



Selection & Erection

GUIDANCE NOTE



IEE Wiring Regulations

BS 7671 : 2001 Requirements for Electrical Installations
Including Amd No 1 : 2002

Reprinted with new cover

Published by: The Institution of Electrical Engineers, Savoy Place,
LONDON, United Kingdom WC2R 0BL.

©2002: The Institution of Electrical Engineers, London

Issued August 1992
Reprinted April 1993, with amendments
2nd edition incorporating Amendment No 1 to BS 7671 – 1996
3rd edition incorporating Amendment No 2 to BS 7671 – 1999
4th edition incorporating Amendment No 1 to BS 7671 – 2001
Reprinted October 2003, new cover only

Copies may be obtained from:

The IEE
PO Box 96, STEVENAGE,
United Kingdom. SG1 2SD

Tel: +44 (0)1438 767 328
Fax: +44 (0)1438 742 792
Email: sales@iee.org
<http://www.iee.org/publish/books/WireAssoc/>

All rights reserved. No part of this publication may be reproduced, stored in a retrieval system or transmitted in any form or by any means — electronic, mechanical, photocopying, recording or otherwise — without the prior written permission of the publisher.

While the author, publisher and contributors believe that the information and guidance given in this work is correct, all parties must rely upon their own skill and judgement when making use of it. Neither the author, the publisher nor any contributor assume any liability to anyone for any loss or damage caused by any error or omission in the work, whether such error or omission is the result of negligence or any other cause. Where reference is made to legislation it is not to be considered as legal advice. Any and all such liability is disclaimed.

ISBN 0 85296 989 9, 2002

Contents

ACKNOWLEDGEMENTS	7
PREFACE	10
INTRODUCTION	11
SECTION 1 THE GENERAL REQUIREMENTS	13
1.1 General	13
1.2 Equipment	13
1.3 Electricity at Work Regulations 1989	14
1.4 The Construction (Design and Management) Regulations 1994	14
1.5 The Building Regulations 2000	15
1.6 Competence	17
SECTION 2 SELECTION AND ERECTION OF EQUIPMENT	19
2.1 Selection and erection of equipment	19
2.2 Operational conditions and external influences	19
2.3 Compliance with standards	19
2.4 Operational conditions and external influences	21
2.5 Identification	22
2.6 Mutual detrimental influence	30
2.7 Compatibility	30
2.8 'Clean' (low noise) earths	32
2.9 LV switchgear and controlgear assemblies	33
SECTION 3 PROTECTION AGAINST OVERCURRENT, ELECTRIC SHOCK AND OVERVOLTAGE	40
3.1 Protective devices	40
3.2 Overcurrent protective devices	41
3.3 Fuses	43
3.4 Circuit-breakers	44
3.5 Insulation monitoring devices	47
3.6 Residual current operated devices (RCDs)	48
3.7 Earthed equipotential bonding and automatic disconnection of supply	59
3.8 Protection against overvoltage	67

SECTION 4	EXTERNAL INFLUENCES	71
4.1	External influences	71
4.2	Ambient temperature (AA)	72
4.3	Solar radiation (AN) and ultra-violet radiation	73
4.4	The IP and IK classifications	74
4.5	Presence of water (AD) or high humidity (AB)	74
4.6	Presence of solid foreign bodies (AE)	75
4.7	Presence of corrosive or polluting substances (AF)	76
4.8	Impact (AG), vibration (AH) and other mechanical stresses (AJ)	78
4.9	Presence of fauna (AL), flora and/or mould growth (AK)	79
4.10	Potentially explosive atmospheres	80
4.11	Choice of protective measures as a function of external influences	80
SECTION 5	INSTALLATION OF CABLES	84
5.1	Cable selection	84
5.2	Cable concealed in structures	88
5.3	Cable routes and livestock	91
5.4	Capacity of conduit and trunking	92
5.5	Selection of cables and wiring systems with low emission of smoke and corrosive gases when affected by fire	92
5.6	'Section 20'	94
5.7	Buried cables	96
5.8	Sealing and fire stopping	99
SECTION 6	SIZING OF CABLES	101
6.1	Current-carrying capacity and voltage drop	101
6.2	Diversity	101
6.3	Neutral conductors	102
6.4	Voltage drop in consumers' installations	104
SECTION 7	OTHER INFLUENCES	106
7.1	Electrical connections	106
7.2	Cables in contact with thermal insulation	108
7.3	Mutual or individual deterioration	111
7.4	Proximity to other services	112
7.5	Plasticiser migration from pvc insulation to the conductor surface	114
SECTION 8	INSTALLATION OF EQUIPMENT	116
8.1	Equipment having a high protective conductor current	116
8.2	Water heating	117
8.3	Safety services	118
8.4	Other equipment	118
8.5	Luminaires	120
8.6	Selection and erection in relation to operation and maintainability	122

APPENDICES	125
APPENDIX A: CABLE CAPACITIES OF CONDUIT AND TRUNKING	126
a) General	126
b) Single-core thermoplastic (pvc) insulated cables in straight runs of conduit not exceeding 3 m in length	128
c) Single-core thermoplastic (pvc) insulated cables; in straight runs of conduit exceeding 3 m in length or in runs of any length incorporating bends or sets	128
d) Single-core thermoplastic (pvc) insulated cables in trunking	129
e) For other sizes and types of cable in conduit or trunking, including flexible conduit	131
f) Background to the tables	133
APPENDIX B: DEGREES OF PROTECTION PROVIDED BY ENCLOSURES	135
IP code for ingress protection	135
IK code for impact protection	141
APPENDIX C: CONVENTIONAL CIRCUIT ARRANGEMENTS AND THE PROVISION OF SOCKET-OUTLETS	143
a) General	143
b) Final circuits using socket-outlets complying with BS 1363 and fused connection units	144
c) Final radial circuits using 16 A socket-outlets complying with BS 4343 (BS EN 60309-2)	148
d) Cooker final circuits in household premises	148
e) Water heating and electric shower final circuits in household premises	149
f) Provision of socket-outlets	149
g) Mounting heights of accessories	152
APPENDIX D: LIMITATION OF EARTH FAULT LOOP IMPEDANCE FOR COMPLIANCE WITH REGULATION 543-01-01	155
APPENDIX E: RESISTANCE AND IMPEDANCE OF COPPER AND ALUMINIUM CONDUCTORS UNDER FAULT CONDITIONS	176
APPENDIX F: SELECTION AND ERECTION OF WIRING SYSTEMS	184
APPENDIX G: NOTES ON METHODS OF SUPPORT FOR CABLES, CONDUCTORS AND WIRING SYSTEMS	191
APPENDIX H: MAXIMUM DEMAND AND DIVERSITY	199
APPENDIX I: MINIMUM SEPARATING DISTANCES BETWEEN ELECTRICITY SUPPLY CABLES AND TELECOMMUNICATIONS OR CONTROL CABLES	204
APPENDIX J: PERMITTED PROTECTIVE CONDUCTOR CURRENTS	208
APPENDIX K: STANDARD SYMBOLS, UNITS AND GRAPHICAL SYMBOLS FOR GENERAL ELECTRICAL PURPOSES	209
APPENDIX L: ADDRESSES OF ASSOCIATED BODIES AND IDENTIFICATION SYMBOLS	217
INDEX	225

Co-operating Organisations

The Institution of Electrical Engineers acknowledges the contribution made by the following organisations in the preparation of this Guidance Note.

Association of Manufacturers of Domestic Appliances
S A MacConnacher BSc CEng MIEE

British Cables Association
C K Reed I Eng MIEE

British Electrotechnical & Allied Manufacturers Association Ltd
R Lewington Associate IEE

British Electrotechnical Approvals Board
P D Stokes MA CEng MRAeS

British Standards Institution
W E Fancourt

City & Guilds of London Institute
H R Lovegrove IEng FIIE

Electrical Contractors' Association
D Locke IEng MIEE ACIBSE

Electrical Contractors' Association of Scotland t/a SELECT
D Millar IEng MIEE MILE

Electrical Installation Equipment Manufacturers' Association Ltd
Eur Ing M H Mullins BA CEng MIEE FIIE

Electricity Association Limited
D J Start BSc CEng MIEE

ERA Technology Ltd
M W Coates B Eng

Federation of the Electronics Industry
F W Pearson CEng MIEE

The GAMBICA Association Ltd
K A Morriss BSc CEng MIEE MInstMC

Health & Safety Executive
Eur Ing J A McLean BSc(Hons) CEng FIEE FIOSH

Institution of Electrical Engineers
W R Allan BEng(Hons) CEng MIEE (Editor)
P R L Cook CEng FIEE MCIBSE
P E Donnachie BSc CEng FIEE
B J Lewis BSc Mphil CEng FIEE
L Markwell BSc CEng MIEE MCIBSE LCGI

Institution of Incorporated Engineers
P Tootill IEng MIEE

Lighting Association
K R Kearney IEng MIEE

National House Building Council
P Crane

National Inspection Council for Electrical Installation Contracting

Safety Assessment Federation Limited
J Gorman BSc(Hons) CEng MIEE

Society of Electrical and Mechanical Engineers serving Local Government
C Tanswell CEng MIEE MCIBSE

Acknowledgements

References to British Standards, CENELEC Harmonisation Documents and International Electrotechnical Committee standards are made with the kind permission of BSI. Complete copies can be obtained by post from:

BSI Customer Services
389 Chiswick High Road
London W4 4AL

Tel:	General Switchboard:	020 8996 9000
	For ordering:	020 8996 7000
	For information or advice:	020 8996 7111
	For membership:	020 8996 7002
Fax:	For orders:	020 8996 7001
	For information or advice:	020 8996 7048

BSI operates an export advisory service — Technical Help to Exporters — which can advise on the requirements of foreign laws and standards. The BSI also maintains stocks of international and foreign standards, with many English translations.

Up-to-date information on BSI standards can be obtained from the BSI website <http://www.bsi-global.com/>

RCD terminology and information provided by the Low Voltage Circuit Breaker Division of EIEMA and is taken from the EIEMA Code of Practice for the Selection and Application of Residual Current Devices currently being prepared for publication.

Illustrations and information of the forms of separation of LV switchgear were provided by The Low Voltage Distribution Switchboard Division of EIEMA.

The EIEMA booklet 'Guide to forms of separation' can be obtained from:

EIEMA
Westminster Tower
3 Albert Embankment
London SE1 7SL.

Tel: 020 7793 3013

Extracts from NHBC Standards, Chapter 8.1, for internal services, on the requirement for notches and holes in joists are reproduced with permission from The National House Building Council (NHBC), Buildmark House, Chiltern Avenue, Amersham, Bucks, HP6 5AP.

Extracts from the LDSA document 'Fire safety guide No 1' on Section 20 buildings are reproduced with permission from The London District Surveyors Association, PO Box 266, London, BR2 9ZN.

Guidance on cable separation in Appendix I was reproduced from The Electrical Contractors Association document 'Recommended cable separations to achieve electromagnetic compatibility (EMC) in buildings' with the permission of the ECA, ESCA House, 34 Palace Court, London, W2 4HY.

The table on colour identification of buried services is reproduced with the permission of The National Joint Utilities Group, 30 Millbank, London, SW1P 4RD.

The tables on cable references in Appendix F were reproduced with permission of Anixter (UK) Ltd, 15 Chesford Grange, Woolston, Warrington, Cheshire, WA1 4RQ.

Copies of Health and Safety Executive documents and approved codes of practice (ACOP) can be obtained from:

HSE Books
P O Box 1999
Sudbury
Suffolk CO10 6FS

Tel: 01787 881165
Fax: 01787 313995

Health and Safety Executive telephone enquiries can be made to:

HSE Info Line on : 08701 545500

Fax and postal enquiries can be made to:

HSE Information Centre

Broad Lane

Sheffield S3 7HQ

Tel: 01142 892345.

Preface

This Guidance Note is part of a series issued by the Wiring Regulations Policy Committee of the Institution of Electrical Engineers to enlarge upon and simplify some of the requirements in BS 7671 : 2001 inc Amd No 1 (formerly the Sixteenth Edition of the IEE Wiring Regulations).

Note that this Guidance Note does not ensure compliance with BS 7671. It is a guide to some of the requirements of BS 7671 but electricians should always consult BS 7671 to satisfy themselves of compliance.

The scope generally follows that of the Regulations and the principal Section numbers are shown on the left. The relevant Regulations and Appendices are noted in the right-hand margin. Some Guidance Notes also contain material not included in BS 7671 but which was included in earlier editions. All of the Guidance Notes contain references to other relevant sources of information.

Electrical installations in the United Kingdom which comply with BS 7671 are likely to satisfy the relevant aspects of Statutory Regulations such as the Electricity at Work Regulations 1989, but this cannot be guaranteed. It is stressed that it is essential to establish which Statutory and other Regulations apply and to install accordingly. For example, an installation in premises subject to licensing may have requirements different from, or additional to, BS 7671, and those requirements will take precedence.

Introduction

This Guidance Note is concerned principally with Part 5 of BS 7671 — Selection and Erection of Equipment.

Neither BS 7671 nor the Guidance Notes are design guides. It is essential to prepare a full design and specification prior to commencement or alteration of an electrical installation. Compliance with the relevant standards should be required.

The design and specification should set out the requirements and provide sufficient information to enable competent persons to carry out the installation and to commission it. A good specification must include a description of how the system is to operate and all the design and operational parameters. It must provide for all the commissioning procedures that will be required and for the provision of adequate information to the user. This will be by means of an operational manual or schedule, and ‘as fitted’ drawings if necessary.

514-09

It must be noted that it is a matter of contract as to which person or organisation is responsible for the production of the parts of the design, specification installation and any operational information. The persons or organisations who may be concerned in the preparation of the works include:

- The Designer
- The Planning Supervisor
- The Installer (or Contractor)
- The Supplier of Electricity
- The installation Owner (Client) and/or User
- The Architect
- The Fire Prevention Officer
- Any Regulatory Authority
- Any Licensing Authority
- The Health and Safety Executive

In producing the design and specification advice should be sought from the installation owner and/or user as to the intended use. Often, as in a speculative building, the intended use is unknown. In such cases the specification and/or the operational manual must set out the basis of use for which the installation is suitable.

131-01-01

Precise details of each item of equipment specified should be obtained from the manufacturer and/or supplier and compliance with appropriate standards confirmed.

132-01-01
511

The operational manual must include a description of how the system as installed is to operate and all commissioning records. The manual should also include manufacturers' technical data for all items of electrical equipment, wiring, switchgear, accessories, etc. and any special instructions that may be needed. The Health and Safety at Work etc. Act 1974 (HSWA) Section 6, and the Construction (Design and Management) Regulations (CDM) are concerned with the provision of information. Guidance on the preparation of technical manuals is given in BS 4884 and BS 4940. The size and complexity of the installation will dictate the nature and extent of the manual.

Section 1 — The General Requirements

1.1 General		
132	'Equipment' is short for 'electrical equipment' and is defined as:	Part 2
510		
511	'Any item for such purposes as generation, conversion, transmission, distribution or utilisation of electrical energy, such as machines, transformers, apparatus, measuring instruments, protective devices, wiring systems, accessories, appliances and luminaires.'	
	Installation designers may need information from the manufacturer as to the suitability of equipment for its intended use. It is not the intention of BS 7671 : 2001 to stifle innovation or new techniques but the Standard only recognises and considers established materials and techniques.	120-02-01 132-01-01 132-01-02 511-01-01 511-01-02
1.2 Equipment		
120	The designer is responsible for the safety of the design. All departures from BS 7671, although the designer is confident regarding safety, must be recorded in the Electrical Installation Certificate.	
130		
131		
132		
133	Chapter 13 of BS 7671 : 'Fundamental principles' outlines basic requirements. Later Chapters describe in more detail particular means of compliance with Chapter 13. Chapter 13 is normally referred to only where it is intended to adopt a method not recognised in later Chapters. The terms allow for interpretation to suit special cases.	Chap 13
510		
511	The phrase 'so far as is reasonably practicable' is used in several Regulations. It should be borne in mind that methods described in later Chapters are considered reasonably practicable in most circumstances.	Chap 13
	Where methods are used which are not described in later Chapters, then the designer has an onus to confirm that the degree of safety is not less than that required by Chapter 13.	

1.3 Electricity at Work Regulations 1989

The requirements of the Electricity at Work Regulations (1989) are intended to provide for the safety of persons gaining access to or working with electrical equipment.

The Memorandum of Guidance on the Electricity at Work Regulations (1989) (Health and Safety Executive Publication HSR25) should be carefully studied and it should be borne in mind that the Electricity at Work Regulations (1989) (the EAW Regulations) apply to designers, installers and users of installations alike.

BS 7671 is intended for designers, installers and those verifying electrical installations and thus includes the design of the installation and the selection and erection of electrical equipment. The user has the responsibility for ensuring that equipment is properly operated and maintained when necessary. The installation designer should assess the expected maintenance and the initial design should make provision for maintenance to be carried out.

131-12-01
341-01-01

Within the EAW Regulations is the requirement for adequate maintenance to prevent danger, and the memorandum to the EAW Regulations advises that regular inspection of electrical systems (supplemented by testing as necessary) is an essential part of any preventive maintenance programme. Regular operational functional testing of safety circuits (emergency switching/stopping etc) may be required — because unlike functional circuits they may be infrequently used. Comprehensive records of all inspections and tests should be made, retained and reviewed for any trends that may arise. The IEE Guidance Note 3 on Inspection and Testing gives guidance on initial and periodic inspection and testing of installations.

1.4 The Construction (Design and Management) Regulations 1994

The Construction (Design and Management) Regulations 1994 (the CDM Regulations) made under the Health and Safety at Work Act 1974 place responsibilities on most installation owners and their professional design teams to ensure a continuous consideration of health and safety requirements during the design, construction, and throughout the life of an installation, including maintenance, repair and demolition. This includes design of the electrical installation, and selection and erection of electrical

equipment for health and safety in installation and general operation. Design work should take into account the practicalities of installation and adequate installation and operation access and maintenance requirements for all equipment. It is important that all those who can contribute to the health and safety of a construction project, particularly clients (the installation users) and designers, understand what they and others need to do under the CDM Regulations, and discharge their responsibilities accordingly.

Designers must consider the need to design in a way which avoids foreseeable risks to health and safety or reduces these risks as far as practicable so that projects they design can be constructed, operated and maintained safely. Where risks cannot altogether be avoided, information on them has to be provided for inclusion in the project health and safety plan. The designer must also co-operate with others to enable all parties to comply with relevant statutory requirements and prohibitions placed on them.

1.5 The Building Regulations 2000

A series of Approved Documents have been published for the purpose of providing practical guidance to the requirements of the Building Regulations 2000.

Approved Documents of particular interest to designers and installers of electrical installations are

- Approved Document L1 – Conservation of fuel and power in dwellings,
- Approved Document L2 – Conservation of fuel and power in buildings other than dwellings
- Approved Document M - Access and facilities for disabled people.

Approved Document L1 contains a requirement that reasonable provision must be made for occupiers to obtain the benefits of efficient lighting.

Approved Document M includes requirements for the mounting heights of accessories, and these are referred to in Appendix C of this Guidance Note.

Internal lighting

One way of demonstrating compliance with Approved Document L1 would be to install, at a reasonable number of locations, where lighting can be expected to have most use, fixed lighting (either lampholders

or complete luminaires) which only take lamps having a luminous efficacy greater than 40 lumens per circuit watt. Examples of lamps which achieve this efficacy are fluorescent lamps and compact fluorescent lamps. A way of ascertaining the number of locations which require energy efficient lighting would be to follow the recommendations in Table 1.1 below.

Table 1.1 Method for determining the number of locations to be equipped as a reasonable provision for efficient lighting

Number of rooms created ¹	Recommended minimum number of locations ²
1 – 3	1
4 – 6	2
7 – 9	3
10 – 12	4

Notes

¹ Hall, stairs and landing(s) count as one room (but may contain more than one fitting)

² Excludes garages, lofts and outhouses

Reproduced by kind permission of the DTLR

External lighting

External lighting includes lighting in porches but does not include lighting in garages and carports. Reasonable provision must be made to enable effective control (for example, a system which will switch the light off when there is sufficient daylight and when not required at night) and/or the use of efficient lamps (such as a system which can only be used with lamps having an efficacy greater than 40 lumens per watt).

Approved Document L2 contains requirements for general lighting efficacy in offices, industrial and storage buildings. Lighting systems in such buildings must be provided with reasonably efficient lamp/luminaire combinations. A way of complying with the requirements would be to provide lighting with an initial efficacy, averaged over the whole building, of not less than 40 luminaire – lumens per circuit watt. Approved Document L also includes requirements for display lighting.

For further information, the Approved Document should be consulted.

It is currently envisaged that an electrical safety requirement applying to 'dwellings' (ie. houses and flats) will be included in the Building Regulations for England and Wales as Approved Document P - Electrical safety. This is expected to state that a way of meeting the requirements for electrical installations is to comply with the requirements of BS 7671 : 2001.

The Building Regulations (Scotland)

The Building Regulations 2000 are not applicable in Scotland, where the Building Regulations (Scotland) apply. The detailed requirements are given in the Technical Standards for compliance with the Building Standards (Scotland) Regulations.

These standards also contain requirements for conservation of fuel and power but have no requirement for mounting heights of accessories.

With regard to electrical installations in Scotland, the requirements of the above Building Regulations are deemed to be satisfied by complying with BS 7671.

1.6 Competence

BS 7671 requires that an assessment be made of the external influences to which the installation is exposed. Amongst these, as indicated in Appendix 5 of BS 7671, is Category BA —classification of the capability of persons. This recognises different levels, from an ordinary person to a skilled person. It must be remembered that a skilled person will not be skilled in all facets of electrical work and consequently will not be competent in all works.

300-01-01
Appx 5

A competent person has sufficient knowledge and experience to carry out the work without danger to him/herself or to other people.

Persons performing electrical work must have sufficient technical knowledge or experience or be adequately supervised such that danger or injury are prevented. The object is that persons dealing with electrical equipment are not placed at risk due to a lack of skills on their own part, or on the part of others. Technical knowledge or experience may include basic knowledge of electricity, experience of electrical work, understanding of the system to be worked on, understanding of the hazards and the

731-01-03
741-01-04

necessary precautions and the ability to recognise at all times whether it is safe for work to continue. Competence also includes a knowledge of safety and safe working practice, and practical skills were needed.

A person possessing technical knowledge or sufficient experience to enable him/her to avoid danger is recognised by BS 7671 as a 'skilled person' and a person adequately advised or supervised by one or more skilled persons to enable him/her to avoid the dangers that electricity may create is an 'instructed person'.

To require, or allow, a person who is not competent to undertake electrical work may be a breach of the statutory Health and Safety legislation, including the Electricity at Work Regulations 1989.

Part 2

EWR
Regulation 16

Section 2 — Selection and Erection of Equipment

2.1 Selection and erection of equipment 510	Chapter 51 gives the basic common rules to which every installation must comply.	510-01-01
2.2 Operational conditions and external influences 512	<p>An assessment by the designer of installation characteristics and conditions will be necessary, including all the requirements of Part 3 of BS 7671 : 2001. The installation must be designed to be suitable for all the relevant conditions and external influences foreseen, including electricity supply effects or effects on the supply.</p> <p>Appendix 5 of BS 7671 details the system of classification of external influences developed in IEC 60364-3, and the classification is indicated in parts of Chapter 52. This system is not in general use in the UK but certain parts can serve as a reminder of conditions to be considered.</p> <p>All equipment must be selected to accommodate the worst foreseeable conditions of service that can be encountered even if such conditions happen rarely.</p>	Part 3 512 510-01-01 331-01-01 Chap 32 Chap 52 Appx 5
2.3 Compliance with standards 511	<p>BS 7671 recognises equipment which complies with a British Standard or Harmonised Standard appropriate to the intended use of the equipment without further qualification. A Harmonised Standard is defined in Part 2 as 'A standard which has been drawn up by common agreement between national standards bodies notified to the European Commission by all member states and published under national procedures'.</p> <p>There is a statutory definition of a Harmonised Standard in Health and Safety Statutory Instrument</p>	511-01-01 Part 2

No 1856 (1992) 'The Supply of Machinery (Safety) Regulations 1992'. This states:

'Harmonised standard' means a technical specification adopted by the European Committee for Standardisation (CEN) or the European Committee for Electrotechnical Standardisation (CENELEC) or both, upon a mandate from the Commission in accordance with Council Directive 83/189/EEC of 28 March 1983 laying down a procedure for the provision of information in the field of technical standards and regulations, and of which the reference number is published in the Official Journal of the European Communities.

EUROPEAN NORMS (ENs)

European Norm EN standards are standards that are required to be adopted by all CENELEC members and to be published with identical text by all members, without any additions, deletions or further technical amendments. Such EN standards then supersede the relevant national standards which are withdrawn to an agreed timescale. They are published as BS ENs in the UK.

HARMONISATION DOCUMENTS (HDs)

Harmonisation Documents (HDs) forming the CENELEC 384 standard are documents based on IEC 60364. Harmonised Standards are standards that have been agreed by all CENELEC members (possibly with national modifications); a National Standard may have further technical additions (so long as they are not in conflict with the HD — but not deletions — made by the relevant national standards committee. BS 7671 is based on a number of CENELEC HDs within the 384 series (see the Preface of BS 7671 on page 7) with extra specific technical material added.

Equipment is sometimes satisfactory only when used in a particular way or with other matching equipment. Certain equipment complying with a foreign standard may be safe when used, for example, with a foreign wiring system, but may not be safe when used in conjunction with traditional UK practice. Where equipment complying with a foreign standard based on an IEC standard is specified, the designer or specifier must verify that the equipment is at least as safe as similar equipment complying with

511-01-01

511-01-02

the relevant British or Harmonised Standard. It is the designer's responsibility to ensure that equipment the designer specifies which is not to a British or Harmonised Standard provides the required performance and degree of protection.

Note that BS 7671 does not insist on approval or certification of the equipment to the relevant Standard, but this may be required in some cases by legislation or by the client.

2.4 Operational conditions and external influences 512

Equipment of all types must be suitable for its situation and use.

Regulation 331-01-01 lists some examples of characteristics which may adversely affect the equipment to be installed or the electricity supply or other services. This list is not exhaustive but shows some details of what the designer should consider. Equipment must operate safely and should be efficient and correctly selected .

331-01-01

The assessment of general characteristics requires a thorough consideration of the purpose of the installation, the building and installation structure and the electricity supply characteristics including voltage, current and frequency, which must be noted during the first part of the design. If, for example, there is doubt that a switch or circuit-breaker can be used with inductive or capacitive circuits (e.g. motors, transformers or fluorescent lighting) advice should be obtained from the manufacturer.

300-01-01
512-01-01
512-02-01
512-03-01

MOTORS

Electric motors may have similar power ratings but different applications. Motors for lifts, industrial plant and machinery, propulsion or ventilation will have differing duty cycles, and will usually be the subject of a Standard. The fixed wiring must be able to match the duty cycles of the connected load. Infrequently used motor-driven equipment with brakes will have different demands on the fixed wiring when compared with, say, a hydro extractor which uses 'plugging' as a method of braking the equipment frequently. The demands on the fixed wiring should be established from the manufacturer's installation instructions. These details will form part of the

512-05-01
331-01-01

512-04-01

552-01-01

installation manual. (See Guidance Note 6 for detailed information on cable selection for motor circuits.)

ELECTROMAGNETIC COMPATIBILITY (EMC)

All equipment must be selected and erected so as to allow safe working, prevent harmful effects to other equipment and not impair the supply arrangements. This includes the consideration of electromagnetic compatibility (EMC) effects, as well as more straightforward considerations such as loading, current and voltage rating, circuit arrangements, etc. Regulation 515-02 specifically requires consideration of EMC when selecting and installing equipment. Both **electromagnetic immunity** (EMI), the protection of equipment from other electromagnetic influences (Regulation 515-02-01), and **electromagnetic emission**, the production and emission of electromagnetic interference by the proposed equipment (Regulation 515-02-02), must be considered. This is a specialist application and advice from the equipment manufacturer should generally be taken. (See Appendix I for further information on cable separation.)

515-02

HARMONICS

Harmonics are an aspect of EMC. Harmonic voltages and currents can cause interference with the normal operation of equipment and overload cables in certain cases (see Sections 2.6 and 6 also).

**2.5 Identification
514**

CABLES

The identification colours for non-flexible cables for fixed wiring are given in Table 51A of BS 7671 — reproduced here as Table 2.1 for convenience. These colours will be revised after 2004.

Table 51A

Flexible cables and flexible cords may be used for fixed wiring, subject to the relevant provisions of the Regulations being met. These provisions are generally considered to relate to physical installation criteria but it should be remembered that the core colours of flexible cables and cords are not the same as those for fixed cables in Table 51A and are laid down in Table 51B.

521-01-04

Table 51B

There is no definition of a "fixed" cable and, as the colour coding for flexible cables is by now well

understood, there is no need to identify the cores of flexible cables or cords when their colour and function comply with Table 51B - even if they have been fixed.

Any other colour identification of the cores of a flexible cord or cable is a deviation from the requirements of BS 7671 and should only be done after careful consideration as to whether in the circumstances it is impossible to comply with the requirements, and the level of safety provided is not less than that by compliance.

The notes of Table 51B say that if the blue core is used for another purpose or it is necessary to identify the phases this is to be done by letters i.e. L1, L2 or L3. A blue core may be used as a phase conductor if the circuit does not have a neutral and this should be identified by means of a suitable letter.

If, after consideration, it is decided that a core is to be used for a function for which its colour is not recognised by Table 51B then its function is to be identified by a letter. A brown core used as a neutral should be identified with an N and a blue core used as a phase conductor should be identified by L1 or L2 or L3. It is better, however, to select the correct cable and identification colours for an installation.

It is a deviation to apply colours to flexible cores to identify them as being used for a purpose other than that which their original colour indicates - if, after due consideration, colours are applied the deviation must be clearly recorded on the Electrical Installation Certificate and in the construction record documentation.

There is also a current installation trend to supply and install multicore cables complying with HD 324: 1977 that have blue insulation on the neutral conductor. It must be noted that this may comply with Regulation 511-01-01 but not with Table 51A. Such cables should be correctly identified at their terminations.

511-01-01
514-06-01

The colour combination green-and-yellow is reserved exclusively for identification of protective conductors and cannot be used for any other purpose. Bare conductors and busbars which are to be used as protective conductors may be identified using green-and-yellow sleeving or tape.

CIRCUITS

A diagram, chart or table giving details of the circuits is required. These details must be used by the person verifying compliance with BS 7671; for example, details of the selection and characteristics of the protective devices are needed for verifying protection against overcurrent and electric shock. The same details will be needed for periodic inspection and testing later on.

514-09-01

A durable copy of the details should be fixed in or near the distribution board which serves the area.

712-01-03(xvii)

For simple installations, the Electrical Installation Certificate, together with the Schedule of Test Results, and the Schedule of Inspections, will meet BS 7671 provided each circuit is identified in the distribution board.

514-08-01

514-09-01

741-01-01

742-01-01

SWITCHGEAR

Labelling of switchgear is very important particularly where the route of the final circuit cables is not obvious. If there is a possibility of confusion some reliable means of identification must be clearly visible. It is necessary for the protective devices to be marked so that they can be identified easily by the user (see BS EN 60439).

Fig 2.1 is a diagram of a typical installation showing the information needed to comply with BS 7671. The method of presentation will depend upon the size and complexity of the installation.

514-09-01

Complex installations demand greater detail. Details of protective measures and cables should be provided as part of the 'As installed' information. When the occupancy of the premises changes the new occupier should have sufficient information to properly operate the electrical installation. Diagrams, charts, tables and schedules should be kept up to date. Such items are essential aids in the maintenance and periodic inspection and testing of an installation.

WARNING NOTICES

The notices called for in Section 514 of BS 7671 are intended to warn persons about the risk of working on or near live parts which may be thought to be isolated.

WARNING NOTICES - voltage

514-10-01

The warning notices regarding voltage concern three different situations:

1. inside an item of equipment or enclosure

Where the nominal voltage (U_0) within an item of equipment or enclosure exceeds 230 volts (e.g. if a non-standard voltage such as 650 V was present), and where the presence of such a voltage would not normally be expected, before access is gained to a live part, there must be a clearly visible warning of the maximum voltage present.

2. between simultaneously accessible items of equipment or enclosures

Where simultaneously accessible terminals or other fixed live parts have a nominal voltage (U_0) between them which exceeds 230 volts (such as where the voltages are from different systems), then a warning notice must be fixed in such a position that anyone, before gaining access to such live parts, is warned of the maximum voltage which exists between those parts.

3. where different nominal voltages exist

The means of access to all live parts of switchgear and other fixed live parts where different nominal voltages exist (e.g. if different nominal voltages such as 110 V and 230 V were present either within or between switchgear or other fixed live parts), must be marked to indicate the voltages present.

Note.

Three-phase 400 V (U) systems have a nominal phase to earth voltage (U_0) of 230 V and do not normally require a warning notice.

OTHER NOTICES

Other notices required by Section 514 are:

- in each position where there are live parts which are not capable of being isolated by a single device
- regarding periodic inspection and testing
- regarding earthing and bonding connections

514-11-01

514-12-01

514-13

Where protection by earth-free local equipotential bonding or protection by electrical separation is used, the bonding conductors must not be connected to Earth. A warning notice to this effect, as specified in Regulation 514-13-02, must be fitted.

471-11-01
471-12-01
514-13-02

SAFETY SIGNS

Item 9 of Appendix 2 of BS 7671 refers to the provision of safety signs as required by the Safety Signs Regulations 1996. Risks should be minimised at the design of an installation and warning signs only used where other methods of avoiding danger are not practical to implement.

Appx 2

WARNING NOTICES and IDENTIFICATION LABELS

Table 2.2 lists the requirements for warning notices and identification labels given in BS 7671. Labels and warning notices should be of a size and type suitable for the location and installed such that they will not be painted over or easily removed or defaced. Labels etc. should be permanently fixed, e.g. by suitable screws or rivets, or resin glues, taking care not to damage equipment, invalidate IP ratings or block vents. Stick-on labels are not advisable and should only be used where heat or damp is not expected, as they cannot be considered permanent.

PIPES AND DUCTS

BS 1710 : 1984 (1991) prescribes a system for the identification of piped services, ducts and electrical conduits by colour. In the system, red is reserved as a safety colour for fire fighting and yellow for warning. Electrical conduits can be identified by completely painting the conduit or painting bands (150 mm in length). The colour for electrical services is orange (O6E51 in BS 4800).

514-02-01

Fig 2.1: Typical installation

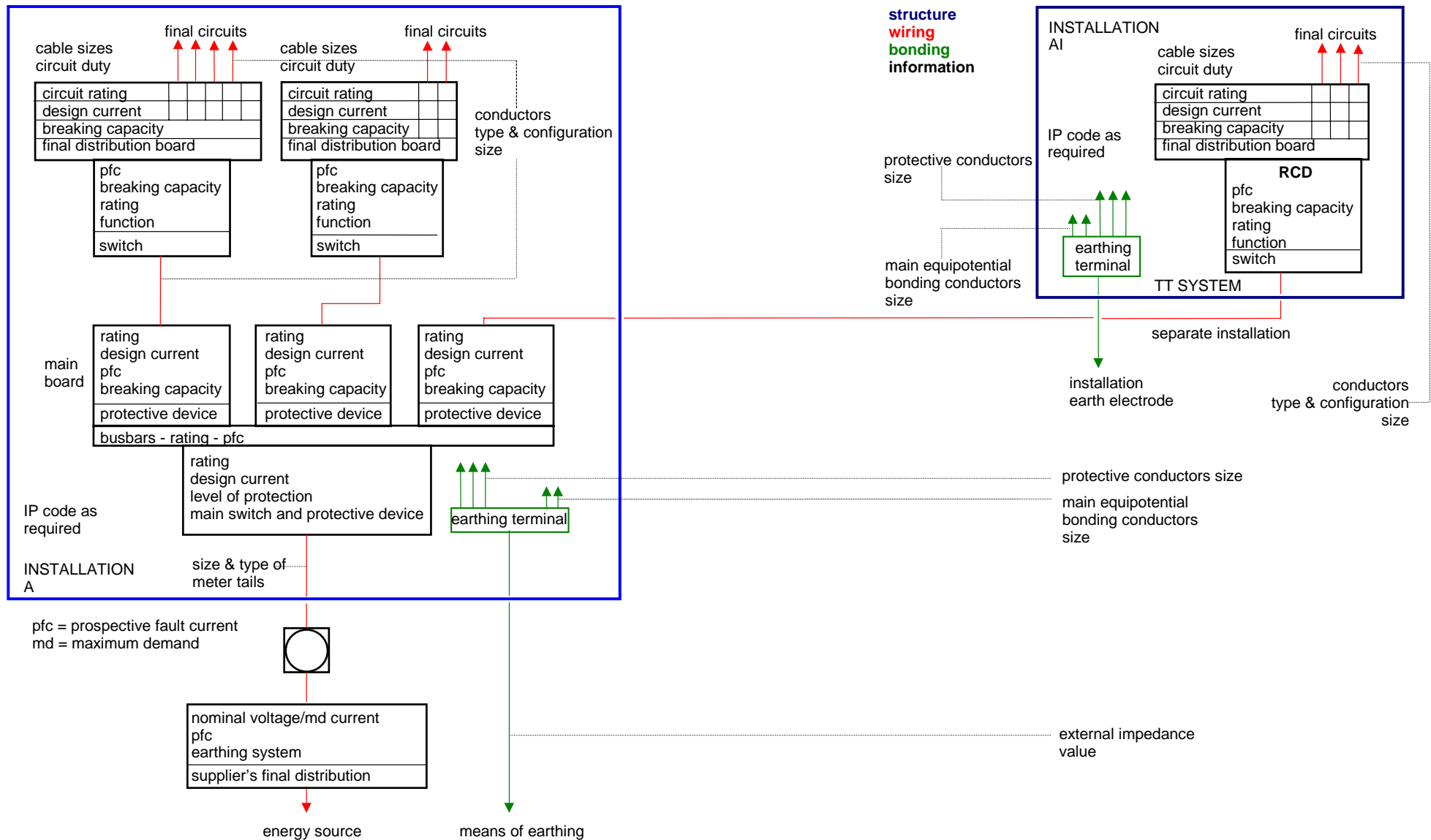


TABLE 2.1 (From TABLE 51A of BS 7671)

Colour identification of cores of non-flexible cables and bare conductors for fixed wiring

Function	Colour identification
Protective (including earthing) conductor and circuits	green-and-yellow
Phase of a.c. single-phase circuit	red ⁽¹⁾
Neutral of a.c. single- or three-phase circuit	black
Phase R of three-phase a.c. circuit	red
Phase Y of three-phase a.c. circuit	yellow
Phase B of three-phase a.c. circuit	blue
Three-wire 460/230 V single-phase a.c. circuits (Centre conductor earthed)	
Outer, phase conductors (either conductor)	red
Centre neutral conductor	black
Two-wire unearthed d.c. circuits	
Positive of d.c. two-wire circuit	red
Negative of d.c. two-wire circuit	black
Three-wire d.c. circuits	
Outer (positive or negative) of d.c. two-wire circuit derived from three-wire system	red
Positive of three-wire d.c. circuit	red
Middle wire of three-wire d.c. circuit ⁽²⁾	black
Negative of three-wire d.c. circuit	blue
Two-wire earthed d.c. circuits	
positive (of negative earthed) circuit	red
negative (of negative earthed) circuit	black
positive (of positive earthed) circuit	black
negative (of positive earthed) circuit	blue
Functional Earth	cream

Notes:

- (1) As alternatives to the use of red, if desired, in large installations, for the supply cables to final distribution boards yellow and blue may also be used. **All single-phase final circuit non-flexible fixed wiring must be red and black.**
- (2) Only the middle wire of three-wire circuits may be earthed.
- (3) The colours in Table 2.1 only apply to fixed installations in buildings and not necessarily to installations in factory built equipment which is excluded from BS 7671 (see Regulation 110-03-01). BS EN 60204-1 details colours for the electrical equipment of machines.
- (4) These colours will be revised after 2004.

TABLE 2.2

Warning notices and identification labels required by BS 7671

Notice, label or identification	Regulation
Isolating device and its installation or circuit (if not obvious)	461-01-05
Switching device for mechanical maintenance (indication of operation)	462-01-02 537-03-02
Protection by electrical separation	471-12-01
Protection by earth-free local equipotential bonding	471-11-01 514-13-02
Areas reserved for skilled or instructed persons	471-13-03 514-13-02
Fireman's switch	476-03-07 537-04-06
Purpose of switchgear and controlgear (if not obvious)	514-01-01
Conduit, identification, where required	514-02-01
Bare protective conductors	514-03-01
Diagrams, charts etc. for installation information	514-09-01
Marking voltages present on means of access	514-10-01
Voltages exceeding 230 V	514-10-01
Live parts not capable of being isolated by a single device	461-01-03 514-11-01
Periodic inspection and testing (see Regulation 611-04-04)	514-12-01
Quarterly test of a residual current device (see Chapters 71 and 73)	514-12-02
Earthing and equipotential bonding connections	514-13-01 542-03-03
Earth-free equipotential bonding	514-13-02
Cables buried in the ground	522-06-03
Caravan inlet	608-07-03
Caravan instructions for supply and periodic inspection and testing	608-07-05
Identification of highway power supply cables	611-04-03
Highway temporary supply unit (identification by marking etc.)	611-06-02

2.6 Mutual detrimental influence

515

Regulation 515-01 requires that there be no harmful effect between electrical and other installations. The best approach, where practicable, is to arrange that the installations are kept separated. Damage can be caused by such influences as thermal effects, electrolysis or corrosion. The thermal effects of other installations — such as hot water systems — must be considered and equipment either designed to operate properly at elevated temperatures or reduced temperatures, or be protected from such effects. Electrolysis may result from leakage currents, or from contact between dissimilar metals in damp conditions, while corrosion may result for example in rusting of unprotected steelwork. Action needs to be taken to obviate these risks.

[131-11](#)
[515-01](#)
[528-02](#)

The Electromagnetic Compatibility (EMC) Regulations place a statutory requirement on designers and constructors to design/construct electrical equipment and systems so that they do not cause excessive electromagnetic interference (emissions) and are not unduly affected by electromagnetic interference from other electrical equipment or systems. Harmonic production and interference, electrostatic discharges, mains-borne signals etc are all types of EM interference to be considered, but the subject is too wide for this Guidance Note and requires specialist advice (see Section 7, and Appendix I for some further information).

[515-02](#)

The protection provided should form a prominent feature of the Building Services Manual. Guidance in the preparation of the manual can be found in BS 4884, BS 4940 and Section 6 of the Health and Safety at Work etc. Act 1974 (HSW Act).

Manufacturers' leaflets for switchgear, luminaires, electrical equipment, accessories, and any special instructions, should be included.

The HSW Act, the Consumer Protection Act and the Construction (Design and Management) Regulations 1994 provide specific requirements for information to be provided.

2.7 Compatibility

512
331

All equipment should be selected and erected so that it will not be susceptible to interference from, or cause harmful effects to, other equipment when used for the purpose for which it was intended, nor impair

[132-01-08](#)
[331-01-01](#)
[512-05](#)

the supply during normal service, including switching operations (see Section 2.4 and 2.6).

