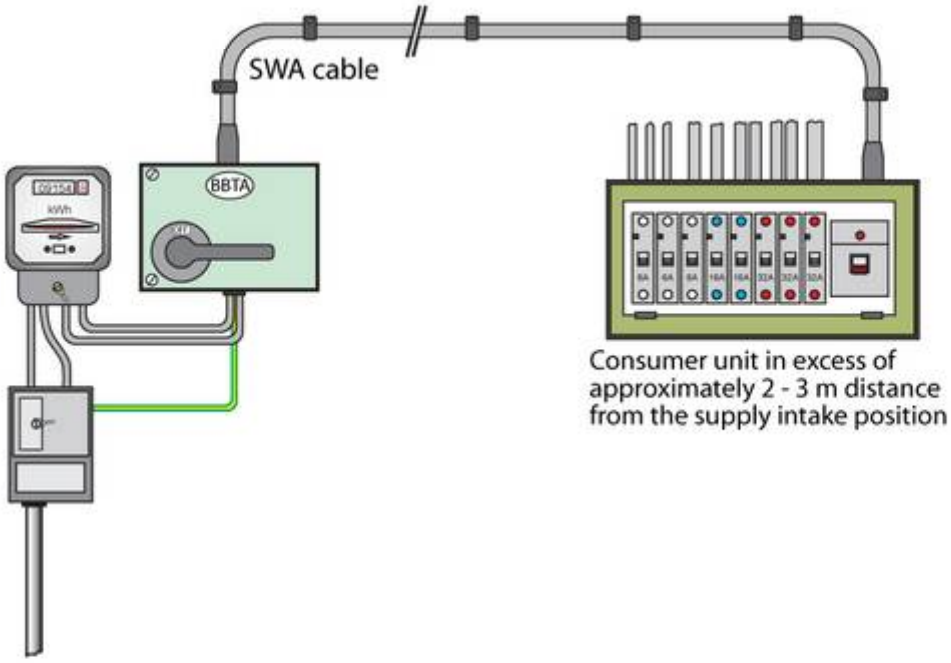
Level 3 Diploma
in
Installing Electrotechnical Systems & Equipment

C&G 2357

Unit 305 - Installation of wiring systems and equipment buildings



B&B Training Associates Ltd
Learning Materials for the Electrical Industry

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Aims and objectives

By the end of this study book you will have had the opportunity to:

Outcome 1 Understand the procedures, practices and statutory and non statutory regulatory requirements for preparing work sites for the installation of wiring systems and associated equipment

- Explain the health and safety requirements and legal duties of employers and employees in establishing a safe working environment.
- Interpret relevant sources of information which will inform installation work.
- Specify the actions required to ensure that electrical installation work sites are correctly prepared in terms of health and safety considerations.

Outcome 2 Understand the procedures for checking the work location prior to the commencement of work activities

- State the preparations that should be completed before electrical installation work starts.
- Explain how to check for any pre-existing damage to customer/client property and state why it is important to do this prior to commencement of any work activity.
- State the actions that should be taken if pre-existing damage to customer/client property is identified.
- Specify methods for protecting the fabric and structure of the property before and during installation work.

Outcome 3 Understand the practices, procedures and regulatory requirements for completing the safe isolation of electrical circuits and complete electrical installations

- Specify and undertake the correct procedure for completing safe isolation with regard to:
  - carrying out safe working practices
  - correct identification of circuit(s) to be isolated
  - identifying suitable points of isolation
  - selecting correct test and proving instruments in accordance with relevant industry
  - guidance and standards
  - correct testing methods
  - selecting locking devices for securing isolation
  - correct warning notices
  - correct sequence for the safe-isolation of an electrical circuit and complete electrical installation.
- State the implications of carrying out safe isolations to:
  - other personnel
  - customers/clients
  - public
  - building systems (loss of supply).

- State the implications of not carrying out safe isolation to:
  - self
  - other personnel
  - customers/clients
  - public
  - building systems (presence of supply).

Outcome 4 Understand the types, applications and limitations of wiring systems and associated equipment

- State the constructional features, applications, advantages and limitations of types of cable State the criteria for correctly selecting wiring systems, equipment and enclosures as appropriate for systems.
- State the constructional features, applications, advantages and limitations of types of cable and conductor containment systems
- Describe how environmental factors can affect the selection of wiring systems, associated equipment and enclosures
- State the types of wiring systems and associated equipment used for:
  - lighting systems
  - power systems (final circuits)
  - distribution systems (sub mains)
  - environmental control/building management systems
  - emergency management systems
  - security systems – fire alarm/prevention; unlawful entry; emergency lighting
  - closed circuit TV, communication and data transmission systems.

Outcome 5 Understand the procedures for selecting and using, tools, equipment and fixings for the installation of wiring systems, associated equipment and enclosures

- State the procedures for selecting and safely using appropriate hand tools, power tools and adhesives for electrical installation work
- State the procedures for selecting and safely using equipment for measuring and marking out for wiring systems, equipment and enclosures
- State the criteria for selecting and safely using tools and equipment for fixing and installing wiring systems, associated equipment and enclosures
- State the criteria for selecting and safely using fixing devices for wiring systems, associated equipment and enclosures, giving consideration to
  - load bearing capacity
  - fabric of structure
  - environmental considerations
  - aesthetic considerations.

Outcome 6 Understand the practices and procedures for installing wiring systems, associated equipment and enclosures

- Specify and apply the installation methods and procedures to ensure that in accordance with the installation specification and statutory and non-statutory regulations:
  - wiring systems, enclosures, cables and components are securely fixed and installed
  - a wiring system's mechanical integrity is maintained
  - no damage to the wiring system or its components has occurred.
- Specify methods and techniques for restoring the building fabric.

Outcome 7 Know the regulatory requirements which apply to the installation of wiring systems, associated equipment and enclosures.

- Specify the main requirements of the following topics in accordance with the current version
  of the IEE wiring regulations and describe how they impact upon the installation of wiring systems, associated equipment and enclosures:
  - selection and erection of wiring systems, associated equipment and enclosures
  - isolation and switching
  - protection against fire
  - protection against electric shock
  - special locations.
  - segregation.
  - flammable/explosive atmospheres

1: Legal duties of employers and employees

In this session the student will:

- Gain an understanding of the duties for employers and employees.

Preparing for work

The key to achieving healthy and safe working conditions is to ensure that health and safety issues are planned, organised, controlled, monitored and reviewed.

Everyone controlling site work has health and safety responsibilities.

These responsibilities are shared by employers and employees

Duties of employers

Employer's or those responsible for the work have, under the Health and Safety at work act, a 'duty of care' to look after, as far as possible, health, safety and welfare of those at work. To achieve this when planning work activities you should start with a risk assessment to spot possible health and safety hazards.

Anyone planning work activities, must:

- make the workplace safe
- prevent risks to health
- ensure that plant and machinery is safe to use, and that safe working practices are set up and followed
- make sure that all materials are handled, stored and used safely
- provide adequate first aid facilities
- tell you about any potential hazards from the work you do and give you information, instructions, training and supervision as needed
- set up emergency plans
- make sure that ventilation, temperature, lighting, and toilet, washing and rest facilities all meet health, safety and welfare requirements
- check that the right work equipment is provided and is properly used and regularly maintained
- prevent or control exposure to substances that may damage your health

- take precautions against the risks caused by flammable or explosive hazards, electrical equipment, noise and radiation
- avoid potentially dangerous work involving manual handling and if it can't be avoided, take precautions to reduce the risk of injury
- provide health supervision as needed
- provide protective clothing or equipment free of charge if risks can't be removed or adequately controlled by any other means
- ensure that the right warning signs are provided and looked after
- report certain accidents, injuries, diseases and dangerous occurrences to either the Health and Safety Executive (HSE) or the local authority, depending on the type of business

Duties of employees

An employer has a duty to maintain mutual trust and confidence in his/her employee. An employer must not, without reasonable and proper cause, conduct themselves in a manner calculated, or likely, to destroy, or seriously damage the relationship of trust and confidence with his/her employee. This duty obliges employers to ensure an employee is treated with dignity at work, and deals with any complaints fairly and seriously.

The duties of an employee differ from those of an employer, and it shall be the duty of every employee while at work

a) to take reasonable care for the health and safety of himself and of other persons who may be affected by his acts or omissions at work; and

b) to co-operate with his/her employer in enabling them to fulfil their legal duties.

The most important responsibilities as an employee are:

- to take reasonable care of your own health and safety
- if possible avoid wearing jewelry or loose clothing if operating machinery
- if you have long hair or wear a headscarf, make sure it's tucked out of the way .
- to take reasonable care not to put other people - fellow employees and members of the public - at risk by what you do or don't do in the course of your work
- to co-operate with your employer, making sure you get proper training and you understand and follow the company's health and safety policies
- not to interfere with or misuse anything that's been provided for your health, safety or welfare
- to report any injuries, strains or illnesses you suffer as a result of doing your job .

- to tell your employer if something happens that might affect your ability to work (eg becoming pregnant or suffering an injury) - your employer has a legal responsibility for your health and safety, they may need to suspend you while they find a solution to the problem, but you will normally be paid if this happens
- if you drive or operate machinery, tell your employer if you take medication that makes you drowsy - they should temporarily move you to another job if they have one for you to do

If you have a problem concerning health and safety in your workplace this should be discussed with your employer, manager or safety representative.

If you are still not happy you should consult the HSE who will investigate the problem.

Exercise 1

1. List six duties an employer must take to ensure a safe working environment for their workforce.

2. List six duties an employee must take to ensure a safe working environment for their colleagues.

3. Describe how the duties of an employer and employee differ.

2: Statutory Regulations

In this session the student will:

- Gain an understanding of the main statutory regulations which affect the way that they work.

As a worker there are many pieces of legislation that provide a legal framework to protect you. These also include the building you are in and the electrical supply that you are working with. They are there to ensure that you do not come to any harm or harm those around you.

More information for any health and safety matters including these pieces of legislation can be found on the Health and Safety Executive (HSE) web site.

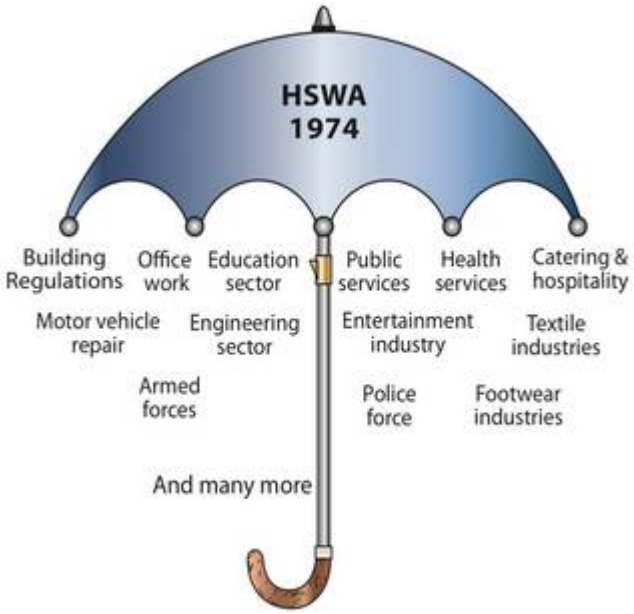
The Health and Safety at Work etc Act.

The Health and Safety at Work etc Act 1974 (HSWA) acts like an umbrella and draws all other statutory safety regulations under its reach.

Not everyone is covered by this umbrella.

People doing DIY at home and domestic servants are not covered.

If cash is received, or work done in 'kind,' then this is considered work and therefore the Act applies.



Everyone has a duty to comply with the Act, including employers, employees, trainees, self-employed, manufacturers, suppliers, designers, importers of work equipment.

The Health and Safety Executive was formed as part of the HSWA, as a body to promote the cause of better Health and Safety at Work

The Electricity at Work Regulations.

This is a legal (statutory) document whereas the Wiring regulations (BS 7671) are not.

The Electricity at Work regulations are concerned with anything that is electrical and used at work.

- This could be anything, from a battery put in a torch, up to a 400 kV power line.

The document is the key form of legislation for anybody working within the electrotechnical industry; it also applies to anyone who works on any electrical item whilst they are at work. The EWR states that before any work is done three things must be in place;

1. The person who is working must be competent to do the task
2. The task must have been planned in such a way that no live working takes place
3. Where live working cannot be avoided, the risks to injury must be limited.

The regulations are divided into sections, these are:

- Regulation 4 systems, work activities and protective equipment
- Regulation 5 strength and capability of electrical equipment
- Regulation 6 adverse or hazardous environments
- Regulation 7 insulation, protection and placing of conductors
- Regulation 8 earthing or other suitable precautions
- Regulation 9 integrity of referenced conductors
- Regulation 10 connections
- Regulation 11 means for protecting from excess of current
- Regulation 12 means for cutting off the supply and for isolation
- Regulation 13 precautions for work on equipment made dead
- Regulation 14 work on or near live conductors
- Regulation 15 working space, access and lighting
- Regulation 16 persons to be competent to prevent danger and injury.

The impact of these regulations on all aspects of electrical work within the industry has been enormous.

The Management of Health and Safety at Work Regulations. (MHSWR)

The MHSWR places duties on employers to introduce specific control measures to ensure the health, safety and welfare of employees and any others who are affected by work activities.

- to carry out formal risk assessments
- to have formal management control systems
- to have specific protective and preventative measures set in place by the employers
- to carry out health surveillance
- to appoint competent persons
- to arrange the necessary contacts with external services
- have procedures set in place for serious and imminent danger
- to provide information for employees
- to encourage and ensure inter-employer cooperation
- to provide job/task specific training
- to assess the capability of those working
- to encourage and detail employee duties.

Workplace (Health and Safety and Welfare) Regulations

The Regulations aim to ensure that workplaces meet the health, safety and welfare needs of all members of a workforce, including people with disabilities and workstations, should be made accessible for disabled people.

The regulations are broken into section to cover areas such as ventilation, temperatures in the workplace, lighting, safety and welfare.

Control of Substances Hazardous to Health (COSHH) Regulations

A substance hazardous to health includes any material or mixture that is harmful to people's health. This includes not only the substance, but also the by-products and not only the workers, but also those who are affected by the work activity.

The duties placed on employers are:

- not to carry out work which is liable to expose an employee to a hazardous substance unless an assessment has been made of the risks to health and safety
- to carry out the risk assessment in the light of appropriate data sheets and to record the findings regularly reviewing them ideally to prevent the exposure
- if the risk of exposure cannot be removed then adequate precautions should be taken with PPE.

Working at Height Regulations

The Work at Height Regulations 2005 applies to all work at height where there is a risk of a fall liable to personal injury. This implies that a fall could occur at ground level or even belowground level.

The regulations cover:

- existing places of work and means of access for work at height
- collective fall prevention (for example guards rails)
- working platforms
- collective fall arrest (for example nets)
- ladders and stepladders
- inspection reports
- revocations

A duty holder must ensure workers:

1. avoid working at height where possible
   - use work equipment or other measures to prevent falls where they cannot avoid working at height, and
   - where they cannot eliminate the risk of a fall, use work equipment or other measures to minimise the distance and consequences of a fall should one occur.

The duty holder's responsibilities include:

- Planning and organising all work at height
- Taking into account of weather conditions that could endanger health and safety
- Ensuring those involved in work at height are trained and competent
- Making sure that the place where work at height is done is safe
- The equipment for work at height is appropriately inspected
- The risks from fragile surfaces are properly controlled
- The risks from falling objects are properly controlled.

Personal Protective Equipment at Work Regulations

This regulation (PPEWR), places significant duties on employers to provide and ensure the correct use of safety equipment.

PPE is defined in the Regulations as *'all equipment (including clothing affording protection against the weather) which is intended to be worn or held by a person at work and which protects him against one or more risks to his health or safety'*, eg safety helmets, gloves, eye protection, high visibility clothing, safety footwear and safety harnesses.

The main requirement of the PPE at Work Regulations 1992 is that personal protective equipment is to be supplied and used at work wherever there are risks to health and safety that cannot be **adequately controlled** in other ways.

The Regulations also require that PPE:

- is properly assessed before use to ensure it is suitable;
- is maintained and stored properly;
- is provided with instructions on how to use it safely; and
- is used correctly by employees.

Manual Handling Operations Regulations 1992 (amended 2002)

The Regulations require **employers** to:

- avoid the need for hazardous manual handling, so far as is reasonably practicable;
- assess the risk of injury from any hazardous manual handling that can't be avoided; and
- reduce the risk of injury from hazardous manual handling, so far as is reasonably practicable.

Employees have duties too. They should:

- follow appropriate systems of work laid down for their safety;
- make proper use of equipment provided for their safety;
- co-operate with their employer on health and safety matters;
- inform the employer if they identify hazardous handling activities;
- take care to ensure that their activities do not put others at risk.

Provision and Use of Work Equipment Regulations PUWER

The Regulations require risks to people's health and safety, from equipment that they use at work, to be prevented or controlled.

What does PUWER do?

The Regulations require that equipment provided for use at work is:

- suitable for the intended use;
- safe for use, maintained in a safe condition and, in certain circumstances, inspected to ensure this remains the case;
- used only by people who have received adequate information, instruction and training; and
- accompanied by suitable safety measures, e.g. protective devices, markings, warnings.

Any equipment which is used by an employee at work is covered.

Similarly, if you use your own equipment at work, it too will be covered by PUWER and you will need to make sure it complies.

Display Screen Equipment at Work Regulations

The Regulations require employers to minimise the risks in VDU work by ensuring that workplaces and jobs are well designed.

The Regulations apply where staffs habitually use VDUs as a significant part of their normal work.

Those who are self employed, work from home or only work occasionally with Display Screen Equipment are still covered under other health and safety at work legislation

The Regulations do not contain detailed technical specifications or lists of approved equipment. Instead, they set more general objectives.

Employers need to look at:

- the whole workstation including equipment, furniture, and the work environment;
- the job being done; and
- any special needs of individual staff.
- Where risks are identified, the employer must take steps to reduce them.

The control of Asbestos regulations 2012

The new regulations Came into force on 6 April 2012, updating previous asbestos regulations

- If existing asbestos containing materials are in good condition and are not likely to be damaged, they may be left in place; their condition monitored and managed to ensure they are not disturbed.
- If you're responsible for maintenance of non-domestic premises, you have a ‘duty to manage’ the asbestos in them, to protect anyone using or working in the premises from the risks to health that exposure to asbestos causes.
- If you want to do any building or maintenance work in premises, or on plant or equipment that might contain asbestos, you need to identify where it is and its type and condition; assess the risks, and manage and control these risks.
- The requirements for licensed work remain the same: in the majority of cases, work with asbestos needs to be done by a licensed contractor. This work includes most asbestos removal, all work with sprayed asbestos coatings and asbestos lagging and most work with asbestos insulation and asbestos insulating board (AIB).
- If you are carrying out non-licensed asbestos work, this still requires effective controls
- The control limit for asbestos is 0.1 asbestos fibres per cubic centimetre of air (0.1 f/cm3). The control limit is not a 'safe' level and exposure from work activities involving asbestos must be reduced to as far below the control limit as possible.
- Training is mandatory for anyone liable to be exposed to asbestos fibres at work. This includes maintenance workers and others who may come into contact with or disturb asbestos (e.g. cable installers), as well as those involved in asbestos removal work.

Exercise 2.

1. What does HSWA stand for?

2. What does EWR stand for?

3. Which group of workers does the HSWA not cover?

4. Which body has hands on responsibility for the day to day running of the HSWA?

5. What is BS 7671?

6. Which one/s of the following are legal documents:
   BS 7671, EWR, HSWA, MHSWR.

7. Can you think of any practical areas that an employer and employee might be responsible for?

8. Considering the responsibilities that employers have; what specific regulations do you think apply to the following?

3: Relevant sources of information

In this session the student will:

- Gain an understanding of how to interpret relevant **sources of information** which will inform installation work.

Much of the information covered in this session was dealt with in earlier units, so it should be treated as revision.

On a large project much of the information you need will all ready have been sourced for you, but there are always times when it is necessary to find some details which might be missing.

The main relevant sources of information are;

- Statutory documents.
- Codes of practice.
- British standards.
- Site drawings.
- Installation specifications – wiring diagrams; fitting and fixing dimensions/drawings-

Technical data.

- Manufacturer's instructions.

Statutory documents

The main statutory documents that you will need were covered in the last session

- The Health and Safety at Work etc Act.
- The Electricity at Work Regulations.
- The Management of Health and Safety at Work Regulations
- Workplace (Health and Safety and Welfare) Regulations
- Control of Substances Hazardous to Health (COSHH) Regulations
- Working at Height Regulations
- Personal Protective Equipment at Work Regulations
- Manual Handling Operations Regulations 1992 (amended 2002)
- Provision and Use of Work Equipment Regulations PUWER
- Display Screen Equipment at Work Regulations
- The control of Asbestos regulations 2012

Codes of practice

Approved codes of practice (ACOPs) give practical advice on how to comply with the law and are approved by the HSE. Failing to comply with an APOC is not an offence in itself. However in court failure to do so would be used to show an offence, the only defence would be to prove other appropriate methods or systems were in place.

Much of the work you do will be governed by codes of practice, such as;

The Construction (Design and Management) Regulations 2007

Safe use of work equipment.

Provision and Use of Work Equipment Regulations

Guide to the building regulations

The Construction (Design and Management) Regulations 2007 (CDM2007)

This Approved Code of Practice (ACoP) provides practical guidance on complying with the duties set out in the Regulations.

The Approved Code of Practice (ACoP) has special legal status and gives practical advice for all those involved in construction work.

The key aim of CDM2007 is to integrate health and safety into the management of the project and to encourage everyone involved to work together to:

- improve the planning and management of projects from the very start;
- identify risks early on;
- target effort where it can do the most good in terms of health and safety; and
- discourage unnecessary bureaucracy.

These Regulations are intended to focus attention on planning and management throughout construction projects, from design concept onwards. The aim is for health and safety considerations to be treated as an essential, but normal part of a project's development – not an afterthought or bolt-on extra.

The Regulations are divided into five parts.

Part 1 The Regulations apply to all construction work in Great Britain and, by virtue of the Health and Safety at Work etc Act 1974 , and apply to both employers and the self-employed without distinction.

Part 2 covers general management duties which apply to all construction projects

- Check competence and resources of all appointees
- Ensure there are suitable management arrangements for the project including welfare facilities
- Allow sufficient time and resources for all stages
- Provide pre-construction information to designers and contractors

Part 3 sets out additional management duties which apply to projects above the notification threshold (projects lasting more than 30 days, or involving more than 500 person days of construction work).

Part 4 of the Regulations applies to all construction work carried out on construction sites, and covers physical safeguards which need to be provided to prevent danger. Duties to achieve these standards are held by contractors who actually carry out the work, irrespective of whether they are employers or are self-employed. Contractors must not allow work to start or continue unless the necessary safeguards are in place.

British standards

The main standard that you have to work to is the IET wiring regulations 17th edition (BS7671:2008 incorporating amendment No 1:2011)

This is the national standard to which all domestic and industrial wiring must conform.

The 17th amendment No 1 contains changes to align it to European documents.

The document is divided into sections;

Scope

Object and fundamental principles

Definitions

Assessment of general characteristics

Protection for safety

Selection and erection of equipment

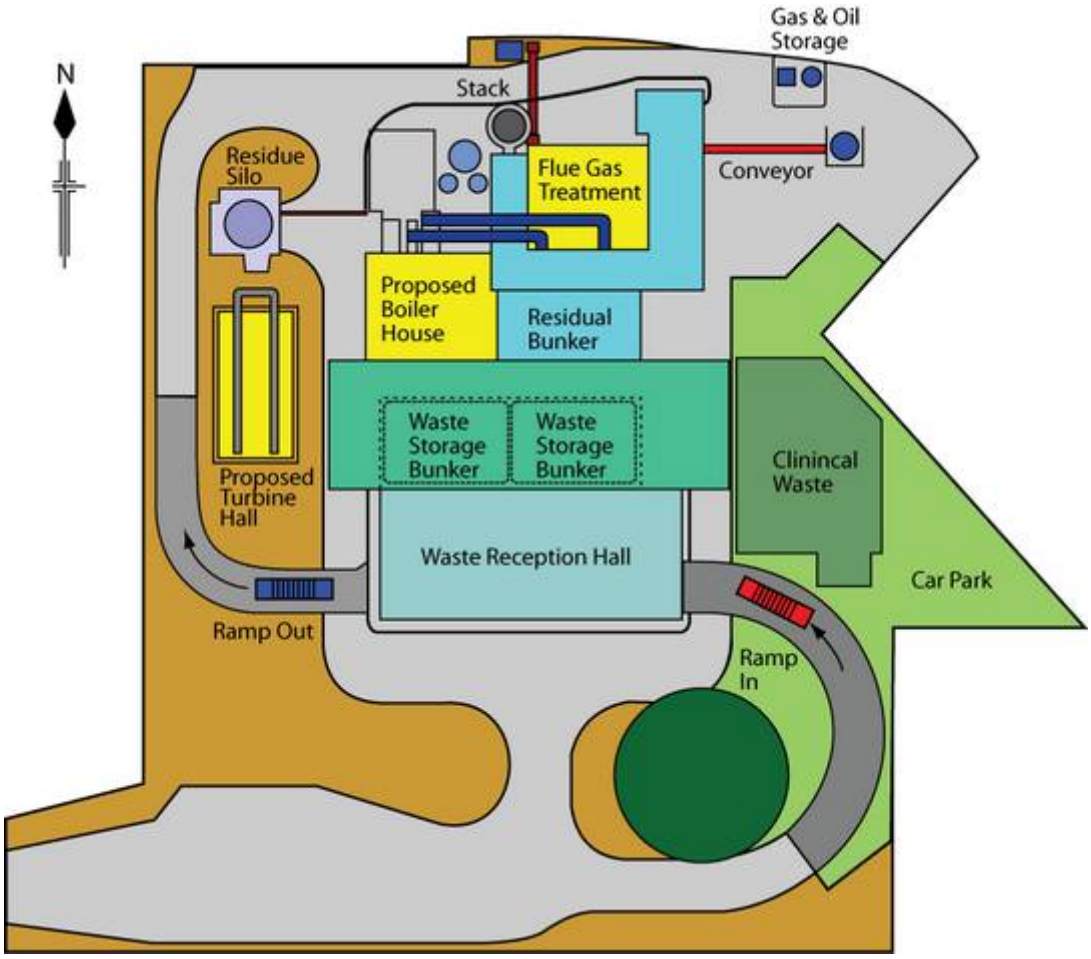
Special installations and locations

Inspection and testing

The HSE web site has useful guidance for all aspects of the health and safety issues on construction sites as well as links to other relevant areas.

Site drawings

Site drawings will be available from the main contractor or architect. Such drawings may not be available or necessary in smaller domestic installation work.



Installation specifications

There are two types of specification that you will be using when installing equipment

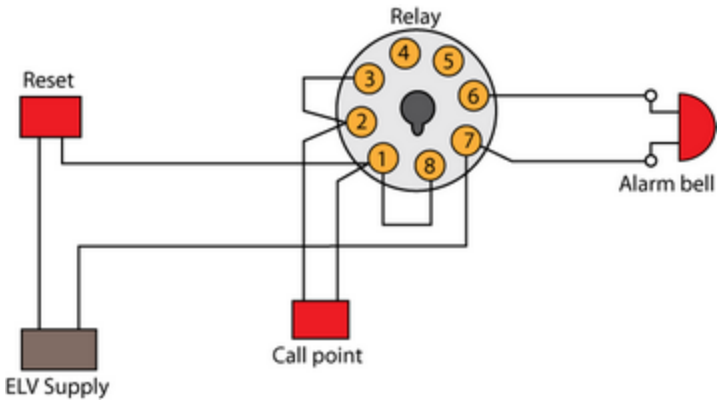
1. Specifications on how the client wants the accessories to look like, for example all switches and socked to have a brass effect.
2. An electrical specification giving the position of all the wiring runs, sockets, lighting and any other equipment to be fitted.

From the site diagram you will have information as to the location of the installation you are concerned with.

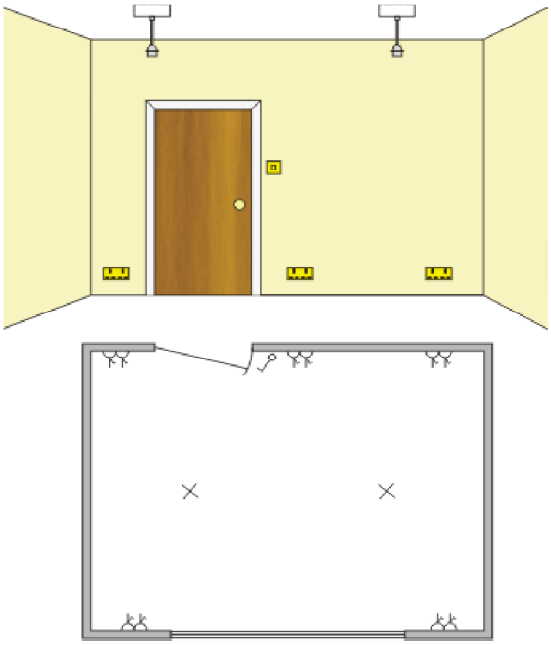
Your installation specifications can be found on wiring diagrams, layout diagrams, which show how a system is to be wired.

Wiring diagrams

Wiring diagrams show components in their correct position and can be drawn to scale



Fixture and fitting or location drawings



These will be needed to show the precise dimensions and positioning of the fixtures and fittings.

Technical data

Technical data sheets should be available and read thoroughly to make sure you understand how to install correctly and how the fitting or fixture operates before any work commences. If you are unsure of any product, information can be sourced from clients, libraries, internet, British standards institute, manufactures and suppliers.

Manufactures instructions

The information that you might need from the manufacturer might be;

The general equipment details, such as operating characteristics, size and assembly instructions any special installations methods.

Having got all the information that you require you then have to interpret how this will work in practise. To do this you need to understand:

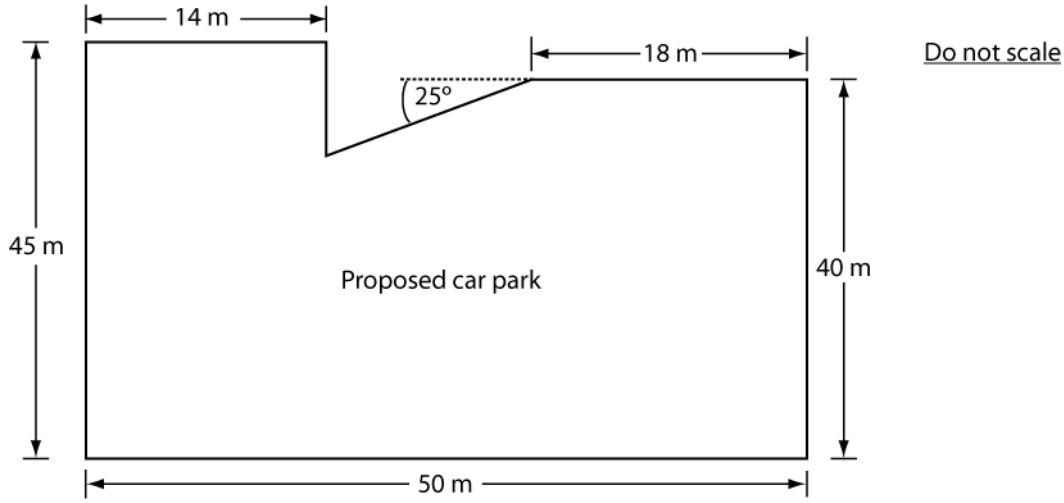
- How things operate
- How it is controlled
- How the various setting affect the performance
- How to make adjustments if needed.

Exercise 3

1. For a standard three-bedroom domestic installation, draw the various symbols that you would expect to see on a site drawing.

2. Using any source available to you find the costs for twenty 1800 mm twin fluorescent luminaires from at least two different manufacturers.

3. For the diagram below, redraw it to a scale of 1:100 (You'll need a sheet of A3 paper). What scale would it need to be to fit onto a sheet of A4 paper?



4. What would a site plan show?

5. Why would it be important to show where underground cables run? What name is given to the drawing that shows the routes?

6. What is the difference between a circuit diagram, a schematic diagram and a layout diagram?

7. What is the relationship between a set of drawings and a specification?

4: Preparing work sites for safe electrical installation activities

In this session the student will:

- Gain an understanding of how to specify the **actions required** to ensure that electrical installation work sites are correctly prepared in terms of Health and Safety considerations.

Everyone controlling site work has health and safety responsibilities. Checking that working conditions are healthy and safe before work begins and ensuring that the proposed work is not going to put others at risk requires planning and organisation.

Gathering as much health and safety information about the project and the proposed site before work begins is important.

Provision for safe access and egress

There should be safe access onto and around the site for people and vehicles.

Construction work should be fenced off and suitably signed.

Access on site

Can everyone get to their place of work safely?

Are access routes free from obstructions and clearly signposted?

Are holes protected with clearly marked and fixed covers to prevent falls?

Are temporary structures stable, adequately braced and not overloaded?

Will permanent structures remain stable during any refurbishment?

Is the site tidy, and are materials stored safely?

Is lighting adequate, especially when work is being carried on after dark outside or inside buildings?

Are vehicles and pedestrians kept apart? They should be separated as much as possible by using barriers and warning signs.

Before any work commences the area should be checked for potential hazards as appropriate to property, personnel and livestock. Livestock as well as being inquisitive are more sensitive to the hazards of electricity; arrangements need to be made to keep animals away from the immediate area for your and their safety.

When people (employees, other contractors or visitors) first come to site, it is important that they receive information about the site hazards and the steps that have been taken to control the risk.

The law

Under the Health and Safety at Work etc Act 1974 (the HSW Act), you have to ensure the health and safety of yourself and others who may be affected by what you do or do not do. It applies to all work activities and premises and everyone at work has responsibilities under it, including the self-employed.

The Management of Health and Safety at Work Regulations. (MHSWR)

The Management of Health and Safety at Work Regulations require a risk assessment to be completed before any work commences and if any significant change to the work or environments happens while the work is in progress.

One of the most important actions required to ensure that electrical installation work sites are correctly prepared in terms of Health and Safety considerations, is to confirm that appropriate risk assessments and method statements have been produced.

Risk assessments

In construction work, many of the hazards are obvious. Most of them can be found on almost every site. The causes of accidents are well known and often repeated. Too often hazards are just seen as an inevitable part of the job, so no action is taken to control the risks they create. Consequently, the rate of accidents and ill health remains high. Action is needed to change this.

What is risk assessment?

A risk assessment is simply a careful examination of what, in your work, could cause harm to people.

- a hazard is anything that may cause harm, such as chemicals, electricity, working from ladders, an open drawer etc;
- the risk is the chance, high or low, that somebody could be harmed by these and other hazards, together with an indication of how serious the harm could be.

The **HSE** publish a guide on how to assess the risks in your workplace

There are five steps;

Step 1 Identify the hazards

Walk around your workplace and look at what could reasonably be expected to cause harm.

Step 2 Decide who might be harmed and how

For each hazard you need to be clear about who might be harmed; it will help you identify the best way of managing the risk.

Step 3 Evaluate the risks and decide on precautions

Having spotted the hazards, you then have to decide what to do about them. The law requires you to do everything 'reasonably practicable' to protect people from harm.

