The IEE

Protection Against Electric Shock

GUIDANCE NOTE 5

IEE Wiring Regulations

5 BS 7671 : 2001 Requirements for Electrical Installations

Including Amd No 1 : 2002

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Contents

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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). Significant changes made in this 4th edition are sidelined.

Note that this Guidance Note does not ensure compliance with BS 7671. It is intended to explain 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 BS 7671 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 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 these will take precedence.

Introduction

This Guidance Note is principally concerned with Chapter 41 of BS 7671 — Protection against electric shock.

Neither BS 7671 nor the Guidance Notes are design guides. It is essential to prepare a full specification prior to commencement or alteration of an electrical installation. 131-01-01

The specification should set out the detailed design and provide sufficient information to enable competent persons to carry out the installation and to commission it. The 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 a diagram, chart or table providing the information required in Regulation 514-09, an operational manual or schedule. 514-09-01

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 and any operational manual.

The persons or organisations who may be concerned in the preparation of the specification include:

The Designer
The Installer
The Distributor of Electricity
The Installation Owner and/or User
The Architect
The Fire Prevention Officer
All Regulatory Authorities
Any Licensing Authority
The Health and Safety Executive

The Insurers
The Planning Supervisor

In producing the design, 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. The specification and/or the operational manual must set out the basis of use for which the installation is suitable.

Precise details of each item of equipment should be obtained from the manufacturer and/or supplier and compliance with appropriate standards confirmed. 132-01 120-02 511

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 switchgear, luminaires, accessories, etc and any special instructions that may be needed. The Health and Safety at Work etc Act 1974 Section 6 is concerned with the provision of information. Guidance on the preparation of technical manuals is given in BS 4884: Technical manuals and BS 4940: Technical information on construction products and services. The size and complexity of the installation will dictate the nature and extent of the manual.

This Guidance Note does not attempt to follow the pattern of BS 7671 too closely. Instead, a particular protective measure is considered in all its aspects, as far as possible, before the next measure is addressed. The order in which the protective measures are considered is not significant. 400-01-01

Section 1 — The Wiring Regulations

1.1 Object 130

One of the principal objects of BS 7671 is the provision of protection against electric shock. 130-01-01

1.2 Electric shock 130

Electric shock is defined as a dangerous physiological effect resulting from the passage of electric current through a human body or livestock. A useful reference document is British Standards Institution (BSI) publication PD 6519 'Guide to effects of current on human beings and livestock'. This relates the magnitude and duration of electric currents to the probable severity of their effects, based on information gathered internationally. Part 2

Two conditions of electric shock are recognised:

(i) under normal conditions, i.e. *Direct contact* which is contact of persons or livestock with live parts, sometimes called electric shock in normal service, and Part 2 130-02-01

(ii) under single fault conditions, i.e. *Indirect contact* which is contact of persons or livestock with exposed-conductive-parts (such as the metallic enclosure of an item of Class I equipment) made live by a fault, sometimes called electric shock in case of a fault. Part 2 130-02-02

With regard to indirect contact, the information referred to above entered the 15th Edition of the Wiring Regulations, as the adoption in normal dry situations of 0.4 s as the maximum disconnection time for a socket-outlet circuit (except for one specifically provided for fixed equipment) and 5 s as that for a circuit feeding fixed equipment.

This approach has been adopted in the International and European Standards, as it offers the most practical means of fulfilling the basic requirements for protection against electric shock.

1.3 Statutory Regulations 110

The Electricity Safety, Quality and Continuity Regulations 2002

1.3.1 There are a number of references to BS 7671 in the Electricity Safety, Quality and Continuity Regulations 2002 and in the Department of Trade and Industry guidance. Regulation 25(2) requires the distributor to refuse connection of the supply if evidence of compliance with BS 7671 is not provided.

1.3.2 Electricity at Work Regulations 1989

As might be expected, the Fundamental Principles of BS 7671 (Chapter 13) and those Electricity at Work Regulations which are concerned with electrical installations are worded similarly. It is intended that, by meeting the technical requirements set out in BS 7671, compliance with the Fundamental Principles and also, therefore, the Statutory Regulations, should be achieved.

Chap 13

120-01-03

Those Electricity at Work Regulations commented on below are of particular relevance to the provision of suitable means of protection against electric shock in the design and construction of an installation:

Regulation	*Commentary*	
4(1)	Addresses the construction of systems. An installation is part of a *system,* and the Regulation embraces the arrangement of its components, including the need for suitable electrical protective devices and other means to prevent danger from electric shock.	Part 2
5	Requires the strength and capability of electrical equipment not to be exceeded and thereby give rise to danger. In the context of protection against electric shock, insulation must remain effective under normal and any likely transient overvoltage conditions. Protective conductors must be adequately rated to survive earth fault conditions and allow satisfactory operation of relevant protective devices.	
7	Requires specified protective measures to be applied, or other suitable precautions to be taken, to prevent danger arising from direct contact.	

8	Requires suitable precautions to be taken to prevent danger arising from indirect contact.
9	Requires the integrity of any referenced conductor, e.g. an earthed neutral or combined neutral and protective conductor, to be ensured to prevent danger.
10	Requires, where necessary to prevent danger, every joint and connection to be mechanically and electrically suitable for use. Joints and connections in live conductors must be properly insulated and capable of safely withstanding any likely fault conditions. Joints and connections in protective conductors (see also Regulation 5 above) must be made at least as carefully as those in live conductors.
12	Requires means to be available for cutting off the supply of electrical energy to, and for isolation of, any electrical equipment.

1.4 Philosophy of shock protection 130

In general, two lines of defence against electric shock are employed by BS 7671. The first is that measures should be taken to prevent, so far as is reasonably practicable, direct contact with live parts i.e. protection under normal conditions, or basic protection. Measures such as insulation of live parts are therefore intended to provide the primary means of protection. Second, a further set of measures is prescribed. In the event of a single fault the risk of electric shock caused by indirect contact is prevented by a fault protective measure, e.g. earthing combined with automatic disconnection of the faulty part of the installation or equipment. Thus, one or more measures of protection against direct contact must be implemented in conjunction with one or more measures of protection against indirect contact, in order to fulfil the requirements of BS 7671 for protection against electric shock.

The detailed requirements for protection against direct and indirect contact are set out in a number of Chapters and Sections of BS 7671, for example:

Chapter 13 Fundamental principles

Chapter 41	Protection against electric shock
Chapter 47	Application of protective measures for safety
Chapter 54	Earthing arrangements and protective conductors

1.5 Protection against both direct and indirect contact 411

Some measures of protection do not distinguish between measures against direct or indirect contact, that is SELV, PELV and limitation of discharge of energy. These are enhanced protective provisions, that is they provide protection against both direct and indirect contact. 471-02 471-03

Protection against direct contact is possible by limiting the current which can pass through the body of a person or livestock to a value which is unlikely to cause danger. The measure, called *protection by limitation of discharge of energy* also provides protection against indirect contact. Since it only applies to low energy circuits, practical application of the measure within installations is very limited, as illustrated by the electric fence example quoted in BS 7671. Even this example is rather exceptional, given that its purpose is to deliver an electric shock, albeit a harmless one. 411-04 471-03-01

Section 2 — Protection Against Direct Contact

(Basic protection or protection under normal conditions)

2.1 Introduction 412

Direct contact is much more likely to result in serious injury or death than indirect contact, for the following reasons:

(i) the body is liable to experience the full supply voltage across it

(ii) the passage of electric current will not be interrupted by overcurrent protective devices.

A person making contact between phase and neutral will be seen by any overcurrent protective device as a small load, and no disconnection will occur.

A person making contact between a phase conductor and earth will produce a small increase in phase current (of the order of 10 to 300 mA), which will not be detected by overcurrent devices e.g. fuses or circuit-breakers. There will, however, be a slight difference between the phase and neutral currents that can be detected by a sufficiently sensitive RCD, if installed, see also Regulation 412-06-01. 412-06-01

In practice, many factors will play a part in determining the extent of injury received from a direct contact electric shock, including an element of chance. Many people experience electric shock at some time in their life. Fortunately for most of them, bodily contact is broken by reflex action before a current path through the main trunk of the body is properly established. Unfortunately, as electrocutions prove, the outcome of electric shock — to which no-one has immunity — is sometimes very different and reflex actions can produce their own hazards e.g. falling off a ladder.

In seeking to provide protection against direct contact, the measures employed must properly take into account any possibility of accidental or inadvertent contact with live parts. Thus, in some situations one physical safeguard may not be sufficient, and further measures will be needed to ensure safe use of the installation.

The fundamental principle is that persons and livestock shall be protected against dangers arising from direct contact by either: 130-02-01

(i) preventing contact with live parts, or

(ii) limiting the current in the event of direct contact.

2.2 Summary of prescribed measures 412

TABLE 2.2

Summary of Prescribed Measures for Direct Contact Protection 412-01-01

(Basic protection or protection under normal conditions)

Measure (protection by)	Purpose	Application	
(i) Insulation of live parts	Prevent contact with live parts	General	412-02 471-04
(ii) Barriers or enclosures	Prevent or deter contact with live parts	General	412-03 471-05
(iii) Obstacles	Prevent or deter unintentional contact with live parts	Limited to areas and locations accessible only to skilled persons or instructed persons under the direct supervision of a skilled person and overhead lines	412-04 471-06
(iv) Placing out of reach	Prevent unintentional contact with live parts	Limited to areas and locations accessible only to skilled persons or instructed persons under the direct supervision of a skilled person and overhead lines	412-05 471-07

Four basic protective measures are prescribed for use in low voltage installations for preventing contact with live parts. These may be used individually or, as is more usual, in combination, and are summarised in Table 2.2.

For special locations and for extra-low voltage systems, reference should be made to the relevant Sections of this Guidance Note.

The factor common to all of the measures is, of course, the prevention of contact with live parts. By definition, the term *live part* includes the phase and neutral conductors in an a.c. installation, and the positive and negative conductors in a d.c. installation, unless otherwise specified in BS 7671. By convention the term does not include dual-function PEN (protective earth and neutral) conductors. Part 2

Where the neutral is reliably connected to earth (as in TN systems in the UK) neutral conductors in distribution boards are considered as 'non-hazardous' live parts and are not additionally shrouded within an enclosure.

The term 'live part' does not include any PEN conductor, nor does it include any protective conductor (PE) even if conducting high protective conductor currents produced by current-using equipment in normal use.

There are requirements for live parts, particularly live conductors (e.g. with respect to isolation and overcurrent protection), that do not apply to conductors with a protective function.

2.3 Insulation of live parts 412

The basic regulation requirements for *insulation* are that it shall completely cover the live parts and be only removable by destruction. The measure is widely used in most installations, and the basic insulation covering on, for example, conductors of cables made to British Standards or equivalent standards, affords adequate protection against direct contact, *providing* the quality and effectiveness of the insulation is commensurate with the voltage to be applied to the conductors and other conditions of use e.g. constant flexing.

Part 2
412-02-01
471-04-01

GN1 : Selection & Erection

Wherever possible, the application of insulation on site should be avoided by employing proper factory-made and factory-tested products and equipment. Where it becomes necessary to apply basic insulation to live parts during the erection of the installation, the quality of that insulation must be verified. This will normally require the use of high voltage test equipment and special test methods. 412-02-01 713-05 GN3 : Inspection & Testing

Some electrical equipment contains live parts which have paint, varnish, lacquer or a similar product applied over them e.g. windings of a motor. Such finishes alone are not considered adequate insulation for protection against direct contact; therefore, live parts treated with any of these must not be accessible through apertures in the enclosure of the equipment concerned e.g. IP2X (see paragraph 2.4 below).

One of the fundamental principles relates to the type of wiring and method of installation including consideration of mechanical damage. An example of this is the requirement that non-sheathed cables for fixed wiring shall be enclosed in conduit, ducting or trunking. 131-07-01(vi) 521-07-03

Further mechanical protection may also be required for cables which are installed under a floor or above a ceiling, or within a wall or partition. Where required, the protection should provide a barrier to prevent the possible penetration of the cable insulation including any insulating sheath — by a tool or fixing. 522-06

During erection, care must be taken to ensure that the effectiveness of insulation is not impaired through rough handling or poor workmanship (such as the removal of too much insulation from conductors at terminations or connections). Precautions are often required to prevent damage by other trades, e.g. to the insulation or sheathing of cables during plastering. Thermoplastic (pvc) insulated cables should not be handled at ambient temperatures below 5 °C, or their insulation will be liable to cracking. 522-01-02

An insulation resistance test is required on completion of the fixed wiring of every installation, to verify that the measure is effective and complies with BS 7671. GN3 : Inspection & Testing

2.4 Barriers or enclosures 412

A *barrier* is intended to provide protection against contact with live parts from any usual direction of access. It need not, for instance, have a top surface if access from above that barrier is unlikely. A barrier may also be removable, e.g. to allow easy access to live parts, in which case one or more requirements specified by BS 7671 must be satisfied. Part 2 412-03 471-05 412-03-04

An *enclosure* is employed to provide protection against contact with live parts from any direction. Part 2

For household installations, barriers or enclosures are an integral part of wiring accessories, consumer units and current-using equipment. This is also true of industrial installations where such features, together with obstacles, may well be specially designed and erected in order to obtain the protective measure.

The protection afforded by the enclosure of virtually any type of electrical equipment may be specified in accordance with the International Protection (IP) Code classification system described in BS EN 60529: 1992 (Specification for degrees of protection provided by enclosures (IP Code)). For protection against direct contact the minimum degree of protection required by BS 7671 is IP2X (or IPXXB) and, in addition, any readily accessible horizontal top surface must provide a degree of protection of at least IP4X. 412-03-01 412-03-02

Further information on the IP Code is given in Appendix B to Guidance Note 1 : Selection & Erection.

Detailed construction requirements for low voltage switchgear and controlgear assemblies, including distribution boards, are given in the relevant parts of BS EN 60439. This Standard covers all low voltage assemblies, both type-tested (TTA) and partially type-tested (PTTA). To comply with the Standard, all external surfaces must conform to the minimum degree of protection stated above, i.e. IP2X. Most applications of barriers are also to be found in the construction of switchgear, etc. BS 7671 permits an opening larger than IP2X in a barrier or an enclosure, for functional reasons or to replace a part. For this purpose the opening must be no larger than is strictly necessary and the cover or barrier covering the opening should only be removable by the use of a tool and be fitted with a suitable permanent warning label. In this connection a coin is not a tool and such BS EN 60439 Appx 1 471-05-02 covers, etc should not have fixings which can be undone by a coin.

BS EN 60439-1 also takes account of those situations where it is necessary, for reasons of operation, to gain access to the interior of an assembly whilst it is still live. Four forms of internal separation of circuits by barriers or partitions fitted within an assembly are specified in Clause 7.7 of the standard.

GN1 : Selection & Erection

When access to the interior of an assembly is required by skilled persons for the purpose of adjustment or maintenance, etc, the first objective should be to isolate the assembly from the supply before gaining access. In these situations, a Form 1 type of assembly (no internal separation) may be suitable unless internal separation is required for other reasons, e.g. to minimise the probability of initiating arc faults. Where isolation is not reasonably practicable for such operations then consideration needs to be given to the specification of an assembly with a higher degree of internal separation. Additional temporary barriers or screens may be required to protect skilled persons from inadvertent direct contact when working within the assembly.

Electrical assemblies, such as those used for the control of boilers or building services, should always be manufactured to BS EN 60439. Panels which do not comply and are not equipped with suitable internal barriers, could allow access by persons who may be electrically unskilled persons and may present a serious and totally unnecessary risk of inadvertent or accidental direct contact. Barriers need not impede the work activity and may, for example, be made of transparent material, which overcomes the need (or temptation) in many instances to remove them. To further aid safe working, such as adjustment of controls, small holes (affording protection of at least IP2X) may be suitably located in the barriers to permit the insertion of a test probe, or a slim tool (e.g. an insulated screwdriver). A similar approach can often be very effective in preventing direct contact in test bays, test rooms and other situations where barriers are particularly suitable.

Where an enclosure or barrier is provided on site during erection, appropriate testing of the enclosure or barrier should be carried out to verify compliance with BS 7671. 713-07-01 GN3 : Inspection & Testing

However, the protection afforded by a barrier or enclosure must not be impaired during erection or maintenance of equipment. A hole in an enclosure, which should be plugged when not used, may not only destroy any IP classification which the enclosure is required to satisfy, but might also lead to direct contact with internal live parts and could be particularly hazardous where the enclosure is accessible to children. Damage and danger may also result from the entry of vermin through small unplugged openings. 529-01-01

2.5 Obstacles 412

Subject to very stringent rules of application (see Table 2.2), an *obstacle* may be employed as a measure of protection against unintentional (inadvertent) contact only with live parts. By definition, an obstacle can be deliberately circumvented, and therefore it affords a lesser degree of protection than that provided by a barrier. Part 2 412-04 471-06

The measure is only to be used in areas accessible to skilled persons or instructed persons under the direct supervision of skilled persons. For some installations or locations of increased shock risk this measure is not to be used, see Part 6 of BS 7671. 471-06-01

An obstacle may be fixed or removable and is not intended to prevent 'live working', which falls within the scope of the statutory regulations. The very nature of an obstacle makes it virtually impossible to prescribe a standard test method, and no test is offered in BS 7671.

With this measure of protection there are certain provisos. An obstacle must have rigidity and be incapable of unintentional removal. An obstacle must also: 412-04-02

(i) where removable and as necessary, be preferably constructed of non-conductive material,

(ii) be of adequate dimensions, and

(iii) be secured at a sufficient minimum distance from bare live parts (see *Arm's reach).* 412-05-03 Part 2

Where this measure is being contemplated, should there be any doubt over the adequacy of the proposed solution or the other necessary precautions which must be taken in conjunction with the use of obstacles, further advice should be sought, e.g. by reference to Health and Safety Executive (HSE) publications.

2.6 Placing out of reach 412

Note : 471-07-01
For some installations or locations of increased shock risk this measure is not to be used, see Part 6 of BS 7671.

Placing bare live conductors *out of reach*, whilst recognized by the Regulations as a means of providing protection against direct contact, must be employed only where it is under direct supervision. Stringent limitations are therefore placed on the application of this approach (see Table 2.2). 412-05 471-07 471-07-01

This limitation is not applied to bare or insulated overhead supply conductors for which minimum heights above ground and other requirements must be satisfied as laid down in Part V of the Electricity Safety, Quality and Continuity Regulations 2002 (Schedule 2). See also 'Notes on methods of support for cables, conductors and wiring systems' appended to the On-Site Guide and Guidance Note 1 : Selection & Erection. 412-05-01

The minimum dimension required by BS 7671 for other than an overhead line corresponds to *Arm's reach* or 2.5 m. The term *'Arm's reach'* should not be confused with simultaneous accessibility of conductive parts. Arm's reach as a concept is in general confined to protection against direct contact, whereas simultaneous accessibility of conductive parts is the basic consideration when dealing with protection against indirect contact. 412-05-02 Part 2

Clearly, if the measure is to be used within an installation, considerable thought has to be given to the location of the live parts, in relation to all work activities undertaken in their vicinity. Production work involving the handling of long metal tubes, bars, etc is likely to present a high degree of risk, making it almost impossible to justify the use of placing out of reach as a protective measure where 412-05-04 such work is undertaken. Maintenance activities must similarly be carefully considered, whether on the electrical installation itself, the fabric of the building (if any) or on any nearby machines or plant. Such activities may also involve the handling of long conducting objects, including metal ladders and access towers.

Consideration must also be given to the following:

(i) reduce to a practicable minimum the amount of exposed live material

(ii) ensure adequate minimum distances to all exposed live parts 412-05-02 412-05-03

(iii) fix suitable warning notices at all likely points of access to the location 471-13-02 471-13-03

(iv) control access to the location, using appropriate means, e.g. locks, written permits

(v) provide any special training for all skilled and instructed persons who are permitted access to the location; also, provide any protective equipment or clothing that may be necessary during their work.

Further advice should be sought where necessary, e.g. by reference to HSE publications.

2.7 Supplementary protection by residual current devices 412

With specific exceptions, supplementary protection by a residual current device must be provided in every circuit intended or reasonably expected to supply portable equipment for use outdoors. This is because there is a risk of flexes being cut or damaged, exposing live conductors, and of contact with true earth in these circumstances. BS 7671 also requires such protection in agricultural and horticultural installations. 471-16 605-03-01

Consideration should also be given to the use of supplementary residual current protection, as appropriate, in situations where the primary protection is provided by a barrier or an obstacle, since skilled persons sometimes make mistakes. An example of this application could be in the supply to equipment undergoing tests in a test bay or test room, where energised live parts are necessarily exposed during the tests.

Notes on the specification of a suitable device and its installation are contained in Guidance Note 1 : Selection & Erection of Equipment. Requirements for the testing of residual current devices are given in Guidance Note 3 : on Inspection & Testing. 3.6 of GN1 2.7.16 of GN3

Residual current devices must not be used as the sole means of protection against direct contact, but, the use of a residual current device is recognised as reducing the risk of injury from electric shock where the device possesses certain specified operating characteristics. Thus, any of the primary measures described earlier may be supplemented by the use of a residual current device to provide additional protection to persons who come into contact with a live conductor and earth. However, it is stressed that a residual current device offers no protection at all for a person making direct contact simultaneously with two live conductors (e.g. hand to hand) having a difference of potential between them, unless that person is also in contact with earth. Part 2 412-06 412-06-02(ii)

Residual current devices do not prevent shock currents flowing through the body, for a current must flow to earth for the residual current device to detect. However, provided the residual current device is sufficiently sensitive and functionally tested periodically it will operate sufficiently quickly to prevent injury.