Regulation 331-01-01 is of particular importance when considering supplies to information technology equipment. This includes computers, electronic office equipment, data transmission equipment and point-of-sale terminals. The power supply units of this type of equipment are particularly well known for causing harmonic generation problems.

331-01-01

Whenever electrical equipment is switched on or off, particularly where inductive loads are involved, high frequency voltage transients occur. This so-called mains-borne noise may cause malfunction in information technology equipment. The capacitance of the circuit cables and the filters incorporated in most information technology equipment attenuate this mains-borne noise. It is good practice to ensure that sources likely to give rise to significant noise (e.g. motors and thermostatically controlled equipment) are kept apart from sensitive equipment. Susceptible electronic equipment should be fed by separate circuits from the incoming supply point of the building. Additional filters (sometimes called 'power conditioners') may be used to reduce this transient noise on existing circuits, and surge protection devices can be installed to divert or absorb transients. (See Section 3.8)

Large switch-on (inrush) current surges which occur with transformers, motors and mains rectifier circuits, can cause excessive short-time voltage drop in the circuit conductors (dips). Inrush currents affect other circuits also and may require larger cable sizes, or the equipment to be put on separate circuits. It should be borne in mind that information technology equipment itself can cause the same problem if switched on in large groups.

Where the maintenance of the supply voltage to especially sensitive equipment such as information technology equipment is considered of importance, the user may need a device such as a motor alternator or uninterruptible power supply (UPS).

2.8 'Clean' (low noise) earths

When information technology equipment is planned functional earthing and a 'clean' (low-noise) earth must be considered. Information on functional earthing is contained in Section 5.5 of Guidance Note 5. Information on earthing requirements for the installation of equipment having high protective conductor currents is located in Chapter 7 of Guidance Note 7. (See also Section 8.1 of this Guidance note).

The protective conductors in a building are subject to transient voltages relative to the general mass of earth. These transients are termed 'earth noise' and are usually caused by load switching. They may be generated by the charging of an equipment frame via the stray capacitance from the mains circuit, or mains-borne transients may be coupled into the earth conductor or frame from mains conductors.

As 'earth noise' can cause malfunction, manufacturers of large computer systems usually make specific recommendations for the provision of a 'clean' mains supply and a 'clean' earth. The equipment manufacturer's guidance must be taken for such installations.

A dedicated earthing conductor may be used for a computer system, provided that:

- (i) all accessible exposed-conductive-parts of the computer system are earthed, the computer system being treated as an 'installation' where applicable 542-04
607-02
- (ii) the main earthing terminal or bar of the computer system ('installation') is connected directly to the building main earthing terminal by a protective conductor 543-01
- (iii) extraneous-conductive-parts within reach of the computer systems are earthed, but not via the protective conductor referred to in (ii) above. 413-02-03

Supplementary bonding between extraneous-conductive-parts and the accessible conductive parts of the computer system is not necessary.

- 2.9 LV switchgear and controlgear assemblies** BS EN 60439-1 : 1999 gives guidance on the forms of separation applicable to factory-built switchgear and controlgear assemblies (switchboards, motor control centres, distribution boards, busbar trunking systems etc.), known as type-tested and partially type-tested assemblies. These forms of separation provide protection against contact with live parts belonging to adjacent devices and protection from the probability of initiating arcing faults and the passage of foreign bodies between units of the assembly. The Standard also gives guidance on other requirements for protection against electric shock.

Definitions given in BS EN 60439-1 are:

Type-tested low voltage switchgear and controlgear assembly (TTA)

A low voltage switchgear and controlgear assembly conforming to an established type or system without deviations likely to significantly influence the performance from the typical ASSEMBLY verified to be in accordance with this standard.

For various reasons, for example transport or production, certain steps of assembly may be made in a place outside the factory of the manufacturer of the type-tested ASSEMBLY. Such an ASSEMBLY is considered as a type-tested ASSEMBLY provided the site assembly is carried out in accordance with the manufacturer's instructions which should be retained for future information. The instructions will include any requirements for submission of the ASSEMBLY to further applicable routine test.

Partially type-tested low voltage switchgear and controlgear assembly (PTTA)

A low voltage switchgear and controlgear assembly, containing both type-tested and non-type-tested arrangements provided that the latter are derived (e.g. by calculation) from type-tested arrangements which have complied with the relevant tests.

It should be noted that the forms of separation have no bearing on the overall ingress protection (IP rating or classification) for the external frame and enclosure of the switchgear assembly etc. This should be specified to the required IP rating (see Appendix B).

BS EN 60439-1 : 1999 is identical to IEC 60439-1 : 1999 with the exception of the additional information given in National Annex NA. Designers and specifiers working on international projects should clarify specific requirements with the manufacturer.

FORMS OF SEPARATION

Four forms of separation are indicated in the main text of BS EN 60439-1 : 1999, but there is no specific detail given on how these forms are to be achieved. It is stated in the BS EN that the form of separation should be agreed between manufacturer and designer/user. It must be remembered that higher forms of separation specified will increase costs but will give better operational flexibility regarding safe working when connecting in additional circuits or carrying out maintenance. This 'trade off' must be carefully assessed.

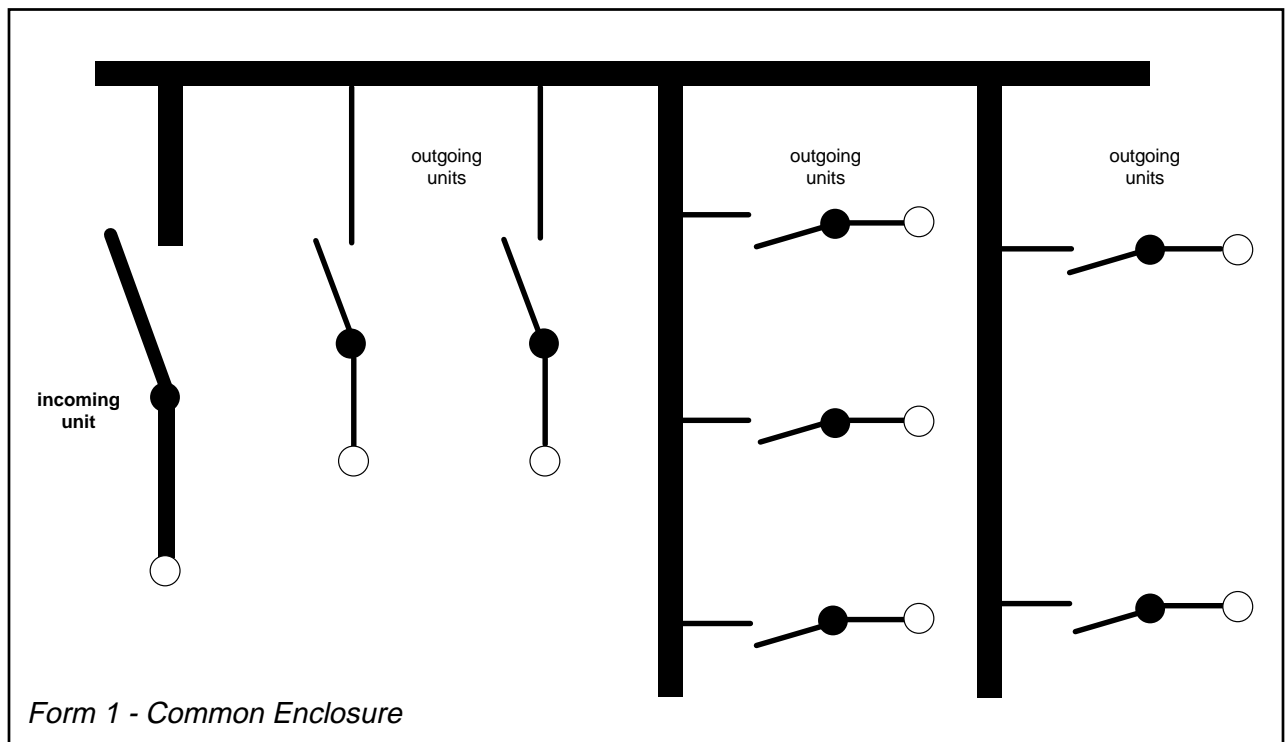
The four forms given have basic definitions and applications, but Forms 2 to 4 can be further subdivided into more specific "Types" (applications) by discussion and agreement with manufacturers.

Further examples beyond the basic definitions in the main text of the standard are given in the National Appendix NA and are described in *Form 1 to Form 4* below.

Form 1

This form provides for an enclosure to provide protection against direct contact with live parts, but does not provide any internal separation of switching, isolation or control items or terminations. These overall assemblies are often known as 'wardrobe' type with large front opening doors, usually with an integral door interlocked isolator. Operating the isolator interrupts all functions but allows the door to be opened to gain access to the assembly for installation or maintenance. Such assemblies normally have lower fault withstand and it may be inconvenient to shut down a whole plant or system for a simple maintenance or repair operation. (See Fig 2.2)

Fig 2.2: **Form 1 Construction**



Form 2

The overall assembly enclosure provides protection against direct contact with live parts; separation is provided between the busbar assembly and switching, isolation, control items and terminations. There is very little advantage of this over Form 1, and the style is similar. Form 2 can be further subdivided into:

- Type 1, in which the busbars are separated by insulation of the bars.
- Type 2, in which the busbars are separated by metallic or non-metallic rigid barriers.

Form 3

The enclosure provides protection against direct contact with live parts, and also separation is provided between the busbars and switching, isolation or control items, and between all these items. Outgoing terminals are not separated from each other, or perhaps from the busbars. Form 3 can be further subdivided into:

- Form 3a, in which outgoing terminals are not separated from the busbars.
- Form 3b, in which outgoing terminals are separated from the busbars.

Form 3b can be further subdivided into:

- Type 1, in which the busbars are insulated for separation.
- Type 2, in which busbar separation is by metallic or non-metallic rigid barriers or partitions.

Form 4

The enclosure provides protection against direct contact with live parts, and internal separation of the busbars from all switching, isolation and control items and outgoing terminations, and separation of all items and outgoing terminations from each other. This allows for access to any single item, such as a switch-fuse or starter, and its outgoing terminations, to enable work to be carried out whilst the assembly remains operational. Protection is also provided against an arcing fault in one device affecting other items. This is the usual form specified for commercial and industrial switchgear and controlgear assemblies, but the designer has to consider whether due to the extra cost such requirements are necessary or justified. Form 4 can be further subdivided into seven types:

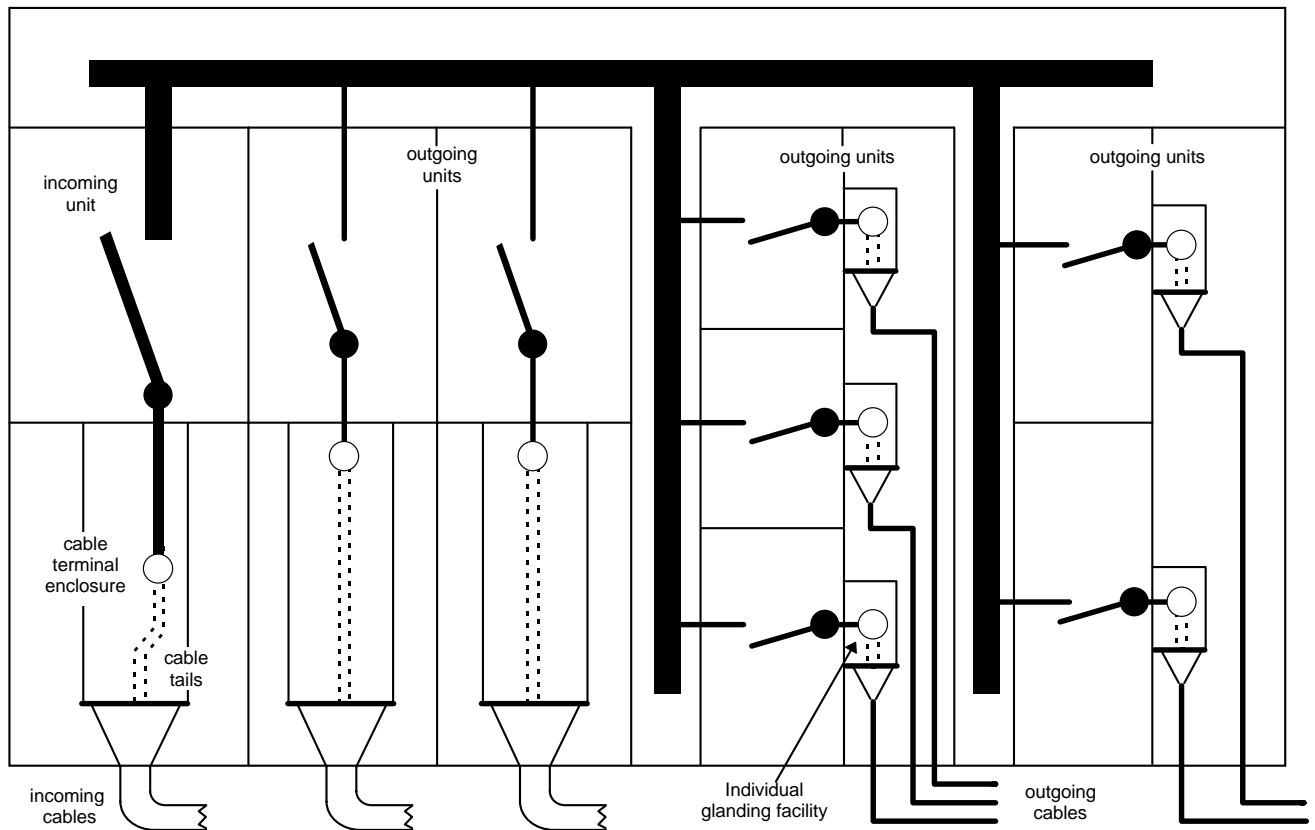
- Type 1, in which the busbars are separated by insulation coverings. Terminals for external conductors are in the same compartment as the associated item of switchgear etc., but cables may be glanded elsewhere.
- Type 2, in which the busbars are separated by metallic or non-metallic rigid barriers or partitions. Terminals for external conductors are in the same

compartment as the associated item of switchgear etc., but cables may be glanded elsewhere.

- Type 3, in which separation requirements are by metallic or non-metallic rigid barriers or partitions. Terminals for external conductors are in the same compartment as the associated item of switchgear etc., and each item has its own integral cable glanding facility.
- Type 4, in which the busbars are separated by insulated coverings. Terminals for external conductors are not in the same compartment as the associated item of switchgear etc., but in separate enclosed spaces, but cables may be glanded elsewhere.
- Type 5, in which busbars are separated by metallic or non-metallic rigid barriers or partitions. Terminals for external conductors are not in the same compartment as the associated item of switchgear etc., but in separate enclosed spaces, and terminals may be separated by insulated coverings. Cables may be glanded in common cabling chambers.
- Type 6, in which all separation requirements are by metallic or non-metallic rigid barriers or partitions. Terminals for external conductors are not in the same compartment as the associated item of switchgear etc., but in separate enclosed spaces, and cables are glanded in common cabling chambers.
- Type 7 in which all separation requirements are by metallic or non-metallic rigid barriers or partitions. Terminals for external conductors are not in the same compartment as the associated item of switchgear etc., but in separate enclosed spaces, and the termination for each item has its own integral glanding facility. (See Fig 2.3)

Switchboard manufacturers therefore cannot give all-embracing assurances for safe working, according to the form of separation with parts of the assembly energised. Specifying a particular form of separation will not guarantee this for any given form number.

Fig 2.3: Form 4 Construction (Type 7)



GENERAL

Assemblies are to be designed and constructed so as to be able to withstand the thermal and dynamic stresses resulting from fault currents up to their rated values. The designer must specify the prospective fault current conditions at the point of installation.

Busbar systems for switchgear and controlgear should be adequately rated for the normal duty and maximum fault current level expected, and should be well supported and braced, as the electromechanical stresses under fault conditions can be severe. However, thermal movement must be allowed for. It is usual for manufacturers to prove their busbar designs with a full short-circuit test by an independent test station up to the rated fault current level on a sample construction. The busbar arrangement can then be certified as a 'type-tested' busbar system.

Tests, as detailed in BS EN 60439 : Part 1, are applied to the complete assembly as relevant at manufacture, including continuity, insulation resistance and perhaps a flash test at high voltage. The designer and installer must be aware that there are statutory requirements under the Electricity at Work Regulations and the CDM Regulations etc. for the safe design, construction, operation and provision for maintenance of electrical equipment assemblies. Adequate access, working space and lighting must be provided where work is to be carried out on or near equipment, in order that persons may work safely.

It must also be realised that Regulation 8 of the Electricity at Work Regulations places an absolute requirement (one that must be met regardless of cost or any other consideration) on protective conductor connections to earth: *"a conductor shall be regarded as earthed when it is connected to the general mass of earth by conductors of sufficient strength and current-carrying capability to discharge electrical energy to earth"*. It may be questioned whether the termination of steel or aluminium wire armour (where used as a protective conductor) with glands into metal gland plates, which themselves may only be bolted to the switchgear or controlgear frame, is an adequate connection. Cable gland "earth tags" and supplementary connections to the equipment earth terminals may be necessary. In any case it should be ensured that any paint or other surface finish on the switchgear does not prevent effective electrical continuity between the adjacent parts.

During site installation and commissioning, tests as required by BS 7671 Part 7 should be carried out on the complete assembly, plus any other specific tests advised by the manufacturer or required by the client, user or engineer. It is not usual to carry out a repeat of specialist tests such as a flash test at site, and in the event of a requirement the manufacturer's advice should be sought.

Section 3 — Protection against Overcurrent, Electric Shock and Overvoltage

3.1 Protective devices 531

The Regulations prescribe requirements for the following devices:

- (i) overcurrent protective devices
- (ii) residual current devices
- (iii) insulation monitoring devices.

413

Earthed equipotential bonding and automatic disconnection of supply (EEBADS)

Protection against indirect contact which relies upon earthed equipotential bonding and automatic disconnection of the supply is intended to reduce the risk of shock by limiting the disconnection time and voltage magnitude in the event of a fault. Where it is not possible to achieve a sufficiently low earth fault loop impedance to operate an overcurrent device within the required disconnection time an RCD may be used for protection from indirect contact.

413-02
471-08

Supplementary equipotential bonding may also be provided in addition to, or instead of, an RCD. Low earth fault loop impedance values, however, lead to high fault current and fast disconnection times.

413-02-04

In TN systems it is preferable for reliable operation for indirect shock protection to be provided by overcurrent devices, including RCBOs operating as overcurrent devices; that is, with loop impedances complying with Table D4 of Appendix D. RCBOs are then providing indirect shock protection as overcurrent devices and supplementary protection against direct contact as residual current circuit-breakers (RCCBs).

413-02-04

471-16

During a fault, voltages are present along the fault path. The protection must ensure that any such voltages are not likely to persist long enough to be dangerous. Access to such voltages may result in electric shock. The equipotential bonding will have

voltages present along it if it forms part of the fault path. Supplementary equipotential bonding may be required in order to keep the magnitude of the voltages between simultaneously accessible exposed- and/or extraneous-conductive-parts low. (See Part 6 of BS 7671 for specific requirements in special locations. Guidance Note 7 also addresses these requirements).

**3.2 Overcurrent
protective
devices
533**

Every circuit must be provided with a means of fault current and overload protection although some parts of a circuit — such as the flexible cord of a luminaire pendant — may be protected against overload by the nature of the load. The devices may be either fuses or circuit-breakers. For TN systems such overcurrent devices can also be used for indirect shock protection, provided that the earth fault loop impedance of the protected circuit is such that the chosen device will operate within the times specified in BS 7671. Regulation 413-02-19 also allows the use of the overcurrent protective device in a TT installation if the earth loop impedance is sufficiently low, and is likely to remain so. However, RCDs are preferred and are usually specified. For TN systems, Tables 41B and D of BS 7671 give maximum permitted earth fault loop impedances. Table 41C gives maximum permitted impedances of circuit protective conductors corresponding to certain types of devices and current ratings of fuses and circuit-breakers. These impedances provide an alternative method of providing earth fault protection. See Guidance Note 5 for further information. For other types of devices and current ratings the manufacturer should be consulted.

533-02
413-02-06
413-02-07
413-02-08
Table 41B
Table 41C
Table 41D
473-01-04

413-02-19

471

Regulation 471-01-01 qualifies the application of the various protective measures described in Chapter 41, and Section 471 should be studied carefully. For the special locations dealt with in Part 6 of BS 7671 lower values may be required, together with additional precautions.

471-01-01

The choice of protective device will depend on a number of factors, including overall installation and maintenance costs, and Table 3.1 gives a brief comparison between fuses and circuit-breakers.

TABLE 3.1
Comparison of overcurrent protective devices

Semi-enclosed fuses	Cartridge fuses	circuit-breakers
Lowest capital costs	Higher capital costs	Highest capital cost
Low maintenance costs	Higher maintenance costs	No maintenance cost
Lowest fault current capacity	Highest fault current capacity	Intermediate fault current capacity
Requires a degree of skill to replace fusewire, fitting of wrong size/rating wire is not prevented	Relatively simple to replace cartridge. Size of cartridge relates to size of fuse carrier in consumer units for domestic installation.	Easy to reset. Unskilled persons able to reset. No replacement or refitting after operation, unless damaged by operation at high fault currents. Can operate on surges.

MOTOR CIRCUITS

With respect to electric motors, note should be taken of BS EN 60947-4-1. This recognises three types of co-ordination with corresponding levels of permissible damage to the starter. Co-ordination of Type 2 in BS EN 60947-4 (i.e. no damage, including permanent alteration of the characteristics of the overload relay, except light contact burning and a risk of contact welding) is required if the starter is to continue to provide overload protection complying with Regulation 433-02-01. Examination and maintenance of the devices is always necessary after a fault.

435-01-01

433-02-01

The selected fuse or circuit-breaker provides short-circuit protection for the motor circuit and the starter overload relay provides protection from overload. In motor circuits the short-circuit protection and overload protection are often provided separately. Overload relays must be selected for the motor duty, and for unusual duties — i.e. frequent starting/ stopping — the manufacturer should be consulted.

The overload relay on the starter is arranged to operate for values of current from just above full load to the overload limit of the motor, but it has a time delay such that it does not respond to either starting currents or fault currents. This delay provides discrimination with the characteristics of the associated fuse or circuit-breaker at the origin of the circuit on fault currents, and prevents operation due to surge currents at start-up.

The starter overload relay can provide overload protection for the circuit in compliance with Regulation 433-02-01 on the basis that:

433-02-01

- (i) its nameplate full-load current rating or setting is taken as I_n , and
- (ii) the motor full-load current is taken as I_b , and
- (iii) the ultimate tripping current of the overload relay is taken as I_2 .

Where the overload relay has a range of settings then items (i) and (iii) should be based on the highest current setting, unless the setting cannot be changed without the use of a tool. (See Guidance Note 6 for further information).

3.3 Fuses 533

Fuses have a rated short-circuit capacity, see Table 3.2, and should be selected such that their rating is not exceeded by the prospective fault current at the point of installation, unless adequate back-up protection is specified.

BS 88-2.1 and BS 88-6 cartridge fuses have the same characteristics, as shown in Appendix 3 of BS 7671.

Appx 3

The size of a tinned copper single-wire element is specified in Table 53A for use where BS 3036 semi-enclosed (rewirable) fuses are selected and there are no manufacturer's instructions.

533-01-04
Table 53A

BS 3036 fuses have a limited fault current breaking capacity and also cannot be relied upon to operate within 4 hours at 1.45 times the nominal current of the fuse element. Correct protection can be obtained by modifying the normal condition $I_n \leq I_2$ such that the fuse rating does not exceed $1.45/2 = 0.725$ times the rating of the circuit conductor. For this reason, larger cables may need to be selected where overload

433-02-01
433-02-03

protection is provided by semi-enclosed fuses than when it is provided by a cartridge fuse or fuses or circuit-breaker. (Appendix 4 of BS 7671 and Guidance Note 6 give further guidance).

Appx 4
GN 6

Note should be taken of the warning regarding the possible inadvertent replacement of a fuse link by one of a higher nominal current rating.

533-01-01

TABLE 3.2

Rated short-circuit capacities of fuses

Device type	Device designation	Rated short-circuit capacity kA
Semi-enclosed fuse to BS 3036 with category of duty	S1A S2A S4A	1 2 4
Cartridge fuse to BS 1361 type I type II		16.5 33.0
General purpose fuse to BS 88-2.1 -6		50 at 415 V 16.5 at 240 V 80 at 415 V

3.4 Circuit-breakers

3.4.1 Circuit-breakers for applications not exceeding 440 V AC (mcbs)

There is a wide range of breaker characteristics that have been classified according to their instantaneous trip performance and Table 3.3 gives some information on the applications of the various types available. These limits are the maximum allowed in miniature circuit-breakers (mcbs) to BS 3871 (now withdrawn) and circuit-breakers (cbs) to BS EN 60898-1, but it should be noted that manufacturers may provide closer limits. For such circuit-breakers, manufacturers' data for I_a may be applied to the formula given in Regulation 413-02-08. (I_a is the current causing automatic operation of the device within the stated time.)

Appx 3

413-02-08

3.4.2 Circuit-breakers for applications not exceeding 1000 V AC (mccbs)

Unlike circuit-breakers to BS EN 60898-1, circuit-breakers complying with BS EN 60947-2 do not have defined characteristics and manufacturers' data must be used. BS EN 60947-2 Amendment 2 : 2001 now includes Annex L, which is for circuit-breakers not fulfilling the requirement for overcurrent protection

(CBIs), derived from the equivalent circuit-breaker. A class X CBI is fitted with integral short-circuit protection, which may, on the basis of the manufacturers' data, be used in conjunction with the starter overload relay, for short-circuit protection.

TABLE 3.3

Circuit-breakers overcurrent protection

Type	Multiple of rated current I_n below which it will not trip within 100 ms	Multiple of rated current I_n above which it will definitely trip within 100 ms	Typical application
1* B	2.7X 3X	4X 5X	Circuits not subject to inrush currents/ switching surges
2* C	4X 5X	7X 10X	Circuits where some inrush current may occur. For general purpose use on fluorescent lighting circuits, small motors etc
C 3*	5X 7X	10X 10X	Circuits where high inrush currents are likely, e.g. motors, large lighting loads, large air conditioning units
D 4*	10X 10X	20X 50X	Circuits where inrush currents are particularly severe, e.g. welding machines, x-ray machines.

Notes:

1. Some non-linear resistive loads, such as large tungsten filament lighting installations, may give rise to high inrush currents.
2. * Due to the withdrawal of BS 3871, Types 1 to 4 mcbs are now obsolete, but are still to be found in use.
3. Type D and Type 4 cbs are special-purpose breakers which require low EFLI and should not be used without due consideration, particularly where this device is to effect protection against indirect contact. Data should be obtained from the manufacturer.

3.4.3 Circuit-breakers - general

All mcbs and cbs have a maximum fault current breaking capacity and care is needed in selection to ensure that this is not exceeded in service. BS 3871 identified this capacity with an 'M' rating, however, in BS EN 60898 the 'M' category ratings for breaking capacities are replaced by a figure in a rectangle (I_{cn}) on the device (see Table 3.4 below). The manufacturer must declare the breaking capacity of the devices at specified power factors of test current. Higher fault current capacities up to 25 kA are recognised for BS EN 60898 devices. Rated values for both standards are given in the following table:

TABLE 3.4 Rated breaking capacity for miniature circuit-breakers to BS 3871, circuit-breakers to BS EN 60898 and RCBOs to BS EN 61009

BS 3871		CBs to BS EN 60898 and RCBOs to BS EN 61009		
Marked on device as 'M' number		I_{cn} (rated capacity) (Marked on device in rectangle)	k	I_{cs} (service capacity)
M1	1000 A			
M1.5	1500 A	1500	1	1500 A
M3	3000 A	3000	1	3000 A
M4.5	4500 A	4500	1	4500 A
M6	6000 A	6000	1	6000 A
M9	9000 A			
		10000	0.75	7500 A
		15000	0.5	7500 A
		20000	0.5	10000 A
		25000	0.5	12500 A

(k — ratio between service short-circuit capacity and rated short-circuit capacity, BS EN 60898 & BS EN 61009).

Two short-circuit breaking capacities, I_{cn} and I_{cs} , are quoted for circuit-breakers:

- I_{cn} the rated short-circuit capacity. (Ultimate short-circuit breaking capacity).
- I_{cs} the service short-circuit capacity. This is the maximum level of fault current operation after which further service is assumed without loss of performance.

For an assigned I_{cn} the I_{cs} value will not be less than the value tabulated in Table 3.4. The I_{cn} of the circuit-breaker must always exceed the prospective short-circuit current at the point of installation, except where back-up protection as specified by the manufacturer is applied.

Fault currents up to 16 kA

Except for London and some other major city centres, the maximum fault current for 230 V single-phase supplies up to 100 A will not exceed 16 kA.

The short-circuit capacity of overcurrent protective devices incorporated within consumer units may be taken to be 16 kA where:

- the current ratings of the devices do not exceed 50 A.
- the consumer unit complies with BS 5486-13 or BS EN 60439-3.
- The consumer unit is supplied through a type 2 fuse to BS 1361 : 1971 rated at no more than 100 A.

MOULDED CASE CIRCUIT-BREAKERS

As mentioned in 3.4.2, moulded case and other types of circuit-breakers to BS EN 60947-2 do not have defined characteristics as do circuit-breakers to BS 3871 or BS EN 60898 and manufacturers' data must be used.

3.5 Insulation monitoring devices **413**

Devices which monitor and indicate the condition of the insulation must be installed in IT systems to indicate a first fault to earth. Such systems may also be used where high degrees of reliability of supply are necessary, as in supplies for safety services.

[413-02-24](#)
[561-01-03](#)

The first fault on such a system would then signal the need for remedial action, allowing time to carry out the procedure before a possible second fault arose.

Such a system calls for a special knowledge and is outside the scope of this Guidance Note. An IT system is not allowed for low voltage public supply in the UK. Their use is generally confined to industrial control systems, or hospital operating theatres and treatment rooms.

110-04-01

3.6 Residual current operated devices (RCDs) 531

A core-balance transformer assembly is used to detect the existence of an earth fault. This detects the out-of-balance current between live conductors (the residual current) that an earth fault produces. A current is then induced which is used to operate the tripping mechanism of a contact system to interrupt the circuit.

Particularly in larger circuits, residual current protection may be provided by an assembly of detectors and relays. Where a power source is needed in order to trip the circuit-breaker concerned steps must be taken to ensure that the tripping supply is available at all times

TERMINOLOGY

There are now a number of terms in use with RCD products, which are described below.

RCD (Residual current device). This is the generic term for all products which use the principle of detecting earth fault current by measuring the difference in current magnitude flowing in different supply conductors.

RCCB (Residual current operated circuit-breaker without integral overcurrent protection). A mechanical switching device designed to make, carry and break currents under normal service conditions and to cause the opening of the contacts when the residual current attains a given value under specific conditions. It is not designed to perform the functions of giving protection against overload and/or short-circuit and must always be used in conjunction with a circuit protection device.

RCBO (Residual current operated circuit-breaker (RCCB) with integral overcurrent protection). A mechanical switching device designed to make, carry and break currents under normal service conditions and to cause the opening of the contacts when the residual current attains a given value under specific conditions. In addition, it is designed to perform the functions of giving protection against overload and/or short-circuit and can be used independently of any other circuit protection device within its rated short-circuit capacity.

CBR (Circuit-breaker incorporating residual current protection). A circuit-breaker providing overcurrent protection and incorporating residual current protection either integrally (an integral CBR) or by combination with a residual current unit which may be factory or field fitted.

Note: The RCBO and CBR have the same application, both providing overcurrent and residual current protection. In general, the term RCBO is applied to the smaller devices whereas CBR is used for devices throughout the current range, with ratings up to several thousand amperes, single- and multi-phase. The RCBO and CBR are more strictly defined by the relevant standards.

SRCD (Socket-outlet incorporating a residual current device (RCD)). A socket-outlet for fixed installations incorporating an integral sensing circuit that will automatically cause the switching contacts in the main circuit to open at a predetermined value of residual current.

PRCD (Portable residual current device). A device consisting of a plug, a residual current device and one or more socket-outlets (or a provision for connection). It may incorporate overcurrent protection.

RCM (Residual current monitor). A device designed to monitor electrical installations or circuits for the presence of unbalanced earth fault currents. It does not incorporate any tripping device or overcurrent protection.

MRCD (Modular residual current device). An independently mounted device incorporating residual current protection, without overcurrent protection and capable of giving a signal to trip an associated switching device.

SRCBOs (Socket-outlets incorporating RCBs) are RCBs — RCCBs with integral overcurrent protection — connected to fixed socket-outlets.

RCCBs and RCBs meet the requirements of BS EN 61008-1 and BS EN 61009-1 respectively. SRCDs should comply with BS 7288 and PRCDs with BS 7071.

CBRs meet the requirements of BS EN 60947-2; this standard is intended to include MRCDs in the next revision.

RCMs should comply with BS EN 62020.

International and European standards are being prepared for SRCDs and PRCDs. In addition, a European standard for SRCBOs is being prepared.

RCDs for load currents below 100 A usually include the transformer and contact system within the same enclosure. Devices for load currents greater than 100 A usually comprise a transformer assembly with a detector and a separate shunt trip circuit-breaker unit or contactor, mounted together.

A WIDE CHOICE

When considering the selection of the RCD the user is provided with a choice of earth leakage sensitivity. Typically, values of residual operating current ($I_{\Delta n}$) are between 10 mA and 2 A with some devices offering adjustment of sensitivity. Adjustable devices must not be installed where they would be accessible to unauthorised persons. It is, however, normal to expect that such devices will be fitted with either a cover that can be sealed or a cover that requires a tool to gain access to the adjustment.

531-02-10

As shown previously in “Terminology”, devices are available with or without integral overcurrent protection or may be associated with an independent modular residual current relay.

The operating function of RCDs may be either independent or dependent on line voltage or dependent on an auxiliary supply. BS 7671 states that RCDs requiring an auxiliary supply and which do not operate automatically in the case of failure of that source shall be used only if:

531-02-06

- (i) protection against indirect contact is maintained by other means, or

- (ii) the device is in an installation operated and maintained by an instructed person or skilled person (because such persons should be aware of the risk).

This requirement reflects the risk of failure of the auxiliary source which could occur whilst the supply voltage remains present. In these circumstances the RCD may not operate although the circuit supply is healthy and the user may not be aware of the auxiliary power supply failure.

A test device is incorporated to allow the operation of the RCD to be checked. Operation of this device creates an out-of-balance condition within the device which establishes the integrity of the electrical and mechanical elements of the tripping device only. It should be noted that the test device does not provide a means of checking the continuity of any part of the earth path nor does it check the minimum operating current or operating time of the RCD.

The introduction of BS EN 61008 and BS EN 61009 extends the classification of residual current devices beyond that of the old UK standard BS 4293, and they include classification of such attributes as time delay facilities and operating characteristics for currents with d.c. components. RCDs are now categorised into three types as detailed below, each of which is available in the 'General' type and the 'S' (Selective) type which incorporates a time delay to provide discrimination of RCDs when connected in series. An RCD used for supplementary protection against direct contact must be of the 'General' type (without intentional time delay). In a TN system the time delay of the 'S' type RCD must not exceed the requirements of Regulation 413-02.

413-02

Types 'AC', 'A' and 'B' RCDs

Type 'AC' RCDs will provide protection against AC earth fault currents.

Type 'A' RCDs will provide protection against AC earth fault currents that contain pulsating DC components.


Type 'B' RCDs will provide protection against DC earth fault currents.

For the majority of applications type 'AC' devices are suitable, with type 'A' being used where special

circumstances exist. Type 'B' devices are manufactured and tested to IEC 60755, which is a Technical Report, with no BS or BS EN equivalent. There is no requirement for the use of type 'A' or type 'B' RCDs in BS 7671.

Type 'A' devices are important due to the wide range of electronic equipment available now which may produce a protective conductor current with a pulsating d.c. component and harmonic currents. These RCDs may utilise electronic circuitry or low remanence core material to more closely match the predetermined current/time trip characteristics allowed by the standards to achieve the most suitable performance characteristics.

DISCRIMINATION

Where, in order to minimise the risk of danger and inconvenience to the user, discrimination is required between residual current devices installed in series, the device operating characteristics must provide the required discrimination. A time delay should be provided in the 'upstream' device by the use of a type S device. Type S devices are identified by the symbol  marked on the device.

531-02-09

Tables 3.5 and 3.6 below (extracted from BS EN 61008 and BS EN 61009) provide comparative data for the devices.

TABLE 3.5

Standard values of break time and non-actuating time for Type AC RCCBs (extract from BS EN 61008)

Type	I_n	$I_{\Delta n}$	Standard values of break time(s) and non-actuating time(s) at a residual current (I_{Δ}) equal to:				
			$I_{\Delta n}$	$2 I_{\Delta n}$	$5 I_{\Delta n}$	500 A	
General	Any Value	Any Value	0.3	0.15	0.04	0.04	Maximum break times
S	≥ 25	> 0.030	0.5	0.2	0.15	0.15	Maximum break times
			0.13	0.06	0.05	0.04	Minimum non-actuating times

TABLE 3.6
Standard values of break time and non-actuating time for operating under residual conditions for Type AC RCBOs (extract from BS EN 61009)

Type	I_n	$I_{\Delta n}$	Standard values of break time(s) and non-actuating time(s) at a residual current (I_{Δ}) equal to:				
	A	A	$I_{\Delta n}$	$2 I_{\Delta n}$	$5 I_{\Delta n}$	$I_{\Delta t}$	
General	Any Value	Any Value	0.3	0.15	0.04	0.04	Maximum break times
S	≥ 25	> 0.030	0.5	0.2	0.15	0.15	Maximum break times
			0.13	0.06	0.05	0.04	Minimum non-actuating times

Definitions:

I_n = rated current of the device.

$I_{\Delta n}$ = rated residual operating current of the device.

$I_{\Delta t}$ = value of current ensuring residual current sensor does not operate before the overload sensor.

The purpose of an RCD in any installation is to provide protection against earth fault currents.

RCDs with a suitable differential current rating and operating time are therefore suitable for:

- protection against indirect contact [413-02-04](#)
- some supplementary protection against direct contact [412-06](#)
- some protection against the risk of fire caused by earth fault currents. [482-02-06](#)
[605-10-01](#)

RCDs are **intended to operate** to provide protection against phase-to-earth and neutral-to-earth faults but **do not operate** in the event of phase-to-phase or phase-to-neutral faults.

An RCD will only restrict the time during which an earth fault current flows. It cannot restrict the magnitude of the fault current, which depends solely on the circuit conditions. [412-06](#)

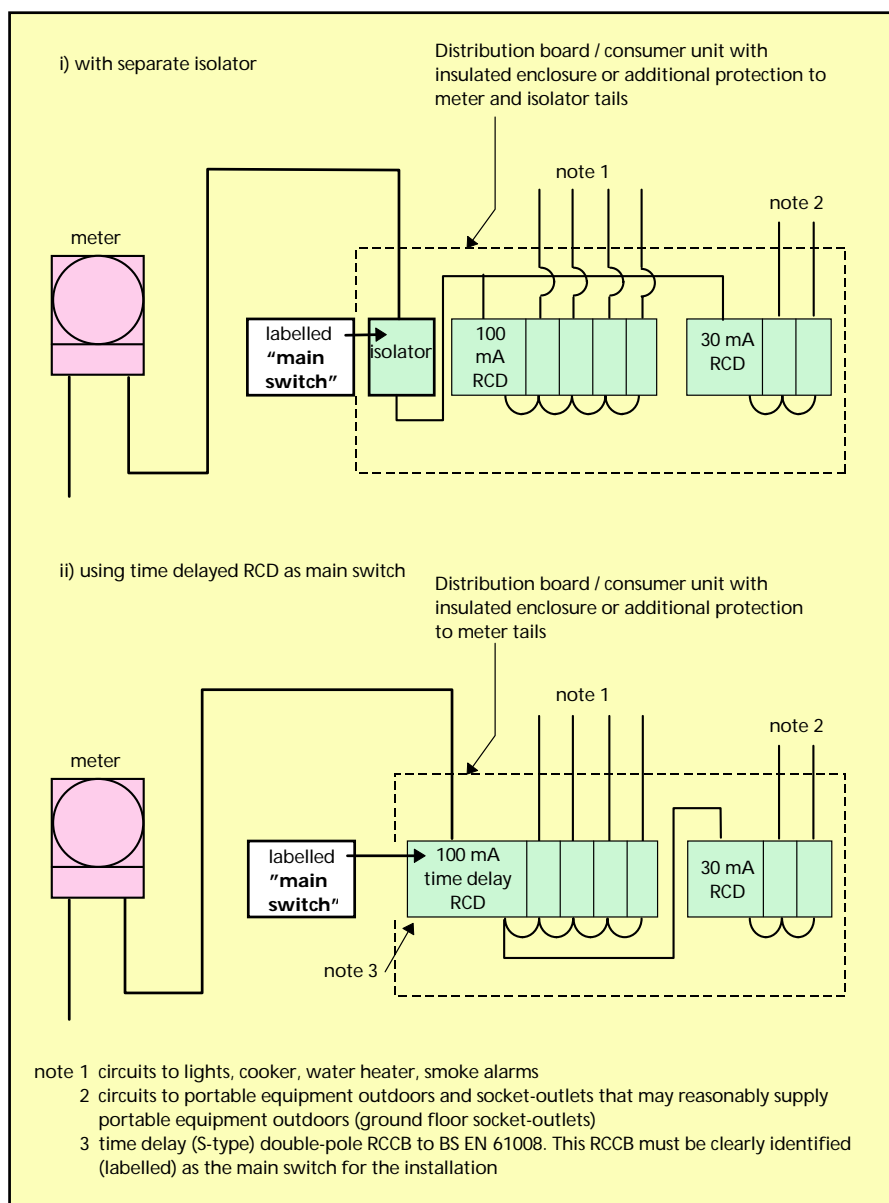
For an installation which is part of a TN system the use of an RCD may be from choice or because the earth fault loop impedance is too high for [413-02-04](#)
[413-02-07](#)

overcurrent protective devices to operate within the maximum permitted disconnection times. In the latter case, a further option is to use supplementary equipotential bonding so that there will be no dangerous potential between simultaneously accessible exposed- and extraneous-conductive-parts.

When an RCD is used the product of the rated residual operating current ($I_{\Delta n}$), in amperes, and the earth fault loop impedance (Z_s), in ohms, must not exceed 50 V. (This requirement is reduced further for some special locations in Part 6 of BS 7671.) This does not mean, however, that the voltage to earth will not exceed 50 V or such other prescribed voltage; its purpose is to ensure that when the voltage does exceed the prescribed voltage the RCD will operate.

413-02-16

Fig 3.1: Installing RCDs in a TT installation



SUPPLEMENTARY PROTECTION AGAINST DIRECT CONTACT

BS 7671 requires that an RCD be used as supplementary protection against direct contact for any socket-outlet rated at 32 amps or less that may reasonably be expected to supply portable equipment for use outdoors. As indicated in the Regulations, the RCD has then to have a rated residual operating current not exceeding 30 mA and an operating time not exceeding 40 ms at a residual current of 5 I_{Δn}. This requirement is met by general type devices complying with BS EN 61008 or BS EN 61009 (or BS 4293).

