safety Executive
Lighting Industry Federation Ltd
Ministry of Defence
Sira Limited
Trades Union Congress
United Kingdom Offshore Operators' Association

The following bodies were also represented in the drafting of the standard, through subcommittees and panels:

Associated Offices Technical Committee
British Cable Makers' Confederation
Department of Energy — Petroleum Engineering Division
Department of the Environment — Building Research Establishment
Electrical Contractors' Association
General Council of British Shipping
Hevac Association
Institute of Petroleum
Institute of Quality Assurance
Institution of Electrical Engineers
Institution of Gas Engineers

This British Standard, having been prepared under the direction of the General Electrotechnical Engineering Standards Policy Committee, was published under the authority of the Board of BSI and comes into effect on 30 June 1989

First published August 1976
First revision June 1989

The following BSI references relate to the work on this standard:
Committee reference GEL/114
Draft for comment 85/21906 DC

ISBN 0 580 17369 0

Amendments issued since publication

Amd. No.	Date of issue	Comments
6477	May 1990	
6333	January 1991	
7871	September 1993	Indicated by a sideline in the margin

Contents

		Page
Committees responsible		Inside front cover
Foreword		iii
Section 1. General		
1	Scope	1
2	Definitions	1
3	Statutory requirements	2
4	Classification of hazardous areas	3
5	Types of protection	3
6	Light metals as construction materials	3
Section 2. Selection of apparatus		
7	Procedure for selecting electrical apparatus	5
8	Certification	7
9	Interconnection of apparatus	8
Section 3. General installation recommendations		
10	General	9
11	Access for inspection	9
12	Plans and records	9
13	Electrical ratings	9
14	Installation of apparatus	9
15	Integrity of insulation	9
16	Automatic overcurrent protection	10
17	Earthing and earth fault protection	10
18	Isolation	10
19	Wiring systems	10
20	Portable and transportable apparatus and its connections	13
Section 4. Inspection, maintenance, testing and repair		
21	General	14
22	Personnel	14
23	Isolation of apparatus	14
24	Precautions concerning the use of igniting agencies	14
25	Initial and periodic inspections	14
26	Initial and periodic testing	15
27	Maintenance recommendations	16
Section 5. Properties of flammable liquids, vapours and gases		
28	General	18
29	Melting point and boiling point	18
30	Relative vapour density	18
31	Flash point	18
32	Flammable (explosive) limits	19
33	Flammable (explosive) range	19
34	Effect of environments with other than normal atmospheric conditions	19
35	Ignition temperature	19
36	Apparatus group	20
37	Recommendations and notes concerning individual materials	20
38	General considerations	20
Section 6. Marking of apparatus		
39	General	29

		Page
40	Marking requirements for apparatus	29
41	Examples of marking of apparatus	29
42	General notes on marking	31
Appendix A Relevant International, European and British Standards and details of the national certifying authority and its certification standards		32
Appendix B Frictional sparking risks with light metals and their alloys		34
Appendix C Degrees of protection by enclosures		35
Appendix D Bibliography of data sources for Table 7		38
Appendix E Calculation of the flammable limits for a mixture of gases		38
Figure 1 — Flammable limits of hydrogen, carbon monoxide and methane containing various amounts of carbon dioxide and nitrogen		41
Figure 2 — Flammable limits of ethane, ethylene and benzene containing various amounts of carbon dioxide and nitrogen		41
Table 1 — Types of protection		4
Table 2 — Selection of apparatus and systems according to zone of risk		6
Table 3 — Relationship between T class and maximum surface temperature		6
Table 4 — Relationship between apparatus group, the former gas group and apparatus class		7
Table 5 — Example of schedule for initial inspection		16
Table 6 — Example of schedule for subsequent inspections		16
Table 7 — Data for flammable materials for use with electrical equipment		25
Table 8 — Protection against contact and ingress of foreign bodies		36
Table 9 — Protection against ingress of water		37
Table 10 — Most frequently used degrees of protection		38
Table 11 — Components of the industrial gas mixture		40
Table 12 — Flammable limits of simpler mixtures		40
Publications referred to		42

Foreword

This Part of BS 5345 has been prepared under the direction of the General Electrotechnical Engineering Standards Policy Committee and is a revision of BS 5345-1:1976, which is withdrawn. Before 1976, installations were made in accordance with CP 1003. However, CP 1003 has now been declared obsolescent and will eventually be withdrawn and should not be used for new installations.

Many industrial processes involve the generation, processing, handling and storage of flammable and potentially explosive gases, vapours and mists. Where such materials may be present appropriate precautions have to be taken to design or locate electrical apparatus so that electrical arcs, sparks, hot surfaces or frictional sparks produced by such apparatus do not cause ignition.

Several techniques are available for the protection of electrical apparatus situated in hazardous areas. These techniques are described in this Part of BS 5345, which takes into account the developments that have taken place in area classification and the design, manufacture and use of electrical apparatus for hazardous areas since its first edition.

This revision of BS 5345-1 has taken into account the requirements of apparatus specifications BS 5501 and BS 4683. Although written largely with BS 5501 in mind, it is recognized that apparatus in accordance with BS 4683 and some earlier standards[1)] is still manufactured and that such equipment will no doubt continue to be in use for a number of years to come.

BS 5345 is divided into nine Parts.[2)] BS 5345-3 to BS 5345-9 deal with the selection, installation and maintenance recommendations appropriate to the types of protection that may be used to achieve safe operation of equipment in potentially explosive atmospheres. BS 5345-1 and BS 5345-2 provide basic recommendations applicable to all Parts. The list of Parts is as follows:

— *Part 1: General recommendations*;

— *Part 2: Classification of hazardous areas*;

— *Part 3: Installation and maintenance requirements for electrical apparatus with type of protection "d". Flameproof enclosure*;

— *Part 4: Installation and maintenance requirements for electrical apparatus with type of protection "i". Intrinsically safe electrical apparatus and systems*;

— *Part 5: Installation and maintenance requirements for electrical apparatus protected by pressurization "p" and by continuous dilution, and for pressurized rooms*;

— *Part 6: Installation and maintenance requirements for electrical apparatus with type of protection "e". Increased safety*;

— *Part 7: Installation and maintenance requirements for electrical apparatus with type of protection N*;

— *Part 8: Installation and maintenance requirements for electrical apparatus with type of protection "s". Special protection*;

— *Part 9: Installation and maintenance requirements for electrical apparatus with type of protection "o". Oil-immersed apparatus, and with type of protection "q". Sand-filled apparatus*[3)].

[1)] These earlier specifications are listed in Appendix A.
[2)] BS 5345 will not now contain a tenth Part dealing with the use of gas detectors. This will be the subject of a separate standard.
[3)] In preparation.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 42, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

Section 1. General

1 Scope

This Part of BS 5345 gives recommendations for the selection, installation and maintenance of electrical apparatus for use in areas where flammable material(s) are generated, processed, handled, stored or otherwise encountered which could give rise to explosive atmospheres.

This standard relates to the precautions necessary to avoid ignition of an explosive atmosphere resulting from electrical arcs and sparks, hot surfaces or frictional sparks from electrical apparatus and installations.

This standard does not cover the following:

a) inherently explosive situations, e.g. explosives manufacturing and processing;

b) underground mining applications;

c) dust atmospheres[4)] or atmospheres containing a mixture of dusts and gases/vapours;

d) areas where abnormal atmospheric conditions occur (see clause **34**);

e) precautions against the effects of static electricity (see BS 5958);

f) precautions against the effects of lightning (but see **19.2.12** and BS 6651);

g) precautions against the effects of high frequency electromagnetic radiation (see BS 6656);

h) precautions against toxic hazards associated with flammable materials;

NOTE The toxic risks associated with flammable materials apply to concentrations that are usually very much less than the lower flammable limit.

i) additional requirements for the installation of electric surface heating systems (see BS 6351).

This standard is applicable to all new permanent installations and, where reasonably practicable, to changes to installations complying with earlier standards. The recommendations for maintenance are applicable to all installations.

The recommendations of this standard are also applicable to those installations that are semi-permanent or temporary. However, in certain circumstances alternative safety measures and procedures may need to be adopted to achieve the same level of safety as that recommended in this standard.

Appendix A contains, for information, a list of relevant international, European and British Standards, together with details of the national certifying authority and its certification standards.

NOTE The titles of the publications referred to in this standard are listed on page 42 and the inside back cover.

2 Definitions

For the purposes of this Part of BS 5345, and of the other Parts of the standard generally, the following definitions apply.

NOTE Further definitions that are particularly relevant to the specific types of protection are included in the appropriate Parts of this British Standard.

2.1
explosive atmosphere

a mixture with air, under atmospheric conditions, of flammable substances in the form of gas, vapour or mist in such proportions that it can be exploded by excessive temperatures, arcs or sparks (the danger is a real one)

2.2
potentially explosive atmosphere

an atmosphere that could become explosive (the danger is a potential one)

2.3
flammable mist

a free suspension in air of droplets of a liquid whose vapour is flammable

2.4
hazardous area

an area in which explosive atmospheres are, or may be expected to be, present in quantities such as to require special precautions for the construction and use of electrical apparatus

2.5
non-hazardous area

an area in which explosive atmospheres are not expected to be present in such quantities that special precautions for the construction and use of electrical apparatus are necessary

2.6
flash point

the minimum temperature at which a material gives off sufficient vapour to form an explosive atmosphere within the apparatus used for flash point determination (see **31.1**)

2.7
ignition temperature

the lowest temperature of a flammable gas or vapour at which ignition occurs when tested as described in International Electrotechnical Commission (IEC) publication IEC 79-4[5)]

[4)] BS 6467 contains a specification for electrical apparatus with protection by enclosure for use in the presence of combustible dusts, and a guide to its selection and use.
[5)] BS 4056, now withdrawn, uses the same test method.

NOTE Ignition temperature was formerly known as auto-ignition or spontaneous ignition temperature.

2.8
flammable material

a gas, vapour, liquid or solid that can react continuously with atmospheric oxygen and that may therefore sustain fire or explosion when such reaction is initiated by a suitable spark, flame or hot surface

NOTE Many liquids and solids, though regarded as flammable, nevertheless do not normally burn. The application of heat to such materials serves to release vapour that may burn with atmospheric oxygen. The heat of the subsequent reaction serves to release further vapour for combustion. Flame may propagate through suspensions of dusts by this mechanism. Liquids can also give rise to flammable mists (see **38.3**).

2.9
apparatus (or system) certification

a formal attestation by a recognized testing station that a prototype or sample of apparatus (or system), constructed to the certification documents, complies with a standard

NOTE Although strictly it is the apparatus design rather than the individual apparatus that is the subject of certification, the term "certified apparatus" and variants upon this have gained acceptance. This is reflected in the standard.

2.10
component certification

a formal attestation by a recognized testing station that a component, constructed to the certification documents, complies with a standard

NOTE The note to **2.9** applies here in respect of components.

2.11
maximum surface temperature

the highest temperature that is attained in service under the most adverse conditions (but within recognized tolerances) by any part or any surface of an electrical apparatus, which would be able to produce an ignition of the surrounding explosive atmosphere

NOTE The most adverse conditions include recognized overloads and any fault condition recognized in the standard for the type of protection concerned and those abnormal operating conditions recognized for the product concerned.

2.12
temperature class (T class)

one of six values of temperature allocated to electrical apparatus derived from a system of classification according to the maximum surface temperature of the apparatus

2.13
apparatus group

the group assigned to electrical apparatus to indicate its suitability for use in mines or surface industry

NOTE For surface industry applications the group may be subdivided for specific gases.

2.14
type of protection

the measures applied in the construction of electrical apparatus to prevent ignition of surrounding explosive atmosphere by such apparatus

NOTE Formerly it was common for an individual item of apparatus to employ one type of protection only; increasingly, apparatus may now employ two or more types of protection. Thus a rotating machine may incorporate a motor carcass in type of protection "d" (flameproof enclosure) and a terminal box in type of protection "e" (increased safety). It has become common usage to refer to "explosion-protected" apparatus rather than to any one type of protection. (See also section 2.)

2.15
degrees of protection provided by enclosures (of electrical apparatus)

the measures applied to the enclosures of electrical apparatus to provide:

a) the protection of persons against contact with or approach to live parts and against contact with moving parts (other than smooth rotating shafts and the like) inside the enclosure and the protection of the apparatus against ingress of solid foreign bodies;

b) the protection of the apparatus inside the enclosure against harmful ingress of water.

2.16
electrical protection

the measures applied to circuits to control the effects of overcurrent and earth fault

3 Statutory requirements

Electrical installations in hazardous areas have to comply with all relevant statutory requirements. Installations in Great Britain at places of work are subject to the requirements of the Health and Safety at Work etc. Act 1974. More specific requirements are imposed in certain classes of premises and legal advice should be sought. It should be noted that the Health and Safety at Work etc. Act 1974 applies to all offshore installations operating in controlled waters designated under the United Kingdom Continental Shelf Act 1964.

4 Classification of hazardous areas

This standard is based on the concept, which is accepted internationally, of dealing with the risk of fire and explosion by area classification. This concept recognizes the differing degrees of probability with which concentrations of flammable gas or vapour may arise in installations in terms of both the frequency of occurrence and the probable duration of existence on each occasion.

The detailed considerations that should be taken into account in area classification are described in BS 5345-2. For completeness, the definitions appropriate to area classification are repeated here.

Zone 0 Zone in which an explosive atmosphere is continuously present, or present for long periods.

Zone 1 Zone in which an explosive atmosphere is likely to occur in normal operation.

Zone 2 Zone in which an explosive atmosphere is not likely to occur in normal operation, and if it occurs it will exist only for a short time.

NOTE Area classification in this standard deals only with risks due to flammable gases, vapours and mists.

When the hazardous areas of a plant have been classified, the remainder will be defined as non-hazardous. In a non-hazardous area normal electrical techniques apply (but see **7.1**).

5 Types of protection

There are at present nine accepted types of protection for electrical apparatus for use in hazardous areas. A description of each type is given in Table 1. The relevant equipment specifications, where they exist, should be referred to for precise definitions of the type of protection.

Apparatus may be protected by one or more types of protection (see **42.4**).

6 Light metals as construction materials

Particular consideration should be given to the location of an apparatus that incorporates light metals in the construction of its enclosure. The propensity of such materials to give rise to sparking that is incendive under conditions of frictional contact has been well established. Reference should be made to Appendix B for further detailed guidance.

Table 1 — Types of protection

Type of protection	Title	Description	Part of BS 5345
"d"	Flameproof enclosure	A method of protection where the enclosure for electrical apparatus will withstand an internal explosion of the flammable gas or vapour (for which it is designed) that may enter it, without suffering damage and without communicating the internal flammation to the explosive atmosphere for which it is designed, through any joints or structural openings in the enclosure.	3
"i"	Intrinsically-safe apparatus or system	A protection technique based upon the restriction of electrical energy within apparatus and in the interconnecting wiring, exposed to a potentially explosive atmosphere, to a level below that which can cause ignition by either sparking or heating effects. Because of the method by which intrinsic safety is achieved it is necessary that n.ot only the electrical apparatus exposed to the potentially explosive atmosphere, but also other (associated) electrical apparatus with which it is interconnected, is suitably constructed.	4
"p"	Pressurization, continuous dilution and pressurized rooms	A method of protection using the pressure of a protective gas to prevent the ingress of an explosive atmosphere to a space that may contain a source of ignition and, where necessary, using continuous dilution of an atmosphere within a space that contains a source of emission of gas, which may form an explosive atmosphere.	5
"e"	Increased safety	A method of protection by which additional measures are applied to an electrical apparatus to give increased security against the possibility of excessive temperatures and of the occurrence of arcs and sparks during the service life of the apparatus. It applies only to an electrical apparatus, no parts of which produce sparks or arcs or exceed the limiting temperature[a] in normal service.	6
N	Type of protection N	A type of protection applied to an electrical apparatus such that, in normal operation, it is not capable of igniting a surrounding explosive atmosphere, and a fault capable of causing ignition is not likely to occur.	7
"s"	Special protection	A concept for those types of electrical apparatus that, by their nature, do not comply with the constructional or other requirements specified for apparatus with established types of protection, but that nevertheless can be shown, where necessary by test, to be suitable for use in hazardous areas in prescribed zones.	8
"o"	Oil-immersion	A method of protection where electrical apparatus is made safe by oil-immersion in the sense that an explosive atmosphere above the oil or outside the enclosure will not be ignited.	9[b]
"q"	Powder/sand filling	A method of protection where the enclosure of electrical apparatus is filled with a mass of granular material such that, if an arc occurs, the arc will not be liable to ignite the outer flammable atmosphere.	9[b]
"m"	Encapsulation	A type of protection in which parts that could ignite an explosive atmosphere by either sparking or heating are enclosed in a compound in such a way that this explosive atmosphere cannot be ignited.	[c]

NOTE 1 Other types of protection are under consideration internationally. These may include type of protection "h" hermetically sealed.

NOTE 2 Whereas in BS 6941 the type of protection is known as type N, in IEC publication 79-15 it is designated type "n".

[a] For definition of "limiting temperature" see **3.5** of BS 5345-6:1976.

[b] In preparation.

[c] Although the existence of type of protection "m" is acknowledged here and BS 5501-8 has been published containing the equipment specification, consideration has yet to be given to recommendations for its selection, installation and maintenance etc. for incorporation in BS 5345. The recommendations in this standard do not therefore necessarily cover type of protection "m".

Section 2. Selection of apparatus

7 Procedure for selecting electrical apparatus

7.1 General

Apparatus for use in hazardous areas should be selected in accordance with each of the following criteria[6]:

a) classification of area;

b) temperature classification;

c) apparatus group;

d) environmental conditions.

Selection procedures according to the above criteria are recommended in **7.2** to **7.5**.

Special considerations may be required for non-hazardous area apparatus that is associated with hazardous area apparatus (see appropriate Parts of BS 5345, e.g. Parts 4 and 6 for intrinsic safety and increased safety apparatus, respectively).

7.2 Selection according to classification of area

Reference should be made to clause **4** and to BS 5345-2 for details of area classification that results in the division of the hazardous area into one or more zones.

Having established the zones, the types of protection to be applied to the electrical apparatus should be selected in accordance with Table 2.

7.3 Selection according to temperature classification

When selecting apparatus according to temperature classification, the maximum surface temperature of the T class of the apparatus (or, where the apparatus is marked with a particular maximum surface temperature, that temperature) should not exceed the ignition temperature of the gases or vapours involved.

NOTE However, BS 5501, subject to certain specified conditions, permits the surface temperature of certain small components of apparatus, e.g. transistors or resistors used in intrinsically-safe electrical circuits, to exceed the temperature class marked on the apparatus if there is no direct or indirect risk of ignition from these components.