Step 4 Record your findings and implement them When writing down your results, keep it simple, for example 'Tripping over rubbish: bins provided, staff instructed, weekly housekeeping checks', or 'Fume from welding: local exhaust ventilation used and regularly checked'.

Step 5 Review your assessment and update if necessary

Few workplaces stay the same. Sooner or later, you will bring in new equipment, substances and procedures that could lead to new hazards.

Check that:

- Everyone is properly trained and competent;
- They have the equipment they need; and
- Agreed work methods are put into practice.

Hazardous substances

Have you identified all harmful substances and materials, such as asbestos, lead, solvents, paints, cement and dust?

Method statements

A method statement is a useful way of recording the hazards involved in specific work at height tasks and communicating the risk and precautions required to all those involved in the work. The statement need be no longer than necessary to achieve these objectives effectively.

The method statement should be clear and illustrated by simple sketches where necessary. Avoid ambiguities or generalisations, which could lead to confusion. Statements are for the benefit of those carrying out the work and their immediate supervisors and should not be overcomplicated.

Equipment needed for safe working should be clearly identified and available before work starts. Workers should know what to do if the work method needs to be changed.

It should contain;

- The name of the person making the statement
- The names of the people responsible for the operation
- People are trained and certified
- All access equipment , safe access and escape routes should be detailed
- All equipment to perform tasks should be listed
- Details of storage should be included
- The actual work to be carried out should be clear
- Hazards need to be listed
- Relationship between trades to detailed
- Any necessary personal protective equipments stated along with barriers and signs
- Any environmental limits and conditions needed to be included
- Details of how to keep those not at work safe
- How any variation on the method statement are to be dealt with

Consider a typical rewire of a house. Prior to work commencing the contractor might reasonably:

- Provide a general description of the work, location, and timescales and provide relevant drawings.
- Consider the space within which persons are to work, including floor spaces and loft and roof access and egress. What happens, for example, should someone fall through a loft?
- Detail any specific hazards that might exist, for example, the presence of asbestos and the like.
- What toilet and washing facilities are available and is there somewhere reasonable to eat lunch etc.
- Are there any general site safety rules that should be followed? For example, how do you limit access to areas where floors have been lifted and trip hazards exist?
- What risk assessment has taken place when considering, for example, live working?

It is not unreasonable prior to starting site work, therefore, for contractors to have in place:

- Risk assessments and method statements.
- Appropriate access equipment – ladders, steps and the like.
- Appropriate power tools and test equipment – all equipment to be adequately tested and, where relevant, calibrated.
- Paperwork is in place for reporting accidents and incidents.
- Plans and processes for restoring site to an appropriate condition.
- Appropriate disposal of old equipment.

Exercise 4

1. Name as many unsafe acts as you can think of. I shall give you one to start with.
   Drinking alcohol at work.

2. Name as many unsafe conditions as you can think of. I shall give you one to start with
   Inadequate guards surrounding moving machinery

3. What is the five-stage process behind risk assessment?

4. You are to install a hand-dryer in a communal toilet block. It is to be fed from a fused connection unit (fcu) and the dryer is set 1m away from the nearest sink. The toilets are in constant use. Carry out a risk assessment and make any comments.

5. Look at one aspect of your current work practice and write a risk assessment on it. Comment on any differences between practice and theory giving reasons why they exist.

6. Get a method statement from work and check whether it meets the requirements of the list given earlier. If not, give reasons why it may not need to cover those areas.

5: Preparation for site work

In this session the student will:

- State preparations that should be completed prior to the commencement of work.

Planning the work

In the previous session we dealt with the importance of Health and safety issues such as carrying out risk and assessments and making method statements.

Gathering as much health and safety information about the project and the proposed site before work begins is important. Other sources of information include:

- the client;
- the designer
- contract documents;

See if there are any unusual features which might affect the work, or how the work will affect others. Pay particular attention to:

- The possibility of asbestos or other contaminants;
- Check the location of overhead power lines and underground services
- Will members of the public have access to the area
- What other activities are going on at the site.

Before any work commences the most important thing you will need are the site drawings and specifications. From these you will be able to produce accurate material and equipment lists compatible with the building structures and fabric.

Part of the planning procedure will be a visit to the site to confirm that the site is ready for the installation. This visit will enable you to look at the condition of the structure and fabric.

This visit will help you to confirm where storage facilities can be placed and the location of suitable washing and toilet areas.

Identifying suitable access equipment

The visit to the site will also have shown you the type of access equipment required.

The Work at Height Regulations 2005 applies to all work at height where there is a risk of a fall liable to cause personal injury. They place duties on employers, the self-employed, and any person who controls the work of others.

The Regulations state:

- all work at height is properly planned and organized;
- all work at height takes account of weather conditions that could endanger health and `safety;
- those involved in work at height are trained and competent;
- the place where work at height is done is safe;
- equipment for work at height is appropriately inspected;
- the risks from fragile surfaces are properly controlled; and
- the risks from falling objects are properly controlled.

Selecting the right means of access and work equipment

When planning for working at height that is unavoidable, the first choice will be to use any existing safe place of work that allows safe access and provides a safe working place. Where it is not reasonably practicable to work safely from the existing place of work, an alternative means of access will be needed.

Traditionally, much work has been done from scaffolding.

However, other means of access (such as MEWPs and tower scaffolds) will ensure collective fall prevention because they are equipped with guard rails.

Ladders are the last resort because they do not prevent a fall.

However, if they are used by competent people and are regularly inspected and well maintained, then their use may be justified providing it is not reasonably practicable to use other work equipment which will prevent or mitigate a fall.

People should only use a ladder, stepladder or stability device if:

- they are competent - users should be trained and instructed to use the equipment safely;
- the ladder or stepladder is long enough –
    - for ladders: don't use the top three rungs;
- ladders used for access should project at least 1 m above the landing point and be tied; alternatively a safe and secure handhold should be available;
    - for stepladders: - don't use the top two steps of a stepladder, unless a suitable handrail is available on the stepladder ;
    - don't use the top three steps of swing-back or double-sided stepladders, where a step forms the very top of the stepladder;
- the ladder or stepladder rungs or steps are level.
- the weather is suitable - do not use them in strong or gusting winds
- they are wearing robust, sensible footwear (eg safety shoes/boots or trainers).
- they know how to prevent members of the public and other workers from using them;
- they are fit - certain medical conditions or medication, alcohol or drug abuse could stop them from using ladders
- they know how to tie a ladder or stepladder properly.

It is also essential to consider what risks there may be in erecting and removing the access equipment as well as using it.

Identification of suitable lifting equipment

The Manual Handling Operations Regulations 1992, as amended in 2002 require that you:

- avoid the need for hazardous manual handling, so far as is reasonably practicable;
- assess the risk of injury from any hazardous manual handling that can't be avoided; and
- reduce the risk of injury from hazardous manual handling, so far as is reasonably practicable.

The use of lifting aids should always be considered.

Tools and equipment

Any tools and equipment selected to complete the task must be safe and fit for purpose.

The Provision and Use of Work Equipment Regulations 1998 (PUWER)

What does PUWER do?

In general terms, the Regulations require that equipment provided for use at work is:

- suitable for the intended use;
- safe for use, maintained in a safe condition and, in certain circumstances, inspected to ensure this remains the case;
- used only by people who have received adequate information, instruction and training; and
- accompanied by suitable safety measures, eg protective devices, markings, warnings.

What equipment is covered by the Regulations?

Generally, **any equipment** which is **used by an employee at work** is covered, for example hammers, knives, ladders, drilling machines, power presses, circular saws, photocopiers, lifting equipment (including lifts), dumper trucks and motor vehicles. Similarly, if you allow employees to provide their own equipment, it is also covered.

Your planning will include making sure that the right equipment is selected for the job

Many accidents happen because people have not chosen the right equipment for the work to be done. Controlling the risk often means planning ahead and ensuring that suitable equipment or machinery is available.

What is work equipment?

'Work equipment' is almost any equipment used by a worker at work including:

- machines such as circular saws, drilling machines, photocopiers, tractors, dumper trucks and power presses;
- hand tools such as screwdrivers, knives, hand saws and meat cleavers;
- lifting equipment such as lift trucks, elevating work platforms, vehicle hoists, **and** lifting slings
- other equipment such as ladders and water pressure cleaners

What do I need to do when selecting equipment?

- look at all the equipment in use, decide what can cause risks, and how.
- consider what can be done to prevent or reduce these risks.
- check whether any of these measures are in place already.
- decide whether more needs to be done.
- then do it!

Make sure hand tools are safe

Many risks can be controlled by ensuring hand tools are properly used and maintained, for example:

hammers - avoid split, broken or loose shafts and worn or chipped heads. Make sure the heads are properly secured to the shafts;

files – these should have a proper handle. Never use them as levers;

chisels - the cutting edge should be sharpened to the correct angle. Do not allow the head of cold chisels to spread to a mushroom shape - grind off the sides regularly;

screwdrivers - never use them as chisels and never use hammers on them. Split handles are dangerous;

spanners - avoid splayed jaws. Scrap any which show signs of slipping. Have enough spanners of the right size. Do not improvise by using pipes etc as extension handles.

Make sure machinery and equipment are maintained in a safe condition

To control the risk you should carry out regular maintenance and preventive checks, and inspections where there is a significant risk. Some types of equipment are also required by law to be thoroughly examined by a competent person.

Inspections should be carried out by a competent person at regular intervals to make sure the equipment is safe to operate.

Any portable tools and equipment used on site should be operated at 110 V via a transformer.

The plant required may be short or long list but will include at least the following:

- power drills
- transformers
- hand lamps
- drill bits and cutters for metal and masonry of the appropriate sizes
- steps.

The list may also include:

- conduit bending machine and vice
- cable tray machine
- circular saw
- stocks and dies
- cutting grease
- water level
- ladders
- scaffolding.

These lists are in addition to the initial assessment of the cables, clips, plugs, fixings, conduit, tray etc. that will also be needed. Remember that to have everything on site from the beginning is not always cost efficient.

When we come to dealing with Personal Protective Equipment (PPE), the plan will need to detail the equipment necessary for the work involved, as we did with the plant and equipment. The PPE list will cover the requirements of at least the following:

- boots
- overalls
- hard hats
- goggles

There may be additional needs for:

- face masks
- knee pads
- raincoats
- reflective over covers
- gloves.

Protection of fabric and structures

During the installation work methods of protecting the fabric and structure need to be planned. The walls and floors must be covered with some protective material such as wood or sheeting. Suitable barriers maybe required to restrict access. If there are items are in the area which could be damaged, they need to be removed into storage; this would have to be discussed with the client as part of the planning process.

Immediately before the installation work commences it would be sensible to visit the site again to make sure conditions have not changed and site is as agreed with the client.

Exercise 5

1. What checks would you make on a pair of wooden ladders?

2. What is the ratio used when erecting a ladder?

3. How far past a working platform, should a ladder extend?

4. At what height does it become necessary to install toe boards?

5. Which set of Regulations cover the use of access equipment?

6. What protective equipment would you wear/use for the following tasks:?
   a) Installing an exterior light at a height of 3 m during winter time
   b) Removing the burrs from a chisel using a grinder
   c) Working near to electric arc welders
   d) Drilling a row of holes along a length of steel girder at a height of 8 m.

7. You have been called out at 5.00 am to a breakdown on a motor at the end of a fish pier. It is wintertime and it is windy and raining. What would be the problems associated with working there and what precautions should you take?

8. You are rewiring a new pig hut on a farm. The half grown pigs are a constant presence. What safety gear would you wear and why?

6: Checking for pre-existing damage

In this session the student will:

- Explain how to check for any pre existing damage to customers property and to state why it is important to do this prior to commencement of the installation
- How to select suitable installation fixing and fitting methods

Pre-existing conditions

Prior to any work commencing on site, it is important that both contractor and client are clear about the condition of the existing building. Issues may arise between the client and the contractor should damage suddenly appear and one blames the other for doing it.

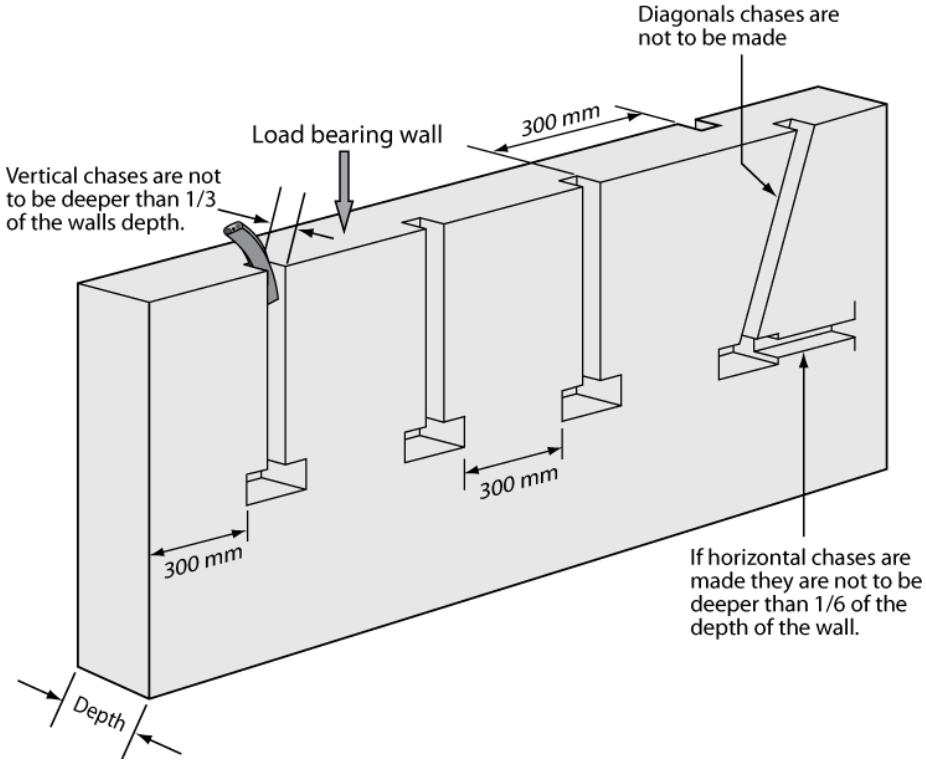
The contractor needs to thoroughly examine the structure, wall and floor fabric, equipment, components, the building decor and floor finishes, taking notes and photographic evidence if necessary. This then needs to be discussed with the client and decisions made as who will be responsible for making good, both to the existing damage, and any damage done during the installation process. The price of the job will depend on the amount of work involved in both making the structure and components sound, and the degree of making good required.

Types of structures

Load bearing walls

A load bearing wall is one which carries the weight of the structure above it as part of its function. Such a wall will, therefore, have been designed to withstand the compressive stresses created by the structure it is supporting. It will be designed to be of a certain type and thickness and seated upon specific foundations or other support means. Therefore, a load bearing wall can't just be chopped into without due consideration of its main role.

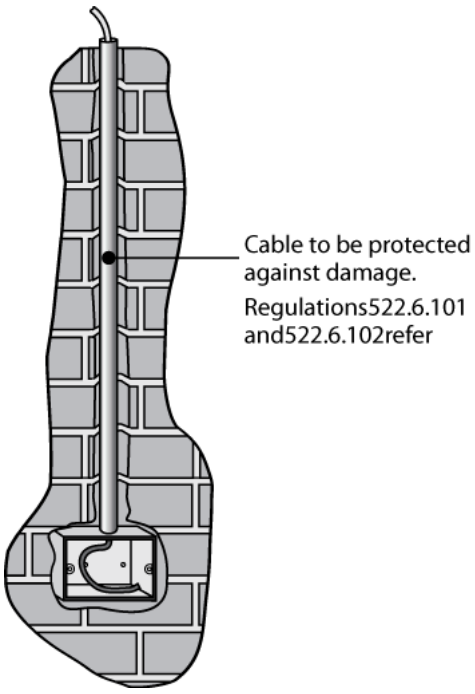
For example, if you chase down the wall in a number of places then you will have reduced the overall thickness of the wall. You should therefore not have any two chases within 300 mm of each other; this includes chases on both sides of the wall.



It is not acceptable for a chase to be within 300 mm of the end of the wall either, or for any diagonal or horizontal chases to be made.

Cables in walls

Where the cables are buried in walls and either plaster or cement rendering is used, the pvc cables should be covered in either steel/pvc conduit or some other form of tubing. This allows for repair and rewire.



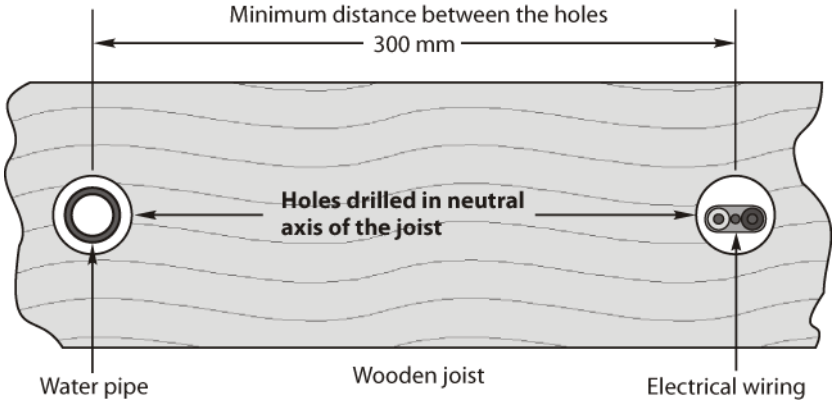
There is an additional problem with pvc cables buried in walls. When cement or plaster 'goes off' it gives off heat. The heat that is generated can be enough to shorten the life of the cable by damaging the pvc (hardens it). The pvc may well end up with a poor insulation resistance reading.

Wooden floors

Cables installed under floors or above ceilings should be installed in accordance with the requirements of Regulation 522.6.100. This requires cables to comply with one or more of the following:

- Are a minimum of 50 mm from the top or bottom of a joist.
- To be armoured in accordance with BS 5467, BS 6724, BS 7846, BS EN 60702-1 or BS 8436.
- Enclosed in earthed conduit or trunking to BS EN 61386-21 and BS EN 50085-2-1 respectively.
- Mechanically protected against damage by the use of a cover plate capable of withstand nails, screws and the like.
- The circuit is part of a SELV/PELV arrangement meeting the requirements of Regulation 414.4.

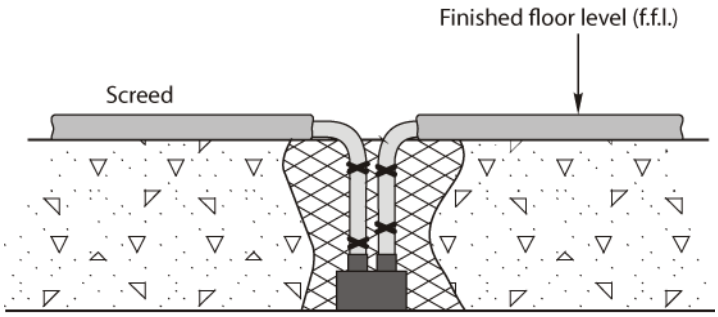
Therefore, cables should be run through the neutral axis (centre of the joist) of a joist or at least drilled to a depth of 50 mm, with any cable deviating from this being protected by steelwork of one type or another. Notching of joists is frowned on as it weakens the floor's support ability. Furthermore, if a number of holes are to be drilled then they should be separated from each other by a distance of 300 mm.



You should also be aware that cables under floors may be exposed to higher levels of heat and/or thermal insulation. You should take into account any future possibility of insulation being added.

Concrete floors

If cables are to be run in concrete floors then they should be buried in heavy gauge steel or pvc conduit. If the conduit is buried in reinforced concrete then the conduit should be fixed to the reinforcing steelwork. If the conduit is buried in the screed, then it should be fixed using crampets or pipe hooks. Any boxes should be fixed either to the shuttering or some other equally robust support. This will allow for the conduit to be kept in place whilst the laying of the concrete takes place. The boxes should also be protected from any concrete getting into them.



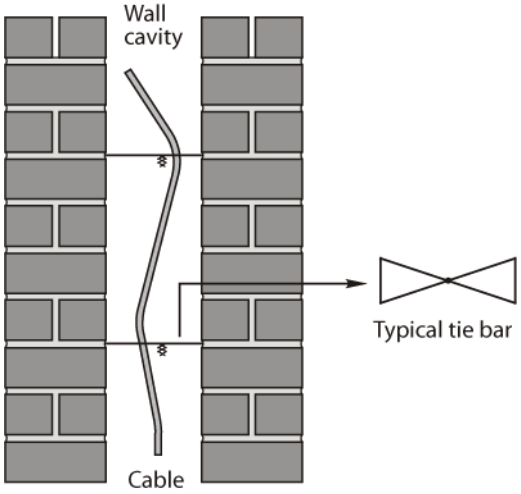
Conduit and boxes would still be fastened to the reinforcing mesh

As with the burying of cables in plastered walls, if cables are not protected by the conduit, then not only is it impossible to repair or rewire the cables without large expense and trouble, but also the heat generated as the concrete goes off would lead to possible damage to the cables.

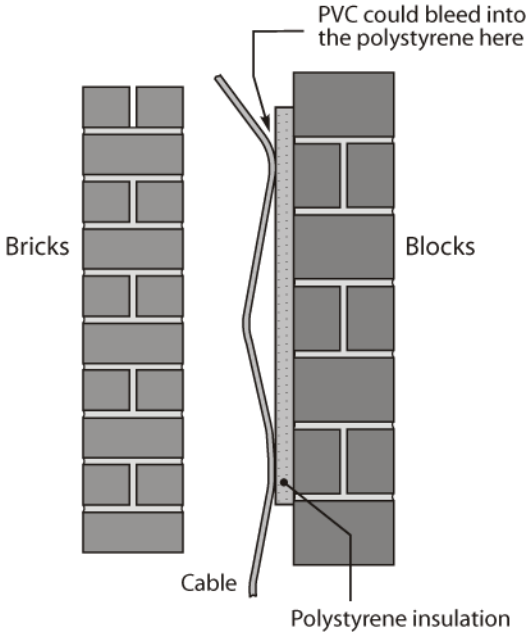
Cavity walls

Cables should preferably not be installed in cavity walls. There are four main reasons for this.

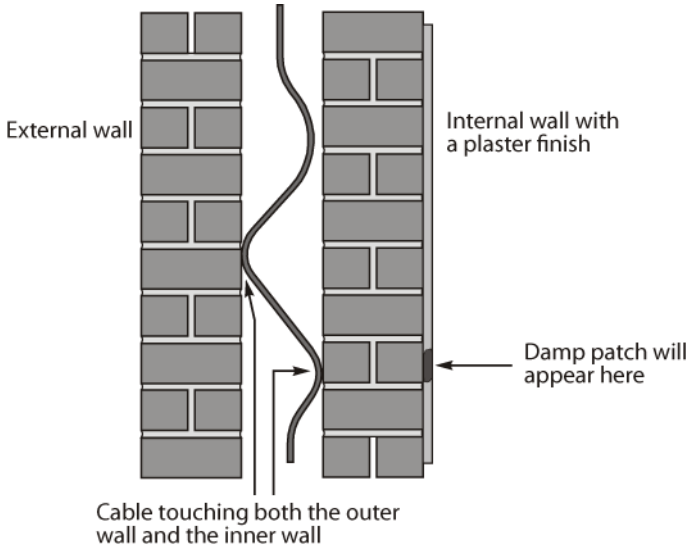
1) As the cable runs down the wall there is no certainty that you would not ‘catch’ the cable against a tie bar or some sharp brickwork.



2) As many walls now have an inner skin with a facing layer of polystyrene attached to it, the pvc can 'bleed' into the polystyrene and weaken.

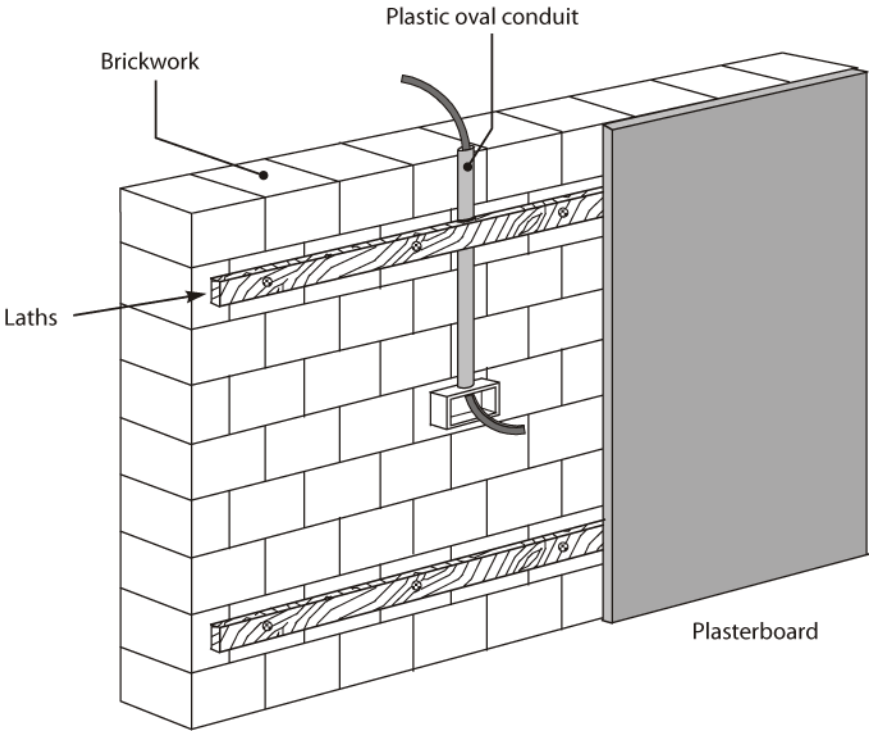


3) Cables may be expected to touch the outer as well as the inner wall. This can lead to damp patches occurring on the inner wall, and the integrity of the wall has been breached.



4) There is no certainty of knowing what will be put into the wall at a later date. For example, in many circumstances additional insulation material is blown into the wall which will lead the current-carrying capacity of the cable to be significantly reduced.

With a dry lined wall there is no real need for any additional protection and simple capping or oval tube will suffice to provide protection whilst the wall board is being put in place, and to allow for later rewire.



In a shop however, there can be shelves erected and it is not unreasonable to assume that some additional protection, such as high impact pvc conduit, may be needed in certain places.

Fair-faced walls

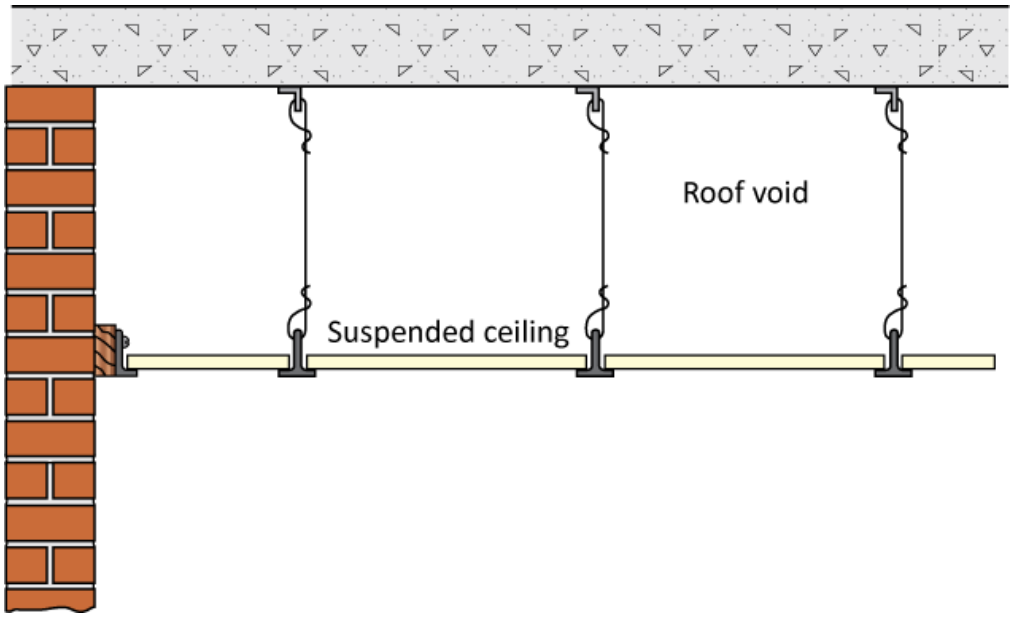
A fair-faced wall is one that is left by the builder in a particular state, whether it is because of the colour of the brickwork or some other reason. There is absolutely no way that the architect or builder is going to want your cable/conduit running down that wall. You should make sure that you can run your cables in some cupboard or in some other 'non-public' area.

If it can't be avoided, then you should begin to look for some way of disguising the cables, or using some other system for installing the necessary cable. This may mean the use of coloured cable sheath (pvc can be coloured), or placing it in places where things such as plants block the appearance. You should never just clip a pvc cable to the surface.

Roof spaces

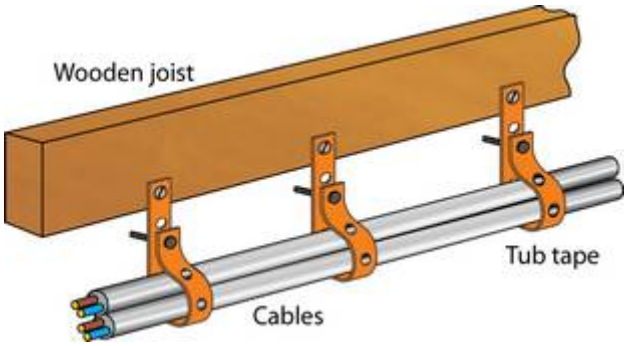
There are two types of roof spaces that you are likely to come across. One is created by the use of a suspended ceiling and the other is usually created by timber and plaster. They should be considered quite differently.

A suspended ceiling is made up of either square or rectangular tiles held together via a grid arrangement. The tiles are usually 600 mm ´ 600 mm or 600 mm ´ 1200 mm in size, and fittings can be used which fit in the grid instead of the tile.



Care should be taken however, as the grid can have very sharp edges and cables should not be run just laying on top of the tiles in the void.

Pvc cables can be installed inside the void and don't need to be installed in any conduit or trunking. They should however be supported with catenary wire or some form of '***tub tape***' (***all round band***).

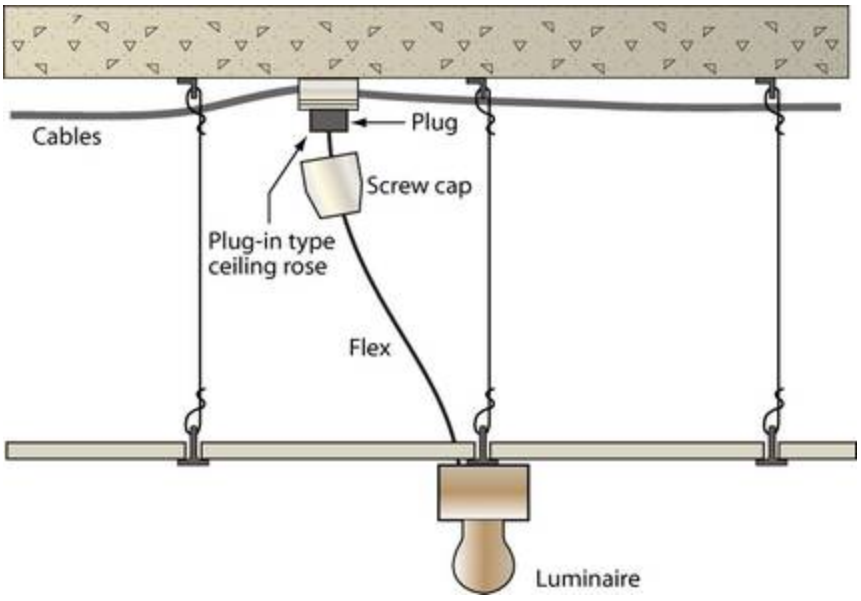


It is not necessary for cables to be run on cable tray or in trunking, however when there is some cable tray or trunking, it should be accessible from a work platform below the ceiling surface. The tray/trunking should not be fixed to the ceiling.

You should also be aware that if there is a fire and the ceiling collapses, then the cables and light fittings would also collapse.

In an accessible roof space (not a suspended ceiling) cables should be routed well away from hatches, access points and walk or crawl ways. If there is no access to the roof then it is acceptable for the cables to be left loose (not clipped) as this allows for rewiring.

You may also want to consider using plug-in ceiling roses when connecting up the each individual fitting. This allows for a much simpler maintenance procedure. Each fitting can be looked at on its own merit.

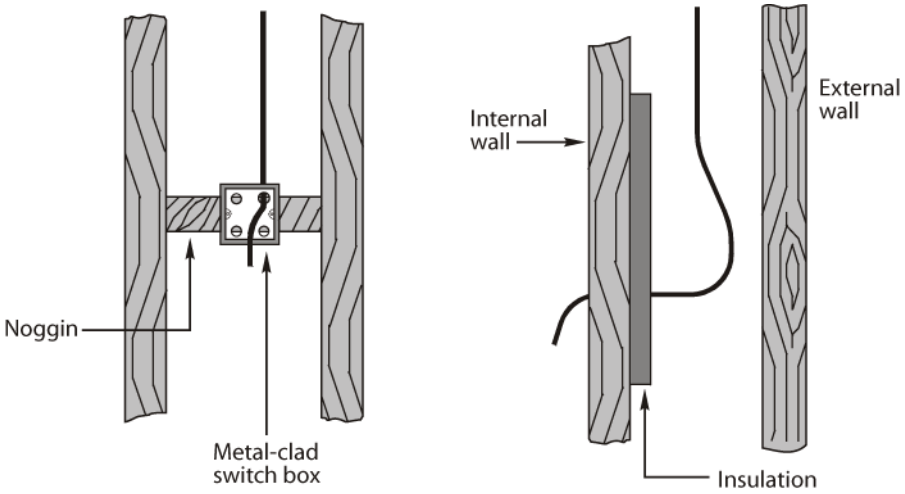


You are not required to use a plug-in ceiling rose, but in the context of a shop where people may be around when maintenance work is being carried out at a later date, it may be a worthwhile option.

Timber frames

With a timber frame property great care should be taken. It will be necessary for the contractor to liaise with the builder to make sure that any cable runs, boxes or equipment don't break any vapour barriers or external walls.

You should make sure that cables in the external wall are installed between the external timber panel and the insulation.

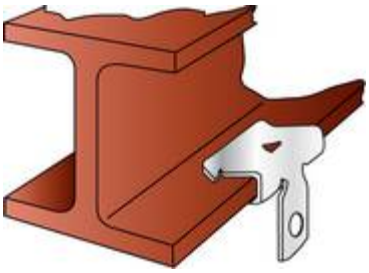


Any boxes should be entered from the rear through a drilled '***noggin***'. The members of the walls should not be notched, but can be drilled with a maximum diameter of hole of 25 mm.

Great care should be taken with the cables as they are run and there must be absolutely no damage to the insulation. Remember that wood burns much more easily than concrete!

Steelwork

Most steelwork in buildings forms part of the frame of the building. In most instances you are not allowed to drill the steelwork (RSJs-Rolled Steel Joists). There are however a large number of specialist fixings that can be clamped onto the steelwork, and in many instances you are able to use fixings created using a 'hilti' gun.