471-16-01

412-06-02

LOCATION OF RCDs

This RCD must be part of the fixed wiring of the installation and in domestic or residential installations can either be installed at the consumer unit as a separate RCD on all socket-outlet circuits (i.e. a split board) or a combined RCD/cb device (RCBO). An alternative is to specifically provide a socket-outlet with integral RCD (SRCD) to BS 7288 at each location where a supply may be taken to be used outdoors. Obviously, socket-outlets on the first floor of a house or in flats above the ground floor will not normally be suitable for use to supply equipment outdoors and so would be unlikely to need RCD protection for this purpose.

SELECTION OF TYPES OF RCDs

It is not good practice to provide a single RCD on the supply to a complete distribution board / consumer unit, which may have lighting circuits etc., as operation will interrupt the whole building supply. Regulation 314-01-01(i) requires installation circuit arrangements to be such that danger is avoided and inconvenience minimised in the event of a fault. It can be argued that protection of an installation by an RCD is not related to the 'circuit' definition of Part 2 of BS 7671, and Regulation 531-04-01 makes specific reference to a single RCD for a TT installation. However, the decision to provide a single RCD, to use a split distribution board / consumer unit or to use RCBOs must be taken on consideration of all the relevant factors, including convenience and maintenance, and not just on initial costs. For example, elderly or infirm persons may not be able to gain access to, or reset, an RCD. On a TT installation, where overall RCD protection is required, it is

314-01-01

531-04-01

advisable to install a split consumer unit with a 30 mA general RCD on the socket-outlet circuits and a 100 mA time delayed S type on the other circuits. See Figure 3.1. A single 30 mA RCD should normally not be installed at the origin of the installation.

SPECIAL LOCATIONS

For some special locations (see Part 6 of BS 7671), eg Zones A and B of swimming pools, if the protective measure against indirect contact is automatic disconnection of supply, the Regulations call for the use of an RCD having a rated residual operating current not exceeding 30 mA. Also, in an agricultural installation an RCD with a residual operating current not exceeding 500 mA is required to be installed to provide some protection against fire caused by earth leakage currents. A 500 mA RCD would not provide supplementary protection for direct contact electric shock.

602-04-01

605-10-01

TT SYSTEMS

BS 7671 recognises that, in a TT system, either RCDs or overcurrent protective devices may be used to provide protection against indirect contact. In many such installations it will not be practicable to attain a sufficiently low value of earth electrode resistance to use overcurrent protective devices. In any event, in a TT system in which protection against indirect contact is provided by EEBADS, all 230 V socket-outlet circuits in those installations have to be protected by an RCD. There is no specific limitation placed on the rated residual operating current, the sole criterion being that there should be compliance with BS 7671. Where the socket-outlet circuit is reasonably expected to supply portable equipment for use outdoors or the circuit installation is part of a special (Part 6) location, the foregoing guidance applies, and an RCD with a 30 mA maximum residual operating current must be provided.

413-02-17

413-02-18

413-02-19

413-02-20

471-08-06

TWO DISTINCT CATEGORIES

From the foregoing, it is seen that it is possible to categorise an RCD into one of two distinct categories according to its fault current operating characteristics:

- (i) an RCD having a rated residual operating current greater than 30 mA. This group is intended solely to give protection against indirect contact or fire.

100 mA, 300 mA and 500 mA RCDs are sometimes said to protect against fire in the event of earth leakage. It should be noted that these units do not offer protection from direct contact as afforded by 30 mA devices.

482-02-06
605-10-01

- (ii) RCDs having a rated residual operating current of 30 mA or less and operating time not exceeding 40 ms at a residual current of 5 $I_{\Delta n}$ as provided by BS 4293, BS 7071, BS 7288, BS EN 61008-1 or BS EN 61009-1. This group is generally referred to as 'high sensitivity'. In addition to giving protection against indirect contact, they are recognised by BS 7671 as giving supplementary protection against **direct** contact. That is, protection of persons who come into simultaneous contact with a live part and earth.

412-06-02

LIMITATIONS AND PRECAUTIONS

When an RCD is used to give supplementary protection against direct contact, it is essential that a basic measure against direct contact is also used. The use of an RCD in a circuit normally expected to have a protective conductor is not considered sufficient for protection for that circuit against indirect contact where there is no such protective conductor, not withstanding if the rated residual operating current of the RCD does not exceed 30 mA.

412-06-01
412-01-01

531-02-05

As well as providing protection against indirect contact and supplementary protection against direct contact, with a suitable differential current rating, RCDs may also provide some protection against fire risk, as stated above. The level of protection is related to the sensitivity of the device. For this purpose an RCD should be chosen with the lowest suitable rated residual operating current. A lower operating current would give a greater degree of protection, but it may also result in unwanted tripping and the connection of a further load at a later date may have an exacerbating effect, due to increased leakage.

The installation designer will often not know the sum total of the protective conductor currents occasioned by the loads. Neither will it always be known which equipment is going to be used, nor (if a number of circuits are to be protected by one RCD) how many of

531-02-04
607

those items of equipment would be energised at any one time.

Knowing the use to which the installation will be put, the designer must deduce the likely total protective conductor current in the protected circuit or make an assessment and state this in the design. In cases of difficulty, circuits may be sub-divided to reduce the possibility of unwanted tripping.

531-02-04

The total leakage of the various items of equipment protected by the RCD concerned should be such that any protective conductor current expected in normal service will not cause unwanted operation of the device. Regulation 607-07-01, which refers to circuits supplying more than one item of equipment having high protective conductor current, requires that the total protective conductor current from the equipment will not trip the RCD.

531-02-04
607-07-01

British Standards with safety requirements for electrical equipment generally include limiting values of protective conductor current. Limits apply when cold and also at operating temperature. For instance, BS EN 60335-1 and BS 3456 Part 101 (which covers the general requirements for safety of household and similar electrical appliances) and other British Standards prescribe the limits shown in Appendix J.

UNWANTED TRIPPING

Unwanted tripping (sometimes called nuisance tripping) of RCDs occurs when a leakage current causes unnecessary operation of the RCD. Such tripping may occur on heating elements, cooking appliances etc., which may have elements which absorb a small amount of moisture through imperfect element end seals when cold. When energised, this moisture provides a conductive path for increased leakage and could operate an RCD. The moisture dries out as the element heats up. Although not precluded in BS 7671, it is not a requirement to use an RCD on such circuits if other satisfactory means of earthing are available. Providing an RCD with a higher residual operating current may solve the problem, but the requirements of the Regulations would still have to be met. For example, the requirement to provide sensitive RCD protection for socket-outlets likely to be used to supply portable/hand-held equipment for use outdoors.

Further information on earth fault protection and application of RCDs is provided in Guidance Note 5. Details of the testing of RCDs are given in Guidance Note 3.

3.7 Earthed equipotential bonding and automatic disconnection of supply 413

The tables of limiting impedances given in Chapter 41 of BS 7671 are for circuits having a nominal voltage to earth (U_o) of 230 V rms a.c. For other values of U_o the tabulated earth fault loop impedance values should be multiplied by $U_o/230$.

413-02

In Appendix 3 of BS 7671, curves have been drawn to represent the slowest cb instantaneous operating times allowed by the standard and median times for fuses. To assist the designer, a set of time/current values for specific operating times has been agreed for each device and is reproduced in a box at the right hand side of each set of curves.

Appx 3

Regulations 413-02-09 and 413-02-13 specify maximum disconnection times for circuits. Regulations 413-02-10, 413-02-11 and 413-02-14 provide maximum earth fault loop impedances (Z_s) which will result in protective devices operating within the required disconnection times (of Regulations 413-02-09 and 413-02-13).

413-02

The maximum earth fault loop impedance (Z_s) for a protective device is given by:

413-02-08

$$Z_s \leq \frac{U_o}{I_a}$$

where:

U_o is the nominal voltage to Earth (the open circuit voltage at the distribution transformer is used in Appendix 3 as U_{oc}).

I_a is the current causing operation of the protective device within the specified time.

As stated in the note to Appendix 3 of BS 7671, in Tables 41B1, 41B2, 41D, 604B1, 604B2, 605B1 and 605B2 the open circuit voltage U_{oc} has been presumed to be 240 V for a nominal supply voltage U_o of 230 V. This allows for the open circuit voltage at the remote distribution transformer.

413-02

The tabulated values in BS 7671 are generally applicable for nominal 230 V supplies within the statutory limits from regional electricity companies. For other supplies the designer will need to determine open circuit voltages and calculate Z_s accordingly.

Where it is not possible to obtain a sufficiently low earth fault loop impedance, there are other options. Either apply local supplementary equipotential bonding or use a residual current device.

413-02-04

Where supplementary equipotential bonding is to be installed it is necessary to connect together the exposed-conductive-parts of equipment in the circuits concerned including the earthing contacts of socket-outlets and extraneous-conductive-parts. Supplementary bonding conductors must be selected to comply with the minimum size requirements of Regulation 547-03, and the resistance (R) of the supplementary bonding conductor between simultaneously accessible exposed-conductive-parts and extraneous-conductive-parts must fulfil the following condition:

413-02-27

413-02-28

$$R \leq \frac{50}{I_a}$$

where:

I_a is the operating current of the protective device:

- (i) for a residual current device, the rated residual operating current $I_{\Delta n}$ in amperes is used
- (ii) for an overcurrent device, the minimum current which disconnects the circuit within 5 s is used.

However, if local supplementary bonding is provided to limit shock voltage magnitude, there is still a requirement to disconnect the supply to the circuit for protection against thermal effects (see Appendix D). The circuit must be designed such that cables and equipment will not be damaged by the thermal effects of the fault current, whatever the disconnection time, as BS 7671 does not limit the disconnection time in this regard. (See Guidance Note 5 for further information.)

The application of RCDs is discussed in Section 3.6.

THE 'ALTERNATIVE METHOD'

Table 41C provides maximum values for the impedance of a final circuit protective conductor (R_2) related to the rating of the final circuit protective device. The protective conductor impedance is measured from the outlet to the main earthing terminal (or point of connection of additional main equipotential bonding if installed to comply with Regulation 413-02-13(ii)). Regulation 413-02-12 permits circuits meeting its requirements to have a disconnection time up to 5 seconds, including socket-outlet circuits. This is because the selection of such maximum protective conductor impedances will limit the magnitude and duration of voltages under earth fault conditions to a level considered to be below normally dangerous levels. The calculation of the impedances given in Table 41C is beyond the scope of this Guidance Note.

413-02-12

TYPES OF PROTECTIVE CONDUCTOR

It is worth noting the provisions of Regulation 543-02-02, and specially that steel wire armour, metal conduit and trunking etc. properly installed and maintained, are suitable for use as protective conductors where they can fulfil the shock, thermal protection requirements, and minimum requirements for cross-sectional area of Section 543 of BS 7671. Separate copper protective conductors are NOT always required. However, for functional reasons, a functional earth connection may need a copper conductor. The manufacturer of the equipment should be consulted.

543-02-02

Extraneous-conductive-parts, such as structural steel or significant internal metal components, may be used as protective bonding conductors, provided they are electrically continuous, suitably sized and precautions are taken to prevent their removal.

543-02-06

BONDING

Main equipotential bonding is required to connect extraneous-conductive-parts, including main services and metallic structural parts as given in Regulation 413-02-02, to the main earthing terminal. Conductors should be selected and installed in accordance with the requirements of Regulation 547-02-01. Table 3.7 below gives guidance on required conductor sizes.

413-02-02

547-02-01

Supplementary equipotential bonding is installed, as appropriate, in accordance with the requirements of Section 547 of BS 7671. Table 3.8 below gives guidance on conductor sizes.

547-03

413-02-28

Protective multiple earthing (PME) is now widely used for low voltage supplies (a TN-C-S system), and has specific requirements for earthing and bonding of the installation. These are discussed in more detail in Guidance Note 5.

EARTHING OF FLUSH METAL ACCESSORY BOXES

It has been questioned whether flush metal accessory boxes come within the definition of 'exposed-conductive-parts', which require to be connected to the circuit protective conductor.

An exposed-conductive-part is defined as follows:

'A conductive part of equipment which can be touched and which is not a live part but which may become live under fault conditions'.

Part 2

In normal use, such accessory boxes cannot be touched. Only when an accessory is removed can its metal accessory box be touched.

However, the view of the Wiring Regulations National Committee is that flush metal accessory boxes should be considered to be exposed-conductive-parts and connected to the main earthing terminal by means of a circuit protective conductor.

Where an accessory does not have an earthing terminal incorporated, such as certain light switches, the circuit protective conductor should be terminated at the earthing terminal in the accessory box.

Where an accessory has an earthing terminal incorporated, the protective conductor should be connected at the earthing terminal. Accessories which have an earthing terminal incorporated, such as

socket-outlets, normally have an earth strap connecting the earthing terminal to one or both of the fixing holes. Flush metal accessory boxes usually have at least one fixed lug. The Wiring Regulations National Committee has agreed that such boxes may be earthed via the tight metal-to-metal contact of the fixing screw in the fixed lug. Consequently, unless both lugs are of the adjustable type, it is not necessary to connect the earthing terminal of the accessory to the earthing terminal in the associated flush metal accessory box by a separate protective conductor (i.e. an earthing tail).

Where the circuit protective conductor is formed by conduit, trunking, ducting or the metal sheath and/or armour of a cable, an earthing tail must be fitted.

543-02-07

Where there is any doubt about the continued effectiveness, reliability and permanence of an earthing connection formed by the screws between an accessory and a metal box, it is recommended that a suitably sized earthing tail is provided.

TABLE 3.7a
Minimum cross-sectional areas (csa) of earthing conductor and main equipotential bonding conductors for TN-S systems

Csa of associated phase conductor ⁽¹⁾	mm ²	4	6	10	16	25	35	50	70
Csa of non-buried ⁽²⁾ earthing conductor ⁽³⁾	mm ²	4	6	10	16	16	16	25	35
Csa of main equipotential bonding conductors ⁽⁴⁾	mm ²	6	6	6	10	10	10	16	25

Notes:

- (1) The phase conductor is the conductor between the origin of the installation and the consumer unit or main distribution board.
- (2) In the event that the earthing conductor is buried (see Table 54A), it must have a csa of at least:
25 mm² copper or 50 mm² steel if not protected against corrosion by a sheath or mechanical damage
16 mm² copper or 16 mm² coated steel if protected against corrosion by a sheath but not protected against mechanical damage.
- (3) The csa of the earthing conductor has been selected in accordance with Table 54G of Regulation 543-01-04. Note that calculation in accordance with Regulation 543-01-03 is also permitted.
- (4) The csa of the main equipotential bonding conductors is in accordance with Regulation 547-02-01.

Where application of the regulations produces a non-standard size, a conductor having the nearest larger standard csa has been used in the above Table.

The above Table applies for copper conductors. Copper equivalent sizes may be used.

Regional Electricity Companies may require conductors with a larger csa than that given above.

TABLE 3.7b
Minimum cross-sectional areas (csa) of earthing conductor and main equipotential bonding conductors for TN-C-S (PME) systems

Csa of supply neutral conductor	mm ²	4	6	10	16	25	35	50	70
Csa of non-buried ⁽¹⁾ earthing conductor ⁽²⁾	mm ²	10	10	10	16	16	16	25	35
Csa of main equipotential bonding conductors ⁽³⁾	mm ²	10	10	10	10	10	10	16	25

Notes:

- (1) In the event that the earthing conductor is buried (see Table 54A), it must have a csa of at least:
25 mm² copper or 50 mm² steel if not protected against corrosion by a sheath or mechanical damage
16 mm² copper or 16 mm² coated steel if protected against corrosion by a sheath but not protected against mechanical damage.
- (2) PME conditions apply, hence the csa of the earthing conductor must comply with the requirements of Section 543 and Section 547. In the above Table, the csa of the earthing conductor has been selected in accordance with Table 54G of Regulation 543-01-04 and, where applicable, Table 54H of Regulation 547-02-01.
- (3) The csa of the main equipotential bonding conductors is in accordance with Table 54H.

Where application of the regulations produces a non-standard size, a conductor having the nearest larger standard csa has been used in the above Table.

The above Table applies for copper conductors. Copper equivalent sizes may be used.

Regional Electricity Companies may require conductors with a larger csa than that given above.

TABLE 3.8
Supplementary bonding conductors

Size of circuit protective conductor mm ²	Minimum cross-sectional area of supplementary bonding					
	Exposed-conductive-part to extraneous-conductive-part		Exposed-conductive-part to exposed-conductive-part		Extraneous-conductive-part to extraneous-conductive-part (1)	
	mechanically protected mm ² 1	not mechanically protected mm ² 2	mechanically protected mm ² 3	not mechanically protected mm ² 4	mechanically protected mm ² 5	not mechanically protected mm ² 6
1.0	1.0	4.0	1.0	4.0	2.5	4.0
1.5	1.0	4.0	1.5	4.0	2.5	4.0
2.5	1.5	4.0	2.5	4.0	2.5	4.0
4.0	2.5	4.0	4.0	4.0	2.5	4.0
6.0	4.0	4.0	6.0	6.0	2.5	4.0
10.0	6.0	6.0	10.0	10.0	2.5	4.0
16.0	10.0	10.0	16.0	16.0	2.5	4.0

Notes:

1. If one of the extraneous-conductive-parts is connected to an exposed-conductive-part, the bond must be no smaller than that required for bonds between exposed-conductive-parts and extraneous-conductive-parts — column 1 or 2.

3.8 Protection against overvoltage

Chapter 44 of BS 7671 is the implementation within the UK of CENELEC harmonisation document HD 384.4.443, which the UK is obliged to adopt by virtue of its membership of CENELEC. This Chapter deals in part with transient overvoltages of atmospheric origin (i.e. lightning strikes). The condition of external influences which exists in the United Kingdom is AQ1 (see below for an explanation), which means that the UK is in the fortunate position of not having to install surge protective devices to protect the wiring and equipment comprising a fixed installation, under normal circumstances.

[Chap 44](#)

SCOPE AND OBJECT

Chapter 44 deals with protection of electrical installations against transient overvoltages:

- of atmospheric origin (i.e. lightning strikes) transmitted by the supply distribution system, and
- switching overvoltages generated by the equipment within the installation.

This is a specific application of the fundamental principles in Regulation 130-06 for protection against overvoltage. In addition, Regulation 132-01-08 requires electrical equipment to be selected so that it will not cause, so far as is reasonable practicable, harmful effects on other equipment or impair the supply during normal service, including switching operations.

[130-06](#)
[132-01-08](#)

Lightning protection of buildings, which is excluded from the scope of BS 7671, is covered by BS 6651 : 1999, Code of practice for protection of structures against lightning.

[BS 6651](#)

AQ CRITERIA

Overvoltages of atmospheric origin are categorised in Appendix 5 of BS 7671 as:

[App 5](#)

AQ1 – Negligible (less or equal to 25 thunderstorm days per year)

AQ2 – Indirect (more than 25 thunderstorm days per year)

AQ3 – Direct.

A risk assessment method may be used instead of the AQ criteria in determining whether surge protection should be used.

[443-02-04](#)

EQUIPMENT CATEGORIES

Chapter 44 requires relevant equipment product standards to have at least the values of withstand voltages of Table 44A. Examples of the type of equipment in each category are given in Table 44B.

Table 44A
Table 44B

Category IV equipment (equipment with very high impulse voltage), has a required minimum impulse voltage of 6 kV, for a nominal voltage of 230 volts. As explained in Table 44B, such equipment is to be used at or in the proximity of the origin of the electrical installation, upstream of the main distribution board. As such equipment is installed at or near the origin of the supply, e.g. an electricity meter, primary overcurrent device or ripple control unit, any transient overvoltage is likely to be at a high value due to there being little or no attenuation.

Category I equipment (equipment with reduced impulse voltage), has a required minimum impulse voltage of 1.5 kV, for a nominal voltage of 230 volts, and is not to be connected to the electricity supply without surge protection. Table 44B comments that Category I equipment is intended to be connected to the fixed electrical installation where protection against transient overvoltage is external to the equipment.

WHERE PROTECTION IS NOT REQUIRED

In the following situations, overvoltage protective devices are not required for protection of an installation against overvoltage of atmospheric origin. The only requirement is that the impulse withstand voltage of equipment is in accordance with Table 44A:

Table 44A

- where an installation is supplied by a low voltage system containing no overhead lines
(A suspended cable having insulated conductors with earthed metallic covering or insulated conductors twisted together, is deemed to be an underground cable for the purposes of Chapter 44.)
- where the condition of external influences AQ1 exists and an installation is supplied by a low voltage network which includes overhead lines, or where an installation includes an overhead line.

As mentioned in the introduction, the condition of external influences AQ1 exists in the United Kingdom.

WHERE PROTECTION IS REQUIRED

Protection of an installation against voltages of atmospheric origin must be provided if the ceramic level at a location corresponds to the condition of external influences AQ2 and the installation is supplied by, or includes, a low voltage overhead line.

A lightning flash density greater than 2.24 flashes/km²/year corresponds to condition AQ2 and although the mean flash density in the UK does not exceed 1.0 flash/km²/year, the flash may be concentrated at a particular location which, as a consequence, will be subject to a higher than expected risk of experiencing a high level of overvoltage. Installations associated with tall isolated structures, for example radio transmitter towers, may require protection if situated in an area where the lightning flash density is 1.0 flash/km²/year. A risk assessment of structures in areas of high lightning activity in the UK is necessary in order to determine whether or not protection of an installation is required.

Where protection against overvoltages of atmospheric origin is required, such protection must be provided in the building by:

- (i) a surge protection device with a protection level not exceeding Category II, or
- (ii) other means providing at least an equivalent attenuation of overvoltages.

Overvoltage protective devices must be located as close as possible to the origin of the installation.

443-02-06

SURGE PROTECTIVE DEVICES (SPDs)

A surge protective device (SPD) is a device that is intended to limit transient overvoltages and divert surge currents. SPDs must have the necessary capability to deal with the current levels and durations involved in the switching surges to be expected at their point of installation.

In most cases, switching overvoltages are less damaging than lightning overvoltages, and SPDs which are effective for protection against lightning overvoltages are also effective against switching surges.

SWITCHING OVERVOLTAGES

Generally, any switching operation, fault initiation, interruption, etc. in an electrical installation is followed by a transient phenomenon in which overvoltages can occur. The sudden change in the system can initiate damped oscillations with high frequencies (determined by the resonant frequencies of the network), until the system is stabilised to its new steady state. The magnitude of the switching overvoltages depends on several parameters, such as the type of circuit, the kind of switching operation (closing, opening, restriking), the loads, and the protection device. In most cases, the maximum overvoltage is up to twice the amplitude of the system voltage, but higher values can occur, especially when switching inductive loads (motors, transformers) or capacitive loads, or even resistive loads connected very near to the terminals of a supply transformer. Also, interruption of short-circuit currents can cause high overvoltages. If current chopping occurs, relatively high energy can be stored in inductive loads, and oscillations can occur on the load side of the opening switch or protective device.

SECTION 4 — External Influences

4.1 External influences

The effect of environmental conditions and general characteristics around various parts of the installation must be assessed to enable suitable electrical equipment to be specified.

300-01-01

A list of external influences relating to Chapter 32 of BS 7671 is given in Appendix 5. These external influences are also identified in Section 522. Chapter 52 of BS 7671 applies to the selection and erection of wiring systems, but the classification of external influences is applicable and relevant to all types of electrical equipment.

Chap 32
Appx 5

522

If every part of the wiring system complies with the IP degree of protection for the worst circumstances expected in the particular location, and correct measures are taken during installation and maintenance, the selection and erection requirements of BS 7671 with respect to external influences will generally be satisfied. Due consideration must be given to the installation of equipment, including fixings, and manufacturers' installation instructions complied with, or the declared IP rating of the equipment may not be achieved. Good workmanship is, as always, required.

133-01-01

All electrical equipment selected must be suitable for its location of use and method of installation, and should not be modified on site unless it is designed and manufactured to allow this. Manufacturers' recommendations and instructions should be followed. BS 7540 : 1994 'Guide to use of cables with a rated voltage not exceeding 450/750 V' gives general cable selection guidance.

512-06-01

Equipment must also be protected against damage and ingress of foreign bodies during construction work. This damage and ingress may be more severe than operational conditions.

References are made in the following sections to certain aspects covered in Section 522. The coding used in Appendix 5 of BS 7671 is given in parenthesis.

4.2 Ambient temperature (AA) 522

Local ambient temperature means the temperature of the air or other medium around the equipment. There can be a wide range between the highest and lowest temperatures around equipment, depending on time of year, artificial heating etc. A design must be based on the most extreme ambient envisaged. In the UK external ambient temperatures between -10 °C and +35 °C commonly occur, and occasionally even lower or higher temperatures than these.

522-01

The cable current-carrying capacity tables in Appendix 4 of BS 7671 are based on an ambient temperature of 30 °C. Where this temperature differs, correction factors are to be used. Appendix 4 Clause 2.1 and Tables 4C1 and 4C2 should be consulted.

Appx 4
Table 4C1
Table 4C2

Although the temperature in most installations in the UK would not usually be over 30 °C, close to a domestic heating appliance or in an industrial environment it may be higher. BS 1363 accessories and cable with an operating temperature rating of 70 °C or lower are not recommended for installation in areas of higher ambient temperature such as airing cupboards, and in particular must not be covered with clothes or other items. Heat resisting cables appropriate to the ambient and equipment temperatures must be utilised.

522-01

Cables in heated floors or other parts must be suitable for the highest temperature reached.

Cables and equipment must be suitable for the lowest likely temperature. In particular, general purpose thermoplastic cables should not be installed in cold places. Attention is drawn to the fact that, as the temperature decreases, thermoplastic compounds become increasingly stiff and brittle, with the result that, if the cable is bent quickly to a small radius or is struck at temperatures in the region of 0 °C or lower, there is a risk of shattering the thermoplastic components.

To avoid the risk of damage during handling, it is desirable that thermoplastic insulated or sheathed

cables should be installed only when both the cable and the ambient temperature are above 0 °C and have been so for the previous 24 hours, or where special precautions have been taken to maintain the cables above this temperature. BS 7540 : 1994 advises a minimum ambient temperature of 5 °C for some types of thermoplastic insulated and sheathed cables.

4.3 Solar radiation (AN) and ultra-violet radiation **522**

Where cables are installed in situations subject to solar or other radiant heat sources, they should be resistant to damage from that source or effectively protected from damage. Cables may need to be derated where there are heat sources or heat is absorbed by solar gain.

[522-02](#)
[522-11](#)

To protect cables from the adverse effects of ultra-violet (uv) radiation, the sheaths often contain carbon black or alternative uv stabilisers. Physically shielding the cables from direct solar radiation may also be necessary. In situations where high ambient temperatures are present (e.g. hot countries) cables will need to be derated. Shielding may be necessary, to protect from both direct heat and heat absorbed from solar radiation, but cables should be freely ventilated. Cable manufacturers will provide guidance on the use of cables outdoors.

Where weather resistance is required the type of cable sheath to give protection should be carefully considered. Cables sheathed with thermoplastic to BS 6746 or synthetic thermosetting to BS 6899 can give adequate performance but natural thermosetting do not perform well. Cable sheathing materials should conform to BS 7655. Protection from mechanical damage may also be required. Additional advice is given in BS 7540.

The exposure of thermoplastic insulation or sheathing to high temperatures for any length of time will lead to softening. If such a temperature is maintained for long periods, the thermoplastic can decompose and give off corrosive products which may attack the conductors and other metalwork. Softening of the thermoplastic may also allow the conductor to move through the insulation if any mechanical force is applied (e.g. cables hanging vertically). Decentralisation

of conductors may also take place where cables are overheated when bunched inside trunking.

4.4 The IP and IK classifications **522**

The designer must assess each area of external influence then ensure the required classification is selected and applied correctly.

512-06

The IP classification standard BS EN 60529 : 1991 identifies degrees of protection against the ingress of solids and water. It has replaced old descriptions such as 'ordinary', 'drip-proof', 'splash-proof' and 'water-tight', which are not defined terms.

The IK classification standard BS EN 50102 describes a system for classifying the degrees of protection provided by enclosures for electrical equipment against external mechanical impacts. The letters IK are followed by two numerals which identify a specific impact energy.

Appendix B of this Guidance Note lists the degrees of protection indicated by these classifications.

4.5 Presence of water (AD) or high humidity (AB) **522**

Any wiring system or equipment selected and installed must be suitable for its location and able to operate satisfactorily without deterioration during its working life. The presence of water can occur in several ways, e.g. rain, splashing, steam/humidity, condensation, and its effects must be considered at each location it is expected to be present. Suitable protection must be provided, both during construction and for the completed installation.

522-03

In damp situations and wherever they are exposed to the weather, all metal sheaths and armour of cables, metal conduit, ducts, trunking, clips and their fixings should be of corrosion-resistant material or finish. They should not be in contact with other metals with which they are liable to set up electrolytic action (see 4.7 also).

522-05

In any situation and during installation, the exposed insulation at terminations and joints of cables which are insulated with hygroscopic material, e.g. mineral insulated cable, must be sealed against the ingress of moisture. Such sealing material, and any material used to insulate the conductors where they emerge from the cable insulation, should have adequate

insulating and moisture-proofing properties and retain those properties throughout the range of service temperatures.

The manufacturer's recommendations regarding the termination and installation of all types of cables must be strictly observed.

In a damp situation, enclosures for cores of sheathed cables from which the sheath has been removed and for non-sheathed cables at terminations of conduit, duct, ducting or trunking systems should be damp-proof and corrosion-resistant. Every joint in a cable should be suitably protected against the effects of moisture.

526

Conduit systems not designed to be sealed should be provided with drainage outlets at any points in the installation where moisture might otherwise collect. Those outlets must not affect the electrical safety of the system, or allow vermin access.

522-03-02

If it is necessary to locate a switch, socket-outlet etc. near to a sink, the device must be protected from any water splashing that may occur. This can be achieved either by locating the device in a position where it will not be exposed to splashing, or providing a splash resistant covering, or providing a weather protected device. (Further information is contained in Appendix C(f), 'Sinks and electrical accessories')

512-06-01

It may occasionally be necessary to consider the installation of cables in locations that permanently contain water, such as fountains and marinas. It must be noted that the plastic insulating and sheathing materials are not totally waterproof and will absorb some water over time. Such cables are not suitable for continuous immersion and a cable manufacturer's advice should be taken for such installations. (See Guidance Note 7 for further information.)

4.6 Presence of solid foreign bodies (AE) 522

Where dusty conditions may be expected to occur, equipment and enclosures for conductors and their joints and terminations should have the degree of protection of at least IP5X. There are two conditions recognised in this particular IP Code, the first condition being where the normal working cycle of

522-04

the equipment concerned causes reductions in air pressure, e.g. thermal cycling effects, and the second condition being where such pressure reductions do not occur. These conditions should be considered during the design and selection procedure and appropriate equipment chosen.

It is necessary to have good operational housekeeping policies to ensure dust is kept to a minimum. A build-up of dust on electrical equipment, cables etc can act as thermal insulation and cause overheating of the equipment or cable. The dust may even be of a type that can ignite if the temperature of equipment rises. However, combustible dusts are outside the scope of this Guidance Note, and reference should be made to BS EN 50281 for further guidance.

To assist in cleaning in dusty installations, a design should be developed in which inaccessible surfaces and locations are minimised and surfaces that can collect dust are made as small as practicable, or sloped to shed dust. Cable ladder rack is preferred to cable tray, and ladder rack should be suspended vertically (i.e. on edge) rather than horizontally.

4.7 Presence of corrosive or polluting substances (AF)
522

In damp situations, where metal cable sheaths and armour of cables, metal conduit and conduit fittings, metal ducting and trunking systems, and associated metal fixings, are liable to chemical or electrolytic attack by materials of a structure with which they may come into contact, it is necessary to take suitable precautions against corrosion, such as galvanising or plating.

522-05

Materials likely to cause such attack include:

- materials containing magnesium chloride which are used in the construction of floors and walls
- plaster coats containing corrosive salts
- lime, cement and plaster, for example on unpainted walls, or over cables buried in chases
- oak and other acidic woods
- dissimilar metals liable to set up electrolytic action.

Application of suitable coatings before erection, or prevention of contact by separation with plastics, are recognised as effective precautions against corrosion.

Contact between bare aluminium conductors, aluminium sheaths or aluminium conduits and any parts made of brass or other metal having a high copper content, should be avoided especially in damp situations, unless the parts are suitably plated. If such contact is unavoidable, the joint should be completely protected against ingress of moisture. Modern, friction welded bi-metallic joints are available for most tape to tape or tape to cable joints. Wiped joints in aluminium sheathed cables should always be protected against moisture by a suitable paint, by an impervious tape, or by embedding in bitumen.

Bare copper sheathed cables should not be laid in contact with zinc plated (galvanised) materials such as cable tray in damp conditions. This is because the electropotential series indicates that zinc is anodic to copper and therefore preferential corrosion of the zinc plating may occur. This action will not affect the copper, but may cause corrosion of the cable tray. The presence of moisture is essential to produce electrolytic action, therefore, in dry conditions this action will not occur. If moisture is present, then electrolytic action will take place, but the extent of any corrosion is dependent upon the relative areas of the two metals and the conductivity of the electrolyte (moisture in this instance). In these circumstances thermoplastic sheathing should be used.

Hostile environments and chemicals also can attack the conductor, its insulation and sheath and any enclosure or equipment.

A few examples of this are:

- petroleum products, creosote, some solvents and hydrocarbons attack rubber and may attack polymeric materials such as thermoplastic
- plasticisers migrate to polystyrene from thermoplastic and also to some types of plaster (see 7.5 also)
- hostile atmospheres (e.g. those in the vicinity of plastics processing machinery, and vulcanising which produces a sulphurous atmosphere)
- coastal areas with salt-laden air
- in areas where animals are kept (agricultural environments, kennels, etc) animal urine can be corrosive.

In such cases the manufacturer's advice should be obtained and care taken in the measures employed.

To provide adequate protection from corrosion, the corrosive substances must be clearly identified and the manufacturer's or a specialist's advice obtained.

**4.8 Impact (AG),
vibration (AH)
and other
mechanical
stresses (AJ)
522**

Any part of the fixed installation which may be exposed to a severe impact must be able to survive it. In workshops where heavy objects are moved, the traffic routes should be avoided. If it is not possible to avoid the traffic routes, heavy duty equipment or localised protection must be provided.

522-06
522-07
522-08

Similarly, a socket-outlet fixed at low level should not be placed where it is likely to be damaged by furniture or cleaning equipment. Approved Document M of the Building Regulations 2000, requires that switches and socket-outlets in dwellings be installed at a height of between 450 mm and 1200 mm from the finished floor level. (See Appendix C(f) Fig C1).

See Appendix B for details of the IK code for classification of the degrees of protection by enclosures against impacts.

Final connections to plant that is adjustable or produces vibration must be designed to accommodate this and a final connection made in flexible cables or conduit or a properly supported cable vibration loop allowed.

Allowance must be made for the thermal expansion and contraction of long runs of steel or plastic conduit or trunking, and adequate cable slack provided to allow free movement. The expansion or contraction of plastic conduit or trunking is greater than that of steel for the same temperature change.

For busbar trunking systems BS EN 60439-2 identifies a busbar trunking unit for building movements. Such a unit allows for the movement of a building due to thermal expansion and contraction. Reference should be made to the manufacturer since requirements may differ with respect to design, current rating or orientation of the busbar trunking system (i.e. riser or horizontal distribution).

Cables crossing a building expansion joint should be installed with adequate slack to allow movement, and a gap left in any supporting tray or steelwork. A flexible joint should be provided in conduit or trunking systems.

522-12

4.9 Presence of fauna (AL), flora and/or mould growth (AK)

Special requirements for animal housing areas will depend on the type and size of animal and its required environment. Section 605 gives some guidance on farm requirements but specialist advice will be needed for more unusual species.

605

Cables and equipment may be subject to attack and damage from plants and animals as well as the environment. The damage may be caused by such diverse occurrences as vermin chewing cables, insect or vermin entry into equipment, physical impact/ damage by larger animals such as can occur in agricultural areas, and plant growth placing excessive strains on equipment over a period of time - a small lighting column base can be moved by tree roots - or choking equipment and blocking ventilation. Rodents have a particular taste for some forms of cable sheath and can gnaw through the cable sheath and insulation to expose conductors. They build nests and the nests are usually constructed of flammable material. Such a combination is ideal for the propagation of fire where the nest surrounds the wiring material. Cables impregnated with anti-vermin compounds have not been found to be successful and may not comply with Health and Safety legislation. Cables should not be routed on likely vermin 'runs', e.g. on the tops of walls or in voids etc., but located in full view for easy inspection for damage.

522-09

522-10

As far as practicable, cables and equipment should be installed away from areas or routes used by animals or be of a type to withstand such attack. Thermoplastic sheathing and insulation may be chewed by vermin and in such areas steel conduit may be required.

The access of insects is difficult to prevent as they can enter through small gaps such as vent holes. Equipment and wiring systems in such locations must be carefully sealed and any vents fitted with breathers etc.

4.10 Potentially explosive atmospheres

The selection and erection of equipment for installations in areas with potentially explosive atmospheres of explosive gases and vapours or combustible dusts is outside the scope of this Guidance Note. The design, and the selection and erection of equipment for such installations requires specialist knowledge.

Further information may be found in BS EN 60079 - Electrical apparatus for explosive gas atmospheres, (parts 10 and 14 have replaced BS 5345), and BS EN 50281 'Electrical apparatus for use in the presence of combustible dust'.

The Dangerous Substances and Explosive Atmospheres Regulations 2002 give the statutory requirements.

4.11 Choice of protective measures as a function of external influences

Where particular risks of danger of fire exist, Chapter 48 of BS 7671 requires that precautions, additional to those in Chapter 42 and Section 527, must be taken. Specialist advice may need to be sought in order to determine whether specific circumstances warrant such precautions.

[Chap 48](#)

[Chap 42
Sect 527](#)

The precautions are applicable to electrical installations in:

- (1) locations where a risk of fire exists due to the nature of processed or stored materials
- (2) locations constructed of combustible materials.

(1) LOCATIONS WHERE A RISK OF FIRE EXISTS DUE TO THE NATURE OF PROCESSED OR STORED MATERIALS

A clear distinction has to be made between installations in locations with explosion risks and locations with risk of fire due to the nature of the process undertaken in the location or because of the nature of materials stored.

If the risk is from the process or materials stored, and there is no explosion risk, the following must be followed:

- (i) restricting electrical equipment to only that necessary for the location
- (ii) selecting only equipment appropriate for the location, e.g. of suitable IP rating

[482-02-01](#)

[482-02-03](#)

(iii) where wiring is not completely embedded in non-combustible material, such as plaster or concrete, selecting wiring systems with non fire propagation characteristics, e.g. cables enclosed in conduit complying with the non flame propagating requirements of BS EN 50086 or ducting or trunking complying with BS EN 50085 or mineral insulated sheathed cable (micc). Cable types complying with BS EN 50265-2.1 or 2.2 are acceptable	482-02-04
(iv) if, of necessity, a wiring system traverses such a location but is not necessary to the use of the location, then the cabling should have no connections unless in an enclosure meeting the Fire Test Requirements of BS 6458 (2.1) with the following test temperatures: 750 °C for surface mounted installations, 850 °C for installation in combustible hollow walls	482-02-05 BS 6458
(v) placing overload and short-circuit protection devices upstream and outside the location	473-01-02 473-02-03
(vi) except for mineral insulated cables and busbar trunking, fitting an RCD with a rated residual operating current of 300 mA or less. Where there is concern that quite low current faults could cause fire, the rated residual operating current should not exceed 30 mA	482-02-06
(vii) providing all wiring systems with a protective conductor. PEN conductors must not be installed for equipment within the location	482-02-07
(viii) installing an isolating device (disconnector) outside the location to switch off all supplies to the location	
(ix) always switching the neutral as well as the phase conductors when isolating equipment	482-02-08
(x) not installing bare and live conductors for sliding contact wiring except where there is no practical alternative, e.g. sliding contacts for a hoist when either an enclosed system or flexible cables should be used	482-02-09
(xi) using only rubber sheathed cables to BS 6008 type HO7 RN-F or equivalent for flexible wiring	482-02-10 BS 6008
(xii) if SELV or PELV circuits are installed, containing all live parts within enclosures to IP5X or providing insulation	

- (xiii) installing all switchgear outside the location unless it is completely enclosed by non-combustible material
- (xiv) protecting all motors (that are not continuously supervised) against excessive temperature by overload protective devices with manual resetting or equivalent 482-02-11
- (xv) protecting motors with : 482-02-11
 - star-delta starting without automatic changeover from star to delta against excessive temperature in the star mode as well as the delta
 - slipping starters from being left with resistance in the rotor circuit
- (xvi) using luminaires with limited surface temperatures only. Fittings manufactured to BS EN 60598 have surface temperatures limited to 90 °C under normal conditions and 115 °C under fault 482-02-12
BS EN 60598
- (xvii) avoiding the use of small spotlights and projectors. Any necessary should be separated from combustible materials by minimum distances as follows: 482-02-13
 - up to 100 W - 0.5 metre
 - between 100-300 W - 0.8 metre
 - between 300-500 W - 1 metre

(Note: greater distances may be necessary if the lamps are focused on combustible material)
- (xviii) taking precautions against components that are likely to run hot, such as lamps, from falling out of luminaires 482-02-14
- (xix) drawing air for heating systems with forced ventilation from areas where dust is not likely to be present. The temperature of heated air must be limited and temperature limiting devices must have manual resets only 482-02-15
- (xx) providing heating appliances with barriers and selecting types likely to prevent the ignition of dust or fibres 482-02-16
482-06-17
- (xxi) ensuring by selection that, in normal operation, enclosures of thermal appliances such as heaters do not attain a temperature higher than 90 °C. 482-02-18

(2) LOCATIONS CONSTRUCTED OF COMBUSTIBLE MATERIALS

Electrical equipment which is to be installed in or on a combustible wall must:

482-03-01
482-03-02

- (i) comply with the relevant standard. There is a requirement on manufacturers to ensure that electrical equipment meets the fire resistance tests within the standards which cover such products; or
- (ii) be separated with a suitable thickness of fire resistant material. As such materials generally provide excellent heat insulation, this could have the effect of making the interior of the enclosure hotter where flush-mounted equipment is separated from the building material by additional thermal insulation.

CABLES AND CORDS

482-03-03

Cables and cords must comply with the requirements of either one of two flame tests which are carried out by manufacturers. These are:

BS EN 50265-2.1 : 1999 Procedures. 1kW pre-mixed flame, or

BS EN 50265-2.2 : 1999 Procedures. Diffusion flame.

Cables manufactured to the following standards all meet the flame tests: BS 5467, BS 6004, BS 6346, BS 6724, BS 6883, BS 7211, BS 7629, BS 7846, BS 7889 and BS 7919. (See Table F1 in Appendix F for a comparison of harmonised cable types to BS 6004). It would be prudent to check with the wholesaler to ensure before purchasing cables that they comply with one of these Standards.

CONDUIT AND TRUNKING SYSTEMS

482-03-04

Conduit systems must be in accordance with BS EN 50086-1 : 1994 General requirements. Trunking systems and ducting systems must be in accordance with BS EN 50085-1 : 1999 General requirements. There is a requirement on manufacturers to ensure that conduit, trunking and ducting systems meet the fire resistance tests within these standards. Further information on both standards is contained in Section 5.1 of this Guidance Note.