Table 7 gives ignition temperatures for a range of flammable materials. Apparatus intended for use with materials not given in Table 7, or where this table does not list the ignition temperature, should be installed only when expert advice confirms its suitability for use with those materials.

The T class is normally assigned to apparatus on the basis of temperature rise tests assuming that the apparatus may be used in a local ambient temperature not exceeding 40 °C. In special cases, apparatus may be designed on request to operate in a local ambient temperature of more than 40 °C. In this case the maximum permitted local ambient temperature will be clearly marked on the apparatus. The T class will have been assigned on the basis of temperature rise tests and the assumption that the apparatus may operate at temperatures up to the maximum permitted local ambient temperature.

When apparatus which has had a T class assigned assuming a 40 °C maximum ambient temperature is to be used at a higher local ambient temperature, for example, because it is mounted on a hot surface, the maximum surface temperature of the apparatus should not exceed the ignition temperatures of the gases or vapours likely to be present. It is also important to check with the manufacturer on the suitability of the apparatus to operate at these higher temperatures. For example, when apparatus is to be mounted under pipe-lagging, it is virtually unaffected by the air temperature, but may fail due to heat from the pipe.

The permitted maximum surface temperatures classified according to BS 5501-1 and BS 4683-1 are given in Table 3.

An example can be given of the relationship between T class and ignition temperature. Cyclohexane has an ignition temperature (see also clauses **35** and **38**) of 259 °C and, therefore, assuming a maximum environmental temperature of 40 °C, apparatus with a temperature class T2 (i.e. 300 °C) would not be suitable, whereas apparatus with a temperature class of T3 (i.e. 200 °C) would be suitable.

NOTE In special cases, apparatus can be marked with a particular temperature as well as one of the six T classes. For example, in the case cited above, if the apparatus were marked with a temperature of 259 °C, as well as the temperature class of T2, it would still be suitable for use in areas where a potentially explosive atmosphere of cyclohexane might form.

In the case of some items of apparatus with type of protection "e" (e.g. motors) the maximum temperature should not exceed the "limiting temperature", which may be determined by the thermal stability of materials used in the apparatus (see BS 5345-6).

[6] Special conditions for safe use apply to any type of certified explosion-protected apparatus where the certification number has a suffix marking of "B" or "X", and these conditions may affect the selection of such apparatus.

Table 2 — Selection of apparatus and systems according to zone of risk

Zone	Type of protection	Part of BS 5345
0	"ia" intrinsically-safe apparatus or system	4
	"s" special protection (specifically certified for use in Zone 0)	8
1	Any explosion protection suitable for Zone 0 and	
	"d" flammable enclosure	3
	"ib" intrinsically-safe apparatus or system	4
	"p" pressurization, continuous dilution and pressurized rooms	5
	"e" increased safety	6
	"s" special protection	8
2	Any explosion protection suitable for Zones 0 or 1 and	
	N[a] type of protection N[b]	7
	"o" oil-immersion	9[c]
	"q" sand filling[d]	9[c]

[a] Alternatively, apparatus that in normal operation is not capable of producing ignition capable arcs, sparks or surface temperatures may also be acceptable for use in Zone 2 where it has been assessed by persons who should:

a) be familiar with the requirements of any relevant standards and codes of practice and their current interpretations;

b) have access to all information necessary to carry out the assessment;

c) where necessary, utilize similar test apparatus and test procedures to those used by recognized testing stations.

[b] Whereas in BS 6941 the type of protection is known as type N, in IEC publication 79-15 it is designated type "n".

[c] In preparation.

[d] The use of apparatus with type of protection "q" in Zone 1 is under consideration.

Table 3 — Relationship between T class and maximum surface temperature

T class	Maximum surface temperature
	°C
T1	450
T2	300
T3	200
T4	135
T5	100
T6	85

7.4 Selection according to apparatus group

7.4.1 *Apparatus groups and subdivisions.* BS 5501 divides electrical apparatus into two basic groups.

a) Group I: electrical apparatus for mines susceptible to firedamp.

b) Group II: electrical apparatus for places with a potentially explosive atmosphere, other than mines susceptible to firedamp.

Some types of Group II apparatus with, for example, types of protection "d", "i" and "s"[7] may be further subdivided according to the nature of the potentially explosive atmosphere for which it is intended. These subdivisions are given in BS 5501 as A, B and C.

NOTE For brevity BS 5501 states apparatus group and subdivision collectively, e.g. Group IIA, dropping the word "subdivision".

7.4.2 *Use of apparatus in potentially explosive atmospheres.* Apparatus that has no subdivision in its group may be used with any of the flammable materials listed in Table 7 subject to consideration of the recommendations of **7.3** and **7.5**.

Apparatus that has a subdivision in its group should be used only with the materials allocated to that subdivision (see Table 7) subject to consideration of the recommendations of **7.3** and **7.5** and **7.4.2** c).

Apparatus with a particular subdivision may be used with flammable materials allocated to a lower subdivision subject to consideration of the recommendations of **7.3** and **7.5**, e.g. Group IIB apparatus may be used with flammable materials allocated to Group IIA, and Group IIC apparatus may be used with flammable materials allocated to Group IIA and Group IIB.

Apparatus that has subdivisions in its group and which is intended for use with flammable materials not given in Table 7 should be installed only when expert advice confirms its suitability for use with those materials.

NOTE In BS 229 and BS 1259 flammable gases and vapours are grouped or classified, respectively, according to the experimental data for limiting safe gaps or igniting currents measured under precisely specified conditions. In the case of BS 1259, many materials are classified according to their chemical similarity with gases and vapours that are already classified on the basis of experimental data. Neither method of grouping takes into account the need for surface temperature classification, since ignition temperatures generally are not related to other combustion characteristics. It is therefore inaccurate to assume that any particular apparatus complying with the design requirements for a group of gases could be used safely with all flammable materials allocated to that group. For this reason, instead of grouping gases, an apparatus itself is now grouped according to design criteria specified in the appropriate Parts of BS 4683 and BS 5501.

The relationship between the apparatus group and the former gas group and apparatus class is given in Table 4.

[7] Apparatus with type of protection "s" may be subdivided as shown above where it uses either or both techniques of types of protection "d" or "i".

Table 4 — Relationship between apparatus group, the former gas group and apparatus class

Representative gas	Apparatus group		Former gas group in BS 229	Former apparatus class in BS 1259
	BS 5501	BS 4683		
Methane	I[a]	I[a]	I[a]	I[a]
Propane	IIA	IIA	II	2c
Ethylene	IIB	IIB	III	2d
Hydrogen	IIC	IIC	IV	2e
Acetylene	IIC	Not allocated	IV[b]	2f
Carbon disulphide	IIC	Not allocated	IV[b]	2f

[a] For underground mining applications.
[b] Although a gas Group IV was allocated, the standard excluded construction requirements for apparatus to be used in this group.

7.5 Selection according to environmental conditions

Current standards for the types of protection listed in Table 1 require that apparatus is normally tested in air and under normal atmospheric conditions. However, oxygen enrichment or variations of pressure or temperature may adversely affect the type of protection afforded to the apparatus. In such cases care should be taken to ensure that the apparatus has been evaluated by a competent authority (see **A.4**) for the specific conditions of use.

Apparatus and its component parts should be constructed so as to guard against electrical and mechanical failure in the intended conditions of use. The integrity of some electrical apparatus may be affected when required to operate under temperature or pressure conditions outside those for which the apparatus has been constructed. In such conditions further advice should be sought.

Particular attention should be given to the need for protection against the weather, the ingress of liquids and particulate matter, corrosion, the effect of solvents and the effect of heat from adjacent plant (see also Appendix C and **27.3** to **27.5**).

Attention is drawn to the risks that can arise with apparatus into which process fluids may be introduced, e.g. pressure switches or canned electric motor pumps. Under fault conditions, e.g. diaphragm or can failure, the fluid may be released inside the apparatus under considerable pressure which may cause any or all of the following:

a) rupture of the apparatus enclosure;

b) an immediate ignition risk;

c) transmission of the fluid along the inside of the cable into a non-hazardous area.

Preferably such apparatus should be designed so that the process fluid containment is in a separate enclosure from the electrical apparatus, but where this is not possible apparatus designed to be vented is acceptable. Failing this a special sealing joint should be used or a length of mineral insulated metal sheathed cable should be introduced in the cable run.

8 Certification

8.1 General

Notwithstanding the statements in this clause concerning certification, apparatus should be selected with a type of protection as recommended in Table 2 for the appropriate zone.

NOTE 1 The term "apparatus" can be generally said to include "systems" also.
NOTE 2 See definitions in **2.9** and **2.10**.

BS 5501 and BS 4683-2 and BS 4683-4 require apparatus to be certified. When conformity with EEC Directives is required, certification is to be carried out by an "approved body" listed by the Commission. (See **A.4** for details of the "approved body" in the United Kingdom.)

In practice for Zone 0 and Zone 1 applications certified apparatus is generally used as an aid to satisfying the statutory requirements listed in clause **3** (but see **8.2**).

For apparatus designed to BS 4683-3 certification is optional.

Apparatus certified to standards other than British Standards or CENELEC European Standards or BASEEFA Standards falls outside the scope of this standard. Such apparatus may, however, be used, but in order to ensure its correct application and installation reference should be made to the relevant national code of practice that deals with these aspects. In cases of doubt about the application or installation of such apparatus expert advice should be sought.

Certified apparatus normally bears the authority's certification mark in addition to all other marking required by the individual standard (see clause **42** for notes on marking to BS 5501).

NOTE 3 BASEEFA has issued certificates to BASEEFA standards when there was no acceptable published British Standard.

NOTE 4 For information on marking of apparatus see section 6 of this standard.

8.2 Uncertified apparatus for Zone 0 and Zone 1

In exceptional circumstances, e.g. research, development, pilot plant and other new projects work, where suitable certified apparatus is not obtainable, other apparatus may be used in Zone 0 and Zone 1. The users of such apparatus should obtain a "document of conformity" to show that the apparatus has been examined and, where necessary, tested by a competent body (using techniques and facilities similar to those normally used by a national certifying authority for the type of protection concerned) and has been found to comply with the requirements of the appropriate standard for the particular type of protection. Such apparatus would not, however, bear the mark of a national certifying authority.

8.3 Assessment of Ex components (see also **42.3**)

A number of components have been assessed for use in potentially explosive atmospheres and may have been given a Component Certificate. Such components may be used with other apparatus where either the certificate for that apparatus identifies the relevant component or where the apparatus including the component has been assessed. Particular attention should always be given to the selection and use of components.

9 Interconnection of apparatus

The safety of individual pieces of apparatus may be influenced by any other apparatus with which it is interconnected. For such system considerations, reference should be made to the Parts of BS 5345 covering individual protection concepts.

Section 3. General installation recommendations

10 General

In addition to any recommendations there may be for installations in non-hazardous areas, further recommendations for installations in hazardous areas as a consequence of the nature of the environment and that are generally applicable to all types of protection are described in clauses **11** to **20**.

The explosion protection of some installations, for example, those using electric surface heating, pressurization "p", etc. is dependent on the overall design of the completed system. In such cases, the appropriate design codes or standards should be used for guidance to carry out the installation (see **A.3** and/or other Parts of BS 5345).

Alterations to apparatus or systems may invalidate any certificate or other documentation relating to that apparatus or system. Such alterations should be made only with the agreement of the owner, occupier or other responsible persons who are in control of the premises, in consultation with the manufacturer where appropriate.

There may be special conditions for safe use listed in the certification documents (see **42.2**) that will affect the method of installation and it is important to ensure that such conditions are properly met.

11 Access for inspection

Installations should be designed and the apparatus and materials installed with a view to providing ease of access for inspection and maintenance.

12 Plans and records

For each site a responsible person should maintain plans or records of the following items:

a) the classification and extent of hazardous areas together with the other information as recommended in **7.4** of BS 5345-2:1983;

b) records sufficient to enable the explosion-protected equipment to be maintained in accordance with its type of protection.

Clause **1.3** of BS 5501-1:1977 indicates that devices in which, according to the manufacturer's specifications, none of the values 1.2 V, 0.1 A, 20 μJ or 25 mW is exceeded need not be certified or marked. The most widespread use of such apparatus is in intrinsically-safe systems where the use of simple apparatus such as thermocouples and switches is usually covered by these rules. A comprehensive record of such apparatus and systems should be maintained so that it may be properly inspected for compliance with the relevant safety documentation.

13 Electrical ratings

Electrical apparatus and materials should be installed, used and maintained within their electrical ratings for power, voltage, current, frequency, duty and such other characteristics where non-compliance might jeopardize the safety of the installation.

In respect of electrical apparatus from non-UK suppliers, because of the differing nature of the supply networks, special care should be taken to ensure that:

a) the voltage and frequency rating are appropriate to the supply system on which the apparatus is to be used;

b) the temperature classification has been established for the correct voltage, frequency, etc.

14 Installation of apparatus

All apparatus should be installed with due regard to the possibility of external mechanical damage affecting the type of protection of the apparatus. Where equipment is to be installed in areas of high mechanical risk, additional measures such as the provision of guards for light transmitting parts may be necessary. However, additional measures should not impair the integrity of the type of protection (see, for example, BS 5345-3).

Special conditions for safe use apply to any type of explosion-protected apparatus where the certificate number has a suffix marking and these conditions may affect certain features of the installation. The certification documents should be studied to ascertain the conditions of installation. The manufacturers should also have provided clear installation instructions.

15 Integrity of insulation

Care should be taken during installation to maintain the degree of electrical insulation provided by the construction of the apparatus so that the possibility of accidental sparking or arcing is avoided.

16 Automatic overcurrent protection

In general, all circuits and apparatus in hazardous areas should be provided with automatic means of disconnection in the event of overcurrent (short circuit and overload) conditions. However, apparatus with particular types of protection may have additional and/or alternative requirements, and reference should be made to the recommendations in the appropriate Parts of BS 5345. Suitable protection should be fitted where there is a danger that three-phase apparatus may be subjected to excess current during single-phase operation.

17 Earthing and earth fault protection

17.1 Earthing of power systems

Earthing of power distribution systems should be in accordance with appropriate recommendations, e.g. CP 1013, Fifteenth edition of the IEE "Regulations for electrical installations" (the Wiring Regulations), 1981 or the IEE Recommendations for the Electrical and Electronic Equipment of Mobile and Fixed Offshore Installations (1983).

High voltage systems, e.g. 3.3 kV and 6.6 kV, should have earth fault protection in addition to overcurrent protection.

17.2 Earthing of intrinsically-safe electrical systems/apparatus "i"

Detailed recommendations are given in BS 5345-4.

17.3 Lightning protection

Recommendations for lightning protection of structures are given in BS 6651 (see also **19.2.12**).

17.4 Electrostatic phenomena

Recommendations for the avoidance of ignition risks due to static electricity are given in BS 5958.

17.5 Cathodic protection

Recommendations for cathodic protection systems are given in CP 1021.

17.6 Protective multiple earthing (PME)

Where the power supply is directly from a system that is protected by protective multiple earthing, special precautions may be required within the hazardous area and specialist advice should be sought.

17.7 Interconnection of earthing systems

The power, lightning, and static earthing systems, where they exist in the same area, should be effectively connected together to ensure as far as possible that all metal work in a particular area is at the same potential under all conditions (see BS 5345-4 for special recommendations for type of protection "i").

18 Isolation

At a suitable point or points outside the hazardous area there should be single or multiple means of isolating electrical supplies to the hazardous area.

Suitable means of isolation should be provided for each circuit or group of circuits, to include all circuit conductors (including neutral conductors). Where the means of isolation is located inside the hazardous area it should be provided with an appropriate type of protection.

Labelling should be provided immediately adjacent to each means of isolation to permit rapid identification of the circuit or group of circuits thereby controlled. There should be effective measures to prevent the restoration of supply to the apparatus whilst the risk of exposing unprotected live conductors to an explosive atmosphere continues.

BS 5345-4 should be referred to for isolation recommendations for circuits for apparatus and systems with type of protection "i".

19 Wiring systems

19.1 General

The types of cable that in principle may be used for installations in hazardous areas are described in this clause. The detailed recommendations for permitted types of cable and their accessories are described in the Parts of BS 5345 dealing with individual types of protection.

For a Zone 0 installation, cables will be either part of an "ia" system (see BS 5345-4) or as recommended for type of protection "s" for Zone 0 (see BS 5345-8).

Types of wiring system that should be used in Zone 1 and Zone 2 areas are:

a) cables drawn into conduit systems (see **19.4**);

b) cables that are otherwise suitably protected against mechanical damage.

NOTE The sheath of a metal sheathed cable should not be used as the neutral conductor.

Examples of the types of cable that are in accordance with the recommendations of b) are:

1) thermoplastics or elastomer insulated screened or armoured cable with or without a lead sheath and with polyvinylchloride (PVC), chlorosulphonated polyethylene (CSP), polychloroprene (PCP), chlorinated polyethylene (CPE) or similar sheath overall;

2) cables enclosed in a seamless aluminium sheath with or without armour, with an outer protective sheath (see also Appendix B);

3) mineral insulated metal sheathed cable (see also Appendix B);

4) thermoplastics or elastomer insulated flexible cable or cord with a flexible metallic screen or armour and a PVC, CSP, PCP, CPE or similar sheath overall;

5) thermoplastics insulated cable with semi-rigid sheath.

For type of protection "i" and for apparatus used in Zone 2 only, other cables may be used (see BS 5345-4 and BS 5345-7).

19.2 General installation recommendations for wiring systems

19.2.1 The cable entry to the apparatus should maintain the integrity of the type of protection of the apparatus. Certain types of cable employ materials that can exhibit significant "cold flow" characteristics which could have adverse effects on the protection of the apparatus. Where such cable is to be used a suitable cable entry device should be employed, e.g. certified glands not employing compression seals or other certified cable entry devices suitable for use with these cables.

19.2.2 Unused cable entries in electrical apparatus should be closed with plugs suitable for the type of protection of the apparatus.

19.2.3 Where accessories, e.g. a junction box, are used for the interconnection of cables, only those accessories that are suitable for the zone concerned should be used.

19.2.4 Electrical continuity between metallic enclosures and conduit, armour or cable sheaths and armour, or across any joints in the conduit or armour, should be maintained by the integrity of the joint itself. If external bonding is necessary, it should be connected directly across the joint.

19.2.5 Where circuits traverse a hazardous area in passing from one non-hazardous area to another, the wiring system in the hazardous area should be in accordance with the recommendations of this standard.