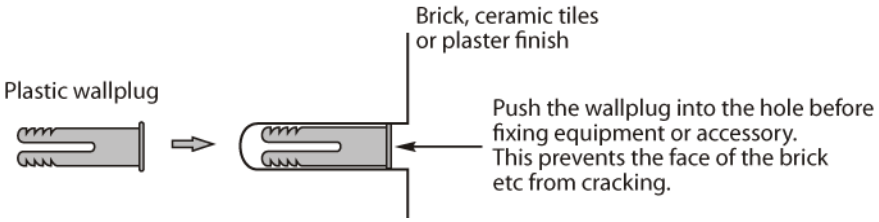
You should also be aware that most steelwork forms an extraneous conductive part and would therefore require main equipotential bonding.

Fixings

It is essential that electrical equipment is erected in such a fashion that it is adequately supported. Regulation 522.8.4 requires cables and conductors do not suffer damage by their own weight. This requires cables to be fixed appropriately. There are vast arrays of fixings that may be used. Some of them are described below.

Wallplug

There are a variety of types of wall plug ranging from plastic to nylon and fibre. They all have the same basic function however.

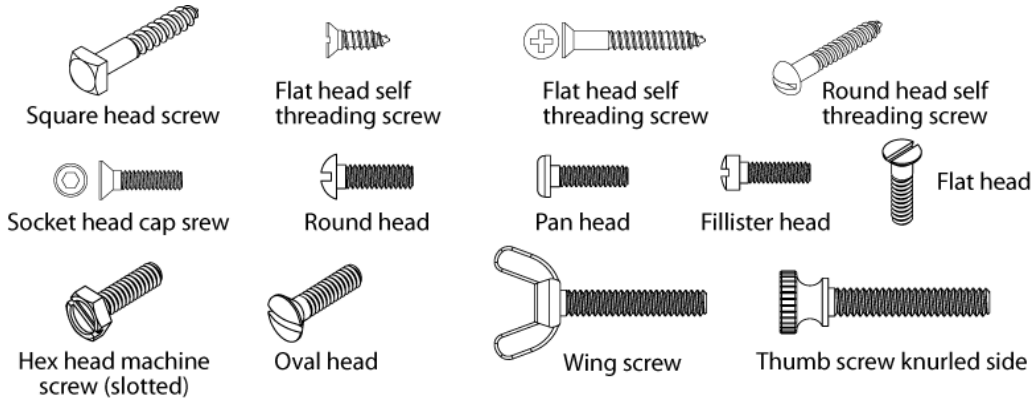


A hole is drilled into the wall (brickwork, concrete) to the depth required for the plug to be completely inserted. You should not be cutting any of the lug off to make it fit in.

The hole drilled should be just large enough for the plug to fit in. It should not be so slack that it turns around in the hole. When the plug is fitted into the hole, then the screw can be inserted.

There are a variety of types of screw and nut and bolt that are used including countersunk, roundheads and even coach bolts.

It should give you some idea of what each type of screw looks like.



Each of these screws can be used in a number of places. Where you need strength without having to worry about what it looks like, a coach bolt is ideal.

Where you need to protect conductors and where you need to be able to have screws showing then either brass or black-japanned roundhead screws are ideal. They are not as strong as coach bolts, but they are adequate for fixing conduit boxes, wall lights etc.

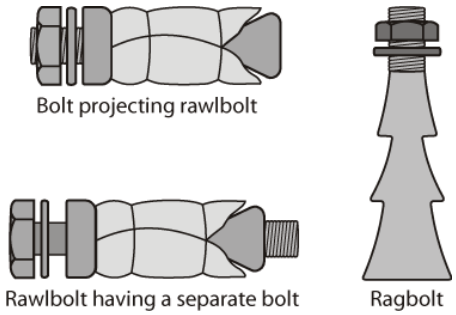
Countersunk screws can be zinc coated or plain steel. They are useful for general fixing where they are not going to be seen. Care must be taken that they don't trap conductors with their sharp edges however.

Different types of wood may require particular types of screws. For example, hardwoods require pre-drilling so that brass screws don't get damaged. Equally when fixing to oak, due to its high moisture content, it is necessary to use brass screws fitted to pre-drilled holes. The brass does not react with the moisture to the same extent as the steel screws we most commonly use.

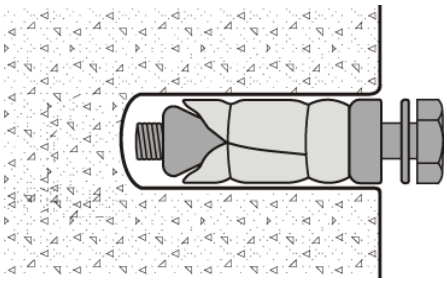
Where fixings of more strength are required, particularly into concrete then rawlbolts can be used.

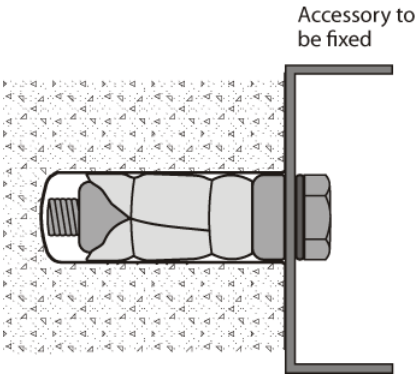
Rawlbolts

Here is a variety of rawlbolts. At the top left, we have the classic rawlbolt which has a central thread with a nut attached. At the bottom left, this rawlbolt has a separate bolt. The rawlbolt on the right is, strictly speaking, a rag bolt and operates a little bit like a rawlplug.



Here you can see that the hole has been drilled just large enough for the sleeve, with the bolt protruding from the hole.





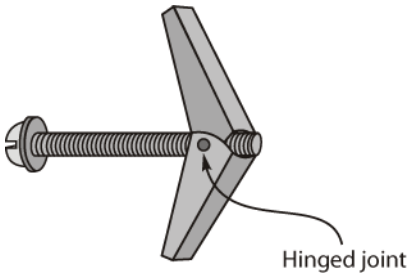
In the final image the nut has been tightened down and the sleeve has expanded. As long as the concrete holds then so will the bolt. This type of fixing is very ugly but also very strong.

The fixings described above are all to do with fixing into brickwork and concrete. Sometimes however the electrician doesn't have the luxury of being able to get a good fixing with a screw. For example, in a plasterboard ceiling, it may be impossible for a good fixing to be found in a wooden joist. It may be that a length of conduit is being fixed vertically up a wall and the wall is hollow.

There are fixings available that can deal with these problems. It is to be remembered that it isn't good enough to cut a length of rawlplug down and squeeze it into a plasterboard ceiling. Fixings must be capable of carrying the weight that is attached to them in their normal life.

Butterfly clips (spring toggle)

Here you can see that the clip is made from a hinged joint with a bolt running through it. The nut is hidden by the hinged joint.



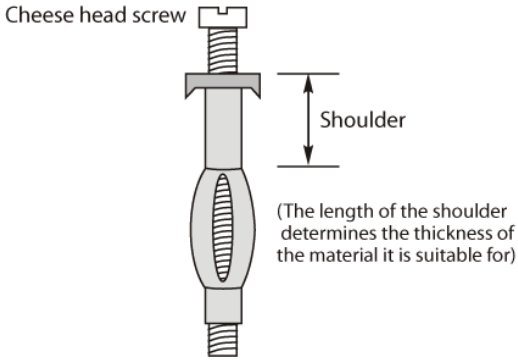
This type of clip is very useful when fixing into plasterboard ceilings where the weight is spread evenly around the fixing.

When the hinged joint is pushed through the hole in the wall the joint springs open and then bolt can then be tightened up.

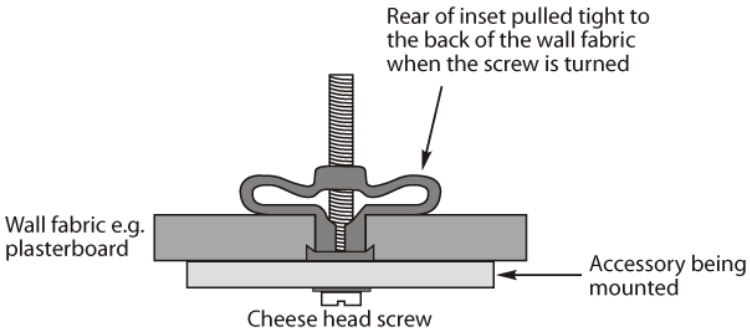
You should remember that the fixing is still only as good as the material into which it is fixed. Never try to hang too much weight on it.

Interset

This type of clip works in the same type of material as the butterfly clip.



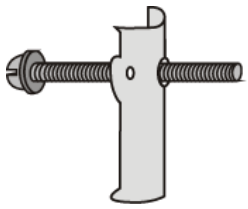
In this instance the sleeve is inserted into the wall and when the bolt is tightened up the sleeve is pulled inwards and forms a block on the inside of the hollow wall.

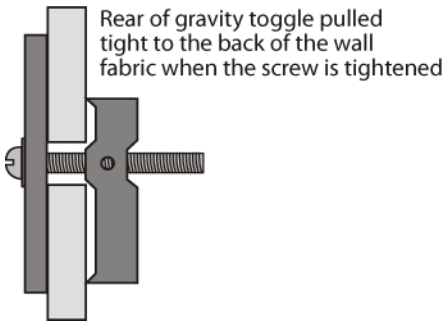


Again, this fixing is only as strong as the wall to which it is fixed.

Gravity toggle

This fixing device is used for vertical walls where gravity can play its part.





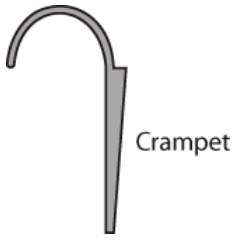
Here we can see that the gravity toggle drops when fitted through the wall, and then clamps onto the work.

Here the toggle is pushed through the wall and drops down.

The bolt is then tightened up. This gives a reasonable fixing but should only be used on walls and not on ceilings.

Crampet

The crampet is a device used to hold conduit in place that is going to be plastered over. It can be fitted into rawlplugs and into joints in the brickwork. However, it is just a holding device.



The final fixings relate to the working with metal; these are nuts and bolts and rivets.

Nuts and bolts

Nuts and bolts are found in a massive number of places. They are used to hold bridges up and keep the smallest of objects in place. They are versatile and are used in trunking and tray work.

Be aware that there is a variety of types of thread. The most common types found in electrical work are isometric and British Association *(*BA*)*.

The common metric ones are M3.5 and M4. 3.5 mm screws are found in switch and socket boxes, whilst 4mm screws are found in conduit boxes.

The common BA types, usually found in older fittings, are 0BA, 2BA, 4BA, 6BA and 8BA.

Rivets

The most common type of rivet used in the electrical trade is the 'pop rivet'. They are used most commonly in sheet metal work and are of particular use when working with trunking.

Pop rivets have to be fitted into a hole just large enough for them, they shouldn't be left so they can move about otherwise they will be too slack and the pieces of metal will move.

Rivets have to be used with a rivet gun that pulls the steel stem through the alloy sleeve, which will then form the rivet. The sleeve is crushed and the two pieces of metal are pulled together.

This has not been an exhaustive listing of all the types of fixing devices that there are; no doubt, you are aware of many more. There are certain key things that you should remember however.

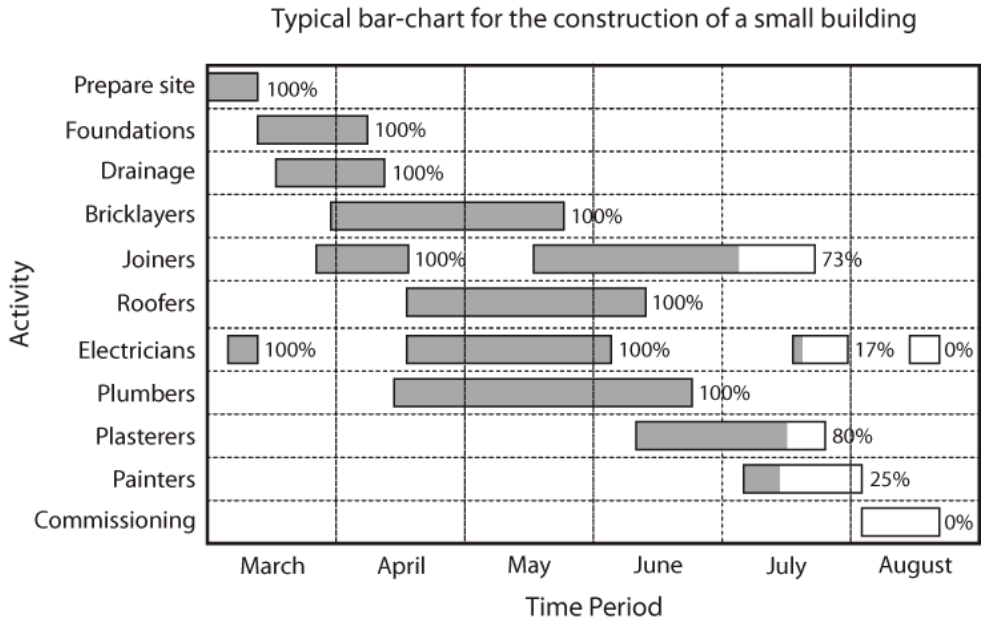
- don't take short cuts
- choose the right method of fixing for the type of material being fixed into
- If you are using any particular fixing mechanism don't take anything from it, you will weaken its ability to perform its job
- choose the right fixing for the setting. Remember, the householder is concerned with aesthetics as well as fittings being securely fastened.

Co-ordinating with other trades

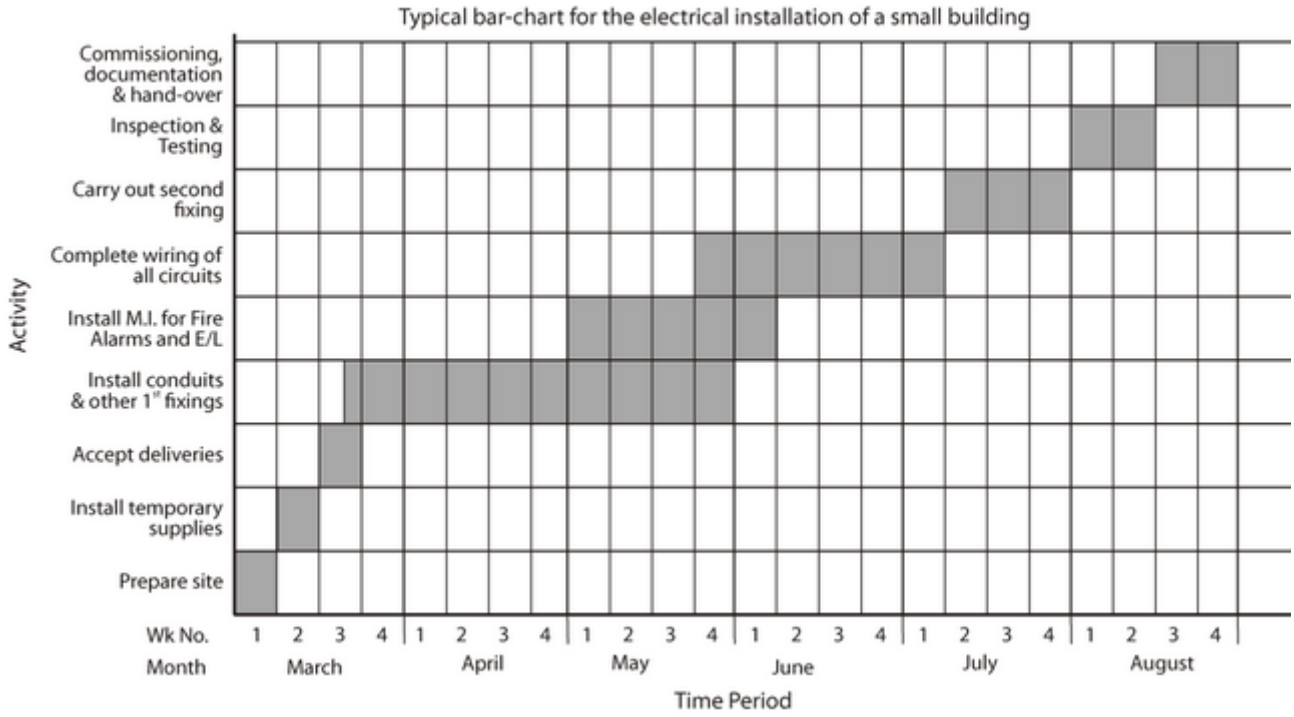
There are a variety of ways in which work activity can be planned. The first and probably simplest to understand is the Gantt chart, usually called the bar chart.

The bar chart is a means of displaying simple activities against time. They are often used on site to display the time that individual trades are operating on site at particular points in the lifetime of the contract.

You can see in this chart that the different trades come on to the site at different times and there are times when the electrical trade is not required on a site. This often occurs between first and second fixing. It is best however if this can be avoided and the people can work on a site all the time as this reduces disruption.



Bar charts show different activities but do not show the interdependence of the activities. A bar chart is a crude measure of the progress of the work. They don't give details of the individual activities for a trade.



The final element is to ensure that all necessary drawings and specifications are on hand. We cannot have the electrician/s standing around asking the plumber where to put the cables! A folder with the required specifications, drawings and risk assessments should be in place.

At various times in the installation you might be required to co-ordinate with other personnel, such as asking when would be the best time to disconnect circuits which might interrupt power supplies to computers, or other equipment. Although this might seem tedious at all times you need to be patient and tolerant. You will at other times need to discuss progress with clients or supervisors, explain what you are doing to visitors to the site, inform others when isolation of equipment or circuits will be taking place, co-ordinate work with plumbers and or plasters and carpenters. At the end of the installation you will need to liaise with the client to hand over test certificates and explain the safe operation of the work you have carried out,

Exercise 6

1. Design a simple check in and out sheet for electrical plant, such as transformers, drills etc. [Make allowance for inspection]

2. Design a simple sheet for checking out cables and accessories. [Consider the need for ordering more]

3. You are about to start work on a new installation. Make a list of the PPE that you might need.

4. An existing installation is to be rewired. The ceilings are set at a height of 6m and the rewire is to be carried out in steel conduit and trunking. List any specific items of access equipment that you might need and the safety precautions you might need to consider.

5. Consider a simple domestic installation. Write a plan for carrying out a complete rewire.

6. Make a list of the tools you would expect to use on a domestic installation.

7: Safe isolation

In this session the student will:

- Be able to specify and undertake the correct procedure for completing safe isolation.
- Be able to state the implications of carrying out and not carrying out safe isolation.

Safe isolation, amongst other things, is done to prevent people receiving electric shocks

Here is a definition of an electric shock.

> An unpleasant sensation produced by the nerves response to a passage of electric current through a part of the body.

To receive a shock you must form part of a circuit. If no circuit is present then there can be no shock.

The severity of a shock depends on a number of factors, such as age, sex, state of health, excitement, and environmental factors, particularly where there is an increase in moisture.

To help prevent shocks, before working on or near electrical circuits and equipment, we isolate.

Isolation is defined in BS 7671 as:

> "A function intended to cut off for reasons of safety the supply from all, or a discrete section, of the installation by separating the installation from every source of electrical energy."

The Electricity at Work Regulations gives information on the requirements of safe isolation. The regulation we are concerned with are;

Regulation 12

Where necessary to prevent danger, suitable means must be available to cut off supplies of electrical energy to equipment and the equipment must be isolated, defined as the secure disconnection of the electrical equipment from every source of electrical energy.

Regulation 13

The means of disconnection of the electrical must be secured in the OFF position, with a warning notice or label at the point of disconnection, and proving dead at the point of work with an approved voltage indicator.

Regulation 14

Dead working should be seen as the normal method of carrying out work on electrical equipment or circuits. Live work should only be carried out in particular circumstances where it is unreasonable to work dead.

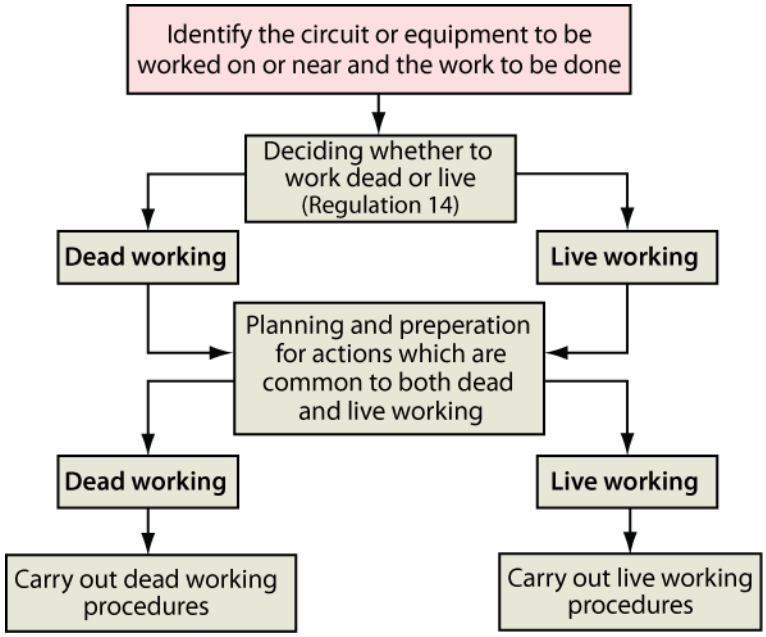
Regulation 16

Requires that no one shall engage in work with electricity unless they are competent to do so.

The HSE produce a booklet HSG85 which gives guidance on the key elements that need to be considered when devising safe working practices for people who carry out work on or near electrical equipment.

The figure below illustrates the sequence of the planning steps. The procedure can be divided into stages as follows:

- deciding whether to work dead or work live
- planning and preparation for actions which are common to both dead and live working



Actions common to both dead and live working

- Identify the circuit or equipment to be worked on or near and the work to be done
- Plan the work
- Specify correct system of work (preferably written)
- Specify level of supervision and whether accompaniment is necessary
- Select and instruct competent workers
- Ensure correct working methods
- Provide and ensure use of appropriate protective equipment
- Provide appropriate information and suitable tools and instruments for workers. Ensure they are fully instructed
- Make arrangements for management checks and supervision of work

Implement DEAD or LIVE working procedures

Dead working procedures

- Identify circuit or equipment to be worked on
- Cut off supply, isolate and secure isolation
- Retain keys. Post ‘caution’ and ‘danger’ notices
- Prove circuit or equipment dead
- Apply circuit main earth(s) where necessary
- Take precautions against adjacent live parts where necessary
- Issue permit-to-work where necessary
- Apply local earth(s) where necessary

Work on or near live conductors should rarely be permitted (regulation 14). Many accidents to electricians, technicians and electrical engineers occur when they are working on equipment that could have been isolated.

Regulation 14 requires that three conditions are met for live working to be permitted where danger may arise. It is stressed that if just one of those conditions cannot be met, live working cannot be permitted and dead working is necessary.

- it is unreasonable in all the circumstances for the conductor to be dead; and
- it is reasonable in all the circumstances for the person to be at work on or near that conductor while it is live; and
- suitable precautions (including, where necessary, the provision of personal protective equipment) have been taken to prevent injury.

It is unreasonable for the work to be done dead

There are some circumstances where it is unreasonable to make equipment dead because of the difficulties it would cause (regulation 14). For example, it may be difficult, if not impossible, to commission a complex control cabinet without having it energised at some time with parts live (but not exposed so that they may be easily touched). Also it may not be realistic to monitor the operation and performance of a control system or to trace a malfunction of such equipment with it dead, i.e. fault-finding.

Justifying live working

Providing the other requirements of regulation 14 have been met, live working can still only be justified if suitable precautions are taken to prevent injury arising from risks identified in the assessment (regulation 14(c)).

The possibility of anyone touching parts at dangerously different potentials at the same time should be avoided by installing temporary insulation or protective barriers. This may mean putting temporary insulating screens over live parts and/or applying insulation to parts that are at earth potential. Temporary screens etc can also help to prevent the risk of accidental short circuit from tools, components, conductors etc.

When work is to be carried out 'near' rather than 'on' live equipment (eg near an overhead line), the essential precautions will often be directed towards ensuring that appropriate and adequate safety clearances are established and maintained.

The people doing the work must be adequately trained and experienced in the type of live work being undertaken (regulation 16).

Live working procedures

- Identify the circuit or equipment to be worked on or near and the work to be done
- Ensure suitable precautions are taken and that suitable protective equipment is used
- Ensure adequate working space, access and lighting. Restrict access to area of live work
- Ensure accompaniment is provided if necessary. Accompaniment to be trained to give assistance

Identification of circuits to be isolated

In many cases actual physical identification will be necessary and this may be aided by the use of appropriate drawings, diagrams and other written information. You should never assume that the labelling or drawings are correct without having proved that the circuit is dead.

Suitable points of isolation

For work on LV electrical equipment or circuits, it is important to ensure that the correct point of isolation is identified, an appropriate means of isolation is used and the supply cannot inadvertently be reinstated while the work is in progress. Caution notices should also be applied at the point(s) of isolation, and the conductors must be proved to be dead at the point of work before they are touched.

The means of isolation can be an adjacent local isolation device such as a plug and socket, switch-disconnector, circuit breaker, fuse etc, as appropriate, which is under the direct control of the competent person carrying out the work. These devices can be used without further precautions provided there is no foreseeable risk that the supply could be reinstated by others.

When there is no such local means of isolation or there is a risk of reinstatement of the supply as above, the circuit or equipment to be worked on should be securely isolated by one of the following methods.

Isolation using a main switch or distribution board (DB) switch-disconnector

Isolation of equipment or circuits using the main switch or DB switch-disconnector is the preferred method. The point of isolation should be locked off using a unique key or combination retained by the person carrying out the work. In the case of multiple isolations on a DB, a multi-lock hasp can be used to prevent access to a main isolator until such time that all persons working on a system have completed their work and removed their padlocks from the hasp.

If locking-off facilities are not provided on the relevant switch then a locked DB door or locked switch-room door is acceptable provided the key or combination is unique, and is retained by the person doing the work. Again, multi-lock hasps can be used to control multiple isolations, although a key box or similar system may be needed to retain and control access to the main door key.

Safe Isolation Practice

Where it is intended that more than one person will be working on circuits supplied from a DB,

(i.e. multiple isolations) and a multi-lock hasp cannot be used to secure the main point of isolation, individual isolation of each circuit by one or more of the methods shown below is recommended, to prevent inadvertent reinstatement of the supply. The principle is that each person carrying out such work should have control of their own point(s) of isolation and not rely on others to prevent inadvertent switching on.

Neutral conductors

All live conductors must be isolated before work can carried out including the neutral conductor as this is a live conductor. The practice of ‘borrowing’ neutrals is not permitted by the BS 7671 but it is not uncommon.

Lighting and control circuits are the most common example, the neutral conductor can become live if an energised load on another circuit is added to it.

Isolation of individual circuits

Where it is not practical to isolate a distribution board, individual circuits supplied from it can be isolated by one of the methods described below, depending on the type of protective device used.

It should be remembered that work carried out inside a live DB is regarded as live working when there is access to exposed live conductors. In this case the appropriate precautions should be taken.

Isolation of individual circuits protected by circuit breakers

Where circuit breakers are used the relevant device should be locked-off using an appropriate locking-off clip with a padlock which can only be opened by a unique key or combination. The key or combination should be retained by the person carrying out the work.

Isolation of individual circuits protected by fuses

Where fuses are used, the simple removal of the fuse is an acceptable means of disconnection. Where removal of the fuse exposes live terminals that can be touched, the incoming supply to the fuse will need to be isolated. To prevent the fuse being replaced by others, the fuse should be retained by the person carrying out the work, and a lockable fuse insert with a padlock should be fitted as above. A caution notice should also be used to deter inadvertent replacement of a spare fuse.

Safe isolation

For the testing of a potentially live source, two pieces of test equipment are required. These are:

Approved voltage tester

Voltage proving unit.

Guidance is provided by the HSE in the form of Guidance Note GS 38 ‘Electrical test equipment for use by electricians’.

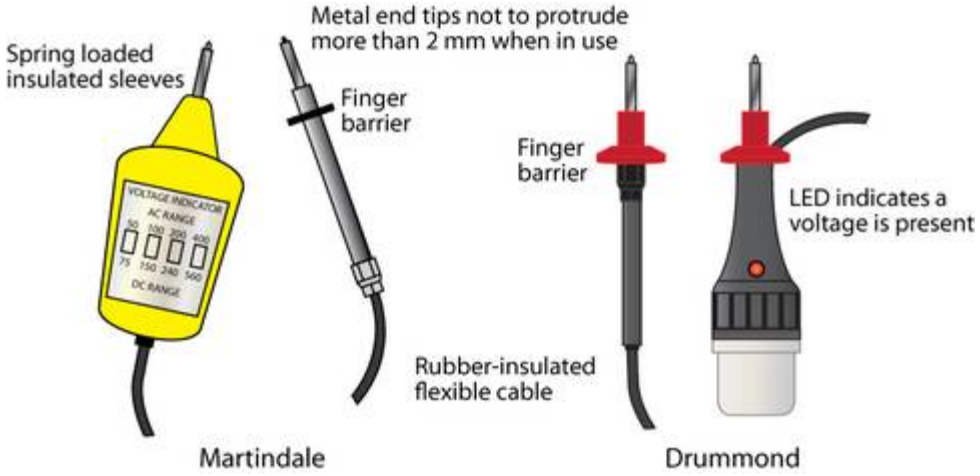
GS 38 reminds electricians of current legislation and their responsibilities relating to the equipment used, the requirements for live working and the nature of the work practices. GS 38 also provides a set of values that should be followed for test leads. In this instance, it is reasonable to assume that an approved voltage tester falls into this criterion. Many of the following will apply to an approved voltage tester, although not necessarily all.

Remember that GS 38 applies to all test leads.

- Adequate insulation. This may depend on the environmental conditions present.
- Have coloured leads to distinguish one lead from another.
- Have finger barriers to stop accidental slipping of hand.
- Be insulated so that the tip of the probe shows no more than 4 mm of bare metal; it is strongly recommended that this is kept to less than 2 mm.
- Be flexible and robust enough for their use.
- Be sheathed to prevent mechanical damage.
- Be long enough for their purpose.
- No part accessible to fingers, even if a lead becomes loose.
- Have fused leads.

You can see that a neon screwdriver does not meet any of the above criteria.

Obviously, there are many varieties of voltage tester and as long as they meet the requirements of GS 38 then you will be fine.



A tester is no use if we cannot guarantee its effectiveness. This is where the proving unit comes into its own. All equipment should be regularly checked to make sure it is good safe working order.

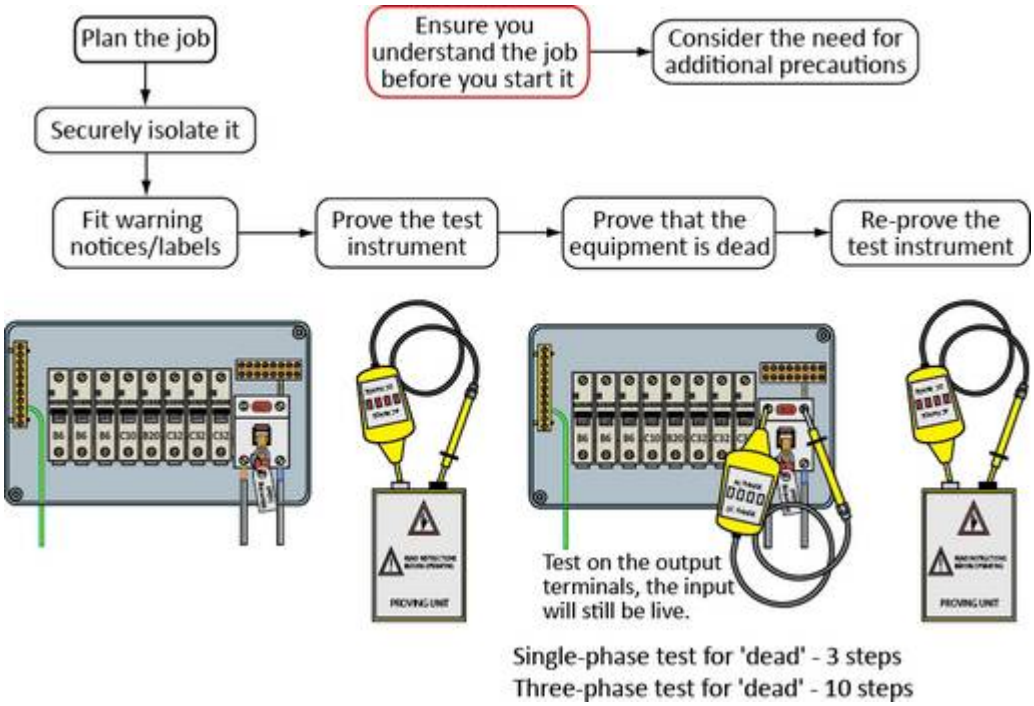
A proving unit is a d.c. voltage source that checks its own status and is then a known reference voltage against which the voltage tester can test itself. Without this, we cannot guarantee the voltage tester, at which point it is useless.

The process of safe isolation

The process for safe isolation of a complete isolation is to find the point to be isolated, decide on the means of isolation, then check that it is safe to isolate, if necessary get permission to isolate.

The process for safe isolation on individual circuits is similar, but you may need permission to remove any loads.

The diagram below shows the procedure you should use for the safe isolation of a piece of equipment or plant.



Warning notices and locking devices for secure isolation

The implications of carrying out safe isolation to self, other personnel, customers, the public and building systems are great. The correct procedures must be carried out at all time. Plenty of notification needs to be give before any circuit is isolated, the consequences could be disastrous if for example you left an operating theatre in darkness or a computer suite with data which wasn't backed up. In some circumstances machinery might suddenly start or stop without warning causing danger to operatives or those using it. To keep yourself safe, no short cuts must be made, the isolation procedures have been developed for a reason.

Re-energising equipment or a circuit

Before re-energising equipment or a circuit you should Inspect and test the work that has been carried out and then inform others.

Exercise 7

1. At what levels of current are you likely to be in danger of death?

2. How does d.c. and a.c. current affect a person?

3. List the procedure for the safe isolation of a supply.

4. List the elements that go into making up a good voltage tester.

5. Why is it necessary to have a voltage proving unit?

6. Why is it important that you seek permission prior to switching of a circuit or fuse board?

7. Give two examples of why it might be necessary to work live.

8. Describe how you would isolate a distribution board located in the refectory of a typical college. List the items of equipment you will need for this task.

8: Types of cables

In this session the student will:

- State the constructional features, applications, advantages and limitations of various types of cable.

In this session we will start to look at wiring systems. The term 'wiring system' generally means cables such as PVC, SWA, MICC and XLPE.

The term 'wiring enclosure' refers to the conduit, trunking, tray and baskets that hold the wiring. We will look at that later.

Insulators and conductors

To correctly choose the right cable for an electrical installation is very important. There are various factors to consider.

- The conductor material
- The conductor size
- The insulation
- The wiring system it will be installed in
- Any environmental factors

Conductors

In the electrical industry there are a wide variety of conductors and insulators that are commonly used, and there is a whole science linked to each area. Typical conductors include:

- copper – by far the most common
- aluminium
- brass
- silver
- steel
- cast iron
- mercury
- tin
- bronze.

The two main metals used for electrical conductors are copper and aluminium.