Section 5 — Installation of Cables

5.1 Cable selection 521

Cables must be selected to comply with the electrical characteristics of current rating, voltage drop etc. as required by Parts 4 and 5 of BS 7671 and the physical protection characteristics as required by Chapter 52. The correct selection and erection of a complete wiring system is necessary to provide compliance with Chapter 52.

Over-specification of cable performance requirements can result in increased installation costs, and the designer must assess performance reasonably. Cables must be selected to perform their required function in the environment throughout their expected life, but there is no justification for over design. (Consideration of the overall lifetime costs of a cable is not overdesign. There may be a trade-off to increase the size of a cable to reduce overall energy losses in the cable during its life.) Regular periodic inspection (and testing as necessary) of an installation must be carried out to monitor cable and equipment conditions, and this should identify changes of use of an installation that would require modifications to the installation during its life. (See IEE Guidance Note 3 for further information).

Cables in emergency and life safety systems must be able to perform their intended function in emergency situations such as fire. BS 6387 "Performance requirements for cables required to maintain circuit integrity under fire conditions" specifies performance requirements and gives test methods for mechanical and fire tests applicable to cables rated at voltages not exceeding 450/750 V and for mineral insulated cables conforming to BS 6207. This standard specifies those requirements of the cables related to characteristics required to enable circuit integrity to be maintained under fire conditions.

The cables are intended to be used for wiring and interconnection where it is required to maintain circuit integrity under fire conditions for longer periods than can be achieved with cables of conventional construction.

Cables tested to this standard are categorised under three separate test conditions. A separate sample of cable can be used for each test.

The first letter indicates a resistance to fire alone (simulated burning):

- A** 650 °C for 3 hours
- B** 750 °C for 3 hours
- C** 950 °C for 3 hours
- S** 950 °C for 20 minutes.

The second letter **W** indicates resistance to fire at 650 °C with water (simulating fire extinguishing for a 30 minute test period).

The third letter indicates resistance to fire with mechanical shock. Mechanical shocks are applied to the cable at specified temperatures of:

- X** 650 °C
- Y** 750 °C
- Z** 950 °C.

The highest cable rating is category CWZ which shows that a cable has passed the most severe test in each category, but not necessarily with the same cable sample. Designers must not assume that to specify any cable with a CWZ rating will provide total integrity in case of fire. Installation conditions and effects must be carefully considered. Cables may perform only for the stated time but may not be fire survivable, and could have only a limited integrity. Mineral insulated cable is the only cable understood to have passed the three tests of BS 6387 using the same sample of cable.

See Guidance Note 4 "Protection against fire" for further information on cable selection for fire protection and alarm systems.

BS 7540 : 1994 "Guide to use of cables with a rated voltage not exceeding 450/750 V" gives guidance on the general use of some types of cable, mainly the general wiring types (see Appendix F also).

General building wiring cables that comply with the requirements of BS EN 50265-1 : 1999 (formerly BS 4066-1: 1995) for flame propagation are considered to have a suitable non-flame propagating property to allow their installation in buildings and between fire zones or compartments without further physical fire protection, unless there is significant risk of fire (e.g. hazardous or flammable materials stored or special processes). Cables not to BS EN 50265-1 may not pass unprotected between building fire compartments or zones and should generally only be used in short lengths and not in areas of fire risk.

527-01-03

527-01-04

Most types of general cable comply with BS EN 50265-1, including thermoplastic insulated and sheathed cables to BS 6004 and thermosetting/SWA/thermoplastic cables to BS 5467. A more severe test is prescribed in BS 4066 Part 3, which tests flame propagation of a group of cables and it may be that cables installed in groups in risers, or control and communications cables where bunched, should be required to comply with this standard.

482-02-04

BS EN 50086 : Conduit systems for electrical installations - replaces:

BS 731 : Pt 1: 1952 (1993): Flexible steel conduits
 BS 4568 : Steel conduit and fittings with metric threads
 BS 4607 : Non-metallic conduit and fittings
 BS 6099 : Conduits for electrical installations.

BS EN 50086 is in various parts; the following parts have been published:

BS EN 50086-1 : 1994	General requirements
BS EN 50086-2-1 : 1996	Particular requirements for rigid conduit systems.
BS EN 50086-2-2 : 1996	Particular requirements for pliable conduit systems.
BS EN 50086-2-3 : 1996	Particular requirements for flexible conduit systems.
BS EN 50086-2-4 : 1994	Particular requirements for conduit systems buried underground.

The British Standards are still valid for conduit materials for repairs or modifications to older installations but the BS ENs should be utilised for new installations.

BS EN 50085-1: 1999: Cable trunking and cable ducting systems for electrical installations - deals with

general requirements and BS EN 50085-2-3 : 2001 gives particular requirements.

These new standards are performance related and allow materials that will satisfy the required performance classification, and, whilst these new Standards do not change any existing material specifications, they provide alignment of requirements throughout Europe. It is no longer correct to mention 'material specification' in relation to these standards. Products meeting the Harmonised Standards may then carry the 'CE' mark. However, it will be necessary to check the technical literature or with the manufacturer for special applications.

527-01-05

The designer must select an appropriate level of performance for application for the specific characteristics of the installation, and again, over-specification in design will increase costs. A listing of performance criteria for conduit is given in Table 5.1 below.

TABLE 5.1
Performance requirements in BS EN 50086-1 :
General conditions for conduit systems

Performance characteristics	Performance classification							
	0	1	2	3	4	5	6	7
Compression, N	0	125	320	750	1250	4000	-	-
Impact, N	-	0.5	1.0	2.0	6.0	20.0	-	-
Low temperature, °C	-	+5	-5	-15	-25	-45	-	-
High temperature, °C	-	+60	+90	+105	+120	+150	+250	+400
IP rating <i>Solid object</i>	-	-	-	2.5 mm	1.0 mm	dust protected	dust tight	-
<i>Water</i>	0	drops	drops at 15°	spray	splash-ing	jets	powerful jets	temporary immersion
Corrosion protection	-	low inside and outside	medium inside and outside	medium inside, high outside	high inside and outside	-	-	-
Tensile strength, N	0	100	250	500	1000	2500	-	-
Suspended load, N	0	20	30	150	450	850	-	-

Specific flame propagation tests are included in the conduit standards. Flame propagation is defined in terms of a pass or fail test based on temperatures consistent with human safety (temperatures above which persons cannot survive). Materials that pass the test are identified as “non flame propagating” and are required to be marked with a clearly legible identification or may be of any colour except yellow, orange or red. Flame propagating conduit must be coloured orange. Related fire products such as smoke production are being considered, but as yet are not covered in the Standards.

527-01-05

5.2 Cable concealed in structures 522

Where a cable is to be concealed in plaster, capping or conduit may be provided to position the cable and to reduce the risk of damage during the plastering process.

522-06

BS 7671 requires that non-sheathed cables for fixed wiring shall be enclosed in conduit, ducting or trunking. Non-sheathed cables must not be installed in building ducts formed in-situ because drawing-in of such cables is likely to damage their insulation.

521-07-03

Cables to be installed on walls and the like should have a sheath and/or armour suitably resistant to any mechanical damage likely to occur or be contained in a conduit system or other enclosure able to guard against such damage.

522-08

Cables concealed within a wall must be carefully routed. The route and depth must be such that the cables are not in an unexpected place. Fixings for other items sharing the space must be positioned so that there is no risk of penetrating the cables. BS 7671 details conventional routes within which there is a high risk of encountering a cable (see Fig 5.1).

522-06

Where a cable is concealed in a wall or partition at a depth of less than 50 mm, it must be installed within 150 mm of the top of the wall or partition or within 150 mm of an angle formed by two adjoining walls or partitions. A cable may be installed outside these zones only in a straight run, either horizontally or vertically to a point, accessory or switchgear (see Fig 5.1). Where this cannot be achieved, the concealed cable must incorporate an earthed metallic covering which complies with the requirements of Chapter 54 for

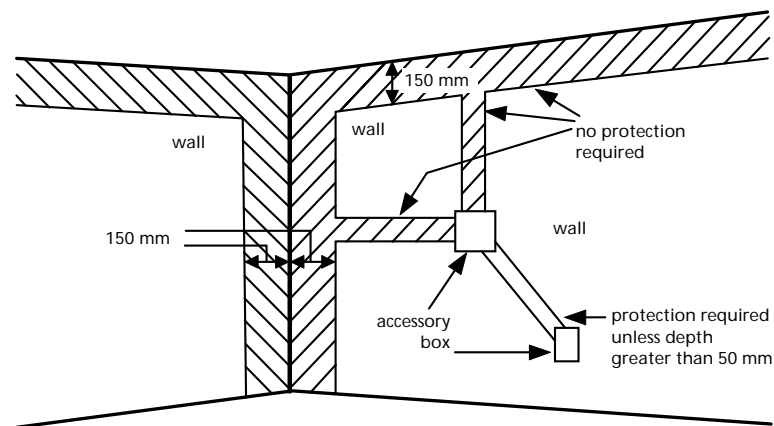
522-06-06

522-06-07

Chap 54

protective conductors. Any penetration of a phase conductor through the metal will then create a fault current to earth and operate the protective device. Alternatively, the cable must be enclosed in earthed conduit, trunking or ducting which satisfies the requirements of Chapter 54 for protective conductors. It must be remembered that for walls or partitions of which both sides are accessible e.g. internal walls within a building, cables installed vertically or horizontally from an outlet on one side of the wall must be at least 50 mm clear of the other side or suitable protection will be required. This may be a problem in modern housing construction, where walls or partitions may be thinner than buildings of traditional construction.

Fig 5.1: **Permitted cable routes**



If a cable is installed under a floor or above a ceiling it shall be run in such a position that it is not liable to damage by contact with the floor or ceiling or their fixings. Cables passing through a joist shall be at least 50 mm from the top or bottom, as appropriate, or be enclosed in earthed steel conduit or have an earthed metallic sheath (see Figs 5.2 and 5.3).

522-06-05

Regulation 522-12-03 requires that penetrations for wiring must not be made in any load bearing (or structural) element of a building unless the integrity of the element can be assured after the penetration. Such assurance is outside the ability of most contractors so great care must be taken to plan cable routes and specialist structural advice is always desirable.

522-12-03 |

It is accepted that there may be a structural problem in older buildings if sections of floor joists continue to be removed for rewiring, plumbing, etc and it may be necessary to reuse existing joist penetrations. The designer and installer will then have to develop a system that complies with the requirements of the IEE Wiring Regulations (BS 7671).

The National House Building Council (NHBC) publish advice in their standard on internal services on the notching and drilling of timber joists and this information is reproduced below for information. It is emphasised that any notching, cutting or drilling should be designed with the approval of a competent structural engineer.

Timber joists and studs should only be notched and drilled within the limits shown in the Table below:

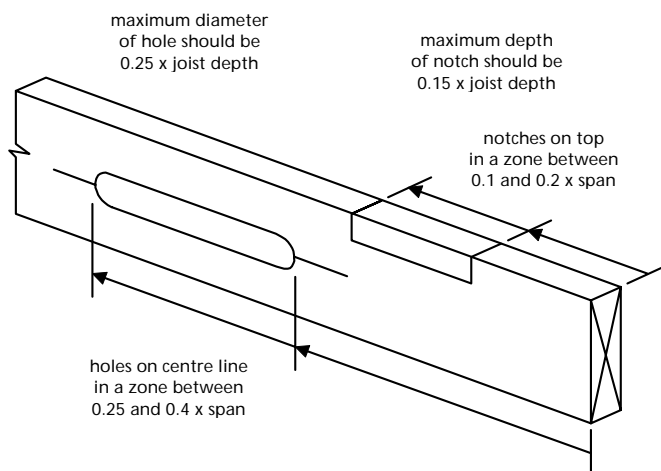
TABLE 5.2 Joist and stud notch and drill limits

Item	Location	Maximum size
Notching joists up to 250 mm depth	top edge 0.1 to 0.2 of span	0.15 x depth of joist
Drilling joists up to 250 mm depth	centre line 0.25 to 0.4 of span	0.25 x depth of joist
Drilling studs	centre line 0.25 to 0.4 of height	0.25 x depth of stud

Regulations 522-06-05 and 07 allow, as an alternative to earthed metal conduit, '*mechanical protection sufficient to prevent penetration of the cable by nails, screws and the like*'. Unless purpose manufactured plates are used effective protection is very difficult to achieve bearing in mind the modern fixings such as self-tapping screws and shot-fired nails that are available.

[522-06-05](#)
[522-06-07](#)

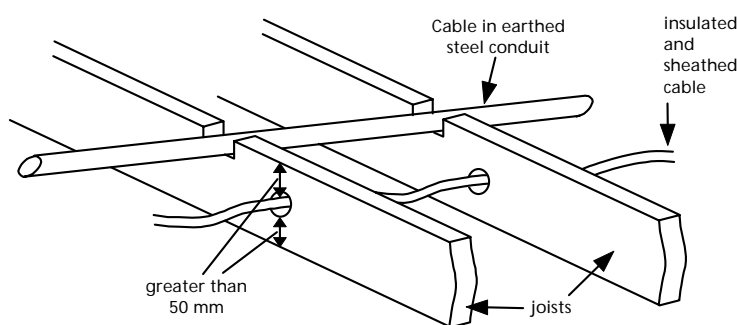
Fig 5.2: Holes in joists



Notches and drillings in the same joist should be at least 100 mm apart horizontally.

It should be noted that the NHBC guidance has slight differences from the Building Regulations Approved Document A1, which recommends that notches should be no deeper than 0.125 times the joist depth and in a position between 0.07 to 0.25 of the span and holes should be of no greater than 0.25 times the joist depth and drilled in the neutral axis of the joist.

Fig 5.3: Cables in floor joists



522-06-05

5.3 Cable routes and livestock 605

Particular attention is needed in locations where livestock is present. (See 4.9 also).

605

Animals in enclosures or buildings may rear up or move as a herd. Such movement can result in severe damage to inappropriately positioned equipment and risks to the animals themselves. Animals may also create corrosive conditions so that normal finishes are

not durable enough. Heavy duty equipment with anti-corrosive finishes should be selected and appropriately sited. Class II installations in heavy duty high impact pvc with suitable Class II accessories and conduit and enclosures have been found to be satisfactory in many cases.

5.4 Capacity of conduit and trunking **522**

Where cables are installed in conduit or trunking care is needed to prevent undue strain when installing the cables. A method for dealing with this is given in Appendix A. This may be used to determine the minimum size of conduit or trunking necessary to accommodate cables of mixed sizes.

522-08

The method employs a 'unit system', each cable size being allocated a factor. The sum of all factors for the cables intended to be run in the same enclosure is compared against the tabulated factors given for conduit or for trunking, to determine the minimum size of conduit or trunking necessary to accommodate those cables. The derivation of the tables is based on practical tests involving an easy draw of cables into the conduit or trunking.

It must be remembered that cables installed in conduit or trunking must be sized to allow also for the thermal effect of the grouping of such cables. Where advantage is taken of grouping factors it may be necessary to indicate this by a local label in the trunking or a note in the installation record documentation to warn future modifiers.

5.5 Selection of cables and wiring systems with low emission of smoke and corrosive gases when affected by fire **52**

When specifying or selecting cables in areas with high levels of public access, such as hospitals, schools, supermarkets and shopping developments, the designer should consider factors which may affect the safety of the occupants, such as:

- (i) where the rapid formation of dense, noxious smoke would be likely to produce injury or panic in individuals or crowds
- (ii) along escape routes, where it is important that the rapid but orderly exit of people is not impeded by smoke or fumes

- (iii) where the formation of corrosive halogen-acid products would have a harmful effect upon expensive equipment, i.e. computer hardware.

A list of British Standards is given in Appendix 1 of BS 7671 and includes reference to cables with low emission of smoke and corrosive gases when affected by fire. These include BS 6724, BS 7211 and BS 7629.

Unplasticised thermoplastic, as used in the manufacture of many cable management products (conduit, ducting, trunking and cable tray), is non flame propagating and is inherently fire-resistant due to its halogen content.

It is not expected that general electrical cables in the quantities installed in most buildings would provide high levels of smoke on their own in a fire, and cables would usually only be expected to burn when other building components are also on fire. However, in some installations such as public buildings and hospitals, it is preferable to take positive action to limit the production of smoke and fumes. Cables with low emission of smoke and corrosive gases when affected by fire have an important place in the installation design.

In general, cables with low emission of smoke and fumes are split into either thermoplastic or elastomeric. Elastomeric cables with low emission of smoke and fumes include EPR, EVA and SILICONE and are extruded on rubber CV (continuous vulcanisation) lines. Thermoplastic cables with low emission of smoke and fumes are processed like thermoplastics and each cable company will have different compound formulations and processing. Generally, cables with low emission of smoke and fumes are flame retardant (with a high oxygen and temperature index), and exhibit low smoke and fume emission with low (or zero — expressed as < 0.5 %) HCL (hydrochloric) acid gas emission. Thermoplastic compounds do not come under the cables with low emission of smoke and fumes category.

Oxygen index (given as limiting oxygen index, or LOI) defines the minimum percentage of oxygen required in an oxygen/nitrogen test atmosphere to just support combustion. A higher figure identifies a more flame retardant cable. This index is not, however, fully

representative of real fire conditions and the more recently established temperature index test gives a better prediction of a material's behaviour.

The temperature index is defined as the temperature at which combustion of the material under test is just possible in a normal atmospheric oxygen concentration. Again, a higher index indicates a better performance.

Tests for smoke and acid gas emission identify the performance of cables in fire conditions. These tests need to take into account the combination effect of all the materials used in a wiring system and environmental conditions. Specific requirements for smoke and acid gas limits must be specified by the designer and statutory authorities where this is relevant. It must be realised that needless over-specification of cables with low emission of smoke and fumes will impose an unnecessary cost burden on a project.

5.6 'Section 20'

Buildings required to comply with the special provisions of "Section 20" in London, and equivalent provisions in other cities, may require special precautions. Cables with a low emission of smoke and corrosive gases when affected by fire, or steel conduit and trunking installations, may be necessary when cables are installed in building voids, such as suspended ceiling voids, where these are used as plenums. Such design requirements should be clarified with the local Fire Officer or Building Control Officer before design commences.

Section 20 of the London Building Acts (Amendment) Act 1939 (as amended primarily by the Building (Inner London) Regulations 1985) is principally concerned with the danger arising from fire within certain classes of buildings which by reason of height, cubic capacity and/or use necessitate special consideration. The types of building coming within these categories are defined under Section 20 of the amended 1939 Act.

As buildings vary so much in height, cubic capacity, layout, siting, use and construction the relevant Council will deal with each case on its merits. The principles seek, in certain buildings (or parts of

buildings) to ensure the safety of the structure against fire.

Section 20 applies where:

- (a) a building is to be erected with a storey or part of a storey at a greater height than:
 - (i) 30 metres, or
 - (ii) 25 metres if the area of the building exceeds 930 square metres
- (b) a building of the warehouse class, or a building or part of a building used for the purposes of trade or manufacture, exceeds 7,100 cubic metres in extent unless it is divided by division walls in such a manner that no division of the building is of a volume exceeding 7,100 cubic metres.

A fire alarm system complying with the current edition of BS 5839-1 should be provided throughout every building except buildings comprising flats and/or maisonettes. These are covered by BS 5839-6 and also may have specific Building Regulations requirements.

In some instances, it may be necessary for such a fire alarm installation to be automatic where the use of the building (or part) warrants it (e.g. in hotels).

In office buildings where the means of escape is based on phased evacuation a number of additional features (such as a public address system) will be necessary.

The fire and rescue service when responding to an emergency in a building, should have the indicator panels and associated manual controls for the building's fire protection systems located together in one place designated as the fire control centre.

Smoke extraction should be provided from each storey by openable windows or by a mechanical smoke extract system.

Diesel engine generators or pumps should be enclosed by walls and a roof, of non-combustible construction having a standard of fire resistance of not less than four hours. Any openings in the walls should be protected by a single self-closing 120 minute door.

Oil storage in connection with the foregoing should comply with the fire authority requirements.

Transformer substations and switchrooms containing electrical oil-cooled transformers or oil-filled switchgear with an oil capacity in excess of 250 litres, will be required to be housed in a fire-resistant substation area. Cast resin, or dry-type transformers may be a viable option, although initially more expensive.

Conditions will normally be imposed requiring details of the general heating, lighting, electrical and ventilating arrangements to be submitted to the local Council for approval before commencement of the works and for such works to be provided and maintained to the satisfaction of the local Council. Periodic inspections may be made by local Council inspectors of the approved heating, lighting, electrical and ventilation installations during installation.

The foregoing Section 20 requirements apply specifically to London, but other large cities have their own similar requirements.

5.7 Buried cables

Cables to be installed in ducts or pipes in the ground are not required by BS 7671 to have armouring and/or a metal sheath, if the duct or pipe is sufficiently strong to resist likely mechanical damage. In case of doubt, a cable fulfilling the requirements of Regulation 522-06-03 should be provided.

[522-06-03](#)

Protective conductors which are buried directly in the ground must comply with the requirements of Regulation 542-03-01.

[542-03-01](#)

All buried cables must be marked by cable covers or a suitable marker tape, and buried conduits or ducts must also be suitably identified. A warning tape above the duct or conduit run would be suitable.

[611-04-03](#)

Cables, conduits and ducts must be buried deep enough to avoid being damaged by any disturbance of the ground reasonably likely to occur. This could include gardening/horticultural works, excavating for any local buried service pipes etc. Generally, it is better to locate cables etc. clear of such possible works.

A depth of burial of less than 500 mm is usually inadvisable as shallow laid cables may be inadvertently damaged by general gardening etc. Cables that cannot be buried at a reasonable depth should be specifically protected, e.g. by ducts encased in concrete, or installed along an alternative route.

Before any excavation is undertaken for cable or other works HSE guidance booklet HSG47 "Avoiding danger from underground services" should be studied, as it provides valuable advice on safety aspects.

It is important to be able to identify exactly where hidden services are located and accurate records, including drawings, should be made before trenches are backfilled. Cable routes should be located on drawings by dimensions from some fixed object that is not expected to change for a considerable time, (e.g. a building). Road and pathway features may be relatively easily changed. Scale drawings are of little value unless very detailed. Concrete route markers may be installed at changes of direction of cable routes and at regular intervals along routes. It may also be useful to lay cable warning marker tape just below ground level along cable routes so this will be exposed at any future digging well before cables are accessed.

514-09-01
611-04-01

The Electricity Safety, Quality and Continuity Regulations 2002 require that all buried cables must be marked or otherwise protected (Regulation 14(2)).

Many public service undertakings with services buried along the public highway have agreed in the National Joint Utilities Group (NJUG) a specific colour identification system for their service or duct work. Generally, each of the Statutory Undertakings has been allocated a specific colour for their underground services. Details are given in Table 5.3.

In addition, Local Authorities and in particular Highway Authorities have allocated themselves colours appropriate for their own installations. These vary from area to area and on occasion may clash with the NJUG colour code. In the interests of safety, Local Authorities should be asked to supply details before excavation is commenced in their area.

TABLE 5.3

Agreed colours of ducts, pipes cables and marker/warning tapes for public service undertaking

(Prepared by National Joint Utilities Group (NJUG) detailed in their publication No 4)

	Colour of duct/pipe/cable buried in ground			Colour of marker/warning tape
Utility	Duct	Pipe	Cable	where used
Gas	Yellow (or pale green)	Yellow	—	Yellow with black legend
Water	Blue	Blue	—	Blue
Electricity	Black	—	Black (Red for some HV)	Yellow with blue legend
BT (British Telecommunications) plc	Light grey	—	Light grey and black	White with blue legend
Mercury Communications Ltd (MCL)	White	—	Black All cable installed in duct	White with blue legend
Cable TV and telecommunications services other than BT and MCL	Green	—	Black All cable installed in duct	Green and/or yellow with identification showing co-axial or optical fibre cable
Highway Authority Services	Duct	Pipe	Cable	Tape
Street lighting England and Wales	Orange	—	Black	Yellow with black legend
Street Lighting Scotland	Purple	—	Purple	Yellow with black legend
Traffic control	Orange	—	Orange	Yellow with black legend
Telecommunications	Light grey	—	Light grey (or black)	Yellow with black legend
Motorways				
England and Wales				
Communications	Purple	—	Grey	Yellow with black legend
Communications power	Purple	—	Black	
Road lighting	Orange	—	Black	
Scotland				
Communications	Black or grey	—	Black	Yellow with black legend
Road lighting	Purple	—	Purple	

Notes:

1. The NJUG code is not retrospective and older installations installed before the code was adopted may not conform to the above colour scheme.
2. Cables installed on private property may not follow the guidelines in this document. The owner concerned should be contacted for information on the colour code applying in these cases.
3. Abandoned ducts are sometimes used for other purposes. Ensure systems are fully identified and traced out before any work is carried out.

The colour code is not universally applied as many of the older services were installed before this allocation was developed. Other means of identifying cables include clay or concrete tiles laid above electricity cables, usually with the word 'electricity' embossed into the top surface. The use of coloured plastic tape or board which would have the details of the service printed on its surface is a more recent method.

Further guidance may be obtained from the National Joint Utilities Group or other specifiers (see Appendix L), or any public services supplier.

Where cables pass through holes in metalwork, brickwork, timber, etc., precautions must be taken to prevent damage to the cables from any sharp edges, or alternatively mechanical protection should be provided, sufficient to prevent abrasion or penetration of the cable.

522-08

5.8 Sealing and fire stopping

Where a cable, conduit, trunking or busbar trunking system passes through a building wall or floor slab it is necessary to seal the hole around the cable etc. to the standard of the original wall or slab to prevent the passage of moisture, condensation, vermin or insects etc. The sealant must be suitable for the cable etc. and the environment and should be flexible to allow some small movement of the cable etc. relative to the building. Seals should be installed when necessary to maintain the building integrity during construction.

527-02-01

527-02-03

527-03-01

Where the penetration is through any part of the construction identified as having a specified fire performance or fire resistance the sealing must maintain the required fire integrity. The sealing method must be flexible and should be specified by the installation designer in liaison with other design team members such as the architect. The sealing must be properly installed through the thickness of the wall or slab, and inspection of the installation of the sealing is required by Regulations 527-04-01 and 712-01-03 item (vii). It is unlikely, however, that the electrical installer will be able to determine the suitability of a particular sealing method and specialist advice should be sought.

527-02-02

527-04-01

712-01-03

Conduits, trunking, ducts or busbar trunking systems passing through the building elements have space inside them that can conduct combustion products or other harmful materials (e.g. explosive gases and vapours) and may need to be sealed internally also. Busbar trunking systems are required by BS EN 60439-2 to provide a fire barrier unit for use when the busbar trunking system passes through horizontal or vertical building divisions. This requirement can be met by the method of construction or by internal fire barrier(s) positioned by the manufacturer to correspond to the building arrangement and certified, for a specific time under fire conditions, to ISO 834. Regulation 527-02-02 states that a non flame propagating wiring system (see 5.1) with a maximum internal cross-sectional area 710 mm² (i.e. 32 mm diameter conduit or smaller or 25 x 25 trunking) does not require to be internally sealed for fire protection. It may, however, still require to be sealed for other reasons, such as condensation.

527-02-02

Section 6 — Sizing of Cables

- 6.1 Current-carrying capacity and voltage drop**
524
525
- The Preface to the current rating and voltage drop tables of Appendix 4 of BS 7671 advise how they should be used to work out the cross-sectional area of a conductor. This will depend, among other factors, on the type of overcurrent protection provided. Guidance Note 6 gives further information on cable sizing.
- The design current of a circuit should be that drawn by the equipment at the nominal voltage of the supply.
- Table 52C of BS 7671 considers only the minimum cross-sectional area of conductor that should be used. The actual cross-sectional area chosen depends on a number of factors, which are explained in the Preface to the tables of Appendix 4 of BS 7671.
- Some loads such as motors, transformers and some electronic circuits take large surge (inrush) currents when they are switched on. Due account must be taken of any extra cumulative heating effect due to motor inrush currents or electric braking current where the motors are for intermittent duty with frequent stopping and starting.
- 6.2 Diversity**
311
- Diversity at any point in time is the actual load (or estimated maximum demand) divided by the potential load (or connected load), usually expressed as a percentage. The load that may be taken for the basis of selection of cable and switchgear capacities, allowing the design diversity, must be the maximum foreseeable load figure that will occur during the life of the installation.
- The maximum connected load is usually the simple sum of all the electrical loads that are, or may be, connected to the installation. The electrical load of
- Appx 4
- 524-01-01
Appx 4
- 552-01-01
- 311-01-01

each item will be the maximum electrical load that item may require, such as the load of an electric motor, unless specific measures have been taken to ensure that, in a group of items with high inertia starting loads, or inrush currents, such loads cannot occur simultaneously. Frequent motor starting will require special consideration.

A safe design diversity would be 100 per cent of the potential (or connected) load but this clearly is not reasonable. This is recognised, for example, in Appendix C of this Guidance Note, where an unlimited number of 13 A socket-outlets may be connected to a single 30 A or 32 A ring final circuit. If there are twenty 13 A socket-outlets (each capable of supplying approximately 3 kW at 230 V) the potential load of the circuit is 60 kW but the maximum permissible for a 30 A circuit is 6.9 kW, a diversity of 11.5 per cent. In practice the actual load on a dwelling ring final circuit is usually well below 6.9 kW, except perhaps in a kitchen or utility room.

The economic design of an electrical installation will almost always mean that diversity has to be allowed. However, where there is doubt as to the factors to be used, an adequate margin for safety should be allowed and consideration should also be given to the possible future growth of the maximum demand of the installation.

Section 433 requires circuits to be so designed that small overloads of long duration are unlikely to occur.

433-01-01

Further information is contained in Appendix C(b) 'Final circuits using socket-outlets complying with BS 1363 and fused connection units'.

For a guide towards the estimation of diversity see Appendix H.

6.3 Neutral conductors 524

Consideration must be given to the cross-sectional areas of neutral conductors. In a single-phase circuit the neutral conductor must have at least the same cross-sectional area as the phase conductor. In circuits for discharge lighting, a reduced neutral conductor is not permitted, where the harmonic content of the phase currents is greater than 10% of the

473
524-02-01

fundamental current. However, Regulation 524-02-02 allows the possibility of a reduced size neutral in polyphase systems where the neutral conductor will not be overloaded (523-01-01). Even with balanced three-phase conditions, there can be high percentages of third harmonic currents which add arithmetically in the neutral conductor, and when assessing the maximum likely neutral current, allowance must be made for any unbalanced loading or harmonics. Overcurrent protection must be provided for the neutral conductor in a polyphase circuit where the harmonic content of the phase currents is such that the current in the neutral conductor is reasonably expected to exceed that in the phase conductors.

524-02-02 |
524-02-03

523-01-01

473-03-04

Where the circuit is for discharge lighting, the design current, in the absence of more exact information, can be taken as:

$$I_b = \frac{1.8 \times \text{lamp rated wattage}}{\text{nominal voltage of circuit}} \text{ amps}$$

The multiplier (1.8) is based on the assumption that the circuit is corrected to a power factor of not less than 0.85 lagging, and it takes into account controlgear losses and harmonic currents. If corrected discharge lighting is used the power factor will be typically 0.85 lag but uncorrected discharge lamps may vary between 0.5 lead and 0.3 lag. For high-frequency circuits, Lighting Industry Federation (LIF) Technical Statement 21 should be consulted.

High neutral currents may be encountered with information technology equipment using switch-mode power supplies. In such equipment the mains input is rectified, the d.c. output being fed to a capacitor which in turn supplies the switch-mode regulator.

It has been suggested that the rms current in the neutral conductor of a three-phase mains circuit can be 1.73 times the rms current in the phase conductors.

Thus, when designing three-phase circuits for equipment incorporating switch-mode power supplies the designer may need to determine from the equipment manufacturer the rms current taken by the equipment and the expected neutral current and its harmonic content. It may sometimes be necessary to

install a neutral conductor of larger size than the associated phase conductor, however, it is preferable to attenuate the harmonic distortion by the use of active filters or similar devices.

BS 7450 : 1991 "Method for determination of economic operation of power cable size" based on overall lifetime costs (including cable and installation costs and the cost of waste energy) may also be of assistance in the determination of optimum conductor sizes based on energy losses.

6.4 Voltage drop in consumers' installations **525**

The prime requirement of this section is that the voltage at the terminals of any fixed current-using equipment should be such that it is within the lower limit allowed by the standard for that equipment. In practical terms it means that the voltage drop should not be such as to impair the safe and effective working of the equipment.

525-01-01

Where information on the effective voltage range of the equipment is not known the installation will be deemed to have complied if the voltage drop does not exceed 4% of the nominal voltage of the supply. This is a requirement that can be practically met for small installations such as domestic and similar where the installation comprises in effect only final circuits. It is not always practicable to comply with a 4% voltage drop in larger installations.

525-01-02

The Electricity Safety, Quality and Continuity Regulations 2002 allow a supply variation of +10% to -6%. When designing large installations with a high voltage supply, the designer can keep the voltage drop on the main distribution circuit to within, say, 10% and allow, say, 4% on final circuits to achieve a practical design.

For intermediate installations it may be necessary to check the actual voltage range at the supply and by calculation determine what voltage drop will be acceptable to keep the voltage at the final sub board within limits. As a rough guide, in such installations a voltage drop of, say, no more than 4% on the distribution circuits with 4% on the final circuits may meet these requirements. It may be necessary to check this by actual measurement in case of doubt.

When deciding on the voltage drop limits to be applied, the designer must bear in mind that a 5 per cent reduction in voltage may result in a 10 per cent reduction in power output, and an even larger drop in the light output of incandescent lamps. Data on the performance and life expectancy of incandescent lamps can be obtained from manufacturers.

Section 7 — Other Influences

7.1 Electrical connections 526

Connections between cables and other equipment must be selected with care. There is a risk of corrosion between dissimilar metals, depending upon the environment. The manufacturers' recommendations must be observed and the Standard followed. The power rating and the physical capacity of terminals must be adequate, as must their physical strength, when terminating larger conductors.

522-05

Thermosetting insulated cables to BS 5467 and thermoplastic cables to BS 6004 : 2000 can operate at higher conductor temperatures than other thermoplastic insulated cables. The higher conductor temperature results in an increased current-carrying capacity (10 to 20 per cent) and higher voltage drop values.

The use of high temperature cable requires careful selection of termination systems and accessories and switchgear which are appropriate to the operating temperature of the cable. Alternatively, where high temperature cable is to be used, it should be derated (its operating current I_z reduced) so as not to allow the conductor temperature to exceed the maximum operating temperature of the equipment to which it is to be connected. Conversely, high temperature cables may be a necessity where the heat of the device may be excessive. Thermoplastic or thermosetting conductors used in this way may need their insulation locally replaced or supplemented by an insulation with a more suitable temperature rating (e.g. at an enclosed luminaire). Where it is necessary to adjust the cross-sectional area of a cable at the point of termination this should be done by the use of a recognised technique such as a butt splice or crimp connector.

512-02-01

523-01-01

Any enclosure must have suitable mechanical and fire resistance properties. Unless exempt, joints must remain accessible for inspection and maintenance.

Sect 514

526-03

526-04

543-03-03

Account must be taken of any mechanical damage and vibration likely to occur. The method of connection adopted should not impose any significant mechanical strain on the connection, nor should there be any mechanical damage to the cable conductors.

526-02-01
526-03-01

Cable glands, clamps and compression-type joints should retain securely all the strands of the conductor. Every compression joint should be of a type which has been the subject of a test certificate as described in BS 4579, and the appropriate tools and methods specified by the manufacturer of the joint connectors should be used. A termination or joint in an insulated conductor, other than a 4 sq mm or greater protective conductor, should be made in an accessory or luminaire complying with the appropriate British Standard. Where this is not practicable, it should be enclosed in material designated non-combustible when tested to BS 476-4 or complying with 'P' to BS 476-2 or the relevant requirements of BS 6458, Section 2.1. Such an enclosure may be formed by part of an accessory and/or luminaire and a part of the building structure.

526-01-01

All connections, including those of ELV 12 V luminaires, must be enclosed in accordance with the requirements of Regulations 422-01-04 and 526-03. The use of unenclosed or taped-up terminal blocks or strips, which themselves may not be tested to any recognised standard, does not comply with the requirements of the Regulations unless the connections are enclosed within a properly constructed junction box or enclosure either to the relevant British Standard (e.g. BS 4662 or BS 5733) or made with a material which passes the glow-wire test of BS EN 60695-2-1/0, 1/3, or is within an enclosure formed from a suitable building material or formed within the building structure. Such building material must be non-combustible, or have suitable ignitability characteristics when tested as specified in BS 476. All insulated, unsheathed cable, such as cable ends stripped back, must be contained in the enclosure.

422-01-04
526-03

Terminations of mineral insulated cables should be provided with sleeves (tails) having a temperature rating similar to that of the seals.

Cable glands should securely retain without damage the outer sheath or armour of the cables. Mechanical cable glands for thermosetting and plastics insulated cables should comply with BS 6121 where appropriate.

Appropriate cable couplers should be used for connecting together lengths of flexible cable or flexible cord. Generally cable couplers must be non-reversible and to an appropriate Standard. On construction sites, where the requirements apply, every plug and socket-outlet must comply with BS EN 60309-2 (BS 4343).

553-02-01
604-01-01
604-12-02

Conduit should be free from burrs and swarf and all ends should be reamed to obviate damage to cables.

Substantial boxes of ample capacity should be provided at every junction involving a cable connection in a conduit system. The designer should be aware that large cables need a greater factor of space for installation and removal.

Regulation 460-01-06 requires a provision for disconnecting the neutral conductor for isolation or testing purposes. A suitable joint will be adequate for smaller cables, but a bolted link could be used for larger conductors due to the physical effort necessary to move the cables for disconnection.

460-01-06
537-02-05

7.2 Cables in contact with thermal insulation 523

Where a cable is to be run in a space in which thermal insulation is likely to be placed, the cable shall wherever practicable be fixed in a position such that it will not be in contact with or covered by the thermal insulation. Where fixing in such a position is impracticable the cross-sectional area of the cable shall be appropriately increased.

523-04-01

For a cable installed in a thermally insulated wall or above a thermally insulated ceiling, the cable being in contact with a thermally conductive surface on one side, current-carrying capacities are tabulated in Appendix 4 of BS 7671, Method 4 being the appropriate Reference Method.

For a single cable likely to be totally surrounded by thermally insulated material over a length of more than 0.5 m, the current-carrying capacity shall be

taken, in the absence of more precise information, as 0.5 times the current-carrying capacity for that cable clipped direct to a surface and open (Reference Method 1).

Where a cable is totally surrounded by thermal insulation for less than 0.5 m the current-carrying capacity of the cable shall be reduced appropriately depending on the size of cable, length in insulation and thermal properties of the insulation. The derating factors in the table below are appropriate to conductor sizes up to 10 mm² in thermal insulation having a thermal conductivity greater than 0.0625 Wm⁻¹ K⁻¹.

TABLE 7.1
Cables surrounded by thermal insulation
(Table 52A of BS 7671)

Length in insulation (mm)	Derating factor
50	0.89
100	0.81
200	0.68
400	0.55
500 and over	0.50

Table 52A is based upon normal cavity insulation such as vermiculite granules. More exact data can be obtained from ERA Report 85-0111 'The temperature rise of cables passing through short lengths of thermal insulation'.

[Table 52A](#)

The current-carrying capacities are the same for cables installed in the following manner (Reference Method 1):

[Table 4A1](#)

- (i) sheathed cables clipped direct or lying on a non-metallic surface (Installation Method 1)
- (ii) sheathed cables embedded directly in masonry, plaster and the like (Installation Method 2).

For cables in conduit in a thermally insulating wall or above a thermally insulating ceiling and where the conduit is in contact with a thermally conductive surface on one side (Method 4), the current-carrying capacities are lower than for Method 1.

[523-04-01](#)

The following notes consider the effect of such derating on various typical circuits.

For domestic lighting circuits, the load does not normally exceed 6 A. The smallest cable used will be 1 mm² with a current-carrying capacity for Method 1 of 15 A (Table 4D2A, Column 6). If totally surrounded by thermal insulation for 0.5 m or a greater length the current-carrying capacity can therefore be taken as 7.5 A.

Appx 4

A cable sometimes used for cooker circuits is 6 mm² which has a current-carrying capacity, when clipped direct, of 46 A, reducing to 23 A if it is installed in thermal insulation. A 30 A or 32 A overcurrent device is usually employed. The current taken by a cooker varies over a wide range and theoretical loads in excess of 23 A can be expected. This would lead to overheating of the cable if continuously carrying such current. Hence, a larger cable may be necessary. Also, the nominal current (I_n) of a protective device must not exceed the lowest of the current-carrying capacities of any of the circuit conductors (I_z).

433-02-01(ii)

The loading of cables feeding socket-outlets is even more varied, and depends on the type of circuit used, i.e. ring or radial, the number of socket-outlets fed from the circuit and the type of load. For example, 2.5 mm² thermoplastic insulated and sheathed cables used in a multi-socket-outlet radial circuit protected by a 20 A overcurrent protective device has a 'clipped direct' current-carrying capacity of 27 A (Table 4D2A, Column 6), reducing to 13.5 A if the cable is embedded in thermal insulation.

When clipped direct the cable could supply up to 6.2 kW without overheating, though because, in this example, the circuit is protected by a 20 A device it should not be loaded to more than 4.6 kW in any event.

Loading as great as this is infrequently encountered and much more common are small loads such as standard lamps and television sets, up to about 1 kW, i.e. 4 A in total.

However, if the cable is later embedded in thermal insulation the reduced current-carrying capacity of

13.5 A would be exceeded if a load of 3.2 kW were connected and overheating is possible.

Thus, the introduction of thermal insulation into cavities where cables are already installed will create the possibility of overheating the cable. The extent of the risk will depend on the type of thermal insulation used and the total loading of the cables.

7.3 Mutual or individual deterioration **522**

BS 7671 requires that materials liable to cause mutual or individual deterioration or hazardous degradation shall not be placed in contact with each other. One commonly used thermal insulation for cavity walls is urea formaldehyde foam and there should be no adverse action between this material and thermoplastic.

522-05-03

Other materials may be used for cavity insulation but the supplier does not always disclose their chemical composition. Before allowing any thermal insulation materials to come into contact with cable insulation or sheath materials the thermal insulation supplier should be asked to confirm in writing that there will be no adverse effect on the cable insulation or sheath. Where there is doubt an inert barrier should be inserted between the cable and the thermal insulation.

Expanded polystyrene sheets or granules are used in construction, e.g. insulating lofts and supporting floors, and may be used in cavity walls. If this material comes into contact with thermoplastic cable sheathing some plasticiser will migrate from the pvc to the polystyrene. The thermoplastic will become less flexible and sticky on the surface, and the polystyrene will become soft and shrink away from the thermoplastic sheathed cable if possible. Such contact between thermoplastic and polystyrene should be avoided. These comments do not apply to unplasticised pvc conduit and trunking systems.

As only the plasticiser is removed from the sheath, it is not expected that the insulation resistance of the cable will be affected if the cable is not disturbed, but this cannot be guaranteed. The cable should be supported away from the polystyrene and a test should be carried out. The cable condition should also be monitored over time in regular periodic

inspections. There is no cure for this migration other than replacement of the cable.