19.2.6 Except for trace heating, fortuitous contact between conduit or the metallic armouring/sheathing of cables and pipework or equipment containing flammable gases, vapour or liquids should be avoided. The insulation provided by a non-metallic outer sheath on a cable will usually be sufficient to avoid this.

19.2.7 A wiring system should be installed, so far as is practicable, in positions that will prevent it being exposed to mechanical damage and to corrosive or solvent agencies and to the effects of heat. Where exposure of this nature is unavoidable, appropriate protective measures should be taken.

19.2.8 All apparatus connections and wiring systems whose functions are not immediately apparent should be clearly marked to enable their relationship to any associated apparatus, connections and wiring systems to be clearly recognized.

19.2.9 Where cables or conduit pass through a floor, wall, partition or ceiling that forms a gas or fire barrier, the hole provided for them should be made good with material determined as incombustible in accordance with the method of BS 476-4 to the full thickness of the floor, wall, partition or ceiling. Alternatively, cable glands or cable transits may be used for this purpose.

19.2.10 Where trunking, ducts, pipes or trenches are used to accommodate cables, precautions should be taken to prevent the passage of flammable gases, vapours or liquids from one area to another and to prevent the collection of flammable gases, vapours or liquids in trenches. Such precautions may involve the sealing of trunking, ducts and pipes and the adequate ventilation or sand filling of trenches.

19.2.11 For terminal connections to fixed apparatus that may be required to be moved a small distance, e.g. motors on slide rails, cables arranged to permit the necessary movement without detriment to the cable, or one of the types of cable suitable for transportable apparatus, may be used. If flexible conduit is used, it and its fittings should be so constructed and assembled that damage to the cable consequent upon its use is avoided. Adequate earthing or bonding should be maintained other than by means of the flexible conduit.

19.2.12 Where an overhead line provides power or telecommunication services to apparatus in a hazardous area it should be terminated in a non-hazardous area and the service continued by buried cable. Suitable surge protection apparatus should be fitted at or near the terminal point. The armouring or metal sheathing of the cable should be electrically continuous, and the end adjacent to the point of connection with the overhead line should be bonded to the earth electrode of the surge protection apparatus. In addition, the armouring or metal sheathing should be independently earthed as near as possible to the lightning protective system, if any, associated with the hazardous area (see also BS 6651).

NOTE Guidance on the application of surge diverters for alternating current power circuits is given in BS 2914.

19.3 Environmental factors affecting choice of wiring system

19.3.1 Insulating materials may be attacked by certain chemicals, and where contact may be sufficiently long that deterioration could result from such exposure, then consideration should be given to the use of a suitable means of protection, e.g. a protective sheath.

19.3.2 Where cables may be subjected to excessive flexing, consideration should be given to the avoidance of fracture, e.g. when using mineral insulated cable, by forming a cable into a loop close to the point of termination.

19.3.3 Where electrolytic corrosion of metal sheath may result from contact with walls or other surfaces to which the cable is attached, it should be kept clear of such surfaces or covered with a protective sheath.

19.3.4 Cables, whether or not manufactured in accordance with a British Standard, are not necessarily intended for wet conditions. Where such conditions persist, the cable manufacturer should be consulted so that the correct construction may be supplied.

19.4 Conduit systems

Conduit should be selected from the following:

a) screwed heavy gauge steel, solid drawn or seam welded in accordance with BS 31 or BS 4568;

b) flexible conduit of metal or composite material construction, e.g. metal conduit with a plastics outer jacket, of heavy or very heavy mechanical strength classification in accordance with BS 731-1.

NOTE 1 The use of plastics conduit of sufficient strength with apparatus having specific types of protection is discussed in the appropriate Parts of BS 5345.

NOTE 2 Attention is drawn to the recommendations of clause **6** with respect to the use of light metals as construction materials.

In installations where vibration, relative movement or excessive stresses may be a potential source of fracturing or loosening of joints, the use of flexible conduit as recommended in b) above may be considered.

All conduits should have corrosion resistance qualities commensurate with the environment in which they will be installed.

Where a run of conduit, irrespective of size, passes from a hazardous area to a non-hazardous area, a stopper box or sealing device should be inserted at the hazardous area boundary or, failing this, on the side remote from the hazardous area.

NOTE 3 The use of a sealing device is essential to the maintenance of certain types of protection (see appropriate Parts of BS 5345).

Elbows of the solid type may be used for the immediate connection of conduit to apparatus.

Surface mounted solid drawn or seam welded conduit should be supported by spacing saddles.

All joints in an assembly of conduit should be prepared before or after assembly so that the development of rust is inhibited and earth continuity and bonding is maintained.

The flexible conduit section should be fitted with terminating fittings, appropriate to the classification of the conduit, that maintain the ingress protection of the conduit system. The flexible conduit section should not be used as the sole means of maintaining the continuity of the protective conductor provided by the rigid system.

The metallic portion of the conduit should be electrically bonded to the rigid system by either a separate conductor or the terminating devices.

NOTE 4 For additional recommendations for conduit systems that are relevant to particular types of protection, see the appropriate Parts of BS 5345.

19.5 Cable systems

19.5.1 *General.* Conductors may be of copper or aluminium, but plain aluminium should not be used for conductors with cross-sectional areas less than 16 mm^2 (see also **B.7** for precautions on the use of aluminium in Ex "d" flameproof enclosures).

Cable runs should, where practicable, be uninterrupted. Where discontinuities cannot be avoided, the joint, in addition to being mechanically and electrically suitable for the situation, should be encapsulated or made in a compound-filled joint box or be protected in accordance with the requirements of the zone.

NOTE Certain types of protection require specific types of cable glands; reference should be made to relevant Parts of BS 5345 for details.

All cables should be provided with adequate mechanical protection. Cables should be adequately supported throughout their length, care being taken to avoid excessive pressure when cleats are used. Horizontal cables may be carried on supports or cable trays or through protective troughs or tubes. Rising cables should be clipped, cleated or otherwise attached to suitable supports that provide adequate mechanical protection and support.

Where single core metal sheathed or armoured cables are used, precautions should be taken to avoid dangerous sheath voltages or currents.

19.5.2 *PVC covered and/or insulated cables.* Attention is drawn to the fact that as temperature decreases, PVC becomes increasingly stiff and brittle with the result that, if PVC cables are bent too sharply or are struck at temperatures of about 0 °C or lower, there is a risk for most PVC cables of shattering the PVC. It is advisable to store PVC cable at temperatures above 0 °C for at least 24 h prior to installation.

19.5.3 *Paper insulated cables.* Where paper insulated armoured cables are used, and particularly where such cables may be exposed to high temperature, preference should be given to non-draining cables complying with BS 6480-1. In the case of other types of paper insulated armoured cables, vertical runs should be avoided.

Cable boxes, if necessary, should be arranged for sealing the cable insulation and should be provided with adequate means for ensuring the earth continuity of metallic sheath and/or armour.

Adequate arrangements should be made to ensure that cable boxes can be filled with the necessary compound or insulating oil according to their design.

19.5.4 *Mineral insulated metal sheathed cables.* Cable terminations should incorporate a seal for the cable insulation and, where necessary, means of ensuring adequate earth continuity.

NOTE Certain types of protection require specific types of seal. Reference should be made to the relevant Parts of BS 5345 for details.

Seals in which compound is used should not be exposed to temperatures that may, in the course of normal working, affect the satisfactory functioning of such compound.

Where there is a risk of mineral insulated cables being exposed to excessive voltages such as inductive surges, surge suppression should be fitted. Where surge suppression devices are installed in hazardous areas, they should be suitably explosion-protected.

19.5.5 *Aluminium sheathed cables.* Aluminium sheathed cables, unless further sheathed with a protective covering, should not be installed in contact with walls or floors. Consideration should be given to the avoidance of frictional contact with such cables (see Appendix B).

19.5.6 *Cables with low smoke producing insulation.* Cables complying with BS 6724 are not necessarily intended for wet conditions (see also **19.3.4**).

20 Portable and transportable apparatus and its connections

Portable and transportable apparatus should have a type of protection appropriate to the zone(s) of use. During use such apparatus should not be transferred from a zone of lower risk to a zone of higher risk unless it is suitably protected for the higher risk. Additionally, the apparatus group and T class should be appropriate to all of the gases and vapours in which the apparatus may be used.

Ordinary industrial portable or transportable apparatus should not be used in a hazardous area unless its use is undertaken under a controlled procedure and the specific location has been assessed to ensure that potentially flammable gas or vapour is absent during the period of use.

Should plugs and sockets be in a hazardous area, they should be suitable for use in the particular zone of risk and should have mechanical and/or electrical inter-locking to prevent danger during insertion or removal of the plug.

In many cases the type of cable to be used will be stated on the apparatus certificate, in cases where this is not so, the cable should be suitable for rough usage and other adverse environmental conditions, e.g. elevated temperatures, presence of solvents. It should also be suitable for the circuit protective arrangements, e.g. where earth monitoring is used, the necessary number of conductors should be included. Where the apparatus needs to be earthed, the cable may include an earthed flexible metallic screen in addition to the earth conductor.

Section 4. Inspection, maintenance, testing and repair

21 General

To minimize the risk of ignition of an explosive atmosphere by electrical apparatus, efficient inspection, maintenance and testing of the apparatus, systems and installations are essential. It should be noted that correct functional operation does not itself indicate conformity with the recommendations for the safe use of apparatus. The general recommendations for inspection, maintenance and testing that are applicable to all types of protection are described in clauses **22** to **27**. Those recommendations that apply only to specific types of protection are described in the appropriate Parts of BS 5345.

22 Personnel

The inspection, testing, maintenance, replacement and repair of apparatus, systems and installations should be carried out only by persons whose training includes instruction on the various types of protection involved. Appropriate refresher training should be given from time to time.

23 Isolation of apparatus

23.1 General

Apparatus should not be opened in a hazardous area until it has been disconnected from its source of supply (see clause **18**) and effective measures, such as the locking of the disconnector in the open position or fuse removal or other acceptable method, have been taken to prevent its being made alive before re-assembly. However, apparatus with type of protection "i" or certain low power apparatus with type of protection N may be opened whilst energized provided that the specific recommendations of the clauses dealing with maintenance in BS 5345-4 and BS 5345-7 are followed. Particular attention should be paid in the case of an apparatus that may be live even after it has been disconnected from a source of supply. For example, electrically driven rotating machinery may produce a voltage at the terminals until it is stationary, and power capacitors even though fitted with discharge resistors take a finite time to bring the terminal voltage to a harmless value.

Where, for purposes of electrical testing, it is essential to restore the supply before the apparatus is re-assembled, then this work should be under a controlled procedure and the specific location assessed to ensure that potentially flammable gas or vapour is absent. For the testing of intrinsically-safe electrical apparatus and systems, see BS 5345-4.

23.2 Field replacement of batteries

Batteries should preferably be replaced in a non-hazardous area. Where batteries have to be replaced in a hazardous area this should be done under a controlled procedure (see clause **24**). However, batteries with type of protection "i" may be replaced in a hazardous area provided that any limiting resistor associated with the battery is not disconnected. Other batteries should be transported through a hazardous area only under a controlled procedure unless other precautions are taken to prevent the occurrence of ignition capable arcs and sparks.

Replacement batteries should be in accordance with the certification documents.

Batteries of all types not being used should be removed promptly from the hazardous area.

24 Precautions concerning the use of igniting agencies

No operation involving the use of a source of ignition, e.g. welding, brazing, unprotected apparatus etc., should be attempted in a hazardous area until the conditions have been made safe by the control of the flammable material that may give rise to the risk. Such operations should be undertaken only on the issue of a gas free certificate confirming that adequate control measures have been taken and that tests have been made and will be repeated at sufficiently frequent intervals to ensure that the safe conditions are maintained.

25 Initial and periodic inspections

All electrical apparatus, systems and installations should be inspected prior to commissioning to confirm that the selection and installation is appropriate and in accordance with BS 5345. Examples of some of the items that should be included in an initial inspection are given in Table 5.

Following any replacement, repair, modification or adjustment, the items concerned should be inspected to ensure that the appropriate recommendations of this standard have been maintained.

If at any time there is a change in the area classification or in the characteristic of the flammable material used in the area, or if any apparatus is moved from one location to another, an inspection should be made to ensure that the type of protection, apparatus group and T class, where appropriate, are suitable for the revised conditions.

The extent, complexity and frequency of inspection of apparatus, systems and installations when in use should be determined by those whose training and experience will enable them to recognize any potential hazards and who are familiar with the operation and the environmental conditions under which the apparatus is used.

The frequency of inspection depends on the type of equipment, the factors governing its deterioration, and the findings of previous inspections. Examples of factors that can affect the deterioration of apparatus or otherwise lead to an unsafe condition are given in Table 6.

It is therefore recommended that once the apparatus has been taken into use, initial intervals between inspections should be of a reasonably short duration and that a system be established to enable subsequent inspection intervals to be reviewed and modified in the light of operational experience. Where inspection intervals and methods are already established and are found by experience to be satisfactory for similar apparatus and environments, these may be used. It is recommended that an inspection record system be operated so that the review of inspection frequencies is effective.

When large numbers of similar items such as luminaires, junction boxes etc. are installed, it may be feasible to carry out inspections on a sample basis provided that the degree of sampling in addition to the inspection frequency is subjected to review.

26 Initial and periodic testing

All electrical apparatus, systems and installations should be tested prior to commissioning and these tests should include the following:

a) insulation resistance measurement;

b) earth electrode resistance measurement;

c) earth loop impedance measurement;

NOTE It may be advantageous to make the earth loop impedance measurement with both a substantial current and with an intrinsically-safe tester to enable the measurement to be made with the intrinsically-safe tester alone for subsequent tests and to allow those results to be compared with the initial test results. It should be noted that tests made with an intrinsically-safe tester may not necessarily identify certain bad connections because of the low test current.

d) setting and, where appropriate, operation of protective devices.

The results of all tests should be recorded and included in the record of inspections described in clause **25**.

The testing of apparatus, systems and installations when in use should be under the control of those whose experience will enable them to recognize the potential hazards and who are familiar with operation and the environmental conditions under which the apparatus is to be used.

Test procedures should be designed to cause the minimum disturbance to the installation or system.

Diagnostic testing and recording of results of such functions as time, operating voltage, circuit resistance, insulation resistance etc. should be used where possible to show trends in electrical condition and to aid the determination of both the nature and frequency of subsequent tests and inspections.

The frequency of testing depends on the type of equipment or system, the factors governing its deterioration and in particular the findings of previous tests. Factors that may affect the deterioration of apparatus are identified in Table 6 and as these should be taken into account in determining the frequency of inspection the frequency of testing will not be greater than, and in fact may be less than, the frequency of inspection for the relevant apparatus or system. The frequency of testing should be established and reviewed in a manner similar to that recommended for the frequency of inspection.

Testing in continuously operating plant and on similar apparatus or systems may be undertaken on a sample basis subject to review similar to that recommended for inspections conducted on a sample basis.

Tests should be made in such a way that low energy or low voltage apparatus and circuits are not subject to damage by excess voltage. For testing electrical systems with type of protection "i", see BS 5345-4.

Tests should be undertaken under a controlled procedure to ensure that the specific location has either been assessed for the absence of a flammable gas or vapour, or that the test method is non-incendive.

It should be borne in mind that certain test instruments that incorporate a power source, when used to test isolated apparatus that has energy storage devices, e.g. capacitors, inductors, or in certain circumstances cables, may lead to incendive sparking if the power source can charge the storage components to levels in excess of 20 μJ.

Table 5 — Example of schedule for initial inspection

Initial inspection items
Apparatus appropriate for the area classification
Correct temperature classification
Appropriate apparatus group or subgroup
Correct circuit identification
Maintenance of integrity of enclosure
Cable entries and stoppers etc. are complete and appropriate to the enclosure
Electrical connections are tight
Satisfactory earthing, bonding etc.
Correct rating of apparatus and components
Damage to apparatus or wiring systems
Adequate environmental protection, e.g. against weather, mechanical damage
No unauthorized modifications
NOTE Items are not listed in any order of priority. Where integrity of type of protection is dependent on electrical protection, this should be verified initially.

Table 6 — Example of schedule for subsequent inspections

Factors affecting integrity of apparatus, systems and installations
Corrosion of enclosures, fixings, cable entries etc.
Damage to apparatus or wiring systems
Undue accumulation of dust and dirt
Loose electrical connections, including those for earthing, bonding etc.
Loose fixings, glands, conduit, stoppers etc.
Condition of enclosure gaskets and fastenings
Leakage of oil or compound
Condition of bearings
Inadvertent contact between rotating and fixed parts
Integrity of guards
Incorrect lamp ratings or type
Undue vibration
Malfunction of relays and protective devices
Unauthorized modifications or adjustments
Inappropriate maintenance, e.g. not in accordance with manufacturer's recommendations
NOTE Items are not listed in any order of priority. Where integrity of type of protection is dependent on electrical protection, this should be verified initially.

27 Maintenance recommendations

27.1 Alterations to apparatus

The general condition of all apparatus should be noted periodically as recommended in clause **25** and appropriate remedial measures should be taken where necessary. Care should be taken, however, to maintain the integrity of the type of protection provided for the apparatus; this may require consultation with the original manufacturer. Replacement parts should be in accordance with the conditions of certification. No alteration that might invalidate the certificate or other document relating to the safety of apparatus should be made to any apparatus without appropriate approval[8)].

27.2 Maintenance of flexible cables

Flexible cables, flexible conduits and their terminators should be inspected at regular intervals and should be replaced if found to be damaged or defective.

27.3 Precautions against corrosion

Metallic enclosures of apparatus should, where necessary, be treated with an appropriate protective coating as a precaution against corrosion, the frequency and nature of such treatment being determined by the environmental conditions.

NOTE For special precautions concerning the use of certain protective materials, e.g. on the flange faces of Ex "d" flameproof apparatus, reference should be made to the appropriate Part of BS 5345 for the type of protection concerned.

27.4 Cleanliness

All parts of installations should be kept clean and free from accumulations of dust and deleterious substances.

27.5 Precautions against excessive temperature rise

Apparatus should be kept free from dust deposits that could cause excessive rise in temperature.

When replacing lamps in luminaires the correct rating and type should be used or excessive temperature rise may result.

The etching, painting or screening of light transmitting parts may lead to excessive temperatures.

8) Guidance on repairs to apparatus used in hazardous areas may be found in BEAMA AEMT Ex Code of Practice. *Repair and overhaul. Ex electrical apparatus*. BEAMA Publication No. 300.

27.6 Removal from service

Should it be necessary for maintenance purposes to withdraw or remove apparatus etc. from service, the exposed conductors should be terminated in an appropriate certified enclosure; alternatively, the cable may be protected adequately by isolating it from all sources of power supply and insulating the ends of the conductors. Should the apparatus be permanently withdrawn or removed from service, associated wiring should be removed or correctly terminated in an appropriate certified enclosure.