Different metals are used for a variety of reasons that relate to their specific properties. These will include how good they are at allowing current to flow, but also will include the strength, malleability, density and their ability to withstand chemical attack. Conductors are usually stranded or solid.

Solid conductors are cheaper to manufacture but harder to install because they are not very pliable.

Conductor	Advantage	Disadvantage
Copper	Easier to joint and terminate	• More costly • Heavier
Aluminium	• Cheaper • Lighter	• Bulker • Not recommended in hazardous areas

Stranded conductors are made up of individual strands that are brought together in set numbers (3.7.19.37)

Cable insulation

BS 7671 has changed the way it shows cable insulation types, you just need to look at appendix 4 to see what is meant by this. Instead, the insulation of a cable is shown under its generic properties of the material such as 'thermoplastic' and 'thermosetting'. This makes it easier for the designer to select the most appropriate cable type for its ability to handle specific conductor operating temperatures.

Thermoplastic insulation

Thermoplastic is also known as thermosoftening and is a polymer that becomes pliable or able to be molded above a specific temperature and return to a solid or hard state upon cooling.

> A simple analogy to a thermoplastic is a chocolate bar. When a chocolate bar is melted, it has the ability to take on a new shape as it cools. This ability to be molded again and again is characteristic of thermoplastics.

When very cold thermoplastic insulation becomes very brittle, and it is for this reason that cable having this type of insulation should not be installed in cold conditions.

Thermosetting insulation

A simple analogy to thermosetting insulation material can be described as being similar to a birthday cake. Once a cake is baked, it takes its final shape. Baking it longer does not increase or decrease the size of the cake. Ultimately if enough heat is applied, it will burn, but not melt like a chocolate bar. This particular characteristic is why thermosets are useful as durable materials that do not soften under high heat, such as car tyres or flat roofing membranes.

Thermosetting materials are created from thermoplastic polymers by a process called curing. During the curing process, the long, individual polymer chains of the thermoplastic become cross-linked by smaller molecules and these are often referred to as cross-linked material. When you see an "XL" in front of an abbreviation for a plastic such as polyethylene (PE), it means that it has been cross-linked, not that it is "extra large." Such thermoset materials are called crosslinked polyethylene or XLPE.

Choosing a material for an application

Knowing that the key difference between a thermoplastic and thermoset is in the way they respond to high temperatures, can be an important aspect of which material to choose. For example, thermoset materials are often chosen for circuits that may experience an overload. This is because thermoset materials have a reduced likelihood of failure if momentarily operated at the higher temperatures that often accompany an overloaded conductor.

Comparatively, thermoplastics are often easier to strip, which makes them easier to process on automated equipment for large volume applications.

Types of cables

Thermoplastic insulated, cable is the most common type used in the UK today. It comes in a variety of shapes and sizes:

Singles

General type is the 6491X which has a thermoplastic insulation, it is commonly installed in surface mounted or embedded conduits or similar closed systems and for fixed protected installation in or on lighting fittings and inside appliances, switchgear and control gear. Operating temperatures: maximum 70°C, and minimum for installing and/or bending 0°C. Use Table 4D1A for current-carrying capacities.

There is a thermosetting insulated cable coded 6491B. This is LSOH which is an abbreviation of low smoke zero halogen. The typical applications are for power & lighting circuits and building wiring. Operating temperature**s:** maximum is 90°C, and the minimum for bending purposes is -15°C.

Use Table 4E1A for current-carrying capacities.

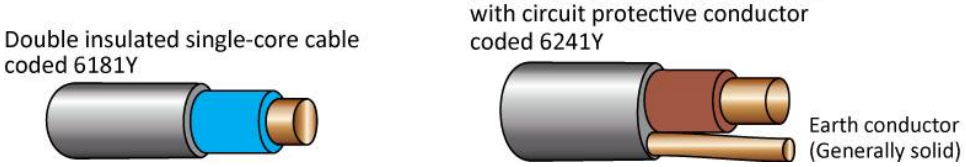
Some local authorities may require this type of cable to be installed in special installations as black smoke from PVC cables can obscure exit routes in the event of a fire.

Low smoke cable has a halogen sheath to prevent poisonous gases and is recommended in enclosed public areas.

There is also Tri-rated cable panel wiring, this is a high temperature, and flame retardant cable designed for use in the switch control, relay and instrumentation panels of power switchgear and for purposes such as internal connectors in rectifier equipment, motor starters and controllers. Tri-rated cable is sometimes referred to as BS6231 Cable or Panel Wire.

Double insulated singles (one conductor covered in two layers of insulation)

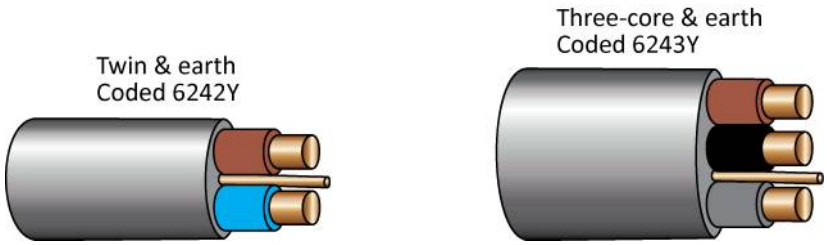
This is used for general building wiring.



Multi-core cables

Used for general wiring mainly in a domestic setting. The outer sheath can be red, white or grey.

Tables 4D2A are used to for the current carrying capacities.



There are a number of advantages and disadvantages to this type of cable.

Advantages	Cheap to install – No special techniques need to be used during installation, so costs can be kept low. Insulation is waterproof – No need to worry about water and electricity mixing. We are not talking about the connections here though. Long-life time – Should last at least 30 years under normal service. Easy to install – No special techniques. Cheap to buy – prices vary from wholesaler to wholesaler but good price discounts can usually be negotiated for the contractor.
Disadvantages	Insulation becomes brittle below 4 ˚C Insulation becomes soft above 60 ˚C Poor mechanical strength – Don't hit it with a lump hammer! Affected by sunlight

Notice that many of the advantages are to do with the type of insulating material used.

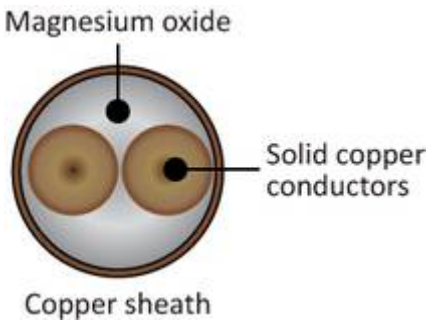
Mineral insulated

MICS (***Mineral Insulated Copper Sheathed***) cable generally consists of copper conductors insulated with compressed ***magnesium oxide*** (***MgO***).

Magnesium oxide

Magnesium oxide is a white powder used as on insulator in mineral insulated cables

Advantage	Can withstand high temperatures The metal sheath means it can withstand mechanical damage
Disadvantage	Must be protected from damp as the magnesium oxide is homogeneous

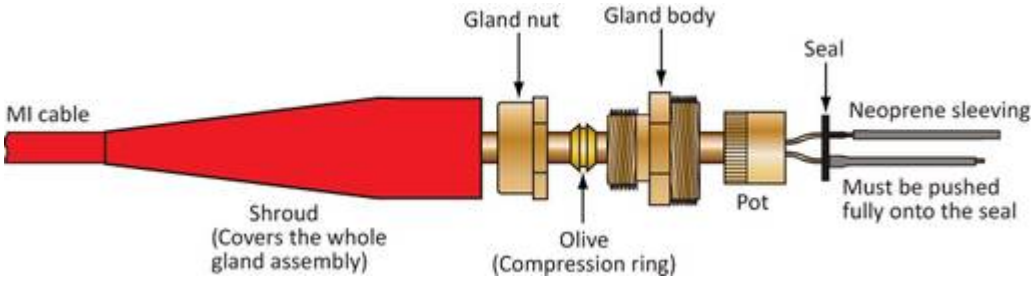


The MI sheath is made of copper and is unaffected by oil, water and will withstand high temperatures. Depending on the type of seal used it can operate at up to 250 °C. After this temperature has been reached the copper sheath oxidises more quickly, although for short periods it can withstand temperatures of 1000 °C.

The sheath is commonly made of a slightly different type of copper to the conductors. However, there are circumstances where, because of the need to run the cable at higher temperatures than 250 °C, that stainless steel or alloy is used, along with special types of conductors.

The cable comes with 1, 2, 3, 4, 7, 12 or 19 conductors, and can range in size from 1.0 mm^2 to 400 mm^2. The cable can be ***light duty*** (500 V) or ***heavy duty*** (750 V). They can be told apart by the thickness of the sheath. Generally at sizes over 4.0 mm^2 the cables are heavy duty.

One of the benefits of MI is its ability to withstand mechanical impact.
The tables to use for the current carrying capacities of this cable are 4G1A and 4G2A.
The diagram below shows an exploded view of the termination arrangement.

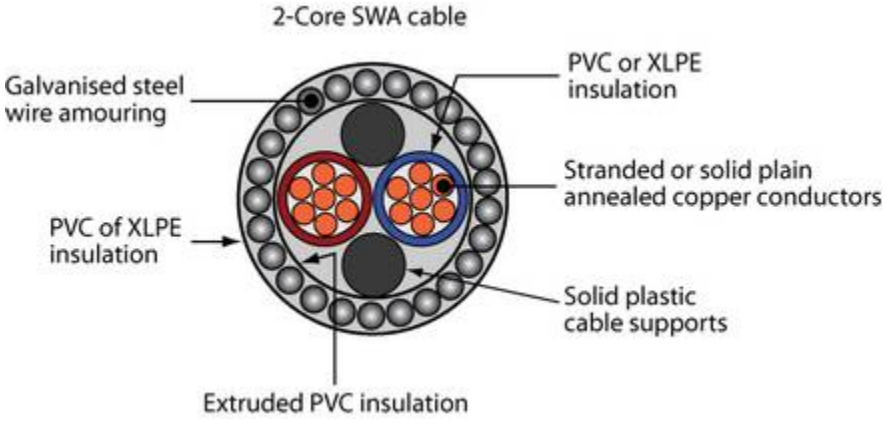


Armoured cables

XLPE

XPLE or cross linked polyethylene is a thermosetting, industrial wire. It has high mechanical strength under high temperature Can be clipped to surface, on trays or in free air where there is little risk of mechanical damage. Suitable for laying into trunking or conduit etc. when mechanical protection is required.

You can see from the diagram that a steel-wire armoured (swa) cable is very different to the type of pvc cables looked at earlier.



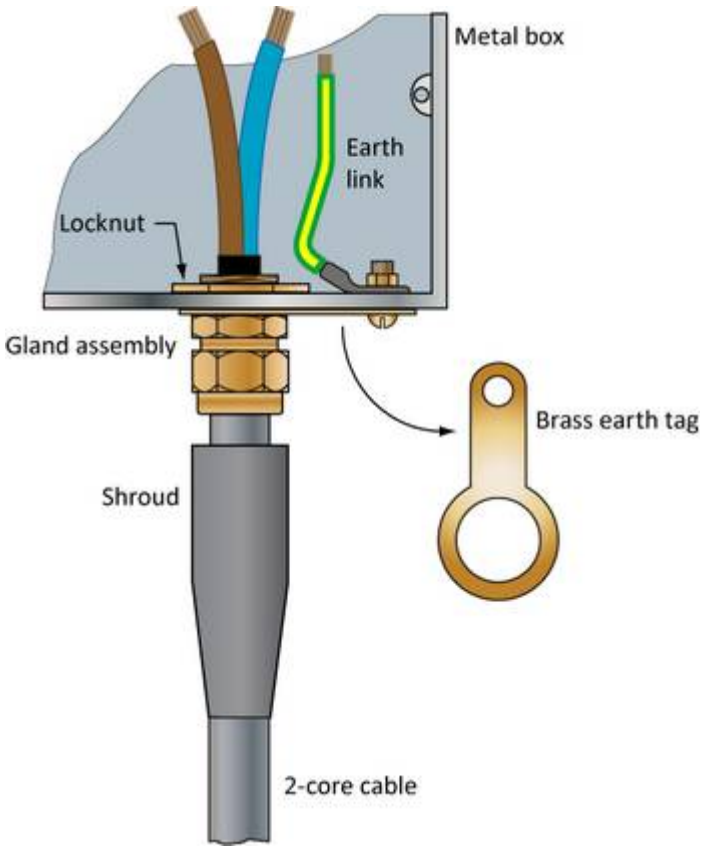
Notice that the cable has an outer layer of cross-linked polyethylene (XLPE); the next layer is made up of stranded steel wire, after which the inner conductors are insulated using pvc. So there are three main layers of covering. Sometimes there is also a further layer of pvc wrapping.

This type of cable is not as common as the thermoplastic insulated and sheathed cable but it has a wide range of uses; main and sub main cables, control circuits etc. It can come in a wide variety of shapes and sizes, from multi-core (21 cores for some) and as large as 300 mm^2 and more. Some of these cables feel more like pipes than cables.

The tables lists some of the advantages and disadvantages.

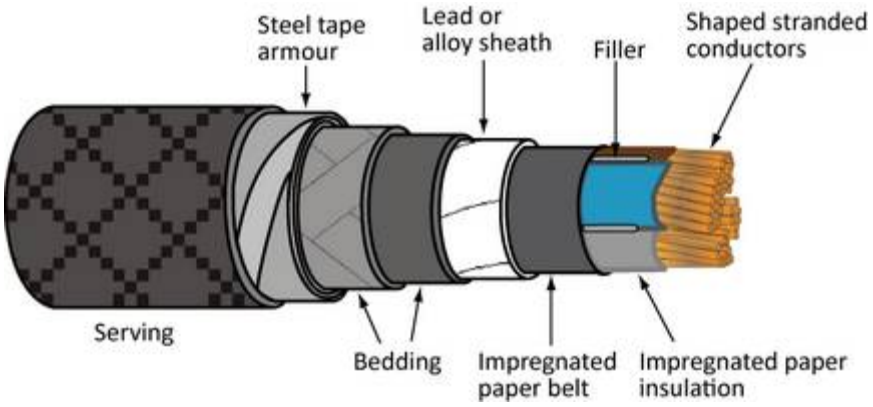
Advantages	Good mechanical strength. Wide variety of choice over type. Can use the armouring as a cpc.
Disadvantages	Expensive to buy. Expensive to install. Large and heavy at times. Require specialist terminations.

You can see that a swa cable requires a particular way of terminating it. The techniques will be shown in your workshop sessions and in the work place.



Instead of the brass earth tag a piranha locknut is used. These earth nuts speed up the installation of cable glands by replacing the earth tag and lock nut to provide a high integrity earth connection. Incidentally, these locknuts are used in the AM2 assessment!

PILC (paper insulated lead covered) is used mainly for supply systems. The paper is impregnated with oil to improve long term performance



Advantage	Good insulator
Disadvantage	Needs special joint methods to prevent the seal being broken

Armoured braided cable

This generally describes SY cable which is used in industrial control and in instrumentation circuits, they are also ideal for automated equipment and many other applications where good flexibility is essential.

They generally require special glands for termination but it is quite common to use compression glands. The technique of terminating this will be demonstrated in the workshop sessions and/or in the workplace.

Data handling cables

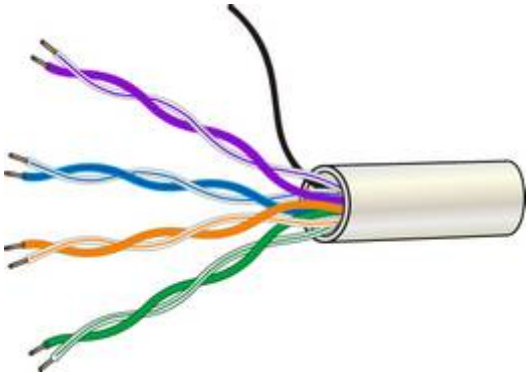
There are five main types of cable available for data networking:

- unshielded twisted pair – UTP
- shielded twisted pair – STP
- screened twisted pair – ScTP
- coaxial
- fibre optic.

It is also worth recognising the difference between those cables that are used for the backbone of the system which connect together servers, switches and routers, and those which connect from the communication room to the wall outlets. The backbone in new installations will commonly be fibre-optic, whilst the cable used to link to the outlets will commonly be UTP cables.

UTP (Unshielded twisted pair)

Twisted wiring is cheap to buy and install with the tools necessary also being less costly than that used for fibre-optic cables. The purpose of the twisting is to reduce noise.

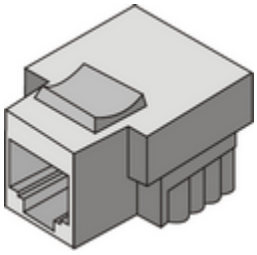


UTP came into common use in LANs (Local Area Networks) with the introduction of Ethernet. Ethernet allows many different devices to connect to the network and is a communications system that enables data to be managed without crashing the system.

There are a number of types of UTP. These are split into categories and are defined by the amount of data they can handle.

- **Category 1** – usually supplies frequencies less than 1 MHz and are used for phone lines
- **Category 2** – supports frequencies up to 4 MHz and is not usually installed
- **Category 3** – supports frequencies up to 16 MHz and was commonly used in the 1980's
- **Category 4** – supports frequencies up to 20 MHz but was quickly replaced by category 5
- **Category 5** – supports frequencies up to 100 MHz and is the common type of cable in use to day
- **Category 6** – supports frequencies up to 500 MHz
- **Class F** – supports frequencies to 1000 MHz

Connectors matter! A loose connection or the wrong type of connector will lead to intermittent connection errors once your system is running.



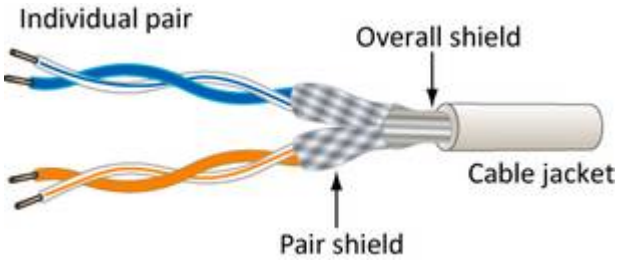
To get the best from your UTP connection you should ensure:

- when connecting to plugs and sockets never untwist more than 12 mm of Category 5 cable
- always use connectors, wall outlets and panels that are compatible with the cable used
- terminate all four pairs so that your system has an element of future-proofing built in.

The real benefits to UTP are cost and size. If the installation is sloppy then UTP will not be able to carry what it's designed for. It should also be run well away from power circuits where electromagnetic interference can affect the signals.

STP

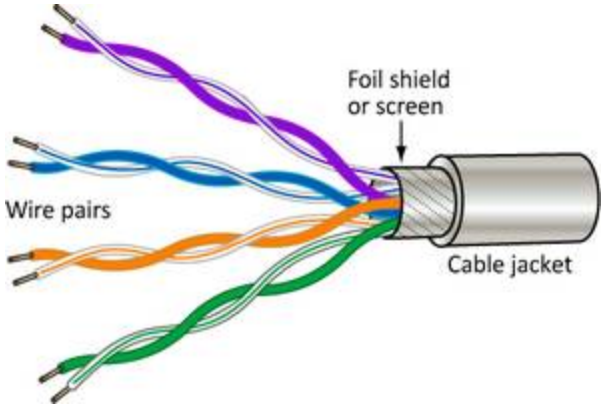
Shielded twisted pair cabling has some clear advantages over UTP. It can carry a wider range of frequencies and is less affected by external electromagnetic sources.



To guarantee a minimum of electromagnetic interference from other sources the STP must:

- have the shield electrically continuous for the whole length
- all components must be shielded so no mixing of UTP and STP
- the shield must enclose both the twisted pair and the core
- the shield must be earthed at each end.

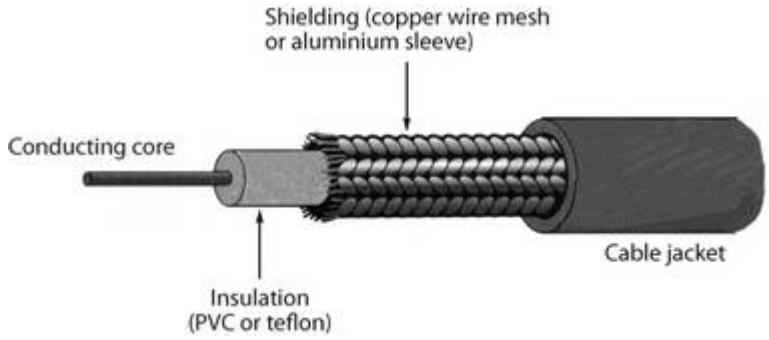
ScTP



You can see that we have a type of hybrid of some elements of UTP and some of the STP. The foil shield is earthed and surrounds all four pairs of twisted pairs. Effectively we have STP shielding four unshielded pairs, this allows for the cable to reduce in size.

Coaxial

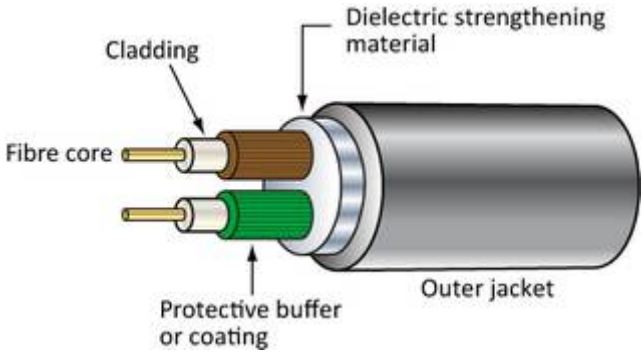
This used to be the most commonly used cable for networking. Coax is more difficult to run and usually more expensive than UTP/STP. Its real advantage is that it has a very wide bandwidth and can handle large amounts of data. In addition it is less susceptible to electromagnetic interference as it has an inherent screen.



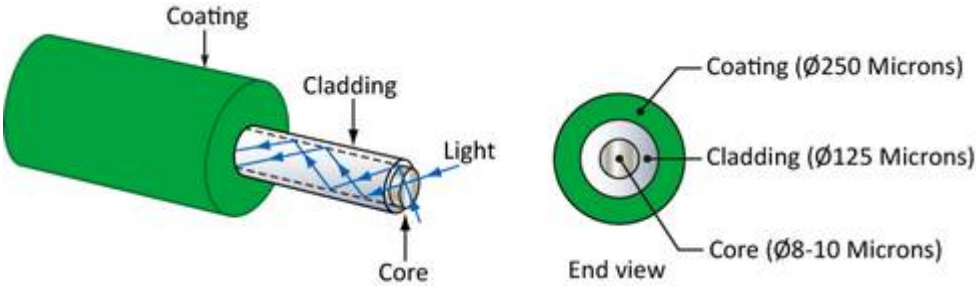
There are a number of different types of coax and the choice of the type will depend on the quality of the data needed to be transmitted and the distance over which that data must be transmitted.

Fibre-optic

All the cable types we have considered so far have had one thing in common – they are copper and carry an electric current, after all that is what a signal is! With fibre-optic cabling not only the cable changes from being made of copper to being made of glass, but the means of transmitting the signal changes from electricity to light.



In effect a light source, usually a laser beam or LED, sends a signal down a very thin length of glass. The light source flashes on and off in the pattern of the electrical signal.



There are some very real advantages to the use of fibre-optic cabling:

- greater data transfer rates
- no electromagnetic interference
- longer lengths of run
- data security is stronger.

The disadvantages are also worth listing:

- high cost of cable and installation
- difficult to install
- health risk during installation.

There is a health risk to the installation of fibre-optic cables. When they are stripped then a shard can pierce the skin, enter the blood stream and even be carried around the body. In addition the fibre can pierce the eyeball causing serious damage.

The types of connectors used in fibre-optics also vary according to the need. However, you should be conscious that the installation of fibre-optic cables is highly specialised particularly when they have to be joined together.

Fire resistant cables

Mineral insulated cables are good for this category but there are specialist cables as well.

FP100

FP100 Cable is a resistant single core cable for use in metal conduits or trunking to achieve a highly robust fire resistant wiring system. It maintains circuit integrity during a fire. When burnt, it produces very low levels of smoke and virtually no (less than 0.5%) acidic gases, thus safeguarding human life and protecting equipment.

FP 200 Gold

This cable is a Multicore fire retardant cable suitable for surface use or within plaster walls for both indoor and outdoor applications. The insulation is fire resistant and is virtually non-ageing up to a temperature of 90°C. Suitable for use with fire alarms and emergency lighting circuits.

FP 400

FP400 is a tough, armoured, fire resistant power cable for essential safety circuits associated with fire detection, fire alarm and emergency lighting. In particular for use in power supplies to safety systems. FP400 maintains circuit integrity during a fire, produces very low levels of smoke and virtually no acidic gases (less than 0.5%) - This safeguards human life and protects equipment.

FP400 handles like a standard armoured cable and can be installed just as easily. No special tools or accessories are needed to install or terminate FP400 and that ensures substantial installation cost savings over traditional MICC.

FP400 is suitable for indoor or outdoor use and may be installed by direct burial, trough, fixed direct, tray or ladder.

Below is a table showing the types of cable and how they might be used

Fixed wiring cables

BS No.	Insulation	Construction	Conductor	Uses
6004	pvc	pvc singles	Copper, solid or stranded	Conduit, trunking where mechanical protection is provided. Should not be immersed in water, covered with plaster or concrete.
6004	pvc	pvc multi-core, non-armoured.	Copper, solid or stranded.	Trays, ladders, cleats, where mechanical damage is unlikely. Can be embedded in plaster, not in concrete.
6346	pvc	SWA or aluminium strip with pvc covering, single and multi-core	Copper or aluminium, solid or stranded	No restrictions. Can be used in ground without additional protection if covered with pvc. Singles must have aluminium armouring.
4553	pvc	Split concentric single-line and earth	Copper, stranded	General use including underground.
6231	90°C pvc	Non-sheathed singles	Copper	High temperature locations in control and equipment wiring.

7211	Thermosetting, LSF type	Non-sheathed singles	Copper	Above ground locations in conduit or trunking.
5467	Elastomeric: xlpe, EP rubber	Armoured	Copper or aluminium, stranded	As for BS 6346 cables, but at higher temperatures. Care to be taken when run with lower temperature cables.
6724	Elastomeric: xlpe, EPR	Single and multi-core armoured	Copper or aluminium	Dry conditions to minimise smoke and corrosive gases during fires.
6007	Elastomeric: vulcanised rubber, butyl or EP rubber, silicone rubber	Non-armoured single-core with various coverings. Multicore, flat or circular with elastomeric sheath	Copper, aluminium, stranded.	High ambient temperatures. Braided coverings for dry conditions only. Sheathed cables resistant to some oils and solvents. Can be obtained with lead sheath where corrosion is severe.
6141	Rubber or pvc, operating up to 150°C	Non-sheathed singles. Sheathed two- and three-core cords	Copper, tinned, stranded, small sizes.	High ambient temperatures. Non-sheathed to be mechanically protected.
6500	Flexible cords, rubber, pvc or glass fibre	Sheathed and unsheathed multicore	Copper, flexible	Connection to hot equipment and industrial applications. Up to 150°C
7269	Thermosetting	Sheathed, two-, three-and four cores, plus cpc	Copper	Alarm and emergency lighting. Above ground.
6207	Mineral	Copper sheathed with or without pvc	Copper (solid)	General wiring, high temperatures, alarm and emergency circuits. Good for low temperatures.

Flexible cables

Type	Uses
Light pvc insulated and sheathed	Households and commercial for light duty.
Ordinary pvc insulated and sheathed	Household and commercial for damp and medium duty. For cooking and heating where not in contact with hot parts. For outdoor use, but not industrial or agricultural. Hand tools.
60 °C rubber insulated braided twin and three-core	Household and commercial for low mechanical stresses.
60 °C rubber insulated and sheathed	Household and commercial for low mechanical stress. Occasional outdoors use. Hand tools.
60 °C rubber insulated oil-resisting and flame retardant sheath	General. Fixed installations protected by conduit.
85 °C rubber insulated HOFR sheathed	General, including hot situations-immersion heaters etc.
85 °C heat resisting pvc insulated and sheathed	General, including hot situations-pendants.
150 °C rubber insulated and sheathed	High ambient temperatures. In or on luminaires.
185 °C glass-fibre insulated single-core twisted twin and three-core	Internal wiring of luminaires only (BS 4533)
185 °C glass-fibre insulated braided circular.	Dry situations at high ambient temperatures and not subject to abrasion of flexing. Wiring of luminaires.

Exercise 8

1. Give three examples of good conductors, three examples of good insulators and one example of a material that is neither a good conductor nor a good insulator.

2. Why would you use aluminium cables rather than copper?

3. Why is it not practical to wire circuits with individual wires in many electrical applications?

4. A cable has to be run through an area which has a steady temperature in excess of 50 ˚C. What type/s of cable could be chosen and why have you made your choice/s?

5. An engineering workshop is being wired in XLPE/SWA/LSF. Why?

6. A three-bedroom house is to be rewired. What cables would you choose and why?

7. Give three advantages of MI cable and two disadvantages.

8. What characteristics would CWZ cable have?

9. Why would you expect to see ScTP rather than a simple UTP cables?

9: Types of containment systems

In this session the student will:

- State the constructional features, applications, advantages and limitations of types of conductor containment systems.

Conduit and trunking

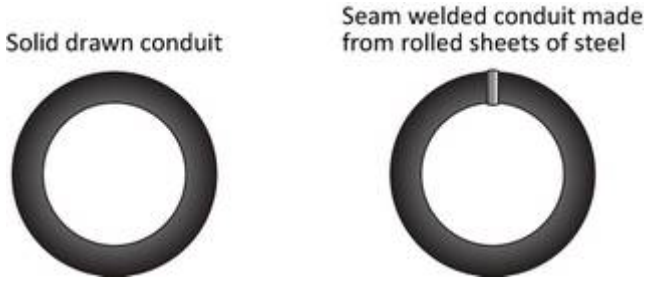
As stated earlier there are many ways in which we can install the cables that provide power to the relevant parts of an installation.

In this session, we will look at the varieties of conduit and trunking, why and where we would use them, and how we decide on what size to choose in any particular set of circumstances.

You will have already come across a wide variety of conductors and cables. In trunking and conduit the most common type of cable used is thermoplastic insulated (pvc) singles. Conduit and trunking can be considered to be a delivery system. They take the cable to where it needs to be, although steel conduit and trunking can be used as circuit protective conductors under certain circumstances.

Steel conduit

Steel conduit is either '***solid drawn***' or '***heavy gauge welded***'. The solid drawn type has no seam whilst the heavy gauge type has been rolled into a tube shape and welded down one edge.



There are other types of conduit that are not as substantial as the solid drawn or heavy gauge welded. This type of conduit is usually called light gauge and it has thinner walls than the heavy gauge conduit, and is less able to withstand mechanical impact.

We'll concentrate mainly on the more substantial type of conduit.

Steel conduit comes in a wide variety of sizes. The older types that you may still come across are The metric sizes are, 16 mm; 20 mm; 25 mm; 32 mm; 38 mm; and 50 mm.

Conduit usually comes in bundles (8 × 3.75 m lengths). Steel conduit comes with a variety of coatings. '***Black enamel***' is the most common but is not suitable for situations where there is a lot of moisture or damp as it can rust. The next most common conduit is '***galvanised***' conduit. This conduit is much better at limiting the damage caused by steel rusting.

The most expensive type and least used is '***stainless steel***' conduit. This conduit is expensive and difficult to bend and thread. It is however excellent when there is a need to be able to wash things down. Possible uses could be in milk parlours on farms, where hygiene is necessary.

Where is it appropriate to use steel conduit?

It would be generally uneconomical to use steel conduit in a house. After all, why do you need a wiring system capable of withstanding hammer blows when you are only burying cables in a wall or hiding them in a loft or under a floor?

Steel conduit is best used when you want to provide good '***mechanical protection***'. A mechanically strong material, it is capable of withstanding a certain amount of rough handling. Steel conduit is strong and long lasting. Garages; factories; schools and hospitals are the most common places to see steel conduit.

Fixtures and fittings

After the conduit has been threaded there are a number of items that it can be attached to. Many of these you will see in the workshop or at work, but here is a list anyway.

Terminal box	This box has one spout coming out of the side of the box. This type of box can be used when you come to the end of a run or you need to get tight into a corner.
Through box	This box has two spouts coming out of opposite sides of the box. This type is often used as a through link.
Angle box	The angle box has two spouts at 90° to each other. Useful for going round corners or changing direction.
Tee box	This box has three spouts forming the shape of the letter 'T'. It also has the benefits of both an angle and through box.

Four-way box This has four spouts at 90° to each other.

Tangent-through box This box has the spouts at one edge of the box. This allows for the box to be placed closer to a wall or ceiling.

Tangent-angle box This is the same as the angle box, with the benefits of the tangent through box.

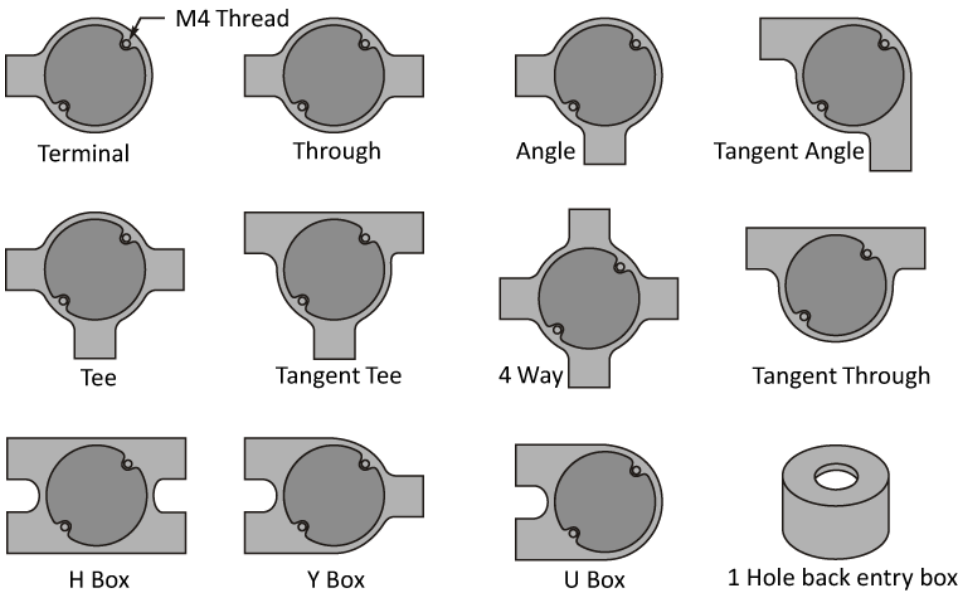
Tangent-tee box This box has the same shape as the tee box but allows for the conduit to be positioned closer to a ceiling or edge.

H box This box has four spouts forming a letter 'H'.

U box This box allows for a 180° change of direction.

Y box The Y box allows for a 180° change of direction along with the benefits of a through box.

Below is a diagram showing the range of conduit boxes available. At the bottom right is a back entry box. These boxes have no spouts coming out of the side of the box, but have holes in the back of the box, which allows for conduits to be joined. You can get one, two, three and four way back entry boxes. There is also a spouted back entry box.



There are a number of other fittings that are used. These are:

Coupler This is a length of tube threaded internally and is used for joining lengths of conduit together.