2.8 Other measures and precautions 412

A number of other requirements of BS 7671 also make a significant contribution to protection against direct contact within virtually any installation. For example, a single-pole fuse, switch or circuit-breaker must be fitted in the phase conductor only. If, incorrectly, such a device is inserted in the neutral conductor, there is every likelihood that, sooner or later, a person will receive a direct contact electric shock from the live conductors being energised when they could reasonably be expected to be dead. Thus, it is vital that a polarity test is made on all circuits of a new installation. Proper identification, as required, of switchgear and all circuits, and provision of any necessary warning notices, are further requirements. 131-13-01 713-09-01

Some industrial processes, such as electrolytic and electrothermal processes, may necessitate a range of precautions being adopted, as the work activity is likely to be near live and uninsulated conductors. For these and similar high-risk locations, the guidelines given in the HSE 'Memorandum of Guidance on the Electricity at Work Regulations 1989' (HSR25, published by HSE books) should be followed.

Section 3 — Protection Against Indirect Contact

(Fault protection or protection under single fault conditions)

3.1 Introduction 413

BS 7671 prescribes protective measures to be used as appropriate in every installation, to reduce to an acceptable level the risk arising from failure of the primary protection, i.e. against direct contact. 413-01

Insulation, the most widely used primary measure, is continuously electrically stressed while the conductors it surrounds or supports are energised. Not surprisingly, therefore, insulation failure will happen from time to time, when the indirect contact protection measures employed must instantly fulfil a vital and possibly life-saving duty.

Only by carrying out relevant periodic inspection and testing can it be established whether the protection measures for indirect contact remain effective. Chap 73 GN3 : Inspection & Testing

A number of terms used in BS 7671 are of particular importance when considering the requirements for protection against indirect contact. Several terms are commented on below, others are considered where they arise in later Sections of this Guidance Note.

System

It is essential for the *type of system,* of which the proposed installation will form a part, to be determined at the earliest stage. Failure to do this could result in the wrong measure(s) being employed or incorrect protective circuit design criteria being applied, either of which could carry potentially serious consequences for the user of the installation at some time during its life. Part 2 312-03-01

Exposed-conductive-part

"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

The term is hyphenated, to emphasise that the words, taken together, have a special meaning as defined in Part 2 of BS 7671. The term must always be stated in full in order to avoid any misunderstanding which can arise from the omission or alteration of any of the words.

Since, by definition, an *exposed-conductive-part* may become live under fault conditions, the term does not include any touchable metallic parts of **Class II** equipment.

The following are everyday examples of exposed-conductive-parts:

- Metallic enclosures of type-tested assemblies (TTA) and partially type-tested assemblies (PTTA);
- Metallic enclosures of wiring systems (conduit, trunking, tray, metallic cable sheaths, etc);
- Metallic wiring accessory boxes and fascias;
- Metallic enclosures of ***Class I*** current-using equipment. Part 2

Extraneous-conductive-part

"A conductive part liable to introduce a potential, generally earth potential, and not forming part of the electrical installation." Part 2

Again, the term is hyphenated. The *extraneous-conductive-parts* listed in BS 7671 include non-electrical services and installation pipes and ducting, which are most often of a distributed nature. Such services, etc may therefore introduce earth potential alongside much of an electrical installation and the equipment served by it, making it quite likely that a person could be in simultaneous contact with an exposed-conductive-part made live by an earth fault and a nearby extraneous-conductive-part. Bonding of extraneous-conductive-parts to minimise the voltages that could arise between these and exposed-conductive-parts during an earth fault is described later. Part 2 413-02-02

Protective conductor

"A conductor used for some measures of protection against electric shock and intended for connecting together any of the following parts: Part 2

(i) exposed-conductive-parts

(ii) extraneous-conductive-parts

(iii) the main earthing terminal

(iv) earth electrode(s)

(v) the earthed point of the source, or an artificial neutral."

It is essential that the designer correctly identifies any particular protective conductor and its specific function, before proceeding to design measures of protection. The figures in Part 2 of BS 7671 should be helpful, and further explanation of the functions of various protective conductors is contained in later Sections of this Guidance Note. Part 2

Indirect contact

"Contact of persons or livestock with exposed-conductive-parts which have become live under fault conditions." Part 2

It is a fundamental principle that persons and livestock shall be protected against dangers that may arise from contact with exposed-conductive-parts during a fault. 130-02-02

3.2 Summary of prescribed measures 413

To satisfy the fundamental principle, five basic protective measures are prescribed. These measures are summarised in Table 3.2. 413-01-01

The measures are intended to be used separately. However, it is sometimes appropriate to employ more than one suitable measure within an installation or a part thereof. For example, measures (iii), (iv) and (v) can be used in this way.

The guidance given in the following sections relates to protection against indirect contact in low voltage installations in general. For extra-low voltage systems and special locations reference should be made to Sections 4 and 8 respectively of this Guidance Note.

TABLE 3.2 413-01-01

Summary of Prescribed Measures for Indirect Contact Protection

(Fault protection or protection under single fault conditions)

Measure (protection by)	Purpose	Application	
(i) Earthed equipotential bonding and automatic disconnection of supply	Under earth fault conditions voltages between simultaneously accessible parts not to be of such magnitude and duration as to be dangerous	General	413-02
(ii) Use of Class II equipment or equivalent insulation	Prevent exposed surfaces of equipment becoming live through basic insulation failure	Where using equipment of particular construction (see Fig 3.8)	413-03
(iii) Non-conducting location	Prevent simultaneous contact with parts which may be at different potentials through basic insulation failure	Special situations under effective supervision	413-04
(iv) Earth-free local equipotential bonding	Maintain simultaneously accessible parts at same potential during a fault	Special situations which are earth-free and under effective supervision	413-05
(v) Electrical separation	Prevent shock current from contact with exposed-conductive-parts during a fault	Individual circuit supplying one item of equipment or, for special situations under effective supervision, several items	413-06

3.3 Earthed equipotential bonding and automatic disconnection of supply 413

Earthed equipotential bonding and automatic disconnection of the supply is the most widely used measure of protection against indirect contact. The measure does not, of course, *prevent* indirect contact. Its purpose, as indicated in Table 3.2 and as stated in BS 7671, is to prevent the occurrence of a voltage of such magnitude and duration between simultaneously accessible conductive parts that an unacceptable risk of electric shock could arise from such contact. 413-02 471-08 471-08-01

The measure embraces several of the fundamental principles referred to earlier and consists of three separately identifiable components:

(i) earthing of installation equipment metalwork (exposed-conductive-parts)

(ii) equipotential bonding, as required, of non-electrical metalwork (extraneous-conductive-parts)

(iii) automatic disconnection of supply.

3.4 Earthing

In adopting the measure, effective *earthing* of each exposed-conductive-part of the installation, with certain exceptions, is essential for two reasons: Part 2

(i) to ensure operation of the protective device in the event of a fault

(ii) to limit the rise in potential above earth potential of exposed-conductive-parts during a fault.

The manner in which the exposed-conductive-parts should be earthed is clearly described, for each type of system, in BS 7671. 413-02-06 413-02-18 413-02-23

The connection with *earth* referred to above forms part of the *earth fault loop* and, within the installation, it contains two protective conductors: the *circuit protective conductor (cpc)* for a particular circuit and the common *earthing conductor.* In a TT system the earth return path may not be of particularly low impedance and therefore the protective measures used have to take this into account. Also, especially in a TT system, there may be more than one earthing conductor, each being Part 2 Part 2 Part 2 Part 2 associated with one or more of the circuits of the installation. The function of both the circuit protective conductor and the earthing conductor is to carry earth fault current, without sustaining damage, until disconnection of the earth fault has taken place. Practical considerations relating to these protective conductors are discussed later in this Guidance Note.

The importance of *maintaining* good earthing throughout the life of an installation can be most readily appreciated by remembering that failure of the *primary* protection, i.e. of the basic insulation of a live part, may lead to an exposed-conductive-part presenting a similar danger to that of direct contact, if the second line of defence is ineffective. An electric shock received in this way cannot truly be attributed to indirect contact. GN3 : Inspection & Testing

Metal cable support systems, e.g. conduit, trunking, ducting, channelling and trays, require earthing even if they are not used as the protective conductor unless the live conductors are separated from the support system:

- by basic insulation plus an earthed screen, sheath or armour of current-carrying capacity equal to that of the live conductors, or
- by basic insulation plus supplementary. An example of such supplementary insulation would be plastic conduit but not cable sheathing.

BS 7671 exempts from earthing certain items of metalwork and certain small exposed-conductive-parts. 471-13-04

3.5 Equipotential bonding

In addition to the *earthing* of exposed-conductive-parts, described above, bonding of — or connecting together — these same exposed-conductive-parts and extraneous-conductive-parts is vital in order to minimise any potential differences that might exist between the parts during an earth fault i.e. to create an *earthed equipotential zone.* Thus, the purpose of the various types of protective bonding referred to in BS 7671 is to equalise potential rather than to carry fault current, although sometimes bonding conductors will also carry fault current where they form part of a parallel earth return path to the source of supply, e.g. the transformer. Part 2 Part 2

The term 'equipotential' is often mistakenly interpreted as meaning that the parts which are bonded together will always be at the same potential, which may only be true in the absence of any earth leakage or earth fault current in the installation. The *point* at which exposed-conductive-parts and extraneous-conductive-parts are electrically connected together, i.e. the main earthing terminal, provides an *equipotential reference* for all of these parts. Part 2

3.6 Main equipotential bonding

This must be carried out in every installation where earthing is employed, yet its importance is often underestimated. Fig 3.6 illustrates part of an electrical installation. The type of system of which it forms a part is not important here. 413-02-02

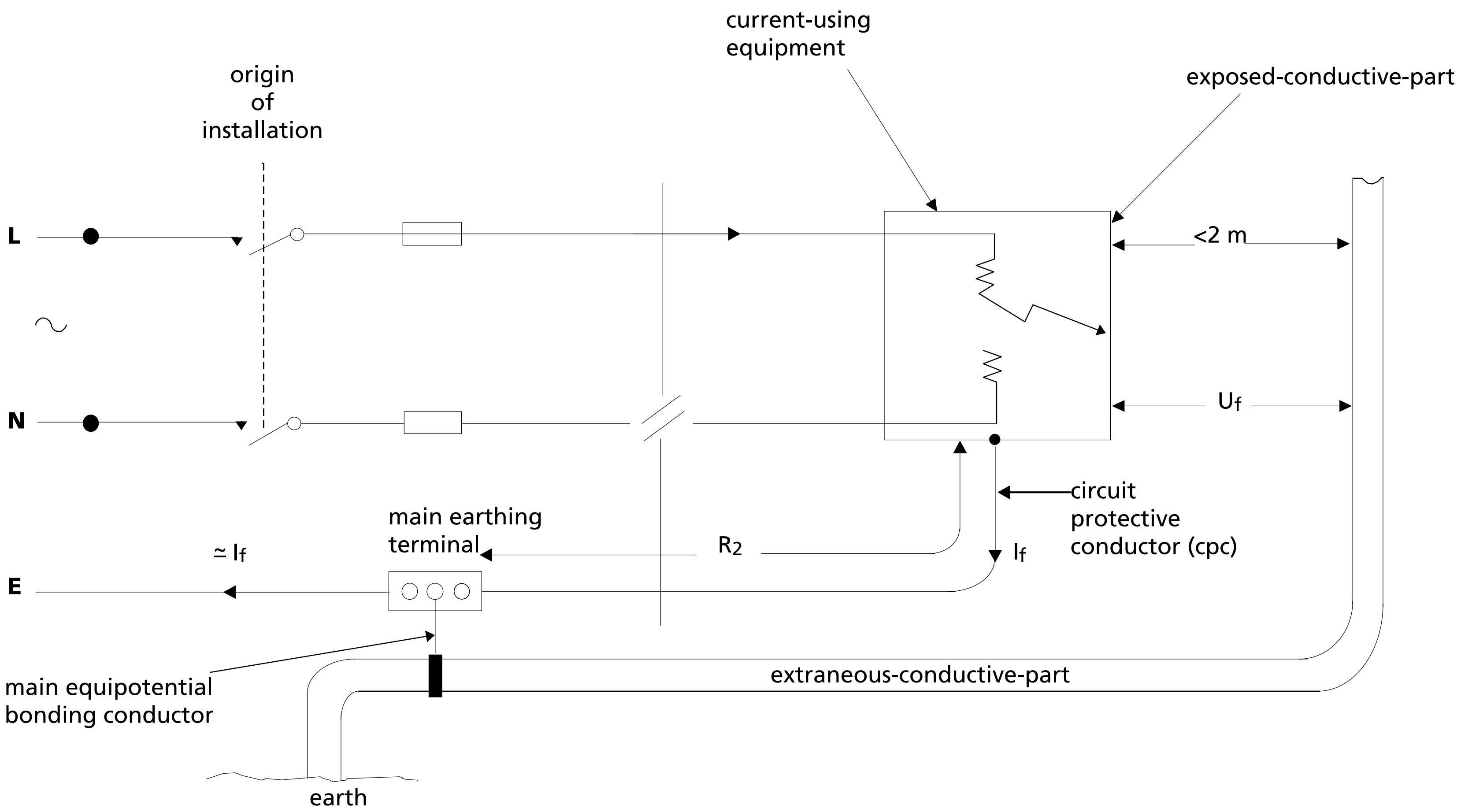
In the circuit shown, an earth fault in the current-using equipment produces a fault current (I_f) which flows along the circuit protective conductor and back to the source. A small proportion of the current may flow through the main equipotential bonding conductor directly to earth, and thence back to the source. The potential difference between the equipment exposed-conductive-part and the simultaneously accessible extraneous-conductive-part is:

$U_f = I_f R_2$ (ignoring any reactance of the circuit protective conductor, and any small effect of current flowing in the main equipotential bonding conductor)

where I_f is the fault current

R_2 is the resistance of the circuit protective conductor.

Fig 3.6 **Illustration of main equipotential bonding**



The effect of connecting the main equipotential bonding conductor to the extraneous-conductive-part is to minimise U_f. Without this conductor, the potential difference would approximate to the voltage drop produced by I_f along the full length of the earth return path, and this could be significantly greater than ($I_f R_2$). Put another way, failure to install all necessary main equipotential bonding conductors within an installation will certainly increase the shock risk associated with indirect contact.

BS 7671 also prescribes requirements for bonding in addition to main equipotential bonding. This is to be provided in certain defined circumstances which are referred to later in this Section. For installations in general, there are no specific requirements for any supplementary equipotential bonding to be installed, provided that the conditions for automatic disconnection are fulfilled, apart from certain special locations, including bathrooms, as stated in Part 6 of BS 7671. However, where a TN-C-S (PME) supply is to be given by a distributor, the installation designer should consult the distributor, to establish the sizing of main and additional equipotential bonding conductors and of the earthing conductor. Practical considerations concerning bonding conductors are discussed later in this Guidance Note.

413-02-04(i)
471-08-01(ii)
547-02-01
Table 54H

3.7 Automatic disconnection of supply

413-02

BS 7671 prescribes automatic disconnection of the supply to any circuit, i.e. distribution circuit or final circuit, in which an earth fault may occur. This is irrespective of how successful the earthing and bonding provisions may be in keeping down the magnitude of voltages that may appear between exposed-conductive-parts and extraneous-conductive-parts during an earth fault, since, even if there is no shock risk, thermal damage may be caused to conductors or their surroundings if earth fault current is allowed to persist.

413-02-05

Whatever the type of system, the operating characteristic of each device for automatic disconnection and the relevant impedance of the associated circuit should be properly co-ordinated to achieve the required disconnection time.

413-02-04

3.7.1 *Automatic disconnection in a TN system*

For an installation forming part of a TN system, overcurrent protective devices will most often be used for automatic disconnection. Earth fault loop impedances are generally lower than for other types of system, and this makes for effective operation of such devices in most instances. 413-02-07 413-02-08

For installations supplied at nominal voltages (U_O) in the range 121 - 277 V to earth the prescribed maximum disconnection times are generally 0.4 s or 5 s, but are 0.2 s for some special locations. Within the earthed equipotential zone created by the main equipotential bonding, the shorter disconnection time relates generally to circuits that supply equipment which involves the user or operator in making substantial physical contact with the equipment e.g. hand-held or where the resistance to earth is low, say due to wet conditions. Thus, the faster disconnection takes into account the greater likelihood of physical contact during the occurrence of an earth fault. 413-02-09 Table 41A 413-02-13

The tables of maximum earth fault loop impedances (Z_S) given in BS 7671 are provided for design purposes only (the values need to be reduced for testing purposes). They are based on the worst case disconnection times of circuit-breakers and median times for fuses. Worst case must be taken for circuit-breakers because of their 'dog leg' characteristic. Otherwise other parameters could reduce the fault current to the extent that the disconnection time increased from the instantaneous value 0.1 s to say 10 s (see Type B circuit-breakers, Fig 3.4 of Appendix 3 of BS 7671). Fuses do not have such disconnection characteristics, small changes in current result in relatively small changes in disconnection time. The data requires adjustment for any nominal voltage to earth other than 230 V. Table 41B1 Table 41B2 Table 41D Appx 3

Example: A 220 V radial circuit protected by a 30 A cartridge fuse to BS 1361 is required to be disconnected within 5 s. The maximum permissible value of Z_S is therefore:

220/230 x 1.92 ohms (from Table 41D) = 1.84 ohms.

This lower impedance ensures the same minimum required earth fault current would flow to cause operation of the fuse in a time not exceeding 5 s.

One set of data only is given for circuit-breakers, embracing both disconnection times. This is because circuit-breakers have an operating characteristic with a vertical portion which embraces tripping times in the range 0.1 s to 5 s. The tabulated Z_S values are therefore related to the operating current of that portion of the circuit-breaker characteristic producing tripping in 0.1 s. Table 41B2 Fig 3.4 Fig 3.5 Fig 3.6

Within the building, it is permitted to extend the 0.4 s disconnection time up to 5 s, providing the impedance of the circuit protective conductor between the main earthing terminal* of the installation and the remote end of the relevant circuit is limited to the prescribed maximum value. 413-02-12 471-08-02 Table 41C

* *Note:* The reference in Regulation 413-02-12 to Regulation 413-02-13(ii) is explained later.

The 5 s limit is achieved by meeting the appropriate tabulated value of Z_S, after applying Table 41C to the circuit protective conductor itself. The principle is that, under earth fault conditions, any voltage between exposed-conductive-parts and simultaneously accessible extraneous-conductive-parts will be reduced so as to reduce the risk of electric shock to an acceptable level.

There is no technical reason why Regulation 413-02-12 should not be employed, within its scope of application, as a standard design approach. Strictly, it does not apply to circuits protected by circuit-breakers because, for these devices, the limiting earth fault loop impedances are the same for both 0.4 s and 5 s disconnection times, as already mentioned. However, maximum values of circuit protective conductor impedance for circuit-breaker protected circuits are given in Table 41C, as limiting the impedance of the circuit protective conductor is a valid alternative method of providing protection against indirect contact for such circuits. 413-02-12

For a circuit supplying *fixed* equipment at a U_0 of 121-277 V outside the earthed equipotential zone, disconnection may be required within 0.4 s. For example, fixed lighting on the outside of a building 471-08-03 would have to be supplied from such a circuit where any luminaire(s) or associated switch(es) has an exposed-conductive-part which might be touched by a person in contact directly with the general mass of earth. In practice, it is likely to prove easier to adopt the 0.4 s disconnection time for all circuits which supply fixed equipment outside the building, except for circuits for which this time cannot readily be achieved and for which the longer disconnection time can be properly justified. 611-02-04

An RCD may be used to provide indirect shock protection in TN systems where the earth fault loop impedance (Z_S) is insufficiently low to operate a fuse or circuit-breaker within the prescribed disconnection time. An RCD may also be required for installations or locations of increased shock risk, such as those in Part 6 of BS 7671. (see Section 8 of this Guidance Note). Where more than one RCD is used they and their circuits should be segregated, or if RCDs are used in series the upstream device needs to be time delayed or S type and the downstream a type for general use, both to BS EN 61008 or BS EN 61009 to achieve discrimination. 413-02-07 413-02-16 413-02-04(ii) 471-08-01 531-02-09

It must be confirmed that the overcurrent device is providing short-circuit protection, which an RCCB is unable to provide.