Similar remarks apply to some fittings which are in contact with cables. In addition to polystyrene and expanded polystyrene, acrylonitrile-butadiene-styrene (ABS), polystyrene and polycarbonate are also affected. Nylon, polyester, polyethylene, polypropylene, rigid pvc and most thermosetting plastics are little affected. Natural rubber grommets can become softened but synthetic rubber and pvc grommets are satisfactory.

Contrary to popular belief, plastic insulated and sheathed cables are not suitable for continuous immersion in water, such as in pools and fountains, as they will absorb an amount of water over time and insulation failure will occur. Manufacturers' advice should be taken for applications involving continued immersion of cables. Cable standards for these purposes are currently being developed.

7.4 Proximity to other services 528

Electrical and all other services must be protected from any harmful mutual effects foreseen as likely under conditions of normal service.

515-01
528-02

Section 528 contains a reference to two voltage bands, equating approximately to ELV and LV. Care must be taken that only compatible circuits are enclosed in the same conduit or trunking, unless the circuit conductors are insulated to the highest voltage present, or other precautions are taken, such as segregation by a separate compartment in an insulated cable system or by an earthed metallic screen.

For safety circuits such as emergency lighting and fire alarms, covered by BS 5266 and BS 5839 respectively, the requirements of the British Standards must be met with respect to segregation. For telecommunications see BS 6701 and Appendix I.

528-01-04

Where malfunction may occur (e.g. crosstalk with a communication system) all conductors, including the protective conductor, must be correctly routed and adequate separation provided from other cables (see Appendix I also). A particular form of harmful effect may occur when an electrical installation shares the

space occupied by an audio frequency induction loop system — this loop system enables a hearing aid with a telecoil to pick up audio signals from the loop. Under these circumstances, if phase(s) and neutral or switch feeds and switch wires are not close together, 50 Hz interference (and its harmonics) may be picked up by the telecoil of the hearing aid.

Conventional two-way switching systems can often produce fortuitous 50 Hz radiating loops, but this can be reduced by arranging the circuits as shown in Figure 7.1.

All the conductors of a circuit should generally follow the same route. Live cables of the same circuit may cause overheating if they enter a ferromagnetic enclosure through different openings.

521-02-01

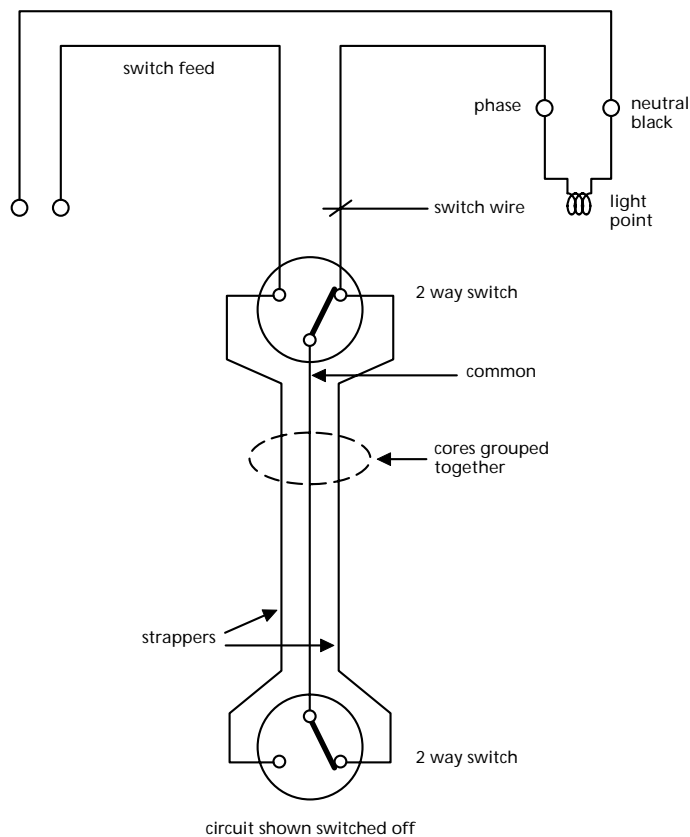
The EMC Regulations require that attention is paid to electrical equipment and installations to limit their electrical interference from other systems (immunity) and their electrical interference with other systems (emission).

515-02

Electrical power systems will usually have immunity from interference from other systems, but may cause emission interference with sensitive electronic systems. In addition, harmonic generation and interference will need to be considered. Electronic systems such as data systems, fire alarms and public address will give the most concern, but detailed information and advice on emission and immunity is not generally available for systems and each installation must be separately considered by experts and any manufacturer's advice acted upon.

Controlgear and factory-made equipment which is certified or declared to comply with relevant emission and immunity standards can be expected to do so, but on site a cable installation may pick up or induce interference unless it is adequately separated or protected. The data in Appendix I can be utilised in the absence of other guidance, but no firm data is available to guarantee these figures. The Electrical Contractors' Association (ECA) publication 'Recommended cable separations to achieve electromagnetic compatibility (EMC) in buildings' (reproduced in part in Appendix I) gives some advice which may be useful.

Fig 7.1: Circuit for reducing interference with induction loop



7.5 Plasticiser migration from pvc insulation to the conductor surface

Installers may occasionally encounter a sticky blue/green deposit in equipment or switch and socket-outlet boxes in older installations wired in thermoplastic insulated cables.

Early manufacture of pvc insulation materials utilised a different formulation from that which is now employed. Thermal cycling of the conductor due to changes in load and conductor temperature drew the thermodynamically unstable insulation plasticiser to the conductor, where, on vertical runs of cable over time the plasticiser liquid worked down the conductor surface to become a sticky blue/green liquid in the accessory box. The material is not corrosive and can be cleaned away with methylated spirit. The blue/green colouring comes from traces of copper absorbed by the liquid. There is no cure for this plasticiser migration, other than replacement of the cable.

As only the plasticiser is removed from the insulation, it is not expected that the insulation resistance of the cable will be affected if the cable is not disturbed but this cannot be guaranteed, and a test should be carried out. The cable condition should also be monitored over time in regular periodic inspections.

Reformulation of pvc compounds in the mid to late 1970's has removed this problem from modern pvc insulated cables.

Migration also happens when bitumen is in contact with pvc. The bitumen absorbs some plasticiser from the pvc. Whilst the amount of loss is insufficient to have much effect on the properties of the pvc, it is enough to cause considerable reduction in the viscosity of the bitumen, and the bitumen may become so fluid that it can run.

Section 8 — Installation of Equipment

8.1 Equipment having a high protective conductor current 607

Levels of permitted protective conductor currents for certain types of equipment are given in Appendix J. The information is taken from relevant British Standards. Where precise information is required the relevant Standards should be consulted.

For appliances incorporating heating elements and motors, the total protective conductor current is to be within the limits specified in Table J1. Part 3 of BS 3456 (BS EN 60335) covers particular requirements for various types of household appliances, and may alter specific limits from the general requirements of Table J1.

Section 607 of BS 7671 contains supplementary earthing requirements for the installation of equipment having high protective conductor currents. These particular requirements complement the protection described in Section 531, in Chapter 41 and in Chapter 54 of BS 7671. Information technology and other electronic equipment usually incorporates radio frequency filters on the mains conductors. In Class I equipment these filters include capacitors connected between the supply conductors and frame and this results in a standing protective conductor current.

On information technology equipment intended for connection to the supply via a 13 A BS 1363 plug, the maximum allowable standing protective conductor current is 3.5 mA as specified in BS EN 60950. However, modern equipment usually has leakages significantly less than this, perhaps 1 mA to 1.5 mA per item.

With desk-top equipment, the use of a number of items of portable equipment connected to a single socket-outlet or a ring or radial final circuit can result in a cumulative protective conductor current of several milliamperes. This current may be high enough to present danger if the protective

conductors become open circuit and, also, may operate an RCD. It should be remembered that an RCD to BS 4293, BS EN 61008 or BS EN 61009 is allowed to operate at any value of residual current between 50 % and 100 % of its rated residual operating current. Therefore, unwanted tripping could occur under normal running conditions. This is even more likely if there is a surge of protective conductor current when switch-on occurs near the peak value of the supply voltage. Regulation 607-07-01 therefore requires that the circuit arrangement must be such that the residual current which may be expected to occur, including switch-on surges, will not trip the device.

607-07-01

Where two protective conductors are used in accordance with Regulation 607-02-04, these must be terminated independently. This requires the distribution board or accessory to be provided with two separate earth terminals.

607-02-04

607-02-05

Information technology equipment connected via BS EN 60309-2 (BS 4343) industrial plugs and socket-outlets is permitted to have higher protective conductor currents. There is a limit of 10 mA above which the special installation requirements detailed in Section 607 of BS 7671 apply.

607-02-03

607-02-04

These special requirements are aimed at providing a high integrity protective conductor. Should the protective conductor of the circuit feeding the equipment fail, the protective conductor current could then pass to earth through a person touching the equipment. As with all installations, the high integrity protective conductor installation must be periodically inspected and tested to ensure its integrity is maintained (see Guidance Note 3 for further details). See Guidance Note 7 for more detailed information on Section 607 of BS 7671.

8.2 Water heating 554

It is particularly important that manufacturers' instructions are followed when installing electrode water heaters or boilers, to isolate simultaneously every cable feeding an electrode and to provide overcurrent protection. Similarly, the installation of water heaters having immersed and uninsulated

554-03

554-05

heating elements must follow makers' instructions and be correctly bonded. The metal parts of the water heater (e.g. taps, metal-to-metal joints, covers) must be bonded to the incoming water pipe and the pipe connected to the main earthing terminal with a dedicated protective conductor independent of the circuit protective conductor. The heater must be permanently connected through a double-pole switch and not by means of a plug and socket-outlet (see Guidance Note 2 also).

554-05-02

554-05-03

8.3 Safety services
56

Safety circuits must have supplies which comply with Chapter 56. The design and construction of any other circuit supplying a safety service must be such that a fault or change in the other circuit does not affect the correct functioning of the safety service. The routes of cables should not render the safety service liable to abnormal fire risk. Such safety services would include:

- (i) fire alarms
- (ii) emergency lighting
- (iii) designated lifts for use in emergency.

563-01-01

563-01-02

8.4 Other equipment
55

Chapter 55 covers requirements for accessories and other equipment, and most of the requirements are reasonably straightforward. Specific requirements are given for typical equipment and accessories. Attention is drawn to Regulation 553-04-01 which allows a choice of accessories to terminate a lighting point.

553-04-01

In larger installations, for convenience of maintenance it may be more practicable to provide a luminaire supporting coupler (LSC) or plug and socket-outlet arrangement to facilitate the removal of luminaires for repair or rearrangement of the lighting layout. Item (v) of Regulation 533-04-01 can include any type of socket-outlet for convenience, but the provision of a socket-outlet with a higher current rating than the design current of the circuit may require local labelling if it were able to be utilised for other purposes.

The installation of LSCs allows an installation to be completed, tested and energised before luminaires are selected and installed. Luminaires could then be

fitted (perhaps after decorating) without interference with the installation, and consequent retesting.

Many modern lighting installations are controlled by sophisticated management systems with automatic sensors and software control. There may not be a suitable British Standard for the hardware of such systems, but the wiring and the selection and erection of the equipment and luminaire connections must still comply with BS 7671.

Accessories must comply with the relevant British Standards and care must be exercised to ensure damage does not occur. Accessories must be of a type and IP rating appropriate to their location and should not be installed in locations where they may suffer impact, wet or dampness or corrosion unless they are of a design specifically for the application. Regulation 512-06-01 applies. This regulation applies to socket-outlets near sinks which must be of a type resistant to water ingress if they are likely to be splashed.

512-06-01

Care must be taken to ensure that the conductor operating temperature does not allow the permitted temperature rise of the accessory or equipment to be exceeded (Regulations 512-02-01 and 523-01-01). Thermosetting insulated cables to BS 5467 or BS 7211 operate at a conductor temperature of 90 °C when carrying their rated current, and are not suitable for connection to accessories or devices with a maximum operating temperature of 70 °C unless the cables are derated. (See Appendix F Table F5 for conductor temperature details).

512-02-01

523-01-01

B15 and B22 bayonet lampholders must comply with BS EN 61184 and Regulation 553-03-03 requires a T₂ temperature rating. This can easily be overlooked by designers and installers. Edison screw Lampholders should comply with BS EN 60238 : 1999, which details temperature ratings.

553-03-03

The installation of autotransformers and step-up transformers must comply with the requirements of BS 7671. Particular care is needed to guard against danger if there is no neutral feed (e.g. on primaries connected across the phases). Where there is a neutral it must be connected to the common terminal of the transformer. Step-up autotransformers are not

555-01

permitted on an IT system. Multi-pole linked switches must be used so that all live conductors, including the neutral if any, can be simultaneously disconnected from the supply (see also Guidance Note 2).

8.5 Luminaires

Luminaires should be manufactured to the requirements of BS 4533, or BS EN 60598, but unfortunately some cheaper or imported types may not be. The installer should be wary of the construction and heat dissipation of these types, and luminaires should be installed strictly in accordance with the manufacturers' instructions.

Luminaires are usually installed on non-combustible surfaces, defined in BS EN 60598-1 as "material incapable of supporting combustion" and taken to include metal, plaster and concrete. However, sometimes it may be necessary to mount luminaires on materials that may be considered to be flammable (e.g. wood and wood based materials of more than 2 mm thick) and in such cases a classified luminaire to BS EN 60598 marked with the symbol



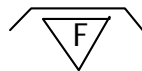
should be selected. In luminaires marked with this symbol the excessive temperatures which may arise in operation or due to the failure of a component will not cause the mounting surface temperature to exceed 90 °C and thereby cause a risk of fire. Originally this mark only covered luminaires with integral control gear but it now applies to all luminaires complying with BS EN 60598.

Luminaires which cannot comply with this criterion must carry a warning notice or have the following symbol.



For simple pendants and wall lights the installation of the luminaire can have some effect on the compliance and it may be necessary for the designer to specify the minimum length of flexible cord or specific mounting details to limit the heat output onto local surfaces. This is especially significant for high power uplighters. (See Guidance Note 4 for further information on thermal effects and protection.)

For recessed luminaires (e.g. downlighters and ELV luminaires) to BS EN 60598 the marking is amended to indicate the temperature rise criteria when in insulated ceilings or enclosed in thermal insulation. The mark is

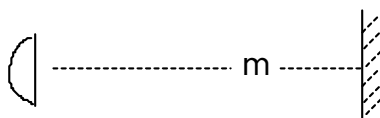


For recessed luminaires not suitable for such installation the mark will be shown crossed out (as previously).

The fire rating of any ceiling or wall which is penetrated to install recessed luminaires must be maintained after the installation of the luminaires, and Regulation 527-01-01 requires the designer to specify how this is to be carried out. Further information on fire protection requirements can be found in Approved Document B of the Building Regulations 2000 and Guidance Note 4. The luminaire manufacturer's advice and instructions must also be followed.

527-01-01

From a thermal view the temperature of illuminated objects is also important and the heat from a wrongly placed luminaire can initiate combustion. Luminaires to BS EN 60598 can also be marked with a symbol to indicate the minimum distance from a lighted object and a maximum lamp wattage.



The lamp type is also important and dichroic lamps, where the heat is conducted away through the lamp and luminaire body rather than radiated as part of the light energy, must only be used in the correct types of luminaire. The luminaire manufacturer's instructions must be followed in all cases.

Regulation 482-02-13 gives the following minimum distances at which spotlights and projectors must be installed from combustible materials:

482-02-13

- (i) rating up to 100 W - 0.5 m
- (ii) rating over 100 W up to 300 W - 0.8 m
- (iii) rating over 300 W up to 500 W - 1.0 m.

Section 526 requires joints between conductors and conductors and equipment to be properly made and

enclosed, and Regulation 526-03-02 details suitable enclosures. This requirement applies to all types of connections in electrical circuits - even to 6 volt and 12 volt ELV luminaires, the connections of which are often below this standard. Regulation 526-03-03 requires the enclosure of the cores of cables from which the sheath has been removed. Not only must the connection between the fixed wiring and the luminaire flexible cable be enclosed but the cores from which the sheath has been removed must also be enclosed. Exposed unsheathed flexible cable is not acceptable on luminaire connections and does not comply with the requirements of BS 7671.

526-03-02

526-03-03

8.6 Selection and erection in relation to operation and maintainability 529

The Electricity at Work Regulations 1989 specifically place a duty on installation or equipment owners or managers (Duty Holders) to ensure the installation or equipment is utilised safely, and persons are protected from danger. In the workplace, ordinary persons are not permitted to access live systems and equipment or carry out electrical work.

All electrical installations should be as simple as possible. All manual components generally accessible should be of the simplest kind. Where not immediately obvious, operating instructions should be displayed adjacent to the component. All other equipment should be located behind lockable doors or accessible only by the use of a tool. The building operator should be provided with full instructions as to the operation and maintenance of the installation, including mechanical operation.

BS 7671 requires an assessment of expected maintenance to be made as part of the design process. Selection of equipment should be relevant to the maintenance (or lack of it) it may receive during its installed and operating life.

341-01-01

Luminaires should be located so that they may be safely relamped and repaired by maintenance personnel from a horizontal surface local to the luminaire. The maintenance personnel should be able to stand directly upon the surface or upon steps at a reasonable height. Where this cannot be achieved consideration should be given to supplementary means of access and/or the luminaire should be equipped with hoisting access or hoisting equipment.

529-01-02

For all items that provide physical protection which may need removal (including lids of cable boxes, trunking, etc.) and replacement, the procedure should be as simple as possible. It should be possible to be carried out by one person without assistance. Where frequent access is likely, lids etc. should be hinged. It must be possible to close all lids and covers without putting pressure on enclosed cables and equipment.

Electrical distribution equipment and switchgear should be located so that all components may be operated and maintained safely. The Electricity at Work Regulations 1989 (Regulation 15) specifically require adequate working space, access and lighting to be provided for all electrical equipment, working on or near which may give rise to danger.

529-01-02

ISOLATION

Where appropriate and to prevent danger suitable means shall be provided to isolate equipment and machinery from all sources of supply. This must include any control systems, even at extra-low voltage, as well as power supplies. The isolation devices must be able to be secured against inadvertent operation and clearly labelled if their use is not obvious.

461-01-02

461-01-05

In the case of equipment supplied through a plug and socket-outlet, accessible for withdrawal of the plug, such separation of the plug and socket-outlet is sufficient. For built-in domestic appliances (such as washing machines) if the plug and socket-outlet are not accessible unless the machine is moved they may not be suitable for isolation. In any event a plug and socket-outlet or similar device must not be selected (specified) as an emergency switching device.

537-04-02

Live incoming connections within electrical enclosures that cannot be isolated should be provided with barriers and, wherever possible, be located in a separate compartment within the main enclosure and fitted with a warning notice.

In consumer units and distribution boards provided with multi-terminal neutral bars and earthing bars, the neutral conductors and circuit protective conductors should be connected to their respective bars in the same order as the line conductors are connected to the fuses or circuit-breakers. This will

facilitate the disconnection of particular circuits and avoid confusion which might cause accidents.

There is specific statutory legislation in the form of the Health and Safety at Work Act 1974 etc. and the Electricity at Work Regulations 1989 which include requirements for safe installation, operation and maintenance. Compliance with the requirements of BS 7671 is likely to provide compliance with relevant aspects of this legislation. The Management of Health and Safety at Work Regulations 1999 also provide a statutory duty on employers to analyse health and safety risks in the workplace, and this will include risks from the electrical system and electrical equipment.

APPENDICES

CONTENTS

Appendix	Page
A Cable capacities of conduit and trunking	126
B Degrees of protection provided by enclosures	135
C Conventional circuit arrangements and the provision of socket-outlets	143
D Limitation of earth fault loop impedance for compliance with Regulation 543-01-01	155
E Resistance and impedance of copper and aluminium conductors under fault conditions	176
F Selection and erection of wiring systems	184
G Notes on methods of support for cables, conductors and wiring systems	191
H Maximum demand and diversity	199
I Minimum separating distances between electricity supply cables and telecommunications or control cables	204
J Permitted protective conductor currents	208
K Standard symbols, units and graphical symbols for general electrical purposes	209
L Addresses of associated bodies and identification symbols	217

Appendix A: Cable capacities of conduit and trunking

a) General

This Appendix describes a method based on practical work and experimentation which can be used to determine the size of conduit or trunking necessary to accommodate cables of the same size, or differing sizes, and provides a means of compliance with the requirements of Chapter 52 of BS 7671.

The method employs a 'unit system', each cable size being allocated a factor. The sum of all factors for the cables intended to be run in the same enclosure is compared against the factors given for conduit, ducting or trunking, as appropriate, in order to determine the size of the conduit or trunking necessary to accommodate those cables.

It has been found necessary, for conduit, to distinguish between:

Case 1, straight runs not exceeding 3 m in length, and

Case 2, straight runs exceeding 3 m, or runs of any length incorporating bends or sets.

The term 'bend' signifies a British Standard 90° bend, and one double set is equivalent to one bend.

For case 1, each conduit size is represented by only one factor. For case 2, each conduit size has a variable factor which is dependent on the length of run and the number of bends or sets. For a particular size of cable the factor allocated to it for case 1 is not the same as for case 2.

For trunking each size of cable has been allocated a factor, as has been each size of trunking.

A number of variables affect any attempt to arrive at a standard method of assessing the capacity of conduit or trunking.

Some of these are:

- (i) reasonable care in installation
- (ii) acceptable use of the space available
- (iii) tolerance in cable sizes
- (iv) tolerance in conduit and trunking.

The following tables can only give guidance of the maximum number of cables which should be drawn in. The sizes should ensure an easy pull with low risk of damage to the cables.

Only the ease of drawing-in is taken into account. The electrical effects of grouping are not. As the number of circuits increases the current-carrying capacity of the cable decreases. Cable sizes have to be increased with consequent increase in cost of cable and conduit.

It may, therefore, be more attractive economically to divide the circuits concerned between two or more enclosures.

The following three cases are dealt with:

Single-core thermoplastic (pvc) insulated cables to BS 6004 or single-core thermosetting cables to BS 7211:

- (i) in straight runs of conduit not exceeding 3 m in length. Tables A1 & A2
- (ii) in straight runs of conduit exceeding 3 m in length, or in runs of any length incorporating bends or sets. Tables A3 & A4
- (iii) in trunking. Tables A5 & A6.

Other sizes and types of cable in conduit or trunking are dealt with in Section e) of this Appendix.

For cables and/or conduits not covered by this Appendix, advice on the number of cables which can be drawn in should be obtained from the manufacturers.

b) Single-core thermoplastic (pvc) insulated cables in straight runs of conduit not exceeding 3 m in length

For each cable it is intended to use, obtain the factor from Table A1.

Add the cable factors together and compare the total with the conduit factors given in Table A2.

The minimum conduit size is that having a factor equal to or greater than the sum of the cable factors.

TABLE A1
Cable factors for use in conduit in short straight runs

Type of conductor	Conductor cross-sectional area mm ²	Cable factor
Solid	1	22
	1.5	27
	2.5	39
Stranded	1.5	31
	2.5	43
	4	58
	6	88
	10	146
	16	202
	25	385

TABLE A2
Conduit factors for use in short straight runs

Conduit diameter mm	Conduit factor
16	290
20	460
25	800
32	1400
38	1900
50	3500
63	5600

c) Single-core thermoplastic (pvc) insulated cables; in straight runs of conduit exceeding 3 m in length or in runs of any length incorporating bends or sets

For each cable it is intended to use, obtain the appropriate factor from Table A3.

Add the cable factors together and compare the total with the conduit factors given in Table A4, taking into account the length of run it is intended to use and the number of bends and sets in that run.

The minimum conduit size is that size having a factor equal to or greater than the sum of the cable factors. For the larger sizes of conduit multiplication factors are given relating them to 32 mm diameter conduit.

TABLE A3
Cable factors for use in conduit
in long straight runs over 3 m, or
runs of any length incorporating
bends

Type of conductor	Conductor cross-sectional area mm ²	Cable factor
Solid or stranded	1	16
	1.5	22
	2.5	30
	4	43
	6	58
	10	105
	16	145
	25	217

TABLE A4
Cable factors for runs incorporating bends and long straight runs

length of run m	Conduit diameter, mm															
	16	20	25	32	16	20	25	32	16	20	25	32	16	20	25	32
	Straight				One bend				Two bends				Three bends			
1	Covered by Tables A1 and A2				188	303	543	947	177	286	514	900	158	256	463	818
1.5					182	294	528	923	167	270	487	857	143	233	422	750
2					177	286	514	900	158	256	463	818	130	213	388	692
2.5					171	278	500	878	150	244	442	783	120	196	358	643
3					167	270	487	857	143	233	422	750	111	182	333	600
3.5	179	290	521	911	162	263	475	837	136	222	404	720	103	169	311	563
4	177	286	514	900	158	256	463	818	130	213	388	692	97	159	292	529
4.5	174	282	507	889	154	250	452	800	125	204	373	667	91	149	275	500
5	171	278	500	878	150	244	442	783	120	196	358	643	86	141	260	474
6	167	270	487	857	143	233	422	750	111	182	333	600				
7	162	263	475	837	136	222	404	720	103	169	311	563				
8	158	256	463	818	130	213	388	692	97	159	292	529				
9	154	250	452	800	125	204	373	667	91	149	275	500				
10	150	244	442	783	120	196	358	643	86	141	260	474				

Additional Factors: For 38 mm diameter use 1.4 x (32 mm factor)
For 50 mm diameter use 2.6 x (32 mm factor)
For 63 mm diameter use 4.2 x (32 mm factor)

d) Single-core thermoplastic (pvc) insulated cables in trunking

For each cable it is intended to use, obtain the appropriate factor from Table A5.

Add all the cable factors so obtained and compare with the factors for trunking in Table A6.

The minimum size of trunking is that size having a factor equal to or greater than the sum of the cable factors.

e) For other sizes and types of cable in conduit or trunking, including flexible conduit

For sizes and types of cable in conduit or trunking other than those given in Tables A1 to A6, the number of cables installed should be such that the resulting space factor does not exceed 35 per cent of the net internal cross-sectional area for conduit and 45 per cent of the net internal cross-sectional area for trunking.

Flexible conduit types may have a smaller internal diameter due to increased wall thickness. The conduit manufacturer's advice should be obtained regarding cable capacity and cable grouping and the required flexibility must be considered. The 35 per cent space factor could also be utilised for flexible conduit.

Space factor is defined as the ratio (expressed as a percentage) of the sum of the overall cross-sectional areas of cables (insulation and any sheath) to the internal cross-sectional area of the conduit or other cable enclosure in which they are installed. The effective overall cross-sectional area of a non-circular cable is taken as that of a circle of diameter equal to the major axis of the cable.

The minimum internal radii of bends of cables for fixed wiring as given in Table G1 should be used. Care should be taken to use bends in trunking systems, specifically with larger cables, that allow adequate bending radius.

TABLE A5
Cable factors for trunking

Type of conductor	Conductor cross-sectional area mm ²	Thermoplastic (pvc), BS 6004 Table 1 Cable factor	Thermosetting BS 7211 Table 3 Cable factor
Solid	1.5	8.0	8.6
	2.5	11.9	11.9
Stranded	1.5	8.6	9.6
	2.5	12.6	13.9
	4	16.6	18.1
	6	21.2	22.9
	10	35.3	36.3
	16	47.8	50.3
	25	73.9	75.4
	35	93.3	95.1
	50	128.7	132.8
	70	167.4	176.7
	95	229.7	227.0
	120	277.6	283.5
	150	343.1	346.4
	185	426.4	433.7
	240	555.7	551.6

Notes:

- (i) cable factors are the cable cross-sectional area using the BS upper limit mean overall diameter
- (ii) the provision of spare space is advisable, however, any circuits added at a later date must take into account grouping (see Appendix 4 of BS 7671 for further details)
- (iii) where thermosetting insulated conductors designed to operate at 90 °C (BS 5467 or BS 7211 etc) are installed together with thermoplastic (pvc) insulated conductors designed to operate at 70 °C, it must be ascertained that the thermoplastic (pvc) insulated conductors will not be damaged. (Regulation 522-01-01).

TABLE A6
Factors for trunking

Dimensions of trunking mm x mm	Trunking factor		Dimensions of trunking mm x mm	Trunking factor
50 x 38	767		200 x 100	8572
50 x 50	1037		200 x 150	13001
75 x 25	738		200 x 200	17429
75 x 38	1146		225 x 38	3474
75 x 50	1555		225 x 50	4671
75 x 75	2371		225 x 75	7167
100 x 25	993		225 x 100	9662
100 x 38	1542		225 x 150	14652
100 x 50	2091		225 x 200	19643
100 x 75	3189		225 x 225	22138
100 x 100	4252		300 x 38	4648
150 x 38	2999		300 x 50	6251
150 x 50	3091		300 x 75	9590
150 x 75	4743		300 x 100	12929
150 x 100	6394		300 x 150	19607
150 x 150	9697		300 x 200	26285
200 x 38	3082		300 x 225	29624
200 x 50	4145		300 x 300	39428
200 x 75	6359			

Note:

- (i) these terms are for metal trunking with trunking thickness taken into account. They may be optimistic for plastic trunking where the cross-sectional area available may be significantly reduced from the nominal by the thickness of the wall material.

f) Background to the tables

The 14th Edition of the IEE Wiring Regulations provided guidance on the number of cables which could be pulled into conduit. Unfortunately, the conduit capacities recommended could not always be achieved and guidance with regard to the effect of length, number of bends etc. was only subjective. Further, the tables had been constructed with the use of an arbitrary space factor of 40 % for conduit and 45 % for trunking; this was later shown to be inappropriate.

The criteria adopted for replacement capacity tables were that the length between pulling-in points should permit 'easy drawing in' and the cables should

not be damaged. These were quite acceptable but, because damage and easy drawing-in were not defined, the selection of an appropriate size of conduit for a group of cables remained, to a large extent, dependent on the experience of the installer.

Practical pulling in of cables was carried out over a wide range of cable and conduit arrangements to provide a rational means of predicting the size of conduit to accommodate a given bunch of mixed sizes of conduit cables (insulated conductors). The scope was limited to conduit sizes from 16 to 32 mm diameter in both steel and plastic and to single thermoplastic (pvc) insulated copper conductors from 1 to 25 mm². Single-wire conductors were included for the 1, 1.5 and 2.5 mm² sizes and multi-wire conductors were covered for sizes from 1.5 to 25 mm². Criteria were that the size of conduit should permit an 'easy pull-in' without insulation damage.

Empirical relationships between numbers and sizes of cables, distance between pull-in points, size of conduit and pulling force were deduced from numerous tests with straight conduit runs using a variety of makes of cable. The effects of type of conduit and ambient temperature were included in the investigation. Considerable variation in results was experienced, but it was possible to determine design centre values for conduit capacities based on a 'unit' approach. The unit system included both solid and stranded conductor cables.

Simple mathematical models were developed during the analysis of the above results which expressed design centre values for conduit capacities using a unit system. For straight conduit runs of 3 m length and upwards and for all lengths which include bends or sets, these models can be used to produce conduit capacity tables or can be adapted for CAD applications. For lengths up to 3 m having no bends or sets a separate empirical table of capacities was developed.

It must be noted that there is no inter-relationship between any of the series of factors for the two different conduit installation cases or for trunking installation, the factors being developed separately for each system.

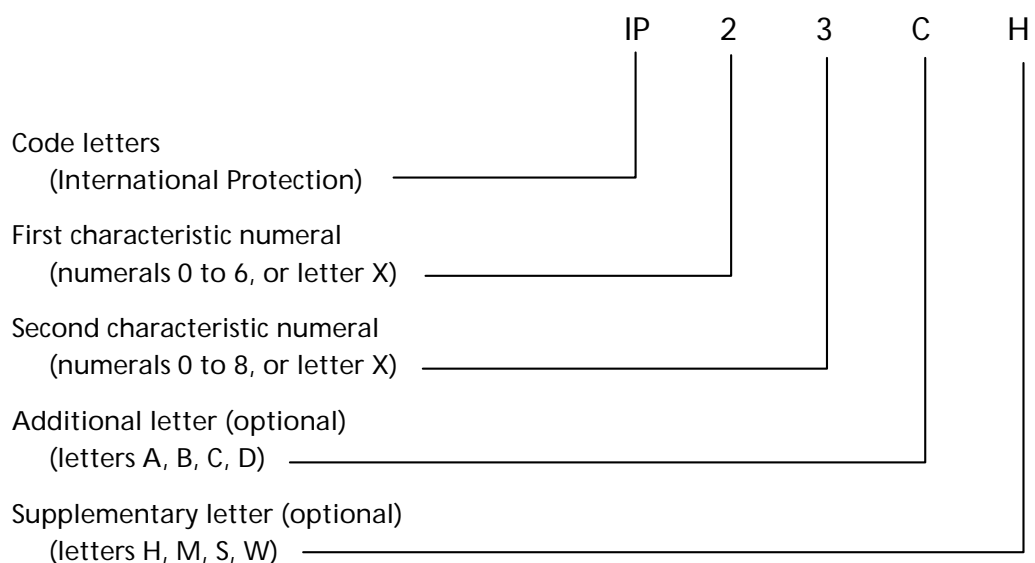
Appendix B: Degrees of protection provided by enclosures

IP code for ingress protection

General

The requirements of the IP Code are given in BS EN 60529 : 1991. This, however, is a standard used to form the basic requirements of electrical equipment standards, and the construction for IP ratings of a specific type of equipment are given in the BS for that type of equipment (e.g., the requirements for IP ratings and relevant constructional requirements for BS EN 60309-2 (BS 4343) plugs and socket-outlets are given in BS EN 60309). For this reason no mention is made directly to BS EN 60529 in BS 7671.

The degree of protection provided by an enclosure is indicated by two numerals and followed by an optional additional letter and/or optional supplementary letter(s) in the following way.



Where a characteristic numeral is not required to be specified, it can be replaced by the letter 'X' ('XX' if both numbers are omitted).

The additional letter and/or supplementary letter(s) may be omitted without replacement. Where more than one supplementary letter is used, the alphabetic sequence shall apply.

Characteristic numerals

First Characteristic Numeral		Second Characteristic Numeral	
(a) Protection of persons against access to hazardous parts inside enclosures		Protection of equipment against ingress of water	
(b) Protection of equipment against ingress of solid foreign objects			
Number	Degree of Protection	Number	Degree of Protection
0	(a) Not protected (b) Not protected	0	Not protected
1	(a) Protection against access to hazardous parts with the back of the hand (b) Protection against foreign solid objects of 50 mm diameter and greater	1	Protection against vertically falling water drops

Number	Degree of Protection	Number	Degree of Protection
2	(a) Protection against access to hazardous parts with a finger (b) Protection against solid foreign objects of 12.5 mm diameter and greater	2	Protected against vertically falling water drops when enclosure tilted up to 15°. Vertically falling water drops shall have no harmful effect when the enclosure is tilted at any angle up to 15° from the vertical
3	(a) Protection against contact by tools, wires or suchlike more than 2.5 mm thick (b) Protection against solid foreign objects of 2.5 mm diameter and greater	3	Protected against water spraying at an angle up to 60° on either side of the vertical
4	(a) As 3 above but against contact with a wire or strips more than 1.0 mm thick (b) Protection against solid foreign objects of 1.0 mm diameter and greater	4	Protected against water splashing from any direction

Number	Degree of Protection	Number	Degree of Protection
5	(a) As 4 above (b) Dust-protected (Dust may enter but not in amount sufficient to interfere with satisfactory operation or impair safety)	5	Protected against water jets from any direction
6	(a) As 4 above (b) Dust-tight (No ingress of dust)	6	Protected against powerful water jets from any direction
No Code		7	Protection against the effects of temporary immersion in water. Ingress of water in quantities causing harmful effects is not possible when enclosure is temporarily immersed in water under standardised conditions
No Code		8	Protection against the effects of continuous immersion in water under conditions agreed with a manufacturer

Additional letter

The 'additional' letter indicates the degree of protection of persons against access to hazardous parts. It is only used if the protection provided against access to hazardous parts is higher than that indicated

by the first characteristic numeral, or if only the protection against access to hazardous parts, and not general ingress, is indicated, the first characteristic numeral being then replaced by an X.

For example, such higher protection may be provided by barriers, suitable shape of openings or clearance distances inside the enclosure.

Refer to BS EN 60529 for full details of the tests and test devices used.

Additional letter	Brief description of protection
A	Protected against access with the back of the hand (minimum 50 mm diameter sphere) (adequate clearance from live parts)
B	Protected against access with a finger (minimum 12 mm diameter test finger, 80 mm long) (adequate clearance from live parts)
C	Protected against access with a tool (minimum 2.5 mm diameter tool, 100 mm long) (adequate clearance from live parts)
D	Protected against access with a wire (minimum 1 mm diameter wire, 100 mm long) (adequate clearance from live parts)

The classification of IPXXB used frequently in BS 7671 indicates that there is no classification for water or dust ingress but protection is provided against access to live parts with a finger.

Supplementary letter

In the relevant product standard, supplementary information may be indicated by a supplementary letter following the second characteristic numeral or the additional letter.

The following letters are currently in use but further letters may be introduced by future product standards.

Letter	Significance
H	High voltage apparatus
M	Tested for harmful effects due to the ingress of water when the movable parts of the equipment (e.g. the rotor of a rotating machine) are in motion
S	Tested for harmful effects due to the ingress of water when the movable parts of the equipment (e.g. the rotor of a rotating machine) are stationary
W	Suitable for use under specified weather conditions and provided with additional protective features or processes

Product Marking

The requirements for marking a product are specified in the relevant product standard. An example could be:

IP23CS

An enclosure with this designation (IP Code):






- (2) protects persons against access to hazardous parts with a finger, and
protects the equipment inside the enclosure against ingress of solid foreign objects having a diameter of 12.5 mm and greater.
- (3) protects the equipment inside the enclosure against the harmful effects of water sprayed against the enclosure at an angle of up to 60° either side of the vertical.
- (C) protects persons handling tools having a diameter of 2.5 mm and greater and a length not exceeding 100 mm against access to hazardous parts (the tool may penetrate the enclosure up to its full length).

(S) is tested for protection against harmful effects due to the ingress of water when all the parts of the equipment are stationary.

If an enclosure provides different degrees of protection for different intended mounting arrangements, the relevant degrees of protection shall be indicated by the manufacturer in the instructions related to the respective mounting arrangements.

Drip Proof and Splash Proof

Certain electrical equipment has been graded against water ingress by the identifications 'Drip Proof' etc. This labelling is now superseded by the IP coding but is given below with an equivalent IP rating for comparison. Comparisons are not exact, and the designer or installer must satisfy themselves that any equipment is suitable for the location of use.

Drip Proof		IPX2
Rain Proof		IPX3
Splash Proof		IPX4
Jet Proof		IPX5
Protected against Immersion in water		IPX7

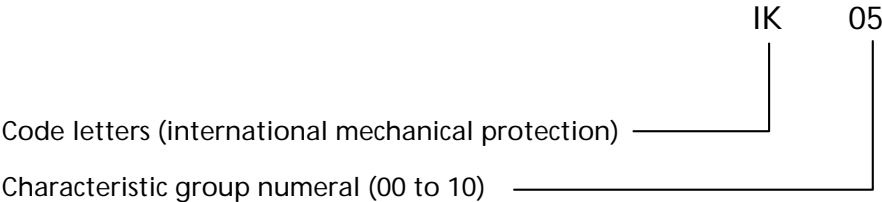
IK code for impact protection

General

BS EN 50102 : 1995 'Degrees of protection provided by enclosures for electrical equipment against external mechanical impacts (IK Code)' introduced a system for classifying the degrees of protection provided by enclosures against mechanical impact. Previously, no such classification existed in the UK although some continental countries had their own classifications.

The standard describes only the general requirements and designations for the system — the application of the system to a specific enclosure type will be covered by the British Standard applicable to that equipment or enclosure. An enclosure is defined as a part providing protection of equipment against certain external influences and protection against contact. This may be considered to include conduit, trunking etc.

In general, the degree of protection will apply to a complete enclosure. If parts of an enclosure have different degrees of protection, they must be separately identified. The coding is separate from the IP rating and will be marked separately in the following way:



Each characteristic group numeral represents an impact energy value as shown below:

IK Code	IK00	IK01	IK02	IK03	IK04	IK05	IK06	IK07	IK08	IK09	1K10
Impact energy in Joules	*	0.15	0.2	0.35	0.5	0.7	1	2	5	10	20

* No protection specified

When higher impact energy is required the value of 50 Joules is recommended.

Appendix C: Conventional circuit arrangements and the provision of socket-outlets

a) General

This Appendix gives details of conventional circuit arrangements which satisfy the requirements of Chapter 43 for overload protection and Chapter 46 for isolation and switching, together with the requirements as regards current-carrying capacities of conductors prescribed in Chapter 52 - Selection and erection of wiring systems and Appendix 4 of BS 7671.

It is the responsibility of the designer and installer when adopting these circuit arrangements to take the appropriate measures to comply with the requirements of other Chapters or Sections which are relevant, such as Chapter 41 - Protection against electric shock, Section 434 - Protection against fault current, Chapter 54 - Earthing and protective conductors, and the requirements of Chapter 52 other than those concerning current-carrying capacities.

Circuit arrangements other than those detailed in this Appendix are not precluded where they meet the requirements of BS 7671.

The conventional circuit arrangements are:

- final circuits using socket-outlets complying with BS 1363-2 and/or connection units complying with BS 1363-4
- final radial circuits using socket-outlets complying with BS EN 60309-2 (BS 4343)
- cooker final circuits in household or similar premises using cooker control units complying with BS 4177 or control switches complying with BS 3676
- water heater circuits
- electric showers.

b) Final circuits using socket-outlets and fused connection units complying with BS 1363

Layout

A ring or radial final circuit, with spurs if any, feeds permanently connected equipment and an unlimited number of socket-outlets. Ring final circuits shall comply with the requirements of Regulation 433-02-04 of BS 7671 and the circuit conductors are to form a ring (with spurs as necessary) starting and finishing at the distribution board or consumer unit protective device, neutral bar and, where appropriate, earth bar.

433-02-04

The floor area served by the circuit is determined by the known or estimated load but does not exceed the value given in Table C1.

An assessment of the loading must be made for the design of an installation, in accordance with Chapter 31 of BS 7671, and adequate circuits provided. (See also Regulation 131-03-01.)

131-03-01

For household installations, a single 30 A or 32 A ring final circuit may serve a floor area of up to 100 m², but consideration should be given to the loading in kitchens which may require a separate circuit. Socket-outlets for washing machines, tumble driers and dishwashers should be located so as to provide reasonable sharing of the load in each leg of the ring, or consideration should be given to a 4 mm² radial circuit. 2.5 mm² radial circuits may also adequately serve areas of a dwelling other than kitchens. For other types of premises, final circuits complying with Table C1 may be installed where, owing to diversity, the maximum demand of current-using equipment to be connected is estimated not to exceed the corresponding ratings of the circuit cables.

The number of socket-outlets should be such as to ensure compliance with Regulation 553-01-07, each socket-outlet of a twin or multiple socket-outlet unit being regarded as one socket-outlet.

553-01-07

Diversity between socket-outlets and permanently connected equipment has already been taken into account in Table C1 and no further diversity may be applied.