Male bush This is made of brass and has an external thread that fits into a coupler or a spout.

Female bush This is also made of brass and fits on the outside of a threaded piece of conduit. They are used to reduce the chance of damage to cables as they leave the end of conduit.

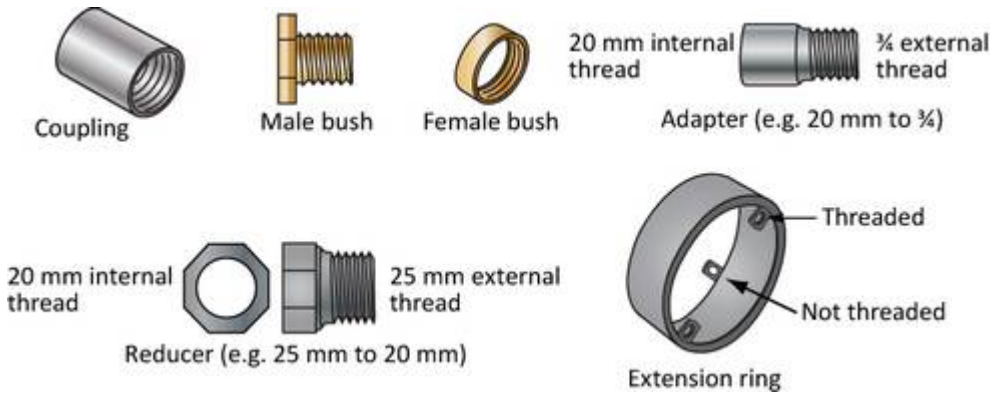
Reducers These enable conduits of different sizes to be joined together.

Adapters Adapters allow a metric piece of conduit to be connected to an older imperial length of conduit.

Inspection bends These are pre made bends that can be threaded onto a piece of conduit. They have a lid attached that enables people to gain access to the cables.

Inspection elbows These are the same as the inspection bends but have a much tighter bend.

Inspection tee Inspection tees are like a small tee box, still with the lid though.



PVC conduit

PVC conduit has been around for a number of years, and has proved to be a flexible and robust wiring system. As with the steel conduit it is more of a delivery system within which cables are drawn in and carried to where they are needed. PVC conduit comes in bundles of 25, and the length of it is slightly longer than steel conduit at 4 m. There are a number of types of PVC conduit just as there are a number of types of steel conduit.

Light gauge This type has a thinner wall, and is less able to withstand hard knocks.

Heavy gauge This type has a thick outer wall, and is very resilient. It can withstand quite strong impacts.

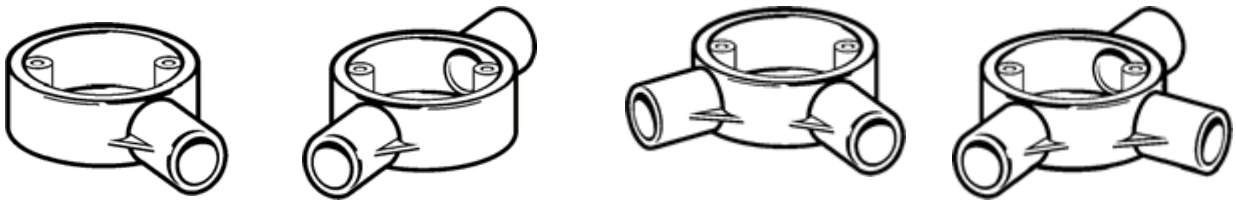
Oval tubing Although this is made from pvc, it is not commonly linked to pvc conduit. Its' most common use is for allowing cables which have been buried in plastered walls to be rewired with ease. It has more similarity to 'capping'.

Light gauge Heavy gauge (thicker walls)

We will concentrate on the heavy and light gauge type of pvc conduit.

Fixtures and fittings

Pvc conduit is not usually threaded, but glued. The type of glue used is very powerful and effectively welds the pvc conduit to any accessory in comes into contact with. There are a number of items that it can be attached to. Many of these are the same as for steel conduit, a selection is shown below.



Terminal box Through box Angle box Tee box

There are a number of other fittings that are used, although they look a little different to the steel accessories of the same name. These are:

Coupler This is a length of tube threaded internally and is used for joining lengths of conduit together.

Male adapter This allows the conduit to be joined to trunking, consumer units etc. It is made up of two parts, a male bush and something that looks like half a coupler.

Female adapter This performs the same function as the male adapter. It also is made up of two parts, a locknut and something that looks like half a coupler.

Expansion coupler Because pvc conduit is affected by heat, it can expand and contract. An expansion coupler placed in long runs, usually every 5 m, allows for the conduit to change in length without distorting.

Male adapter Female adapter Expansion coupling (larger than coupling above) Coupling (larger than for steel conduit)

It must always be remembered when installing pvc conduit that it does not manage extremes of temperature very well. In cold conditions it can, when being worked, shatter. This can be dangerous, particularly if it is being bent close to your face and eyes. In hot conditions the pvc becomes very soft and can end up being permanently damaged and distorted. In addition pvc may be affected by direct sunlight. This is called '***solar gain***'. If the conduit is going to be in direct sunlight then the black pvc withstands this process better than the white pvc conduit.

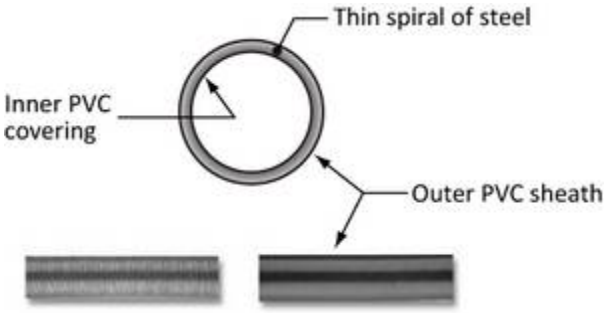
Within the two extremes of temperature pvc conduit may be used in many areas. It is particularly useful on farms where its' ability to withstand mechanical damage is important. More importantly its non-conducting properties allows for earth faults to be limited to certain areas limiting the risk to animals.

No doubt, you have seen them before.

Flexible conduit

Imagine that a machine or something that can vibrate or moved has been installed. It is to be wired from a distribution board via steel or pvc conduit, which the constant movement of the machine would eventually damage; they are too rigid. It therefore becomes necessary to use some other means of connecting the load to the rest of the wiring system.

There are two possible options, either to use some form of flex, although this is limited in size and strength, or to use flexible conduit. This conduit has a pvc outer sheath and an inner layer made up of thin spiral of steel or pvc.



This type of conduit is more robust than flex, although it is not acceptable to use it as a protective conductor.

Special glands must be used that clamp the flexible conduit to the gland.

Cable trunking

As with conduit, cable trunking comes in all types and sizes. The three most common types are:

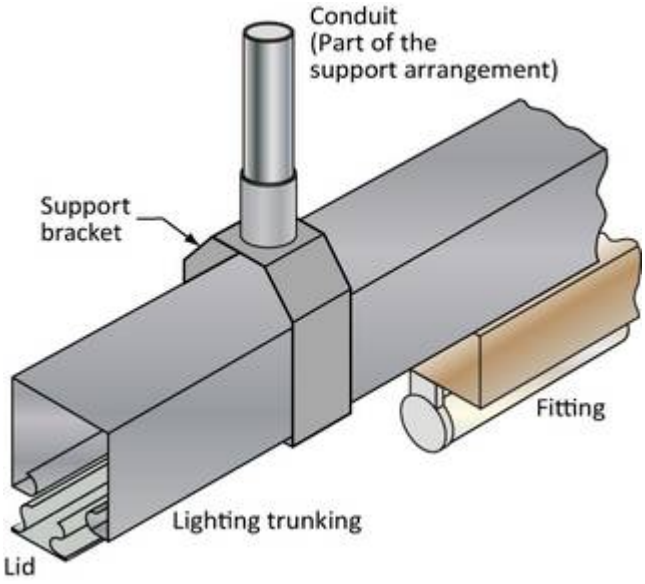
- sheet steel
- galvanised or enamelled steel-covered with an extra coating
- pvc.

Trunking is commonly installed in the same types of installation as conduit, although there are one or two variations.

Pick up any appropriate catalogue and you will come across an almost infinite variety of trunking types. We will have a brief look at the variety of types that you may come across more regularly and see where they might be used.

Lighting trunking

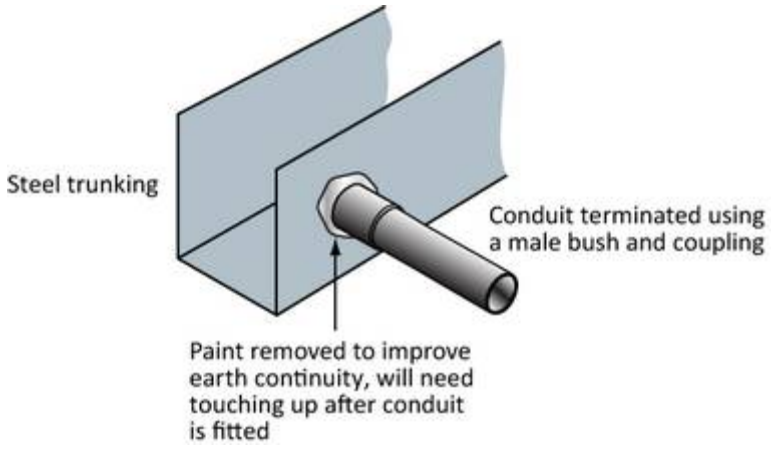
This type of trunking is usually made of steel and has an inner lip. This allows not only for fittings to be installed directly onto the trunking via special clips, but it also allows for lid to be snapped into place.



It is a very versatile trunking in that you can move the fittings about reasonably and you can also change the fittings without too much trouble. It does however take some time to install and can, if insufficient care is taken, look terrible if it isn't straight. This trunking is often seen in schools, hospitals etc.

Joining conduit to trunking

The flexibility of trunking as a containment system is made possible by the ease with which conduit can be fastened to the trunking wherever a load point is. The cross-sectional area of the conduit and trunking means that a circuit protective is not always necessary, providing the joint is mechanically strong and it is not made out of plastic!



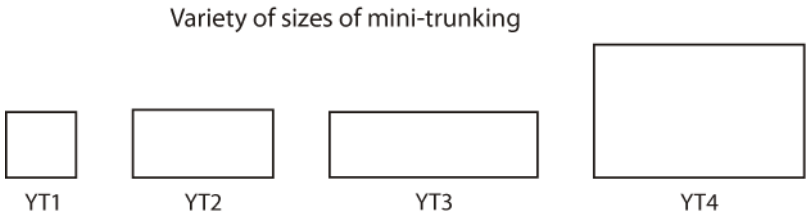
It is worthwhile having a brief recap on some of the qualities of the different types of conduit and their relative advantages and disadvantages. Below is a table listing some of them.

Conduit Type	Advantages	Disadvantages	Where used
Steel	Mechanically strong; Can be used as protective conductor.	Expensive to install; Difficult to change once installed.	Factories, garages, workshops etc.
PVC	Mechanically Strong; Doesn't introduce an earth; Easier than steel to install.	Doesn't like extremes of temperature; Can be affected by oils; Requires a protective conductor.	Farms, workshops, schools etc.
Flexible	Flexible; Isn't damaged by vibration.	Should only be used for short lengths-not very mechanically strong; Requires a protective conductor.	Short links to machines and appliances.

Mini trunking

This is probably the most common type of trunking in use. There are many makers of it, and it ranges in size from a size capable of fitting one 2.5 mm^2 thermoplastic insulated and sheathed twin and earth cable up to those capable of fitting many more cables.

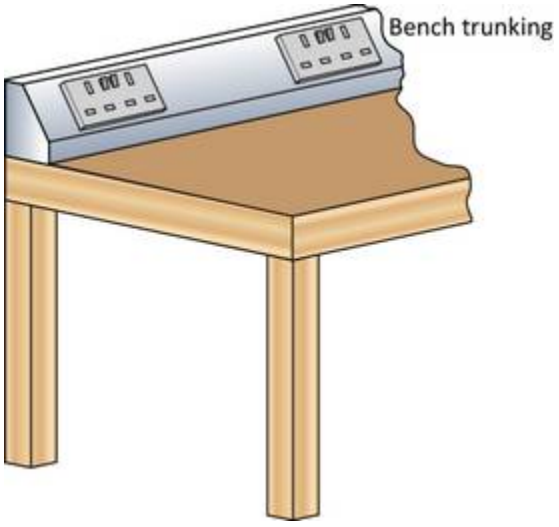
The trunking is usually white and comes with a number of fittings and adaptors. Again sockets and switches can be fitted to the trunking although it is more common to just butt the trunking up to the outlet.



It is generally used when you don't want to chop out and damage decorations, or when you want to hide cables from prying fingers. Mini trunking is not usually used in very long runs, but in short runs, often down walls.

Bench trunking

This trunking as you can tell from its name is fitted on the top of benches with socket outlets and other accessories fitted onto the surface of it. It is most commonly used in schools and colleges and is predominantly plastic.

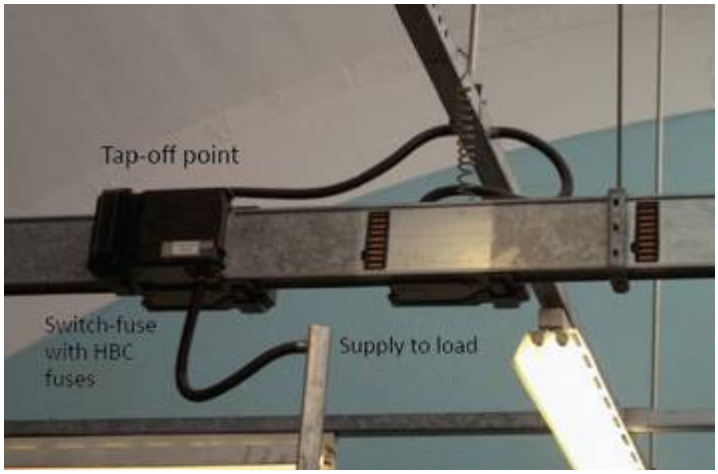


Again, segregation can be achieved, which allows extra accessories to be fitted at a later stage with little extra effort.

Busbar trunking

This is a very special type of trunking. No cables are drawn into this type of trunking, as there are large copper bars in place to begin with.

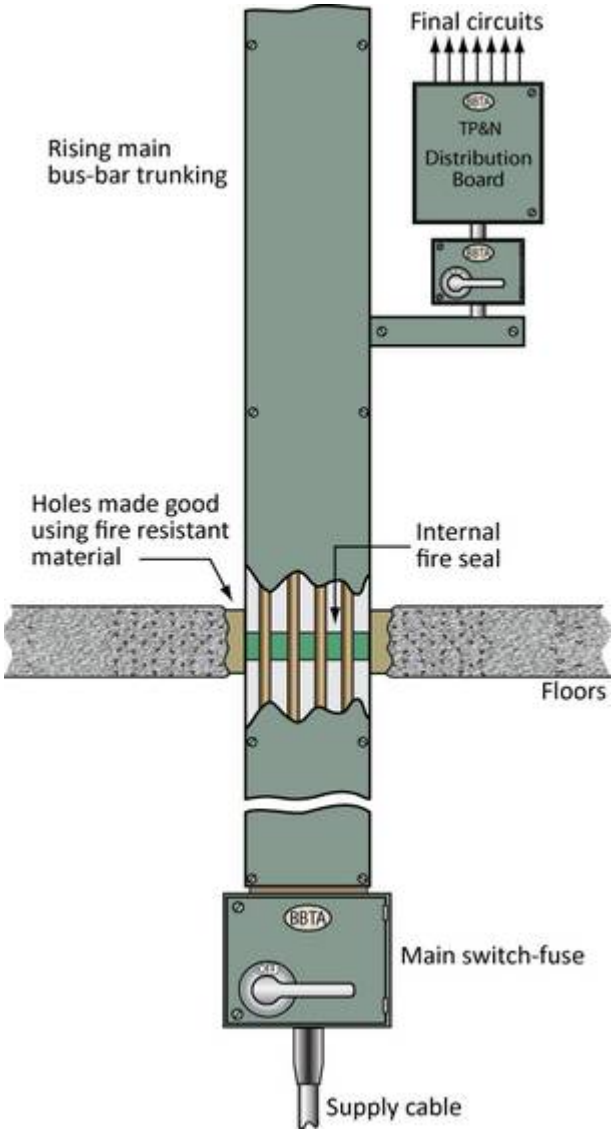
This trunking is found in two places generally. Either it is run horizontally at high level around an engineering workshop, or vertically through high-rise buildings. When it is run vertically it is called rising main trunking.



The picture here shows the 'normal' busbar trunking that could be run around an engineering workshop. You can see that there are 'tap-off' points.

This type of trunking is very flexible in that it allows for machinery to be moved around and 'plugged-in' to the busbar trunking wherever it is needed.

The trunking may not be flexible but the system is.



The image shows a rising main system. This trunking system also allows for power to be 'tapped-off'. This occurs most commonly on every floor.

There are certain things that do have to be considered when using this type of trunking. At each floor level there must be some means of sealing the trunking that rises through a floor that is a fire barrier or passes through a wall that is a fire barrier.

This sealing is to prevent fire from passing up through the trunking to each floor. This is because the trunking acts like a chimney when there is a fire. The level of sealing against fire that the trunking requires depends on what the designer of the building wants. It should be capable of withstanding fire for at least one hour though (BS 476 refers).

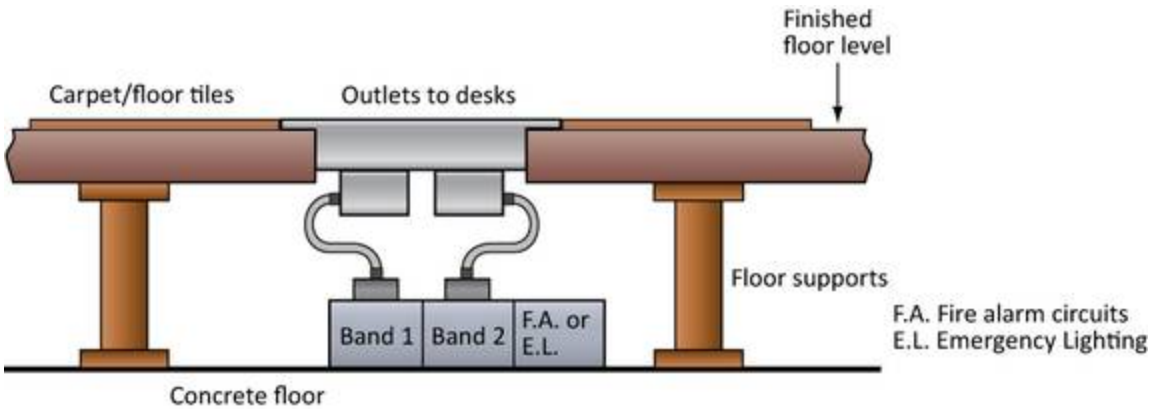
Powertrack

Powertrack system use solid track throughout their length, there are three main types, suspended, wall mounted and underfloor. Wall mounted tracks are used in offices etc where appliances and equipment can be plugged in anywhere along the track. The socket is inserted and then becomes part of the circuit.

Underfloor systems are used in large open plan areas where the common run of track is fed from the distribution board, via track feeding boxes. Lighting track is similar to the underfloor system.

Under floor trunking

Under floor trunking is a useful means of delivering power to points that are spread out, like desks in offices.



In the figure above you can see that the trunking has a number of compartments. We will look at why later on.

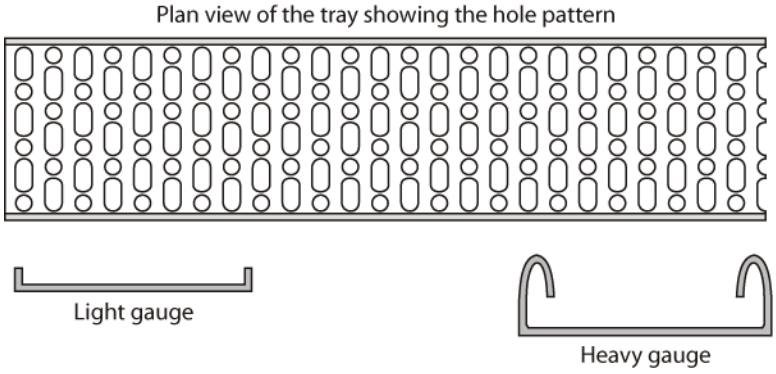
Cable tray, basket tray and ladder rack

As with the types of trunking and conduit, cable tray has a number of variations that can be found in manufacturers catalogues.

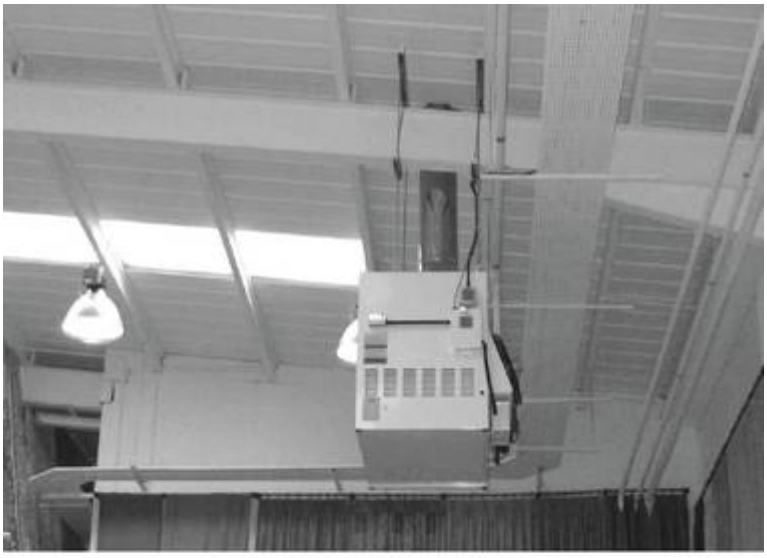
Sizes range from 50 mm to 300 mm and can be heavy or light gauge. It can also be coated and can be plastic, although this is not that common.

The only differences between heavy and light gauge tray is the thickness of the tray and the edge of heavy gauge tray is turned over.

Cable tray is a delivery system and is most often used in industrial premises, as it is not the most attractive of delivery systems. It is usually used to deliver steel wire armoured and MI cables, although they are not the only type. It is not normally used to deliver just one cable.



Cable tray's main advantage is that it supports cables along the whole of their run. This stops the cables being snagged. It is also easily bent and is therefore of particular use where there are plenty of obstructions in a cable run.



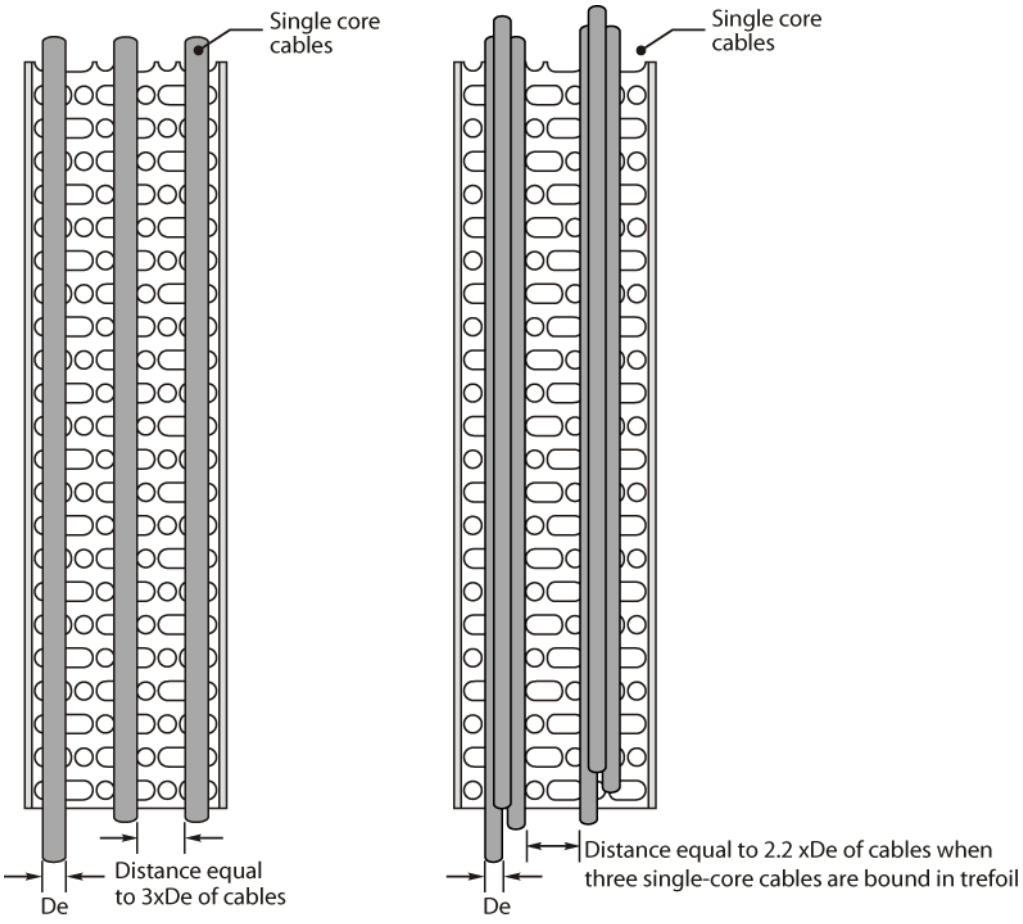
Light duty traywork fixed around a department store

Heavy duty traywork used to support groups of SWA cables

Hole made good around cables as they pass through a wall

When any cable calculations are carried out one of the factors we have to consider is called '***grouping***' (***C_g***). Grouping takes into account the heat that is emitted by cables and the effect that they all have on each other. With cable tray, grouping has to be taken into account in the same way except for the odd exception.

If multicore cables are separated by at least their diameter then we don't need to take into account grouping. If single core cables are run then they need to be separated by at least twice their diameter.

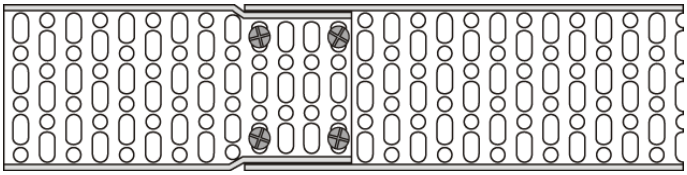


The two methods shown in the diagram are found in Table 4A2 of BS 7671, with the distance between them being a measure of the correction factors necessary for grouping purposes in a cable calculation. Anything touching or closer than the distances given and you have to take into account grouping in your cable calculations.

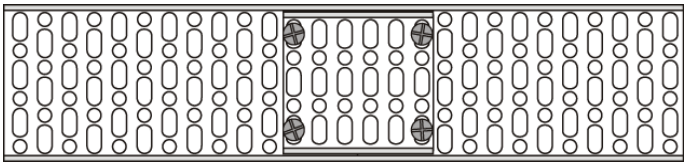
Most cables on tray are fixed using tele-cleats, all-round band (tub tape), or cable ties. It is not recommended that you just use odd ends of steel armouring.

Over the next few pages are a series of diagrams showing a variety of techniques for joining and bending cable tray. We will not go into much detail, as you will get to use these techniques when you are at work or in a workshop. There is no short cut for experience and no book, however good, will help you to produce the goods if you don't practise. Each diagram is labelled.

Overlapped edge

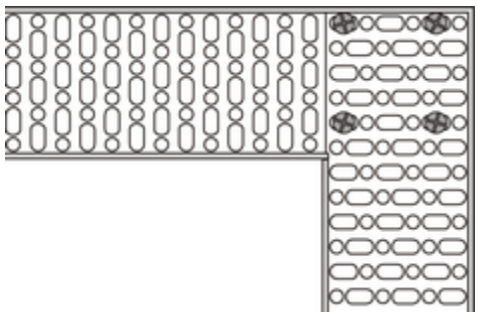


Coupler

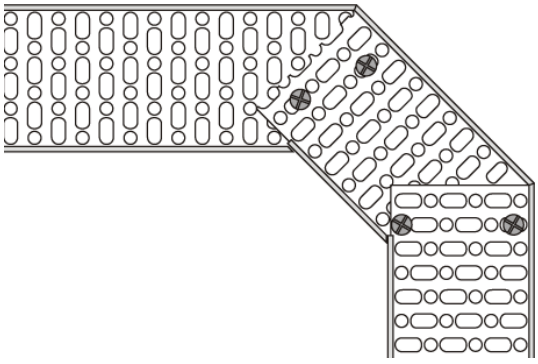


Bends

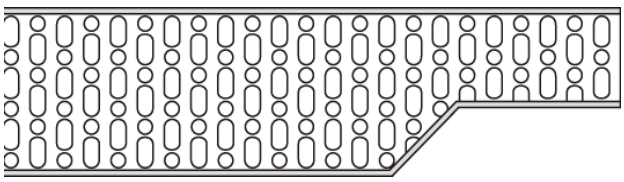
90˚-This bend should try to be done without breaking the tray. The point of the bend should be left intact.



90˚ (2 × 45˚ angles)-This bend uses three separate lengths of cable tray.



Reducer



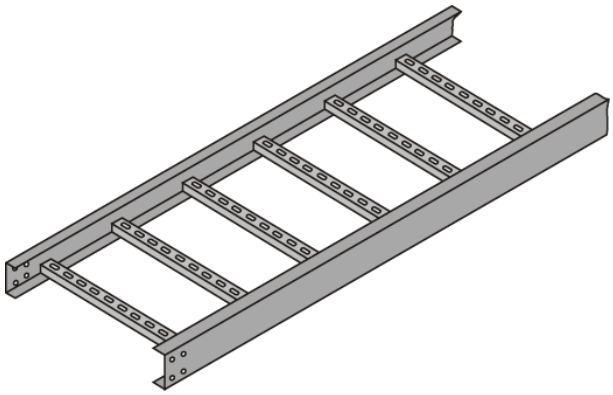
These are just a few of the types of things you may have to do. However, it is recommended that you use the bends and accessories that are provided. This reduces the amount of work you have to do.

Always buy the bends if you can, so much time and labour can be saved!

Ladder rack

If large cables are to be used then cable tray is probably not as robust a delivery system as ladder rack. Ladder rack looks exactly as the name suggests. Like a ladder it has stiles and rungs.

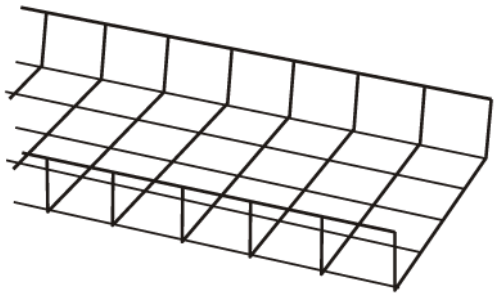
Ladder rack comes in a wide range of sizes up to 1m or more in width. It is commonly seen on large industrial sites, providing solid support to armoured cables. It is not a recommended means of supporting smaller cables, as they tend to sag whereas large cables tend to stay where they are put.



Basket tray

Basket tray is very similar to cable tray in its use, but with wider applications for smaller power and lighting cables.

Wire mesh, used to provide support to small cables such as data communications



Can be painted to provide ease of identification for systems needing different colour codes

Basket tray is commonly used in commercial installation where large numbers of small cables need to be kept tidy. The sizes range in a similar way to cable tray.

Modular wiring systems

Modular wiring systems are becoming standard practice for busbar and lighting distribution in modern offices, retail, healthcare, educational and leisure environments.

Many experts forecast that traditional conduit and cabling methods will be replaced by modular wiring systems on projects throughout the United Kingdom.

Modular wiring systems comprise cable assemblies and enclosures manufactured off-site so that on-site connection work merely involves connecting the various components to complete the power, lighting or data installation. Using modular wiring provides number of significant benefits:

A complete electrical installation with a minimum number of system components ensures infinite design flexibility and greatly reduced time and installation costs. Every system component is factory tested in a quality-controlled environment, this not only ensures electrical safety, it also minimises the need for skilled trades on site and eases future maintenance.

With modular wiring, the number of system configurations available ensures maximum choice and flexibility in design.

Ducting

Ducting is commonly used in larger installations to run cables and other services such as heating and water pipes. Cables are generally water resistant, but the insulation materials will breakdown if left under water without additional protection.

Exercise 9

1. Write out Regulations 522.8.1 and 522.8.2

2. List the common types of steel and pvc conduit.

3. What problems are there with flexible conduit?

4. Where would you expect to use steel conduit, and why?

5. Where would you expect to use pvc conduit, and why?

6. An engineering workshop in a college is being refitted. What type/s of conduit might you use and why?

7. List three types of trunking available.

8. Where would you expect to use under floor trunking and why?

9. An open-plan office has a number of desks situated at a variety of locations throughout the room. What types of trunking might you use and what reasons can you give for your choice/s?

10. Investigate rising main busbar systems – what types are available?

11. Investigate how 'power poles' are used in relation to underfloor trunking. What particular problems are created by using power poles?

10: Environmental factors

In this session the student will;

understand how environmental factors can affect the selection of wiring systems and associated equipment and enclosures

Selection and erection of wiring systems in relation to external influences

Section 522 details more of the external influences that may affect the installation. You can see from the headings which ones may apply to an installation. Appendix 5 supplies the coding for the letters found next to the headings in this section.

Each condition of external influence is designated by a code consisting of two letters and a number. The first letter relates to the general category of external influence, the second letter the nature of the external influence and the number, the class within each external influence.

For e.g. **CB2** indicates fire propagation within a building

Ambient temperature (AA) - Regulation Group 522.1

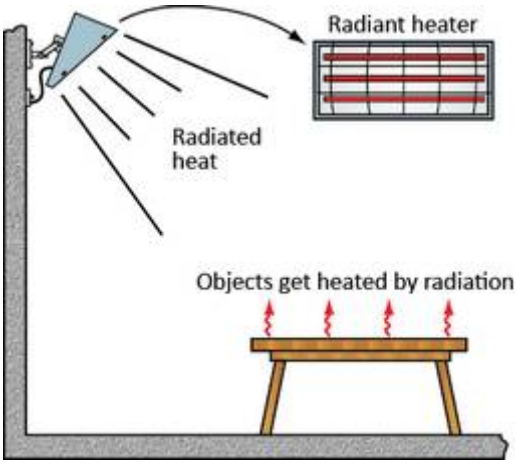
This takes into account the temperature of the surrounding environment. If this temperature is high, more than 30 ^{0}C then a factor must be applied to the cables installed.

Cables are affected by the temperature surrounding them. The cables that carry current produce heat, the rate at which cable can lose this heat, will be dependent on the surrounding area. The colder the area the quicker the heat can be dissipated. In a hot area the heat that the cable can lose will be small, this maybe a problem in boiler rooms and also in insulated lofts and walls.

Low temperature can damage PVC cables; if they have been stored below 0^0 C they may be damaged beyond use. At low temperatures above 0^0 C the cables may need to be warmed slowly before use.