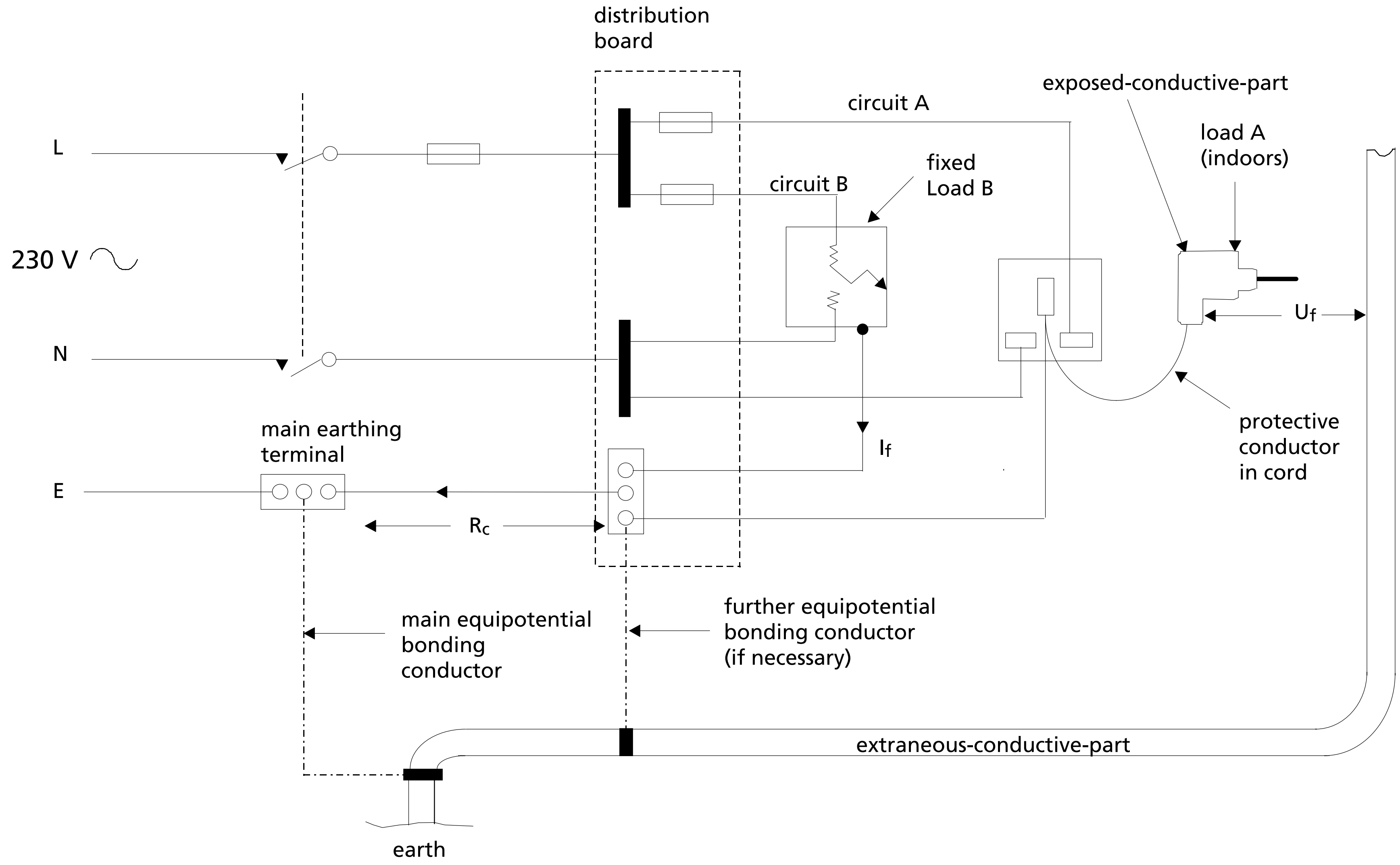
If protection against indirect contact is to be provided by the residual current element of an RCBO the tabulated values of maximum earth fault loop impedance (Tables 41B2, 604B2 and 605B2) are not applicable and Regulation 413-02-16 applies. 413-02-16

3.7.2 *Mixed disconnection times* 413-02-13

The requirements for mixed disconnection times apply for any final circuits supplied from the same distribution board, distribution circuit or sub-main. This includes adjacent boards supplied from a common circuit or with a common bonding connection.

Mixed disconnection times within an installation can give rise to a particular problem. Consider two final circuits of an installation as shown in Fig 3.7.2.

Fig 3.7.2 **Final circuits having 'mixed' disconnection times (Regulation 413-02-13)** 413-02-13



Both circuits are fitted with fuse devices for protection against overcurrent and indirect contact. Circuit A is required to be disconnected in accordance with Table 41A, i.e. in a time not exceeding 0.4 s. Circuit B supplies fixed equipment and may have a disconnection time of up to 5 s. An earth fault in Load B would raise the potential of the distribution board earth terminal by 413-02-09 413-02-13

$U_f = I_f R_c$

with respect to the installation main earthing terminal. Due to the common circuit protective conductor, U_f would appear between the exposed-conductive-part of load A (even if not switched on at the time) and the simultaneously accessible extraneous-conductive-part. Thus, indirect contact involving the load A equipment might take place for a time exceeding 0.4 s. To minimise the risk 413-02-13 of shock, BS 7671 requires **one** of the following conditions to be fulfilled:

(i) the impedance, R_c, of the common circuit protective conductor shall be limited, in accordance with Table 41C, to the tabulated value applicable to the circuit B fuse, or

(ii) equipotential bonding shall be applied between the distribution board earth terminal and relevant extraneous-conductive-parts.

Condition (i) is rather similar to applying the alternative design approach of Regulation 413-02-12 described earlier to circuit B, the difference being that here the Table 41C data are applied only to the common circuit protective conductor between the two earth terminals, not to the full length of the circuit protective conductor for circuit B.

Condition (ii) involves the installation of a further, localised, arrangement of main equipotential bonding conductors. This is *not* supplementary equipotential bonding. The further bonding is to prevent a voltage appearing between the exposed-conductive-parts of healthy equipment and adjacent extraneous-conductive-parts, due to the circumstances described above.

All the extraneous-conductive-parts which enter areas served by a mixed distribution board must be bonded. If the board feeds equipment on a number of floors of a building, the extraneous-conductive-parts on all these floors must be bonded to the distribution board.

Other ways of avoiding or overcoming the problem could include:

(i) design all circuits supplied from a common distribution board or distribution circuit to achieve disconnection within 0.4 s

(ii) use RCD (RCCB or RCBO) protection. This would have to include, in the example illustrated, fixed equipment circuit B. Fitting an RCD to socket-outlet circuit A would not solve the possible problem, since the RCD would be unaffected by the appearance of the voltage U_f and any current this might send through the body of a person who makes simultaneous contact with the exposed-conductive-part of load A and the nearby extraneous-conductive-part.

3.7.3 *Automatic disconnection in a TT system*

Other than in exceptional circumstances in which steel reinforcement of underground concrete or similar structure is available for use, in TT systems it is often difficult and costly to achieve a sufficiently low earth electrode resistance for overcurrent devices to be used for indirect shock protection. The Regulations 413-02-19
state that RCDs are preferred to overcurrent devices and RCDs are required to protect socket-outlets 471-08-06
whichever means is adopted for overcurrent protection, so there are few circumstances where RCDs are not used.

If protection against indirect contact is to be provided by an RCD the tabulated values of maximum earth fault loop impedance (Tables 41B1, 41B2 and 41D) are not applicable. However, overcurrent protective devices are still required to protect the circuits against overload, phase to neutral, phase to phase, and (if electrode resistance is very low) phase to earth faults.

The condition to be met for each TT circuit (see Fig 3.7.3) is:

$R_A I_a \leq 50$ V for normal dry situations 413-02-20 and

$R_A I_a \leq 25$ V for installations of increased shock risk. 471-08-01

If the protection is by an RCD this becomes:

$R_A I_{\Delta n} \leq 50$ V for normal dry locations 413-02-20

and $R_A I_{\Delta n} \leq 25$ V for construction sites, agricultural premises and medical locations 604-05-01 605-06-01 GN7 : Special Locations

where:

R_A is the sum of the resistances of the earth electrode and the circuit protective conductor(s) connecting it to the exposed-conductive-part

I_a is the current causing the automatic disconnection of the protective device within 5s

$I_{\Delta n}$ is the rated residual operating current, in amperes.

For typical RCD rated residual operating currents, the resistance of the electrode to earth must not exceed the values given in Table 3.7.3 below.

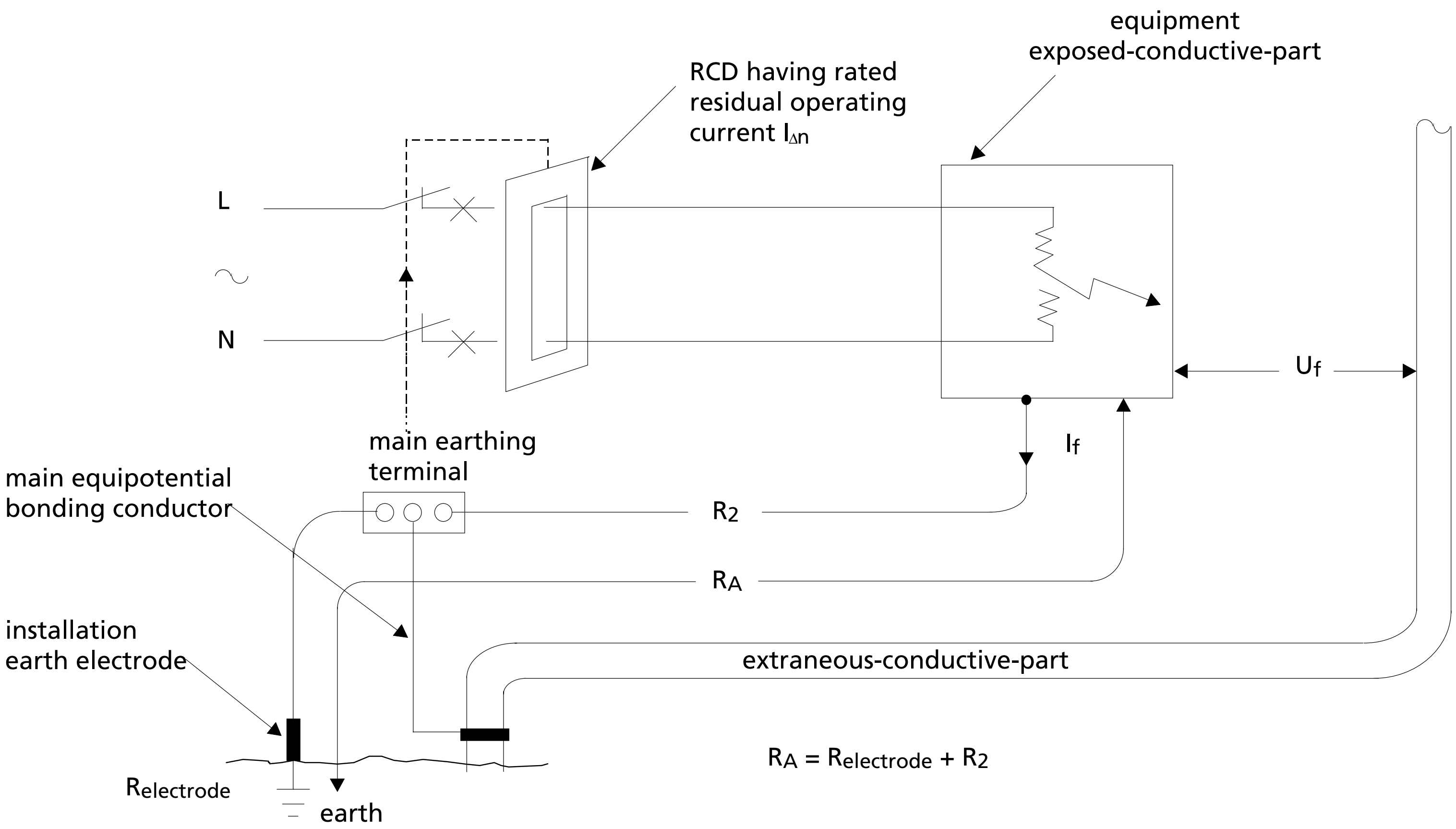
TABLE 3.7.3
Maximum values of earth electrode resistance for TT installations

RCD rated residual operating current $I_{\Delta n}$	Maximum value of electrode resistance to earth See **NB** below	
	normal dry locations	construction sites, agricultural and horticultural premises
30 mA	1660 Ω	830 Ω
100 mA	500 Ω	250 Ω
300 mA	166 Ω	83 Ω
500 mA	100 Ω	50 Ω

Note:
For most installations the resistance of any circuit protective conductor R_2 is small compared with the maximum value of R_A allowed for typical RCDs and can be neglected.

NB: For reliability over time in normal circumstances the earth electrode resistance should not exceed 200 Ω whatever the rated residual operating current.

Fig 3.7.3 **RCD-protected circuit in a TT system**



The formulae $R_A I_{\Delta n} \leq 50$ V and $R_A I_{\Delta n} \leq 25$ V do not limit the voltage to 50 V or 25 V as such, for the fault current I_f must exceed I_a or $I_{\Delta n}$ for the device to operate. However, they do ensure that if the fault current is too low to operate the device, then the voltage between true earth and the protective conductor will not exceed 50 V or 25 V respectively.

Where, instead of an RCD, an overcurrent protective device is fitted, generally only a low rated fuse would be capable of producing disconnection within 5 s. For instance, an installation earth electrode in the range 1 to 5 ohms could be considered a very good earth for most locations in the United Kingdom. At 5 ohms, plus (say) 0.2 ohm for the circuit protective conductor, the maximum permitted value of I_a will be 50/5.2 = 9.62 A. From BS 88 fuse characteristics even a 6 A fuse would not provide compliance. At 1 ohm plus 0.2 ohm, the maximum I_a is 50/1.2 = 41.7 A. For this, BS 88 fuses up to, but not including, 16 A rating could fulfil the condition. Certain low rated mcbs could also fulfil this latter condition only. Hence the reason why RCD protection is the preferred option in a TT system. Appx 3 Fig 3.3A Fig 3.3B

For a circuit supplying fixed equipment and protected by a fuse, if it is desired to check the actual earth fault loop impedance as well as the value of R_a, which represents part of it, the Z_s data of Table 41D may be used.

3.7.4 *Automatic disconnection in an IT system* 413-02-21 to 413-02-26

BS 7671 prescribes a series of detailed requirements to be fulfilled in an IT system if this measure is to be used. As IT systems are a specialist application, the requirements are not considered any further here.

3.7.5 *Automatic disconnection in a reduced low voltage system*

The *reduced low voltage system* described in BS 7671 is the familiar 110 V centre-tap earthed system. The much reduced nominal voltage to earth (55 V single-phase or 63.5 V three-phase), while being a little above the nominal extra-low voltage range, provides a much higher degree of safety than, say, 230 V in an indirect contact (or direct contact) situation. The Part 2 471-15 471-15-02 specified maximum disconnection time is therefore 5 s for any circuit, including socket-outlets, irrespective of whether the current-using equipment is to be used within the earthed equipotential zone or outside it, e.g. outdoors. 471-15-06

Table 471A provides limiting earth fault loop impedance data (Z_S), which obviates the need to convert the 230 V data given in the tables of Chapter 41. Table 471A

If the source is a transformer it must comply with BS 3535-2 : 1990 'Specification for transformers for reduced system voltage'. The neutral point or mid point of the source must be earthed, and an overcurrent protective device for automatic disconnection of earth faults is required to be fitted in each phase conductor. 471-15-04 471-15-06

Paragraph 4.6 provides guidance on ascertaining the loop impedance at the limit of a secondary circuit of a step-down transformer by calculation.

Care is required in the selection of a portable generator for a reduced low voltage system. Many 240/110 V single-phase generators do not have a centre-tap available and could therefore only be earthed on one pole. This would not constitute a reduced low voltage system as prescribed in BS 7671, and it would not provide the same degree of protection against indirect contact. It would be a low voltage system. (See HSE Information Document HSE 482/2). 471-15-03

3.7.6 *Automatic disconnection and portable equipment outdoors*

With specified exceptions, every circuit intended or reasonably expected to supply portable equipment for use outdoors, whether or not including a socket-outlet, is required to be provided with supplementary protection against direct contact by means of an RCD. While the RCD is primarily to reduce the risk associated with direct contact, it will also provide an enhanced degree of protection against indirect contact. 471-16

The *primary* circuit to a 415/110 V or 240/110 V portable transformer unit when used outdoors must be RCD protected to comply with the above-mentioned requirement.

3.7.7 *Automatic disconnection and alternative supplies*

An important aspect of providing protection against indirect contact which can be readily overlooked by the designer is the need to ensure satisfactory operation of the relevant protective device(s) when the installation, or part thereof, is energised from a second source. This may be an alternative LV feed, a standby generator supply or an uninterruptible power supply (ups). To be certain that the requirements of BS 7671 for protection against electric shock (and short-circuit) will still be satisfied, the designer must obtain full information for the alternative or special supply and make the necessary checks on his or her design, which will have been based upon the characteristics of the normal supply source. 313-01 313-02 551-04

A generator control panel or uninterruptible power supply (ups) equipment may include self-protection, a feature of which is the rapid collapse of output voltage to the load. This will inhibit the operation of any fault protective device situated beyond the equipment terminals and the feature cannot be assumed to provide a fail-safe operational arrangement for the user. Safety of the system as a whole must be ensured by, if necessary, involving the equipment supplier.

3.8 Use of Class II equipment or equivalent insulation 413-03

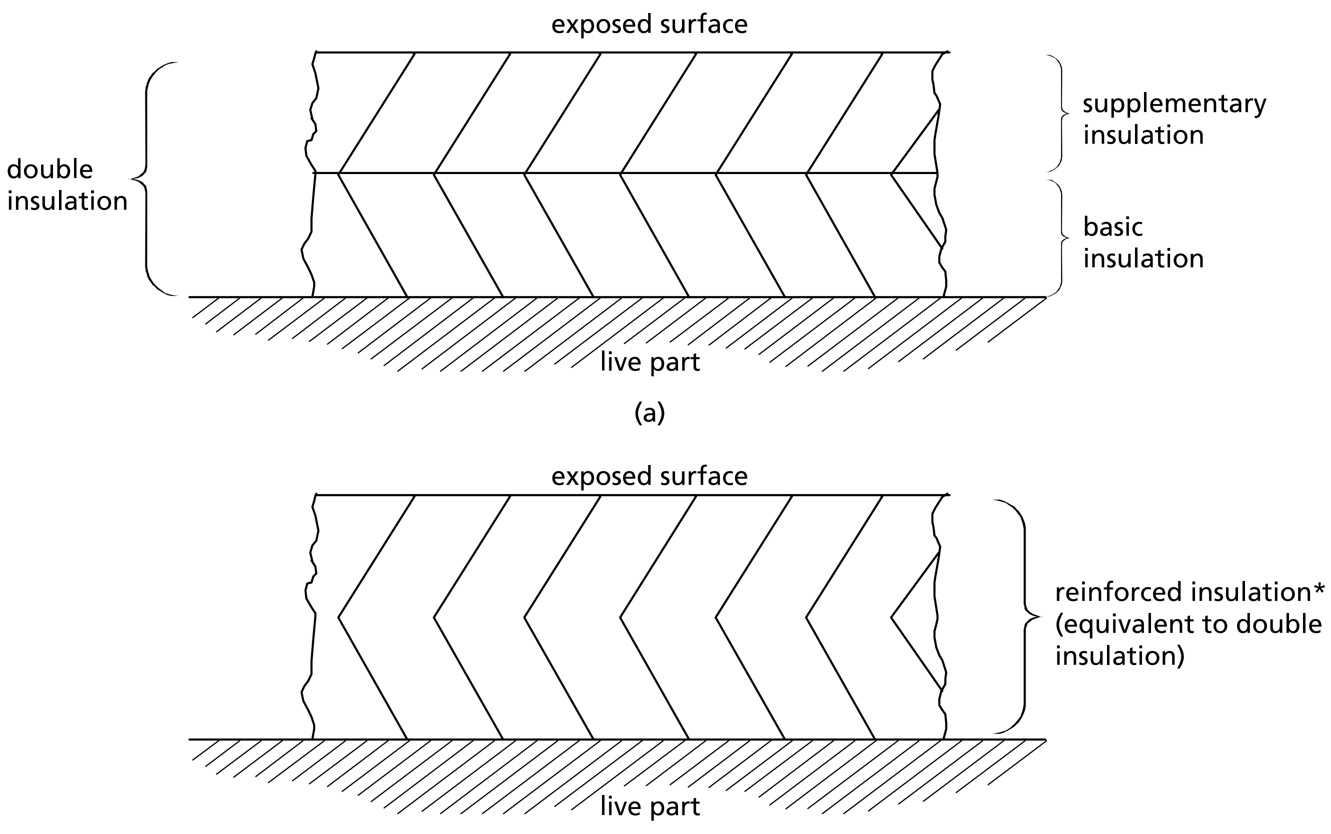
As indicated in the Summary of Prescribed Measures (Table 3.2), this measure relates to the use of equipment of particular construction. It is intended to prevent indirect contact by permitting the use only of equipment which has no exposed-conductive-parts and which cannot therefore give rise to the possibility of indirect contact in use. 413-03 471-09

The measure is generally applicable to individual items of equipment such as switchgear and controlgear assemblies, luminaires and current-using equipment. Terms used in this Section, i.e. Class I, Class II, and the various types of insulation referred to, are defined in Part 2 of BS 7671. Further information is contained in BS 2754 : 1976 (1999) Memorandum 'Construction of electrical equipment for protection against electric shock'. Fig 3.8 illustrates the various insulation types.

3.8.1 *Class II equipment*

Class II equipment may have a durable and substantially continuous enclosure of insulating material which envelops all metal parts except small parts such as nameplates, screws and rivets (but these small parts have to be isolated from live parts by insulation at least equivalent to reinforced insulation).

Fig 3.8 **Types of insulation**



Class II equipment having a substantially continuous metallic enclosure must have double insulation throughout, except that where such insulation is manifestly impracticable, reinforced insulation is used. The metallic enclosure, as indicated earlier in this Guidance Note, is not considered likely to become live in the event of a fault and is not therefore an exposed-conductive-part.

Equipment standards allow Class II equipment to be provided with means for maintaining the continuity of protective conductors not associated with the equipment itself. Where a Class II enclosure is provided with a terminal specifically for this purpose, it shall be clearly identified. If equipment has double or reinforced insulation throughout there is no need to connect this earthing terminal to a protective conductor for the purpose of protection against electric shock since protection is provided by the double or reinforced insulation. Regulation 413-03-09 specifically allows a protective conductor to pass through a Class II enclosure in order to serve another item of equipment. 413-03-09

Where this measure is used for fixed current-using equipment, the responsibility of the designer is equipment of Class II construction complying with appropriate British Standards. In other circumstances, supplementary or reinforced insulation can be applied on site during erection of the installation. However, a difficulty arises in that where this is done, it has to be verified that the final result provides an equivalent degree of safety to that achieved from similar type tested Class II equipment. To check compliance, it might be unwise to electrically stress the site-applied insulation to the level of high voltage specified in the British Standard then to put the insulation into service. It would be better to make up a sample test piece of an identical insulation arrangement and subject *that* to the full BS test requirements. If it is satisfactory, then the insulation which has been applied to the installation equipment could be tested at a lower voltage related to the working voltage of the equipment, using the BS test requirements for guidance. Where such site-applied insulation is in the form of prefabricated parts supplied by the equipment manufacturer, e.g. busbar insulation applied after site assembly of a sectionalised switchboard, these test requirements do not apply.