TABLE C1
Typical final circuits using BS 1363 socket-outlets in household installations

Type of circuit		Overcurrent protective device Rating A	Minimum conductor cross-sectional area*		Maximum floor area served++ m ²
			Copper conductor thermoplastic or thermosetting insulated cables mm ²	Copper conductor mineral insulated cables mm ²	
1	2	3	4	5	6
A1	Ring	30 or 32	2.5	1.5 ⁺	100
A2	Radial	30 or 32	4	2.5	75
A3	Radial	20	2.5	1.5	50

Notes

* The tabulated values of conductor size may need to be increased where more than two circuits are grouped together, but may be reduced for fused spurs.

Table C1 applies to thermoplastic (pvc) or thermosetting insulated cables of the type identified in Table 4A1 from Appendix 4 of BS 7671 in installation Method 1 and Method 3, and installed in accordance with those installation methods, and mineral insulated cable (MICC) as identified in Table 4J1A installed in accordance with reference methods 1, 11, 12 and 13 of Table 4A1.

⁺ 1.5 sq mm two-core MICC installed for a ring final circuit with a protective device rated at not more than 32 A or a radial circuit with a protective device rated at not more than 20 A may be taken as having a conductor not operating at a temperature above 70 °C and may be used to comply with the relevant requirements of Regulation 512-02-01. 1.5 sq mm four core MICC will not comply with Regulation 433-02-04 at 70 °C.

++ The socket-outlets are to be as evenly distributed between circuits as is reasonable.

Table C1 is applicable for circuits protected by fuses to BS 3036, BS 1361 and BS 88 and circuit-breakers, types B and C to BS EN 60898 or BS EN 61009-1 and BS EN 60947-2 and types 1, 2 and 3 to BS 3871.

Where two or more ring final circuits are installed the socket-outlets and permanently connected equipment to be served should be reasonably distributed among the circuits.

Circuit protection

The overcurrent protective device is of the type, and has the rating, given in Table C1.

Conductor size

The minimum size of conductor in the circuit and in non-fused spurs is given in Table C1. However, if the cables of more than two circuits are bunched together or the ambient temperature exceeds 30 °C, the size of conductor is increased and is determined by applying the appropriate correction factors from Appendix 4 of BS 7671 such that the size then corresponds to a current-carrying capacity not less than:

- 20 A for circuit A1
- 30 A or 32 A for circuit A2 (i.e. the rating of the overcurrent protective device)
- 20 A for circuit A3 (i.e. the rating of the overcurrent protective device).

433-02-04 |

The conductor size for a fused spur is determined from the total current demand served by that spur, which is limited to a maximum of 13 A.

When such a spur serves socket-outlets the minimum conductor size is:

- 1.5 mm² for thermoplastic (pvc) or thermosetting insulated cables, with copper conductors
- 1 mm² for mineral insulated cables, with copper conductors.

For a 30 A or 32 A ring final circuit with a protective device in accordance with the requirements of Regulation 433-02-04 supplying 13 A socket-outlets to BS 1363, a conductor with a minimum csa of 2.5 sq mm is deemed to comply with the requirements of Regulation 433-02-01 if the current-carrying capacity (I_z) of the cable is not less than 20 A and if, under intended conditions of use, the load current in any part of the ring is unlikely to exceed for long periods the current-carrying capacity (I_z) of the cable.

433-02-04

433-02-01 |

Electrical accessories to BS 1363 etc. are designed for a maximum operating temperature at their terminals, and are designed for use with thermoplastic (pvc) insulated conductors operating at a maximum conductor temperature of 70 °C.

Thermosetting cables can operate with conductor temperatures up to 90 °C and some types of mineral insulated cable can operate with conductor temperatures up to 105 °C.

Such temperatures can damage accessories (see Regulation 512-02-01 of BS 7671). Consequently, when used, such cables must be derated to comply with this requirement (see notes 2 & 5 of Table 4E2A, etc. of Appendix 4 of BS 7671).

512-02-01

Spurs

The total number of fused spurs is unlimited, but the number of non-fused spurs is not to exceed the total number of socket-outlets and items of stationary equipment connected directly in the circuit.

A non-fused spur feeds only one single or one twin socket-outlet or one permanently connected item of electrical equipment. Such a spur is connected to a circuit at the terminals of socket-outlets or at junction boxes or at the origin of the circuit in the distribution board.

A fused spur is connected to the circuit through a fused connection unit, the rating of the fuse in the unit not exceeding that of the cable forming the spur and, in any event, not exceeding 13 A. The number of socket-outlets which may be supplied by a fused spur is unlimited.

Permanently connected equipment

Permanently connected equipment is locally protected by a fuse complying with BS 1362 of rating not exceeding 13 A or by a circuit-breaker of rating not exceeding 16 A and of a type listed above and is controlled by a switch meeting the requirements of Regulation 476-03-04. A separate switch is not required where compliance with 476-03-04 is provided by a circuit-breaker.

c) Final radial circuits using 16 A socket-outlets complying with BS EN 60309-2 (BS 4343)

General

A radial circuit feeds equipment the maximum demand of which, having allowed for diversity, is known or estimated not to exceed the rating of the overcurrent protective device and in any event does not exceed 20 A. The number of socket-outlets is unlimited.

Circuit protection

The overcurrent protective device has a rating not exceeding 20 A.

Conductor size

The size of conductor is determined from Appendix 4 of BS 7671, applying the appropriate correction factors, and is such that it then corresponds to a current-carrying capacity not less than the rating of the overcurrent protective device.

Types of socket-outlet

Socket-outlets have a rated current of 16 A and are of the type appropriate to the number of phases, circuit voltage and earthing arrangement. Socket-outlets incorporating pilot contacts are not included.

d) Cooker final circuits in household premises

The final circuit supplies a control switch complying with BS 3676 or a cooker control unit (with a socket-outlet incorporated) complying with BS 4177. Assessment of the risks associated with the installation of a cooker control unit should always be made. A socket-outlet near a cooker could invite accidents if inappropriately located by allowing cables or equipment near hot surfaces. A cooker control unit with a socket-outlet should be installed so as to minimise the risk of such accidents; if this is not possible it is perhaps better that cooker control units should not incorporate a socket-outlet. A modern kitchen should have an adequate number of socket-outlets.

The rating of a cooking appliance circuit is determined by the assessment of the current demand of the cooking appliance(s), and control unit socket-outlet if any, in accordance with Table H1 of Appendix H. A

30/32 A circuit is suitable for most household cookers, but a 40/45 A circuit may be necessary for larger cookers.

A circuit of rating exceeding 15 A but not exceeding 50 A may supply two or more cooking appliances where these are installed in one room. One switch may be used to control all the appliances. The control switch should be placed in a readily accessible position. Attention is drawn to the need to afford discriminative operation of protective devices as stated in Regulation 533-01-06.

476-03-04

533-01-06

e) Water heating and electric shower final circuits in household premises

The final circuit must supply the full load of the electric shower. No diversity is allowable on the final circuit. Electric showers are usually in the range of 6 kW to 10 kW.

The final circuit supplies a self-contained electric shower unit, and should be an individual circuit. A separate local switch may also be installed. Supplementary equipotential bonding is required in accordance with Regulations 601-04-01 and, where applicable, 601-04-02.

601-04-01

601-04-02

Immersion heaters, fitted to storage vessels in excess of 15 litres capacity, or permanently connected heating appliances forming part of a comprehensive electric space heating installation should be supplied by their own separate circuits. Immersion heaters should not be connected by a plug and socket-outlet, but by a switched cord outlet connection unit complying with BS 1363-4.

f) Provision of socket-outlets

There is no statutory requirement for the minimum provision of socket-outlets, but the number of socket-outlets needed in a dwelling has risen significantly over the years, and can be expected to continue to rise as more electrical goods become available, and people's working practices change, with working from home becoming more common. Table C2 makes

proposals for the provision of socket-outlets in modern dwellings.

Number of socket-outlets

Regulation 553-01-07 requires that an adequate number of socket-outlets be provided and located to allow the use of portable equipment with the length of flexible cord normally fitted. Long extension leads, trailing sockets and extending flexible cords which are incorrectly or inappropriately located can create tripping hazards and can damage and cause wear and overheating of the flex when flexible cords are placed under carpets, etc. In order, so far as is possible, to make the use of multiway adaptors or extension leads unnecessary an adequate number of fixed socket-outlets should be installed as listed in Table C2. Multi-way adaptors, long extension leads, trailing socket-outlets and extending flexible cords should never be used unattended and should always be visible and accessible throughout their length.

553-01-07

Unfortunately, no matter how good the overall layout some socket-outlets will inevitably become inaccessible behind furniture when the dwelling is furnished, and the designer should consider this in the initial provisions. Also, the continued future growth in appliances and equipment should be expected, and so what may seem initially an over-generous provision ultimately may not be. The Copper Development Association (CDA) research into recently built dwellings (under two years old) has shown that generally 50% of householders considered they did not have an adequate provision of socket-outlets. This rose to 70% in the category of owners of the "normal" three-bedroom home.

TABLE C2
Recommended provision of socket-outlets
(All socket-outlets are twin)

Location	No. of outlets	Notes
Lounge	6 to 10	(1) (2) (3) (9)
Dining	3	
Kitchen	6 to 10	(3) (4) (5) (9)
Double Bedroom	4 to 6	(3)
Single Bedroom	4 to 6	(3) (6) (9)
Bedsitter	4	
Hall	2	(7)
Stairs/Landing	1	
Loft	1	(7)
Study/Home office	6	(7) (8) (9)
Garage	2	
Utility Room	2	(5)

(This table was prepared with the kind assistance of the ECA, Select, NHBC, CDA and EIEMA).

Notes

- (1) The number of outlets depends to some extent on the size of the room (e.g. through lounge), as larger areas may require more outlets on a pro-rata basis.
- (2) Two twin socket-outlets should be located close to the TV aerial outlet to allow for TV, video etc. and ancillary equipment supplies.
- (3) Larger dwellings may require proportionally more socket-outlets pro-rata than smaller dwellings as the occupants of more expensive homes usually have a higher disposable income and hence may have more electrical appliances and equipment.
- (4) Kitchens should have the provision of several convenience socket-outlets around work surface areas as well as the provision of specific socket-outlets for washing machines and other appliances where built-in. Due to the expected load it may be sensible for the kitchen/utility area socket-outlets to be on a separate radial or ring final circuit.
- (5) A lower number of socket-outlets may be appropriate in a kitchen where the washing machine, dryer, freezer etc. are expected to be in a separate utility room.
- (6) Bedrooms intended for younger persons should have adequate provision of socket-outlets for computer and electronic equipment.

- (7) One twin socket-outlet should be near any telephone outlet for supplies to any telephone, answerphone or fax equipment.
- (8) The provisions for an office at home may require more consideration with the user to identify and locate all necessary equipment than is the case with an ordinary domestic installation.
- (9) The increasing use of IT and other electrical equipment in the home with high protective conductor currents may require the application of Regulation 607-02-06 to accommodate cumulative leakage currents. 607-02-06
- (10) In Scotland, the Technical Standards for compliance with the Building Standards (Scotland) Regulations 1990 Part Q gives the minimum number of socket-outlets for dwellings.

Sinks and electrical accessories

How close are electrical accessories, such as socket-outlets, permitted to be to a sink? This question is commonly asked, not only by members of the public, but also by electrical contractors and designers concerning both domestic and commercial premises.

Some are under the impression that a minimum distance is given in BS 7671 within which electrical accessories must not be installed. This is not true. It is impractical to prescribe such a distance in BS 7671, given the fact that many kitchens are very small. It is almost inevitable therefore, in many situations, that socket-outlets will be installed which are simultaneously accessible to sink tops.

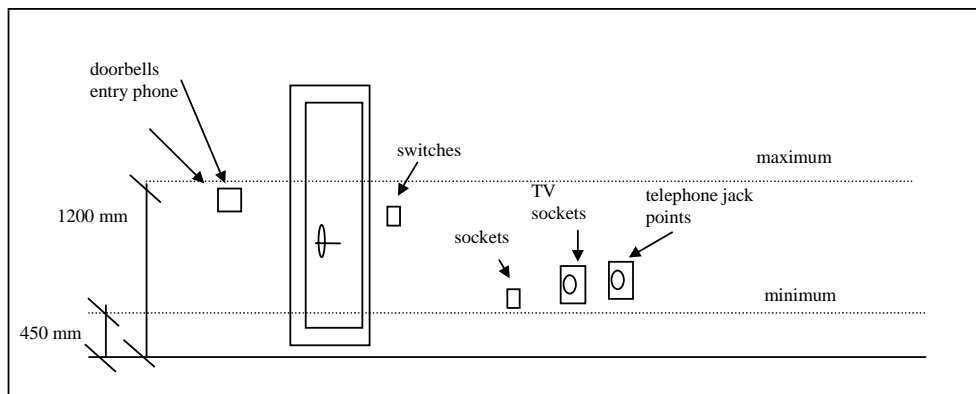
The type of accessory installed must be of a design appropriate to its location as required by Regulations 512-06-01 and 522-03-01. Where BS 1363 accessories are used, they should be installed as far from the sink as possible. As a general recommendation, BS 1363 accessories should be mounted above sink height at a horizontal distance of not less than 300 mm from the edge of the sink top. 512-06-01
522-03-01

g) Mounting heights of accessories

Accessories must be mounted at a height which will make them accessible but prevent damage by their being struck or wetted by floor cleaning equipment, and allow a comfortable bending radius for larger or stiff flexible cords. (Regulation 553-01-06). The Building Regulations 2000 Approved Document M, Access and facilities for disabled people, contains appropriate 553-01-06

mounting heights between 450 mm and 1200 mm for electrical equipment in dwellings (see Fig C1).

Fig C1: **Heights of switches, sockets etc.**



From Approved Document M, 1999 edition Section 8.

BS 8300 : 2001 'Design of buildings and their approaches to meet the needs of disabled people - Code of Practice'.

BS 8300, which applies to all types of buildings, contains a number of recommendations which could affect the design of an electrical installation. The requirements concerning the location of outlets, switches, controls and meters are shown in the extract from the standard given on the following page.

It should be noted that this document is not mandatory unless directly referred to in the specification or the specification contains a general requirement to the effect that the electrical installation must comply with all relevant standards and codes. In case of doubt, the exact requirements of the client must be ascertained prior to undertaking the project.

BS 8300 : 2001 Extract

10.5.2 Location of outlets, switches, controls and meters

All outlets, switches and controls, including 2-way switching, should be positioned consistently in relation to doorways and corners within a building and in a logical sequence to suit passage through the building.

NOTE 1 By using vertical strips as switches, instead of single height switches, users can operate the switch at whichever height is convenient for them.

Preferably, light switches should align horizontally with door handles for ease of location when entering a room.

Electrical socket-outlets, telephone points and TV sockets should be located at least 400 mm but not more than 1000 mm above the floor. Socket-outlets whose plugs are likely to be removed and replaced frequently should be located at the top of the range (see figure below).

NOTE 2 Switches close to the floor or skirting are difficult and dangerous because they require users to stoop or kneel to operate them. The higher the socket-outlet, the easier it is to push in or pull out the plug.

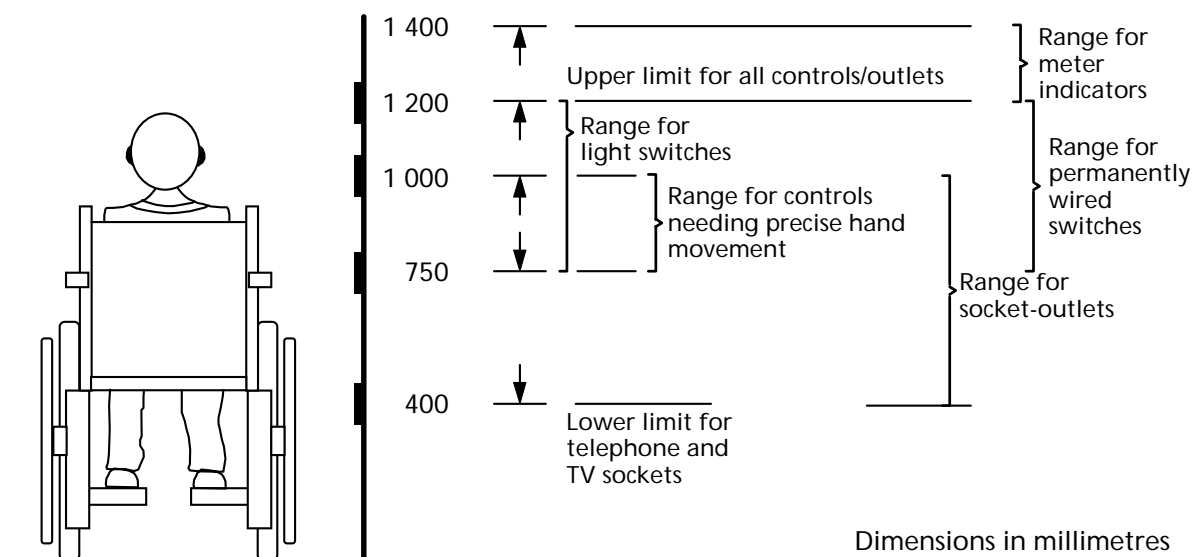
Switches for permanently wired appliances (e.g. fused spurs or reset switches for alarm calls) should be mounted within the range between 750 mm and 1200 mm (see figure below).

Meters should be mounted between 1200 mm and 1400 mm from the floor so that the readings can be viewed by a person standing or sitting. Pre-pay meters should be accessible, but protected so children cannot tamper with them.

All switches and controls that require precise hand movement/dexterity, e.g. for heating installations, ventilation etc., should be in a zone 750 mm to 1000 mm from the floor (see figure below) so that wheelchair users and those standing can operate them.

The maximum height of simple push button controls, including isolator switches and circuit-breakers, that require limited dexterity should be 1200 mm (see figure below).

Outlets, switches and controls should be at least 350 mm from room corners .



Appendix D: Limitation of earth fault loop impedance for compliance with Regulation 543-01-01

Regulation 543-01-01 indicates that the cross-sectional area of a protective conductor, other than an equipotential bonding conductor, shall be:

543-01-01

- (i) calculated in accordance with Regulation 543-01-03, or
- (ii) determined in accordance with Regulation 543-01-04.

In some cases the type of wiring system it is intended to use determines which of the two methods can be followed. For instance, the widely used flat twin and flat three-core thermoplastic (pvc) insulated and thermoplastic (pvc) sheathed cables with protective conductors (cables to Table 5 of BS 6004) do not comply with Table 54G of Regulation 543-01-04 (other than the 1 mm² size) and therefore Method (i) must be used.

Where Method (i) is used, in order to apply the formula given in Regulation 543-01-03 it is essential that the time/current characteristic of the overcurrent protective device in the circuit concerned is available. A selection of such characteristics for fuses and circuit-breakers is given in Appendix 3 of BS 7671. For other types of device the advice of the manufacturer has to be sought. The time/current characteristics given in Appendix 3 indicate the values of I_a against various disconnection times for the devices tabulated and give co-ordinates for fixed times. For cbs the curves indicate the maximum operating current I_a of a particular type of cb and RCBO (see Table 3.3, Section 3.4 of this Guidance Note for cb type details). However, for hrc fuses, the curves given in Appendix 3 of BS 7671 are

drawn on the median of the 'windows' provided for each rating in the fuse standard.

Assuming that the size and type of cable to be used have already been determined from consideration of other aspects such as mechanical protection and installation requirements together with the magnitude of the design current of the circuit and the limitation of voltage drop under normal load conditions, the first stage is to calculate the earth fault loop impedance, Z_s . If the cable it is intended to use does not incorporate a suitable protective conductor, that conductor has to be chosen separately. Regulation 543-02-02 details what may be used as a protective conductor.

543-02-02

For cables having conductors of cross-sectional area not exceeding 35 mm², their inductive reactance can be ignored so that where these cables are used in radial circuits, the earth fault loop impedance Z_s is given by:

$$Z_s = Z_e + (R_1 + R_2) \text{ ohms} \quad (1)$$

Z_e is that part of the earth fault loop impedance external to the circuit concerned, R_1 is the resistance of the circuit phase conductor from the origin of the circuit where Z_e is taken to the most distant socket-outlet or other point of utilization, and R_2 is the resistance of the circuit protective conductor from the origin of the circuit where Z_e is taken to the most distant socket-outlet or other point of utilization, at normal conductor operating temperature.

Similarly, where such cables are used in a ring circuit without spurs, the earth fault loop impedance Z_s is given by:

$$Z_s = Z_e + 0.25 R_1 + 0.25 R_2 \text{ ohms} \quad (2)$$

where Z_e is as described in (1) above, R_1 is now the total resistance of the phase conductor between its ends prior to them being connected together to complete the ring, and R_2 is similarly the total resistance of the protective conductor.

Note: Strictly, the above equations are vectorial, but arithmetic addition to determine the earth fault loop impedance may be used, as it gives a pessimistically high value for that impedance.

Having determined Z_s , the operating current I (in this case, the earth fault current I_f) is given by:

$$I = \frac{U_{oc}}{Z_s} \text{ amperes} \quad (3)$$

where:

U_{oc} is the open circuit nominal voltage to earth (phase to neutral voltage) at the origin of the supply, usually the distribution transformer.

For the purposes of this Appendix, in accordance with BS 7671 Appendix 3, the open circuit voltage U_{oc} has been presumed to be 240 V for a nominal supply voltage U_o of 230 V. This allows the formula to become:

$$I_f = \frac{U_o}{Z_s} \quad (4)$$

where:

U_o is the nominal phase to earth supply voltage.

From the relevant overcurrent protective device time/current characteristic the time (t) for disconnection corresponding to this earth fault current is obtained.

Substitution for I_f , t and the appropriate k value in the equation

$$S = \frac{\sqrt{I_f^2 t}}{k} \quad (5)$$

Where:

S is the circuit protective conductor minimum cross-sectional area in mm^2

from Regulation 543-01-03, this calculation then gives the minimum cross-sectional area of the protective conductor that will provide adequate thermal capacity to withstand the heat produced by the passage of fault current without damage. This has to be equal to or less than the circuit protective conductor size originally chosen (which has resistance R_2). This calculation is usually known as the adiabatic calculation. Where the phase and protective conductors comply with the minimum size

requirements of Table 54G of BS 7671 this adiabatic calculation is not necessary, as the conductors comply with the requirements of Regulation 543-01-04.

543-01-04

In order to assist the designer, when the cables it is intended to use are to Table 5 of BS 6004, or Table 7 of BS 7211, or are other thermoplastic (pvc) insulated and sheathed cables to the relevant British Standards, Tables D1 to D3 give the maximum earth fault loop impedances (Z_s) for circuits having phase and protective conductors of copper from 1 mm² to 16 mm² cross-sectional area and where the overcurrent protective device is a fuse to BS 88-2.1, BS 88-6, BS 1361 or BS 3036. The tables also apply if the protective conductor is bare copper and in contact with cable insulated with thermoplastic (pvc).

For each type of fuse, two tables are given:

- (i) where the circuit concerned feeds socket-outlets and the disconnection time for compliance with Regulation 413-02-09 is 0.4 s, and
- (ii) where the circuit concerned feeds fixed equipment only and the disconnection time for compliance with Regulation 413-02-13 is 5 s.

Table D4 gives the maximum earth fault loop impedances for circuits where the overcurrent protective device is a circuit-breaker (cb) to BS 3871 Part 1 (now withdrawn) or BS EN 60898. The values given apply to both 0.4 s and 5 s disconnection times since, in practice, the overcurrents corresponding to the 0.4 s and 5 s disconnection times both cause the circuit-breaker to operate within 0.1 s.

It should always be remembered that circuit-breakers will operate within 0.1 s whenever the fault current is equal to or greater than the upper limit of their 'instantaneous' tripping band. That is:

For Type B circuit-breakers - Fault current $\geq 5 I_n$
For Type C circuit-breakers - Fault current $\geq 10 I_n$
For Type D circuit-breakers - Fault current $\geq 20 I_n$

Where the adiabatic calculation of S for compliance with Regulation 543-01-03 is carried out, the value of t in equation (5) is 0.1s.

For circuits protected by cbs, compliance with Table D4 provides compliance with Regulation 543-01-01 where the protective conductors range from 1 mm² to 16 mm² cross-sectional area and the rated current of the cbs range from 5 A to 63 A.

In each table the earth fault loop impedances given correspond to the appropriate disconnection time from a comparison of the time/current characteristic of the device concerned and the equation given in Regulation 543-01-03.

The tabulated values apply only when the nominal voltage to earth (U_o) is 230 V.

For guidance on conductor resistances, see Appendix E.

The tabulated loop impedances are design figures assuming final conductor temperatures appropriate to earth fault conditions. For testing purposes the loop impedances must be reduced. For example, if testing at an ambient of 10 °C using cables to Table 5 of BS 6004, the maximum permitted test loop impedance is given by:

$$Z_{test} \leq (Z_{FX} - Z_e) \frac{0.96}{1.20} + Z_e \quad (6)$$

where:

Z_{FX} is the loop impedance given by Tables D1, D2, D3 or D4

Z_e is the supply earth loop impedance

1.20 is the multiplier from Table E2

0.96 is the ambient correction factor following Table E3.

TABLE D1

**Maximum earth fault loop impedance (in ohms)
when overcurrent protective device is a fuse to
BS 3036**

**(1) For circuits feeding socket-outlets — 0.4
second disconnection**

Protective conductor mm ²	Fuse rating, amperes				
	5	15	20	30	45
1	10	2.67	1.85	NP	NP
1.5	10	2.67	1.85	1.14	NP
2.5 to 16.0	10	2.67	1.85	1.14	0.62

**(2) For circuits feeding fixed equipment — 5
seconds disconnection**

Protective conductor mm ²	Fuse rating, amperes				
	5	15	20	30	45
1	18.5	5.58	3.50(ii)	NP	NP
1.5	18.5	5.58	4.00	2.60(ii)	NP
2.5	18.5	5.58	4.00	2.76	1.50(ii)
4 to 16.0	18.5	5.58	4.00	2.76	1.66

Notes:

(i) A value for k of 115 from Table 54C of BS 7671 is used for this table. This is also suitable for cables to Table 5 of BS 6004.

(ii) Limited by thermal considerations of the protective conductor cross-sectional area, see Regulation 543-01-03.

NP Protective conductor, fuse combination not permitted.

TABLE D2

**Maximum earth fault loop impedance (in ohms)
when overcurrent protective device is a fuse to
BS 88-2.1 or BS 88-6**

**(1) For circuits feeding socket-outlets — 0.4
second disconnection**

Protective conductor mm ²	Fuse rating, amperes							
	6	10	16	20	25	32	40	50
1	8.89	5.33	2.82	1.85	1.50	0.86(ii)	NP	NP
1.5	8.89	5.33	2.82	1.85	1.50	1.09	0.83(ii)	NP
2.5 to 16.0	8.89	5.33	2.82	1.85	1.50	1.09	0.86	0.63

**(2) For circuits feeding fixed equipment — 5
seconds disconnection**

Protective conductor mm ²	Fuse rating, amperes							
	6	10	16	20	25	32	40	50
1	14.10	7.74	4.00(ii)	2.18(ii)	1.32(ii)	0.84	NP	NP
1.5	14.10	7.74	4.36	3.04	1.63(ii)	1.22	NP	NP
2.5	14.10	7.74	4.36	3.04	2.40	1.92	1.08(ii)	0.71(ii)
4	14.10	7.74	4.36	3.04	2.40	1.92	1.41	1.00(ii)
6 to 16.0	14.10	7.74	4.36	3.04	2.40	1.92	1.41	1.09

Notes:

(i) A value for k of 115 from Table 54C of BS 7671 is used for this table. This is also suitable for cables to Table 5 of BS 6004.

(ii) Limited by thermal considerations of the protective conductor cross-sectional area, see Regulation 543-01-03.

NP Protective conductor, fuse combination not permitted.

TABLE D3

**Maximum earth fault loop impedance (in ohms)
when overcurrent protective device is a fuse to
BS 1361**

**(1) For circuits feeding socket-outlets — 0.4
second disconnection**

Protective conductor mm ²	Fuse rating, amperes				
	5	15	20	30	45
1	10.90	3.43	1.78	1.00(ii)	NP
1.5	10.90	3.43	1.78	1.20	0.43(ii)
2.5 to 16.0	10.90	3.43	1.78	1.20	0.60

**(2) For circuits feeding fixed equipment — 5
seconds disconnection**

Protective conductor mm ²	Fuse rating, amperes				
	5	15	20	30	45
1	17.10	5.22	2.18(ii)	1.00(ii)	NP
1.5	17.10	5.22	2.80(ii)	1.50(ii)	0.43(ii)
2.5	17.10	5.22	2.93	1.92	0.66(ii)
4	17.10	5.22	2.93	1.92	0.88(ii)
6 to 16.0	17.10	5.22	2.93	1.92	1.00

Notes:

(i) A value for k of 115 from Table 54C of BS 7671 is used for this table. This is also suitable for cables to Table 5 of BS 6004.

(ii) Limited by thermal considerations of the protective conductor cross-sectional area, see Regulation 543-01-03.

NP Protective conductor, fuse combination not permitted.

TABLE D4

Maximum measured earth fault loop impedance (in ohms) when overcurrent protective devices are circuit-breakers to BS EN 60898 or RCBOs to BS EN 61009

Table 41B2
413-02-05

(i) both 0.4 and 5 seconds disconnection times (see Note 1 and Note 2)

circuit-breaker type	circuit-breaker rating (amperes)											
	6	10	16	20	25	32	40	50	63	80	100	125
B	8.00	4.80	3.00	2.40	1.92	1.50	1.20	0.96	0.76	0.60	0.48	0.38
C	4.00	2.40	1.50	1.20	0.96	0.75	0.60	0.48	0.38	0.30	0.24	0.19
D	2.00	1.20	0.75	0.60	0.48	0.38	0.30	0.24	0.19	0.15	0.12	0.10

Maximum measured earth fault loop impedance (in ohms) when overcurrent protective devices are mcbs to BS 3871

(ii) both 0.4 and 5 seconds disconnection times (see Note 1)

mcb type	mcb rating (amperes)												
	5	6	10	15	16	20	25	30	32	40	45	50	63
1	12.00	10.00	6.00	4.00	3.75	3.00	2.40	2.00	1.88	1.50	1.33	1.20	0.95
2	6.86	5.71	3.43	2.29	2.14	1.71	1.37	1.14	1.07	0.86	0.76	0.69	0.54
3	4.80	4.00	2.40	1.60	1.50	1.20	0.96	0.80	0.75	0.60	0.53	0.48	0.38

Notes:

- (i) A value for k of 115 from Table 54C of BS 7671 is used. This is suitable for thermoplastic (pvc) insulated and sheathed cables to Table 5 and Table 6 of BS 6004 and for Isf insulated and sheathed cables to Table 7 of BS 7211. The k value is based on both the thermoplastic (pvc) and Isf cables operating at a maximum operating temperature of 70 °C.
- (ii) In TN systems it is preferable for reliable operation for indirect shock protection to be provided by overcurrent devices including RCBOs operating as overcurrent devices; that is, with loop impedance complying with the table above. RCBOs are then providing indirect shock protection as circuit-breakers, and supplementary protection against direct contact as RCDs. If however the residual current element of an RCBO has been selected to provide protection against indirect contact the tabulated values of maximum earth fault loop impedance do not apply.

413-02-04
471-16

Selection of a circuit protective conductor

As previously stated, Regulation 543-01-01 allows the selection of a circuit protective conductor (cpc) by calculation in accordance with Regulation 543-01-03 or by reference to Table 54G to select the minimum size, in accordance with Regulation 543-01-04.

Table 54G provides a method to establish the minimum size of cpc based on the area of the phase conductor of the circuit. In many cases the material and size of the intended cpc is established by the selection of the wiring system to be used - i.e. steel wire armoured cables, steel conduit, mineral insulated cables etc. If the cross-sectional area of the armour, conduit etc. is found to comply with the requirements of Table 54G then calculation of the thermal capacity is not usually necessary.

Steel conduit and trunking

For some types of cpc, e.g. steel conduit, a check to prove compliance with Table 54G is quite simple, and minimum cross-sectional areas of heavy gauge steel conduit and steel trunkings are listed in Table D5. Taking the value of k_1 as 115 for thermoplastic (pvc) from Table 43A and k_2 as 47 from Table 54E it can be shown that heavy gauge steel conduit is a suitable protective conductor for all sizes of conductor that can be drawn into it in accordance with Appendix A.

A well installed and maintained steel conduit and cable trunking system can provide an adequate cpc for a final circuit (Regulation 543-02-02). Unfortunately, conduit and trunking impedance data for the calculation of earth fault loop impedances of circuits utilising conduit or trunking as a protective conductor is not readily available and so the practice of installing a separate cpc has arisen. This is usually uneconomical and unnecessary.

However, when a conduit or trunking is to be utilised as a protective conductor, all joints must be tight and secure, and the system protected from corrosion. The cross-sectional area of the protective conductor must be taken as the minimum of any variations of size along the route. Consideration must also be made of the possible further reduction in cross-sectional area at conduit running couplers and cable trunking couplers, with only metal-to-metal contact at bolt holes even when copper links are fitted. Flanged couplers may be necessary to provide adequate continuity at conduit connections onto trunking systems. It must be remembered that the Electricity at Work Regulations 1989 require that an adequate connection to earth be provided where this is needed to prevent danger (Regulation 8).

TABLE D5
Cross-sectional areas of steel conduit and trunking

Heavy Gauge Steel Conduit to BS 4568 Pt 1

Nominal diameter (mm)	Minimum steel cross-sectional area (sq mm)
16	64.4
20	82.6
25	105.4
32	137.3

Steel Surface Trunking BS 4678-1 (sample sizes)

Nominal size (mm x mm)	Minimum steel cross-sectional area without lid (sq mm)
50 x 50	135
75 x 75	243
100 x 50	216
100 x 100	324
150 x 100	378

Steel Underfloor Trunking BS 4678-2 (sample sizes)

Nominal size (mm x mm)	Minimum steel cross-sectional area without lid (sq mm)
75 x 25	118
100 x 50	142
100 x 100	213
150 x 100	284

The requirements of Regulation 543-03, as they apply, must be complied with in respect of the preservation of electrical continuity, for a protective conductor common to several circuits. The cross-sectional area must either be calculated to provide adequate capacity for the most onerous conditions of any of the several circuits, or sized from Table 54G to correspond with the largest phase conductor of the several circuits. Therefore, a metal conduit or trunking could serve as a cpc to all the group of circuits it encloses.

Formulae for the calculation of the resistance and inductive reactance values of steel conduit and steel ducting and trunking are published in IEE Guidance Note 6.

Steel-wire armoured cables

If a BS 88 fuse or a circuit-breaker is selected for overload protection of thermoplastic (pvc)/SWA/thermoplastic (pvc) cable to BS 5346 or XLPE/SWA/thermoplastic (pvc) cable to BS 5467 then for an earth fault disconnection time of up to 5 s the steel armouring will have a sufficient cross-sectional area to comply with Regulation 543-01-03 with two exceptions. These exceptions are two-core 240 sq mm and 300 sq mm XLPE/SWA/thermoplastic (pvc) to BS 5467.

From I, t and k, the required minimum cross-sectional area of wire armour required, S , can be calculated and compared with the area provided by the cable. The cross-sectional areas of steel-wire armour on thermosetting insulated cables to BS 5467 and thermoplastic (pvc) insulated cables to BS 6346 are given in Tables 12E and 12F of the Commentary on BS 7671 : 2001 (IEE Wiring Regulations).

It will be found that, if the protective device is one of the standard types mentioned in the Regulations and if its rating is not greater than the current rating of the cable, the cross-sectional area of the armour is greater than required to comply with the Regulations. This assumes that the earth fault loop impedance of the circuit is such as to ensure that the device will operate in not more than 5 seconds on the occurrence of a fault of negligible impedance.

TABLE D6

**Copper conductor, thermoplastic (pvc) insulated
steel-wire armoured cables to BS 6346 and fuses
to BS 88**

Fuse Rating	Required area of SWA (5 seconds disconnection)	Smallest cable providing required area of SWA			
		2 core	3 core	4 core (equal)	4 core (red. neut.)
A	sq mm	sq mm	sq mm	sq mm	sq mm
* 63	14.3	1.5 (20 A)	1.5 (18 A)	1.5 (18 A)	-
80	21	4 (37 A)	4 (31 A)	2.5 (24 A)	-
100	28	10 (69 A)	6 (42 A)	4 (31 A)	-
125	35	10 (69 A)	6 (42 A)	4(31 A)	-
160	46	16 (90 A)	16 (77 A)	10 (58 A)	-
200	61	25 (121 A)	25 (102 A)	16 (77 A)	-
250	77	70 (220 A)	70 (220 A)	50 (155 A)	35 (125 A)
315	107	95 (270 A)	70 (190 A)	50 (155 A)	70 (190 A)
400	133	120 (310 A)	95 (230 A)	70 (190 A)	70 (190 A)
500	178	185 (410 A)	150 (310 A)	120 (310 A)	120 (270 A)
630	224	240 (485 A)	185 (350 A)	150 (310 A)	150 (310 A)
800	350	-	-	400 (550 A)	400 (550 A)

*For BS 88 fuses of 6 A - 50 A ratings, the required armour area is, of course, less than that required for the 63 A fuse and the cables with 1.5 sq mm conductors, the smallest in BS 6346, provide areas exceeding the required minima.

TABLE D7

Copper conductor, thermoplastic (pvc) insulated steel wire armoured cables to BS 6346 and miniature circuit-breakers to BS 3871 and circuit-breakers to BS EN 60898

(XLPE Cables to BS 5467 also comply with the following requirements)

Circuit-breaker designation	Required area of SWA (5 second disconnection)	Smallest cable providing required area of SWA		
		2 core	3 core	4 core
	sq mm	sq mm	sq mm	sq mm
*30/32 A Type 1	6.1	1.5 (20 A)	1.5 (18 A)	1.5 (18 A)
30/32 A Type 2 or Type B	10.7	1.5 (20 A)	1.5 (18 A)	1.5 (18 A)
30/32 A Type 3 or Type C	13.7	1.5 (20 A)	1.5 (18 A)	1.5 (18 A)
50 A Type 1	10.2	1.5 (20 A)	1.5 (18 A)	1.5 (18 A)
50 A Type 2 or Type B	17.8	1.5 (20 A)	1.5 (18 A)	1.5 (18 A)
50 A Type 3 or Type C	21.8	4 (37 A)	4 (31 A)	4 (31 A)

*For 5 A - 20 A circuit-breakers of all types to BS 3871 and 6 A - 25 A for BS EN 60898, the 1.5 sq mm cables provide armour areas exceeding the required minima.

TABLE D8

**Copper conductor, 90 °C thermosetting insulated
steel-wire armoured cables to BS 5467 and fuses
to BS 88**

Fuse Rating	Required area of SWA (5 second disconnection)	Smallest cable providing required area of SWA			
		2 core	3 core	4 core (equal)	4 core (red. neut.)
A	sq mm	sq mm	sq mm	sq mm	sq mm
* 25	28.2	16 (114 A)	16 (100 A)	16 (100 A)	-
160	37	16 (114 A)	16 (100 A)	16 (100 A)	-
200	50	35 (190 A)	25 (133 A)	25 (133 A)	25 (133 A)
250	62	50 (228 A)	25 (133 A)	25 (133 A)	25 (133 A)
315	87	95 (356 A)	70 (247 A)	50 (195 A)	50 (195 A)
400	108	95 (356 A)	95 (304 A)	70 (247 A)	70 (247 A)
500	145	185 (540 A)	150 (408 A)	95 (304 A)	95 (304 A)
630	182	185 (540 A)	150 (408 A)	120 (350 A)	150 (408 A)
800	286	-	-	240 (550 A)	300 (627 A)

* For fuses to BS 88 of lower rating than 125 A, cables with 16 sq mm conductors, the smallest size in BS 5467, provide armour areas exceeding the required minima.

Tables are also given below identifying which of the standard sizes of steel-wire armoured cables can be utilised to comply with Table 54G.

TABLE D9

Thermoplastic (pvc)/SWA/thermoplastic (pvc) cables to BS 6346. Insulation operating at 70 °C.
For Table 54G, $k_1 = 115$ (103 for 400 sq mm) from Table 43A and $k_2 = 51$ from Table 54D

sq mm conductor	minimum csa of steel cpc required to comply with Table 54G - sq mm	Actual armour csa from BS 6346		
		2-core	3-core	4-core
1.5	3.4	15	16	17
2.5	5.7	17	19	20
4	9.0	21	23	35
6	13.6	24	36	40
10	22.6	41	44	49
16	36.1	46	50	72
25	36.1	60	66	76
35	36.1	66	74	84
50	56.4	74	84	122
70	79.0	84	119	138
95	107.2	122	138	160
120	135.3	(131)	150	220
150	169.2	(144)	211	240
185	208.6	(201)	230	265
240	270.6	(225)	(260)	299
300	338.3	(250)	(289)	(333)
400	403.9	(279)	(319)	(467)

(—) Indicates that the cable does not comply with Table 54G. Therefore, the cpc size must be confirmed by calculation as indicated by Regulation 543-01-03 or a supplementary cpc of the full conductor size must be installed.

There are times when an XLPE insulated cable, normally rated at 90 °C, may be run alongside thermoplastic (pvc) insulated cables operating at 70 °C. Under such circumstances the 90 °C thermosetting insulated cable must be limited to the lower operating temperature of 70 °C, and Table D10B should be sought to determine if the armour complies with Table 54G.

TABLE D10A

90 °C thermosetting insulated steel-wire armoured cables to BS 5467 and BS 6724.

Insulation operating at 90 °C.

For Table 54G, $k_1 = 143$ from Table 43A and $k_2 = 46$ from Table 54D

sq mm conductor	minimum csa of steel cpc required to comply with Table 54G - sq mm	Actual armour csa from BS 5467 and BS 6724		
		2-core	3-core	4-core
1.5	4.7	15	16	17
2.5	7.8	17	19	20
4	12.5	19	21	23
6	18.7	22	23	36
10	31.1	(26)	39	43
16	49.8	(41)	(44)	(49)
25	49.8	(42)	62	70
35	49.8	62	70	80
50	77.8	(68)	78	90
70	108.8	(80)	(90)	131
95	147.7	(113)	(128)	(147)
120	186.6	(125)	(141)	206
150	233.2	(138)	(201)	(230)
185	287.6	(191)	(220)	(255)
240	373.1	(215)	(250)	(289)
300	466.3	(235)	(269)	(319)
400	521.07	(265)	(304)	(452)*

* Not applicable to BS 6724.

(—) Indicates that the cable does not comply with Table 54G. Therefore, the cpc size must be confirmed by calculation as indicated by Regulation 543-01-03 or a supplementary cpc of the full conductor size must be installed.

TABLE D10B

90 °C thermosetting insulated steel-wire armoured cables to BS 5467 and BS 6724.

Insulation operating at 70 °C.

For Table 54G, $k_1 = 115$ from Table 43A and $k_2 = 51$ from Table 54D

sq mm conductor	minimum csa of steel cpc required to comply with Table 54G - sq mm	Actual armour csa from BS 5467 and BS 6724		
		2-core	3-core	4-core
1.5	3.4	16	17	18
2.5	5.7	17	19	20
4	9.0	19	21	23
6	13.6	22	23	36
10	22.6	26	39	43
16	36.1	41	44	49
25	36.1	42	62	70
35	36.1	62	70	80
50	56.4	68	78	90
70	79.0	80	90	131
95	107.2	113	128	147
120	135.3	(125)	141	206
150	169.2	(138)	201	230
185	208.6	(191)	220	255
240	270.6	(215)	(250)	289
300	388.3	(235)	(269)	(319)
400	451.0	(265)	(304)	(452)*

* Not applicable to BS 6724.