27.7 Fastenings and tools

Where special bolts and other fastenings or special tools are required, these items should be available and should be used.

Section 5. Properties of flammable liquids, vapours and gases

28 General

Available data applicable only to the use of electrical apparatus in hazardous areas are given in Table 7 for those flammable gases and vapours that have been allocated to apparatus groups. The physical properties of these materials, which have to be considered when the degree of risk appropriate to a particular application or installation is being assessed, are defined and discussed in clauses **29** to **36** in the same order as that in which they are given in Table 7 (see also BS 5345-2). In addition clause **37** gives recommendations and notes relating to specific materials.

Properties of the flammable materials given in Table 7 are generally for materials in the pure form and may be different if there are impurities or where there are mixtures of materials. In such cases and where materials not listed in Table 7 are concerned, expert advice should be sought. For descriptions of the concepts of temperature classification and apparatus grouping see **7.3** and **7.4**.

NOTE The data for Table 7 have been obtained from a number of references (see Appendix D). Some minor variations in data appear when references are compared but usually the discrepancy is not significant.

29 Melting point and boiling point

The melting and boiling points have their usual meanings, and the data listed in Table 7 apply at standard atmospheric pressure.

30 Relative vapour density

The relative vapour density of a material is the mass of a given volume of the material in its gaseous or vapour form compared with the mass of an equal volume of dry air at the same temperature and pressure. It is often calculated as the ratio of the relative molecular mass of the material to the average relative molecular mass of air (the value of the latter being approximately 29).

The effect of relative vapour density on the spread of a vapour release into the atmosphere is discussed in BS 5345-2.

31 Flash point[9)]

31.1 General

Flash point data are normally associated with flammable materials in the liquid phase. There are a few materials, however, that give off sufficient vapour in the solid phase to form flammable mixtures with air. For these materials and materials that sublimate, i.e. pass from solid to vapour without the normal intermediate liquid phase, flash point data will be associated with the materials in their solid form.

The test apparatus used for the measurement of flash point is normally one of two types, of which there are several variants. These are called generally open cup and closed cup flash point testers. For most liquids the flash point determined by the closed cup method is slightly lower (in the region of 5 % to 10 % when measured in °C) than that determined by the open cup method. Flash points measured by the more sensitive closed cup method are, therefore, normally used and are given in Table 7. Open cup values are given in parentheses. The symbol < (less than) indicates that the flash point is below the value stated, this value probably being the limit of the apparatus used.

31.2 Materials having high flash points

Some materials have such high flash points that they do not form flammable mixtures with air at normal ambient temperatures, even when exposed to the sun in tropical locations. These should not be discounted as ignition hazards, however, because exposure to a suitably hot surface or use of the material at a temperature above its flash point may create a flammable mixture locally, which may be ignited by the same hot surface or an alternative ignition source. It is therefore necessary to consider the limitation of surface temperatures even when materials of high flash point are being processed. A liquid below its flash point can form a flammable mist if released under pressure as a jet.

Materials having high flash points may be used in processes involving high temperatures and possibly high pressures. The normal or accidental release to the atmosphere of compounds under such conditions may present local explosion risks that would not normally be associated with high flash point materials. Materials having high flash points can form flammable mixtures with air at subatmospheric pressures.

[9)] For definition see **2.6**.

31.3 Classification of flash points

In some industries, it has been found convenient to group materials into prescribed ranges of flammability according to their flash points to facilitate safe handling. In certain applications, legislation specifies the limits for these ranges.

32 Flammable (explosive) limits

All combustible gases and vapours are characterized by flammable limits between which the gas or vapour mixed with air is capable of sustaining the propagation of flame.

The limits are called the lower flammable limit (LFL) (lower explosive limit LEL) and the upper flammable limit (UFL) (upper explosive limit UEL) and are usually expressed as percentages of the material mixed with air by volume. They are also sometimes expressed as milligrams of material per litre of air. Where appropriate, both sets of data are included in Table 7.

Where flammability is presented for materials with flash points above 40 °C, the determinations have been made at an elevated temperature sufficient to give the quoted concentration.

33 Flammable (explosive) range

The range of gas or vapour mixtures with air between the flammable limits, within which the gas/air mixture is continuously flammable, is the flammable range. Gas/air mixtures outside this range are non-flammable under normal atmospheric conditions. Concentrations above the UFL in free atmospheric conditions cannot be controlled and further dilution with air will produce mixtures within the flammable range.

34 Effect of environments with other than normal atmospheric conditions

The data given in Table 7 apply only to mixtures of flammable gases and vapours with air under normal conditions of atmospheric temperature and pressure or at suitably elevated temperatures if the flash point of the vapour is above the normal ambient temperature. Caution should be exercised, therefore, in assessing the explosivity of gas or vapour with air under environmental conditions that are other than normal. An increase in pressure, temperature or oxygen content of the mixture will generally broaden the flammability range.

35 Ignition temperature

The ignition temperature of a material is the minimum temperature under prescribed test conditions at which the material will ignite and sustain combustion when mixed with air at normal pressure, without initiation of ignition by spark or flame. Ignition temperature should be clearly distinguished from flash point (see clause **31**).

The majority of ignition temperatures listed in Table 7 have been determined with the test apparatus and procedure described in IEC 79-4[10)] or with equivalent test apparatus. Where a determination by a method other than that in IEC 79-4[10)] provides the only data available, the classification may be regarded as provisional only and has been, for guidance, enclosed in parentheses in Table 7. In such cases the corresponding T class has been given in parentheses and has been determined from the lowest reported ignition temperature.

The direct result of established ignition temperatures is to limit the surface temperatures of electrical apparatus in hazardous areas so that they do not present an ignition risk. Formerly, permitted surface temperatures were limited to a certain proportion of the measured ignition temperature (commonly 80 %) to provide a factor of safety. It is now generally accepted that the sensitivity of the recognized test methods is such that the maximum surface temperature (see **2.11**) of electrical apparatus may safely be allowed to rise to the ignition temperature of the gas or vapour that presents the explosion risk. Where more than one flammable material may be present in a particular application, the surface temperature should be limited to the lowest value of the ignition temperatures of the combustibles concerned or the ignition temperature of the particular mixture as determined by test. However, where there is a possibility of catalytic interaction between the components or where mixtures of hydrogen, moisture or hydrocarbons with carbon monoxide occur, the surface temperature may need to be less than the lowest ignition temperature of the individual components and expert advice should be sought.

[10)] Reference is made in IEC 79-4 to the use of asbestos. The Council of Asbestos at Work Regulations 1988 apply to every process involving asbestos as defined in the Regulations in any premises to which the Health and Safety at Work etc. Act (1974) applies.

The value for ignition temperature is dependent on the method chosen for its measurement. In particular, factors such as the geometry, dimensions and materials of the test apparatus influence the measured ignition temperature. Care should be exercised, therefore, if the ignition temperature data contained in this Part of BS 5345 are applied to equipment other than electrical apparatus.

36 Apparatus group

Apparatus groups shown in column 14 of Table 7 may be applicable to types of protection "i", "d", "s" and "p". Some are determined experimentally by minimum ignition current (MIC) and/or maximum experimental safe gap (MESG) determinations and others by chemical similarity.

37 Recommendations and notes concerning individual materials

The information and recommendations in a) to d) concern the use of acetylene and carbon disulphide, coke oven gas, methane and xylene.

a) *Acetylene and carbon disulphide*. For apparatus which has a subdivision in its group and which complies with the requirements of BS 5501, acetylene and carbon disulphide are grouped IIC. Apparatus certified to Group IIC of BS 4683 is satisfactory for use only with hydrogen. Such apparatus would need special assessment for use with acetylene and carbon disulphide.

b) *Coke oven gas*. Coke oven gas is a mixture of hydrogen, carbon monoxide and methane. If the sum of the concentrations of hydrogen and carbon monoxide is less than 75 %, Group IIB or IIC flameproof apparatus is recommended. It is recommended that intrinsically-safe apparatus should be Group IIC for all concentrations.

c) *Methane*. Industrial methane includes methane mixed with not more than 15 % by volume of hydrogen.

d) *Xylene*. The ignition temperature of *o*-xylene is 464 °C, that of *p*-xylene is 528 °C and that of *m*-xylene is 525 °C.

38 General considerations

38.1 Relation between ignition temperature and maximum surface temperature

The vapour given off from a flammable liquid will form a flammable mixture with air, provided that the temperature of the liquid is at or above its flash point. The flammable mixture may then be ignited by one of several means: a flame, a suitable frictional spark, an electrical spark of sufficient energy or a hot surface. If, on the other hand, the local ambient temperature and that of the electrical apparatus etc. are below the boiling point, the vapour will eventually condense to a mist of liquid droplets and spread as such both through the atmosphere and over the surfaces of the apparatus. It is in the latter respect that adequate resistance to chemical attack may be particularly important.

For ignition by a hot surface, the surface temperature has generally to be greater than the ignition temperature of the flammable material. Therefore, to ensure that ignition by hot surfaces does not occur, it is necessary that the maximum surface temperature should not be greater than the ignition temperature. This has led to the concept of temperature classification described in **7.3**.

NOTE Surfaces that are catalytically active can ignite vapours at temperatures lower than the normal ignition temperature.

38.2 Mixtures of materials

Single-component flammable materials are not often encountered in practice. Most frequently, mixtures of two or more materials are present, in ratios that may vary between prescribed limits. Consideration has then to be given to the characteristics required for electrical apparatus in the light of the properties of each individual component present. Often this will impose no difficulty since, by the nature of the process, the various materials will possess similar chemical properties and, often, similar combustion properties.

There are occasions, however, when this is not the case. The materials may fall within different apparatus subdivisions, i.e. Group IIA, IIB or IIC, or have widely different ignition temperatures. In these cases, it is possible to give only the most general of rules for guidance. In general it should be assumed that, at some time during the process or the life of the plant, the component in the mixture having the most demanding of the characteristics being considered, e.g. the apparatus subdivision, the flammable limits, the flash point or ignition temperature, will be present as the largest proportion of the mixture, and the electrical installation should be designed accordingly.

Particular consideration should be given to those materials whose behaviour may be anomalous. It is known, for example, that carbon monoxide, with which Group IIA apparatus may be safely used, may be added in considerable quantity to hydrogen without altering the group of the apparatus, namely Group IIC, that has to be used with this latter compound. Carbon monoxide also exhibits unusual behaviour under other test conditions. For example, it has been shown that the addition of moisture to mixtures of carbon monoxide with air to the point of saturation serves to change the apparatus subdivision for this material from Group IIA to Group IIB. This change in apparatus subdivision is also observed if methane is added to carbon monoxide in the proportion 15 % : 85 % by volume.

However, this can impose limitations that may be severe, and further consideration of the relative rates and quantities of the materials used in the process and the degree of control thereof may be required. Some relaxation may then be possible, but expert advice should always be sought in these circumstances.

When the individual components of mixtures and their proportions of the total mixture are precisely known or can be sustained, it is often possible to calculate the resultant flammable limits for the mixture with air. Examples of this are described in Appendix E. However, if the mixture is predominantly carbon monoxide, expert advice should be sought.

38.3 Mists

The characteristics described in this Part of BS 5345 apply to mixtures of gases and vapours only with air. The distinction to be drawn between a gas and a vapour in this context is simply that the latter may be in contact with its liquid phase at normal temperature and pressure, whereas a gas cannot be liquefied under normal atmospheric conditions. In practice, mists consisting of clouds of condensed vapour can also occur. In general, the characteristics described in this standard should be considered applicable to mists, since local ignition sources or hot surfaces generally may serve to restore the condensed material to its vapour phase.

Table 7 — Data for flammable materials for use with electrical equipment

1	2	3	4	5	6	7	8	9	10	11	12	13	14
Flammable material	Formula	Melting point	Boiling point	Relative vapour density	Flash point	Flammable limits				Ignition temperature		T class of suitable apparatus	Apparatus group
						LFL	UFL	LFL	UFL				
		°C	°C		°C	Vol. %	Vol. %	mg/L	mg/L	°C			
acetaldehyde	CH_3CHO	– 123	20	1.52	– 38	4	57	73	1 040	140		T4	IIA
acetic acid	CH_3COOH	17	118	2.07	40	5.4	16	100	430	485		T1	IIA
acetic anhydride	$(CH_3CO)_2O$	– 73	140	3.52	54	2.7	10	—	—	(334)		(T2)	IIA
acetone	$(CH_3)_2CO$	– 95	56	2.0	– 19	2.15	13	60	310	535		T1	IIA
acetonitrile	CH_3CN	– 45	82	1.42	5	—	4.4	16	—	523		T1	IIA
acetyl chloride	CH_3COCl	– 112	51	2.7	4	5.0	—	—	—	390		T2	IIA
acetylene (see clause **37**)	$CH{\equiv}CH$	– 81	– 84[a]	0.9	—	1.5	100	—	—	305		T2	IIC
acrylonitrile	$CH_2{=}CHCN$	– 82	77	1.83	– 5	3	17	65	380	480		T1	IIA
allyl alcohol	$CH_2{=}CHCH_2OH$	—	—	—	21	—	—	—	—	—		[b]	IIA
allyl chloride	$CH_2{=}CHCH_2Cl$	– 135	45	2.64	– 20	3.2	11.2	105	360	485		T1	IIA
allylene	$CH_3C{\equiv}CH$	– 103	– 23	1.38	—	1.7	—	28	—	—		T	IIB
ammonia	NH_3	– 78	– 33	0.59	—	15	28	105	200	630		T1	IIA
amphetamine	$C_6H_5CH_2CH(NH_2)CH_3$	—	200	4.67	< 100	—	—	—	—	—		[b]	IIA
aniline	$C_6H_5NH_2$	– 6	184	3.22	75	1.2	8.3	—	—	617		T1	II(A)
benzaldehyde	C_6H_5CHO	– 26	179	3.66	65	1.4	—	60	—	190		T4	II(A)
benzene	C_6H_6	– 6	80	2.7	– 11	1.2	8	39	270	560		T1	IIA
blast furnace gas	mixture	—	—	—	—	28.0	70.0	—	—	—		[b]	IIA
blue water gas	mixture	—	—	—	—	—	—	—	—	—		T1	IIC
1-bromobutane	$CH_3(CH_2)_2CH_2Br$	– 112	102	4.72	< 21	2.5	—	230	—	265		T3	IIA
bromoethane	C_2H_5Br	– 119	38	3.75	< – 20	6.7	11.3	300	510	510		T1	IIA
buta-1,3-diene	$CH_2{=}CHCH{=}CH_2$	– 109	– 4	1.87	—	2.1	12.5	25	290	430		T2	IIA
butane	C_4H_{10}	– 138	– 1	2.05	– 60	1.5	8.5	37	210	365		T2	IIA
butanone (ethyl methyl ketone)	$C_2H_5COCH_3$	– 86	80	2.48	– 1	1.8	11.5	50	350	505		T1	IIA
butan-1-ol	$CH_3(CH_2)_2CH_2OH$	– 89	118	2.55	29	1.7	9.0	43	350	340		T2	IIA
butyl acetate	$CH_3COOCH_2(CH_2)_2CH_3$	– 77	127	4.01	22	1.4	8	58	360	370		T2	IIA
butyl glycolate (butyl hydroxyacetate)	$HOCH_2COOC_4H_9$	—	356	4.45	61	—	—	—	—	—		[b]	IIB
butyl styrene	$C_6H_5C(CH_2)_3{=}CH_2$	—	—	—	—	—	—	—	—	—		[b]	IIB
butylamine	$C_4H_9NH_2$	– 104	63	2.52	– 9	—	—	—	—	(312)		(T2)	IIA
butyldigol	$CH_3(CH_2)_3OCH_2{-}CH_2OCH_2CH_2OH$	88	231	5.59	78	—	—	—	—	225		T3	IIA
butyraldehyde	$CH_3CH_2CH_2CHO$	– 97	75	2.48	< – 5	1.4	12.5	42	380	230		T3	IIA
but-1-ene	$CH_2{=}CHCH_2CH_3$	– 185	– 6	1.95	—	1.6	10	35	235	385		T2	IIA
but-2-ene[c]	$CH_3CH{=}CHCH_3$	—	4	1.94	—	1.7	9	—	—	(325)		(T2)	IIB
carbon disulphide (see clause **37**)	CS_2	– 112	46	2.64	– 20	1.0	60	30	1 900	102		T5	IIC
carbon monoxide (see **38.2**)	CO	– 205	– 191	0.97	—	12.5	74.2	145	870	605		T1	IIA

Table 7 — Data for flammable materials for use with electrical equipment

1	2	3	4	5	6	7	8	9	10	11	12	13	14
Flammable material	**Formula**	**Melting point**	**Boiling point**	**Relative vapour density**	**Flash point**	**Flammable limits**				**Ignition temperature**		**T class of suitable apparatus**	**Apparatus group**
						LFL	**UFL**	**LFL**	**UFL**				
		°C	°C		°C	Vol. %	Vol. %	mg/L	mg/L	°C			
chlorobenzene	C_6H_5Cl	45	132	3.88	28	1.3	7.1	60	520	637		T1	IIA
1-chlorobutane	$CH_3(CH_2)_2CH_2Cl$	– 123	78	3.2	< 0	1.8	10	65	390	(460)		(T1)	IIA
chloroethane (ethyl chloride)	C_2H_5Cl	– 136	12	2.22	—	3.6	15.4	95	400	510		T1	IIA
2-chloroethanol	CH_2ClCH_2OH	– 70	129	2.78	55	5.0	16	160	540	425		T2	IIA
chloroethylene (vinyl chloride)	CH_2=CHCl	– 154	– 14	2.15	—	3.8	29.3	95	770	470		T1	IIA
chloromethane (methyl chloride)	CH_3Cl	– 98	– 24	1.78	—	10.7	13.4	150	400	625		T1	IIA
chloromethyl methyl ether	CH_3OCH_2Cl	– 103	60	—	—	—	—	—	—	—		[b]	IIA
1-chloropropane (*n*-chloropropane)	C_3H_7Cl	– 123	37	2.7	– 18	2.8	10.7	70	300	(592)		(T1)	IIA
2-chloropropane (*iso*-chloropropane)	$(CH_3)_2CHCl$	—	47	2.7	– 32	2.6	11.1	—	—	520		T1	IIA
α-chlorotoluene (benzyl chloride)	$C_6H_5CH_2Cl$	– 39	179	4.36	60	1.2	—	55	—	585		T1	IIA
1-chloro-2, 3-epoxypropane	OCH_2CHCH_2Cl	– 57	116	3.30	(40)	—	—	—	—	—		[b]	IIA
coal tar naphtha	Mixture	—	—	—	—	—	—	—	—	272		T3	IIA
coke oven gas (see clause **37**)	Mixture	—	—	—	—	—	—	—	—	500		T1	(see clause **37**)
cresol[d]	$CH_3C_6H_4OH$	11	191	3.73	81	1.1	—	45	—	555		T1	IIA
crotonaldehyde	CH_3CH=CHCHO	– 75	102	2.41	13	2.1	15.5	—	—	(230)		(T3)	IIB
cumene (*iso*-propylbenzene)	$C_6H_5CH(CH_3)_2$	– 97	152	4.13	36	0.88	6.5	—	—	420		T2	IIA
cyclobutane	$\underbrace{CH_2(CH_2)_2CH_2}$	– 91	13	1.93	—	1.8	—	42	—	—		[b]	IIA
cycloheptane	$\underbrace{CH_2(CH_2)_5CH_2}$	—	119	3.39	< 21	—	—	—	—	—		[b]	IIA
cyclohexane	$\underbrace{CH_2(CH_2)_4CH_2}$	7	81	2.9	– 18	1.2	7.8	40	290	259		T3	IIA
cyclohexanol	$\underbrace{CH_2(CH_2)_4CHOH}$	24	161	3.45	68	1.2	—	—	—	300		T2	IIA
cyclohexanone	$CH_2(CH_2)_4CO$	– 31	156	3.38	43	1.4	9.4	53	380	419		T2	IIA
cyclohexene	$CH_2(CH_2)_3CH$=CH	– 104	83	2.83	< – 20	1.2	—	—	—	(310)		(T2)	IIA
cyclohexylamine	$CH_2(CH_2)_4CHNH_2$	– 18	134	3.42	32	—	—	—	—	290		T3	IIA