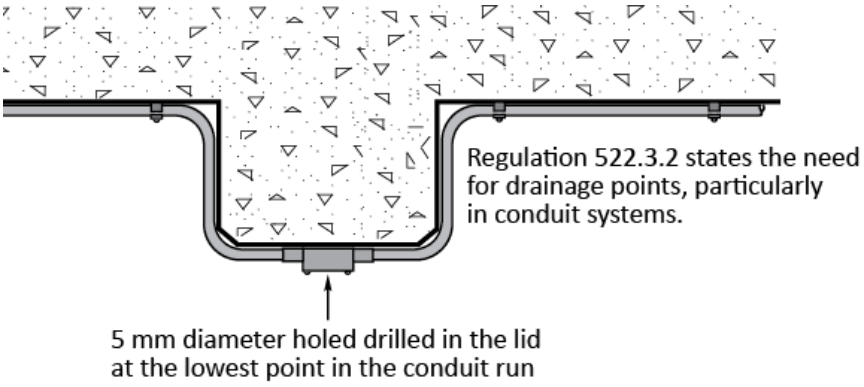
These Regulations also force us to consider what we are installing in a particular temperature. As an example, thermoplastic insulation is not very good at low or high temperatures.

External heat sources - Regulation Group 522.2



Here we have to consider the direct impact of a heat source on the installation. It could be where a brazing hearth is situated or a welding bay.

Presence of water (AD) or high humidity (AB) - Regulation Group 522.3



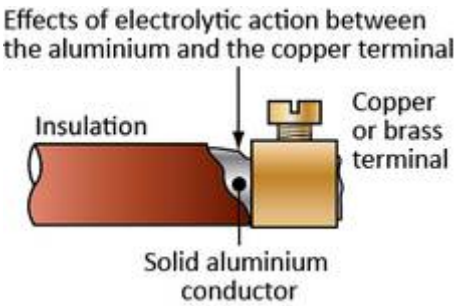
Water and high humidity are an obvious factor to consider. Regulation 522.3.2 states the need for drainage points, particularly in conduit systems. Other Standards indicate that this should be a hole of 5 mm diameter or an area of at least 20 mm^2.

Presence of solid foreign bodies (AE) - Regulation Group 522.4

Any objects, including dust, must not affect the safe operation of the wiring system. The IP code must be reasonable!

Presence of corrosive or polluting substances (AF) - Regulation Group 522.5

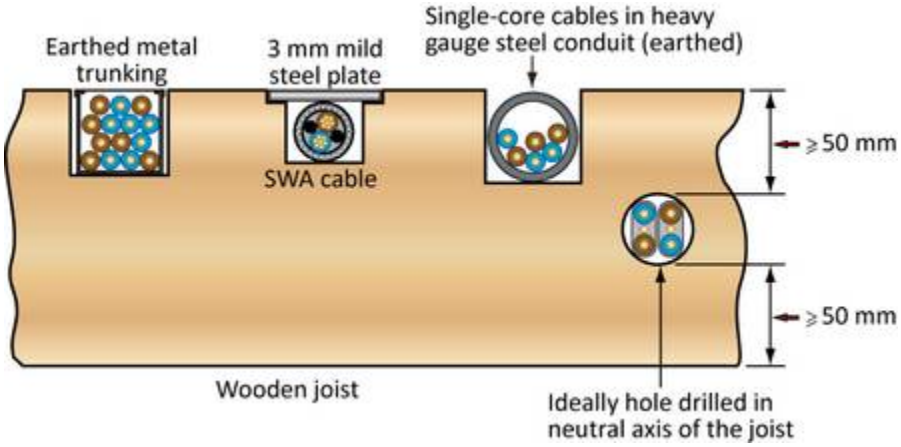
The materials may need to be changed here, for example some metals may need additional protection.



Thermoplastic insulation does not do well when placed near or in oil. Equally, aluminium and copper, when placed next to each other, will react with each other and an increase in resistance will occur. This must be avoided.

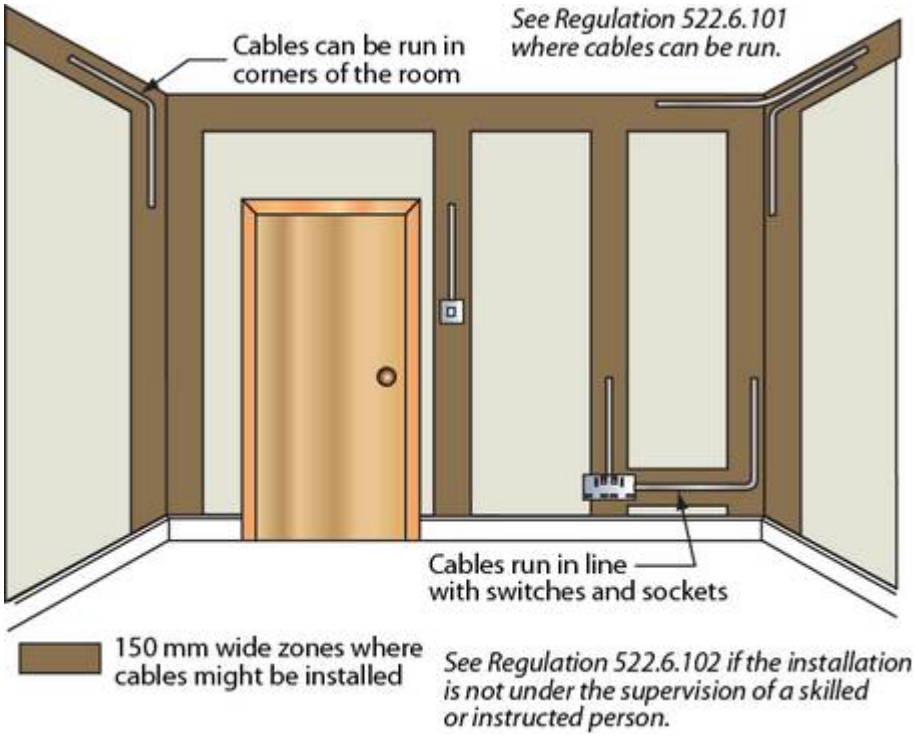
Impact (AG) - Regulation Group 522.6

Here, we are looking at mechanical damage. The most obvious is the running of cables under floors and in walls, and the need to take extra precautions through the joists and down the walls.

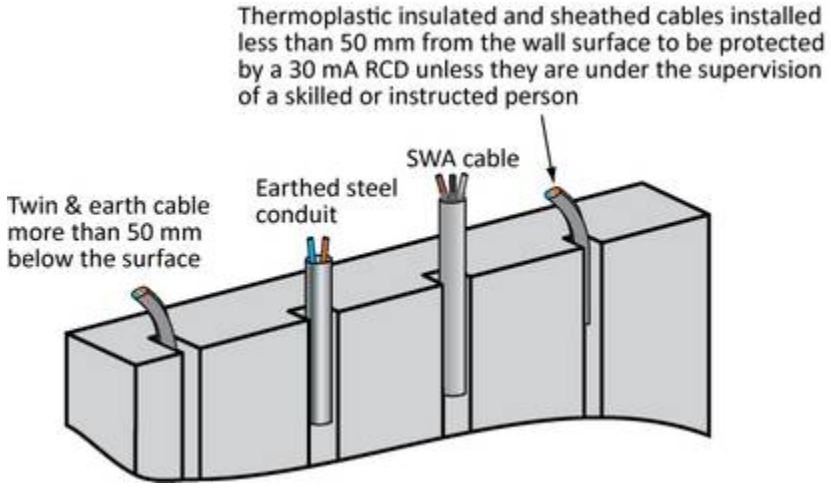


The first diagram shows how compliance with Regulation 522.6.100 might be achieved.

The figure here shows where Regulation 522.6.101 permits cables to be installed in walls.

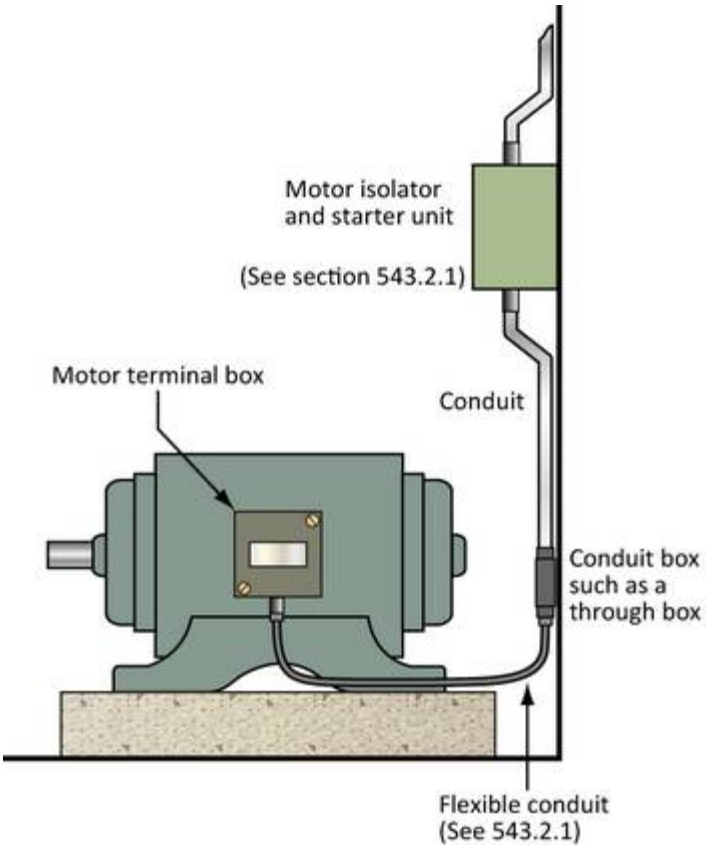


It should be noted that where the installation is under the control of either a skilled or instructed person, the requirement for circuits to be protected by RCDs having a rated residual operating current of 30 mA and an operating time of 40 ms at a residual current of $5I_{\Delta n}$ is not required.



Vibration (AH) - Regulation Group 522.7

An example of due care here might be to do with the connecting to a motor where vibration can lead to connections working loose.

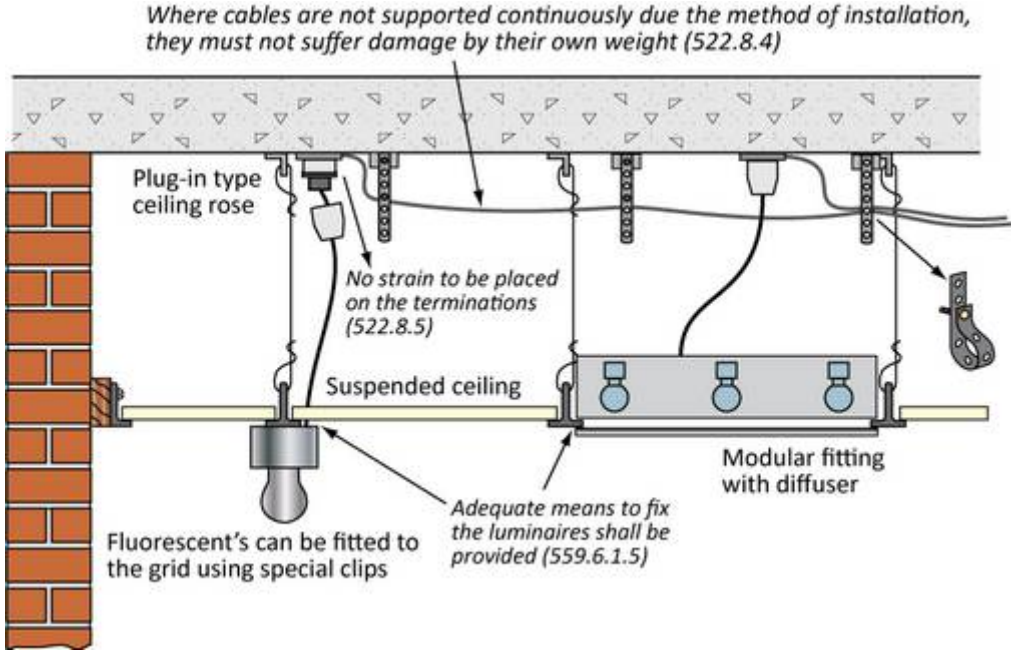


To limit the effects of vibration, it is common practice to use flexible conduit for the connection to a motor. It is also possible to use SWA and SY cable as the final connection.

Other mechanical stresses (AJ) - Regulation Group 522.8

To prevent damage to cable the effect of mechanical stress needs to be considered, this will very much depend on the type of installation and the anticipated level of damage.

Catenary wires or other means such as tub tape should be used to support cables.

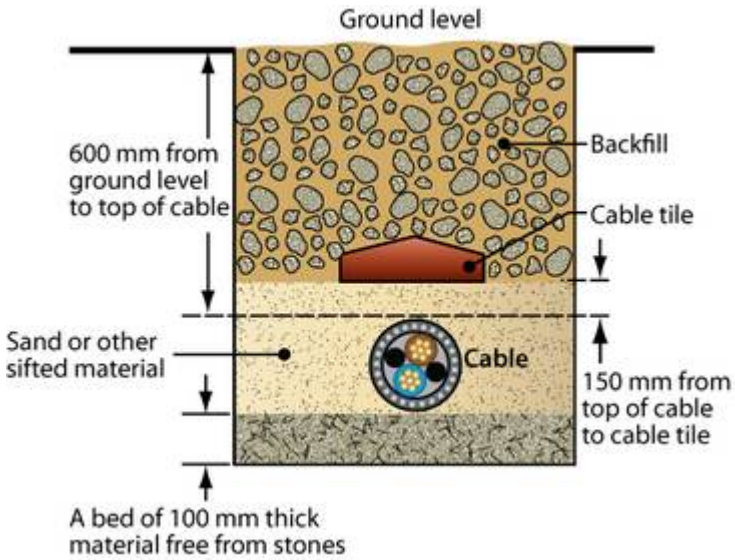


Flexible cables can be put under stress. Appendix 4 Table 4F3A gives the maximum loads for different types of cable. Vibration can also cause breakdown of the insulation.

Underground cables should be metal sheathed or armoured to resist mechanical damage

Here we are being called on to take due care when we are installing cables. Bends should not be too tight. Cables should be clipped at regular intervals so that they do not have to support themselves.

Buried cables 522.8.10



Buried cables should be adequately protected from disturbance.

A cable buried in the ground shall incorporate an earthed armour or metal sheath or both.

The location of the cable shall be marked by cable tiles or by a suitable marking tape.

Presence of flora and/or mould growth (AK) - Regulation Group 522.9

Plants and mould or fungus. Choose the wiring system carefully.

Presence of fauna (AL) - Regulation Group 522.10

This describes vermin.

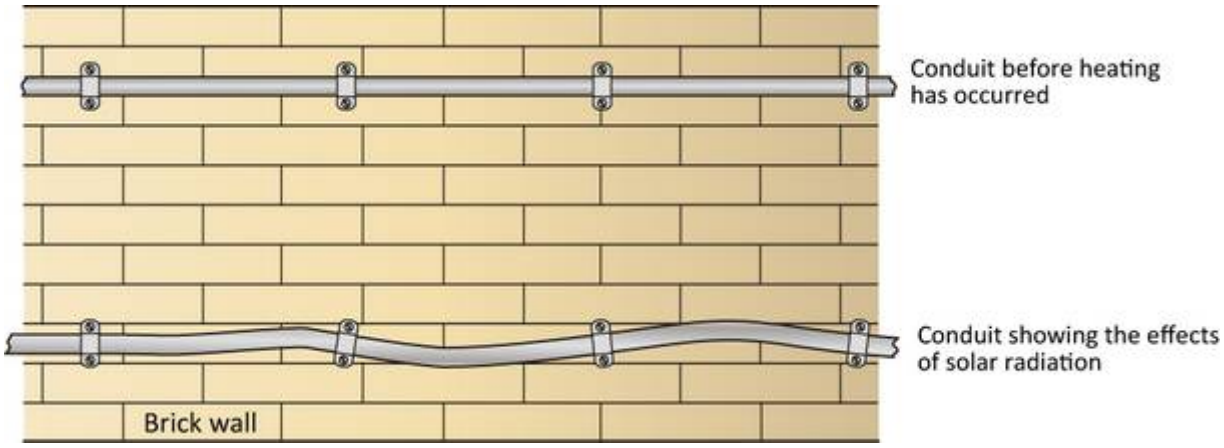
There are two types of damage that can be done by animals. Mice and rats are particularly fond of gnawing cables. In areas where there is an increased likelihood of the presence of rodents cables should be given extra protection and installed in conduit or trunking. This will hopefully prevent them being partially or fully chewed through leaving a dangerous condition.

On farms this will be particularly necessary; the installation should be kept well out of the reach of the animals to prevent the corrosive effects of urine as well as any damage caused by rubbing or gnawing.

Solar radiation (AN) - Regulation Group 522.11

We are not dealing with purely heat, but with the ability of the sun, even when the day appears cold, to provide heat, via radiation, to exposed objects. You would need to take particular care with thermoplastic conduit.

Solar radiation can increase the temperature of the cable by up to 20 %, which translates to a de-rating factor of about 10 %. Account must be taken of this when running cables outside.



PVC should not be installed in direct sunlight, as this causes the cables to harden and to crack.

Seismic effects (AP) - Regulation Group 522.12

Not such a significant problem in the UK, although there are certain areas of the country that get occasional earth tremors.

Wind (AS) - Regulation Group 522.13

You are pointed to Regulation Groups 522.7 (vibration) and 522.8 (other mechanical stresses).

Nature of processed or stored materials (BE) - Regulation Group 522.14

Here you are pointed towards Regulation Group 522.7.

Building design (CB) - Regulation Group 522.15

Here you are considering whether account has been taken of any movement the building may have. This could apply to tall chimneys etc. Not every point needs to be considered. However, when you look at a particular installation, you should think. To stop and consider the installation and the processes involved is essential. To consider all aspects before you begin will also remove any unexpected surprises.

Moisture

As water and electricity do not mix care must be taken at all times to make sure the installation remains water tight. Suitable glands should be used where necessary.

Corrosive substances

Metal cables sheaths, cable armouring, cable fixing and glands can suffer from corrosion when exposes to certain substances. In areas where there is a possibility of corrosion occurring you may need to use PVC coated tray or cables.

Corrosion can be caused by

- Acids in wood
- Unpainted walls
- Plaster undercoats
- Some floor materials

Having two different metals together can cause an electrolytic action, for example where brass glands are used with steel boxes, in an area where moisture is present.

Exercise 10

1. Name five environmental factors that will affect your choice of wiring system

2. What problems are associated with flora (presence of plant-life/tree roots etc.) and fauna?

3. Consider the following situations and state the environmental conditions that may apply:
   i) a farm shed housing cattle in winter
   ii) a small shop in a busy town centre having new security light fitted
   iii) a large machine shop having a series of welding machines installed
   iv) a fish dock
   Hint; use the classifications found in Appendix 5.

Questions 4 to 7 are scenarios for you to decide what factors will affect the choice of wiring system. Remember not to choose a wiring system, but rather the factors that will affect your choice.

Be careful about the things you consider. Try not only to think of the electrical factors but also any of the mechanical and/or usage factors that you will need to consider.

Use the notes from previous sessions to help you.

4. A farm shed separate from the farm house is to be wired. It provides cover for cattle.

5. A busy coffee shop is to be rewired.

6. A sub-main cable is to be run for 65 m between two school buildings. It is to be run across a playing field.

7. A factory that produces furniture is to have a new cnc machine installed. The area is rich in dust.

11: Types of wiring systems for different types of circuits

In this session the student will:

- State the types of wiring system associated with different types of circuit.

In the last couple of session we have looked at wiring systems, containment system and environmental factors. In this session we will combine all the systems to offer some options on how circuits might be wired.

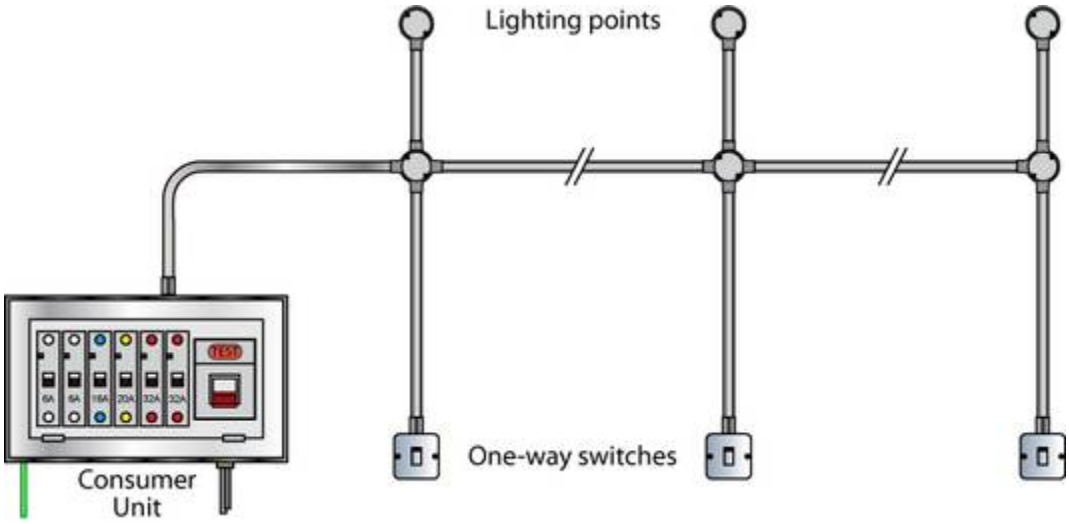
Lighting systems

Besides special lighting systems in shops and offices which use a lighting track, there are only three ways in which lighting circuits are wired.

- Loop-in (commonly used in conduit and trunking)
- Three-plate method
- Joint or junction box.

Loop-in method

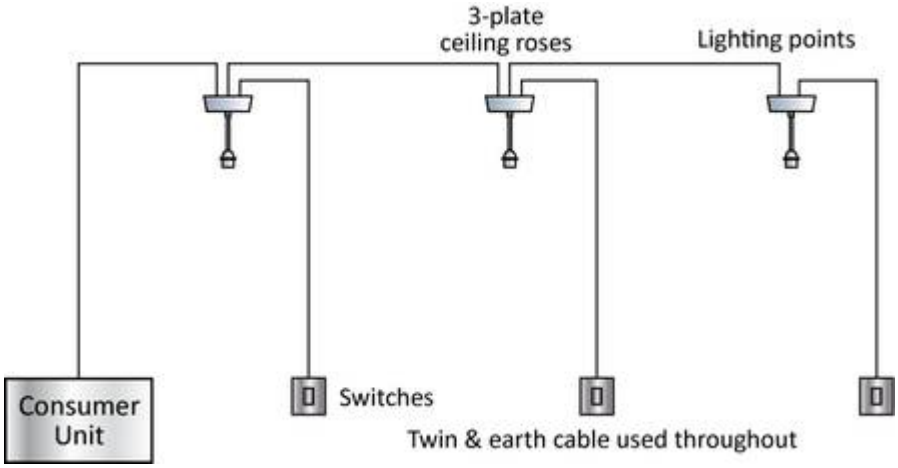
The conduit/trunking method, usually called the loop-in method is shown below. In this method thermoplastic (pvc) insulated single-core cables are usually used.



Here we have three lamps controlled via three one-way switches. We must make sure that we supply the switches and provide a neutral to the lamps.

Three-plate ceiling rose

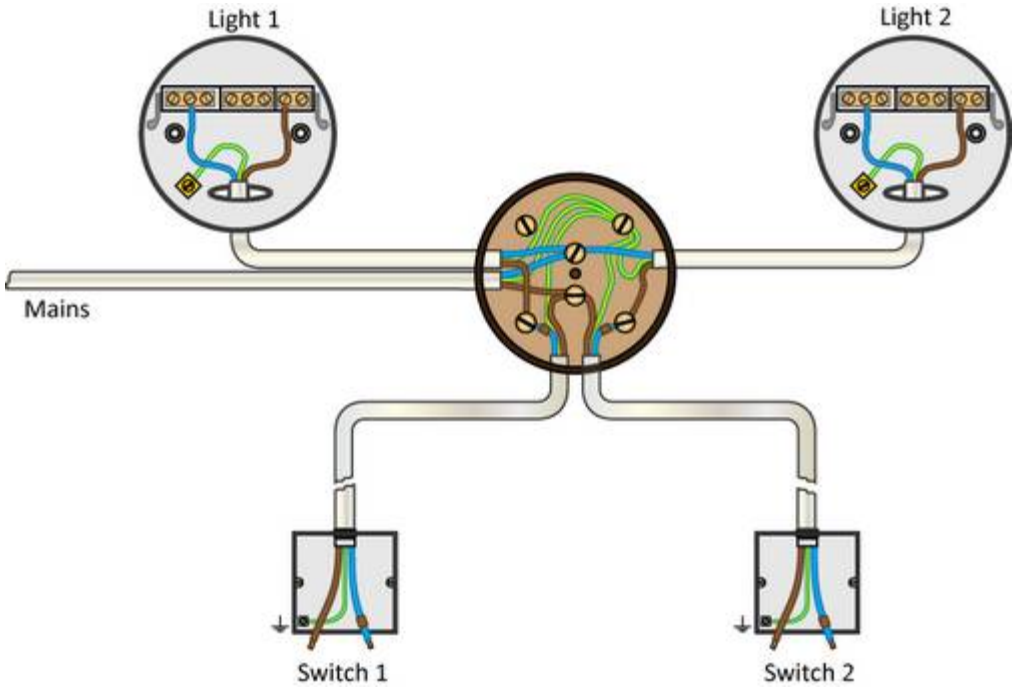
With the three-plate method a twin and earth cable is run around all the lamp fittings in a radial circuit. Have a look at the layout below.



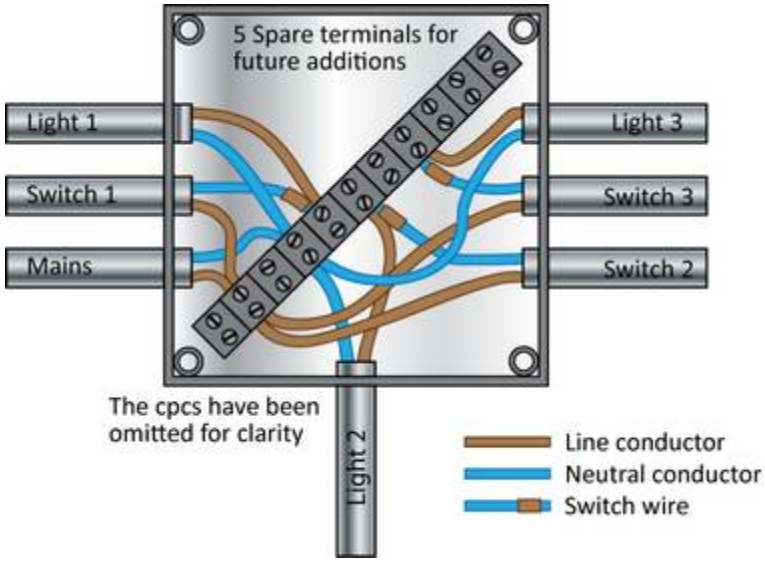
Joint/Junction box method

This method is not so widely used as the loop-in method but depending upon the area that you work in the country, you may come across this method of wiring quite frequently.

This method brings all cables to a common point (usually a large joint box) and makes all the connections there.



A variation on the junction box is the RB4 which is really large joint box. It contains a strip of connectors spread across the box. It is worthwhile labelling the cables so that you know where they have come from.



All the permanent feeds to the switches are supplied from the line conductor from the consumer unit. All the neutrals from the loads are connected to the neutral from the mains. The switch wires from the switches and the lights are then simply connected to each other in a spare connector.

The figure above shows a standard 20 A 6-way joint box. This is quite limiting compared to the RB4, yet for smaller installations it is adequate.

Of the main types considered the choice comes down to what the building construction is and environmental conditions there are.

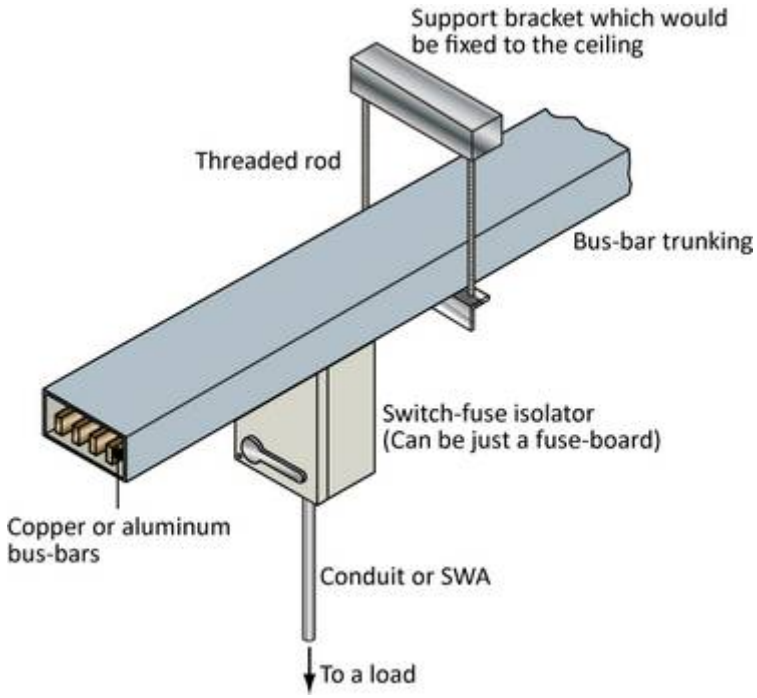
If the building is of a steel type construction then a conduit and trunking system would be ideal. If the building was of a domestic nature then a twin and earth method of wiring would be appropriate. If the building was a sports complex then a mixture of systems would need to be considered.

Power systems

Apart from a domestic environment whereby all power circuits would be wired in twin & earth (6242Y), the choice for industrial and commercial environments is large.

The circuit arrangement is still the same however, whether it is domestic, commercial or industrial installations. A ring final circuit will always be wired from the fuse board, to all the socket outlets and then back to the fuse board. A radial circuit will always be fed in one cable from the fuse board. The size of the cable will be dependent upon the loading and on the length of run.

Steel trunking and conduit offers the best flexibility along with ease of wiring at a fairly cheap cost. If the building was a factory with long production lines then busbar trunking could be used whereby there are plenty of tap-off boxes regularly placed to feed machinery from.



This method allows machines to be moved without alteration to the wiring system. The busbar itself is fed from a large armoured cable to a switched fuse which then locks on to the bars.

Over the years as many more electrical appliances have begun to be used, the amount of recommended socket-outlets in an installation has varied and increased Table 55.1 in BS 7671 gives the types and ratings of a variety of sockets.

There are a variety of types of socket:

- BS 1363 socket outlets are rated at 13 A and are the type of socket-outlet that you would expect to see in a ring final circuit etc.
- BS EN 60309-2 (formerly BS 4343) socket-outlets are found most commonly in industrial situations where the loading of equipment is larger than be fed from a typical 13 A socket outlet.

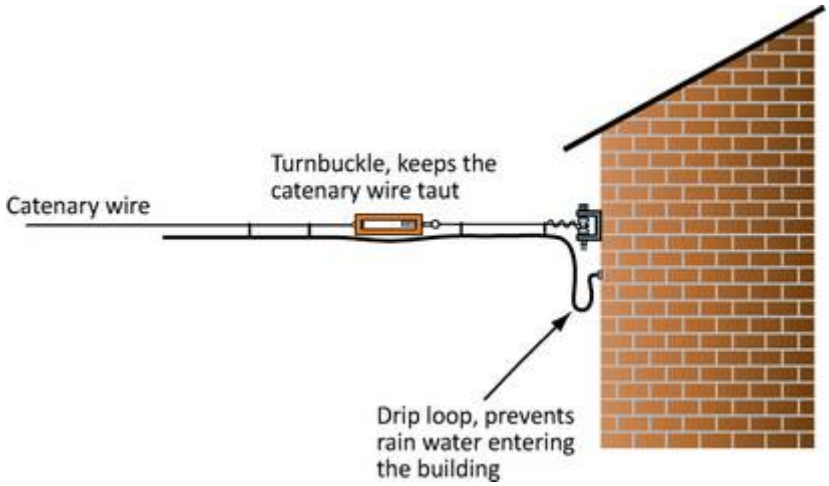
BS EN 60309-2 socket-outlets are rated from 25 V up to 750 V using a variety of colours and pin positions.

Voltage rating (V)	Colour
25	Violet
50	White
110-130	Yellow
220-130	Blue
380-415	Red
55-750	Black

Distribution systems

A distribution circuit is any circuit taken from the main intake position, to supply at fuse board at a different location.

The use of SWA lends itself for these types of circuits. The SWA can be supported by cable tray, placed in ducts or buried underground. It can also be supported on catenary wires where the distance between buildings is not too far and is not open to busy vehicular traffic.



See Table D2 in the On-Site Guide for details on maximum heights and lengths.

Environmental control/building management systems (BMS)

Before we can consider what wiring system to use, we need to understand what this heading means.

Current technology allows buildings to be set up more energy efficiently.

As we have just been looking at, all buildings have some form of mechanical and electrical services in order to provide the facilities necessary for maintaining a comfortable environment. These services have to be controlled by some means to ensure, that there is adequate hot water, the radiators are on, or possibly cooling is provided to ensure comfortable conditions

These controls take the form of manual switching, time clocks or temperature switches that operate the on and off signals for enabling pumps, fans or valves etc.

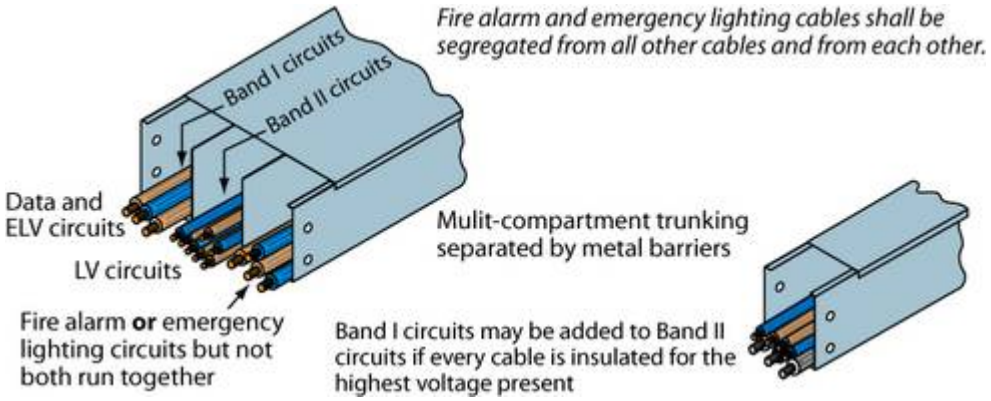
The purpose of a Building Management System (BMS) is to automate and take control of these operations in the most efficient way possible for the occupiers/business.

The BMS is a "stand alone" computer system that can calculate the pre-set requirements of the building and control the connected plant to meet those needs. Its inputs, from sensors around the building and feeds the information into programmes. These programmes can use this information to decide the necessary level of applied control.

A modem is also connected to the system to allow remote access.

The level of control via the BMS is dependent upon the information received from its sensors and the way in which its programmes tell it to respond to that information. As well as offering a precise degree of control to its environment, it can be made to alarm on conditions that can't meet specification or warn of individual items of plant failure.

Now we can begin to see what system to use. For the sensors and transducers, we can use SY cable which can be multi-core and is braided for protection and noise suppression. This could be mounted on traywork. We could also use communication cables for the transmission of data. This would need to be run segregated from other circuit to avoid interference and thereby prevent corruption of data. A suitable containment system for this would be multi-compartment trunking which is available in both steel and plastic depending upon the aesthetics required.