471-09-01
413-03-01
713-05-02
GN3 : Inspection & Testing

Exposed metalwork of Class II equipment must not be in contact with any exposed-conductive-parts of the installation. An example of how this could happen would be a Class II luminaire having exposed metalwork fixed to a connection box of a metallic conduit system in such a manner that there is metal-to-metal contact between exposed metalwork and the box. It is not because there would be a greater risk of electric shock from this arrangement than if Class I equipment were used, but that the advantage of using Class II equipment could be to some extent reduced. 471-09-02

3.8.2 *Installations where Class II equipment is the sole means of protection against indirect contact*

BS 7671 also permits this measure to be used as the sole means of protection against indirect contact for a whole installation or circuit, provided that the installation or circuit will be under effective supervision in normal use, to ensure that no changes are made that would impair the effectiveness of the construction. 471-09-03

Wiring systems within an installation are considered to meet the requirements of Regulation 413-03, protection by use of Class II equipment or by equivalent insulation, if mechanical protection is provided by: 413-03 471-09-04

- the non-metallic sheath of cable or,
- non-metallic trunking, ducting or conduit,

the wiring system being installed in accordance with the requirements of Chapter 52.

Except where a circuit is under *effective* supervision, it must be provided with a circuit protective conductor even if, at the time of installation, that circuit is supplying an item of Class II equipment. Unless there is an effective control system the possibility that Class II equipment may subsequently be replaced by Class I equipment cannot be overlooked. 471-09-02 471-09-03

It is practically impossible to exercise continuously effective control over any socket-outlet to ensure that only Class II portable equipment will be plugged into it in installations where the sole means of protection against indirect contact is by Class II equipment. Socket-outlets with an earth connection must not be used in installations where the sole means of protection against indirect contact is by Class II equipment, and it is preferable that sockets are not installed. This is intended to ensure that only equipment approved by the person exercising supervision is connected.

3.9 Non-conducting location 413-04

Protection by non-conducting location has been included in BS 7671 since 1981 because it was traditionally used overseas, where it can be supported by the knowledge and understanding of other trades, such as plumbing. Similar support may not generally be available in the UK and accordingly **the Institution of Electrical Engineers strongly advises against the use of this method of protection.**

This protective measure is an alternative to others in Section 413 e.g. 413-02, earthed equipotential bonding and automatic disconnection of supply. However, it allows Class 0 equipment that might have a metal case (exposed-conductive-part) that is not connected to the earthing terminal. A protective device will not operate in the event of a fault to such an exposed-conductive-part.

The following notes are provided to assist designers who may be involved in installing non-conducting locations overseas. They outline the principles upon which the method is based, but in no way do they provide a full design guide.

This measure requires that there is adequate physical separation between exposed-conductive-parts and extraneous-conductive-parts which could be at different potentials if there was a failure of the basic insulation of the equipment concerned. The second line of defence against indirect contact is obtained by the insulating nature of the floor and walls of the location itself. The minimum insulation resistance to be achieved is such that any shock current would be well under 10 mA. To prevent any reduction in the insulation resistance of the walls and especially the floor, the surfaces must be kept clean and dry, and it may be necessary to control the air humidity in the location. 413-04-07 413-04-04

The separation distance between conductive parts (whether they are exposed or extraneous) between which a voltage can exist in the event of insulation failure in the equipment concerned or elsewhere in the system must be not less than 2.5 m. If the parts are outside the zone of arm's reach the minimum separation between them becomes 1.25 m. Two other arrangements are also acceptable: 413-04-07(i)

— effective obstacles, as far as possible made of insulating material, fixed between exposed-conductive-parts and extraneous-conductive-parts 413-04-07(ii)

— insulation applied to or enclosing extraneous-conductive-parts to prevent access, or inserted to prevent the introduction of a potential (usually earth) into the location. Such insulation would need to be tested. 413-04-07(iii) 713-08-02

Socket-outlets installed in a non-conducting location must not incorporate earthing contacts. The implication here is that such a socket-outlet would be used only to supply mobile or portable Class II equipment and effective supervision is vital to ensure that no Class I equipment is brought into the location. 413-04-03

The continued effectiveness of this measure can be very difficult to guarantee, since there is always the risk that other conductive parts could be introduced at a later date, such as mobile or portable Class I equipment, as above-mentioned, or metallic water or other service pipes, which would invalidate compliance. There could also be the possibility that a fault voltage appearing on conductive parts within the non-conducting location might be transferred beyond the location via an extraneous-conductive-part, such as a water pipe, which has been added after completion of the installation. Hence the need for implementation in the working place of really effective supervision of the whole location, including all of its electrical equipment and all other equipment and services. For non-conducting locations, BS 7671 does not prescribe any specific notice requirements. Nonetheless, a suitable notice should be fixed in a prominent position adjacent to every point of access to the location. The notice should state that the location is a Non-Conducting Location, and give details of the person-in-charge who alone will 413-04-05 413-04-06 authorise any equipment to be taken into or any work to be undertaken in the location.

This protective measure is not to be confused with additional precautions taken in electrical repair shops, test bays etc to restrict the accessibility of exposed or extraneous-conductive-parts. Such locations will be primarily protected by Earthed Equipotential Bonding and Automatic Disconnection of Supply (EEBADS) or electrical separation.

3.10 Earth-free local equipotential bonding 413-05

The application of this measure is strictly limited to special situations which are earth-free, and where its use is fully justified on operational grounds. An example would be a medical, special electronic or communications equipment application, where vital functional equipment, while having exposed-conductive-parts (i.e. not being Class II equipment or having equivalent insulation), will not operate satisfactorily if connected to a means of earthing. The location where the measure is applied may have a non-conducting floor, or a conductive floor which is insulated from earth and to which every accessible exposed-conductive-part within the location is connected by local equipotential bonding conductors. The measure requires effective supervision and regular inspection and testing of the protective features employed. 413-05 471-11 413-05-02 413-05-04

The correct implementation of the requirements results in a 'Faraday cage' and prevents the appearance of any dangerous voltages between simultaneously accessible parts within the location concerned. Thus, in this application of equipotential bonding, the use of the word 'equipotential' really does reflect what it means for a first fault on the equipment, although this may not hold true for two simultaneous faults.

This measure cannot be applied to an entire installation and it is difficult to co-ordinate safely with other protective measures used elsewhere in the installation. In particular, precautions are necessary at the threshold of the earth-free equipotential location. Also, a warning notice is required to be fixed at every point of access into the location to warn against the importation of an earth. 413-05-04 471-11-01 514-13-02

The form of supply to the equipment in the location necessitates special consideration. Employing the mains supply of a TN system would import an earth into the location via the earthed neutral conductor which, in the event of a neutral fault to an exposed-conductive-part, would earth the equipment. Earth-free local equipotential bonding is normally associated with electrical separation which overcomes this problem, but where two measures of protection are to be used in the same location care must be taken to ensure that the particular requirements for each measure are fully satisfied and, most important, are mutually compatible.

3.11 Electrical separation 413-06

This measure may be used for an individual circuit which, preferably, should supply only one item of electrical equipment. The separated circuit may be supplied at a voltage up to 500 V a.c. rms. 471-12-01 413-06-02(iv)

The source of supply to the separated circuit must be either: 413-06-02

— an isolating transformer complying with BS 3535-1 : 1996 (BS EN 60742) 'Isolating transformers and safety isolating transformers' (e.g. a bathroom shaver supply unit), or

— one of the specified alternatives.

There must also be no connection between the separated source (i.e. the output winding if an isolating transformer is used) and earth, so that no path will exist for shock current to flow to earth in the event of failure of basic insulation.

It is important to make certain that the separated circuit is not accidentally earthed because, should this happen, the circuit and its supply become a TN system and the person protected would then be at risk from any voltage which could appear between simultaneously accessible parts in the event of a second earth fault. It becomes increasingly difficult to guarantee that the circuit will not become accidentally earthed as its length increases and this is particularly so if the circuit includes flexible cables which may be susceptible to mechanical damage. Hence, flexible cables and cords are required to be 413-06-03(i) 413-06-03(ii) visible where they are liable to such damage and regular inspection of these cables and cords is strongly recommended.

While not being the preferred method, a separated circuit may be run in a multicore cable with other circuits or be accommodated in the same enclosure (conduit, trunking or ducting) as other cables, provided that neither the sheath of that cable nor the enclosure is metallic. This is because of the risk that the separated circuit could become accidentally earthed via such a sheath or enclosure. 413-06-03(iii)

Exposed-conductive-parts (if any) of the source of the separated supply must not be connected to the exposed-conductive-part(s) of the equipment being supplied. If there is only one item of equipment on the separated supply, its exposed-conductive-part must therefore not be intentionally connected to another circuit or to earth. If, however, the separated circuit feeds a number of items of equipment, the exposed-conductive-part of those items (except the source itself) are to be connected together by an insulated equipotential bonding conductor and not connected to earth or to other protective conductors, etc. In addition, any exposed-conductive-part of the source shall not be simultaneously accessible with any exposed-conductive-part of equipment supplied by the separated circuit. 413-06-02(iii)(b) 413-06-04 413-06-05(i) 471-12-01

A warning notice is also required to be fixed at every point of access into the location to warn against the importation of an earth. 514-13-02

Overcurrent detection should be provided in each pole of the separated circuit. This is to provide not only overload and/or short-circuit protection, but also automatic disconnection of any circuit that supplies two or more items of equipment, if two faults to exposed-conductive-parts occur and these are fed by conductors of different polarity. Such a two-fault occurrence would, in effect, be a short-circuit via the equipotential bonding conductor connecting together the two relevant exposed-conductive-parts. If this bonding were missing or not effective, then the two-fault occurrence could lead to the full supply voltage appearing between the exposed-conductive-parts thereby creating a very serious shock hazard. 473-03-01 413-06-05(iv) 413-02-04

A fairly common application of electrical separation is the servicing and diagnostic testing of electronic equipment, e.g. television receivers. Here, each set being worked on is supplied via its own isolating transformer, so that there is no electrical connection between them. However, the danger of direct contact remains for a person servicing a live chassis, and other less obvious ways of receiving electric shock can also arise. This is why, in these applications of the measure, further precautions are usually included and might, for instance, include a detection circuit for each separated circuit which will provide a suitable warning of a first fault appearing in the separated circuit.

Section 4 — Protection by Means of Extra-low Voltage

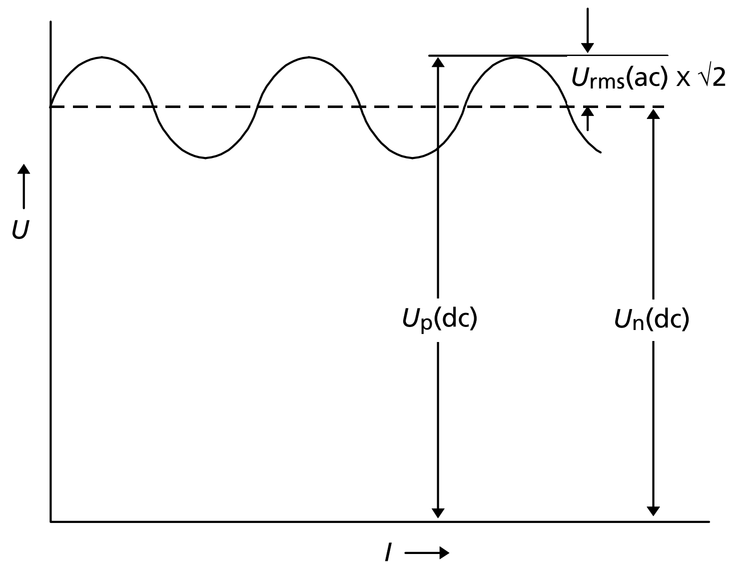
4.1 Introduction
411

Extra-low voltage is defined in BS 7671 as nominal voltage 'normally not exceeding 50 V a.c. or 120 V ripple-free d.c., whether between conductors or to Earth'. The meaning of 'ripple-free' is defined in Regulation 411-02-09 for the purposes of this regulation, although the definition may be applied more widely, and it is also illustrated in Fig 4.1.

Part 2

411-02-09

Fig 4.1 **Approximate calculation of permissible ripple content of nominal d.c. voltages**



Permissible peak value (U_p)
$U_p(dc) = U_n(dc) + U_{rms}(ac) \times \sqrt{2}$
$U_n(dc)$ = nominal d.c. voltage

Example for 10 % ripple content and $U_n(dc) = 120$ V
$U_p(dc) = 120 \text{ V} + 12 \text{ V} \times \sqrt{2} = 137$ V which approximates to 140 V.

Excessive ripple can undermine the otherwise relative safety of extra-low voltage (ELV) described below, as it will tend to increase the risk of heart fibrillation (uncoordinated muscular contractions of the heart) arising from an electric shock.

Extra-low voltage may be used either because the equipment or process concerned is designed to operate at ELV, or as a deliberate measure to reduce the danger of electric shock. Regarding the latter, the risk of harm from electric shock at extra-low voltage, whether received by direct or indirect contact, is drastically reduced when compared to a similar situation involving low voltage at, say, 220-240 V to earth. This will be readily appreciated from a study of the information given in BSI publication PD 6519, Guide to effects of current on human beings and livestock.

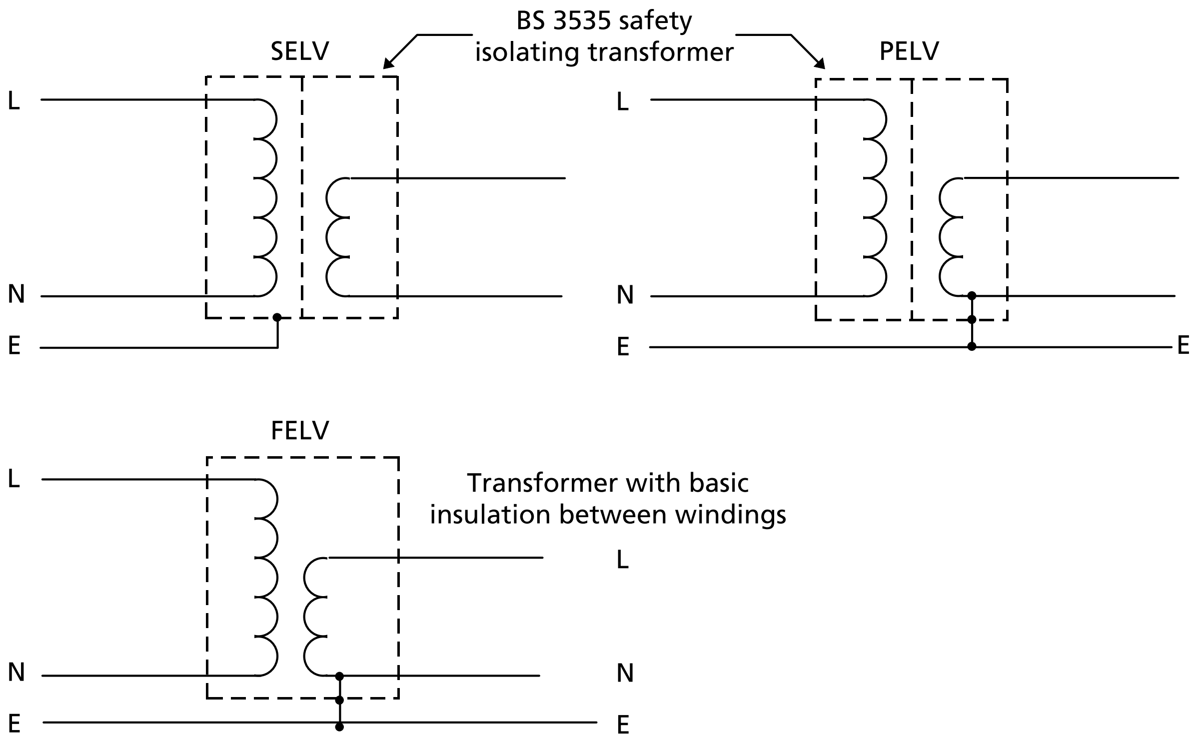
The protective measures to be taken in using ELV are dependent upon the location, the source of supply and the degree of separation from other electrical systems. For locations of increased shock risk the particular requirements of Part 6 of BS 7671 must be met. While some aspects of Part 6 are covered in the final Section of this Guidance Note, it is convenient to consider here, in addition to the general application of ELV, some of the particular requirements. 400-02-01 471-01-01

4.2 General

Three ELV systems are recognized:

SELV separated extra-low voltage
PELV protective extra-low voltage
FELV functional extra-low voltage.

Fig 4.2 **Extra-low voltage systems**



Regulation 411-02-02 lists the allowed sources for SELV (and PELV). In Fig 4.2 the source for SELV and PELV is a safety isolating transformer complying with BS 3535.

4.3 SELV

SELV (separated extra-low voltage) is an ELV system which is electrically separated from earth and from other systems in such a way that a single fault cannot give rise to the risk of electric shock. It should be appreciated that if a single fault were to occur it is intended that this should be confined to the SELV system and not involve any conductive parts of another system. Thus, the construction of a SELV system necessitates the use of high-integrity equipment and materials.

Part 2
411-02
471-02

Where an ELV system is derived from a completely independent source, e.g. a battery or an engine-driven generator, and if there is no other electrical system in the vicinity, the precautions to be taken relate only to the ELV system itself.

If the nominal voltage of a SELV system exceeds 25 V a.c. rms or 60 V ripple-free d.c. protection against direct contact must be provided by insulation of live parts and, as necessary, the use of barriers or enclosures. At lower voltages, protection is afforded by the extra-low voltage itself between live parts. Protection against indirect contact is provided by electrical separation of all conductive parts of the system from other conductive parts. 411-02-09

SELV is most often used where extra-low voltage is specifically chosen as a safety measure. In certain locations, such as certain zones of swimming pools or certain medical locations, it is the only measure against electric shock permitted and, since even ELV carries some risk of electric shock, the requirements for this measure are also made more stringent, e.g. nominal voltage limited to 12 V a.c. or 30 V d.c. 471-02-01 602-04-01 GN7 - Ch 10

The source for SELV must be of a high standard to minimise the risk of a higher voltage appearing on the conductors of the system. Where the source is a transformer it must be a *safety* isolating transformer complying with BS EN 60742 (also numbered BS 3535-1 : 1996). There is a difference between a safety isolating transformer and an isolating transformer, and the former is specifically intended for SELV circuits. 411-02-02 411-02-03 411-02-04

Wherever practicable, SELV circuits must be physically separated from those of any other system. If this is impracticable special precautions are again needed to prevent low voltage appearing on any of the ELV conductors due to a fault between a SELV circuit and another system. Special insulation tests must also be carried out on completion of the installation between the SELV and low voltage systems, to verify the integrity of the precautions taken. 411-02-06 GN3 : Inspection & Testing

The degree of safety afforded by a SELV system depends crucially upon it being isolated both from earth and from any other system. If this cannot be achieved and — very importantly — maintained throughout its life, the extra-low voltage system cannot depend solely upon the precautions for SELV. It is for this reason that for many general applications of ELV the designer would be prudent to implement appropriate further prescribed measures, some of which are referred to below. 411-02-07 411-02-08 471-14

Since SELV is an unearthed system overcurrent protective devices must, where required, be fitted in both live conductors. Also, to minimise the risk of danger, socket-outlets in a SELV system are required to be of a pattern which is non-interchangeable with those used for any other system, either low voltage or different ELV, in the same premises, and to have no earth contact (this is to prevent a connection to earth being made in the future, possibly by a person who is ignorant of the system). 431-01-01 411-02-10

In certain locations subject to particular requirements, live parts must be insulated and, as appropriate, barriers or enclosures provided, irrespective of the nominal voltage. Even where precautions against electric shock are not specifically required, insulation of live parts may still be necessary, often with added mechanical protection, to guard against the risk of short-circuits. This is particularly important with the terminals of high-power batteries and where the ELV system involves high-current circuits and hence high energy levels, e.g. electroplating. 601-03-02 602-03-01 603-03-01 605-02-02 606-02-01 GN7 - Ch 10

4.4 PELV

PELV (protective extra-low voltage) is an ELV system which is not electrically separated from earth, but otherwise satisfies all the other requirements for SELV, see Fig 4.2. Part 2 471-14-01 471-14-02

If the nominal voltage of a PELV system exceeds 25 V a.c. rms or 60 V ripple-free d.c. protection against direct contact must be provided by insulation of live parts and, as necessary, the use of barriers or enclosures.

Additional measures of protection against direct contact may not be required if:

(i) the equipment is within a building in which main equipotential bonding is applied

(ii) the voltage does not exceed 25 V a.c. rms or 60 V ripple-free d.c. in normally dry locations, except in medical locations where protection by insulation of live parts or by barriers or enclosures is essential at all times GN7 - Ch 10

(iii) the voltage does not exceed 6 V a.c. rms or 15 V ripple-free d.c. in all other locations.

PELV circuits rely for protection against indirect contact faults introduced from the primary circuit, on the primary circuit protection. It must be confirmed that this protection against indirect contact is appropriate for the location.

Faults elsewhere on the installation will introduce fault voltages into the PELV system via the protective conductor.

4.5 FELV

FELV (*functional extra-low voltage*) is used when extra-low voltage is required for functional purposes, such as machine control systems. Part 2 411-03 471-14

The supply may be either from a safety source or from a transformer with simple separation between the primary and secondary windings, that is, basic insulation. 411-02-02

Protection against direct contact (basic protection) must be provided by insulation, barriers or enclosures for the FELV circuit. Protection against indirect contact (fault protection) is provided by connecting exposed-conductive-parts of the FELV circuit to the protective conductor of the primary circuit, provided the primary circuit is protected by earthed equipotential bonding and automatic disconnection of the supply. 412-02 412-03 413-02

Protection against indirect contact by automatic disconnection of supply in the event of a fault to earth on the secondary side of the system is not a requirement.

In practice, most ELV systems require the full range of precautions to be taken against danger arising from any associated low voltage system. Also, to prevent 471-14-06 danger, socket-outlets in a FELV system are required to be of a pattern which is non-interchangeable with those used for any other system in the same premises.