Table 7 — Data for flammable materials for use with electrical equipment

1	2	3	4	5	6	7	8	9	10	11	12	13	14
Flammable material	Formula	Melting point	Boiling point	Relative vapour density	Flash point	Flammable limits				Ignition temperature		T class of suitable apparatus	Apparatus group
						LFL	UFL	LFL	UFL				
		°C	°C		°C	Vol. %	Vol. %	mg/L	mg/L	°C			
cyclopentane	$CH_2(CH_2)_3CH_2$	– 93	47	—	– 37	—	—	—	—	(380)		(T2)	IIA
cyclopropane	$CH_2CH_2CH_2$	– 127	– 33	1.45	—	2.4	10.4	40	185	495		T1	IIA
decahydronaphthalene	$CH_2(CH_2)_3CHCH(CH_2)_3CH_2$	– 43	196	4.76	54	0.7	4.9	40	280	260		T3	IIA
decane	$C_{10}H_{22}$ (approx.)	– 30	173	4.9	96	0.8	5.4	—	—	205		T3	IIA
dibutyl ether	$(C_4H_9)_2O$	– 95	141	4.48	25	1.5	7.6	48	460	185		T4	IIB
dichlorobenzene	$C_6H_4Cl_2$	– 18	179	5.07	66	2.2	9.2	130	750	(640)		(T1)	IIA
1,1-dichloroethane	CH_3CHCl_2	– 98	57	3.42	– 10	5.6	16	225	660	440		T2	IIA
1,2-dichloroethane (ethylene dichloride)	CH_2ClCH_2Cl	– 36	84	3.42	(5)	6.2	15.9	—	—	(413)		(T2)	IIA
1,1-dichloroethylene (vinylidene chloride)	$CH_2=CCl_2$	—	37	3.4	– 18	7.3	16	—	—	(570)		(T1)	IIA
1,2-dichloroethylene (1,2-dichloroethene)	ClCH=CHCl	– 122	33	3.55	– 10	9.7	12.8	220	650	(440)		(T2)	IIA
1,2-dichloropropane	$CH_3CHClCH_2Cl$	< – 80	96	3.9	15	3.4	14.5	160	690	555		T1	IIA
diethyl ether	$(C_2H_5)_2O$	– 116	34	2.55	< – 20	1.7	36	50	1 100	170		T4	IIB
diethyl ketone	$C_2H_5COC_2H_5$	—	—	—	(55)	—	—	—	—	—		[b]	IIA
diethyl oxalate	$(COOC_2H_5)_2$	– 41	180	5.04	76	—	—	—	—	—		[b]	IIA
diethyl sulphate	$(C_2H_5)_2SO_4$	– 25	208	5.31	104	—	—	—	—	—		[b]	IIA
diethylamine	$(C_2H_5)2NH$	– 50	56	2.53	< – 20	1.7	10.1	50	305	(310)		(T2)	IIA
2-diethylaminoethanol	$(C_2H_5)_2NC_2H_4OH$	—	161	4.04	(60)	—	—	—	—	—		[b]	IIA
diethyldichlorosilane	$(C_2H_5)_2SiCl_2$	—	—	—	—	—	—	—	—	—		[b]	IIC
dihexyl ether	$(CH_3(CH_2)_5)_2O$	– 43	227	6.43	75	—	—	—	—	185		T4	IIA
di-isobutylene	$C_2H_5CH(CH_3)CH(CH_3)C_2H_5$	– 106	105	3.87	(2)	—	—	—	—	(305)		(T2)	IIA
di-isopropyl ether	$((CH_3)_2CH)_2O$	– 86	69	3.52	– 28	1.4	21	—	—	(416)		(T2)	IIA
dimethyl ether	$(CH_3)_2O$	– 141	– 25	1.59	—	3.7	27.0	38	520	—		[b]	IIB
dimethylamine	$(CH_3)_2NH$	– 92	7	1.55	—	2.8	14.4	52	270	(400)		(T2)	IIA
dimethylaniline[e]	$C_6H_3(CH_3)_2NH_2$	2	194	4.17	63	1.2	7.0	60	350	370		T2	IIA
dimethylformamide (formdimethylamide)	$HCON(CH_3)_2$	– 61	152	2.51	58	2.2	15.2	—	—	(440)		(T2)	IIA
1,4-dioxane	$OCH_2CH_2OCH_2CH_2$	10	101	3.03	11	1.9	22.5	70	820	379		T2	IIB
1,3-dioxolane	$OCH_2CH_2OCH_2$	– 26	74	2.55	(2)	—	—	—	—	—		[b]	IIB
dipentyl ether	$(C_5H_{11})_2O$	– 69	170	5.45	(57)	—	—	—	—	170		T4	IIA
dipropyl ether	$(C_3H_7)_2O$	122	90	3.53	< 21	—	—	—	—	170		T4	IIB
ditertiary butyl peroxide	$(CH_3)_3COOC(CH_3)_3$	—	—	—	18	—	—	—	—	170		T4	IIB
1,2-epoxypropane (propylene oxide) (methyloxirane)	CH_3CHCH_2O	—	—	—	– 37	—	—	—	—	—		[b]	IIB

Table 7 — Data for flammable materials for use with electrical equipment

1	2	3	4	5	6	7	8	9	10	11	12	13	14
Flammable material	Formula	Melting point	Boiling point	Relative vapour density	Flash point	Flammable limits				Ignition temperature		T class of suitable apparatus	Apparatus group
						LFL	UFL	LFL	UFL				
		°C	°C		°C	Vol. %	Vol. %	mg/L	mg/L	°C			
ethane	CH_3CH_3	– 183	– 87	1.04	—	3.0	15.5	37	195	515		T1	IIA
ethanethiol	C_2H_5SH	– 148	35	2.11	– 20	2.8	18	70	460	295		T3	IIA
ethanol (ethyl alcohol)	C_2H_5OH	– 144	78	1.59	12	3.3	19	67	290	425		T2	IIA
ethanolamine (2-aminoethanol)	$NH_2CH_2CH_2OH$	10	172	2.1	85	—	—	—	—	—		[b]	IIA
2-ethoxyethanol	$C_2H_5OCH_2CH_2OH$	—	135	3.1	95	1.8	15.7	—	—	235		T3	IIB
ethoxyethyl acetate	$CH_3COOCH_2CH_2OC_2H_5$	—	156	4.6	47	—	—	—	—	380		T2	IIA
ethyl acetate	$CH_3COOCH_2CH_3$	– 83	77	3.04	– 4	2.1	11.5	75	420	460		T1	IIA
ethyl acetoacetate	$CH_3COCH_2COOC_2H_5$	—	180	—	(84)	—	—	—	—	295		T3	IIB
ethyl acetylene	$C_2H_5C{\equiv}CH$	—	—	—	—	—	—	—	—	—		[b]	IIB
ethyl acrylate	$CH_2{=}CHCOOC_2H_5$	> – 75	100	3.45	9	1.8	—	74	—	—		[b]	IIB
ethyl benzene	$C_2H_5C_6H_5$	– 95	135	3.66	15	1.0	6.7	44	—	431		T2	IIA
ethyl cyclobutane	$C_2H_5CHCH_2CH_2CH_2$	—	—	2.0	< – 16	1.2	7.7	—	—	210		T3	IIA
ethyl cyclohexane	$C_2H_5CH(CH_2)_4CH_2$	—	131	3.87	14	0.9	6.6	—	—	262		T3	IIA
ethyl cyclopentane	$C_2H_5CH(CH_2)_3CH_2$	—	103	3.4	1	1.1	6.7	—	—	260		T3	IIA
ethyl formate	$HCOOCH_2CH_3$	– 80	54	2.55	< – 20	2.7	16.5	80	500	440		T2	IIA
ethyl methacrylate	$CH_2{=}CCH_3COOC_2H_5$	—	240	3.9	(20)	—	—	—	—	—		[b]	IIA
ethyl methyl ether	$CH_3OC_2H_5$	—	8	2.087	—	2.0	10.1	49	255	190		T4	IIB
ethyldigol	$C_2H_5O(CH_2)_2O(CH_2)_2OH$	—	202	4.62	94	—	—	—	—	—		[b]	IIA
ethylene	$CH_2{=}CH_2$	– 169	– 104	0.97	—	2.7	34	31	390	425		T2	IIB
ethylenediamine (1,2-diaminoethane)	$NH_2CH_2CH_2NH_2$	8	116	2.07	34	—	—	—	—	385		T2	IIA
ethylene oxide (epoxy ethane) (oxirane)	CH_2CH_2O	– 112	11	1.52	—	3.7	100	55	1 820	440		T2	IIB
formaldehyde	HCHO	– 117	– 19	1.03	—	7	73	87	910	424		T2	IIB
formic acid	HCOOH	—	101	1.6	68	—	—	—	—	(520)		(T1)	IIA
2-furaldehyde (furfuraldehyde)	OCH=CHCH=CCHO	—	161	3.3	60	2.1	19.3	—	—	315		T2	IIA
furan	CH=CHCH–CHO	—	—	—	60	—	—	—	—	—		[a]	IIA
heptane	C_7H_{16}	– 91	98	3.46	– 4	1.1	6.7	46	280	215		T3	IIA
heptan-1-ol	$C_7H_{15}OH$	– 34	176	4.03	60	—	—	—	—	—		[b]	IIA
heptan-2-one (amyl methyl ketone)	$CH_3CO(CH_2)_4CH_3$	– 35	151	3.94	(49)	—	—	—	—	—		[b]	IIA
hept-2-ene (2-heptene)	$CH_3(CH_2)_3CH{=}CHCH_3$	—	—	—	< 0	—	—	—	—	—		[b]	IIA

Table 7 — Data for flammable materials for use with electrical equipment

1	2	3	4	5	6	7	8	9	10	11	12	13	14
Flammable material	Formula	Melting point	Boiling point	Relative vapour density	Flash point	Flammable limits				Ignition temperature		T class of suitable apparatus	Apparatus group
						LFL	UFL	LFL	UFL				
		°C	°C		°C	Vol. %	Vol. %	mg/L	mg/L	°C			
hexane	$CH_3(CH_2)_4CH_3$	– 95	69	2.97	– 21	1.2	7.4	42	265	233		T3	IIA
hexan-2-one (butyl methyl ketone)	$CH_3CO(CH_2)_3CH_3$	– 56	28	3.46	23	1.2	8	50	330	(530)		(T1)	IIA
hydrogen cyanide	HCN	—	26	0.90	– 18	5.6	40	—	—	(538)		(T1)	IIB
hydrogen sulphide	H_2S	– 86	– 60	1.19	—	4.3	45.5	60	650	270		T3	IIB
hydrogen (see clause **37**)	H_2	– 259	– 253	0.07	—	4.0	75.6	3.3	64	560		T1	IIC
4-hydroxy-4-methylpentan-2-one	$CH_3COCH_2C(CH_3)_2OH$	– 47	166	4.0	58	1.8	6.9	—	—	680		T1	IIA
isopentane (2-methylbutane)	$(CH_3)_2CHCH_2CH_3$	—	—	—	< – 51	—	—	—	—	—		[b]	IIA
isopropyl nitrate	$(CH_3)_2CHONO_2$	—	105	—	20	2	100	—	—	175		T4	IIB
iso-octane	$(CH_3)_2CHCH_2C(CH_3)_3$	—	—	—	– 12	—	—	—	—	411		T2	IIA
kerosine	Mixture	—	150	—	38	0.7	5	—	—	210		T3	IIA
(*RS*)-*p*-mentha-1,8-diene (dipentene)	$C_{10}H_{16}$	– 75	175	4.66	42	0.7	6.1	—	—	237		[b]	IIA
metaldehyde	$(C_2H_4O)_4$	246[f]	112[a]	6.07	36	—	—	—	—	—		[b]	IIA
methane (firedamp) (see **7.4.1**)	CH_4	– 182	– 161	0.55	—	5	15	—	—	595		T1	I
methane (industrial) (see clause **37**)	CH_4	—	—	—	—	—	—	—	—	—		T1	IIA
methanol	CH_3OH	– 98	65	1.11	11	6.7	36	73	350	455		T1	IIA
2-methoxyethanol	$CH_3OCH_2CH_2OH$	– 86	124	2.63	39	2.5	14	80	630	285		T3	IIB
methyl acetate	CH_3COOCH_3	– 99	57	2.56	– 10	3.1	16	95	500	475		T1	IIA
methyl acetoacetate	$CH_3CO_2CH_2COCH_3$	—	170	4.0	67	—	—	—	—	280		T3	IIA
methyl acetylene	$CH_3C{\equiv}CH$	—	– 23	1.4	—	1.7	—	—	—	—		[b]	IIB
methyl acrylate	$CH_2{=}CHCOOCH_3$	< – 75	80	3.0	– 3	2.8	25	100	895	—		[b]	IIB
methyl cyclobutane	$CH_3CHCH_2CH_2CH_2$	—	—	—	—	—	—	—	—	—		[b]	IIA
methyl cyclohexane	$CH_3CH(CH_2)_4CH_2$	– 127	101	3.38	– 4	1.15	6.7	45	—	260		T3	IIA
methyl cyclohexanol	$C_7H_{13}OH$ (isomer not stated)	– 38	168	3.95	68	—	—	—	—	295		T3	IIA
methyl cyclopentane	$CH_3CH(CH_2)_3CH_2$	—	72	2.9	< – 7	—	—	—	—	—		[b]	IIA
methyl formate	$HCOOCH_3$	– 100	32	2.07	< – 20	5	23	120	570	450		T1	IIA
methyl methacrylate	$CH_2{=}CCH_3COOCH_3$	—	—	—	(10)	—	—	—	—	—		[b]	IIA
2-methyl propan-1-ol (isobutyl alcohol)	$(CH_3)_2CHCH_2OH$	– 108	107	2.55	—	1.7	10.9	—	—	408		(T2)	IIA
methyl styrene	C_9H_{10} (isomer not stated)	—	172	4.1	57	0.7	—	—	—	(495)		(T1)	IIA
methylamine	CH_3NH_2	– 92	– 6	1.07	—	5	20.7	60	270	430		T2	IIA

Table 7 — Data for flammable materials for use with electrical equipment

1	2	3	4	5	6	7	8	9	10	11	12	13	14
Flammable material	**Formula**	**Melting point**	**Boiling point**	**Relative vapour density**	**Flash point**	**Flammable limits**				**Ignition temperature**		**T class of suitable apparatus**	**Apparatus group**
						LFL	**UFL**	**LFL**	**UFL**				
		°C	°C		°C	Vol. %	Vol. %	mg/L	mg/L	°C			
4-methylpentan-2-one (isobutyl methyl ketone)	$(CH_3)_2CHCH_2COCH_3$	– 80	116	3.45	16	1.4	7.5	—	—	(459)		(T1)	IIA
morpholine	$OCH_2CH_2NHCH_2CH_2$	– 3	128	3.0	(40)	—	—	—	—	(310)		(T2)	IIA
naphtha	Mixture	—	35	2.5	– 6	0.9	6	—	—	290		T3	IIA
naphthalene	$C_{10}H_8$	80	218	4.42	77	0.9	5.9	45	320	528		T1	IIA
natural gas	Mixture	—	—	—	—	—	—	—	—	—		T1	IIA
nitrobenzene	$C_6H_5NO_2$	6	211	4.25	88	1.8	—	90	—	480		T1	IIA
nitroethane	$C_2H_5NO_2$	– 90	115	2.58	27	—	—	—	—	410		T2	IIB
nitromethane	CH_3NO_2	– 29	101	2.11	36	—	—	—	—	415		T2	IIA
1-nitropropane	$C_3H_7NO_2$	– 108	131	3.06	49	—	—	—	—	420		T2	IIB
nonane	C_9H_{20}	– 54	151	4.43	30	0.8	5.6	37	300	205		T3	IIA
nonanol[g]	$C_9H_{19}OH$	—	178	4.97	75	0.8	6.1	—	—	—		[b]	IIA
n-hexanol[h]	$C_6H_{13}OH$	– 45	157	3.5	63	1.2	—	—	—	—		[b]	IIA
octaldehyde	$C_7H_{15}CHO$	—	163	4.42	52	—	—	—	—	—		[b]	IIA
octane	$CH_3(CH_2)_6CH_3$	– 56	126	3.93	13	1.0	3.2	—	—	210		T3	IIA
octanol[i]	$C_8H_{17}OH$	– 16	195	4.5	81	—	—	—	—	—		[b]	IIA
paraformaldehyde	poly(CH_2O)	—	25	—	70	—	—	—	—	300		T2	IIB
paraldehyde (2,4,6-trimethyl-1,3,5-trioxane)	$(CH_3CHO)_3$	12	124	4.56	17	1.3	—	70	—	235		T3	IIA
pentane (mixed isomers)	C_5H_{12}	– 130	36	2.48	< – 20	1.4	8.0	41	240	285		T3	IIA
pentane-2,4-dione (acetylacetone)	$CH_3COCH_2COCH_3$	– 23	140	3.5	34	1.7	—	—	—	340		T2	IIA
pentanol (mixed isomers)	$C_5H_{11}OH$	– 78	138	3.04	34	1.2	10.5	44	380	300		T2	IIA
pentylacetate	$CH_3COOC_5H_{11}$	– 78	147	4.48	25	1.0	7.1	60	550	375		T2	IIA
petroleum	Mixture	—	—	—	< – 20	—	—	—	—	—		T3	IIA
phenol	C_6H_5OH	41	182	3.24	75	—	—	—	—	605		T1	IIA
propane	$CH_3CH_2CH_3$	– 188	– 42	1.56	—	2.0	9.5	39	180	470		T1	IIA
propanethiol (propyl mercaptan)	C_3H_7SH	—	—	—	—	—	—	—	—	—		[b]	IIB
propan-1-ol (propyl alcohol)	$CH_3CH_2CH_2OH$	– 126	97	2.07	15	2.15	13.5	50	340	405		T2	IIB
propan-2-ol (isopropyl alcohol)	$(CH_3)_2CHOH$	– 86	83	2.07	12	2.0	12	—	—	425		T2	IIA
propene	$CH_2{=}CHCH_3$	– 185	– 48	1.5	—	2.0	11.7	35	210	(455)		(T1)	IIA
propylacetate	$CH_3COOCH_2CH_2CH_3$	—	—	—	14	—	—	—	—	—		[b]	IIA
propylamine	$CH_3(CH_2)_2NH_2$	– 101	32	2.04	< – 20	2.0	10.4	49	260	(320)		(T2)	IIA
pyridine	Mixture	– 42	115	2.73	17	1.8	12.0	56	350	550		T1	IIA