Emergency management systems

Before we can consider what type of wiring system would be appropriate for an emergency management system, we need to understand what one is.

An emergency system is one whereby standby power supplies are activated in the event of power failure of the normal supply. These back-up supplies would be for safety circuits of the type listed in the note to Group 560.1 of BS 7671.

In today's world the reliability of power systems has not merely become a desirable quality, but rather a necessity. Standby power supplies are used to supply electrical loads when the prime power source fails, which is normally the mains power supply.

There are two main types of power supply. These are:

- generator based
- battery based.

For any standby supply for safety purposes Regulation Group 313.2, Chapter 35 and Chapter 56 of BS 7671 state the requirements for safety standby supplies.

There are in effect four types of standby power supply, with some variation within the four basic areas. These are:

- load isolation
- uninterruptible power supply (UPS)
- standby or short break power supply
- frequency conversion.

All of these possible options can be provided by either dynamic or static means.

Regulation 560.4.1 details the classifications for an electrical safety service supply.

UPS (Uninterruptible Power Supply)

Where it is required to provide a 'no-break' supply, i.e. one that never fails even though the supply does, it is necessary to install a UPS.

In general the main supply feeds the UPS system. This system incorporates a battery back-up. The load is supplied by the UPS system. When the main supply fails then the battery back-up 'kicks in' and the supply is maintained for a period.

Standby or short break systems

As the name suggests a standby system supplies power to a system when the main supply fails. It does not provide an uninterruptible supply however, and there may be many seconds delay until the supply is restored.

This is the type most commonly used for emergency lighting systems. Obviously there are a number of variations that are possible. It is beyond the scope of this study book to cover them all.

Where generating sets provide back up for systems, not necessarily emergency lighting systems, then a variety of options are open to you. However, in its simplest format the failure of the main supply is sensed via equipment that sends a signal to the prime mover's (generator's) starter system. This sensing system monitors the supply for under-voltage and over-voltage, phase failure and phase reversal, and for frequency variations beyond preset levels.

Regulation Group 560.7 details the specific requirements for circuits of safety services.

Circuits	Demand	Regulation
Not to pass through zones exposed to explosion risk	Safety circuits must be protected from catastrophic failure	560.7.2
Overload protection may be omitted where the risk of the loss of supply is a greater hazard	An overload may be less of a problem than a fire	560.7.3
Overcurrent devices shall be selected and erected so as to avoid an overcurrent in one circuit impairing the correct operation of other safety circuits	One failure should not lead to failure of everything	560.7.4
Not to be installed in lift shafts	Except for ire service lifts	560.7.8
Diagrams	Maintainers need to know what exists	560.7.10
List of equipment made available	Users have to be able to use the system	560.7.11
Operating instructions shall be available	Users have to be able to use the system	560.7.12
Cable types	Wiring systems matter and failure of the cabling must not be allowed to happen	560.8.1

For the wiring system used, you would expect to see something that offers reliability of supply in the event of fire or mechanical damage. For this you would install XLPE/SWA for the feed to the distribution boards. For the individual safety circuits and for the signal/control cables you would probably use singles in conduit and trunking having the cable code 6491B.

Security systems

Security systems describe circuits such as emergency lighting, fire alarm and intruder prevention. To be able to consider what would be the most appropriate wiring system, it is necessary to have an understanding of some of the requirements of each of circuits.

Emergency lighting

Emergency lighting within any installation is essential. If there is a large amount of smoke and fumes then it is very disorienting to find your way out. If there is a fire, then it would be common for the lights to no longer work and to be in the pitch dark with smoke adding to the sense of being closed in is very frightening. For this reason emergency lighting levels equivalent to the light given off by a full moon are the minimum required

There is a requirement that every workplace:

'shall have suitable and sufficient lighting, and also that suitable and sufficient emergency lighting shall be provided and maintained in any room in circumstances in which persons at work are specially exposed to danger in the event of failure of artificial lighting'.

The introduction of *The Regulatory Reform (Fire Safety) Order 2005 for England and Wales* has a significant on all aspects of fire prevention, fire alarms systems and emergency lighting systems.

These regulations state;

You must have a suitable fire detection and warning system. This can range from a shouted warning to an electrical detection system. Whatever system you have it must be able to warn people in all circumstances.

You must have safe routes to leave the premises. If only one route is available you may need to make it fire resisting or install an automatic fire detection system

With emergency lighting there is some terminology that you should be familiar with.

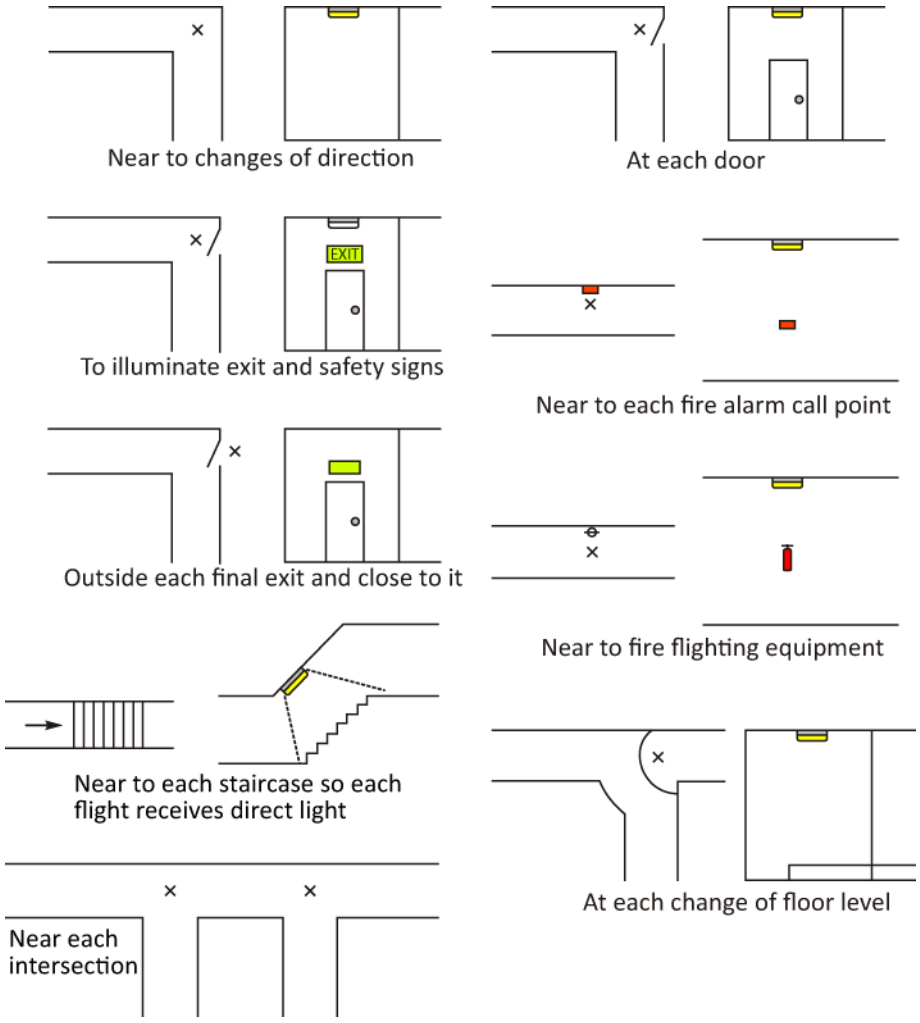
Escape lighting	this is short term lighting for between 1hr-3hr.
Standby lighting	this is long term lighting and allows for some continuation of work and has a higher level of illuminance.
Open area lighting	this is designed to provide structured lighting to avoid panic as the general public move towards safe exits or escape routes.
High-risk area lighting	this is primarily for those working in high risk areas or dangerous situations. In the event of fire or other event there needs to be sufficient lighting to allow safety shut-down procedures to be safely carried out.

It is necessary to emphasize that The Regulatory Reform (Fire Safety) Order requires, where necessary the following:

- emergency routes and exits must lead as directly as possible to a place of safety
- in the event of danger, it must be possible for persons to evacuate the premises as quickly as possible
- the number, distribution and dimensions of emergency routes and exits must be adequate having regard to the use, equipment and dimensions of the premises and the maximum number of persons who may be present there at any one time
- emergency doors must open in the direction of escape
- sliding or revolving doors must not be used for exits specifically intended as emergency exits
- emergency doors must not be so locked or fastened that they cannot be easily and immediately opened by any person who may require to use them in an emergency
- emergency routes and exits must be indicated by signs; and
- emergency routes and exits requiring illumination must be provided with emergency lighting of adequate intensity in the case of failure of their normal lighting.

This is law; and to support the law BS 5266 provides guidance on the process of design and installation for emergency lighting systems.

Positioning of emergency lights



You can see where emergency lights need to be positioned under normal circumstances.

The length of time that emergency lights must guarantee to work is called the duration. This is the name given to the time that an emergency luminaire remains lit at the minimum design output after a mains failure. The ranges of times are set out in BS 5266, but fall within a 1 to 3 hour time-frame.

Emergency lighting comes in two main formats: centralised battery back-up systems and individual self-contained systems which have their own internal battery. Within these two formats there are three types of lighting arrangement.

- Maintained
- Non-maintained
- Sustained

Maintained emergency lighting

In a maintained system the same lamp is used by both the mains supply to the fitting and by the emergency back-up system, this is irrespective of it being from an integral battery or from the centralised back-up supply. The light is permanently on. It is only when the supply fails that the back-up battery is connected across the lights. You would not notice a great deal of difference in the light levels. This has the advantage that it is easy to see if a lamp has failed.

Non-maintained emergency lighting

This is only activated when the mains supply fails. When this happens, the battery is connected across the fitting. This has the disadvantage that should a lamp be broken, it would not be detected until there was a power failure. For this reason there must be regular testing of the emergency lighting.

With either system the supply to the light is on when the power supply fails.

Sustained emergency lighting

With this method, there is an additional lamp within the main luminaire that is lit upon failure of supply to the mains. This additional lamp can be supplied from a centralised battery back-up system or from an emergency battery contained within the fiiting.

Additional lighting
Emergency Lighting should also be provided in;
Lifts
Toilet areas (especially disabled)
Escalators
Motor and plant rooms
Covered car parks

With all these factors in mind, there can only be one wiring system suitable that is either MI or FP wired separately or in segregated trunking. The cables can either be clipped direct or suitably supported on cable tray using heat resistant tie wraps.

Fire alarm systems

As with emergency lighting systems, fire alarm systems now fall under the Regulatory Reform (Fire Safety) Order 2005 for England and Wales.

Fire alarms are installed for two reasons, usually both at the same time. These are:

- protection of life
- protection of property.

Fire detection equipment needs to comply with BS 7671 (IEE Wiring Requirements) as well as BS 5839.

Potential causes of fire within electrical installations

Electrical installations, especially temporary ones, should be of sufficient capacity for the intended use and designed, installed, inspected and maintained by competent personnel. The installation should meet BS 7671:2008 requirements for electrical installations, which includes a special section on construction sites.

Fire alarm systems

Care has to be taken when designing a fire alarm system. Careful thought must be given to the escape time of people, the purpose of the system, the response time of the fire brigade etc.

Fire alarm systems come in many shapes and sizes, and will depend on the type of installation and the depth of the client's pocket.

Fire alarm systems come in many shapes and sizes.

- Type P automatic detection system for the protection for property;
- Type L automatic detection system for the protection of life;
- Type M is a manually operated system for the protection of life.

Property protection

A good fire alarm system will automatically detect fire at an early stage, indicate its location
And raise the alarm.

Protection of property has two classifications

- P1 All areas of the building must be covered with detectors, with the exception of toilets and voids less than 800 mm high.
- P2 Only areas of defined high risk, a fire resisting construction should separate the areas.

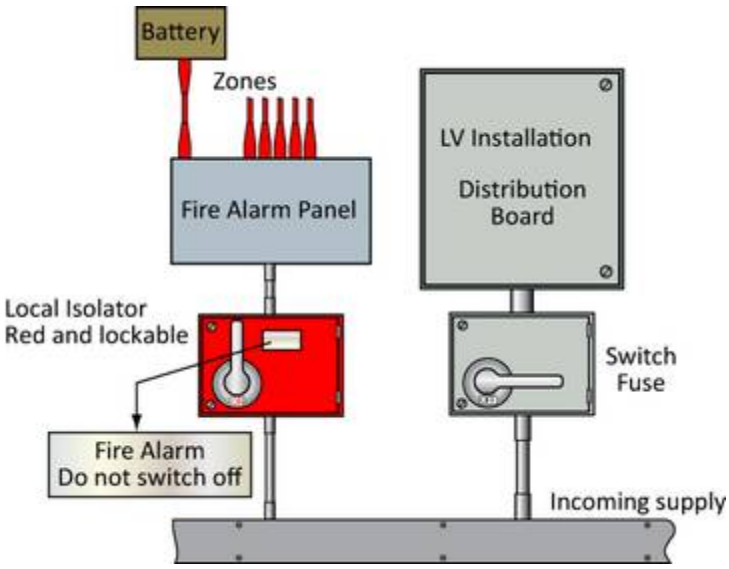
Life protection is usually classified as;

- M The most basic
- L1 All areas of the building must be covered with detectors, with the exception of toilets and voids less than 800 mm high.
- L2 Only provides protection in areas which could lead to a high risk to life.
- L3 Protection of escape routes including
  Corridors, passageways and circulation areas
  Stairwells

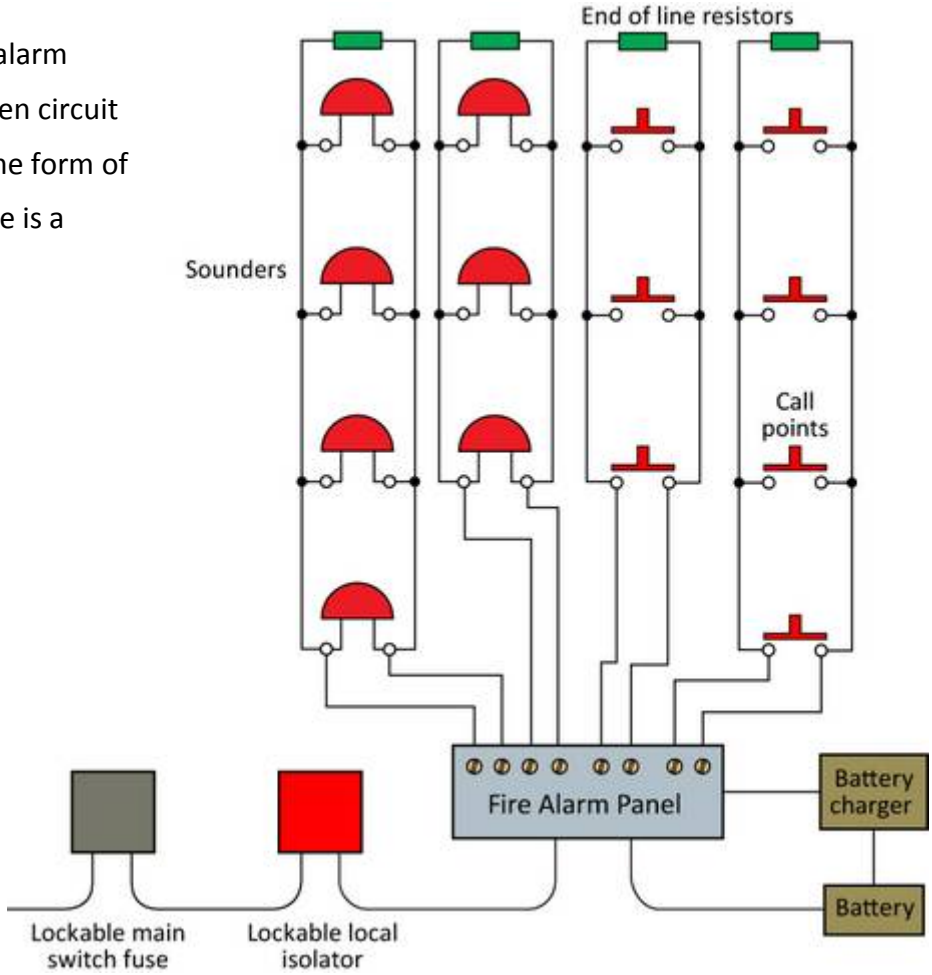
Fire alarm circuits

Fire alarm circuits ideally should not be protected by an RCD. Unwanted tripping is considered to be more dangerous than an earth fault. In those situations where an RCD must be used, such as with a TT supply, then the RCD must be dedicated to the alarm supply circuit and should have a trip rating in excess of 100 mA.

Here you can see how a supply has a dedicated local isolator appropriately labelled. The batteries act as the backup when the main supply fails.
The manual call points need to comply with BS 5364, and should be located on exit routes, floors, floor landings, and staircases.
No person should need to travel more than 30 m to break a glass.



Schematic of a simple fire alarm
Most fire alarms use an open circuit system combined with some form of monitoring to check if there is a break in the circuit.



The final aspect to a fire alarm system is the automatic call systems that can be set in place so that the fire services can be automatically called.

There are four methods that can be used. These are:

- Direct

  Private line and as such can be expensive. Very reliable but some fire brigades do not like them as they take time to test and advise about fault warnings
- BT operator

  This guards against failure to receive an emergency call but requires someone to be on duty
- Direct or BT operator through alarms by carrier

  Signal is sent to local exchange and fed into multiplex system, which then transfers it to relevant points
- Central station operator

  Uses the public telephone system to send coded signals to an automatically dialled control room

The types of cables that may be used are varied. The most common cable is MICC (PYRO). MI has excellent heat resistant qualities and will withstand fire for quite a period. Other cables that can be used are those like FP200 or FP400 which have anti smoke properties as well. Whatever type is used they must have fire resisting properties and must have a cross-sectional area greater than 1 mm^2.

If a trunking containment system is used, they must be clipped using fire resistant supports within the trunking.

Fire alarms BS 5839	Emergency lights BS 5266
Physical segregation of at least 300mm^2	Physical segregation
Use of MI	Use of MI
Cables to BS 6387 Cat. AWX or SWX and incorporating an earthed metallic screen and an overall insulating sheath (FP200; Firetex)	Cables to BS 6387 Cat. B

Cables to BS 6837 are suitable as fire alarm and emergency lighting. They XLPE with low smoke zero halogen properties and have a steel wire armouring.

However, you must look to the specific British Standards for emergency lighting systems, fire alarm systems and other safety service systems.

Closed circuit TV, communication and data transmission systems

In this topic we will consider three specific areas of intruder protection

- Security
- CCTV
- Door entry systems

Security systems

A basic alarm system will contain at least the following

- A closed loop circuit
- A means of tamper-proofing
- A means of zoning
- Panic button
- Entry and exit system
- A bell or sounder

Closed circuit system

Basically, this system has a series of switches that are closed and these keep the power to the relay on until they are broken. When the switches open, the relay de-energises and the alarm is called.

The main advantage of the closed system is that it is fail safe/. The disadvantage is that the relay or coil is energized all the time.

The call points on this type of alarm could be pressure pads, magnetic strips, reed switches etc.

This type of circuit can be enhanced by running a tamper proof loop with zoned loops. Should this be broken even if the alarm is switched off the alarm will automatically sound.

Alarm systems all contain the same elements

- Sounder
- Power supply
- Switch/detector
- Control panel
- Closed circuit TV

CCTV

At its most basic, a CCTV system camera transmits a signal to a monitor or video. The connection is made via coaxial, fibre-optic or single twisted-pair cable, with wireless transmitters, web cameras and camera servers added. Video multiplexing is now used to record multiple cameras onto a single tape.

CTV is used in many different environments:

- retail security
- hotels and lodgings
- offices
- educational facilities
- day-care facilities
- manufacturing or industrial facilities
- gambling facilities.

Cameras

Some camera types available are:

- Board a lens mounted directly to a circuit board. These cameras are easy to disguise and are commonly hidden
- Bullet are similar to board cameras but are shaped like a length of lipstick
- Fixed dome the camera remains in a fixed position. The camera can be larger than for either board or bullet and gives greater clarity of vision
- Pan/tilt/zoom (PTZ) is a dome camera with the ability for the operator to move the camera within the dome
- Full-sized much greater range of options, but very obvious
- Network instead of using video output this connects directly to the computer network and functions as part of the BEMS (building management) system.

Control of CCTV

- Devices used to manage and control the images are;
- Video switchers – an early low cost method used to manage images.
- Quads – these take four images and display them on a monitor.
- Multiplexers – these are used to record multiple cameras onto a single tape.
- Matrix – used on large sites where hundreds of cameras are monitored.

Recorders

The range of storage devices and file types available has grown in recent years. Effectively there are two types of recording system:

- analogue
- digital

Analogue

The standard method is to use a VTR (video tape recorder). There are a number of ways in which the recording can take place:

- continuous lots of tape used, but useful for monitoring critical areas;
- event triggered used to record specific events occurring like a robbery

Digital

The digital recording of data is varied and due consideration has to be given to the nature of the file type (jpeg, mpeg etc.) as well as the nature of the storage device which can be:

- hard drives
- digital tape
- DV tape
- combination – usually hard drive and tape
- digital multiplexing
- digital single-channel – is a bit like a digital VCR

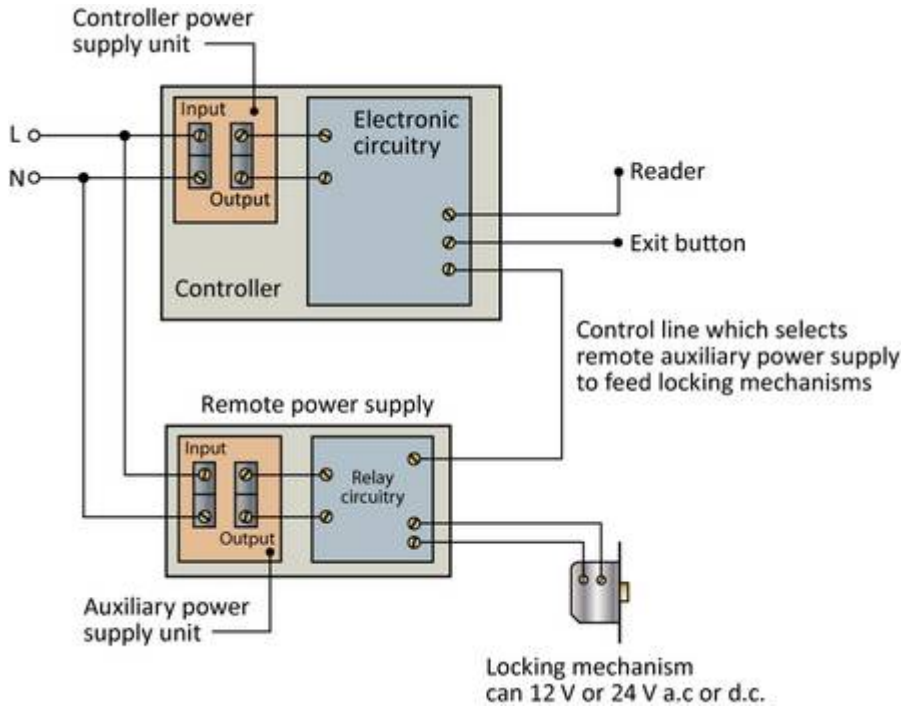
Door entry systems

When electronic means are used to control access to a building a range of options are available. This brief section will consider simple door entry systems.

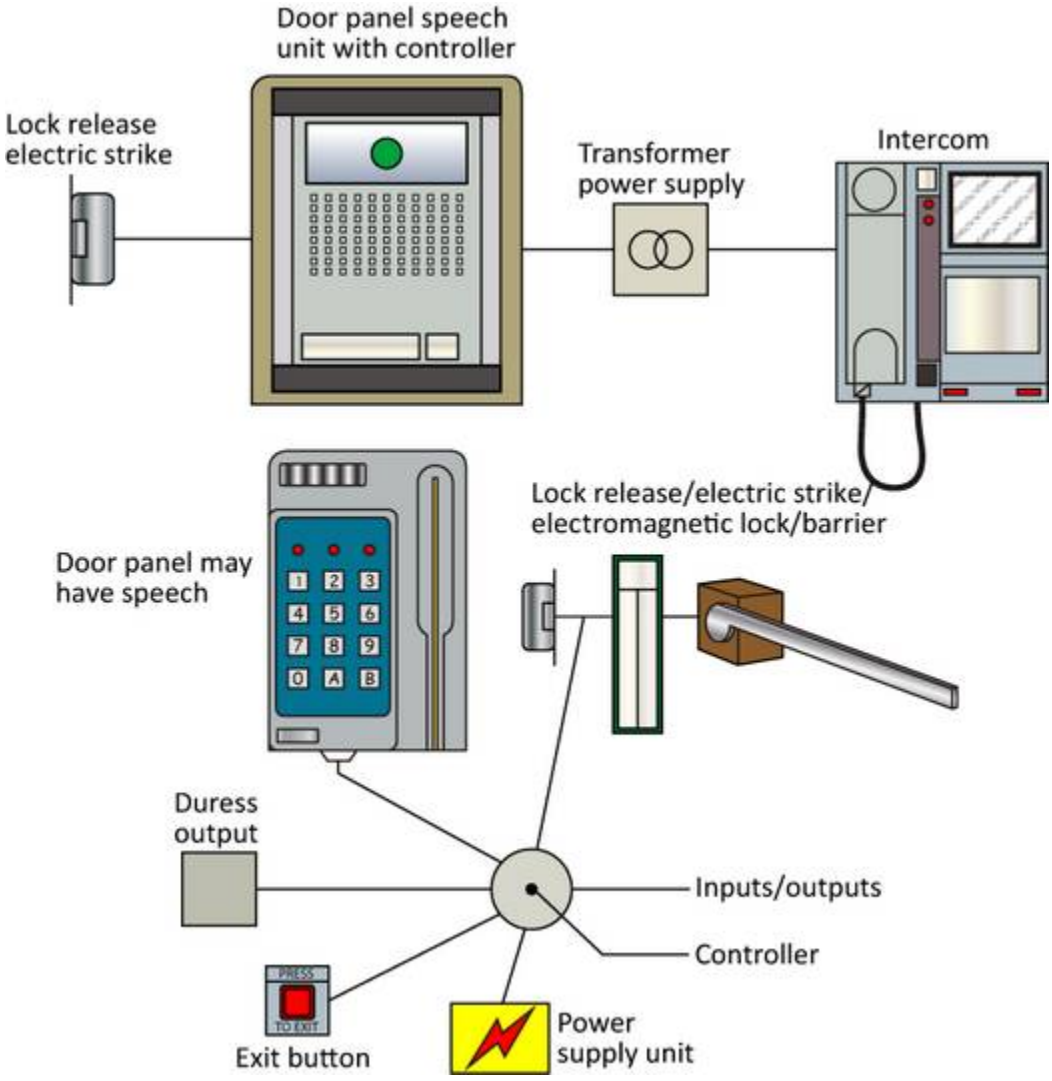
Any door entry system will contain:

- an electronic means of locking and unlocking the door
- something to close the door once it is open – spring-loaded device
- a sensing device to act as a check on whether the door has actually closed
- a controller – to allow the person inside the building to signal the lock to open.

The electronic means of locking and unlocking the door is tied to a solenoid. (See the diagram on the next page).



Electronic access



Wireless CCTV

These systems do not require cable back to the monitor or video recorder; they rely on an inbuilt transmitter which then transmits the image to the equipment. They can transmit for 100 m outdoors to 30 m indoors. They do require a power supply.

The cable used for these systems will invariably be coaxial for the CCTV and data cables such as twisted pair or fibre optic for the transmission of signals. The loading of security systems is not large and volt-drop is not normally a concern. What is important is that the signals are not degraded by noise interference.

Exercise 11

1. A new emergency lighting system is to be installed. The cables are to be run with the normal power circuits in existing steel trunking. What precaution would you need to make?

2. Why does it matter that an emergency light exists outside an emergency exit as well as inside?

3. A church is to be completely rewired. The following requirements must be met:
   - External floodlights used to highlight the structure of the church;
   - Lighting of the main body of the church;
   - Lighting for choir stalls to be individually controlled by choristers;
   - Spotlights used for additional effect near altar.

4. A shop within a shopping arcade is to be refurbished. The shop used to sell clothing and is now to become a coffee shop.
   i) State the environmental factors that may apply
   ii) What wiring system would you choose, giving reasons for your choice?

5. A commercial office on the second floor of a three storey building has been let to new tenants. The supply is three-phase four-wire 400 V TN-C-S. The supply at the second floor is from a tap-off on a rising main busbar.
   i) State the environmental factors that may apply
   ii) State the type of circuits that you would expect to design
   iii) State what wiring systems you would utilise for each of the circuit types you have chosen.
6. A large warehouse for storing spare parts is being built, and as the designer you have been asked to design an appropriate electrical installation.

   What wiring systems would you choose and why have you made such a choice?

12: Tools

In this session the student will:

- State the procedures for selecting and safely using hand tools, power tools and adhesives for electrical installation work
- State the procedures for selecting and safely using measuring and marking out tools.

Tools and equipment

Any tools and equipment selected to complete the task must be safe and fit for purpose.

The Provision and Use of Work Equipment Regulations 1998 (PUWER)

What does PUWER do?

In general terms, the Regulations require that equipment provided for use at work is:

- suitable for the intended use;
- safe for use, maintained in a safe condition and, in certain circumstances, inspected to ensure this remains the case;
- used only by people who have received adequate information, instruction and training; and
- accompanied by suitable safety measures, eg protective devices, markings, warnings.

Many accidents happen because people have not chosen the right equipment for the work to be done. Controlling the risk often means planning ahead and ensuring that suitable equipment or machinery is available.

Make sure hand tools are safe

Many risks can be controlled by ensuring hand tools are properly used and maintained, for example:

Hammers - avoid split, broken or loose shafts and worn or chipped heads. Make sure the heads are properly secured to the shafts;

Files - these should have a proper handle. Never use them as levers;

Chisels - the cutting edge should be sharpened to the correct angle. Do not allow the head of cold chisels to spread to a mushroom shape - grind off the sides regularly;

Screwdrivers - never use them as chisels and never use hammers on them. Split handles are dangerous;

Spanners - avoid splayed jaws. Scrap any which show signs of slipping. Have enough spanners of the right size. Do not improvise by using pipes etc as extension handles.

Make sure machinery and equipment are maintained in a safe condition

To control the risk you should carry out regular maintenance and preventive checks, and inspections where there is a significant risk. Some types of equipment are also required by law to be thoroughly examined by a competent person.

Inspections should be carried out by a competent person at regular intervals to make sure the equipment is safe to operate.

Any portable tools and equipment used on site should be operated at 110 V via a transformer.

Power tools

Power tools should operate from a 110 V supply which is centre tapped to earth so that the maximum voltage should not exceed 55 V. If a mains voltage is used RCDs should be used with a rated tripping current of no greater than 30mA and having no time delay.

Power tools should be checked before use;

- ✓ no bare wires visible
- ✓ cable covering not damaged
- ✓ cord grips in place
- ✓ plug in good condition
- ✓ outer casing not damaged
- ✓ cables and equipment suitable for environment
- ✓ no evidence of overheating
- ✓ RDCs tested

Power tools

There are now many power tools used for fixing, nail guns, staplers, cordless riveters, etc. These along with compressors and airlines are particularly dangerous pieces of equipment and should not be used without proper training.

Tools

As an electrician you will need to acquire tools to be able to carry out your job. There will be tools that you use all the time and other that you will only use occasionally.

As these will hopefully last you for a long time it is worth investing in as good a quality as you can afford. Use them only as they were intended.

Your tool box will need to contain most of the following;

Hand tools

Side cutters

These are the standard fare of the electrician and they do need to be adequately insulated.

Cutters and insulation strippers

The insulation strippers allow you to measure the amount of insulation to be removed.

Long-nosed pliers

As the name implies and useful for getting to things just out of reach in confined spaces

Pliers

These need to be insulated and are great for cutting heavier cables and twisting multi-stranded conductors

Screwdrivers

Terminal driver

Small and insulated.

Socket driver

Slightly larger and able to fit the head of the screw without damaging it.

Large screwdriver

Essential for larger screws.

Electric screw driver

A real labour saving tool.

Saws

Junior hacksaw

Small but useful.

Tenon saw

Useful for cutting joints in timber.

Electricians Knife

Many have Stanley knives but these are frowned on as they are so sharp.

Pad saw

Used for cutting the edge of floorboards so that they can be lifted.

Hammers

Claw hammer

Essential for general use and lifting floorboards

Lump hammer

Essential for chopping out boxes

Ball Pein

Also called an engineer's hammer. Used in metalwork.

Clipping hammer

Good for small clips holding pvc cables

Hand drills

When using these drills, always hold them so that they are vertical and turn the handles in a clockwise direction. However, the use of cordless drills has made these two almost redundant!

Power drills

Drills need handling carefully and goggles are to be used at all times, especially when drilling into steel and brick/concrete. Electric drills ideally should be used from a 100 V transformer.

Spanners and grips

Assorted spanners are required for tightening nuts. Grips such as Footprints are useful when installing steel conduit.

Chisels

There are a wide range of chisels which you will need for chopping out wood and brick/concrete.

Files

Used for removing rough edges or even changing the shape, smoothing and making things smaller. They can be round, half round flat and come in different grades of cut fine, medium or rough.

Reamers are used to remove burrs from inside conduit

Crimping tools

Cables can be terminated by crimping. The lugs are placed over the conductor and the crimping tool squeezes them together. The action squeezes the conductor and insulation simultaneously.

Your toolbox would also contain items such as electricians' tape, assorted clips, fuses of various sizes, screws of various types, greensleeving, grommet strip, fuse wire, nuts and bolts etc. All of these are useful to have to hand for immediate use.

Adhesives

There are a variety of adhesives that you may need, repairing wood work for example would need wood glue, and 'super' glues are good for repairing plastics. These needed to be treated with caution as they can glue you as well and also cause allergic reactions.

The adhesive used when welding plastic conduit fittings to the plastic conduit is called Egaweld.

Measuring and marking out

As an electrician you will have to measure and mark out lengths of cable, position of fittings, check for levels etc. There are a variety of tools to help you do this. Some of these are fragile and need handling with care

Rulers

These come in sizes from 150 mm (6") up to 600 mm (2'). They are most useful when they are made from stainless steel (don't rust), and they are used particularly when working with trunking and tray work.

Tape

As with rulers, tapes come in a variety of shapes and sizes. They usually range from 3 m (10') to 30 m (100'). For the average electrician a 5m tape should be more than sufficient. Tapes are made from a springy type of steel and are coated to prevent rust. The tape rolls back into its container after use by simply letting go of it.

Laser distance measurers

These are hand held and are used primarily for interior work, such as a wall or ceiling. These are useful for measuring long distances such as corridors.

They also come with an extractable metal tape where the measurement has a digital readout and also a laser level.

Spirit level

This is the most basic of tools used for getting things straight.

A spirit level is effectively a straight edge with a liquid set in a glass or plastic bulb. When the spirit level is flat, the bubble in the liquid sits in the centre of the glass bulb. If it is not flat then the bubble migrates to one end or the other.

Laser levellers

These are the electronic equivalent to a spirit level; they are useful in finding the level around the outside of a room or over long distances.

Beware of the dangers of using laser equipment. The laser beam will blind!