(—) Indicates that the cable does not comply with (Table 54G. Therefore, the cpc size must be confirmed by calculation as indicated by Regulation 543-01-03 or a supplementary cpc of the full conductor size must be installed.

Mineral insulated cable with copper sheath

Cross-sectional areas of the copper sheath of light duty and heavy duty mineral insulated cables to BS 6207 are given in the Table D11, in which compliance with Table 54G is indicated.

TABLE D11

Cable size reference	Effective sheath area mm ²
500 V Grade (Light duty)	
2L1	5.4
2L1.5	6.3
2L2.5	8.2
2L4	10.7
3L1	6.7
3L1.5	7.8
3L2.5	9.5
4L1	7.7
4L1.5	9.1
4L2.5	11.3
7L1	10.2
7L1.5	11.8
7L2.5	15.4
750 V Grade (Heavy duty)	
1H6.0	8.0
1H10	(9.0)
1H16	(12.0)
1H25	(15.0)
1H35	(18.0)
1H50	(22.0)
1H70	(27.0)
1H95	(32.0)
1H120	(37.0)
1H150	(44.0)
1H185	(54.0)
1H240	(70.0)
2H1.5	11
2H2.5	13
2H4	16
2H6	18
2H10	24
2H16	30
2H25	38

TABLE D11 *continued*

Cable size reference	Effective sheath area mm ²
750 V Grade (Heavy duty)	
3H1.5	12
3H2.5	14
3H4	17
3H6	20
3H10	27
3H16	34
3H25	42
4H1.5	14
4H2.5	16
4H4	20
4H6	24
4H10	30
4H16	39
4H25	49
7H1.5	18
7H2.5	22
12H2.5	34
19H2.5	37

(—) Indicates that the cable does not comply with Table 54G. Therefore, the cpc size must be confirmed by calculation as indicated by Regulation 543-01-03 or a supplementary cpc must be installed.

It can be seen that all multicore sizes comply with Table 54G but, with the exception of 1H6 and 1H35, the Heavy duty single-core micc cables do not. Although these cables singularly do not comply, usually single-core cables would be run in pairs for a single-phase circuit, or three or four for a three-phase circuit. The sheath sections, if bonded together, would then sum together and comply for some conductors. (See Regulation 523-05-01 also).

523-05-01

Thermoplastic (pvc) insulated and sheathed cables to BS 6004

These common wiring cables have a cpc of a reduced size from that of the phase conductor for all sizes excepting 1.0 sq mm. Consequently, only the 1.0 sq mm cables (6241Y, 6242Y and 6243Y) will comply with Table 54G. The standard conductor sizes of these cables are identified in Table E1 of Appendix E.

Consequent upon this, calculations are required for the cpc in circuits in which this type of cable is used, usually in domestic installations. The IEE On-Site Guide contains Table 7.1 which giving calculated maximum

circuit lengths for various arrangements of conventional circuits and types of protective device.

Similar cable size constructions apply to thermosetting cables to Table 7 of BS 7211: 1994. These cables however, can have a conductor operating temperature of up to 90 °C. Regulation 523-01-01 requires that equipment and accessories connected to such conductors operating at temperatures exceeding 70 °C must be suitable for operation at such higher temperatures.

Domestic accessories and equipment are not usually suitable for operation at such higher temperatures and consequently cables to BS 7211 cannot be used at their full rating and should be considered as thermoplastic (pvc) insulated and sheathed types.

Appendix E: Resistance and impedance of copper and aluminium conductors under fault conditions

To check compliance with Regulation 434-03-03 and/or Regulation 543-01-03, i.e. to evaluate the equation $S^2 = I^2 t/k^2$ it is necessary to establish the impedances of the circuit conductors to determine the fault current I and hence the protective device disconnection time t .

Similarly, in order to design circuits for compliance with BS 7671, the limiting values of earth fault loop impedance given in Tables 41B1, 41B2 and 41D of BS 7671, or for compliance with the limiting values of the circuit protective conductor given in Table 41C, it is necessary to establish the relevant impedances of the circuit conductors concerned. (See IEE Guidance Note 5 for more information on this subject.)

Where the circuit overcurrent protective device characteristics comply with those given in Appendix 3 of BS 7671, in Regulation 413-02-05 the increase in circuit conductor temperature at fault has been deemed to be taken into account and only the normal conductor operating temperature needs to be considered.

The equation given in Regulations 434-03-03 and 543-01-03 has been based on the assumption of a constant value of fault current but in practice that current changes during the period of the fault because, due to the rise in temperature, the conductor resistance increases.

The rigorous method for taking into account the changing character of the fault current is too complicated for practical use and over the range of temperatures encountered in BS 7671 a sufficiently accurate method is to calculate conductor impedances based on the full load current temperature of the conductor (i.e. 70 °C for thermoplastic (pvc) insulated conductors, and 90 °C for thermosetting insulated conductors) for devices given in Appendix 3 of BS 7671.

Appendix 3 does not include all types of devices, for example circuit-breakers (MCCBs) to BS EN 60947-2 : 1994. Earth fault loop impedances are not tabulated in BS 7671 for MCCBs nor are characteristics shown in Appendix 3. It may be that these devices do comply with the current Regulation requirements, but there is a wide variety of devices, with adjustable ranges and characteristics, and if there is any doubt, the temperature rise of the average of the initial and final fault temperatures must be utilised. The device manufacturer's advice may be required.

Most manufacturers will, however, provide details of the maximum allowable impedance values for both 0.4 second and 5 seconds disconnection.

The following conductor resistance Table E1 is limited to conductor cross-sectional areas up to and including 35 mm², i.e. to conductors having negligible inductive reactance. For larger cables the reactance is not negligible. This reactance is independent of temperature and depends on conductor size and cable make up, and it may be necessary to obtain information from the manufacturer as regards the resistive and reactive components of the impedance of the cables it is intended to use.

Alternatively, values can be calculated for some cables from the volt drop data given in Appendix 4 of BS 7671. Volt drop data is given in terms of mV/A/m (which is mΩ/m) at full load conductor temperature. Single-phase figures give the resistance/reactance/impedance volt drop for both phase and neutral conductors, which must be divided by two. Three-phase resistance/reactance/impedance volt drop values are given for a balanced three-phase conductor. The figures must be divided by $\sqrt{3}$ (1.732) to give a figure for the phase conductor only. It should be noted that the reactive component, and consequently the impedance, also varies significantly depending on the cable installation conditions and method. The correct details must be chosen.

Table E1 gives values of ($R_1 + R_2$) per metre for various combinations of sizes of conductors up to and including 35 mm² cross-sectional area (see Appendix D for descriptions of R_1 and R_2). It also gives values of resistance per metre for each size of conductor. These values are given at both 20 °C and 70 °C for thermoplastic (pvc) insulation when Table 54C applies.

Table E2 gives the multipliers to be applied to the values given in Table E1 for the purpose of calculating the resistance, at maximum permissible operating temperature of the phase conductors and/or circuit

protective conductors, in order to determine compliance with, as applicable:

- (i) earth fault loop impedances of Tables 41B1, 41B2 or 41D
- (ii) equation in Regulation 434-03-03
- (iii) equation in Regulation 543-01-03
- (iv) earth fault loop impedance and resistance of protective conductor of Table 41C
- (v) earth fault loop impedances of Appendix D in this Guidance Note.

Where it is known that the actual operating temperature under normal load is less than the maximum permissible value for the type of cable insulation concerned (as given in the tables of current-carrying capacity), the multipliers given in Table E2 may be reduced. (See Appendix 4 of BS 7671 for further details.)

TABLE E1
Values of resistance/metre for copper and
aluminium conductors and of (R₁ + R₂)/metre in
milliohms/metre

Cross-sectional area mm ²		Resistance/metre or (R ₁ + R ₂)/metre (mΩ/m) at 20 °C		Resistance/metre or (R ₁ + R ₂)/metre (mΩ/m) at 70 °C in compliance with Table 54C	
Phase conductor	Protective conductor	Plain copper	Aluminium	Plain copper	Aluminium
1	—	18.10		21.72	
*1	1	36.20		43.44	
1.5	—	12.10		14.52	
*1.5	1	30.20		36.24	
1.5	1.5	24.20		29.04	
2.5	—	7.41		8.89	
2.5	1	25.51		30.61	
*2.5	1.5	19.51		23.41	
2.5	2.5	14.82		17.78	
4	—	4.61		5.53	
*4	1.5	16.71		20.05	
4	2.5	12.02		14.42	
4	4	9.22		11.06	
6	—	3.08		3.70	
*6	2.5	10.49		12.59	
6	4	7.69		9.23	
6	6	6.16		7.39	
10	—	1.83		2.20	
*10	4	6.44		7.23	
10	6	4.91		5.08	
10	10	3.66		4.39	
16	—	1.15	1.91	1.38	2.29
*16	6	4.23	—	5.89	—
16	10	2.98	—	3.58	—
16	16	2.30	3.82	2.76	4.58
25	—	0.727	1.20	0.87	1.44
25	10	2.557	—	3.07	—
25	16	1.877	—	2.25	—
25	25	1.454	2.40	1.74	2.88
35	—	0.524	0.868	0.63	1.04
35	16	1.674	2.778	2.01	3.33
35	25	1.251	2.068	1.50	2.48
35	35	1.048	1.736	1.26	2.08

* Identifies copper phase/protective conductor arrangement that complies with Table 5 or Table 6 of BS 6004 : 2000 for thermoplastic (pvc) insulated and sheathed single, twin or three-core and cpc cables (i.e. 6241Y, 6242Y or 6243Y cables), and similar cable constructions for thermosetting cables to BS 7211 : 1998.

TABLE E2

Operating temperature multipliers to Table E1

Insulation material		70 °C thermoplastic (pvc)	85 °C thermosetting	90 °C thermosetting
Multiplier	54B	1.04	1.04	1.04
	54C	1.20	1.26	1.28

The multipliers given in Table E2 are based on the simplified formula given in BS 6360 for both copper and aluminium conductors, namely, that the resistance temperature coefficient, α , is 0.004 per °C at 20 °C. This is $R = R_{20} [1 + \alpha \Theta]$ where Θ is the temperature in degrees Celsius between the initial 20 °C ambient and the final full load conductor temperature, and R_{20} is the conductor resistance at 20 °C.

54B applies where the protective conductor is not incorporated or bunched with cables, or for bare protective conductors in contact with cable covering (assumed initial temperature 30 °C).

54C applies where the protective conductor is a core in a cable or is bunched with cables (assumed initial temperature 70 °C or greater).

Verification

For verification purposes of earth fault loop impedances at installation completion the person carrying out testing will need the maximum values of the phase and protective conductor resistances of a circuit at the ambient temperature expected during tests. This may be different from the reference temperature of 20 °C used for Table E1.

Table E3 gives correction factors that may be applied to the 20 °C Table E1 values to take account of the ambient temperature (for test purposes only). See IEE Guidance Note 3 - Inspection and Testing - also.

TABLE E3
Ambient temperature multipliers to Table E1

Expected ambient temperature	Correction factor
5 °C	0.94
10 °C	0.96
15 °C	0.98
25 °C	1.02

Tables have been published in the IEE 'On-Site Guide' to provide maximum circuit earth fault loop impedances at 20 °C ready for test comparison (see Appendix 2 of the On-Site Guide).

Mineral insulated cable with copper sheath

Values of conductor resistance (R₁) and sheath resistance (R₂) per metre for copper sheathed light duty and heavy duty mineral insulated cables to BS 6207 are given in Table E4.

TABLE E4
Values of R₁ and R₂ for mineral insulated cable with copper sheath

Cable ref	R ₁ Conductor resistance 20 °C	R ₂ Sheath resistance 20 °C	R ₁ Conductor resistance	R ₂ Sheath resistance	R ₁ Conductor resistance	R ₂ Sheath resistance
			Exposed to touch 70 °C sheath		Not exposed to touch 105 °C sheath	
			Ohms/km	Ohms/km	Ohms/km	Ohms/km

500 V Grade (Light duty)

2L1	18.1	3.95	21.87	4.47	24.5	4.84
2L1.5	12.1	3.35	14.62	3.79	16.38	4.1
2L2.5	7.41	2.53	8.95	2.87	10.03	3.1
2L4	4.61	1.96	5.57	2.22	6.24	2.4
3L1	18.1	3.15	21.87	3.57	24.5	3.86
3L1.5	12.1	2.67	14.62	3.02	16.38	3.27
3L2.5	7.41	2.23	8.95	2.53	10.03	2.73
4L1	18.1	2.71	21.87	3.07	24.5	3.32
4L1.5	12.1	2.33	14.62	2.64	16.38	2.85
4L2.5	7.41	1.85	8.95	2.1	10.03	2.27
7L1	18.1	2.06	21.87	2.33	24.5	2.52
7L1.5	12.1	1.78	14.62	2.02	16.38	2.18
7L2.5	7.41	1.36	8.95	1.54	10.03	1.67

Table E4 continued

Cable ref	R ₁ Conductor resistance 20 °C	R ₂ Sheath resistance 20 °C	R ₁ Conductor resistance	R ₂ Sheath resistance	R ₁ Conductor resistance	R ₂ Sheath resistance
	Ohms/km	Ohms/km	Exposed to touch 70 °C sheath		Not exposed to touch 105 °C sheath	
			Ohms/km	Ohms/km	Ohms/km	Ohms/km
750 V Grade (Heavy duty)						
1H10	1.83	2.23	2.21	2.53	2.48	2.73
1H16	1.16	1.81	1.4	2.05	1.57	2.22
1H25	0.727	1.4	0.878	1.59	0.984	1.72
1H35	0.524	1.17	0.633	1.33	0.709	1.43
1H50	0.387	0.959	0.468	1.09	0.524	1.18
1H70	0.268	0.767	0.324	0.869	0.363	0.94
1H95	0.193	0.646	0.233	0.732	0.261	0.792
1H120	0.153	0.556	0.185	0.63	0.207	0.681
1H150	0.124	0.479	0.15	0.542	0.168	0.587
1H185	0.101	0.412	0.122	0.467	0.137	0.505
1H240	0.0775	0.341	0.0936	0.386	0.105	0.418
2H1.5	12.1	1.9	14.62	2.15	16.38	2.33
2H2.5	7.41	1.63	8.95	1.85	10.03	2
2H4	4.61	1.35	5.57	1.53	6.24	1.65
2H6	3.08	1.13	3.72	1.28	4.17	1.38
2H10	1.83	0.887	2.21	1.005	2.48	1.09
2H16	1.16	0.695	1.4	0.787	1.57	0.852
2H25	0.727	0.546	0.878	0.618	0.984	0.669
3H1.5	12.1	1.75	14.62	1.98	16.38	2.14
3H2.5	7.41	1.47	8.95	1.66	10.03	1.8
3H4	4.61	1.23	5.57	1.39	6.24	1.51
3H6	3.08	1.03	3.72	1.17	4.17	1.26
3H10	1.83	0.783	2.21	0.887	2.48	0.959
3H16	1.16	0.622	1.4	0.704	1.57	0.762
3H25	0.727	0.5	0.878	0.566	0.984	0.613
4H1.5	12.1	1.51	14.62	1.71	16.38	1.85
4H2.5	7.41	1.29	8.95	1.46	10.03	1.58
4H4	4.61	1.04	5.57	1.18	6.24	1.27
4H6	3.08	0.887	3.72	1	4.17	1.09
4H10	1.83	0.69	2.21	0.781	2.48	0.845
4H16	1.16	0.533	1.4	0.604	1.57	0.653
4H25	0.727	0.423	0.878	0.479	0.984	0.518
7H1.5	12.1	1.15	14.62	1.3	16.38	1.41
7H2.5	7.41	0.959	8.95	1.09	10.03	1.18
12H1.5	12.1	0.744	14.62	0.843	16.38	0.912
12H2.5	7.41	0.63	8.95	0.713	10.03	0.772
19H1.5	12.1	0.57	14.62	0.646	16.38	0.698

The calculation of $R_1 + R_2$ for mineral insulated cables is different from the method for other cables, in that the loaded conductor temperature is not usually given. Table 4J of Appendix 4 of BS 7671 gives normal full load sheath operating temperatures of 70 °C for thermoplastic (pvc) sheathed types and 105 °C for bare cables not in contact with combustible materials, in a 30 °C ambient. Magnesium oxide is a relatively good thermal conductor, and being in a thin layer, it is found that conductor temperatures are usually only some 3 °C higher than sheath temperatures.

However, calculations are complicated as the sheath is of copper which is manufactured to a different material standard to that of the conductors and the α factor of 0.004 at 20 °C for normal copper conductor temperature correction does not apply. An α value of 0.00275 at 20 °C can be used for sheath resistance change calculations. Table E4 gives calculated values of R_1 and R_2 at a standard 20 °C and at standard sheath operating temperatures, and these can be used directly for calculations at full load temperatures.

An estimate of the sheath temperature can be made for a partially loaded cable, in any higher ambient temperature, using the following formula:

Approximate sheath temperature =

$$T_{amb} + \left[\left(\frac{I_b}{I_t} \right)^2 \times 40 \right]$$

where:

T_{amb} is actual ambient temperature

I_b is circuit design current

I_t is tabulated current-carrying capacity of the cable.

Steel-wire armour, steel conduit and steel trunking

Formulae for the calculation of the resistance and inductive reactance values of the steel-wire armour of cables, steel conduit, ducting and trunking are published in IEE Guidance Note 6.

Generally, it is accepted that there is approximately a 10 °C difference between the conductor temperature and the outer sheath temperature for a steel-wire armoured cable at full load.

Appendix F: Selection and erection of wiring systems

General

To conform to the requirements of BS 7671, Regulations 511-01-01 and 521-01-01, wiring systems must utilise cables complying with the relevant requirements of the applicable British Standard, or Harmonised Standard.

511-01-01

521-01-01

Alternatively, if equipment complying with a foreign national standard based on an IEC Standard is to be used, the designer or other person responsible for specifying the installation must verify that any differences between that standard and the corresponding British Standard or Harmonised Standard will not result in a lesser degree of safety than that afforded by compliance with the British Standard.

Where equipment to be used is not covered by a British Standard or Harmonised Standard or is used outside the scope of its standard the designer or other person responsible for specifying the installation must satisfy themselves and confirm that the equipment provides the same degree of safety as that afforded by compliance with the Regulations.

A 'wiring system' is defined in Part 2 of BS 7671 as 'An assembly made up of cable or busbars and parts which secure and, if necessary, enclose the cable or busbars'. This can be read to only mean factory made systems, but it is intended to cover all cable types.

Cables are also identified with a voltage grade, to identify the maximum system working voltage for which they are suitable. Conduit wiring cable (6491X) etc. are designated 450/750 V and are harmonised within CENELEC under HD 21 and HD 22. Wiring cables such as flat twin and earth (6242Y) are designated 300/500 V and are not harmonised but are constructed to a British Standard. Armoured cables are designated 600/1000 V and are not harmonised, but are also constructed to a British Standard. There is no difference in utilising types of any of these designations on the UK 230/400 V supply system.

BS 7540 : 1994 is a guide to use for cables with a rated voltage not exceeding 450/750 V and gives installation application advice.

TABLE F1 Comparison of harmonised cable types to BS 6004

Type	British Standard Table No	Code Design	Conductor class	Voltage grade	Number of cores	Cross-sectional range mm ²	Temperature °C	
							Installation (minimum)	Storage (maximum)
Thermoplastic (pvc) insulated								
non-sheathed	1	H07V-U	1	450/750	1	1.5 - 16	+5	+40
non-sheathed	1	H07V-R	2	450/750	1	1.5 - 630	+5	+40
non-sheathed	1	H07V-K	5	450/750	1	1.5 - 240	+5	+40
non-sheathed	2	H05V-U	1	300/500	1	0.5 - 1.0	+5	+40
Thermoplastic (pvc) sheathed	3		1/2	300/500	2 - 5	1.5 - 35	+5	+40
Thermoplastic (pvc) sheathed	4	6181Y 6192Y 6193Y	1/2	300/500	1 - 3	1 - 35	+5	+40
Thermoplastic (pvc) sheathed	5	6242Y 6243Y	1/2	300/500	2 - 3	1.0 - 16	+5	+40
Thermoplastic (pvc) sheathed	6	6192Y 6242Y	2	300/500	2	1.5 - 2.5	+5	+40

TABLE F2

Designation system for cables complying with the European Harmonisation Standard

Cable Reference

1	2	3	4	5	-	6	7	8	9
<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>

1. Basic Standards H Harmonised Standards A Authorised National Standards (derived from a harmonised cable standard) N Non Authorised National Standards	6. Type of Conductor A Aluminium Copper (no code letter) F Flexible for movable installations (Class 5 IEC 228) H Highly flexible for movable installations (Class 6 IEC 228) K Flexible for fixed installations (Class 5 IEC 228) R Stranded (Class 2 IEC 228) U Solid (Class 1 IEC 228) Y Tinsel
2. Rated Voltage 03 300/300 Volt 05 300/500 Volt 07 450/750 Volt 1 600/1000 Volt	
3 & 4 Insulation & Sheathing Material B Ethylene Propylene Rubber (EPR) E Polyethylene (PE) (low density LDPE) E2 Polyethylene (High density) HDPE E4 Polytetrafluoroethylene (PTFE) E6 Ethylene Tetrafluoroethylene (ETFE) E7 Polypropylene (PP) G Ethylene-Vinyl-Acetate (EVA) J Glass fibre braid (GFB) N Polychloroprene (PCP) N4 Chlorosulphonated Polyethylene (CSP) Q Polyurethane (PU) Q2 Polyethylene-Terephthalate (PETP) Q4 Polyamide (PA) R Natural Rubber S Silicone T Textile braid V Polyvinyl-Chloride (PVC) V2 Heat Resistant Polyvinyl-Chloride (HR PVC) X Cross Linked Polyethylene (XLPE)	7. Number of Cores
	8. Protective Conductor X Without protective core G With protective core
5. Special Construction & Shapes H Flat Construction with Divisible Cores H2 Flat Construction, Non Divisible Core H5 Two or more cores twisted together non sheathed	9. Nominal Cross-Sectional Area of Conductors in sq mm
	Additional Designations Concentric Conductors & Screens A Concentric Aluminium Conductor C Concentric Copper Conductor A7 Aluminium/Laminate Screen C4 Overall Copper Braid Screen C5 Cores Individually Copper Braid Screen C7 Lapped Copper (Wire, Tape or Strip) Screen Special Components D3 Central Strainer (Textile or Metallic) D5 Central Filler (Not Load Bearing) Armours Z2 Steel Wire Armour Z3 Flat Steel Wire Armour Z4 Steel Tape Armour Z5 Steel Wire Braid

Reproduced with kind permission of Anixter (UK) Ltd.

TABLE F3
Commonly used cable type reference numbers

* = number of cores (e.g. 2183Y is 3 core)

0361	Welding cable, tinned copper conductor, vulcanised rubber insulation/tough rubber sheath. BS 638.	658*TQ	Circular, EPR insulation/CSP bedding/galv. mild steel wire braid armour/CSP sheathed 600/1000V BS 6883, ship wiring cable (circular conductors).
2093Y	3 core, thermoplastic heat resisting insulation/ thermoplastic heat resisting sheathed. Circular, 300/300V BS 6500, flexible cord	658*TQ(S)	As 658*TQ but with shaped conductors.
218*Y	Circular, thermoplastic insulation/thermoplastic sheathed. 300/300V BS 6500, flexible cord.	694*X	Circular, thermoplastic insulation/thermoplastic bedded/single steel wire armoured/thermoplastic sheathed 600/1000V BS 6346, mains wiring cable.
2192Y	2 core, thermoplastic insulation/thermoplastic sheathed Flat 300/300V. BS 6500, flexible cord.	694*X(S)	As 694*X but with shaped conductors.
2213	3 core, vulcanised rubber insulation/tough rubber sheathed/cotton braid, 300/300V BS 6500, flexible cord.	HO7V-R	Single core, thermoplastic insulation 4 sq. mm - 400 sq. mm, 450/750V to BS 6004.
318*	Circular, vulcanised rubber insulation/tough rubber sheathed, 300/500V BS 6500, flexible cord.	HO7V-U	Single core, thermoplastic insulation, 1.5 sq. mm - 2.5 sq. mm, (solid) 450/750V to BS 6004.
318*Y	Circular, thermoplastic insulation/thermoplastic sheathed 300/500V BS 6500, flexible cord.	HO5V-U	Single core, thermoplastic insulation, 1.0 sq mm (solid) 300/400V to BS 6004
318*P	Circular, vulcanised rubber insulation/PCP sheathed, 300/500V BS 6500, flexible cord.	HO5RR-F	Circular, vulcanised rubber insulation/tough rubber sheathed. 300/500V to BS 6500
318*TQ	Circular, EPR insulation/CSP sheathed 300/500V BS 6500, flexible cord.	HO3VV-F	Circular, thermoplastic insulated/thermoplastic sheathed, 300/300V to BS 6500.
618*Y	Circular, thermoplastic insulation/thermoplastic sheathed 1 sq mm - 35 sq mm 300/500V BS 6004 50 sq mm - 630 sq mm gen in acc BS 6346, wiring cable.	HO3VVH2-F	Flat 2 core, thermoplastic insulated/thermoplastic sheathed, 300/300V to BS 6500.
619*Y	Flat, thermoplastic insulation/thermoplastic sheathed 300/500V BS 6004, wiring cable.	HO5VV-F	Circular, thermoplastic insulated/thermoplastic sheathed, 300/500V to BS 6500.
624*Y	Flat, thermoplastic insulation - laid up in parallel with a bare CPC within one interstice/thermoplastic sheathed 300/500V BS 6004, wiring cable.	HO5VVH2-F	Flat, 2 core, thermoplastic insulated/thermoplastic sheathed, 300/500V to BS 6500.
6491X	Single core, thermoplastic insulation 1 sq. mm - 630 sq. mm. 450/750V BS 6004.	HO5V-K	Single core, thermoplastic insulation 0.5 sq. mm - 1.0 sq. mm 300/500V to BS 6500.
657*TQ	Circular, EPR insulation/CSP sheathed 600/1000V BS 6883, ship-wiring cable. (circular conductors).	HO7V-K	Single core, thermoplastic insulation, 1.5 sq. mm - 2.5 sq. mm, 450/750V to BS 6004.
657*TQ(S)	As 657*TQ but with shaped conductors	HO7RN-F	Circular, rubber insulated/rubber sheathed, 450/750V to BS 6007.
		(AL)	To denote aluminium conductors. To be added after other suffix, if used e.g. 6491X(AL) and 6242Y(AL).
		(S)	Shaped conductors.

Reproduced with kind permission of Anixter (UK) Ltd.

TABLE F4
Applications of cables for fixed wiring

Type of cable	Uses	Comments
Thermoplastic (pvc), thermosetting or rubber insulated non-sheathed	In conduits, cable ducting or trunking	(i) intermediate support may be required on long vertical runs (ii) 70 °C maximum conductor temperature for normal wiring grades — including thermosetting types (4) (iii) cables run in pvc conduit shall not operate with a conductor temperature greater than 70 °C (4)
Flat thermoplastic (pvc) or thermosetting insulated and sheathed	(i) general indoor use in dry or damp locations. May be embedded in plaster (ii) on exterior surface walls, boundary walls and the like (iii) overhead wiring between buildings (6) (iv) underground in conduits or pipes (v) in building voids or ducts formed in-situ	(i) additional protection may be necessary where exposed to mechanical stresses (ii) protection from direct sunlight may be necessary. Black sheath colour is better for cables in sunlight (iii) see Note (4) (iv) unsuitable for embedding directly in concrete (v) may need to be hard drawn (HD) copper conductors for overhead wiring (Note 6)
Split-concentric thermoplastic (pvc) insulated and sheathed	General	(i) additional protection may be necessary where exposed to mechanical stresses (ii) protection from direct sunlight may be necessary. Black sheath colour is better for cables in sunlight
Mineral insulated	General	With overall pvc covering where exposed to the weather or risk of corrosion, or where installed underground, or in concrete ducts
Thermoplastic (pvc) or XLPE insulated, armoured, thermoplastic sheathed	General	(i) additional protection may be necessary where exposed to mechanical stresses (ii) protection from direct sunlight may be necessary. Black sheath colour is better for cables in sunlight
Paper-insulated, lead sheathed and served	General, for main distribution cables	With armouring where exposed to severe mechanical stresses or where installed underground

Notes:

- (1) The use of cable covers (preferably conforming to BS 2484) or equivalent mechanical protection is desirable for all underground cables which might otherwise subsequently be disturbed. Route marker tape should also be installed, buried just below ground level.
- (2) Cables having thermoplastic (pvc) insulation or sheath should preferably be installed only where the ambient temperature is above 0 °C, and has been for the preceding 24 hours. Where they are to be installed during a period of low temperature, precautions should be taken to avoid risk of mechanical damage during handling. A minimum ambient temperature of 5 °C is advised in BS 7540 : 1994 for some types of thermoplastic (pvc) insulated and sheathed cables.
- (3) Cables must be suitable for the maximum ambient temperature, and shall be protected from any excess heat produced by other equipment, including other cables.
- (4) Thermosetting cable types (to BS 7211 or BS 5467) can operate with a conductor temperature of 90 °C. This must be limited to 70 °C when drawn into a conduit etc. with thermoplastic (pvc) insulated conductor (521-07-03) or connected to electrical equipment (512-02-01 and 523-01-01), or when such cables are installed in plastic conduit or trunking.
- (5) For cables to BS 6004, BS 6007, BS 7211, BS 6346, BS 5467 and BS 6724, further guidance may be obtained from those standards. Additional advice is given in BS 7540 : 1994 'Guide to use of cables with a rated voltage not exceeding 450/750 V' for cables to BS 6004, BS 6007 and BS 7211.
- (6) Cables for overhead wiring between buildings must be able to support their self-weight and any imposed wind or ice/snow loading. A catenary support is usual but hard drawn copper types may be used.

TABLE F5

Applications of flexible cables and cords to BS 6007 : 1993, BS 6141 : 1991 and BS 6500 : 2000 generally

Type of flexible cord	Uses
Light thermoplastic (pvc) insulated and sheathed	Indoors in household or commercial premises in dry situations, for light duty
Ordinary thermoplastic (pvc) insulated and sheathed	(i) indoors in household or commercial premises, including damp situations, for medium duty (ii) for cooking and heating appliances where not in contact with hot parts (iii) for outdoor use other than in agricultural or industrial applications (iv) electrically powered hand tools
60 °C thermosetting insulated braided twin and three-core	Indoors in household or commercial premises where subject only to low mechanical stresses
60 °C thermosetting insulated and sheathed	(i) indoors in household or commercial premises where subject only to low mechanical stresses (ii) occasional use outdoors for supplies to equipment (iii) electrically powered hand tools
60 °C thermosetting insulated oil-resisting and flame-retardant sheath	(i) general, unless subject to severe mechanical stresses (ii) fixed installations protected in conduit or other enclosures
85 °C thermosetting insulated HOFR sheathed	General, including hot situations e.g. night storage heaters and immersion heaters
85 °C heat resisting thermoplastic (pvc) insulated and sheathed	General, including hot situations e.g. for pendant luminaires
150 °C thermosetting insulated and braided	(i) at high ambient temperatures (ii) in or on luminaires
185 °C glass-fibre insulated single-core twisted twin and three-core	For internal wiring of luminaires only and then only where permitted by BS 4533
185 °C glass-fibre insulated braided circular	(i) dry situations at high ambient temperatures and not subject to abrasion or undue flexing (ii) wiring of luminaires

Notes:

- (1) Cables and cords having thermoplastic (pvc) insulation or sheath should preferably not be used where the ambient temperature is consistently below 0 °C. Where they are to be installed during a period of low temperature, precautions should be taken to avoid risk of mechanical damage during handling.
- (2) Cables and cords shall be suitable for the maximum ambient temperature, and shall be protected from any excess heat produced by other equipment, including other cables.
- (3) For flexible cords and cables to BS 6007, BS 6141 and BS 6500 further guidance may be obtained from those standards, or from BS 7540 : 1994 'Guide to use of cables with a rated voltage not exceeding 450/750 V'.
- (4) When used as connections to equipment flexible cables and cords should be of the minimum practical length to minimise danger and in any case of such a length that allows the protective device to operate correctly.
- (5) When attached to equipment flexible cables and cords should be protected against tension, crushing, abrasion, torsion and kinking particularly at the inlet point to the electrical equipment. At such inlet points it may be necessary to use a device which ensures that the cable is not bent to an internal radius below that given in the appropriate part of Table 4 of BS 6700. Strain relief, clamping devices or cord guards should not damage the cord.
- (6) Flexible cables and cords should not be used under carpets or other coverings, or where furniture or other equipment may rest on them. Flexible cables and cords should not be placed where there is a risk of damage from traffic passing over them.
- (7) Flexible cables and cords should not be used in contact with or close to heated surfaces especially if the surface approaches the upper thermal limit of the cable or cord.

British Standards

Most cables in general use today are manufactured to a specific British Standard (or Standards) that covers the design, materials, manufacture, testing and performance of the cable. The designer of the installation has to select a cable type that is suitable for the performance required and the relevant British Standard is usually specified.

511-01
522

The cable manufacturer will provide full details of cables and the standards to which they are manufactured, and BS 7671 Appendix 4 indicates the relevant British Standards for each cable type in the current rating tables. A full listing of British Standards referred to in BS 7671 is provided in Appendix 1 of that Standard.

Fire stopping

All cable routes that pass between building fire zones or areas, must be adequately sealed against the transmission of flames and/or smoke between zones or areas.

527-02

The specification for such fire stopping is outside the scope of this Guidance Note but should provide fire resistance to a standard at least equal to the original element of the building construction. The specification for fire stopping should be detailed by the Project Architect or Designer for all services (i.e. cables, pipes etc.) and should comply with the requirements of the Building Regulations, as applicable. Intumescent materials are commonly used.

All voids within ducts, trunking, busbar trunking systems etc should be filled, as well as the space around such ducts, trunkings and busbar trunking systems where they pass through walls etc. It is not usual, however, to seal the inside of conduits, except in classified hazardous areas, as required by the relevant codes or standards.

527-02-02

Appendix G: Notes on methods of support for cables, conductors and wiring systems

This Appendix describes methods of support for cables, conductors and wiring systems which satisfy the relevant requirements of Chapter 52 of BS 7671. The use of other methods is not precluded where specified by a competent person, having due regard for protection of the cable from mechanical damage. The methods described in this Appendix make no specific provisions for fire or thermal protection of the cables. All cable installations and routings must be carefully considered and protection provided as required. The advice of the local authority and the Fire Officer must be taken as necessary on the project. The Project Architect and Designer must also comply with the CDM Regulations (see IEE Guidance Note 4 also).

Cables generally

Items (i) to (ix) below are generally applicable to supports on structures which are subject only to vibration of low severity and a low risk of mechanical impact:

- (i) Non-sheathed cables, installed in conduit without further fixing of the cables, precautions taken against undue compression or other mechanical stressing of the insulation at the top of any vertical runs exceeding 5 m in length
- (ii) Cables of any type, installed in factory made ducting or trunking without further fixing of the cables, vertical runs not exceeding 5 m in length without intermediate support
- (iii) Sheathed and/or armoured cables drawn into ducts formed in-situ in the building structure. The internal surfaces of the duct must be protected to prevent abrasion of the cables, especially when drawing-in. Ducts should also be adequately sealed against the spread of fire and smoke. Vertical runs not exceeding 5 m in length without intermediate support

- (iv) Sheathed and/or armoured cables installed in accessible positions, support by clips at spacings not exceeding the appropriate value stated in Table G2
- (v) Cables of any type, resting without fixing in horizontal runs of ducts, conduits, factory made cable ducting or trunking
- (vi) Sheathed and/or armoured cables in horizontal runs which are inaccessible and unlikely to be disturbed, resting without fixing on part of a building, the surface of that part being reasonably smooth
- (vii) Sheathed and/or armoured cables in vertical runs which are inaccessible and unlikely to be disturbed, supported at the top of the run by a clip and a rounded support of a radius not less than the appropriate value stated in Table G1
- (viii) Sheathed cables without armour in vertical runs which are inaccessible and unlikely to be disturbed, supported by the method described in (vii) above; the length of run without intermediate support not exceeding 2 m for a lead sheathed cable or 5 m for a thermosetting or thermoplastic (pvc) sheathed cable
- (ix) Thermosetting or thermoplastic (pvc) sheathed cables, installation in conduit without further fixing of the cables, any vertical runs being in conduit of suitable size and not exceeding 5 m in length.

Cables in particular conditions

- (x) Flexible cords used as pendants, attachment to a ceiling rose or similar accessory and lampholder by the cord grip or other method of strain relief provided in the accessories (see Table 4H3A of BS 7671 for maximum mass supportable by flexible cords)
- (xi) Temporary installations and installations on construction sites, protection and supports so arranged that there is no appreciable mechanical strain on any cable termination or joint, and the cables are protected from mechanical damage
- (xii) Caravans, for sheathed flexible cables or cords in inaccessible spaces such as ceiling, wall and floor spaces, support at intervals not exceeding 0.25 m for horizontal runs and 0.4 m for vertical runs. In caravans for horizontal runs of sheathed flexible cables or cords passing through floor or ceiling joists in inaccessible floor or ceiling spaces, securely bedded in thermal insulating material, no further fixing is

required. (See Regulation 608-06 for details of caravan wiring systems.)

Overhead wiring

- (xiii) Cables sheathed with thermosetting or thermoplastic (pvc), supported by a separate catenary wire, either continuously bound up with the cable or attached thereto at intervals not exceeding those stated in Column 2 of Table G2, and the minimum height above ground being in accordance with Table G3
- (xiv) Support by a catenary wire incorporated in the cable during manufacture, the spacings between supports not exceeding those stated by the manufacturer and the minimum height above ground being in accordance with Table G3
- (xv) Spans without intermediate support (e.g. between buildings) of multicore sheathed cable, with or without armour, terminal supports so arranged that no undue strain is placed upon the conductors or insulation of the cable, adequate precautions being taken against any risk of chafing of the cable sheath, and the minimum height above ground and the length of such spans being in accordance with the appropriate values indicated in Table G3. Hard drawn (HD) copper conductors may be necessary for longer spans. Cable manufacturers' advice should be complied with
- (xvi) Bare or insulated conductors of an overhead line for distribution between a building and a remote point of utilisation (e.g. another building) supported on insulators, the lengths of span and heights above ground having the appropriate values indicated in Table G3 or otherwise installed in accordance with the Electricity Safety, Quality and Continuity Regulations 2002
- (xvii) Spans without intermediate support (e.g. between buildings) and which are in situations inaccessible to vehicular traffic, insulated or multicore sheathed cables installed in heavy galvanised steel conduit, the length of span and height above ground being in accordance with Table G3, provided that the conduit shall be earthed in accordance with Parts 4 and 5 of BS 7671, shall be securely fixed at the ends of the span, and shall not be jointed in its span.

Conduit and cable trunking

- (xviii) Rigid conduit supported in accordance with Table G4
- (xix) Cable trunking supported in accordance with Table G5
- (xx) Conduit embedded in the material of the building, suitably treated against corrosion if necessary
- (xxi) Pliable conduit embedded in the material of the building or in the ground, or supported in accordance with Table G4.

TABLE G1
Minimum internal radii of bends in cables for fixed wiring

Insulation	Finish	Overall diameter*	Factor to be applied to overall diameter of cable to determine minimum internal radius of bend
Thermosetting or thermoplastic (pvc) (circular, or circular stranded copper or aluminium conductors)	Non-armoured	Not exceeding 10 mm	3(2)†
		Exceeding 10 mm but not exceeding 25 mm	4(3)†
		exceeding 25 mm	6
	Armoured	Any	6
Thermosetting or thermoplastic (pvc) (solid aluminium or shaped copper conductors)	Armoured or non-armoured	Any	8
Mineral	copper sheath with or without covering	Any	6‡
Flexible cables	Sheathed	Any	No specific provision, but no tighter than the equivalent sized non-armoured cable**

Notes:

- * For flat cables the diameter refers to the major axis.
- ** Flexible cables can be damaged by too tight, or repeated bending.
- † The figure in brackets relates to single-core circular conductors of stranded construction installed in conduit, ducting or trunking.
- ‡ For mineral insulated cables, the bending radius should normally be limited to a minimum of 6 times the diameter of the bare copper sheath, as this will allow further straightening and re-working if necessary. However, cables may be bent to a radius not less than 3 times the cable diameter over the copper sheath, provided that the bend is not re-worked.

Conduit bends

The radius of every conduit bend must be such as to allow compliance with the minimum bending radii of cables installed in the conduit (e.g. see table above). In addition, the inner radius of the bend shall not be less than 2.5 times the outside diameter of the conduit.

TABLE G2

Spacings of supports for cables in accessible positions the entire support derived from the clips

Maximum spacings of clips									
Overall (1) diameter of cable	Non-armoured thermosetting, plastics, or lead sheathed cables				Armoured cables		Mineral insulated copper sheathed cables		
	Generally		In caravans						
	(2) Horizontal	(2) Vertical	(2) Horizontal	(2) Vertical	(2) Horizontal	(2) Vertical	(2) Horizontal	(2) Vertical	(2) Vertical
	1	2	3	4	5	6	7	8	9
	mm	mm	mm	mm	mm	mm	mm	mm	mm
	≤9	250	400			—	—	600	800
>9	≤15	300	400			350	450	900	1200
>15	≤20	350	450	250 (for all sizes)	400 (for all sizes)	400	550	1500	2000
>20	≤40	400	550			450	600	2000	3000

Notes:

For the spacing of supports for cables having an overall diameter exceeding 40 mm, or conductors of cross-sectional area 300 mm² and larger, the manufacturer's recommendations should be observed.

- (1) For flat cables taken as the dimension of the major axis.
- (2) The spacings stated for horizontal runs may be applied also to runs at an angle of more than 30° from the vertical. For runs at an angle of 30° or less from the vertical, the vertical spacings are applicable.
- (3) The spacings given in this table are maxima, and for good workmanship in certain circumstances the spacings may need to be reduced.

TABLE G3

Maximum lengths of span and minimum heights above ground for overhead wiring between buildings etc.