4.6 Calculation of loop impedance PELV and FELV circuits

If it is wished to ascertain the loop impedance by calculation , the impedance at the end of a circuit fed from the secondary of a step-down transformer is given by:

$$Z_{sec} = Z_p \times \left(\frac{V_s}{V_p}\right)^2 + \frac{Z\%\,tran}{100}\,\frac{(V_s)^2}{VA} + (R_1 + R_2)_s$$

where:

Z_p is the loop impedance of the primary circuit including that of the source of supply, Z_e

Z% is the percentage impedance of the step-down transformer

VA is the rating of the step-down transformer

V_s is the secondary voltage

V_p is the primary voltage

$(R_1 + R_2)_s$ is the secondary circuit phase and protective conductor resistances.

If data on the step-down transformer is not available, this may be simplified to:

$$Z_{sec} = 1.25 \left\{ Z_p \times \left(\frac{V_s}{V_p}\right)^2 + (R_1 + R_2)_s \right\}$$

$$Z_{sec} = 1.25 \left\{ (Z_e + (2R_1)_p) \times \left(\frac{V_s}{V_p}\right)^2 + (R_1 + R_2)_s \right\}$$

where:

1.25 is a factor to compensate for an underestimate.

Z_e is the external phase-neutral/earth loop impedance

$(2R_1)_p$ is the primary circuit phase plus neutral conductor impedance.

Section 5 — Earthing

5.1 Connections to earth 542

It is necessary to determine the type of *system,* i.e. TN-S, TN-C-S, TT, etc, of which the proposed installation will form a part, before proceeding with the installation design. Part 2 312-03-01

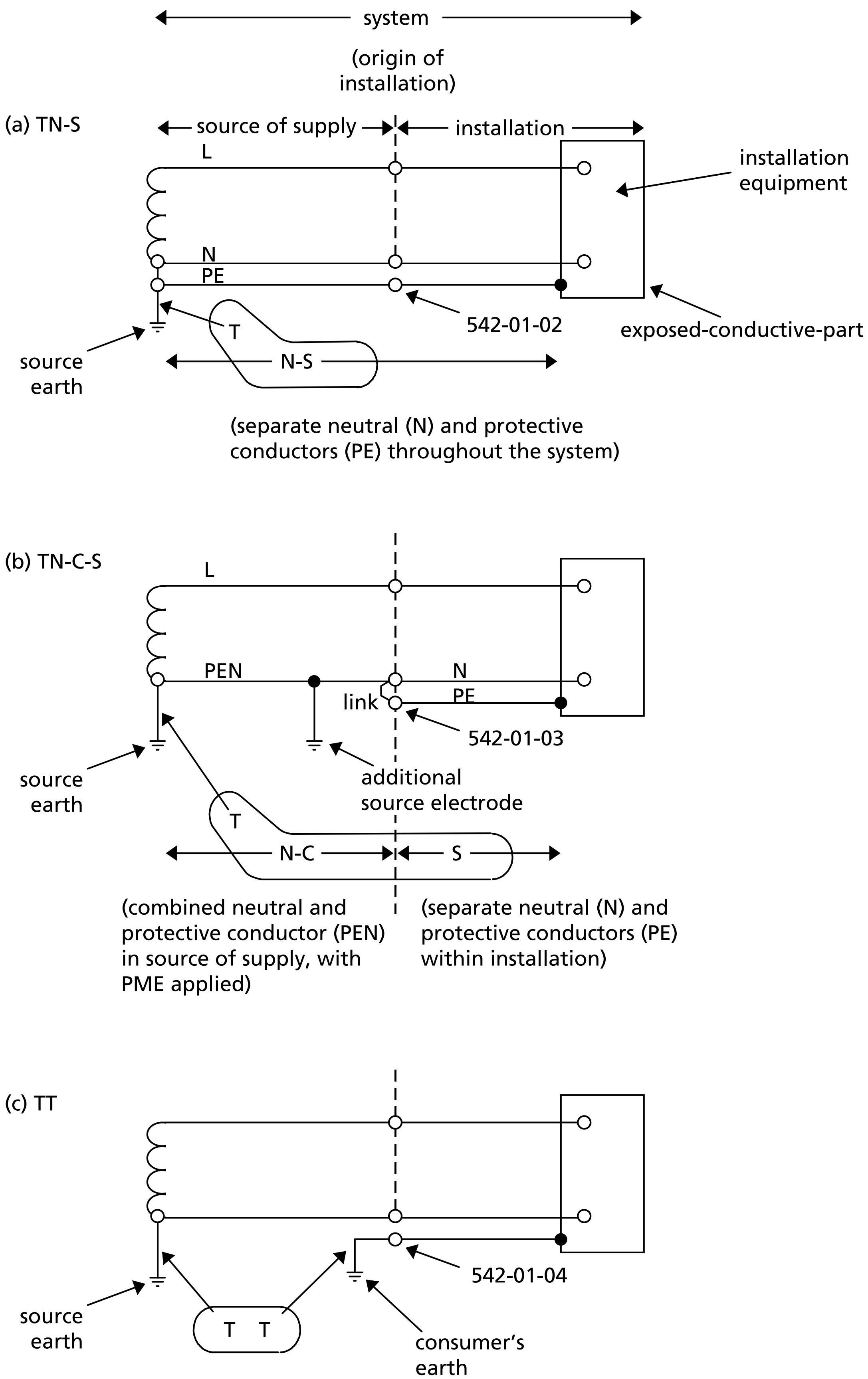
A distributor is required on request to provide a statement on the type of earthing (Reg 28 of the Electricity Safety, Quality and Continuity Regulations) and unless inappropriate for reasons of safety, the distributor is required to make available his supply neutral conductor or protective conductor for connection to the consumer's earth terminal (Reg 24). For a low voltage supply given in accordance with the Electricity Safety, Quality and Continuity Regulations 2002 the supply system will be TN-S, TN-C-S(PME) or TT, and most commonly for new supplies TN-C-S. TN-C and IT systems are both very uncommon in the UK, the former because it requires an exemption from the Electricity Safety, Quality and Continuity Regulations which invoke special installation arrangements and the latter because the source is not directly earthed and this is not permitted for a low voltage public supply in the UK (Reg 8).

System descriptions are given in BS 7671. Part 2

For TN-S, TN-C-S and TT systems the following explanations should aid a full understanding of the earthing arrangements and their scope of application. The nomenclature of these system types is as follows:

T = Earth (from the French word *Terre*)
N = Neutral S = Separate C = Combined

Fig 5.1 **System earthing arrangements**



A TN-S system (Fig 5.1(a)) has the neutral of the source of energy connected with earth at one point only, at or as near as is reasonably practicable to the source, and the consumer's earthing terminal is typically connected to the metallic sheath or armour of the distributor's service cable into the premises or to a separate protective conductor of, for instance, an overhead supply. 542-01-02

A TN-C-S system (Fig 5.1(b)) has the supply neutral conductor of a distribution main connected with earth at source and at intervals along its run. This is usually referred to as protective multiple earthing (PME). With this arrangement the distributor's neutral conductor is also used to return earth fault currents arising in the consumer's installation safely to the source. To achieve this, the distributor will provide a consumer's earthing terminal which is linked to the incoming neutral conductor. 542-01-03

PME sources offer a number of advantages over TN-S, among which are:

— the connection with earth is more reliable not being dependent upon armouring continuity etc.

— the PEN conductor, being of copper or aluminium, provides a lower impedance return path for earth fault currents than (say) steel armour or a lead sheath

— use of the neutral as a combined neutral and protective conductor represents a material saving.

Main equipotential bonding is an important requirement for installations supplied from TN-C-S (PME) systems, in view of the risk of danger in the event of an open circuit neutral fault on the distributor's low voltage network. Regulation 25(2) prevents a distributor from providing a PME supply to premises with inadequate bonding because the installation would not comply with BS 7671. 413-02-02

A TT system (Fig 5.1(c)) has the neutral of the source of energy connected as for TN-S, but no facility is provided by the distributor for the consumer's earthing.

With TT, the consumer must provide his or her own connection to earth, i.e. by installing a suitable earth electrode local to the installation. The circumstances in which a distributor will not provide a means of earthing for the consumer are usually where the distributor cannot guarantee the earth connection back to the source, e.g. a low voltage overhead supply, where there is the likelihood of the earth wire either becoming somehow disconnected or even stolen. A distributor also might not provide means of earthing for certain outdoor installations, e.g. a construction site temporary installation, leaving it to the consumer to make suitable and safe arrangements for which they are fully responsible. The electricity distributor is required to make available his supply neutral or protective conductor for connection to the consumer's earth terminal, unless inappropriate for reasons of safety (Reg 24). Construction site, farm or swimming pool installations might be inappropriate unless additional precautions are taken, such as an additional earth electrode (see paragraph 9.3). 542-01-04

Large consumers may have one or more HV/LV transformers dedicated to their installation and installed adjacent to or within their premises. In such situations the usual form of system earthing is TN-S. It is not necessary for the star (neutral) point of the transformer LV secondary to be brought out at the transformer cable box in order to earth this point. The usual and most convenient means of earthing the source neutral is for the connection to earth to be made at the first accessible position in the LV system at which the neutral is terminated, i.e. LV feeder pillar or main LV switchboard.

Regulation 8(4)(5) of the Electricity Safety, Quality and Continuity Regulations (ESQCR) prohibits TNC systems in a consumers installation. However if the person operating an extensive low voltage network on a site can be described as a distributor as defined by the ESQCR and not a consumer then he may operate a TNC cable system to supply individual premises (installations). Each individual premise must be TN-C-S. If a TNC (PME) distribution system is used, the requirements for protective multiple earthing laid down in Part II of the Electricity Safety, Quality and Continuity Regulations for distributors must be closely followed, treating each building as if it housed a separate consumer.

In any premises where there are a number of buildings each having its own low voltage installation, care must be taken over the earthing of any circuit having its origin in one installation and which also runs into one or more other buildings. Unless suitable precautions are taken, the protective conductor (e.g. metallic cable sheath) of the circuit may be subjected to earth fault conditions exceeding its capability. Such a circuit may, for example, be concerned with a fire or security system. 542-01-09

5.2 Earth electrodes

A wide variety of types of earth electrode are recognised by BS 7671. The most suitable type for a particular system will depend upon a number of factors, the single most important of these being the soil resistivity of the ground. If earth rods are to be driven it may be necessary to go down several metres before a good conductive layer is reached, especially where the water table is low. Rods can only be as effective as the contact they make with the surrounding material. Thus, they should be driven into virgin ground, not disturbed (backfilled) ground. Where it is necessary to drive two or more rods and connect them together to achieve a satisfactory result, the separation between rods should be at least equal to their combined driven depth to obtain maximum advantage from each rod. 542-02 542-02-01

In some locations low soil resistivity is found to be concentrated in the topsoil layer, beneath which there may be rock or other impervious strata which prevents the deep driving of rods, or a deep layer of high resistivity. Only a test or known information about the ground can reveal this kind of information. In such circumstances, the installation of copper earth tapes, or pipes or plates, would be most likely to provide a satisfactory earth electrode.

Closely spaced buildings may sometimes make it difficult to find ground suitable for driving an earth electrode. Electrodes which employ suitable structural or other underground metalwork, or the metal reinforcement of concrete embedded in the ground may then be of particular advantage.

Whatever form an earth electrode takes, the possibility of soil drying and freezing, and of corrosion, must be taken into account. Preferably, testing of an earth electrode should be carried out under the least favourable conditions, i.e. after prolonged dry weather. 542-02-02 542-02-03 GN3 : Inspection & Testing

Further information on earthing principles and practice can be found in BS 7430 : 1998 'Code of Practice for Earthing' (formerly CP 1013: 1965).

5.3 Earthing conductors

The earthing conductor of an installation is part of the earth current path. It is therefore important that the conductor is adequately sized and, particularly where buried partly in the ground, of suitable material and adequately protected against corrosion and mechanical damage. 542-03

The size of an earthing conductor is arrived at in basically the same way as for a circuit protective conductor (paragraph 6.2), except that Table 54A of BS 7671 must be applied to any buried earthing conductor. For a TN-C-S (PME) supply, the designer will additionally require it to be no smaller than the main bonding conductors. 542-03 547-02 Table 54H

5.4 Main earthing terminals or bars

Every installation must have a main earthing terminal or bar for connection of the following to the earthing conductor: 542-04 542-04-01

(i) the circuit protective conductors

(ii) the main bonding conductors

(iii) functional earthing conductors (if required)

(iv) lightning protection system bonding conductor (if any).

Note especially item (iv) in the above list. This requirement of BS 7671 is a reversal of the established practice in the UK of attempting to keep the lightning protection system (LPS) and the electrical installation entirely segregated from each other. The down conductors of any LPS must still be connected 413-02-02 to their own earth electrodes, which must be tested before the cross-bond is made (see BS 6651 : 1999, Code of practice for protection of structures against lightning, for further information on where and how this should be done).

For a larger installation having an LV switchboard, the main earth bar will often be located within the switchboard. An alternative arrangement, sometimes used, is for the earth bar to be fixed external to the switchboard, i.e. mounted on insulating supports on the switchroom wall. This makes for ready inspection of both its condition and the connections of the protective conductors. Disconnection of protective conductors for testing, where necessary, is also made easier by this arrangement. 542-04-02 543-03-03

A main earth bar needs to be adequately sized for mechanical and electrical purposes. If the bar is drilled to receive bolts for the connection of protective conductors, its minimum cross-sectional area (csa), i.e. taking into account the diameter of the largest hole drilled in it, should be not less than the csa of the earthing conductor (assuming they are of the same material).

A permanent label with the words 514-13-01

Safety Electrical Connection DO NOT REMOVE

should be permanently fixed at or near the point of connection of every earthing conductor to an earth electrode, at or near the point of connection of every bonding conductor to an extraneous-conductive-part, and at the main earth terminal where separate from the main switchgear.

5.5 Functional earthing 545

Confusion sometimes arises over the difference between protective earthing (PE) and *functional earthing* (FE). Protective earthing, as the name suggests, is provided for the protection of people, livestock and property, and for the most part is what this Guidance Note is concerned with. A functional earth is, however, only provided to enable equipment to operate correctly. At no time does the FE offer protection to either the user or the equipment. Part 2

Examples of FEs are:

(i) to provide 0 (zero) volt reference point

(ii) to enable an electromagnetic screen to be effective

(iii) to provide a signalling path for some types of communications equipment.

The most common use of FEs is for telecommunications purposes. It is permissible for the FE to be terminated onto the electrical installation main earthing terminal or bar. The wiring used will normally be of copper and at least 1.5 mm^2 in size. It should be coloured cream, as recommended in BS 6701 : 1994 and Table 51A of BS 7671, and at the main earthing terminal it should have a label (or embossed sheath) marked 'Telecomms' Functional Earth. Electrical installers who come across such FEs which are particularly common in commercial buildings, should not interfere with these connections. Table 51A

Functional earthing may also be required for other equipment and should be coloured cream. The connection to earth should again be made to the main earthing terminal or bar and be clearly labelled as to its purpose.

5.6 Combined protective and functional arrangements 546

Where earthing arrangements are installed for combined protective and functional purposes, the requirements for protective measures must always take precedence. A particular application of this is the use of a combined protective and neutral conductor (PEN) in a TN-C installation. The detailed requirements of BS 7671 for such an installation are tightly drawn; also, an exemption to the Electricity Safety, Quality and Continuity Regulations 2002 must be obtained by consumers for adoption of this arrangement and hence TN-C installations are fairly rare. 542-01-06 546-01-01 546-02

Section 6 — Circuit protective conductors

6.1 General

A circuit protective conductor forms part of the earth fault loop in the event of an earth fault in the circuit with which it is associated. The function of a circuit protective conductor is therefore to carry earth fault current without damage either to itself or to its surroundings, e.g. insulation. At the same time, it must be an efficient conductor to assist in automatic disconnection of the supply to the faulty circuit within the prescribed maximum time, i.e. 0.4 s or 5 s or other limit, if applicable. 543-02

The circuit protective conductor types available within BS 7671 include wiring enclosures such as rigid metal conduit, metal trunking, ducting or riser system, also the metal covering of cables, i.e. the sheath, screen or armouring.

There are only three instances in BS 7671 where a separate circuit protective conductor is prescribed:

(i) through flexible or pliable metal conduit 543-02-01

(ii) subject to specified criteria, in a final circuit intended to supply equipment producing protective conductor current in excess of 10 mA in normal service 607-02

(iii) to connect the earthing terminal of an accessory to metal conduit, trunking or ducting. 543-02-07

Apart from these instances, there are circumstances for which it is recommended that consideration be given to the provision of a *separate* circuit protective conductor if metal conduit, trunking or ducting is used. These include:

(i) industrial kitchens, laundries, other 'wet areas'

(ii) locations where chemical attack or corrosion of the metal wiring enclosure or cable sheath may be expected

(iii) circuits exceeding 160 A rating and any location where the integrity of the metal-to-metal joints in the conduit/trunking installation cannot be ensured over the life of the installation.

Note
Where full information concerning correct and reliable earthing is provided by the manufacturer, such systems may be used up to their maximum rating.

It is stressed that where a separate circuit protective conductor is installed, any metal cable management system must still be properly constructed, provide good continuity throughout its run and be earthed. The metalwork is still an exposed-conductive-part containing live conductors and might otherwise give rise to danger in the event of an insulation fault. 413-02-06

6.2 Sizing of circuit protective conductors

There are several factors which may influence or determine the size required for a circuit protective conductor.

A *minimum* cross-sectional area of 2.5 mm^2 copper is required for any separate circuit protective conductor, i.e. one which is not part of a cable or formed by a wiring enclosure or contained in such an enclosure. An example would be a bare or insulated copper conductor clipped to a surface, run on a cable tray or fixed to the outside of a wiring enclosure. Such a circuit protective conductor must also be suitably protected if it is liable to suffer mechanical damage or chemical deterioration or be damaged by electro-dynamic effects produced by passing earth fault current through it. If mechanical protection is not provided the minimum size is 4 mm^2 copper or equivalent. 543-01-01 543-02-03 543-03-01

BS 7671 provides two methods for sizing protective conductors including earthing conductors (see also Table 54A). The easier method is to determine the protective conductor size from Table 54G, but this may produce a larger size than is strictly necessary, since it employs a simple relationship to the cross-sectional area of the phase conductor(s). Oversizing is particularly liable to happen where the size of the live conductors of the circuit has been increased in order to satisfy grouping or voltage drop. It should also be noted that, except for 1 mm^2, "twin with cpc" cables do not comply with Table 54G, as the protective conductor is smaller than the live conductors (see Appendix A). For circuits that employ 543-01-01 543-01-04 these cables, the adequacy of the protective conductor must be checked by using the second method of sizing.

The second method involves a formula calculation. The formula is commonly referred to as the 'adiabatic equation' and is the same as that used for short-circuit current calculations (see Regulation 434-03-03). It assumes that no heat is dissipated from the protective conductor during an earth fault and therefore errs on the safe side. Even so, application of the formula will in many instances result in a protective conductor having a smaller csa than that of the live conductors of the associated circuit. This is quite acceptable. 543-01-03

Regulation 543-01-03 states :

543-01-03 The cross-sectional area, where calculated, shall be not less than the value determined by the following formula or shall be obtained by reference to BS 7454:

$$S = \frac{\sqrt{I^2 t}}{k}$$

where:

S is the nominal cross-sectional area of the conductor in mm^2.

I is the value in amperes (rms. for a.c.) of fault current for a fault of negligible impedance, which can flow through the associated protective device, due account being taken of the current limiting effect of the circuit impedances and the limiting capability ($I^2 t$) of that protective device.

Account shall be taken of the effect, on the resistance of circuit conductors, of their temperature rise as a result of overcurrent - see Regulation 413-02-05.

t is the operating time of the disconnecting device in seconds corresponding to the fault current I amperes.

k is a factor taking account of the resistivity, temperature coefficient and heat capacity of the conductor material, and the appropriate initial and final temperatures.

Values of k for protective conductors in various use or service are as given in Tables 54B, 54C, 54D, 54E and 54F. The values are based on the initial and final temperatures indicated below each table.

Where the application of the formula produces a non-standard size, a conductor having the nearest larger standard cross-sectional area shall be used.

The fault current I is given by U_O/Z_S

where:

U_O is the nominal voltage

Z_S the earth fault loop impedance at the furthest accessory.

The calculation of Z_S is described in Appendix B, for an assumed (design) protective conductor size.

Where I has been determined, t is obtained for standard devices from the time/current characteristics in Appendix 3 of BS 7671 or from manufacturers' data.

The adiabatic equation can then be used to confirm that the design protective conductor size exceeds that given by the adiabatic equation above.

Appendix A provides maximum values of earth fault loop impedance for all the common overcurrent devices. If the values of earth fault loop impedance given in the tables for the particular device and particular size of circuit protective conductor are not exceeded, the requirements of the adiabatic equation will be met, as will the indirect shock protection requirement.