Table 7 — Data for flammable materials for use with electrical equipment

1	2	3	4	5	6	7	8	9	10	11	12	13	14
Flammable material	Formula	Melting point	Boiling point	Relative vapour density	Flash point	Flammable limits				Ignition temperature		T class of suitable apparatus	Apparatus group
						LFL	UFL	LFL	UFL				
		°C	°C		°C	Vol. %	Vol. %	mg/L	mg/L	°C			
p-cymene	$CH_3C_6H_4CH(CH_3)_2$	– 70	177	4.62	47	0.7	5.6	—	—	435		T2	IIA
styrene	$C_6H_6CH=CH_2$	– 31	145	3.6	30	1.1	8.0	45	350	490		T1	IIA
tetrafluoroethylene	$CF_2=CF_2$	—	—	—	—	—	—	—	—	—		[b]	IIB
tetrahydrofuran	$CH_2(CH_2)_2CH_2O$	– 108	64	2.49	– 17	2.0	11.8	46	360	224		T3	IIB
tetrahydrofurfuryl alcohol	$OCH_2CH_2CH_2CHCH_2OH$	—	178	3.52	70	1.5	9.7	60	410	280		T3	IIB
tetrahydrothiophen	$CH_2(CH_2)_2CH_2S$	—	—	—	—	—	—	—	—	—		[b]	IIA
3a,4,7,7a-tetrahydro-4, 7-methanoindene	$CHCH=CHCH_2CHCHCH=CHCHCH_2$	—	—	—	(32)	—	—	—	—	—		[b]	IIA
thiophene	$CH=CHCH=CHS$	—	84	2.90	– 1	—	—	—	—	—		[b]	IIA
toluene	$C_6H_5CH_3$	– 95	111	3.18	6	1.2	7	46	270	535		T1	IIA
toluidine[j]	$CH_3C_6H_4NH_2$	– 16	200	3.7	85	—	—	—	—	480		T1	IIA
triethylamine	$(C_2H_5)_3N$	– 115	89	3.5	0	1.2	8	50	340	—		—	IIA
α,α,α-trifluorotoluene	$C_6H_5CF_3$	—	102	5.0	12	—	—	—	—	—		[b]	IIA
trimethylamine	$(CH_3)_3N$	– 117	3	2.04	—	2.0	11.6	49	285	(190)		(T4)	IIA
trimethylbenzene	$C_6H_3(CH_3)_3$	– 45	165	4.15	—	—	—	—	—	470		T1	IIA
1,3,5-trioxane	$OCH_2OCH_2OCH_2$	62	115	3.11	(45)	3.6	29	135	1 110	410		T2	IIB
turpentine	Mixture	—	149	—	35	0.8	—	—	—	254		T3	IIA
vinyl acetate	$CH_3COOCH=CH_2$	—	—	—	– 7	—	—	—	—	—		[b]	IIA
xylene (see clause **37**)	$C_6H_4(CH_3)_2$	– 25	144	3.66	30	1.0	6.7	44	335	464		T1	IIA

NOTE The presence of impurities can affect the various properties.
See also clauses **28** to **38** for information and recommendations relating to Table 7.
[a] Sublimation temperature.
[b] T class data not available. Seek expert advice.
[c] Applicable to both *trans* and *cis* forms.
[d] Data relate only to *m*-cresol and *p*-cresol; *o*-cresol is less hazardous.
[e] Data relate to ortho form. *N, N*-dimethylaniline is slightly more hazardous (lower flash point).
[f] In an enclosed vessel.
[g] Data relate to the form *di*-isobutyl carbinol but data for nonan-1-ol are close.
[h] Data relate to hexan-1-ol. Where data are available for other isomers they are similar.
[i] Data relate to octan-1-ol. Data for other isomers give higher flash point.
[j] Data relate to both ortho and para forms.

Section 6. Marking of apparatus

39 General

Internationally, the symbol "Ex" denotes explosion protection. Compliance with one or more CENELEC standard types of protection is denoted by the symbol "EEx" (see BS 5501-1). The symbol should be accompanied by a lower case letter to indicate the type of protection used. The letter code is described in clause **5**.

NOTE Whereas in BS 6941 the type of protection is known as type N, in IEC 79-15 it is designated type "n". See also Table 2 and clause **5**.

The marking requirements for the various types of explosion protected apparatus have changed over the years and individual standards may need to be consulted for specific guidance. However, the marking requirements have been rationalized in the BS 5501 (EN 50014 to EN 50020) series of standards and these general requirements are described in clauses **40** and **41** of this standard.

40 Marking requirements for apparatus

The general marking requirements described in this clause are intended to aid the user in identifying the type of protection and to assist identification of the particular explosion risk for which the apparatus is suitable (see also clause **12**). The marking requirements for BS 5501[11)] apparatus include the following, but for full information, including exceptions, reference should be made to that standard.

a) Identification of the manufacturer. The manufacturer may be identified by name or trademark.[12)]

b) The manufacturer's type designation for the apparatus.

c) The indication of the testing station and the certificate reference.

Apparatus complying with a standard in the EN 50014 to EN 50020 series will be marked with the symbol "EEx" as well as the testing station reference. (Apparatus certified by BASEEFA will also carry the BASEEFA mark comprising the letters "Ex" within a formalized crown.) Additionally, when either a Certificate of Conformity to one of the harmonized standards listed in the EEC Directive 79/196/EEC or an Inspection Certificate has been issued by an approved body recognized by the EEC, the Distinctive Community Mark may also be fixed to apparatus of such types.

NOTE Published EEC "Commission Directives", e.g. 84/47/EEC and 88/571/EEC, list accepted amendments to the listed harmonized standards in EEC Directive 79/196/EEC.

d) Identification of the type of protection (see clause **41**).

e) The apparatus group.

NOTE For further information see clause **41**.

f) The T class or maximum surface temperature. This requirement is described in **7.3**.

g) Any other relevant information.

NOTE Other relevant information will normally include voltage and current ratings, under prescribed conditions where necessary, and such other information as may be necessary for the satisfactory operation of the apparatus.

The marking includes, therefore, not only the manufacturer's name and rating data with which all electrical apparatus should normally be marked, but also sufficient additional information to indicate the suitability of the apparatus for use in particular flammable atmospheres. This is explained in clauses **41** and **42**.

41 Examples of marking of apparatus

41.1 General

The following examples are included to illustrate the application and interpretation of the marking requirements in BS 5501 and BS 6941. They do not represent all the variations of marking that are possible, nor is it intended to include in these examples all the marking requirements that are usually specified. More detailed marking requirements that are relevant to particular types of protection are described in the appropriate Parts of BS 5345 and in the relevant apparatus standards.

41.2 Flameproof enclosure "d"

The marking on apparatus with type of protection "d" will normally include the following details to indicate compliance with BS 5501-5 (identical with European Standard EN 50018):

a) the symbol for the type of protection "d";

b) the apparatus group and subdivision;

c) the temperature classification.

For example:

A marking EEx d IIB T5 indicates that the enclosure complies with Group IIB requirements and that the apparatus has a temperature classification of T5.

[11)] Marking requirements for other standards, i.e. BS 4683 and BASEEFA Standards, are contained in those standards.
[12)] In case of apparatus certified by BASEEFA to standards other than BS 5501 this marking may be supplemented or replaced by identification of the trade agent who may be distinguished from the manufacturer by the letter "A" in a circle adjacent to his name or mark. For certified apparatus the certificate holder will normally be the manufacturer.

A marking EEx d II (NH_3) T2 indicates that the enclosure has been tested with ammonia instead of the representative test gas for Group IIA, i.e. propane. This apparatus may only be safely used with ammonia.

A marking EEx d IIB+H_2 T4 indicates that the enclosure complies with Group IIB requirements and with the requirements for hydrogen which is allocated to apparatus Group IIC. The enclosure will have been tested with hydrogen instead of with both of the BS 5501-5 representative test gases for Group IIC, i.e. acetylene and hydrogen. The apparatus may be used safely with flammable gases allocated to apparatus Groups IIA, IIB and with hydrogen.

41.3 Increased safety apparatus "e"

The marking on apparatus with type of protection "e" will normally include the following to indicate compliance with BS 5501-6 (identical with European Standard EN 50019):

a) the symbol for the type of protection "e";

b) the apparatus group;

c) the temperature classification.

For example:

A marking EEx e II T3 indicates that the apparatus may be used safely with all flammable gases and vapours allocated to apparatus Group II, subject to a temperature classification of T3.

41.4 Intrinsic safety "i"

41.4.1 *Intrinsically-safe apparatus*. Intrinsically-safe apparatus can be category "ia" or "ib" and may be suitable for connection to external circuits subject to certain possible limitations on their characteristics.

The marking on apparatus with type of protection "i" will normally include the following to indicate compliance with BS 5501-7 (identical with European Standard EN 50020):

a) the symbol for the apparatus category which includes that for type of protection "i";

b) the apparatus group and subdivision;

c) the temperature classification.

For example:

A marking EEx ia IIC T5 indicates that the apparatus group is Group IIC and that the apparatus has a temperature classification of T5.

A marking EEx ia II(NH_3) T2 indicates that the apparatus has been tested with ammonia in place of the representative test gas for Group IIA, i.e. propane. The apparatus may only be safely used with ammonia.

Additionally, there may be marking to indicate the limiting characteristics of external circuits, e.g. L_{ext} = 12 μH, C_{ext} = 1 200 pF, U_{max} = 28 V.

The additional marking indicates the limiting values of inductance, capacitance and voltage of the external circuits which may be connected to the apparatus for safe use in the apparatus group and temperature class indicated.

41.4.2 *Associated electrical apparatus*. Associated electrical apparatus installed in a non-hazardous area can be category "ia" or "ib". This limitation in its use is denoted on the marking by enclosing the applicable symbols in square brackets.

The marking on such apparatus includes the following:

a) the symbol for the apparatus category which includes the type of protection "i";

b) the apparatus group and subdivision.

For example:

A marking [EEx ib] IIC indicates compliance with BS 5501-7. There is no requirement to mark an apparatus temperature classification since the apparatus is installed in a non-hazardous area.

Associated electrical apparatus installed in a hazardous area and protected by an additional type of protection complying with BS 5501 would be marked, for example:

EEx d [ib] IIC T6.

41.4.3 *Intrinsically-safe electrical systems "i"*. Certified intrinsically-safe electrical systems "i" that comply with BS 5501-9 will be marked as described in **41.4.1**, and additionally will be marked in a strategic position with the letters SYST.

For intrinsically-safe electrical systems "i" complying with BS 5501-9 that have not been certified, marking that permits positive identification of the system and reference for the relevant system description will normally be applied.

41.5 Type of protection N

There is no BS 5501 series standard for type of protection N. The relevant standard is BS 6941[13)], and the marking on this apparatus will normally include the following to indicate compliance with that standard:

a) the symbol of the type of protection N and the apparatus category;

b) the apparatus group;

c) the temperature classification.

For example:

A marking Ex N II T3 indicates that the apparatus may be used in Zone 2 areas with all flammable gases and vapours allocated to apparatus Group II, subject to a temperature classification of T3.

41.6 Other types of protection

The types of protection that have not been included in the examples in **41.2** to **41.5** will normally be marked in accordance with similar rules.

42 General notes on marking

42.1 General

In **42.2** to **42.4** some of the finer details of marking requirements that have not been indicated in the examples in **41.2** to **41.4** are explained.

42.2 Certificate number

The certificate number may refer to a single design or to a range of apparatus of similar design. The same number may also be used for modifications to the original design.

The certificate number followed by "X" (in the UK previously "B") indicates that special conditions for safe use apply, and therefore particular attention should be paid to certification documents.

The certificate number may also be followed by "/S". This suffix indicates that the apparatus so marked is suitable for installation in a non-hazardous area only, but that it may form part of a certified system.

42.3 Ex component certificates/approval

Component parts or subassemblies forming part of certified apparatus may be the subject of separate component certificates. In the case of components for apparatus certified to the European Standards (EN 50014 to EN 50020) a "component certificate" is given. For other components a "component approval" is given. Components that have either type of certificate will generally be marked in accordance with the rules described in clauses **39** to **41**, with the addition of the letter "U" after the certificate number.

42.4 Multiple types of protection

42.4.1 Increasingly, electrical apparatus for hazardous areas may incorporate more than one type of protection. The examples in **42.4.2** and **42.4.3** serve to illustrate the marking requirements that will normally be applied.

42.4.2 A flameproof apparatus such as a motor may incorporate an increased safety terminal box. In this case, where each type of protection is readily and separately identifiable, each enclosure will normally be marked accordingly.

42.4.3 An apparatus with type of protection "e" (increased safety) overall may incorporate sparking contacts protected by a flameproof enclosure (type of protection "d"). In this case, the types of protection that are used internally cannot be identified by external examination other than by inspection of the marking plate. The external marking will indicate the overall protection, which will determine the installation requirements, and may indicate the additional protective features in a secondary manner.

For example:

A marking EEx e d IIC T3 indicates an increased safety apparatus with internal flameproof enclosure having a T3 temperature classification.

[13] Other than for luminaires or for motors where BS 4533-102.51 and BS 5000-16 respectively are the appropriate standards. The marking requirements of these standards differ in detail however.

Appendix A Relevant International, European and British Standards and details of the national certifying authority and its certification standards[14)]

A.1 Standards produced by CENELEC (European Commission for Electrotechnical Standardization)

EN 50014 to EN 50020, EN 50028 and EN 50039 have been prepared by CENELEC Technical Committee 31. These standards represent technical texts accepted by 17 CENELEC Member National Committees (including the UK), in the three official CENELEC languages, and which carry the strict obligation to be implemented as a national standard, unaltered in presentation or content. This has been done by publishing BS 5501-1 to BS 5501-9, which are identical with EN 50014 to EN 50020, EN 50028 and EN 50039, respectively (see **A.3**).

A.2 Standards produced by IEC (International Electrotechnical Commission)

As part of a continuing process towards international standardization, many countries including the UK participate in the International Electrotechnical Commission (IEC). This organization produces recommendations which are intended to form the basis for the national standards of each participating country. As specifications for each type of protection and ancillary subjects are developed, these are published in a sequential series of standards each of which is a Part of IEC 79 (see **A.3**). The following Parts of IEC 79 have already been published:

IEC 79, *Electrical apparatus for explosive gas atmospheres.*

IEC 79-0, *Part 0: General requirements.*

IEC 79-1, *Part 1: Construction and test of flameproof enclosures of electrical apparatus.*

IEC 79-1A, *First supplement Appendix D: Method of test for ascertainment of maximum experimental safe gap.*

IEC 79-2, *Part 2: Pressurized enclosures.*

IEC 79-3, *Part 3: Spark test apparatus for intrinsically-safe circuits.*

IEC 79-4, *Part 4: Method of test for ignition temperature.*

IEC 79-4A, *First supplement.*

IEC 79-5, *Part 5: Sand-filled apparatus.*

IEC 79-6, *Part 6: Oil-immersed apparatus.*

IEC 79-7, *Part 7: Construction and test of electrical apparatus, type of protection "e".*

IEC 79-8, *Part 8: Classification of maximum surface temperatures.*

IEC 79-9, *Part 9: Marking.*

IEC 79-10, *Part 10: Classification of hazardous areas.*

IEC 79-11, *Part 11: Construction and test of intrinsically-safe and associated apparatus.*

IEC 79-12, *Part 12: Classification of mixtures of gases or vapours with air according to their maximum experimental safe gaps and minimum igniting currents.*

IEC 79-13, *Part 13: Construction and use of rooms or buildings protected by pressurization.*

IEC 79-14, *Part 14: Electrical installations in explosive gas atmosphere (other than mines).*

IEC 79-15, *Part 15: Electrical apparatus with type of protection "n".*

The following IEC standards cover related topics:

IEC 34, *Rotating electrical machines — Part 5: Classification of degrees of protection provided by enclosures for rotating machines* (= BS 4999-20).

IEC 144, *Degrees of protection of enclosures for low-voltage switchgear and controlgear* (≡ BS 5420).

IEC 529, *Classification of degrees of protection provided by enclosures* (≡ BS 5490).

A.3 Relevant British Standards

British Standards relevant to the use of electrical apparatus in hazardous areas are as follows:

BS 31, *Specification. Steel conduit and fittings for electrical wiring.*

BS 229, *Specification. Flameproof enclosure of electrical apparatus*[15)].

BS 731, *Flexible steel conduit for cable protection and flexible steel tubing to enclose flexible drives — Part 1: Flexible steel conduit and adaptors for the protection of electric cable.*

BS 889, *Specification for flameproof electric lighting fittings.*

BS 1259, *Intrinsically safe electrical apparatus and circuits for use in explosive atmospheres*[16)].

[14)] The information contained in this appendix was correct at the time of printing the standard but because of various subsequent updates etc. of the standards referred to it is recommended that the reader check for up-to-date references.
[15)] Obsolescent: though superseded by BS 4683-2, this specification remains valid for the manufacture of existing certified equipment for use in established installations. It is intended that BS 229 will eventually be withdrawn.
[16)] Obsolescent.