Type of system 1	Minimum height of span above ground			
	Maximum length of span 2	At road crossings 3	In positions accessible to vehicular traffic, other than crossings 4	In positions inaccessible to vehicular traffic (t) 5
			m	m
Cables sheathed with plastics or having an oil-resisting and flame-retardant (hofr) sheath without intermediate support.	3			3.5
Cables sheathed with plastics or having an oil-resisting and flame-retardant (hofr) sheath, in heavy gauge steel conduit of a diameter not less than 20 mm and not jointed in its span.	3	5.8 (for all types)	5.2 (for all types)	3
Bare or covered overhead lines supported by insulators without intermediate support.	30			3.5
Cables sheathed with plastics or having an oil-resisting and flame-retardant (hofr) sheath, supported by a catenary wire.	No limit			3.5
Overhead cable incorporating a catenary wire.	Subject to Item (xiv)			3.5
Bare or covered overhead lines installed in accordance with the Overhead line Regulations (item 16).	No limit			5.2

Notes:

- (t) This column is not applicable in agricultural premises.
1. In some special cases, such as in yacht marinas or where large cranes are present, it will be necessary to increase the height of span above ground over the minimum given in the Table. It is preferable to use underground cables in such locations.
 2. Schedule 2 of the Electricity Safety, Quality and Continuity Regulations 2002 should be consulted for the minimum height above ground of overhead lines

TABLE G4
Spacings of supports for conduits

Nominal diameter of conduit	Maximum distance between supports					
	Rigid metal		Rigid insulating		Pliable	
	Horizontal	Vertical	Horizontal	Vertical	Horizontal	Vertical
mm	m	m	m	m	m	m
Up to 16	0.75	1.0	0.75	1.0	0.3	0.5
Over 16 and up to 25	1.75	2.0	1.5	1.75	0.4	0.6
Over 25 and up to 40	2.0	2.25	1.75	2.0	0.6	0.8
Over 40	2.25	2.5	2.0	2.0	0.8	1.0

Notes:

- (1) The figures given above are the maximum spacings.
- (2) Conduit boxes supporting luminaires or electrical accessories will require separate fixing.
- (3) Plastic conduits will require closer spacing of fixings in areas of high ambient temperature, and note must be taken of the manufacturer's declared maximum temperature.
- (4) The spacings in the table allow for maximum fill of cables in compliance with Appendix A and thermal limits to the relevant British Standards. They assume that the conduit is not exposed to other mechanical stress.
- (5) A flexible conduit should be of such a length that it does not need to be supported in its run.

TABLE G5
Spacings of supports for cable trunking

Cross-sectional area of trunking	Maximum distance between supports			
	Metal		Insulating	
	Horizontal	Vertical	Horizontal	Vertical
mm ²	m	m	m	m
Up to 700	0.75	1.0	0.5	0.5
Over 700 and up to 1500	1.25	1.5	0.5	0.5
Over 1500 and up to 2500	1.75	2.0	1.25	1.25
Over 2500 and up to 5000	3.0	3.0	1.5	2.0
Over 5000	3.0	3.0	1.75	2.0

Notes:

- (1) The spacings in the table allow for maximum fill of cables in compliance with Appendix A and thermal limits to the relevant British Standards. They assume that the trunking is not exposed to other mechanical stress.
- (2) The above figures do not apply to lighting suspension trunking, or where specially strengthened couplers are used.
- (3) Plastic trunking will require closer spacing of fixings in areas of high ambient temperature, and note must be taken of the manufacturer's declared maximum temperature.

Spacing of supports for busbar trunking systems

There is no standard arrangement for the spacing of supports for busbar trunking systems and therefore the manufacture will provide details of the method of mounting. Supports, where applicable, must be located in specific positions using the spacing dimensions given in the installation instructions.

Different attitudes or mounting arrangements can change the orientation of the conductors within the busbar trunking system and may affect the current-carrying capacity of the system. Where a derating factor is necessary the manufacturer will provide details of the corresponding mounting factor (k_2) to determine the allowable current of the system using the following formula:

$$I = k_2 \times I_n$$

where: I is the allowable current
 k_2 is the mounting factor
 I_n is the declared rated current

Appendix H: Maximum demand and diversity

This Appendix gives some information on the determination of the maximum demand for an installation and includes the current demand to be assumed for commonly used equipment. It also includes some notes on the application of allowances for diversity.

The information and values given in this Appendix are intended only for guidance because it is impossible to specify the appropriate allowances for diversity for every type of installation and such allowances call for special knowledge and experience. The figures given in Table H2, therefore, may be increased or decreased as decided by the competent person responsible for the design of the installation concerned. For blocks of residential dwellings, large hotels, industrial and large commercial and office premises, the allowances are to be assessed by a competent person.

The current demand of a final circuit is determined by adding the current demands of all points of utilisation and equipment in the circuit and, where appropriate, making an allowance for diversity. Typical current demands to be used for this summation are given in Table H1. For the standard circuits using BS 1363 socket-outlets detailed in Appendix C, an allowance for diversity has been taken into account and no further diversity should be applied.

TABLE H1
Current demand to be assumed for points of utilisation and current-using equipment

Point of utilisation or current-using equipment	Current demand to be assumed
Socket-outlets other than 2 A socket-outlets and other than 13 A socket-outlets see note 1	Rated current
2 A socket-outlets	At least 0.5 A
Lighting outlet see note 2	Current equivalent to the connected load, with a minimum of 100 W per lampholder
Electric clock, electric shaver supply unit (complying with BS 3535), shaver socket-outlet (complying with BS 4573), bell transformer, and current-using equipment of a rating not greater than 5 VA	May be neglected
Household cooking appliance	The first 10 A of the rated current plus 30% of the remainder of the rated current plus 5 A if a socket-outlet is incorporated in the control unit
All other stationary equipment	British Standard rated current, or normal current

Notes:

- 1 See Appendix C for the design of standard circuits using socket-outlets to BS 1363-2 and BS EN 60309-1 (BS 4343).
- 2 Final circuits for discharge lighting must be arranged so as to be capable of carrying the total steady current, viz. that of the lamp(s) and any associated gear and also their harmonic currents. Where more exact information is not available, the demand in volt amperes is taken as the rated lamp watts multiplied by not less than 1.8. This multiplier is based upon the assumption that the circuit is corrected to a power factor of not less than 0.85 lagging and takes into account control gear losses and harmonic current.

The current demand of a distribution system or distribution circuit supplying a number of final circuits may be assessed by using the allowances for diversity given in Table H2, which are applied to the total current demand of all the equipment supplied by that circuit and not by adding the current demands of the individual final circuits obtained as outlined above. In Table H2 the allowances are expressed either as percentages of the current demand or, where followed by the letters f.l., as percentages of the rated full load current of the current-using equipment. The

current demand for any final circuit which is a standard circuit arrangement complying with Appendix C is the rated current of the overcurrent protective device of that circuit.

An alternative method of assessing the current demand of a circuit supplying a number of final circuits is to add the diversified current demands of the individual circuits then apply a further allowance for diversity, but with this method the allowances given in Table H2 are not to be used, the values to be chosen being the responsibility of the designer of the installation.

The use of other methods of determining maximum demand is not precluded where specified by a competent person.

After the design currents for all the circuits have been determined, enabling the conductor sizes to be chosen, it is necessary to check that the design complies with the requirements of Part 4 of BS 7671 and that the limitation on voltage drop is met.

TABLE H2
Allowances for diversity

Purpose of final circuit fed from conductors or switchgear to which diversity applies	Type of premises		
	Individual household installations including individual dwellings of a block	Small shops, stores, offices and business premises	Small hotels, boarding houses, guest houses, etc.
1. Lighting	66 % of total current demand	90 % of total current demand	75 % of total current demand
2. Heating and power (but see 3 to 8 below)	100 % of total current demand up to 10 amperes +50 % of any current demand in excess of 10 amperes	100 % f.l. of largest appliance +75 % f.l. of remaining appliances	100 % f.l. of largest appliance +80 % f.l. of 2nd largest appliance +60 % f.l. of remaining appliances
3. Cooking appliances	10 amperes +30 % f.l. of connected cooking appliances in excess of 10 amperes +5 amperes if socket-outlet incorporated in control unit	100 % f.l. of largest appliance +80 % f.l. of 2nd largest appliance +60 % f.l. of remaining appliances	100 % f.l. of largest appliance +80 % f.l. of 2nd largest appliance +60 % f.l. of remaining appliances
4. Motors (other than lift motors which are subject to special consideration)	not applicable	100 % f.l. of largest motor +80 % f.l. of 2nd largest motor +60 % f.l. of remaining motors	100 % f.l. of largest motor +50 % f.l. of remaining motors
5. Water-heaters (instantaneous type)*	100 % f.l. of largest appliance +100 % f.l. of 2nd largest appliance +25 % f.l. of remaining appliances	100 % f.l. of largest appliance +100 % f.l. of 2nd largest appliance +25 % f.l. of remaining appliances	100 % f.l. of largest appliance +100 % f.l. of 2nd largest appliance +25 % f.l. of remaining appliances
6. Water-heaters (thermostatically controlled)	no diversity allowable†		
7. Floor warming installations	no diversity allowable†		

TABLE H2
Continued

Purpose of final circuit fed from conductors or switchgear to which diversity applies	Type of premises		
	Individual household installations including individual dwellings of a block	Small shops, stores, offices and business premises	Small hotels, boarding houses, guest houses, etc.
8. Thermal storage space heating installations		no diversity allowable†	
9. Standard arrangement of final circuits in accordance with Appendix C	100 % of current demand of largest circuit +40 % of current demand of every other circuit	100 % of current demand of largest circuit +50 % of current demand of every other circuit	
10. Socket-outlets other than those included in 9 above and stationary equipment other than those listed above	100 % of current demand of largest point of utilisation +40 % of current demand of every other point of utilisation	100 % of current demand of largest point of utilisation +75 % of current demand of every other point of utilisation	100 % of current demand of largest point of utilisation +75 % of current demand of every other point in main rooms (dining rooms, etc) +40 % of current demand of every other point of utilisation

Notes:

- * For the purpose of this Table an instantaneous water-heater is deemed to be a water-heater of any loading which heats water only while the tap is turned on and therefore uses electricity intermittently.
- † It is important to ensure that the distribution boards etc. are of sufficient rating to take the total load connected to them without the application of any diversity.

Appendix I: Minimum separating distances between electricity supply cables and telecommunications or control cables

The adverse effects of electromagnetic interference (EMI) on an installation and its equipment is a problem that many have experienced. Designers and installers faced with this phenomenon have, in the past, overcome the problems in a number of ways e.g. use of filtering devices, earthing and bonding, and segregation or separation of cables.

However, to comply with a European Directive on EMC, manufacturers and installers must ensure that equipment, when installed, will:

- (a) not interfere with other equipment in the vicinity (e.g. it must limit its emissions), and
- (b) be able to withstand likely interference levels present in the vicinity (e.g. it must have sufficient immunity).

Regulation 515-02 of BS 7671 outlines the requirements for emission of electromagnetic influences and interference from such influences, but does not give any guidance on how these should be achieved.

To comply with the statutory requirements of the Electromagnetic Compatibility Regulations 1992 as amended only equipment manufactured so as to comply with the relevant standards for protection against interference and, where available, for immunity is used, e.g.:

BS EN 55011 for Industrial, scientific and medical equipment.

BS EN 55015 for Electrical lighting and similar.

BS EN 55022 (and BS EN 55024) for Information technology equipment.

Where equipment does not have a specific standard, or where a specific standard covers only emissions and

not immunity, equipment should conform to the appropriate generic standard:

For domestic, commercial and light industrial equipment these are:

BS EN 50081-1 for emissions, and BS EN 50082-1 for immunity.

For heavy industrial equipment:

BS EN 50081-2 for emissions, and BS EN 50082-2 for immunity.

Further information is also available in British Standards on segregation of cables e.g. BS 6701 : 1994 (as amended) for the installation of telecommunication cables.

The avoidance of problems should be given due regard at the design stage and segregation is considered to be a way of overcoming the problems of EMI.

The segregation details given in Table I1 apply only to cases where adjacent runs of both power and signal cables are envisaged.

With regard to the figures in the table, it is important to note that these are minimum distances and it is assumed the equipment connected to the IT cables meets the Generic Standards, which may well not be the case for existing equipment. Moreover, the manufacturers of electronic equipment may, in addition to any requirements for cable separation on the grounds of safety, specify that greater separations are used for installations including their equipment.

A major factor affecting the performance of the cables in EMC terms is the quality of termination of the screen. It is therefore important that the correct termination is used.

The figures apply to up to 100 m parallel run and with up to 125 A flowing in the power cable.

TABLE I1
Example of power cable and information technology cables that run parallel with a metallic divider

	Without divider or non-metallic divider (1)	Aluminium divider	Steel divider
Unscreened power cable and IT cable	200 mm	100 mm	50 mm
Unscreened power cable and screened IT cable	50 mm	20 mm	5 mm
Screened power cable and unscreened IT cable	30 mm	10 mm	2 mm
Screened power cable and screened IT cable (2)	0	0	0
<p>Note 1: It is assumed that in case of a metallic divider, the design of the cable management system will achieve a screening attenuation related to the material used for the divider.</p> <p>Note 2: The screened IT cables shall comply with EN 50288 series.</p>			

Therefore, for horizontal cabling the following applies:

- If the full length is no greater than 35 m no separation is required.
- For lengths greater than 35 m the separation distances apply to the full length excluding the final 15 m attached to the outlet.

The second amendment to BS 7671 : 1992, AMD 9781 deleted circuit categories and substituted "Voltage Bands". Band I effectively covers ELV circuits (including SELV), and Band II effectively covers LV circuits. These bands only relate to separation for electrical safety and do not relate to separation for electromagnetic interference requirements. It is still possible in some cases, to have a cable for a 230 V power circuit near to a cable for an intruder alarm. This method of installation would be unlikely to meet the requirements of the legislation, and interference on the security system could be experienced.

The need for system cables to be separated is in conflict with the usual building design for the minimum space to be allowed for cable routes but, generally, separation between system cables should be as large as possible, though available space will always be a limiting requirement. Especially sensitive systems or systems that will emit interference should be identified and adequate provisions made in the design with the advice of the system manufacturer. It may be that building designers will have to allow more space for electrical cable routes and risers than

they would wish. All cable systems should be identified as necessary for ease of future modification and maintenance.

High voltage system cables should be segregated from cables of other systems and clearly identified as a general safety precaution, as well as for EMC reasons. If separation cannot be achieved some form of protective screen or barrier may be required. Table I2 recommends minimum separation distances between systems.

TABLE I2
Separation of systems

Voltage to earth	Normal separation distances	Exceptions to normal separation distances, plus conditions to exception
Exceeding 600 V a.c. and 900 V d.c.	150 mm	50 mm, as long as a divider which maintains separation of 50 mm is inserted between two sets of cables. The divider should be made of a rigid, non-conducting, non-flammable material

Appendix J: Permitted protective conductor currents

Protective conductor/ touch current measurement is an alternative to the in-service insulation test for use if the insulation resistance test either cannot be carried out or gives suspect test results. The current is measured from live parts to earth for Class I equipment, or from live parts to accessible surfaces of Class II equipment.

The current is to be measured within 5 seconds after the application of the test voltage and must not exceed the values in Table J1.

For practical purposes the test voltage is the supply voltage.

TABLE J1
Measured protective conductor/ touch current

Appliance Class	Maximum Current note (1)
Portable or hand-held Class I equipment	0.75 mA
Class I heating appliances	0.75 mA or 0.75 mA per kW, whichever is the greater, with a maximum of 5 mA
Other Class I equipment	3.5 mA
Class II equipment	0.25 mA
Class III equipment	0.5 mA

Notes to Table J1:








- (1) The values specified above are doubled:
- if the appliance has no control device other than a thermal cut-out, a thermostat without an “off” position or an energy regulator without an “off” position.
 - if all control devices have an “off” position with a contact opening of at least 3 mm and disconnection in each pole.
- (2) Equipment with a protective conductor current designed to exceed 3.5 mA shall comply with the requirements of Section 607 of BS 7671.
- (3) The nominal test voltage is:
- 1.06 times rated voltage, or 1.06 times the upper limit of the rated voltage range, for appliances for d.c. only, for single-phase appliances and for three-phase appliances which are also suitable for single-phase supply, if the rated voltage or the upper limit of the rated voltage range does not exceed 250 V;
 - 1.06 times rated line voltage divided by 1.73, or 1.06 times the upper limit of the rated voltage range divided by 1.73 for other three-phase appliances.

Appendix K: Standard symbols, units and graphical symbols for general electrical purposes

BS 3939: Graphical symbols for electrical power, telecommunications and electronics diagrams has been replaced by BS EN 60617, however, the two standards are identical. Installation layout symbols are contained in BS EN 60617-11: 1997. The following symbols are extracted mainly from BS EN 60617, supplemented by references from other Standards.

A. General symbols

V	.....	volts
A	.....	amperes
Hz	.....	hertz
W	.....	watts
kW	.....	kilowatts
F	.....	farads
p.u.	.....	per unit
ph	.....	phase
p.f.	.....	power factor
L	.....	line
N	.....	neutral
h	.....	hours
min	.....	minutes
s	.....	seconds
===	(or d.c.)	..... direct current
~	(or a.c.)	..... alternating current

2 ~	.....	two-phase alternating current
2N ~	.....	two-phase alternating current with neutral
3 ~	.....	three-phase alternating current
3N ~	.....	three-phase alternating current with neutral
IPXX	.....	IP number (see Appendix B)
		Fault (indication of assumed fault location).
		Class II appliance (Equipment in which protection against electric shock does not rely on basic insulation only, but in which additional safety precautions such as supplementary insulation are provided, there being no provision for the connection of exposed metalwork of the equipment to a protective conductor, and no reliance upon precautions to be taken in the fixed wiring of the installation (see BS 2754)).
		Class III appliance (Equipment in which protection against electric shock relies on supply at SELV and in which voltages higher than those of SELV are not generated (see BS 2754)).
		Safety isolating transformer. Class III equipment must be supplied from a safety isolating transformer to BS 3535. The safety isolating transformer will have this identifying mark upon it.
		Isolating transformer.
		Protective earth, general symbol (preferred to ).

In the International System of units (known as SI), there are Seven base units, as shown below; other quantities are derived from these.

Quantity	Name of base unit	Unit symbol
Length	metre	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Thermodynamic temperature	kelvin	K
Amount of substance	mole	mol
Luminous intensity	candela	cd

Multiples and sub-multiples of quantities:

10^{18}	exa	E				10^{-3}	milli	m
10^{15}	peta	P	10^2	hecto	h	10^{-6}	micro	μ
10^{12}	tera	T	10^1	deca	da	10^{-9}	nano	n
10^9	giga	G	10^{-1}	deci	d	10^{-12}	pico	p
10^6	mega	M	10^{-2}	centi	c	10^{-15}	femto	f
10^3	kilo	k				10^{-18}	atto	a

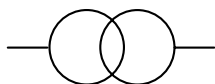
Powers in steps of 3 are preferred, but some others have common usage (e.g. centimetre, cm; decibel dB).

SI Derived units

The units of all physical quantities are derived from the base and supplementary SI units, and certain of them have been named. These, together with some common compound units, are given here:

Quantity	Unit name	SI Units	Unit symbol
Force	newton	kg m/s ²	N
Energy	joule	N m	J
Power	watt	J/s	W
Pressure, stress	pascal	N/m ²	Pa
Electric potential	volt	J/C, W/A	V
Electric charge, electric flux	coulomb	A s	C
Magnetic flux	weber	V s	Wb
Magnetic flux density	tesla	Wb/m ²	T
Resistance	ohm	V/A	Ω
Conductance	siemens	A/V	S
Capacitance	farad	C/V	F
Inductance	henry	Wb/A	H
Celsius temperature	degree Celsius	K	°C
Frequency	hertz	s ⁻¹	Hz
Luminous flux	lumen	cd sr	lm
Illuminance	lux	lm/m ²	lx
Activity (radiation)	becquerel	s ⁻¹	Bq
Absorbed dose	gray	J/kg	Gy
Dose equivalent	sievert	J/kg	Sv
Mass density	kilogram per cubic metre		kg/m ³
Torque	newton metre		N m
Electric field strength	volt per metre		V/m
Magnetic field strength	ampere per metre		A/m
Thermal conductivity	watt per metre kelvin		Wm ⁻¹ K ⁻¹
Luminance	candela per square metre		cd/m ²

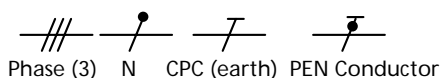
B. Symbols for use in schematic wiring diagrams



Transformer - general symbol



General wiring, with joint



Phase (3) N CPC (earth) PEN Conductor

Identification of specific conductors



Operating device, general symbol (coil)



Make contact - normally open



Break contact - normally closed



Manually operated switch, general symbol



Three-phase winding - delta



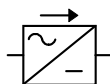
Three-phase winding - Star



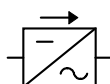
Changer, general symbol
Converter, general symbol

Notes:

- (1) If the direction of change is not obvious, it may be indicated by an arrowhead on the outline of the symbol.
- (2) A symbol or legend indicating the input or output quantity, waveform etc. may be inserted in each half of the general symbol to show the nature of the change.



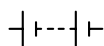
Rectifier



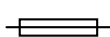
Invertor



Primary cell - longer line positive, shorter line negative

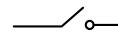


Battery



fuse link, rated current in amperes

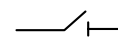
Making and breaking current:

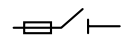
 switch

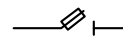
 switch-fuse

 fuse-switch

Isolating:

 Isolator (Disconnecter), general symbol

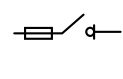
 Disconnecter - fuse (fuse combination unit)

 Fuse - disconnector

 Circuit breaker suitable for isolation

Making, breaking and isolating:

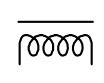
 Switch - disconnector

 Switch - disconnector - fuse (fuse combination unit)

 Fuse - switch - disconnector

 Capacitor, general symbol

 Inductor, coil, winding or choke

 Inductor, coil, winding or choke with magnetic core

 Semiconductor Diode - general symbol



Microphone



Loudspeaker



Antenna, general symbol



Machine, general symbol
* Function M = Motor G = Generator



Generator, general symbol



Indicating instrument, general symbol
* function V = Voltmeter A = Ammeter etc



Integrating instrument or Energy meter
* function Wh = Watt-hour
VARh = Volt ampere reactive hour



Lamp, or signal lamp, general symbol

C. Location symbols for installations



Machine, general symbol
* function etc



Load, general symbol
* details



Motor starter, general symbol
* indicates type etc



Socket-outlet, general symbol



Switched socket-outlet



Switch, general symbol



2 way switch, single-pole



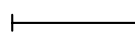
Intermediate switch



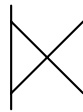
Pull switch, single-pole



Lighting outlet position - general symbol



Fluorescent luminaire, general symbol



Wall mounted luminaire



Emergency lighting luminaire (or special circuit)



Self-contained emergency lighting luminaire



Push button



Clock, general symbol



Bell



Buzzer



Horn



Telephone handset, general symbol

Appendix L: Addresses of associated bodies and identification symbols

Amalgamated Engineering and Electrical Union (AEEU)
Hayes Court
West Common Road
Hayes Kent BR2 7AU

Tel: 020 8462 7755
Fax: 020 8462 4959

Association of Consulting Engineers (ACE)
Alliance House
12 Caxton Street
London SW1H 0QL

Tel: 020 7222 6557
Fax: 020 7222 0750

Association of Manufacturers of Domestic
Appliances (AMDEA)
Rapier House
40-46 Lamb's Conduit Street
London WC1N 3NW

Tel: 020 7405 0666
Fax: 020 7405 6609

ASTA Certification Services
ASTA House
Chestnut Field
Rugby
Warwickshire CV21 2TL

Tel: 01788 578435
Fax: 01788 573605

British Approvals Service for Cables (BASEC)
23 Presley Way
Crownhill
Milton Keynes
Buckinghamshire MK8 0ES

Tel: 01908 267300
Fax: 01908 267255

British Approval Services for Electrical Equipment
in Flammable Atmospheres (BASEEFA)
{This service will be closed down in June 2003}
(See Electrical Equipment Certification Services)

British Cables Association (BCA)
Cable House
56 Palace Road
East Molesey
Surrey KT8 9DW

Tel: 020 8941 4079
Fax: 020 8783 0104

British Electrical Systems Association (BESA)
Westminster Tower
3 Albert Embankment
London SE1 7SL

Tel: 020 7793 3000
Fax: 020 7793 3003

British Electrotechnical & Allied Manufacturers'
Association (BEAMA)
Westminster Tower
3 Albert Embankment
London SE1 7SL

Tel: 020 7793 3000
Fax: 020 7793 3003

British Electrotechnical Approvals Board (BEAB)
1 Station View
Guildford
Surrey GU1 4JY

Tel: 01483 455 466
Fax: 01483 455 477

British Radio and Electronic Equipment
Manufacturers' Association (BREMA)
Landseer House
19 Charing Cross Road
London WC2H 0ES

Tel: 020 7930 3206
Fax: 020 7839 4613

British Standards Institution (BSI)
(also BSI Technical Help for Exporters)
389 Chiswick High Road
London W4 4AL

Tel: 020 8996 9000
Fax: 020 8996 7400

Building Services Research and Information
Association (BSRIA)
Old Bracknell Lane West, Bracknell
Berkshire RG12 7AH

Tel: 01344 426511
Fax: 01344 487575

Chartered Institution of Building
Services Engineers (CIBSE)
Delta House
222 Balham High Road
London SW12 9BS

Tel: 020 8675 5211
Fax: 020 8675 5449

City and Guilds (C & G)
76 Portland Place
London W1N 4AA

Tel: 020 7278 2468
Fax: 020 7278 9460

Copper Development Association
Verulam Industrial Estate
224 London Road
St Albans
Hertfordshire AL1 1AQ

Tel: 01727 731200 (Technical Helpline)
Fax: 01727 731216

Department of Trade and Industry (DTI)
1 Victoria Street
London SW1H 0ET
Tel: 020 7215 5000
Fax: 020 7222 0612

Electricity Association Ltd (EA)
30 Millbank
London SW1P 4RD

Tel: 020 7963 5700
Fax: 020 7963 5959

Electrical Contractors' Association (ECA)
ESCA House
34 Palace Court
London W2 4HY

Tel: 020 7313 4800
Fax: 020 7221 7344

Electrical Equipment Certification
Services (formerly BASEEFA)
{This service will be closed down in June 2003}
Harpur Hill
Buxton
Derbyshire SK17 9JN

Tel: 01298 28000
Fax: 01298 28244

Electrical Installation Equipment Manufacturers'
Association Ltd (EIEMA)
Westminster Tower
3 Albert Embankment
London SE1 7SL

Tel: 020 7793 3013
Fax: 020 7793 3003

Energy Industries Council (EIC)
Newcombe House
45 Notting Hill Gate
London
W11 3LQ

Tel: 020 7221 2043
Fax: 020 7221 8813

Engineering Equipment & Material Users'
Association (The) (EEMUA)
14-15 Belgrave Square
London SW1X 8PS

Tel: 020 7235 5316/7
Fax: 020 7245 8937

ERA Technology Ltd
Cleeve Road
Leatherhead
Surrey KT22 7SA

Tel: 01372 367000
Fax: 01372 367099

Federation of the Electronics Industry (FEI)
Russell Square House
10-12 Russell Square
London WC1B 5EE

Tel: 020 7331 2000
Fax: 020 7331 2040

Fibreoptic Industry Association (FIA)
10-15 The Arcade Chambers
High Street
Eltham
London SE9 1BG

Tel: 020 8959 6617 and 0208 850 5614

GAMBICA
(Association for the Instrumentation, Control and
Automation Industry in the UK)
Westminster Tower
3 Albert Embankment
London SE1 7SW

Tel: 020 7793 3050
Fax: 020 7793 7635

Health and Safety Executive (HSE)
Rose Court
2 Southwark Bridge
Southwark
London SE1 9HS

Tel: 020 7717 6000
Fax: 020 7717 6717

Health and Safety Information Line Tel: 08701 545500

Health and Safety Executive
Library and Information Service
Health and Safety Laboratories
Broad Lane
Sheffield S3 7HQ

Tel: 01142 892345
Fax: 01142 892333

HSE Books
PO Box 1999
Sudbury CO10 6FS

Tel: 01787 881165
Fax: 01787 313995

Institution of Electrical Engineers (IEE)
Savoy Place
London WC2R 0BL

Tel: 020 7240 1871
Fax: 020 7497 8863
www.iee.org
Technical Enquiries Tel: 01438 765599

Institution of Incorporated Engineers (IIE)
Savoy Hill House
Savoy Hill
London WC2R 0BS

Tel: 020 7836 3357
Fax: 020 7497 9006

Joint Industry Board for the
Electrical Contracting Industry (JIB)
Kingswood House
47-51 Sidcup Hill
Sidcup DA11 9HP

Tel: 020 8302 0031
Fax: 020 8309 1103

Lighting Association Ltd (The) (LA)
Stafford Park 7
Telford TF3 3BD

Tel: 01952 290905
Fax: 01952 290906

London District Surveyors Association
PO Box 266
Bromley BR2 9ZN

Tel: 07958 496 044

Lighting Industry Federation Ltd (LIF)
Swan House
207 Balham High Road
London SW17 7BQ

Tel: 020 8675 5432

Fax: 020 8673 5880

National Electrotechnical Training (NET)
34 Palace Court
London W2 4HY

Tel: 020 7313 4846

Fax: 020 7221 7344

National House Building Council (NHBC)
Buildmark House
Chiltern Avenue
Amersham HP6 5AP

Tel: 01494 434477

Fax: 01494 728521

National Inspection Council for Electrical Installation
Contracting (NICEIC)
Vintage House
37 Albert Embankment
London SE1 7UJ

Tel: 020 7564 2323

Fax: 020 7564 2370

National Joint Utilities Group (NJUG)
30 Millbank
London SW1P 4RD

Tel: 020 7963 5720

Fax: 020 7963 5989

Royal Institute of British Architects (RIBA)
66 Portland Place
London W1N 4AD

Tel: 020 7580 5533

Fax: 020 7255 1541

The Safety Assessment Federation (SAFED)
Nutmeg House
60 Gainsford Street
Butlers Wharf
London SE1 2NY

Tel: 020 7403 0987

Fax: 020 7403 0137

www.safed.co.uk

SELECT - Trading name of Electrical
Contractors' Association of Scotland
Bush House
Bush Estate
Midlothian EH26 0SB

Tel: 0131 445 5577
Fax: 0131 445 5548

Telecommunications Industry Association (TIA)
20 Drakes Mews
Crownhill
Milton Keynes MK8 0ER

Tel: 01908 265090
Fax: 01908 263852

United Kingdom Accreditation Service (UKAS)
21-47 High Street
Feltham
Middlesex TW13 4UN

Tel: 020 8917 8400
Fax: 020 8917 8500

Identification Symbols



British Approvals Board for Telecommunications

BABT is the UK Notified Body for the TTE Directive and the UK regulatory body responsible for the approval of terminal

equipment for connection to UK and European public networks.



British Electrotechnical Approvals Board

BEAB is the UK National Certification Body for domestic and

light commercial electrical equipment.



IEC International Certification Agreement (IECEE/CB) and the Cenelec

Certification Agreement (CCA)

The two schemes facilitate international trade in electrical equipment through mutual acceptance of reports and test certificates. They allow approval marks relating to electrical safety to be gained world-wide, normally without further testing.



CE marking denotes that a product conforms to certain New Approach EC Directives designed to remove barriers to trade within the European Union.

Before the product can be offered for sale anywhere within the EU it must conform to the requirements of all the Directives that apply to the product.

European



Telecommunications Standards Institute

ETSI is the European body

responsible for the generation of standards for equipment to be attached to, or used within, telecommunications networks, including radio equipment. These include voluntary test standards (ETs) as well as those forming the basis of regulatory requirements (TBRs) for the TTE Directive.



Federation Communications Commission

The FCC is the independent government agency in the USA responsible for regulating all forms of communications and use of the radio spectrum, by the general public in the USA.



National Accreditation for Measurement and Sampling

NAMAS accreditations of test and calibration laboratories are granted by the United

Kingdom Accreditation Service (UKAS). NAMAS accreditation is a recognition that the test procedures and quality systems operated by a laboratory meet required standards, in particular those of BS 45001.



British Approvals Service for Cables (BASEC)



Underwriters Laboratories

(UL) is the largest of the USA's nationally recognised testing laboratories, offering testing and certification (Listing) to established national and International standards of safety.



Voluntary Control Council for Interference by Information Technology Equipment

The VCCI EMC compliance programme applies to the

Information Technology Equipment (ITE) to be supplied for the Japanese market and although it is voluntary, it is widely supported by not only major Japanese companies but overseas companies as well.



Product Conformity Certification
Product Approval

Production Conformity Certification Product Approval

Product Conformity Certification involves an assessment of the product type against the requirements of a National Standard

and an assessment of the manufacturer's Quality Management System against BS 5750 or equivalent. Where a product type is outside the scope of a National Standard due to for example special design features ASTA will produce an ASTA Standard for the purposes of Product Approval. Such a Standard will make use of the requirements in National Standards wherever possible.



Certification of Supplier
Quality Management Systems

Certification of Supplier Quality Management Systems

The Scheme which is open to any manufacturer provides third party certification of a manufacturer's Quality Management System to BS 5750: Part 1, 2 or 3. (ISO 9001, ISO 9002 or ISO 9003). On request, the scheme can be extended to cover any other national or international management system quality Standard. The Scheme was developed initially for single firm application and, as such, does not depend upon the production and general release of assessment or technical schedules. Any special requirements, unique to an Applicant and his defined scope, are prescribed in quality plans called up by the manufacturer's Quality Manual and related working procedural documents. Provision has been made within the Scheme for special assessment schedules to be produced and published should this be considered desirable by a particular industrial sector.

Index

A

Accessories, mounting height of	Fig C1
Agricultural installations	
cable routes and equipment	5.3
residual current device required	3.6
Airing cupboards	4.2
Ambient temperature	
cables in high or low	4.2
correction factors for	4.2
Animal houses	4.9
Assemblies, LV switchgear etc.	2.9
Associated bodies, addresses of	Appx L
Autotransformers	8.4

B

Bonding	
of water heater (immersed and uninsulated elements)	8.2
main equipotential	3.7; Table 3.7a, 3.7b
supplementary equipotential	3.7; Table 3.8
British Standards, compliance with	2.3
Building Regulations	
2000	1.5; Fig C1
Scotland	1.5
Buried cables	5.7

C

Cable couplers and connections	7.1
Cables	
application and selection	Appx F
as overhead wiring	Appx G
at building expansion joint	4.8
bending radii	Appx G
buried in ground	5.7
colour coding	2.5; Table 2.1
concealed in structures	5.2
conduit capacity	5.4; Appx A
cord, flexible	
in caravans	Appx G
pendant	Appx G
current-carrying capacity	6.1
entering ferromagnetic enclosure	7.4
fire stopping	5.8
flexible	2.5

<i>Cables (cont'd)</i>	
handling at low temperature	4.2
identification	2.5
in contact with thermal insulation	7.2; 7.3
in heated floors	4.2
installation of	5
installed in conduit or trunking	5.4; Appx A
in temporary installations	Appx G
livestock	5.3
methods of support	Appx G
non-sheathed for fixed wiring	5.2
protection from	
external heat sources	4.3
high ambient temperature	4.2; 4.3
solar radiation	4.3
resistance	Appx E
sealing	5.8
Section 20	5.6
selection of	
for ambient temperature	4.2
for low corrosive gas emission	5.5
for low smoke emission	5.5
for reduced fire propagation	5.1; 5.5
separation	Appx I
sizing of	
cross-sectional area	6.1; 6.3
current-carrying capacity	6.1
support	Appx G
type reference numbers	Table F3
under floors	5.2
voltage drop	2.7; 6.1; 6.4
Capacities of conduit and trunking	5.4; Appx A
Catenary cables for overhead wiring	Appx G
Certification bodies, identification symbols	Appx L
Circuit arrangements, conventional	Appx C
Circuit protective conductors	
order of connection	8.6
Clean (low noise) earth	2.8
Combustible materials, location of	4.11(2)
Compatibility	2.7
Competence	1.6
Competent persons	Introduction; 1.6
Compliance with standards	2.3
Compression joints	7.1
Conductors	
cross-sectional area	6.3
identification	2.5; Table 2.1
order of in distribution board	8.6
resistance	Appx E

Conduit	
cable capacity	5.4; Appx A
spacings of supports for	Appx G
Connections, electrical	7.1
Construction (Design and Management Regulations) 1994	1.4
Control cables, separation	Appx I
Conventional circuit arrangements	Appx C
Cooker circuits	Appx C
D	
Damp conditions	4.5; 4.7
Dedicated earthing conductor	2.8
Degradation of materials	7.3
Degrees of protection (enclosures, IP & IK)	4.4; Appx B
Design of installations	Introduction
Designation system for cables	Table F2, F3
Designer	1.2; 1.3; 1.4
Deterioration of materials	7.3
Devices, protective	3.1
Dichroic lamps	8.5
Disabled people	Appx C g)
Diversity	
definition	6.2
estimation of	Appx H
Drip proof	Appx B
Dusty locations	4.6
E	
Earth, clean (low-noise)	2.8
Earthed equipotential bonding and automatic disconnection	3.1; 3.7
Earthing conductor	
dedicated	2.8
sizing of	3.7; Table 3.7a, 3.7b
Earthing of flush metal accessory boxes	3.7
Earth fault loop impedance	Appx D
Earth leakage current	
see protective conductor current	
Electrical connections	7.1
Electricity at Work Regulations 1989	1.3
Electric shock, protection against	3
EMC Regulations	2.4; 2.6; 7.4; Appx I
Emergency lighting	7.4; 8.3
Enclosures	4.4; Appx B
Energy efficient lighting	1.5
Equipment	
and BS 7671	1.2
definition	1.1
having high protective conductor current	8.1
operational requirements	2.4

<i>Equipment (cont'd)</i>	
permitted protective conductor current	Appx J
selection and erection	2
supports to	8.4
European standards	2.3
Expansion joints, wiring system at	4.8
Expansion, thermal	
of conduit and trunking	4.8
Experience	1.6
External influences	
ambient temperature	4.2
design	2.2
external heat sources	4.3
fauna and flora	4.9
general	4.1
high humidity	4.5
impact	4.8
IP and IK classifications	4.4; Appx B
list of	4.1
presence of	
corrosion or polluting substances	4.7
solid foreign bodies	4.6
water	4.5
solar radiation	4.3
vibration	4.8
F	
Ferromagnetic enclosures	
cables entering	7.4
Fire alarm systems	5.5; 7.4; 8.3
Fire, cable performance in	5.1
Fire stopping	5.8
Fixed wiring, colour identification	2.5
Forms of separation, LV assemblies	2.9
Fuses	3.1; 3.3
H	
Harmonic currents	2.4; 2.7; 6.3
Harmonised Standard	2.3
Heated floors, cables in	4.2
Heights of switches, sockets etc	Fig C1
High humidity (AB)	4.5
High protective conductor current	
see protective conductor current	

I	
Identification	
cables	2.5
circuits	2.5
colour coding	2.5; Table 2.1
labelling	
labels	Table 2.2
live parts, simultaneously accessible	2.5
protective conductors	2.5
switchgear	2.5
marking	
protective devices	2.5
safety signs	2.5
notices	2.5
pipes and ducts	2.5
protective conductors	2.5
Switchgear	2.5
Symbols	Appx L
Warning notices	2.5; Table 2.2
Immersion heaters	Appx C
Impact	
mechanical	4.8
protection	Appx B
Induction loop, hearing aid	7.4
Inductive loads	2.7
Information technology equipment	2.7; 8.1
Installation of cables	5
Insulation, electrical	3.1
Insulation monitoring devices	3.5
IP and IK codes	4.4; Appx B
J	
Joint, cable crossing building	
expansion	4.8
Joints	
in cables	4.7
in conductors	7.1
in enclosures	7.1
sealing of	4.5
Joists, notching and drilling	5.2
L	
Labelling	2.5
Lamps	8.5
Leakage current, earth	
see protective conductor current	
Lifetime costs	5.1
Lighting installations	1.5; 8.4; 8.5
Lighting points	8.4
Lightning, protection against effects of	3.8
Limitation of earth fault loop impedance	Appx D

Live incoming connections	8.6
Livestock, presence of	5.3
Locations of combustible construction	4.11(2)
Low-noise earth	2.8
Luminaires	8.5
Luminaires, arrangements for maintaining	8.4; 8.6
LV switchgear, etc. assemblies	2.9
M	
Main equipotential bonding	3.7; Table 3.7a, 3.7b
Maintainability	8.6
Material degradation and deterioration	7.3
Materials, locations constructed of combustible	4.11(2)
Maximum demand	6.2; Appx H
Mechanical impact	4.4; 4.8; Appx B
Metal accessory boxes, earthing of	3.7
Miniature circuit-breakers	3.4
Motors	2.4
Motor starters	3.2
Moulded case circuit-breakers	3.4
Mutual deterioration	7.3
Mutual detrimental influence damage by	
chemical action	7.3
corrosion	2.6
electrolysis	2.6
EMC	2.6; Appx I
N	
Neutral conductors	
order of connection	8.6
sizing of	6.3
O	
Operational	
conditions	2.2
manual	Introduction
requirements	
motor circuits	2.4
selection and erection	8.6
switchgear	2.4
Ordinary persons	8.6
Other services	7.4
Overcurrent	
protection against	3
protection devices	3.1; 3.2
Overhead wiring	Appx G
Overvoltage, protection against	3.8

P

Pendants	8.5
Permitted protective conductor currents	8.1; Appx J
Plasticiser, migration of	7.5
Potentially explosive atmospheres	4.10
Power sockets	Appx C f); Table C2
Protection against overvoltage	3.8
Protection by	
automatic disconnection	3.1; 3.7
enclosures	2.9
fuses	3.1; 3.3
overcurrent protective devices	3.2
RCDs	3.1; 3.6
Protective conductor current	
and residual current devices	3.6; 8.1
high	8.1
permitted	Appx J
Protective devices	3.1
Protective measures as a function of	
external influences	4.11
Proximity to	
hearing aid induction loop	7.4
other services	7.4

R

Radiant heat sources	4.3
Residual current devices	
agricultural installations	3.6
selection and location	3.6
use of	3.1; 3.6
where high protective conductor current	8.1
Resistance of conductors	Appx E

S

Safety services	
cable routes	8.3
segregation	7.4
supplies	8.3
Sealing and fire stopping	5.8
Sealing of terminations and joints	4.5
Section 20	5.6
Segregation	7.4
Selection of wiring systems	Appx F
Separation of cables	Appx I
Shower circuits	Appx C
Sink, location of sockets near to	4.5
Sizing of cables	6
SI units	Appx K
Skilled person	1.6
Socket-outlets, provision of	Appx C; Table C2
Solar radiation, protection from	4.3

Space factor	Appx A
Specification	Introduction
Splash proof	Appx B
Spotlights	8.5
Statutory requirements	1.3; 1.4
Standards, compliance with	2.3
Substations	5.6
Supplementary equipotential bonding	3.7; Table 3.8
Support, methods of	
cables and conductors	Appx G
wiring systems	Appx G
Surge protective devices	3.8
Switch, double-pole for water heaters	8.2
Switching overvoltages	3.8
Switch-mode power supplies	6.3
Symbols for general electrical purposes	Appx K
T	
Technical knowledge	1.6
Telecoms cables — separation	Appx I
The Construction (Design and Management) Regulations 1994	1.4
Thermal expansion and contraction of conduit and trunking	4.8
Thermal insulation, cables in	7.2; 7.3
Transformers	
auto	8.4
step-up	8.4
Trunking	
cable capacity	5.4; Appx A
spacing of supports	Appx G
U	
Uninterruptible power supply	2.7
Units, SI	Appx K
Unwanted tripping of RCDs	3.6
UV radiation	4.3; Appx F
V	
Vibration	4.8
Voltage drop	2.7; 6.4
W	
Wall lights	8.5
Warning notices	2.5; 8.6; Table 2.2
Washing machine	8.6
Water heating	8.2
Wiring systems	
methods of support	Appx G
selection and erection	Appx F
X	
XLPE (thermosetting) insulated cables	7.1