Section 7 — Equipotential bonding

7.1 Main equipotential bonding 543

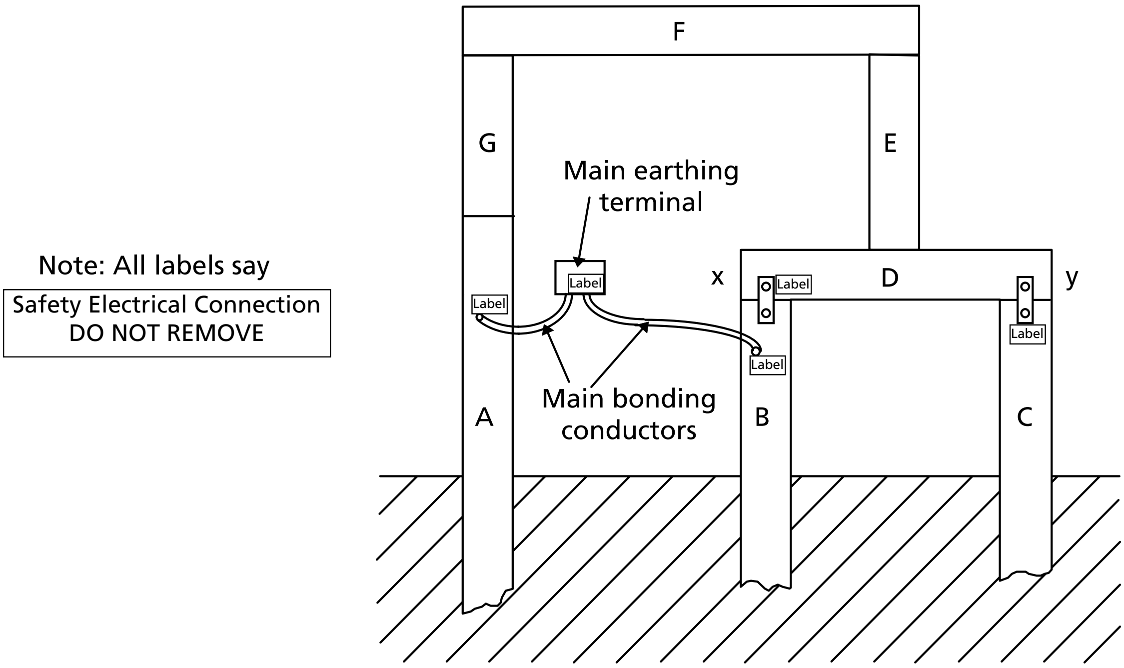
Main *equipotential bonding* creates an earthed equipotential zone within which all exposed-conductive-parts and extraneous-conductive-parts within the installation are connected to the main earthing terminal or bar of the installation by either circuit protective conductors or main equipotential bonding conductors. By definition, therefore, there must not be any substantial* extraneous-conductive-part within the zone which is not bonded, or the principle of the equipotential zone is breached and the presence of such a part could be a danger, especially if it is simultaneously accessible with any exposed-conductive-part of the installation. Part 2 413-02

* Excludes any part of small dimensions that cannot be readily or reliably bonded and which cannot be gripped or contacted by a major surface of the human body, e.g. does not exceed 50 mm x 50 mm.

Main equipotential bonding conductors should be kept as short as practicable and be routed to minimise the likelihood of damage or disturbance to them. The connections to gas, water and other services entering the premises must be made as near as practicable to the point of entry of each service, on the consumer's side of any insulating section or insert at that point or any meter. Any substantial extraneous-conductive-part which enters the premises at a point remote from the main earthing terminal or bar must also be bonded to this terminal or bar. 547-02-02

Extraneous-conductive-parts should preferably be bonded using individual main equipotential bonding conductors. Alternatively, two or more such parts may share a main equipotential bonding conductor, but where this arrangement is employed the conductor should be continuous, i.e. disconnection of the conductor from one extraneous-conductive-part must not interfere with or endanger the security of the bonding of the other part(s). Similar considerations would also apply to any additional main equipotential bonding that is installed to satisfy Regulation 413-02-13(ii).

Fig 7.1 **Main bonding of structural steelwork**



A, B and C are extraneous-conductive-parts. A and B are bonded directly to the main earth terminal. C is bonded by reliable connections X and Y.

E, F and G although not reliably connected to the main earthing terminal do not require main bonding. They may require supplementary bonding if accessible in areas of increased shock risk.

Where the installation is within a building which has exposed metallic structural parts, then these parts must also be bonded if they are extraneous-conductive-parts, i.e. the structural metalwork is in contact with the ground or other unbonded earthed metalwork. Where the structure concerned is assembled from components which are welded, bolted or even riveted together then one main bonding connection will often suffice, see Fig 7.1.

413-02-02
547-02-01
543-02-06

If doubt exists over the electrical continuity between the main bond and the parts of the structure in contact with earth, it is recommended that a continuity test should be carried out to determine the extent, if any, of cross-bonding between main structural components that may be required in order to achieve this continuity.

When carrying out such tests the possibility of unsuitable or fortuitous earth paths must be considered.

Bonding the earthed metallic structural parts of a building to the main earthing terminal, where practicable, can be a useful means of improving the overall effectiveness of the equipotential zone of the installation.

Sizing requirements for main equipotential bonding conductors are given in BS 7671. However, it is recommended that the electricity distributor or supplier should be asked to confirm their agreement to the proposed size(s) it is intended to install. 547-02-01 Table 54H

A permanent label is required to be fixed at or near the point of connection of every main equipotential bonding conductor to an extraneous-conductive-part. 514-13-01(ii)

7.2 Supplementary equipotential bonding

Supplementary equipotential bonding is applied, where necessary, in order to reinforce the equipotential zone. Applied in a particular location within an installation, e.g. a bathroom, it has the effect of re-establishing the equipotential reference *at that location* for all the exposed-conductive-parts and extraneous-conductive-parts which are bonded together locally. This further reduces any potential differences that may arise between any of these parts during an earth fault. 601-04-01 GN7 : Special locations

Supplementary equipotential bonding is required by BS 7671 to be provided in the following situations:

(i) where the conditions for automatic disconnection cannot be fulfilled (unless, alternatively, a suitable RCD is fitted and will achieve satisfactory disconnection of the supply in the event of an earth fault) 413-02-04

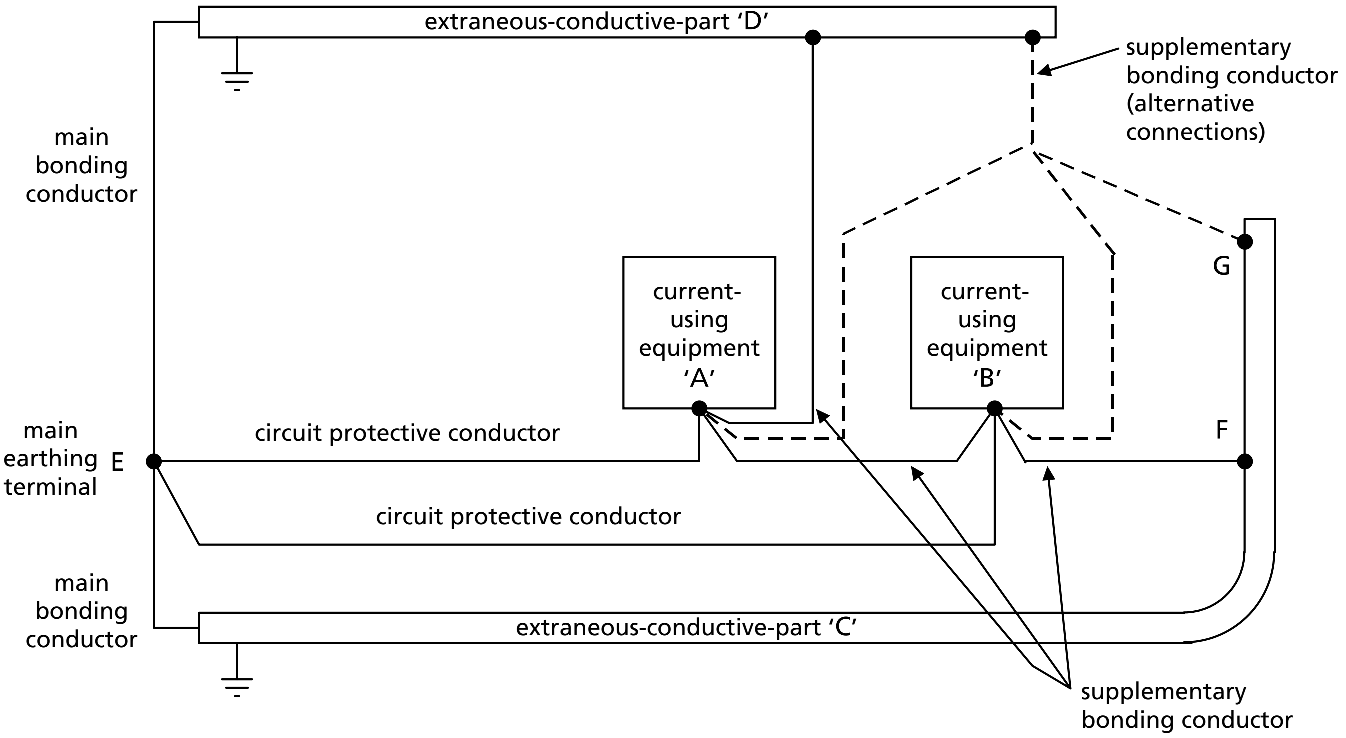
(ii) for some installations and locations of increased shock risk. 471-08-01(ii) Part 6 GN7

Where supplementary equipotential bonding is to be installed it must comply with Regulations 413-02-27 and 547-03, and also Regulation 413-02-28 or, as appropriate, any overriding particular requirements. 413-02-27 413-02-28 547-03

Consider Fig 7.2.1 which shows two items of current-using equipment 'A' and 'B' and the circuit protective conductors of the circuits feeding them, together with two separate extraneous-conductive-parts 'C' and 'D'. In accordance with BS 7671 the circuit protective conductor and the extraneous-conductive-parts are connected to the main earthing terminal (E) of the installation. 413-02-02 413-02-06

Supplementary equipotential bonding is effected by making the connections shown. It is not a requirement of BS 7671 to run a bonding conductor back to the main earthing terminal of the installation, although, as here, the locally bonded parts will be connected to this terminal by way of one or more protective conductors and/or extraneous-conductive- parts. 413-02-27

Fig 7.2.1 **Illustrating the application of supplementary equipotential bonding in a particular location**



The bonding conductor between equipment 'A' and 'B' must comply with Regulation 547-03-01, while that between equipment 'B' and extraneous-conductive- part 'C' must comply with Regulation 547-03-02. 547-03-01 547-03-02

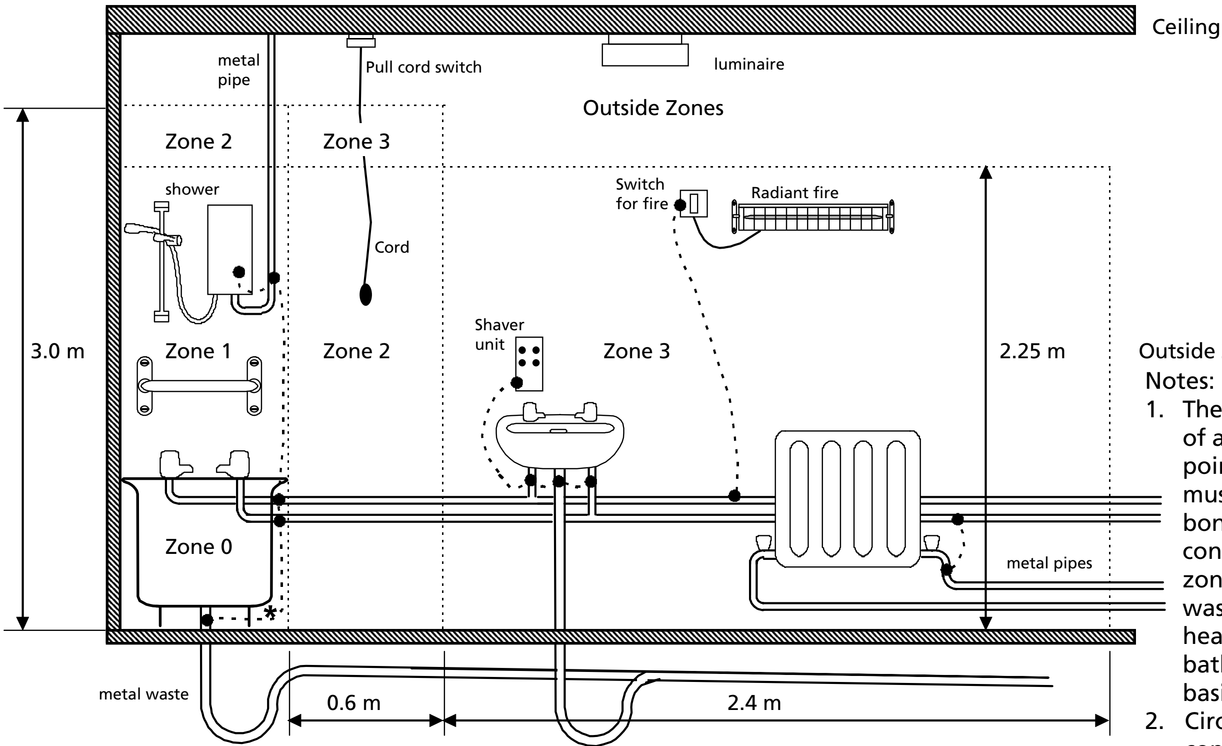
The extraneous-conductive-part 'D' as indicated by the broken lines is connected either to equipment 'A' or equipment 'B' or to extraneous-conductive-part 'C'. If it is connected to either item of current-using equipment the bonding conductor must comply with Regulation 547-03-02 or, if to extraneous-conductive-part 'C', with Regulation 547-03-03. 547-03-03

It should be noted that, as permitted by Regulation 547-03-04, the portion of extraneous-conductive-part 'C' between the points 'F' and 'G' can be considered to be part of the supplementary equipotential bonding. 547-03-04 543-02-02(vii) 543-02-06

Bathrooms

In zones 1, 2 and 3 of a location containing a bath or shower supplementary bonding is required between the terminals of circuit protective conductors of circuits supplying Class I and Class II equipment and extraneous-conductive-parts in the zones, see Figs 7.2.2 and 7.2.3. This then allows Class II equipment to be replaced by Class I during the life of the installation, without the need for further supplementary bonding. 601-04-01 601-04-02

Fig 7.2.2 **Supplementary bonding in a bathroom - metal pipe installation**

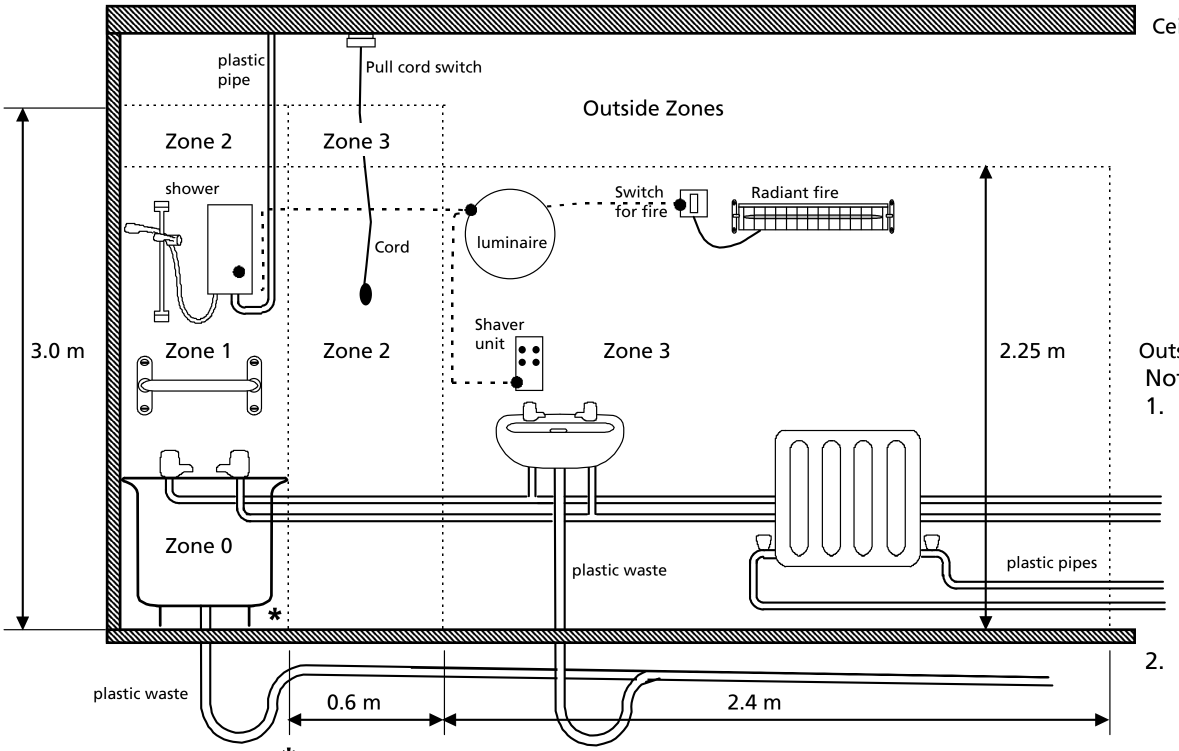


* Zone 1 if the space is accessible without the use of a tool.
Spaces under the bath, accessible only with the use of a tool, are outside the zones.

Notes:

1. The protective conductors of all power and lighting points within the zones must be supplementary bonded to all extraneous-conductive-parts in the zones, including metal waste, water and central heating pipes, and metal baths and metal shower basins.
2. Circuit protective conductors may be used as supplementary bonding conductors.

Fig 7.2.3 **Supplementary bonding in a bathroom - plastic pipe installation**



Notes:

1. The protective conductors of all power and lighting points within the zones must be supplementary bonded. The bonding connection may be to the earth terminal of a switch or accessory supplying equipment.
2. Circuit protective conductors may be used as supplementary bonding conductors.

* Zone 1 if the space is accessible without the use of a tool.
Spaces under the bath, accessible only with the use of a tool, are outside the zones.

Extraneous-conductive-parts

In carrying out an assessment of what requires to be bonded the designer (or possibly the installer) may encounter difficulty in determining whether a part is actually an extraneous-conductive-part as defined, i.e. is likely to introduce a potential, generally earth potential. In cases of doubt, a measurement of the resistance (R_X) between the conductive part concerned and the main earthing terminal of the installation should be made.

The part can be considered not to be an extraneous-conductive-part if the resistance R_X is such that

$$\frac{U_o}{R_b + R_X} < I_b$$

where:

U_o is the nominal voltage to earth

R_b is the resistance of the human body

I_b is the value of the current through the human body which should not be exceeded.

The values of both R_b and I_b should be chosen from the data in BS PD 6519 and are dependent on the conditions which are expected to arise in the installation concerned.

For example, where the shock risk is likely to be from hand-to-hand contact, it is suggested that a suitable value to take for I_b would be 10 mA and for R_b 1000 ohms, leading to a value of R_x of 22,000 ohms (when U_o = 230 V), below which the part concerned is taken to be an extraneous-conductive-part.

If an acceptably high resistance is measured under dry conditions in a situation where at times moisture is to be expected, then either the test should be repeated under 'worst conditions', or bonding should be applied.

It is necessary to look a little further when deciding about the bonding of metalwork accessible to people or livestock outside the building and in contact with the ground. For example, an unbonded metal window frame inserted in a brick building is not likely to present a hazard, but when it is bonded it may well achieve a considerable rise in potential during the permitted 5 s clearance of a fault within the installation. This could be dangerous to a window cleaner outside the building, with wet hands and standing on damp ground or on a metal ladder. On the other hand, a metal window frame in a metal-clad building could introduce earth potential into the location.

There is no single answer to the bonding of extraneous-conductive-parts, each situation has to be considered on its own merits, and a decision made which, on balance, will provide the greater degree of safety.

The possibility of using the extraneous-conductive-part itself as the bonding conductor permits a considerable economy in installation. There is, for example, seldom any need for clamps and cable at each and every pipe entering or leaving a domestic hot water cylinder.

Tests will establish whether additional conductors are necessary or not.

A permanent label is required to be fixed at or near the point of connection of every bonding conductor to an extraneous-conductive-part. Where there are a number of such connections in proximity it may be overdoing it to label each one separately, in which case one or perhaps two suitably placed labels could suffice. 514-13-01(ii)

Section 8 — Special Installations or Locations

8.1 The increased risks 600

The particular requirements set out in the various Sections of Part 6 supplement or modify the general requirements of other parts of BS 7671. Supplement here means that *additional requirements* have to be met. Modify means that *restrictions* are placed on the choice of protective measures for safety that may be used and/or *tighter criteria* have to be met. Table 8.1 summarises, for each location, the factors for the supplementary or modified requirements for protection against electric shock. The notes following explain the column headings (1)-(4) of the Table.

Part 6

600-01

TABLE 8.1
Part 6: The Increased Risks

		Wetness (1)	Absence of, or minimal clothing (2)	Presence of earthed metal (3)	Arduous conditions (4)
601	Bathrooms and Showers	X	X	X	
602	Swimming Pools	X	X	X	
603	Hot Air Saunas	X	X	X	X
604	Construction Sites	X	X	X	X
605	Agricultural and Horticultural Premises	X	X	X	X
606	Restrictive Conductive Locations (5)	X		X	X
608	Caravans and Motor Caravans	X	X		X
608	Caravan Parks	X	X		X
610	Reserved for medical locations	X	X	X	
611	Highway Power Supplies and Street Furniture	X		X	X

GN7 - Ch 10

Notes:

(1) *Wetness*

Wetness means presence of water or humidity, or conditions or work activity causing perspiration. Any of these leads to reduced body resistance by lowering the skin contact resistance. In varying degrees wetness applies to all of the installations and locations listed in Table 8.1.

(2) *Absence of, or minimal, Clothing*

Apart from bathrooms, swimming pools, saunas and caravans and their sites, where the absence of clothing or minimal clothing is to be reasonably expected, the situation may occur elsewhere. Summer working conditions on construction sites and in agricultural and horticultural premises, especially greenhouses, may cause persons working there to remove clothing.

(3) *Presence of Earthed Metal*

In all the locations except caravans and their sites there is the presence of considerable amounts of earthed metal.

(4) *Arduous Conditions*

Arduous conditions are environmental conditions, working conditions or activity that give rise to increased risk of electric shock arising from the effect such conditions may have on the installation or equipment supplied by it.

(5) *Restrictive Conductive Locations* Part 2

Examples of restrictive conductive locations are any metal tank, boiler shell or other metallic vessel into which a person may need to enter, and could also include a large metal pipe that would admit such entry. Such a location does not, however, have to be the inside of a metallic vessel. A plant room could constitute such a location if it is likely that a person working in it will come into bodily contact with substantial areas of conductive material and that such contact is unavoidable.

Here, removal of clothing may be less likely; indeed, special protective clothing may be worn, but perspiration as noted in item (1) above is relevant. If equipment is faulty, the likelihood and severity of electric shock is increased by the conductive environment and the difficulty of escape.