BS 2538, *Specification for air-cooled flameproof single-phase lighting transformer units supplied from high voltage systems.*

BS 3573, *Specification for polyethylene-insulated copper-conductor telecommunication distribution cables.*

BS 4121, *Specification for mechanical cable glands for rubber and plastics insulated cables*[17].

BS 4137, *Guide to the selection of electrical equipment for use in division 2 areas*[18].

BS 4533, *Luminaires — Part 102: Particular requirements — Section 102.51: Specification for luminaires with type of protection N.*

BS 4568, *Specification for steel conduit and fittings with metric threads of ISO form for electrical installations*

— Part 1: Steel conduit, bends and couplers;

— Part 2: Specification for fittings components.

BS 4683, *Specification for electrical apparatus for explosive atmospheres*[19]

— Part 1: Classification of maximum surface temperatures (≠ IEC 79-8);

— Part 2: The construction and testing of flameproof enclosures of electrical apparatus (= IEC 79-1);

— Part 3: Type of protection N[20]*;*

— Part 4: Type of protection "e" (≠ IEC 79-7)[18].

BS 4999, *General requirements for rotating electrical machines — Part 105: Classification of degrees of protection provided by enclosures for rotating machinery* (≡ EN 60034-5).

BS 5000, *Specification for rotating electrical machines of particular types or for particular applications*

— Part 16: Motors with type of protection N;

— Part 17: Machines with flameproof enclosure.

BS 5308, *Instrumentation cables*

— Part 1: Specification for polyethylene insulated cables;

— Part 2: Specification for PVC insulated cables.

BS 5420, *Specification for degrees of protection of enclosures of switchgear and controlgear for voltages up to and including 1 000 V a.c. and 1 200 V d.c.* (≡ IEC 144).

BS 5490, *Specification for classification of degrees of protection provided by enclosures* (≡ IEC 529).

BS 5501, *Electrical apparatus for potentially explosive atmospheres*

— Part 1: General requirements (≡ EN 50014);

— Part 2: Oil immersion "o" (≡ EN 50015);

— Part 3: Pressurized apparatus "p" (≡ EN 50016);

— Part 4: Powder filling "q" (≡ EN 50017);

— Part 5: Flameproof enclosure "d" (≡ EN 50018);

— Part 6: Increased safety "e" (≡ EN 50019);

— Part 7: Intrinsic safety "i" (≡ EN 50020);

— Part 8: Encapsulation "m" (≡ EN 50028);

— Part 9: Specification for intrinsically safe electrical systems "i" (≡ EN 50039).

BS 5958, *Code of practice for control of undesirable static electricity.*

BS 6004, *Specification for PVC-insulated cables (non-armoured) for electric power and lighting.*

BS 6053, *Specification for outside diameters of conduits for electrical installations and threads for conduits and fittings* (= IEC 423).

BS 6081, *Specification for terminations for mineral insulated cables.*

BS 6099, *Conduits for electrical installations — Part 1: Specification for general requirements* (≡ IEC 614-1).

BS 6121, *Specification for mechanical cable glands for elastomer and plastics insulated cables.*

BS 6207, *Specification for mineral-insulated cables* (≠ IEC 702-1).

BS 6346, *Specification for PVC-insulated cables for electricity supply.*

BS 6351, *Electric surface heating*

— Part 1: Specification for electric surface heating devices (≠ IEC 800);

— Part 2: Guide to the design of electric surface heating systems (≠ IEC 800).

BS 6480, *Specification for impregnated paper-insulated cables for electricity supply — Part 1: Lead or lead alloy sheathed cables for working voltages up to and including 33 kV* (≠ IEC 55).

BS 6500, *Specification for insulated flexible cords and cables* (≠ IEC 227, IEC 245).

BS 6651, *Code of practice for the protection of structures against lightning.*

BS 6656, *Guide to prevention of inadvertent ignition of flammable atmospheres by radio-frequency radiation.*

[17] Withdrawn.
[18] Obsolescent.
[19] No further Parts of BS 4683 will be published but the existing Parts will remain valid until further notice.
[20] Superseded by BS 6941.

BS 6724, *Specification for armoured cables for electricity supply having thermosetting insulation with low emission of smoke and corrosive gases when affected by fire.*

BS 6941, *Specification for electrical apparatus for explosive atmospheres with type of protection N* (≠ IEC 79-15).

CP 1003, *Electrical apparatus and associated equipment for use in explosive atmospheres of gas or vapour other than mining applications*[21)]

— *Part 1: Choice, installation and maintenance of flameproof and intrinsically-safe apparatus;*

— *Part 2: Methods of meeting the explosion hazard other than by the use of flameproof or intrinsically-safe electrical equipment;*

— *Part 3: Division 2 areas.*

CP 1013, *Earthing.*

CP 1021, *Code of practice for cathodic protection.*

A.4 Approved bodies in the UK for the certification of electrical apparatus for use in hazardous areas

In the UK, the following bodies are approved in accordance with the EEC Directive (Article 14 of 76/117/EEC) for the certification of electrical apparatus for use in hazardous areas.

Health and Safety Executive
BASEEFA
Harpur Hill
Buxton
Derbyshire
SK17 9JN

SIRA Certification Service
Saighton Lane
Saighton
Chester
CH3 6EG

When conformity with the EEC Directive is not required, but third party certification of product conformity with the relevant British Standard is required, the user of this British Standard is advised to contact, through BSI, the Association of Certification Bodies.

BASEEFA has issued certificates to BASEEFA standards when there was no acceptable published British Standard. The BASEEFA certification standards that are currently available or being prepared are as follows:

SFA 3002, *Petrol metering pumps.*

SFA 3004, *Shunt diode safety barriers.*

SFA 3006, *Battery operated vehicles.*

SFA 3007, *Instruments for measuring gas concentration.*

SFA 3009, *Special protection.*

SFA 3012, *Intrinsic safety.*

Appendix B Frictional sparking risks with light metals and their alloys[22)]

B.1 The risk of ignition due to frictional sparking, which though present with ferrous and certain other metals is sufficiently improbable to be discounted, may be sufficiently severe when certain light metals and their alloys are involved that special consideration has to be given to their use, particularly in the more hazardous areas. It is generally recognized that the recommendations in **B.2** to **B.7** should be noted. (See also BS 5501-1.)

B.2 It has been clearly established that incendive frictional sparking can occur in circumstances where certain light metals or their alloys are brought into frictional contact resulting from impact with other materials, particularly when the other material is an oxygen carrier such as rust. Suitable safeguards have therefore to be taken to prevent the occurrence of such frictional contact in circumstances where a flammable atmosphere may be present, as the simultaneous occurrence of the two sets of circumstances could lead to ignition.

B.3 As with other ignition risks, the first safeguard is to avoid the occurrence of flammable atmospheres and to site the apparatus whenever practicable in locations where such atmospheres are not likely to occur.

B.4 For rigidly mounted electrical apparatus with light metal enclosures and aluminium armoured or sheathed cable sited in Zone 2 areas, the frictional sparking risk may be disregarded except in those particular circumstances where heavy impact might also initiate the release of flammable material. This applies also in Zone 1 areas, unless the impact risk is high, when the use of light metal enclosures or aluminium protected cables should be avoided unless they are provided with a robust protective covering. Such apparatus and cables should not be used in Zone 0 areas.

[21)] Obsolescent.

[22)] The term "light metal" refers to such materials as aluminium, magnesium and titanium which are characterized by their ability when finely divided to react exothermically with atmospheric oxygen and, as a result, to ignite a flammable atmosphere. The term "light alloy" refers to an alloy containing at least 50 % of a light metal by atomic proportions.
It should be noted that BS 5501-1 requires that alloys used in the construction of enclosures of electrical apparatus of Group II do not contain more than 6 % of magnesium by weight.

B.5 Portable and transportable apparatus with light metal or light alloy enclosures that are otherwise unprotected against frictional contact should not be taken into hazardous areas unless special precautions are taken to ensure safety. Such precautions may include a special permit to work in the assured absence of a flammable atmosphere, though more satisfactory safeguards may be taken by, for example, coating the apparatus with an abrasion resistant material. When such coatings are used they should be subject to regular and careful inspection. The continued use of the apparatus should not be permitted if inspection reveals that the protective material has become damaged to the extent that the underlying protected metal is visible, until such damage has been satisfactorily repaired.

These precautions should be adopted even for apparatus intended for use in Zone 2 areas only, since it may be difficult in practice to prevent the transfer of unprotected portable apparatus to an area of greater risk.

B.6 Provided that the protective cowls for light metal fans on motors (fanhoods) are designed so that they are not readily deformed, such fans may be used in Zone 1 and Zone 2 areas since other modes of failure, e.g. bearing failure, are more likely to create a source of ignition. If plastics fans or cowls are used as alternatives, they should be of anti-static material.

B.7 Until further information is available, the use of aluminium conductors in Ex "d" flameproof enclosures should be avoided in those cases where a fault leading to potentially severe arcing involving the conductors may occur in the vicinity of a plain flanged joint. Adequate protection may be afforded by suitable conductor and terminal insulation to prevent the occurrence of faults or by using enclosures with spigot or threaded joints.

Appendix C Degrees of protection by enclosures

C.1 Protection code

A coded classification has been developed to indicate the degree of protection afforded by an enclosure to the internal electrical apparatus against the entry of liquids and solid materials. Though developed initially for types of apparatus limited to switchgear and controlgear, the classification has been applied to a wider range of apparatus so that eventually all electrical apparatus for use in hazardous areas may be marked to indicate the degree of protection provided by enclosure.

The classification and the requirements to be met are recognized internationally and are described in detail in BS 5420 and BS 5490. A slightly amended version of this classification which is applicable to rotating electrical machines is described in BS 4999-105. The latter specification is identical to EN 60034-5, which is based on IEC 34-5 with modifications.

NOTE A significant difference between BS 5420 and BS 5490 is that the latter requires, in certain tests for dust ingress, the pressure inside the equipment to be maintained below atmospheric pressure.

The classification provides for degrees of protection for:

a) protection of persons against contact with or approach to live parts and against contact with moving parts inside the enclosure, and protection of apparatus against ingress of solid foreign bodies;

b) protection of apparatus against ingress of water;

c) protection of apparatus against mechanical damage (under consideration).

It should be emphasized that this classification is supplementary to and not an alternative to the types of protection that are necessary to ensure protection in explosive gas-air mixtures. The classification is particularly important for apparatus with type of protection "e" (see Part 6 of this standard).

C.2 Enclosure designation

The designation used to indicate the degrees of protection consists of the letters "IP" followed by two "characteristic numerals" indicating conformity with the degree of protection described.

The first characteristic numeral (see Table 8) designates the degree of protection of persons against contact with or approach to live parts and against contact with moving parts inside the enclosure and of apparatus against ingress of solid foreign bodies.

NOTE A single characteristic numeral is used to designate these two means of protection since they are compatible in effect.

The second characteristic numeral (see Table 9) designates the degree of protection provided by the enclosure against harmful ingress of water.

In addition, BS 5490 recognizes the use of the letter X to replace an omitted numeral where only one characteristic is required, e.g. IPX5 or IP2X. BS 5490 also gives a list of standard letters S, M and W which qualify the conditions associated with the degree of protection.

Table 8 — Protection against contact and ingress of foreign bodies

First characteristic numeral	Degree of protection
0	No protection of persons against contact with live or moving parts inside the enclosure. No protection of equipment against ingress of solid foreign bodies.
1	Protection against accidental or inadvertent contact with live or moving parts inside the enclosure by a large surface of the human body, e.g. a hand, but not protection against deliberate access to such parts. Protection against ingress of large solid foreign bodies exceeding approximately 50 mm diameter.
2	Protection against contact with live or moving parts inside the enclosure by fingers not exceeding 80 mm in length. Protection against ingress of medium size solid foreign bodies exceeding approximately 12 mm diameter.
3	Protection against contact with live or moving parts inside the enclosure by tools, wires or such objects of thickness greater than 2.5 mm. Protection against ingress of small solid foreign bodies exceeding 2.5 mm diameter.
4	Protection against contact with live or moving parts inside the enclosure by tools, wires or such objects of thickness greater than 1 mm. Protection against ingress of small solid foreign bodies exceeding 1 mm diameter.
5	Complete protection against contact with live or moving parts inside the enclosure. Protection against harmful deposits of dust. The ingress of dust is not totally prevented, but dust cannot enter in an amount sufficient to interfere with satisfactory operation of the equipment enclosed.
6	Complete protection against contact with live or moving parts inside the enclosure. No observable ingress of dust[a].

[a] When subjected to the test for characteristic numeral 5.

Table 9 — Protection against ingress of water

Second characteristic numeral	Degree of protection
0	No protection.
1	Protection against drops of water. Drops of water falling vertically on the enclosure have no harmful effect.
2	Protection against drops of water. Drops of falling water have no harmful effect when the enclosure is tilted at any angle up to 15° from its normal position.
3	Protection against rain or spraying water. Water falling at an angle equal to or smaller than 60° with respect to the vertical has no harmful effect.
4	Protection against splashing. Water splashed from any direction has no harmful effect.
5	Protection against water jets. Water projected by a nozzle from any direction under stated conditions has no harmful effect.
6	Protection against conditions on ships' decks (deck watertight equipment). Water from heavy seas or water projected in powerful jets does not enter the enclosures under prescribed conditions.
7	Protection against immersion in water. It is not possible for water to enter the enclosure under stated conditions of pressure and time.
8	Protection against indefinite immersion in water under specified pressure. It is not possible for water to enter the enclosure.

C.3 Protection of equipment against mechanical damage

The protection of equipment against mechanical damage is not covered in BS 5490 and is shown as "under consideration" in BS 5420.

C.4 Degrees of protection

Table 10 gives the most frequently used degrees of protection[23)] in accordance with the descriptions given in **C.2**. The characteristic letters and numerals should normally be marked on the enclosure.

C.5 Particular requirements for rotating electrical machines

For rotating machines complying with the requirements of BS 4999-105, the code for the degree of enclosure protection departs from that described in **C.1** to **C.4** for apparatus generally in the following details.

a) The IP enclosure classification may be followed by a letter indicating whether the protection against harmful ingress by water (or liquid) was tested with the machinery stationary (letter S) or in operation (letter M).

The absence of the letter S or M indicates that the protection was assessed with the machine both running and stationary.

b) When all parts of a machine do not have the same degree of protection, the designation of the lowest degree should be shown first, followed, if applicable, by the other designation with reference to the part to which it applies.

c) Total protection against the ingress of solid foreign bodies (category 6, Table 8) is not provided for.

C.6 Test conditions

For details of the test conditions necessary for establishing the degree of protection of an enclosure, and particularly for the conditions appropriate to rotating electrical machines, the appropriate specification should be consulted.

[23)] Given only in BS 5420.

Table 10 — Most frequently used degrees of protection

Characteristic letters	First characteristic numeral (protection against contact and ingress of foreign bodies)	Second characteristic numeral (protection against ingress of liquid)								
		0	1	2	3	4	5	6	7	8
IP	0	IP00	—	—	—	—	—	—	—	—
	1	IP10	IP11	IP12	—	—	—	—	—	—
	2	IP20	IP21	IP22	IP23	—	—	—	—	—
	3	IP30	IP31	IP32	IP33	IP34	—	—	—	—
	4	IP40	IP41	IP42	IP43	IP44	—	—	—	—
	5	IP50	—	—	—	IP54	IP55	—	—	—
	6	IP60	—	—	—	—	IP65	IP66	IP67	IP68

Appendix D Bibliography of data sources for Table 7

Further data on the properties of flammable materials may be found in the following references, some of which were used in the compilation of Table 7.

Fire Protection Association (London). *Fire and related properties of industrial chemicals*, reprinted 1974.

National Fire Protection Association (Boston, Mass.). *Fire protection guide on hazardous materials*, seventh edition, 1978.

Hilado, C.J. and Clark, S.W. "Auto-ignition temperatures of organic chemicals", *Chemical Engineering*, September 4 1972, 75.

Publications of the Engineering Sciences Data Unit (UK). (A list of properties is in preparation.)

Whessoe Technical Computing Services. CHEMSTOR, Chemical and Hazard Enquiry Service.

Mullins, B.P. *Spontaneous ignition of liquid fuels*, AGARD 1955.

Lunn, G.A. and Phillips, H. "A summary of experimental data on the maximum experimental safe gap", *SMRE Report T2*, 1973.

Nabert, K. and Schon, G. "Safety characteristics of combustible gases and vapours", *Deutsche Eichverlag*, 1963 (revised 1980).

Toxic and Hazardous Industrial Chemicals Safety Manual, 1975/76 (Japan).

Coward, H.F. and Jones, G.W. "Limits of flammability of gases and vapors", *US Bureau of Mines Bulletin* 503, 1952.

Zabetakis, M.G. "Flammability characteristics of combustible gases and vapors", *US Bureau of Mines Bulletin* 627, 1965.

Appendix E Calculation of the flammable limits for a mixture of gases

NOTE 1 This appendix is primarily intended for use with BS 5345-2.

NOTE 2 The accuracy of the equation shown below has been tested carefully for many mixtures. Whilst the equation is often correct, or very nearly so, there are some marked exceptions. It seems that the limits (lower and upper) of mixtures of hydrogen, carbon monoxide and methane, taken two at a time or all together, and of water gas and coal gas may be calculated with approximate accuracy. The same is true for mixtures of the simpler paraffin hydrocarbons including natural gas. Sometimes, however, the differences between calculated and observed values are very large. Le Chatelier's law is useful when its applicability has been proved, but it should not be applied indiscriminately.

E.1 Limits for simple gas mixtures

E.1.1 *General*

Frequently, explosion risks arise from mixtures of flammable materials with air. Though only the most general of rules can be indicated for ensuring the safe use of electrical apparatus with mixtures of gases, it is often desirable to be able to establish with some degree of confidence the flammable limits for such mixtures in order that local explosion risks can be avoided. A method that may be used to calculate the flammable limits for most mixtures of flammable gases is described in **E.1.2**. Though this method achieves a satisfactory degree of accuracy for most applications, it is always advisable to exercise caution where the expected total concentration of combustible gas is near to the calculated value for the appropriate flammable limit. Particular care should also be taken in circumstances where catalytic effects between individual components of a mixture are suspected. General purpose calculations cannot take such effects into account.

E.1.2 *Method of calculation*

The method of calculation is based on a simple relationship due to Le Chatelier connecting the lower flammable limits for any two gases in air with the lower limit for any mixture of them. The relationship is expressed by the following equation:

$$\frac{n_1}{N_1} + \frac{n_2}{N_2} = 1 \qquad (1)$$

where

N_1 and N_2 are the lower flammable limits in air for each combustible gas separately (in %);

n_1 and n_2 are the percentages of each gas present in any mixture of them that is itself a lower limit mixture.

The equation indicates, for example, that a mixture of air, carbon monoxide and hydrogen that contains one-quarter of the amount of carbon monoxide and three-quarters of the amount of hydrogen necessary to form lower limit mixtures with air independently, i.e. one-quarter of 12.5 % approximately and three-quarters of 4 % respectively, will itself be a lower limit mixture.

The equation may be generalized to apply to any number of gases. Thus

$$\frac{n_1}{N_1} + \frac{n_2}{N_2} + \frac{n_3}{N_3} + \ldots = 1 \qquad (2)$$

The equation may be applied also to upper limit mixtures with suitable redefinition of the terms n_1 etc. and N_1 etc.

The equation may be rendered more useful as follows.

NOTE It is assumed that the terms used are consistent, i.e. they are all lower limit mixtures or they are all upper limit mixtures.

Let p_1, p_2, p_3 etc. represent the proportions of each combustible gas present, ignoring air and inert gases, so that

$$p_1 + p_2 + p_3 + \ldots = 100 \qquad (3)$$

and let L represent the flammable limit (upper or lower, as appropriate) so that

$$L = n_1 + n_2 + n_3 + \ldots \qquad (4)$$

Since $n_1/L = p_1/100$, then, substituting in equation (2)

$$L/100\ (p_1/N_1 + p_2/N_2 + p_3/N_3 \ldots) = 1 \qquad (5)$$

and therefore

$$L = \frac{100}{\frac{p_1}{N_1} + \frac{p_2}{N_2} + \frac{p_3}{N_3} + \ldots} \qquad (6)$$

E.1.3 *Example*

As an example of the use of this equation, consider the determination of the lower limit for a gas mixture representative of natural gas.

The natural gas might comprise:

methane	in the proportion of 80 % (p_1) (lower limit 5.32 %)
ethane	in the proportion of 15 % (p_2) (lower limit 3.22 %)
propane	in the proportion of 4 % (p_3) (lower limit 2.37 %)
butane	in the proportion of 1 % (p_4) (lower limit 1.85 %)

The lower flammable limit of this mixture with air would be

$$L = \frac{100}{\frac{80}{5.32} + \frac{15}{3.22} + \frac{4}{2.37} + \frac{1}{1.85}} = 4.55\ \% \qquad (7)$$

E.2 Limits for complex industrial gas mixtures

E.2.1 *Method of calculation*

A flammable gas mixture encountered in many industrial processes comprises hydrogen, carbon monoxide, methane, nitrogen, carbon dioxide and oxygen. The procedure to be used for calculating the flammable limits for mixtures of these gases is as follows.

a) The composition of the mixture is first recalculated on an air-free basis. The amount of each gas is expressed, therefore, as a percentage of the total air-free mixture.

b) A somewhat arbitrary dissection of the air-free mixture obtained from step a) is made into simpler mixtures, each of which contains one flammable gas only and part or all of the nitrogen and carbon dioxide.

c) The appropriate limits for each of the mixtures obtained from step b) are obtained from available data (see Figure 1 and Figure 2, which give available data for the flammable limits of hydrogen, carbon monoxide, methane, ethane, ethylene and benzene with various amounts of carbon dioxide and nitrogen as inert diluent components).

d) The limits of the air-free mixture are then calculated from the data for the dissected mixtures obtained in step c) using equation (6), where p_1, p_2, p_3 etc. are the proportions of the dissected mixtures, in percentages, and N_1, N_2, N_3 etc. are their respective limits.

e) From the limits of the air-free complex mixture thus obtained, the limits of the original complex mixture, which included air, can be deduced.

E.2.2 ***Example***

The following is an example of the step-by-step calculation outlined in **E.2.1**.

Table 11 — Components of the industrial gas mixture

Constituent components of industrial gas mixture	Composition	Composition calculated on air-free basis
	%	%
Carbon dioxide	13.8	15.9
Oxygen	2.8	0.0
Carbon monoxide	4.3	5.0
Methane	3.3	3.8
Hydrogen	4.9	5.7
Nitrogen	70.9	69.6

a) The constituent components of the gas mixture are indicated in Table 11. The composition of the air-free mixture, indicated in column 3 of Table 11, may be calculated as follows.

The amount of air in the mixture is 2.8 × 100/20.9 or 13.4 %. The air-free mixture is therefore 86.6 % of the whole. When the original proportions of carbon dioxide, carbon monoxide, methane and hydrogen are divided by 86.6 and multiplied by 100, the air-free percentages are obtained. The nitrogen percentage is the difference between 100 and the sum of these percentages.

b) The flammable gases are paired with the inert gases to form separate mixtures, as shown in Table 12.

c) The flammable limits for the separate or dissected mixtures, taken from Figure 1, are indicated in columns 7 and 8 of Table 12.

d) The values for the flammable limits of these simpler mixtures and the percentages of the air-free mixture that each of these simpler mixtures represents (see column 5 of Table 12) permit calculation of the flammable limits for the complex air-free mixture.

Thus, the lower flammable limit (LFL) (in %) is given by the following equation:

$$\text{LFL} = \frac{100}{\frac{22.5}{61} + \frac{24.7}{36} + \frac{34.2}{50} + \frac{18.6}{32}} = 43\ \% \qquad (8)$$

The upper flammable limit (UFL) (in %) is given by the following equation:

$$\text{UFL} = \frac{100}{\frac{22.5}{73} + \frac{24.7}{41.5} + \frac{34.2}{76} + \frac{18.6}{64}} = 61\ \% \qquad (9)$$

e) As the air-free mixture is 86.6 % of the complete sample mixture, the flammable limits in air for the sample mixture are 43 × 100/86.6 and 61 × 100/86.6, or 50 % and 70 % respectively. Thus, the original sample will be flammable within the limits of 50 % and 70 % in air.

E.2.3 ***Further information***

Further notes on the limitations of these calculations and the precautions that should be taken with such calculations are available (see Coward, H.F. and Jones, G.W. "Limits of flammability of gases and vapors", *US Bureau of Mines Bulletin* 503, 1952).

Table 12 — Flammable limits of simpler mixtures

1	2	3	4	5	6	7	8
Flammable material	Amount of flammable material	Carbon dioxide	Nitrogen	Total	Ratio of inert to flammable gas	Flammable limits from Figure 1	
						Lower	Higher
	%	%	%	%		%	%
Carbon monoxide	5.0	—	17.5	22.5	3.5	61.0	73.0
Methane	3.8	—	20.9	24.7	5.5	36.0	41.5
Hydrogen	5.7 { 3.0	—	31.2	34.2	10.4	50.0	76.0
	5.7 { 2.7	15.9	—	18.6	5.9	32.0	64.0
Total	14.5	15.9	69.6	100.0	—	—	—

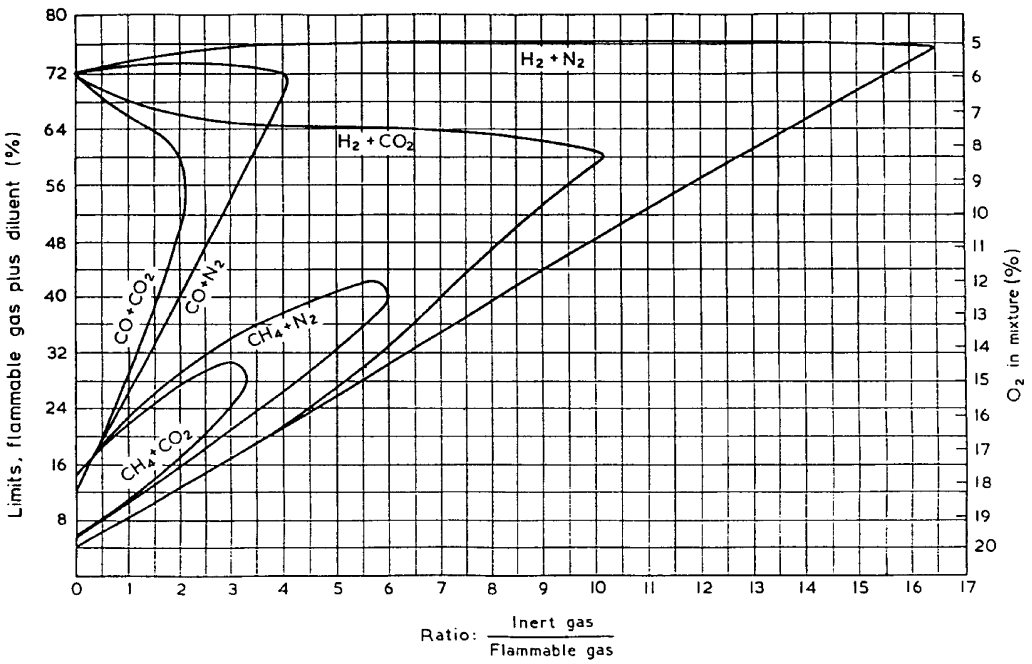

Figure 1 — Flammable limits of hydrogen, carbon monoxide and methane containing various amounts of carbon dioxide and nitrogen

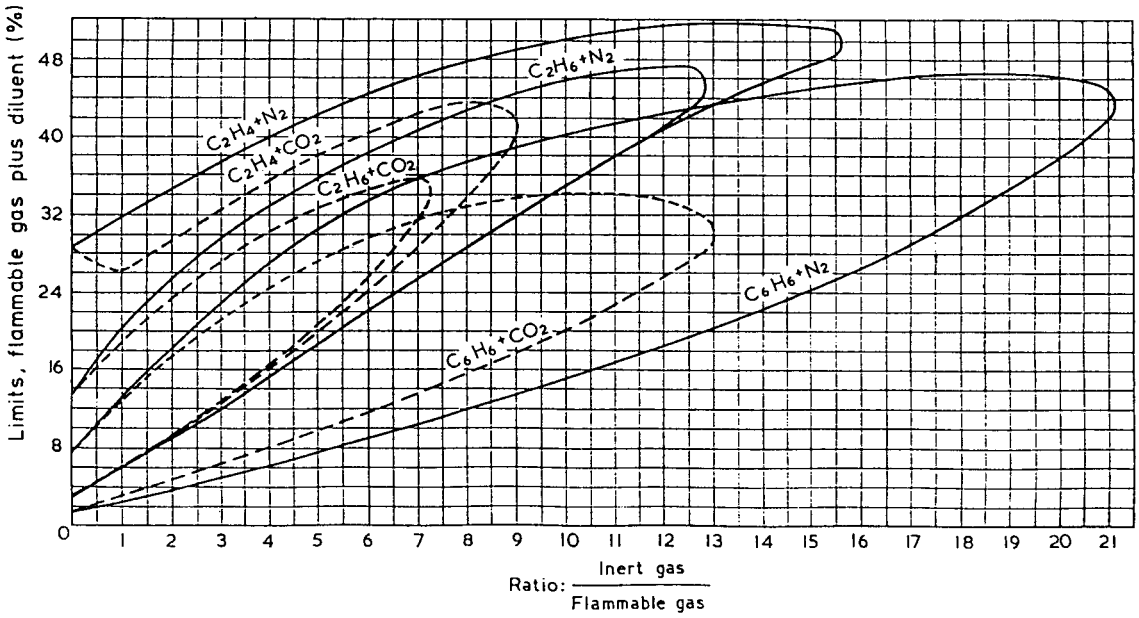

Figure 2 — Flammable limits of ethane, ethylene and benzene containing various amounts of carbon dioxide and nitrogen

Publications referred to

BS 31, *Specification. Steel conduit and fittings for electrical wiring.*

BS 229, *Specification. Flameproof enclosure of electrical apparatus*[24)].

BS 476, *Fire tests on building materials and structures.*

BS 476-4, *Non-combustibility test for materials.*

BS 731, *Flexible steel conduit for cable protection and flexible steel tubing to enclose flexible drives.*

BS 731-1, *Flexible steel conduit and adaptors for the protection of electric cable.*

BS 889, *Specification for flameproof electric lighting fittings.*

BS 1259, *Intrinsically safe electrical apparatus and circuits for use in explosive atmospheres*[10)].

BS 2914, *Specification for surge diverters for alternating current power circuits.*

BS 4533, *Luminaires.*

BS 4533-102, *Particular requirements.*

BS 4533-102.51, *Specification for luminaires with type of protection N.*

BS 4568, *Specification for steel conduit and fittings with metric threads of ISO form for electrical installations.*

BS 4568-1, *Steel conduit, bends and couplers.*

BS 4568-2, *Fittings components.*

BS 4683, *Specification for electrical apparatus for explosive atmospheres.*

BS 4683-1, *Classification of maximum surface temperatures.*

BS 4683-2, *The construction and testing of flameproof enclosures of electrical apparatus.*

BS 4683-4, *Type of protection "e"*[10)].

BS 4999, *General requirements for rotating electrical machines.*

BS 4999-105, *Classification of degrees of protection provided by enclosures for rotating machinery.*

BS 5000, *Specification for rotating electrical machines of particular types or for particular applications.*

BS 5000-16, *Rotating electrical machines with type of protection N.*

BS 5000-17, *Machines with flameproof enclosure.*

BS 5308, *Instrumentation cables.*

BS 5308-1, *Specification for polyethylene insulated cables.*

BS 5308-2, *Specification for PVC insulated cables.*

BS 5345, *Code of practice for selection, installation and maintenance of electrical apparatus for use in potentially explosive atmospheres (other than mining applications or explosives processing and manufacture).*

BS 5345-2, *Classification of hazardous areas.*

BS 5345-3, *Installation and maintenance requirements for electrical apparatus with type of protection "d". Flameproof enclosure.*

BS 5345-4, *Installation and maintenance requirements for electrical apparatus with type of protection "i". Intrinsically safe electrical apparatus and systems.*

BS 5345-5, *Installation and maintenance requirements for electrical apparatus protected by pressurization "p" and by continuous dilution, and for pressurized rooms.*

BS 5345-6, *Installation and maintenance requirements for electrical apparatus with type of protection "e". Increased safety.*

BS 5345-7, *Installation and maintenance requirements for electrical apparatus with type of protection N.*

BS 5345-8, *Installation and maintenance requirements for electrical apparatus with type of protection "s". Special protection.*

BS 5345-9, *Installation and maintenance requirements for electrical apparatus with type of protection "o". Oil-immersed apparatus, and with type of protection "q". Sand-filled apparatus*[25)].

[24)] Obsolescent
[25)] In preparation.

BS 5420, *Specification for degrees of protection of enclosures of switchgear and controlgear for voltages up to and including 1 000 V a.c. and 1 200 V d.c.*

BS 5490, *Specification for classification of degrees of protection provided by enclosures.*

BS 5501, *Electrical apparatus for potentially explosive atmospheres.*

BS 5501-1, *General requirements.*

BS 5501-2, *Oil immersion "o".*

BS 5501-3, *Pressurized apparatus "p".*

BS 5501-4, *Powder filling "q".*

BS 5501-5, *Flameproof enclosure "d".*

BS 5501-6, *Increased safety "e".*

BS 5501-7, *Intrinsic safety "i".*

BS 5501-8, *Encapsulation "m".*

BS 5501-9, *Specification for intrinsically safe electrical systems "i".*

BS 5958, *Code of practice for the control of undesirable static electricity.*

BS 6004, *Specification for PVC-insulated cables (non-armoured) for electrical power and lighting.*

BS 6053, *Specification for outside diameters of conduits for electrical installations and threads for conduits and fittings.*

BS 6081, *Specification for terminations for mineral insulated cables.*

BS 6121, *Specification for mechanical cable glands for elastomer and plastics insulated cables.*

BS 6207, *Specification for mineral-insulated cables.*

BS 6346, *Specification for PVC-insulated cables for electricity supply.*

BS 6351, *Electric surface heating.*

BS 6351-1, *Specification for electric surface heating devices.*

BS 6351-2, *Guide to the design of electric surface heating systems.*

BS 6467, *Electrical apparatus with protection by enclosure for use in the presence of combustible dusts.*

BS 6467-1, *Specification for apparatus.*

BS 6467-2, *Guide to selection, installation and maintenance.*

BS 6480, *Specification for impregnated paper-insulated cables for electricity supply.*

BS 6480-1, *Lead or lead alloy sheathed cables for working voltages up to and including 33 kV.*

BS 6500, *Specification for insulated flexible cords and cables.*

BS 6651, *Code of practice for the protection of structures against lightning.*

BS 6656, *Guide to prevention of inadvertent ignition of flammable atmospheres by radio-frequency radiation.*

BS 6724, *Specification for armoured cables for electricity supply having thermosetting insulation with low emission of smoke and corrosive gases when affected by fire.*

BS 6941, *Specification for electrical apparatus for explosive atmospheres with type of protection N.*

CP 1003, *Electrical apparatus and associated equipment for use in explosive atmospheres of gas or vapour other than mining applications.*

CP 1013, *Earthing.*

CP 1021, *Cathodic protection.*

IEC 79, *Electrical apparatus for explosive gas atmospheres.*

IEC 79-4, *Method of test for ignition temperature.*

IEC 79-4A, *First supplement.*

NOTE See also the bibliographies in Appendix A and Appendix D.

BSI — British Standards Institution

BSI is the independent national body responsible for preparing British Standards. It presents the UK view on standards in Europe and at the international level. It is incorporated by Royal Charter.

Revisions

British Standards are updated by amendment or revision. Users of British Standards should make sure that they possess the latest amendments or editions.

It is the constant aim of BSI to improve the quality of our products and services. We would be grateful if anyone finding an inaccuracy or ambiguity while using this British Standard would inform the Secretary of the technical committee responsible, the identity of which can be found on the inside front cover. Tel: 020 8996 9000. Fax: 020 8996 7400.

BSI offers members an individual updating service called PLUS which ensures that subscribers automatically receive the latest editions of standards.

Buying standards

Orders for all BSI, international and foreign standards publications should be addressed to Customer Services. Tel: 020 8996 9001. Fax: 020 8996 7001.

In response to orders for international standards, it is BSI policy to supply the BSI implementation of those that have been published as British Standards, unless otherwise requested.

Information on standards

BSI provides a wide range of information on national, European and international standards through its Library and its Technical Help to Exporters Service. Various BSI electronic information services are also available which give details on all its products and services. Contact the Information Centre. Tel: 020 8996 7111. Fax: 020 8996 7048.

Subscribing members of BSI are kept up to date with standards developments and receive substantial discounts on the purchase price of standards. For details of these and other benefits contact Membership Administration. Tel: 020 8996 7002. Fax: 020 8996 7001.

Copyright

BSI
389 Chiswick High Road
London
W4 4AL