8.2 Supplementary and modified requirements

The Regulations concerned are summarised in Table 8.2. However, it is emphasised that a full study of each Sections of Part 6 is required before any attempt is made to apply the particular requirements.

The structure of each Section is similar in presentation to the arrangement of the general requirements of BS 7671. It will be noted that each Section begins with a definition of its scope of application. It is important to appreciate the scope of any section before attempting to apply its particular requirements.

Table 8.2, a note

The prohibition on metallic wiring systems in swimming pools requires explanation in view of exposed-conductive-parts of equipment and extraneous-conductive-parts being permitted in the relevant locations. In many parts of Europe, metallic wiring systems are not permitted as circuit protective conductors due to doubt being cast on their continuity. 602-06-01

8.3 Equipment having high protective conductor currents

Earthing requirements for the installation of equipment having high protective conductor currents in normal service are also included in Part 6, and were briefly referred to earlier in Section 6 of this Guidance Note that deals with circuit protective conductors. However, no reference is made in Tables 8.1 and 8.2 herein. This is because such equipment itself does not constitute an installation or a location. Equipment that falls within the scope of Section 607 may be installed virtually anywhere inside a building, with some obvious exceptions, and the locations where this is most likely will not be subject to any of the factors to which Table 8.1 relates. Sect 607

8.4 Equipotential bonded floor grids

Amendment No 1 to BS 7671 : 1992 deleted the specific requirement to install equipotential grids in solid floors of zones B and C of swimming pools. There is a requirement for any metal grid installed in a solid floor of these zones to be connected to the local supplementary bonding, as such a grid could make the floor an extraneous-conductive-part. 602-03-02

If the requirements for a PME installation of paragraph 9.4.3 cannot be met, a grid will need to be installed and supplementary bonded.

Any metallic grid installed in the floor of a location for livestock must be connected to the local supplementary bonding. Where use is made of the PME terminal, particularly in dairies, the installation of metallic grids or meshes is recommended (see paragraph 9.4.5). 605-08-03

In communal shower and bathing areas and the like, any metallic floor grids should be connected to the local supplementary bonding. 601-09-04

The purpose of an equipotential grid is to extend the equipotential bonding connecting all extraneous- and exposed-conductive-parts to the floor. In the event of a fault, the floor and accessible metalwork will be maintained at essentially the same potential.

CENELEC discussed a detailed proposal for such equipotential grids, but such detail was not considered appropriate for inclusion in harmonization documents. However, it may be considered as guidance for swimming pools as follows:

In zone B of permanent basin installations, a potential equalization grid should be provided below and close to the horizontal surface surrounding the basin and commencing at not more than 0.6 m from the rim of the basin. The grid should be provided by one of the following two methods:

(i) conductors laid parallel to the rim of the basin approximately 0.6 m between each other and connected to each other at not fewer than two places, or

(ii) concrete reinforcing steel mesh welded together at joints.

The cross-sectional dimensions of conductors for method (i) should be not less than:

— 100 mm^2 hot galvanised steel strip of 3 mm minimum thickness;

— 10 mm diameter hot galvanised steel round bar;

— 50 mm^2 copper strip of 2 mm minimum thickness;

— 35 mm^2 copper round rod.

For method (ii) standard constructional steel mesh may be used.

Standard factory-made welded steel mesh for the reinforcement of concrete to BS 4483 : 1998 Table 1 would appear to meet the requirement of (ii) above.

Sufficiently good contact between adjoining mesh sheets can usually be achieved by binding them together with metal wire for 50 mm at 1 m intervals.

Two reliable connections to the grid, protected against corrosion and preferably at opposite ends, should be accessible to facilitate testing and inspection.

Further guidance on special locations is given in Guidance Note 7, Special Locations.

TABLE 8.2 **Special Locations — Summary of Regulations**

		Protection for Safety			Application of Protective Measures		Selection and Erection of Equipment					
Special installation or location 1	Assessment requirements 2	Against both direct and indirect contact 3	Against direct contact 4	Against indirect contact 5	Against direct contact 6	Against indirect contact 7	Wiring systems 8	Switchgear and controlgear 9	Plugs and socket-outlets 10	Luminaires 11	Other equipment 12	Environment 13
601 Bathrooms or Showers	Zones to be determined 601-02. Requirements for medical locations.	SELV: Additional requirements 601-05-01	Certain measures prohibited	RCDs 601-08-02 601-09. Supplementary bonding 601-04	Certain measures prohibited 601-05-02	Certain measures prohibited 601-05-03	Limited to equipment in zones 601-07	Location and selection 601-08	General prohibition except for SELV 601-08 and shaver outlets 601-06	IP requirement 601-06	Fixed equipment 601-09	Humid. Near bath or shower IPX4 required 601-06-01
602 Swimming Pools	Zones to be determined 602-01-01 602-02	SELV: Additional requirements 602-03-01	Certain measures prohibited	Supplementary bonding Metal grids to be bonded 602-03-02	Certain measures prohibited 602-04-02	Certain measures prohibited 602-04-02	Surface metallic systems prohibited 602-06-01	Location and selection 602-07	Selection 602-07 602-08	Underwater 602-04-01 General 602-08 Out of zones Chapter 55	General Specification 602-08	Humid. Enclosures 602-05-01
603 Saunas	Zones to be determined 603-02-01	SELV: Additional requirements 603-03-01	Certain measures prohibited	—	Certain measures prohibited 603-04-01	Certain measures prohibited 603-05-01	Flexible cords 603-07-01	Location and selection 603-06-01 603-06-02 603-08-01	None permitted 603-08-02	Luminaires 603-09-01	Specific items only 603-08	Humid IP24 603-06-01
604 Construction Sites	Reduced low voltage. Voltage limits applicable to equipment 604-02-02 (BS 7375 also applies)		Certain measures prohibited	Reduced disconnection times 604-04-01 Additional requirements 604-03 Supplementary bonding 604-07-01	—	Limitations and additional requirements 604-08 Reduced low voltage 604-02-02 604-02-06	Location and erection 604-10	Location and specification 604-11	Additional requirements 604-12 Cable couplers 604-13	Luminaires to be suitable for voltage and environment 604-02-02	Assemblies 604-09-01 Protection 604-09-02	All risks possible. Wet and dusty. Impact possible. Protection 604-09-02
605 Agricultural and Horticultural	Applies to agricultural & horticultural premises - not to all places where animals are kept (Zoos, etc)	SELV: Additional requirements 605-02-02	RCDs on all socket-outlets not from a SELV supply 605-03	Reduced disconnection times 605-04-01 Supplementary bonding 605-08	—	More stringent requirements than Part 4 605-09	—	Location 605-13	RCDs for all socket-outlets 605-03-01, except for SELV sockets	Luminaires to be suitable for environment 605-11-01	IP requirement 605-11-01 Electric fence controllers 605-14	All risks possible. Wet, dust and impact. Possible vermin damage 605-11-01

		Protection for Safety			Application of Protective Measures		Selection and Erection of Equipment					
Special installation or location 1	Assessment requirements 2	Against both direct and indirect contact 3	Against direct contact 4	Against indirect contact 5	Against direct contact 6	Against indirect contact 7	Wiring systems 8	Switchgear and controlgear 9	Plugs and socket-outlets 10	Luminaires 11	Other equipment 12	Environment 13
606 Restrictive Conductive Locations	Physical Movement Constrained	SELV Additional requirements 606-02-01	—	—	Certain measures prohibited 606-03-01	Specific measures required 606-04-01	—	—	For handlamps and tools (SELV only) 606-04-02 606-04-04	Supplies to handlamps 606-04-02	Location of sources 606-04-06 Fixed equipment supplies 606-04-05 Equipment requiring functional earth 606-04-03	—
608 Div 1 Caravans	—	—	—	Overcurrent protection to disconnect all live conductors (phase and neutral) 608-04-01	Certain measures prohibited 608-02-01	Certain measures prohibited 608-03-01 Double-pole RCD 608-03-02 Bonding 608-03-04	Additional requirements 608-06	Caravan inlet 608-07 Notices 608-07-03 608-07-05	Accessories generally 608-08 Mains power connection 608-07 608-08-08	Installation and fixing 608-08-06 Dual voltage 608-08-07	Connection devices and flexes 608-08-08 Independent systems to be segregated 608-05-01	Normal domestic
608 Div 2 Caravan Parks	—	—	—	—	Certain measures prohibited 608-10-01	Certain measures prohibited 608-11-01 PME not allowed 608-13-05	Underground supplies 608-12-01 608-12-02 Overhead supplies 608-12-03	Location 608-13-01	Selection and protection 608-13-02 to 608-13-06	—	—	General UK weather conditions IPX4 608-13-02
609 Marinas See also GN7 - Ch 9	Specific requirements for "offshore" areas. Salt atmosphere corrosive	SELV	RCDs on all socket-outlets except in standard buildings	Disconnection times as 413-02 Class II	Certain measures prohibited	Certain measures prohibited PME not allowed for "offshore" area	Adequate protection and support necessary in all areas	Location and protection from elements	RCDs specific supplies to boats	Location and protection from elements	—	General UK weather conditions

		Protection for Safety			Application of Protective Measures		Selection and Erection of Equipment					
Special installation or location 1	Assessment requirements 2	Against both direct and indirect contact 3	Against direct contact 4	Against indirect contact 5	Against direct contact 6	Against indirect contact 7	Wiring systems 8	Switchgear and controlgear 9	Plugs and socket-outlets 10	Luminaires 11	Other equipment 12	Environment 13
610 Reserved for Medical Locations See GN7 - Ch 10	Increased risk of electric shock in surgical procedures. Requirements for cleaning in design	SELV PELV Additional requirements	Insulation Barriers or enclosures	Reduced disconnection times. Electrical separation Class II	Protection by obstacles and placing out of reach not permitted	Certain measures prohibited RCDs in IT systems not permitted	Install to allow cleaning by chemical detergents.	Location and selection	RCDs only in TN-S and TT systems and on special supplies	Certain areas require IP rating for cleaning	Specialist medical electrical equipment	Usually clean and dry Indoor only
611 Highway Power Supplies, Street Furniture and Street Located Equipment	For distribution circuits, street furniture and street located equipment 611-01-01	—	—	—	Certain measures prohibited or restricted 611-02-01 611-02-02	Certain measures prohibited 611-02-03 Disconnection time 5 s 611-02-04 Bonding limit 611-02-05	Protection and marking of cables 611-04 Temporary supplies 611-06	Special restrictions 611-03-01 611-03-02 Temporary supplies 611-06	Temporary supply can be by socket-outlet and plug 611-06 see also 604	Access to light source secured 611-02-02	—	General UK weather conditions 611-05-02

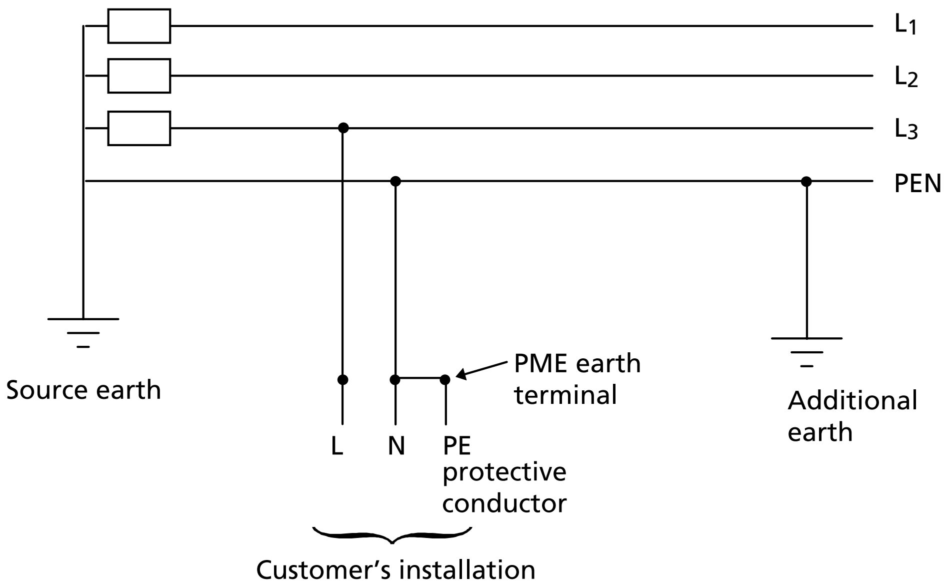
Section 9 — Protective Multiple Earthing

9.1 Introduction

The Electricity Safety, Quality and Continuity Regulations 2002 permit the distributor to combine neutral and protective functions in a single conductor provided that, in addition to the neutral to earth connection at the supply transformer, there are one or more other connections with earth. The notes of guidance to the Electricity Safety, Quality and Continuity Regulations refer to Electricity Association Limited publication G12/3 1995 for details of suitable earthing arrangements.

The supply neutral may then be used to connect circuit protective conductors of the customer's installation with earth if the customer's installation meets the requirements of BS 7671. This protective multiple earthing (PME) has been almost universally adopted by supply companies in the UK as an effective and reliable method of providing their customers with an earth connection. Such a supply system is described in BS 7671 as TN-C-S.

Fig 9.1 **PME earth terminal**



A protective multiple earthing terminal provides an effective and reliable facility for the majority of installations. However, under certain supply system fault conditions (external to the installation) a potential can develop between the conductive parts connected to the PME earth terminal and the general mass of earth.

9.2 Supply system

There are multiple earthing points on the supply network, and providing bonding within the building complies with BS 7671 it is unlikely that such a potential as described above would in itself constitute a hazard. However, there are areas of special risk within or outside buildings, and there are special situations and installations where it is appropriate to take additional measures for part or all of the installation, such as an additional connection with earth at the consumer's earth terminal see 9.3. Alternatively, it may be appropriate not to use the PME earthing terminal and provide earth fault protection with a separate earth electrode and RCD.

Special risk within buildings

The potential difference between true earth and the PME earth terminal is of importance when:

(i) body contact resistance is low (little clothing, damp/wet conditions)

(ii) there is relatively good contact with true earth.

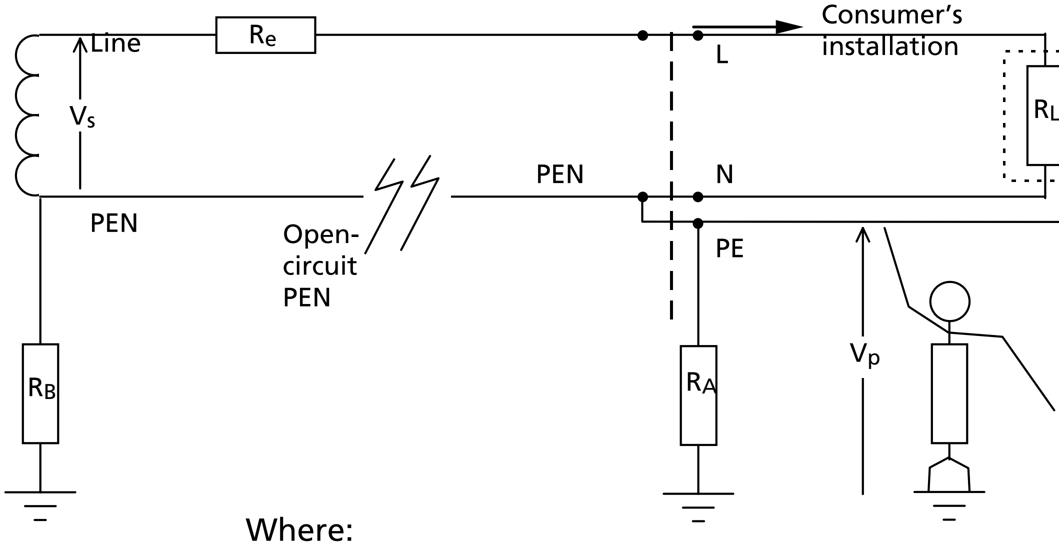
Special risk outside buildings

Contact with true earth is always possible outside a building and if exposed- and/or extraneous-conductive-parts connected to the PME earth terminal are accessible outside the building, people may be subjected to a voltage difference, between these parts and earth.

9.3 Additional earth electrode for PME supplies

In the unlikely event of the PEN conductor of the supply becoming open circuit, touch voltages perhaps causing some discomfort may arise on exposed metal in customers installations downstream of the open circuit. The effect can be mitigated by connection of a suitable earth electrode to the main earth terminal of the customers installation. The value of the resistance-to-earth necessary to limit the touch voltages to a given value depends on the load and the network parameters, see Fig 9.3

Fig 9.3 **Schematic of a PME system with an open circuit PEN conductor**



Where:

V_s is the nominal supply (source) voltage

V_p is the touch voltage

R_e is the external supply resistance

R_L is the load resistance (V_s^2 / wattage)

R_A is the resistance of the additional earth electrode including parallel earth (e.g. water and gas pipes)

R_B is the resistance to earth of the neutral point of the power supply.

Neglecting R_e as it is small compared with R_L and R_A and neglecting R_B as this errs on the safe side, maximum resistance to earth R_A of the electrode to keep the touch voltage below a given value V_p is

$$R_A = R_L \times \frac{V_p}{(V_s - V_p)}$$

Tabulated below are maximum values of R_A for the additional earth electrode, necessary to reduce the touch voltage to 50 V and 100 V for a range of single-phase loads and a nominal supply voltage of 230 V.

TABLE 9.3
Additional electrode maximum resistance to earth, R_A, necessary to reduce the touch voltage to 50 and 100 V

Load KW	R_L ohms	R_A ohms	
		for V_p = 50 V	for V_p = 100 V
7	8.2	2.1	5.8
3	19.2	5.1	13.7
2	28.8	7.5	20.5
1	57.6	15.1	41.0

9.4 Special locations

The Electricity Association provides guidance on PME in its Engineering Recommendation G12/3, 'Requirements for the application of protective multiple earthing to low voltage networks'. The guidance given in this Section is based on Part 6 of G12/3.

9.4.1 Remote supplies

A physically isolated building may be supplied via both a long LV distribution main and a long individual service. If these circumstances are coupled with an unbalanced load a potential difference will be evident between the PME terminal and true earth. This rise in neutral potential is transferred to metalwork connected to the PME terminal, and may be noticeable in such locations as shower areas, where simultaneous contact with true earth (a wet concrete floor) and the PME terminal (shower pipes) may be possible.

G12/3 recommends that such floors should incorporate a metal grid connected to the supplementary bonding within the shower/bathing area. Certainly. if there is a grid in the floor it must be connected to the local supplementary bonding. An alternative approach would be not to use the PME earthing terminal and to afford protection by means of RCDs and an independent earth electrode, that is, treat as part of a TT system.

9.4.2 Sports pavilions

Where no shower area exists nor is likely to exist in a sports pavilion, PME may be offered provided the appropriate metalwork is bonded. Where a shower exists PME should only be applied where there is an earth grid in the floor of the shower area, supplementary bonded to accessible metal pipework, etc. An alternative would be to plumb the installation in plastic pipes.

9.4.3 Swimming pools

Swimming pools supplied with their own dedicated service should be protected with an RCD. All metalwork should be bonded and connected to an earth electrode. Where a swimming pool forms part of a residence, all metalwork and pipes supplying the pool should be connected to an earth electrode and segregated from the rest of the building. An RCD should then be used to protect the supplies to the pool area and the swimming pool installation treated as part of a TT system. Where segregation of pipes and metalwork around a pool is impracticable, e.g. in an indoor pool, the installation of a metal grid around the pool and the supplementary bonding of adjacent metalwork is recommended together with an RCD in addition to PME.

9.4.4 Agricultural and horticultural premises

A PME terminal may be used in these premises provided main equipotential bonding has been carried out and the additional measures required by Section 605 of BS 7671 have been provided, e.g. reduced disconnection times, supplementary bonding, RCD protection.

The general principles to be adopted for separate buildings utilizing a PME terminal are as follows:

(i) each separate building should have a designated main earthing terminal within the building

(ii) any main equipotential bonding required in a separate building to external services, structural metalwork, etc, should be connected to the designated earth terminal. The cross-sectional area of the bonding conductor should be selected from Table 54H of BS 7671 using the electricity distributor's supply neutral conductor as reference

Table 54H

(iii) the cross-sectional area of the protective conductor in the cable supplying the separate building should be not less than that determined in (ii) above.

However, where in remote buildings all extraneous-conductive-parts cannot be bonded to the earthing terminal, the pipes and metalwork of isolated buildings, **whether or not they have an electricity supply**, should be segregated from metalwork connected to the PME earthing terminal. Any supplies to such buildings should be controlled by an RCD and the associated earth electrode and earthing conductor should be segregated from any metalwork connected to the PME earthing terminal, and the segregated installation treated as part of a TT system.

Where segregation is not possible then the alternative of using suitable earth electrodes and RCDs for the whole of the installation should be considered. Alternatively, if a dedicated transformer is used to supply the premises then protective neutral bonding (PNB) may be used.

A suitable metallic mesh should be installed in the concrete floor of a dairy and bonded in accordance with the PME requirements. (See 9.4.5 below)

9.4.5 Livestock/ dairies

Particular care must be taken in areas where livestock are housed as they are sensitive to small potential differences. A suitable metallic mesh should be installed in the concrete floor of a milking parlour and bonded in accordance with the PME requirements.

If PME is to be applied to an existing milking parlour the steel reinforcement in the floor should be bonded. Alternatively, if small voltage differences are unacceptable the area concerned should be protected by an RCD and the associated earthing system segregated electrically from the remainder of the installation.

Note: If PME is to be used and the steel reinforcing mesh of the concrete cannot be bonded or does not exist, the customer must be advised that in milking parlours the small voltage differences referred to above may adversely affect livestock feeding at milking and also milk output. For details consult the current edition of BS 7671. 605-08

9.4.6 Building and construction sites, quarries, etc

It may be difficult to satisfy the electricity distributors bonding requirements because of the large number of parts of the building works that are extraneous-conductive-parts. In these circumstances a PME earthing terminal may not be provided.

Regional electricity companies may be prepared to offer a TN-S supply to large sites requiring their own substation where the earthing terminal can be connected directly to the transformer neutral.

For quarries, see also 9.4.9 below.

9.4.7 Caravan parks and marinas

Regulation 9(4) of the Electricity Safety, Quality and Continuity Regulations does not allow the combined neutral and protective conductor to be connected electrically to any metalwork in a caravan or boat. This prevents PME terminals being used for caravans or boat mooring supplies, although they may be used for fixed premises on the sites, such as the site owner's living premises and any bars or shops, etc. Account is taken of this in Section 608 of BS 7671 608-13-05
with respect to caravans, and also will be for marinas when a section is included in the standard.

The extension of PME to toilets and amenity blocks is not recommended as there is a high probability of people going barefoot and being in good contact with true earth through wet concrete floors.

9.4.8 Petrol filling stations

The reference publication is "Guidance for the design, construction, modification and maintenance of petrol filling stations", published by the APEA and the Institute of Petroleum, which recommends a TT supply for hazardous areas. This publication supersedes most but not all of HSE publication 'Petrol Filling Stations: Construction and Operation' (HSG(4)41). Sections replaced include Hazardous area classification, Part 1 - Planning construction and installation and Part 3 - Electrical installation, equipment, inspection and testing. A separate earth electrode and RCD or other alternative arrangement is required to ensure the segregation of petrol filling area earthing and that of the PME earth of the distribution network. A PME earth may be used for permanent buildings such as shops and restaurants.

9.4.9 Mines and quarries

A supply taken to an underground shaft, or for use in the production side of a quarry, must have an earthing system which is segregated from any system bonded to the PME terminal. Any supply taken to a permanent building can be given a PME terminal provided the building electrical installation wiring complies with BS 7671. Where a mine or quarry requires a supply both to a permanent building and either an underground shaft or the production side of the quarry, precautions must be taken to ensure that these latter supplies have their earthing system segregated from the PME earth system. Further details are given in HSE publications:

L118, ISBN 07176 2458 7, Health and Safety at Quarries - Quarries Regulations 1999, Approved Code of Practice.

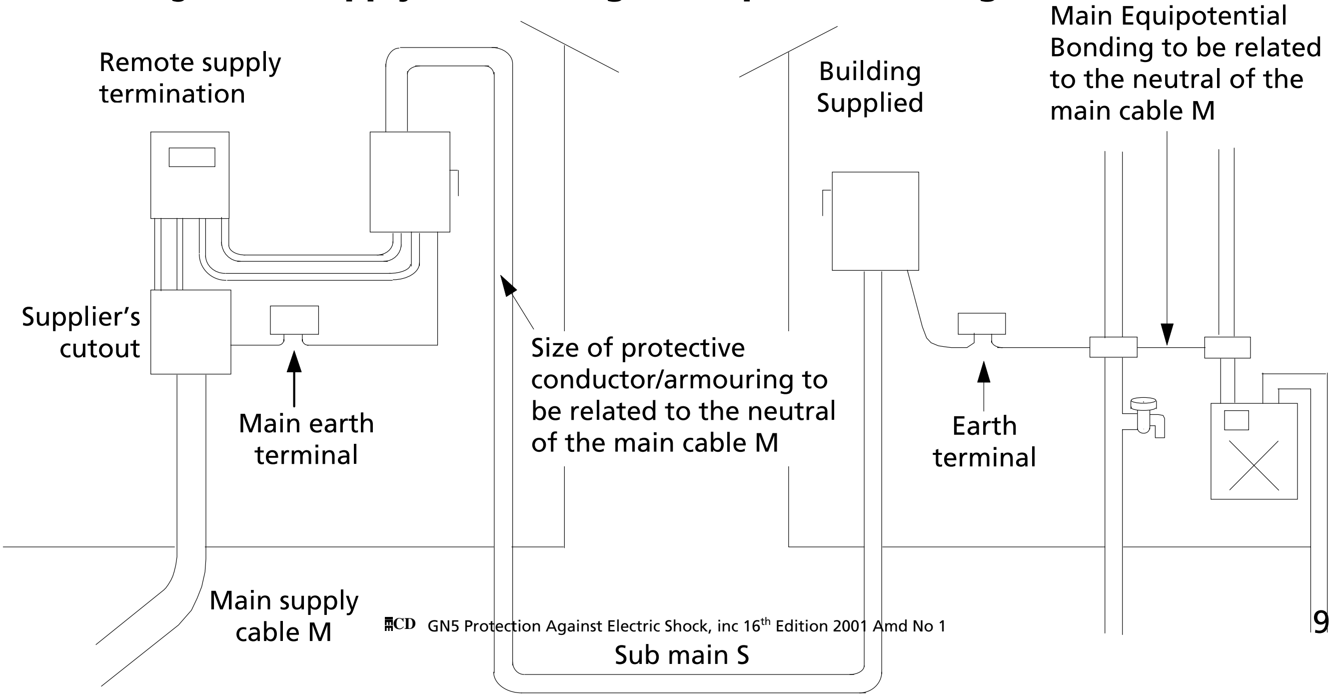
L128, ISBN 07176 2074 3, The use of electricity in mines - Electricity at Work Regulations 1989, Approved Code of Practice.

9.4.10 Supply terminating in a separate building

Occasionally a service will terminate in a position remote from the building it supplies. The size of the PME bonding in the building supplied must be related to the size of the incoming supply cable, in accordance with Regulation 547-02-01 and Table 54H of BS 7671. If the size of the circuit protective conductor of the cable between the supply intake position and the building is less than that of the PME bonding conductor, a suitable additional conductor will have to be installed or the PME earth not used.

547-02-01
Table 54H

Fig 9.4.10 **Supply terminating in a separate building**



9.4.11 PME and outside water taps

Under an open-circuit supply neutral condition the potential of an outside water tap will rise above earth potential. A person coming into contact with the tap could receive an electric shock and the shock could be severe, if that person were barefooted. The probability of these two conditions occurring together is considered to be so small that the use of PME where a metal outside tap exists is not precluded.

It is recommended, however, that a plastic insert be provided in the pipe to the outside water tap.

9.4.12 Highway power supplies

Street electrical fixtures were exempted from the requirements of Regulation 7 of the former Electricity Supply Regulations 1988 as amended. The exemption allowed the minimum copper equivalent cross-sectional area of the main equipotential bonding conductor to be reduced to 6 mm^2 in specific circumstances. As the Electricity Safety, Quality and Continuity Regulations do not specify minimum sizes of main bonding conductors, it is to be presumed that it would be reasonable to allow the reduction in size for street lighting equipment in the same circumstances as before. Although BS 7671 at present has a minimum size of 10 mm^2 for supply neutral conductors of 35 mm^2 csa or less, it would seem appropriate to reduce the minimum size to 6 mm^2 for supply neutral conductors of 6 mm^2 csa or less, see Regulation 547-02. However, the departure from Part 5 would need to be recorded on the Electrical Installation certificate. Table 54H

9.4.13 High rise buildings

For guidance on the application of PME to high rise buildings and building complexes, guidance should be sought from the electricity supply company and Engineering Recommendation G12/3.

Appendix A: Maximum Permissible Measured Earth Fault Loop Impedance

Tables A1 to A4 in this Appendix give the maximum permissible measured earth fault loop impedances (Z_S) for compliance with the shock protection requirements of Regulation 413-02-08 and the protective conductor requirements of Regulation 543-01-03 for conventional thermoplastic (pvc) insulated final circuits. The values are those that must not be exceeded when the tests are carried out at an ambient temperature of 10 °C to 20 °C. Table A5 provides correction factors for other ambient temperatures.

When the cables to be used are to Tables 4, 7 or 8 of BS 6004 or Tables 3, 5, 6 or 7 of BS 7211, or are other thermoplastic (pvc) or lsf cables to these British Standards, and if the cable loading is such that the maximum operating temperature is 70 °C, then Tables A1, A2 and A3 give the maximum earth loop impedances for circuits:

(a) with protective conductors of copper and having from 1 mm^2 to 16 mm^2 cross-sectional area, and

(b) where the overcurrent protective device is a fuse to BS 88-2 or BS 88-6, BS 1361 or BS 3036.

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

(ii) where the circuit concerned feeds fixed equipment only and the disconnection time for compliance with Regulation 413-02-13 is 5 s.

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.

Table A4 gives the maximum measured Z_S for circuits protected by circuit-breakers to BS 3871 and BS EN 60898, and RCBOs to BS EN 61009.

Notes: The impedances tabulated in this Appendix are lower than those in Tables 41B1, 41B2 and 41D of BS 7671 as these are measured values at an assumed conductor temperature of 10 °C, whilst those in BS 7671 are design figures at the conductor normal operating temperature.

TABLE A1
Maximum measured earth fault loop impedance (in ohms) when overcurrent protective device is a semi-enclosed fuse to BS 3036
(see Note)

(i) 0.4 second disconnection

Protective conductor (mm^2)	Fuse rating (amperes)				
	5	15	20	30	45
1.0	8.00	2.14	1.48	NP	NP
1.5	8.00	2.14	1.48	0.91	NP
2.5 to 16.0	8.00	2.14	1.48	0.91	0.50

(ii) 5 seconds disconnection

Protective conductor (mm^2)	Fuse rating (amperes)				
	5	15	20	30	45
1.0	14.80	4.46	2.79	NP	NP
1.5	14.80	4.46	3.20	2.08	NP
2.5	14.80	4.46	3.20	2.21	1.20
4.0 to 16.0	14.80	4.46	3.20	2.21	1.33

Note: A value for k of 115 from Table 54C of BS 7671 is used. This is suitable for pvc insulated and sheathed cables to Tables 4, 7 or 8 of BS 6004 and for lsf insulated and sheathed cables to Tables 3, 5, 6 or 7 of BS 7211. The k value is based on the cables operating at a maximum operating temperature of 70 C.

NP indicates that the protective conductor, fuse combination is NOT PERMITTED.

TABLE A2
Maximum measured earth fault loop impedance (in ohms) when overcurrent protective device is a fuse to BS 88
(see Note)

(i) 0.4 second disconnection

Protective conductor (mm^2)	Fuse rating (amperes)							
	6	10	16	20	25	32	40	50
1.0	7.11	4.26	2.26	1.48	1.20	0.69	NP	NP
1.5	7.11	4.26	2.26	1.48	1.20	0.87	0.67	NP
2.5 to 16.0	7.11	4.26	2.26	1.48	1.20	0.87	0.69	0.51

(ii) 5 seconds disconnection

Protective conductor (mm^2)	Fuse rating (amperes)							
	6	10	16	20	25	32	40	50
1.0	11.28	6.19	3.20	1.75	1.24	0.69	NP	NP
1.5	11.28	6.19	3.49	2.43	1.60	1.12	0.67	NP
2.5	11.28	6.19	3.49	2.43	1.92	1.52	1.13	0.56
4.0	11.28	6.19	3.49	2.43	1.92	1.52	1.13	0.81
6.0 to 16.0	11.28	6.19	3.49	2.43	1.92	1.52	1.13	0.87

Note: A value for k of 115 from Table 54C of BS 7671 is used. This is suitable for pvc insulated and sheathed cables to Tables 4, 7 or 8 of BS 6004 and for lsf insulated and sheathed cables to Tables 3, 5, 6 or 7 of BS 7211. The k value is based on the cables operating at a maximum operating temperature of 70 C.

NP indicates that the protective conductor, fuse combination is NOT PERMITTED.

TABLE A3

Maximum measured earth fault loop impedance (in ohms) when overcurrent protective device is a fuse to BS 1361

(see Note)

(i) 0.4 second disconnection

Protective conductor (mm^2)	Fuse rating (amperes)				
	5	15	20	30	45
1.0	8.72	2.74	1.42	0.80	NP
1.5	8.72	2.74	1.42	0.96	0.34
2.5 to 16.0	8.72	2.74	1.42	0.96	0.48

(ii) 5 seconds disconnection

Protective conductor (mm^2)	Fuse rating (amperes)				
	5	15	20	30	45
1.0	13.68	4.18	1.75	0.80	NP
1.5	13.68	4.18	2.24	1.20	0.34
2.5	13.68	4.18	2.34	1.54	0.53
4.0	13.68	4.18	2.34	1.54	0.70
6.0 to 16.0	13.68	4.18	2.34	1.54	0.80

Note: A value for k of 115 from Table 54C of BS 7671 is used. This is suitable for pvc insulated and sheathed cables to Tables 4, 7 or 8 of BS 6004 and for lsf insulated and sheathed cables to Tables 3, 5, 6 or 7 of BS 7211. The k value is based on both the cables operating at a maximum operating temperature of 70 C.

NP indicates that the protective conductor, fuse combination is NOT PERMITTED.

TABLE A4

Maximum measured earth fault loop impedance in ohms *(Note 1)* when overcurrent protective device is a circuit-breaker to BS 3871 or BS EN 60898 or an RCBO to BS EN 61009 *(Note 2)*

(i) both 0.4 and 5 seconds disconnection times

circuit-breaker type	circuit-breaker rating (amperes)															
	5	6	10	15	16	20	25	30	32	40	45	50	63	80	100	125
1	9.60	8.00	4.80	3.20	3.00	2.40	1.92	1.60	1.50	1.20	1.06	0.96	0.76	—	—	—
2	5.49	4.57	2.74	1.83	1.71	1.37	1.10	0.91	0.86	0.69	0.61	0.55	0.43	—	—	—
B	—	6.40	3.84	—	2.40	1.92	1.54	—	1.20	0.96	0.86	0.77	0.61	0.48	0.38	0.30
3&C	3.84	3.20	1.92	1.28	1.20	0.96	0.77	0.64	0.60	0.48	0.42	0.38	0.30	0.24	0.19	0.15
D	1.92	1.60	0.96	0.64	0.60	0.48	0.38	0.32	0.30	0.24	0.22	0.19	0.15	0.12	0.09	0.08

Note 1: 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 Tables 4, 7 or 8 of BS 6004 and for lsf insulated and sheathed cables to Tables 3, 5, 6 or 7 of BS 7211. The k value is based on the cables operating at a maximum operating temperature of 70 C.

Note 2: If 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.

TABLE A5
Ambient temperature correction factors

Ambient temperature (°C)	Correction factors
5	0.98
10 - 20	1.00
25	1.06

The correction factor is applied to Tables A1 to A4 if the ambient temperature is not 10 °C, e.g. if the ambient temperature is 25 °C the measured earth fault loop impedance of a circuit protected by a 32 A type 1 circuit-breaker should not exceed 1.50 x 1.06 = 1.59 Ω.

Appendix B: Resistance of Copper and Aluminium Conductors

(This appendix is reproduced as Appendix 1 of GN3 and Appendix 9 of the On-Site Guide).

To check compliance with Regulation 434-03-03 and/or Regulation 543-01-03, i.e. to evaluate the equation 434-03-03 543-01-03

$$s^2 = \frac{I^2 t}{k^2}$$

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.

Fault current $I = U_O/Z_S$

where:

U_O is the nominal voltage to earth,

Z_S is the earth fault loop impedance.

$Z_S = Z_e + R_1 + R_2$

where:

Z_e is that part of the earth fault loop impedance external to the circuit concerned,

R_1 Is the resistance of the phase conductor from the origin of the circuit to the point of utilization,

R_2 is the resistance of the protective conductor from the origin of the circuit to the point of utilization.

Similarly, in order to design circuits for compliance with 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 at their operating temperature.

TABLE B1
Values of resistance/metre for copper and aluminium conductor and of ($R_1 + R_2$) per metre at 20 °C in milliohms/metre

Cross-sectional area (mm^2)		Resistance/metre or ($R_1 + R_2$)/metre (mΩ/m)	
Phase conductor	Protective conductor	Copper	Aluminium
1	—	18.10	
1	1	36.20	
1.5	—	12.10	
1.5	1	30.20	
1.5	1.5	24.20	
2.5	—	7.41	
2.5	1	25.51	
2.5	1.5	19.51	
2.5	2.5	14.82	
4	—	4.61	
4	1.5	16.71	
4	2.5	12.02	
4	4	9.22	
6	—	3.08	
6	2.5	10.49	
6	4	7.69	
6	6	6.16	
10	—	1.83	
10	4	6.44	
10	6	4.91	
10	10	3.66	
16	—	1.15	1.91
16	6	4.23	—
16	10	2.98	—
16	16	2.30	3.82
25	—	0.727	1.20
25	10	2.557	—
25	16	1.877	—
25	25	1.454	2.40
35	—	0.524	0.868
35	16	1.674	2.778
35	25	1.251	2.068
35	35	1.048	1.736
50	—	0.387	0.641
50	25	1.114	1.841
50	35	0.911	1.509
50	50	0.774	1.282

Table B1 gives values of ($R_1 + R_2$) per metre for various combinations of conductors up to and including 50 mm^2 cross-sectional area. It also gives values of resistance (milliohms) per metre for each size of conductor. These values are at 20 °C.

TABLE B2
Ambient temperature multipliers(α) to Table B1

Expected ambient temperature	Correction factor
0 °C	0.92
5 °C	0.94
10 °C	0.96
15 °C	0.98
20 °C	1.00
25 °C	1.02
30 °C	1.04
40 °C	1.08

Note:
The correction factor is given by:
{1 + 0.004 (ambient temp - 20 °C}
where 0.004 is the simplified resistance coefficient per °C at 20 °C given by BS 6360 for copper and aluminium conductors.

For verification purposes the designer will need to give the values of the phase and circuit protective conductor resistances at the ambient temperature expected during the tests. This may be different from the reference temperature of 20 °C used for Table B1. The correction factors in Table B2 may be applied to the Table B1 values to take account of the ambient temperature (for test purposes only).

Standard overcurrent devices

Table B3 gives the multipliers to be applied to the values given in Table B1 for the purpose of calculating the resistance at maximum operating temperature of the phase conductors and/or the circuit protective conductors in order to determine compliance with, as applicable:

(a) earth fault loop impedance of Table 41B1, Table 41B2 or Table 41D of BS 7671
(b) earth fault loop impedance and resistance of protective conductor of Table 41C of BS 7671.

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 B3 may be reduced accordingly.

TABLE B3
Conductor temperature factor F for standard devices

Table 41B1
Table 41B2
Table 41C
Table 41D

Multipliers to be applied to Table B1 for devices in Tables 41B1, 41B2, 41C and 41D

Conductor Installation	Conductor Insulation		
	70 °C thermoplastic (pvc)	85 °C thermosetting (rubber) note 4	90 °C thermosetting note 4
Not incorporated in a cable and not bunched - note 1, 3	1.04	1.04	1.04
Incorporated in a cable or bunched - note 2, 3	1.20	1.26	1.28

Table 54B

Table 54C

Note 1 See Table 54B of BS 7671. These factors apply when protective conductor is not incorporated or bunched with cables, or for bare protective conductors in contact with cable covering.

Table 54B

Note 2 See Table 54C of BS 7671. These factors apply when the protective conductor is a core in a cable or is bunched with cables.

Table 54C

Note 3 The factors are given by
F = 1 + 0.004{conductor operating temperature - 20°C}
where 0.004 is the simplified resistance coefficient per °C at 20°C given in BS 6360 for copper and aluminium conductors.

Note 4 If cable loading is such that the maximum operating temperature is 70°C, 70°C factors are appropriate.

Non-standard overcurrent devices

The multipliers given in Table B3 provide corrections for conductor resistances from 20 °C to the maximum conductor operating temperature for cables incorporated in a cable or bunched and to 30 °C for those not incorporated in a cable or bunched.

These factors are valid irrespective of the overcurrent device and whether or not it is listed in Appendix 3 of BS 7671.

The figures given in Appendix 3 of BS 7671 reflect the worst-case characteristics allowed by the standard for circuit-breakers and the median time for fuses.

If manufacturers' characteristics are to be used, either because the characteristics are not specified in the particular standard e.g. BS EN 60947-2, or because the device is "quicker" than required by the standard, the designer will need to seek assurance from the manufacturer that the characteristics given are robust, i.e. there is a high probability that the characteristics will be met over the life of the device.

Appendix C: Minimum Separation Distance between Electricity Supply Cables and Telecommunications Cables

(From BS 6701: 1994 Code of Practice for installation of apparatus intended for connection to certain telecommunication systems)

TABLE C1
Minimum separation distance between internal and external electricity supply cables carrying voltages in excess of 600 V a.c. or 900 V d.c. to earth, and telecommunications cables (Band I).

Voltage to earth	Normal separation distance	Exceptions to normal separation distance, plus conditions to exceptions
Exceeding 600 V a.c. or 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.

TABLE C2

Minimum separation distance between external low voltage electricity supply cables operating in excess of 50 V a.c. or 120 V d.c. to earth, but not exceeding 600 V a.c. or 900 V d.c. to earth (Band II), and telecommunications cables (Band I).

Voltage to earth	Normal separation distance	Exceptions to normal separation distance, plus conditions to exceptions
Exceeding 50 V a.c. or 120 V d.c., but not exceeding 600 V a.c. or 900 V d.c.	50 mm	Below this figure a non-conducting divider should be inserted between the cables.

TABLE C3

Minimum separation distance between internal low voltage electricity supply cables operating in excess of 50 V a.c. or 120 V d.c. to earth, but not exceeding 600 V a.c. or 900 V d.c. to earth (Band I), and telecommunications cables (Band II).

Voltage to earth	Normal separation distance	Exceptions to normal separation distance, plus conditions to exceptions
Exceeding 50 V a.c. or 120 V d.c., but not exceeding 600 V a.c. or 900 V d.c.	50 mm	50 mm separation need not be maintained, provided that: (i) the LV cables are enclosed in separate conduit which if metallic is earthed in accordance with BS 7671 **OR** (ii) the LV cables are enclosed in separate trunking which if metallic is earthed in accordance with BS 7671 **OR** (iii) the LV cable is of the mineral insulated type or is of armoured construction

Notes:

(1) Where the LV cables share the same tray then the normal separation should be met.

(2) Where LV and Telecommunications cables are obliged to cross, additional insulation should be provided at the crossing point; this is not necessary if either cable is armoured.

Index

H

I

L

M

N

O

T

U

W