Plumb line

A plumb line is merely a length of string with a weight attached at one end. Although you can make your own up, it is probably best to buy one. The chalk-a-matic has a sealed compartment for powdered chalk. The beauty about using this is that the line is chalked automatically as it is pulled out.

Centre punch

A centre punch is used after the centre of something has been found. The idea is to make an indent into the metal that can be easily located by the drill bit. This stops the drill bit wandering about on top of the metal.

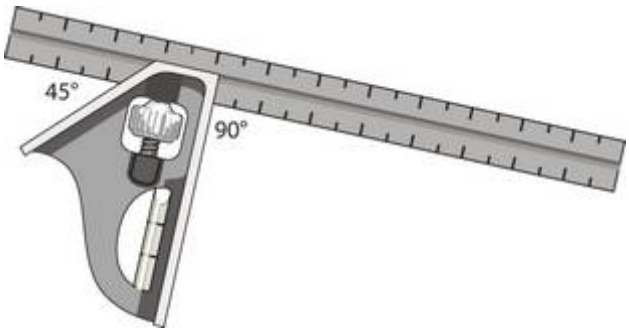
When you have marked out the centre of a piece of work, prior to it being drilled, you then hit the marked centre with a hammer and centre punch – only once!

However, there is available an auto punch which does away with the hammer, just push down hard and it makes the indentation

Auto centre punch

Squares

These are an excellent tool for marking out conduit, trunking and cable tray work. They give a good 90 º angle and many give a good 45 º angle as well.



For most instances, this is more than sufficient for any work that you likely to come across

Test equipment

The essentials here are a multimeter (with appropriate test leads to GS38), voltage tester and proving unit, insulation resistance tester, low resistance ohmmeter, RCD tester, earth loop impedance tester and a prospective short circuit current tester. Now admittedly not every electrician needs to carry around all these items of equipment at any one time, but they should always be accessible.

Exercise 12.

1. State the requirements of PUWER.

2. List at least 5 items to look for in making sure an electric drill is safe to use.

3. What safety checks should you perform before using a hammer?

4. Why should you not use a screwdriver as a chisel?

5. What do you usually carry in your toolbox and why?

6. List at least 6 devices used for marking out, measuring distances and levelling?

7. You are going to be installing a junction box under floor boards. List the tools that you would need to lift the boards and then replace without damaging them.

8. You are to fix a length of steel conduit between two adaptable boxes situated 5m apart.
   The run contains two bends. List the tools and equipment that you would need to put into the works van before setting out from the office.

13: Fixing devices

In this session the student will:

- State the criteria for selecting fixing devices for wiring systems. and equipment

There are a large number of fixing devices, to choose from, when choosing your device you need to give consideration to the;

- Load bearing capacity
- Fabric of the structure
- Environmental considerations
- Aesthetic considerations

Fixing devices

There are such a number of different types of fixing that there isn't room to cover them all in this session. However, we can look at some of the most common.

Whatever type of fixing device you use, the device is required to hold the equipment to the wall, floor ceiling or partition without causing damage.

The drill, screw, and fixing device should all be of the correct size in respect of each other.

An ordinary drill bit is sufficient for wood but a tungsten carbide-tipped masonry drill will be needed for brick work. Use a slow speed for drilling masonry.

Masonry drill bit

Wood drill bit

Hammer or percussion drills are recommended for harder substances such as concrete.

Fixings for light weight devices

Wall plug (plastic plug)

There are a variety of types of wall plug ranging from plastic to nylon and fibre. They all have the same basic function however

A hole is drilled into the wall (brickwork, concrete) to the depth required for the plug to be completely inserted. You should not be cutting any of the wallplug off to make it fit in.

The hole drilled should be just large enough for the plug to fit in. It should not be so slack that it turns around in the hole. When the plug is fitted into the hole, then the screw can be inserted.

The wallplugs are colour coded for different sizes.

Similar to the rawlplug is a fixing device known as a 'rocket' or 'star plug'. These are used for securing fitting such as socket-outlets to Thermalite construction buildings. To fit a 'rocket' simply drive the fitting into wall with a hammer. The process of fixing is then the same as for a rawlplug.

Redidrives

The redidrive is widely used to fix electrical enclosures to plasterboard partition walls and ceilings. The ready-drive is screwed into the building fabric using a crosshead screwdriver. The enclosure is then secured to the wall using a screw in a similar way to using a rawlplug.

Another alternative to the above is a plastic plug similar to a wall plug, but when used the rear of the plug compresses against the back of the plasterboard.

Spring and gravity toggles

Here you can see that the spring toggle has a hinged joint with a bolt running through it. The nut is hidden by the hinged joint.

This type of clip is very useful when fixing into plasterboard ceilings where the weight is spread evenly around the fixing.

The gravity toggle is off-centered so that the long end drops down when placed in the void. These only work in vertical fixings whereas the spring toggle can be used for vertical and horizontal fixings.

You should remember that the fixing is still only as good as the material into which it is fixed. Never try to hang too much weight on it.

Heavy fixing devices

Where fixings of more strength are required, particularly into concrete then rawlbolts can be used.

Rawlbolts

Here is a variety of rawlbolts. At the top left, we have the classic rawlbolt which has a central thread with a nut attached.

The next rawlbolt has a separate bolt. Useful where a flush fixing is required.

These rawlplug has many variations as can be seen by the hook variant.

The bottom rawlbolt is strictly speaking, a rag bolt. These are placed in wet concrete and allowed to set.

Screws

Screws are usually used when fixing items to wood.

The size of a screw is determined by;

- the length of the screw
- the size of the screw
- the type of head
- the metal used in construction

Wood screws are measured across the shank, which is usually parallel all the way down to the end where it tapers to allow the screwing action to be easily started.
Wood screws are given numbers from 2-18, 6, 8 and 10 are the most common.

On a thick or hard piece of wood, to make the drilling easier a pilot hole is made with a smaller size drill or a bradawl. This is essential when drilling into hardwoods such as Oak or Mahogany etc.

Screw Head Types

Always use the right driver for the screw head you are working on. Some look the same but they are not. If you damage the screw head you will have difficulty getting the screw back out if you need to.

Slotted

This is the original screw; these are used less often now because the screwdriver can slip out of the slot, slowing the job down

Phillips

This screw type is very popular –you find them in a very wide range of applications.

Pozidriv®

It looks a lot like a Phillips screw head, but it includes 4 more contact points

TORX®

These are gaining popularity.

Screw types

			
Countersunk (flathead)	Countersunk (crosshead)	Raised head	Decorative screws
Used for general fitting, spacer bars etc. The head must be flush or slightly below the surface	The crosshead prevents the screwdriver from slipping; therefore the screws can be fitted faster. Used for low-density chipboard and soft woods.	Used for decorative hardware such as door trims. Comes in different finishes for aesthetic consideration	Screws can be unsightly so thought needs to be taken in choosing screws. These mirror screws conceal the head.

Environmental consideration for screws

Different types of finishes are applied to screws.

- **Zinc plating:** Because of steel's tendency to rust, you'll never get bare steel fasteners. The most common covering is zinc, but this won't stand up to outdoor conditions.
- **Black Oxide:** Most common on socket head cap screws and other machines screws. This provides very mild protection against corrosion and usually has an oil film added for additional protection.
- **Brass screws:** these are used because they are more pleasing to look at. They are water resistant so can be used outside. Pure brass is soft so unless it is to be used for decorative purposes only it is usually mixed with another metal.
- **Galvanic Corrosion:** when different metals are placed together an electrolytic reaction takes place, so using brass screws alongside zinc would not be a good idea

Bolts

Bolts are used in all types of engineering, along with a washer and nut. The bolt passes through the clearance hole in the parts to be joined.

Locking devices

Locking devices like the nut and bolt are used on parts of machinery etc, which may need removing for maintenance or repair. On machines and engines the vibration can cause the nut to slowly come loose. This is dangerous; therefore the right type of locking device needs to be used.

Spring washers

- When the nut is tightened, the washer is compressed, and because the washer is sharp it digs into the nut and the component, preventing it from working loose.
- The washers can be single or double coiled
- The washers are only generally used the once

Locknut

- The bottom nut is tightened with a spanner
- The top nut is then tightened, the friction in the threads and between the nut faces prevents them from rotating
- Lock nut are always bevelled

Split pin

- This can be used with ordinary nuts or castle nuts
- When using with ordinarily nuts it is essential that the split pin is in contact with the nut when tightening
- The split pin is opened after insertion to prevent it falling out
- Split pins can only be used once
- The bolt is usually left 2-3 threads protruding

Castle nuts

- The castle nut has a cylindrical extension with grooves
- The nut is tightened, the stud is drilled opposite a groove, and the split pin inserted, stopping the nut from turning
- The split pin is opened to prevent it falling out
- The pin can only be used once

Simmonds locknut

- The Simmonds lock nut has a nylon insert
- The threads on the end of the stud bite into the nylon
- Friction keeps the nut tight
- These nuts can only be used once

Washers

Serrated washer

- When the nut is tightened, the serration is flattened preventing rotation
- This washer can only be used once

Tab washers

- When the nut is tightened, one tab is bent onto the flat side of the nut and the other tab is bent over the edge of the component
- The washers can only be used once
- The washers can have any number of tabs

Tab washers are commonly used in the automotive industry.

Nails

Nails are made in different lengths and gauges (thickness). The longer the nail the greater the thickness although some nails can come in different gauges. Nails are made from different materials depending on what characteristics are required and are designed around strength, corrosion protection and gripping capabilities.

A nail relies on the friction between itself and the surrounding material for its holding power, therefore a long nail will have more holding power than a short nail of the same gauge.

If a nail bends while it is being hammered, it can be tapped sideways to straighten it and then

hammered home. If a nail buckles then it needs to be removed, sometimes a nail will buckle if it hits a solid object such as another nail or a knot in the wood. If this is the case then reposition a new nail.

Round head nails

Used for general woodwork, made with smooth or chequered head. Can split the wood

Round lost head nails

Used for joinery, head is punched below the surface for a better finish.

Lost oval head nails

Used for joinery and flooring, to avoid splitting the wood, the long oval side should follow the grain of the wood.

Smaller head than Oval brad head for a neater finish.

Cut floor nails

Used for fastening down floor boards, the blunt tip punches a hole which helps to stop the wood splitting.

Clout nails

Used for sheet material and roofing felt and tiles.

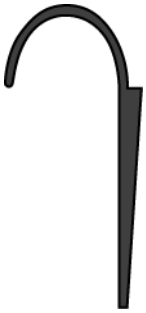
Plasterboard nails

Used for fixing plasterboard sheets. Has jagged edges to give very high resistance and holding power.

Masonry nails

Used for fixing to masonry, very hard to prevent bending or buckling.

Crampet

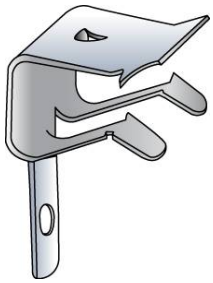


The crampet is a device used to hold conduit in place that is going to be plastered over. It can be fitted into rawlplugs and into joints in the brickwork. However, it is just a holding device.

Rivets

A device for joining metal together

Snap-on fixing



The girder clip has to be firmly hammered onto the girder. The clip is made from a very strong and spring-loaded material. It is fairly easy to knock into place, but extremely difficult to remove.

Exercise 13

For each of the following examples list the fixing device you would use:

1. A socket outlet to plastered brick wall

2. A wall lamp to plasterboard wall

3. A motor to concrete floor

4. Plastic conduit to a brick wall

5. SWA cable to RSJ beam

14: Installing wiring systems 1.

In this session the student will:

- Specify and apply the installation methods and procedures for installing thermoplastic cables.

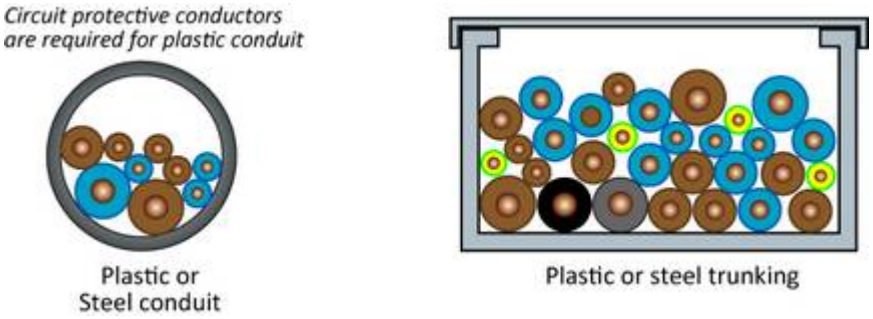
In the previous sessions we looked at various methods in which circuits can be wired. Now it is time to look at how these systems are installed.

We also considered some of the more important environmental factors; these will be mentioned again where appropriate to reinforce understanding.

- Wiring system
  - Single-core cable
  - Multi-core thermoplastic cable
  - Multi-core thermosetting cables
  - Mineral insulated cables
  - Data cables
- Containment systems
  - Conduit
  - Trunking
  - Busbar trunking
  - Tray

Installing

The thermoplastic-insulated 'singles' type of cable can be installed in a number of different ways. The ***singles*** are installed within conduit or trunking. This is necessary to provide adequate mechanical protection. Mechanical strength is a measure of a cable or system's ability to withstand forces such as hammer blows, bumps, scrapes etc.

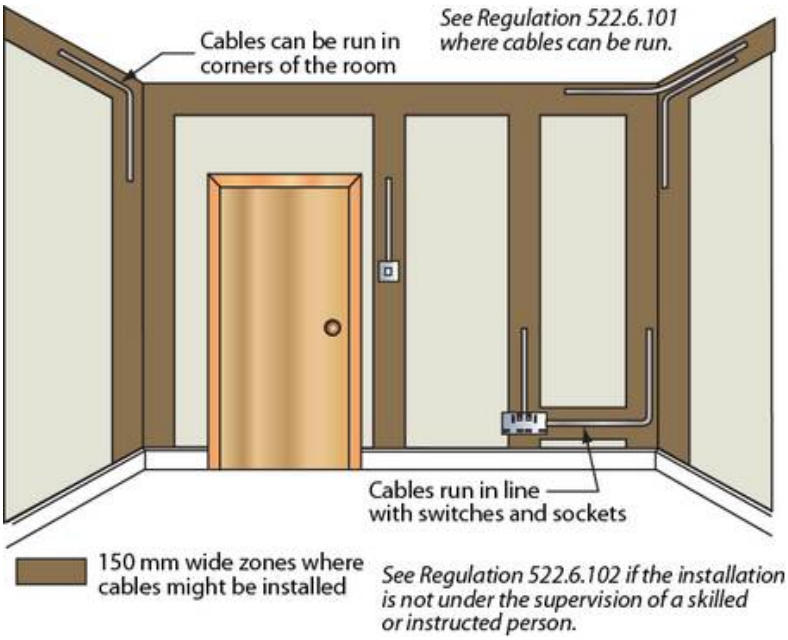


The more common variety of thermoplastic insulated cable is the double insulated twin and three-core type. This type is installed without usually any extra need of protection.

There are certain aspects that need to be considered when installing this cable system.

The first thing to consider is the type of building or property that the cable is to be installed in. Cables running through walls, running up and down walls, in ceiling voids, under floors, through insulation all need extra care and thought.

We will look at a few examples of how this works out.



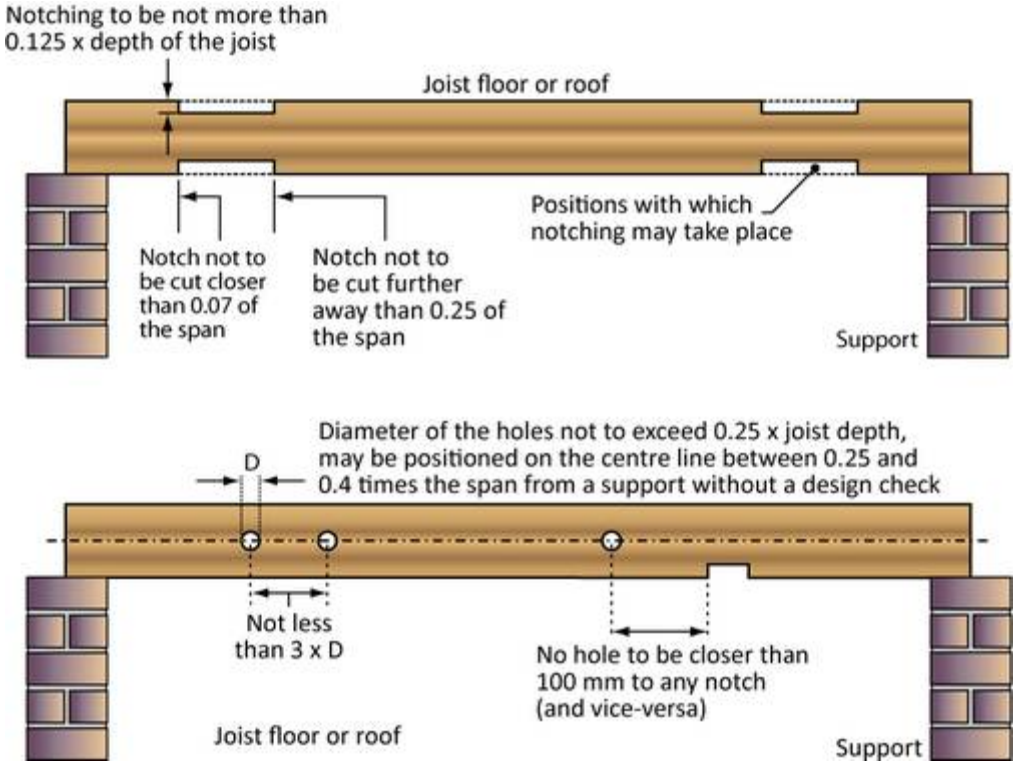
You can see from the figure here how cables are expected to run down and across walls. If you are going to run cables in any other area then you must use additional means of mechanical protection such as steel conduit. This will stop people nailing hidden cables when trying to put up pictures etc.

(Regulation 522.6.101 refers)

When it comes to cables being run under floors and through joists, certain other design considerations need to be taken into account. For example, it would not be very wise to drill too many holes in joists, as they are there to support the floor or ceiling.

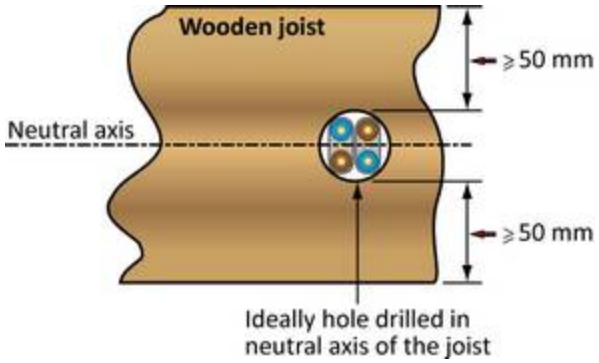
Too many holes lead to a weakening of the structure. In certain circumstances, there are

situations where you are not allowed to drill holes into supports.

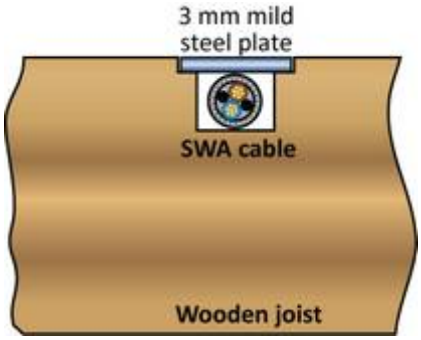


Both BS 5268-2: 2002 and BS 8103-3: 1996 provide guidelines on how deep down holes should be drilled in joists. This depends very much on the depth of the joist itself. In the figure above and below we can see permissible ways of passing cables through a joist.

Joist drilled

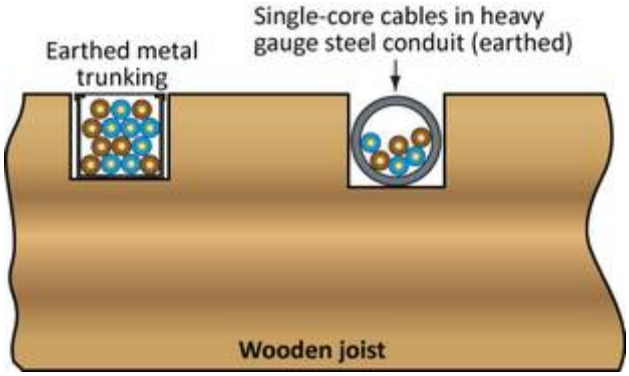


- The hole for the cable should be at least 50 mm measured vertically from the top or bottom of the joist.
- The diameter of the hole must not exceed 0.25 times the depth of the joist.
- The holes must be drilled in the neutral axis, i.e. the middle of the joist.



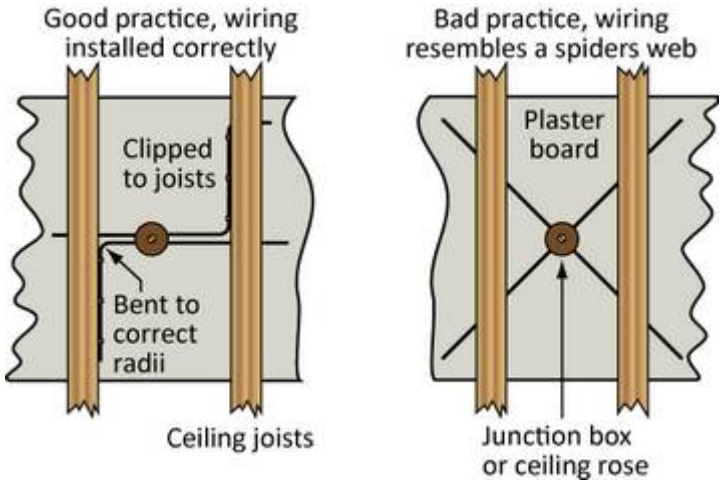
- Cables to have an earthed metallic covering such as a SWA.
- Be mechanically protected against damage sufficient to prevent penetration of the cable by nails screws and the like. This could be achieved by the use of a metal plate.

Joists notched



- Cables to be enclosed in earthed trunking or conduit.
- The notches to allow for this containment system to be installed are not to be closer to the support than 0.07 of the span, nor be further away from the support than 0.25 times the span.
- The depth of the notch to be no deeper than 0.125 times the depth of the joist.

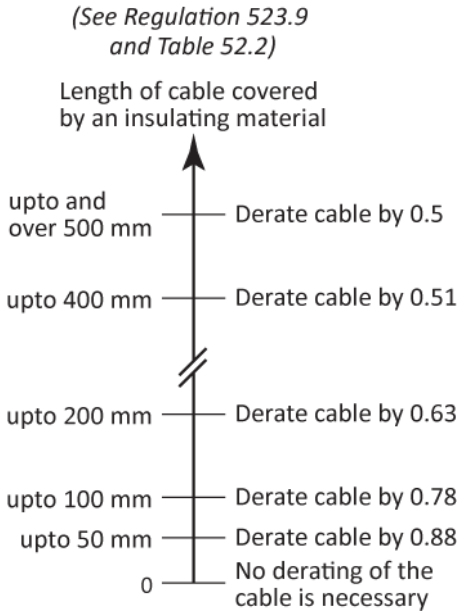
Cables laid in ceiling voids are another setting where care must be taken. It is not acceptable merely to lay cables across the ceiling when and where you like. Other services such as gas and water are there, and there may well be insulation and other items that are stored there.



Notice that the cables are run at right angles, and not diagonally. There can be a danger of running the cables in what is called a '***spiders' web***'. This is not acceptable!

To prevent damage to the roof structure, when installing cables in lofts it is important that the roof rafters are **not** notched in any way.

Extra care should be taken when running in ceiling voids where there is insulation. When insulation is around, then the cables may have to be increased in size to compensate for their inability to give off their heat.

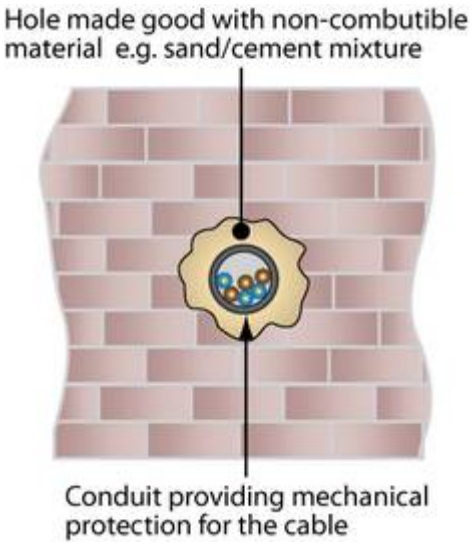


Regulation 523.9 describes the de-rating that must be applied when cables are run for even a short length in insulation. Notice that it only takes 0.5 m (18”) to de-rate the cable by half.

Notice that the de-rating of the cable starts at only 50 mm (2”).

The reason why these figures cannot be averaged is that a cable is only as strong as its weakest point. This means that it only takes one ‘***hot spot***’ to damage the whole of the cable. Damage at one point means damage at all points.

When cables are run through fire-resisting elements, such as walls or ceilings, care must be taken to ensure that the PVC sheath can’t be damaged.

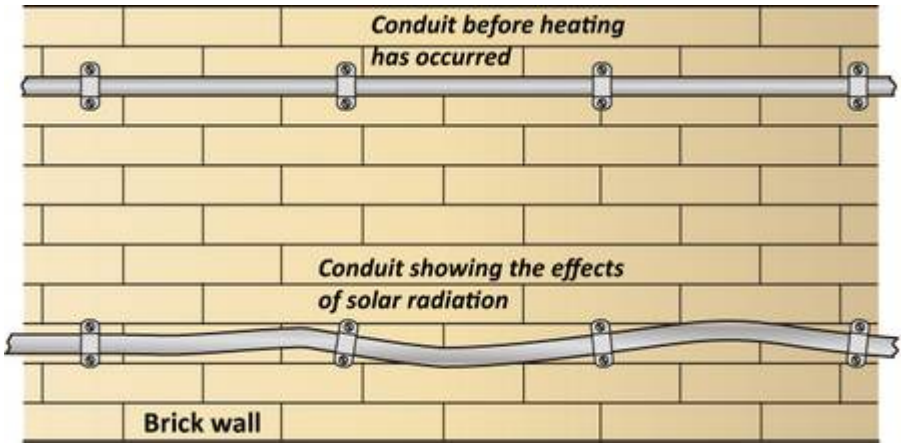


Any hole may be filled with an intumescent seal which expands as it gets hotter and so seals up a hole when a fire exists.

When you pass cables through fire-resisting element, it would be wise to install the cable in conduit. This allows the cables to be rewired later.

Other effects on cables are caused by ***solar radiation*** and damage by ‘***fauna, flora and mould growth***’.

Solar radiation can increase the temperature of the cable by up to 20 %, which translates to a de-rating factor of about 10 %. Account must be taken of this when running cables outside.



Fauna, flora etc., includes factors such as rats, plants, etc. Rats eat pvc, particularly when it is run in farms etc. They use it to sharpen their gnawing teeth, and it will be a common occurrence to find that a fault on a farm installation has been caused by vermin.

Care should be taken not to run the cable where vermin can get at it, or to give it additional protection. It may be that other wiring systems that can withstand the rats etc. need to be chosen.

There are many other points that may need to be considered when installing cables. These may include where the cables are run relative to other services, or whether cables are run near materials that can damage the PVC, such as oil etc.

Clipping

Thermoplastic insulated and sheathed cables can be installed in a variety of ways, as has already been seen. Conduit, trunking, on cable tray or on the surface of walls, is all valid and reasonable ways of delivering the circuits to where we need them. It is not acceptable to have them installed in a haphazard way.

Cables need support. If they were just laid on the ceiling or under a floor, people could trip over it or pull at it. It would be expected that there would be a problem sooner rather than later. The clips that are usually used have been around for a number of years now.

Appendix D of the On-Site Guide (2011) (OSG) gives details on the distance between supports for cables and wiring systems as well as the acceptable bending radii for cables and wiring systems. Particular consideration should be given to Table D1 for support distances and D2 for heights across roads and the like for overhead wiring systems.

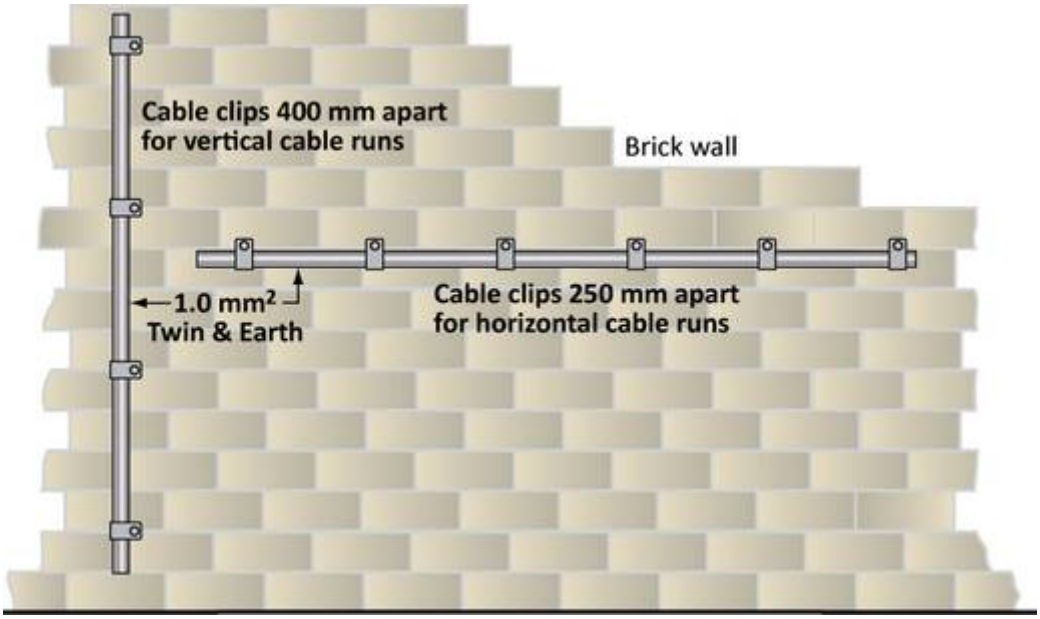
There are recognised maximum distances for the support of cables. Fill in the table.

Cable diameter (mm)	**Type of cable pvc/pvc**	**Vertical Max. distance**	**Horizontal Max. distance**
d ≤ 9	1 mm^2 twin-and-earth 1-10 mm^2 singles		
9 < d ≤ 15	1.5-4 mm^2 twin-and-earth 1-1.5 mm^2 three core-and-earth		
15 < d ≤ 20	6-10 mm^2 twin-and-earth 2.5-4 mm^2 three core-and-earth		
20 < d ≤ 40	16 mm^2 twin-and-earth 6-16 mm^2 three core-and-earth		

Notice that these values are valid only for PVC cables. Regulations 522.8.4 & 522.8.5 speak about the need for adequate support to stop any undue mechanical stress on the conductors.

Looking below we can see what this table means.

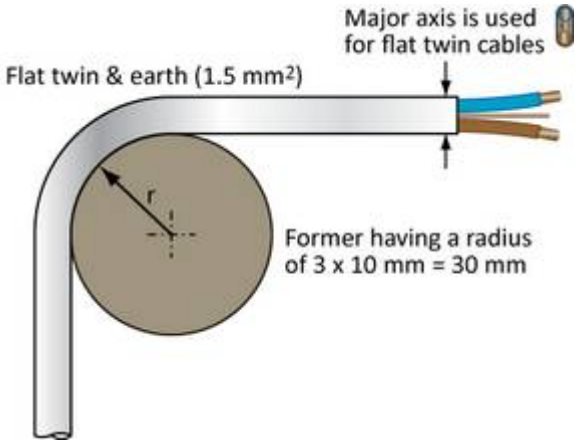
Cable clipped direct



Bending

Care must also be taken when bending cables. It is no good simply messing around with the conductors. Too much movement can lead to breaks in the conductors due to the copper '***work hardening***'. Regulation 522.8.3 sets the scene for good practice, but as it so often does, it doesn't tell us what that good practice is!

Guidance is given in Appendix D of the OSG and reference should be made to Table D5.



Looking at the figure here for example, we can see the shape of a 'good' bend. Notice how the radius of the bend is measured.

The cable runs round the circle formed. This varies depending on the cable size.

Take another look at Appendix 4 of your On Site Guide.

Below is a table showing appropriate bending radii for a variety of cable sizes. Again, the ones chosen are for thermoplastic insulated cables only. Fill in the details.

Conductor material	**Cable diameter ϕ mm**	**Minimum radii factor, n, (radius=n×ϕ)**
Copper/Aluminium	ϕ≤10	
Copper/Aluminium	10<ϕ≤25	
Copper/Aluminium	25<ϕ	
Copper/Aluminium	All shaped conductors	

You can see that the multiplying factors are used for getting the ***minimum*** bending radius, ***not*** the maximum. You can always do a '***slower***' bend you should never do a '***tighter***' bend.

Consider that a 10 mm diameter gives a cable size of up to 1.5 mm^2 twin and earth. A 10 mm to 25 mm diameter cable covers most thermoplastic insulated cables.

Exercise 14.

1. State three advantages and three disadvantages when using pvc-insulated cables.

2. How far apart should the clips be when supporting a 2.5 mm twin and earth cable clipped down from the ceiling?

3. What is the minimum internal bending radius of 2.5 mm^2 twin and earth?

4. State three ways in which a cable could be installed under a floor when run at right angles to the joists.

5. What makes up 'good practice' when clipping cables in a loft?

6. How much allowance should be made for solar radiation?

7. What problems are associated with flora (presence of plant-life/tree roots etc.) and fauna?

15: Installing wiring systems 2.

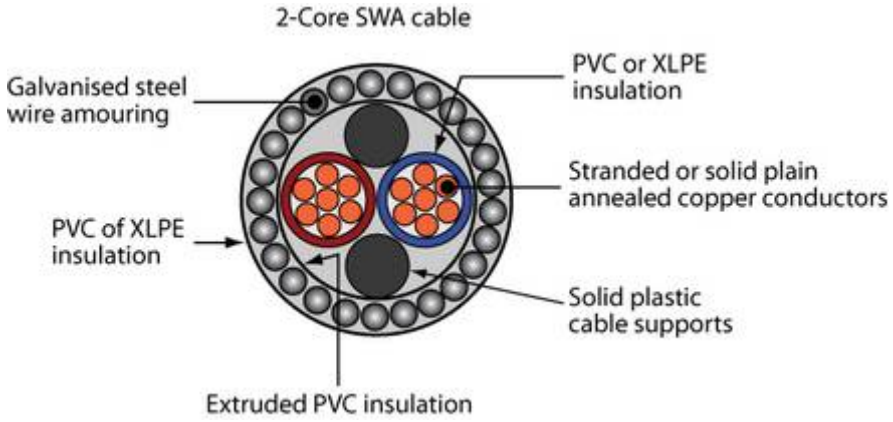
In this session the student will:

- Specify and apply the installation methods and procedures for installing thermosetting cables.
- Specify and apply the installation methods and procedures for installing MI and FP cables.

Armoured cables

This session continues on from the last and considers the uses of steel-wire armoured cables in electrical installation work.

You can see from the figure below that a steel-wire armoured (swa) cable is constructed very differently to the type of cables previously discussed.



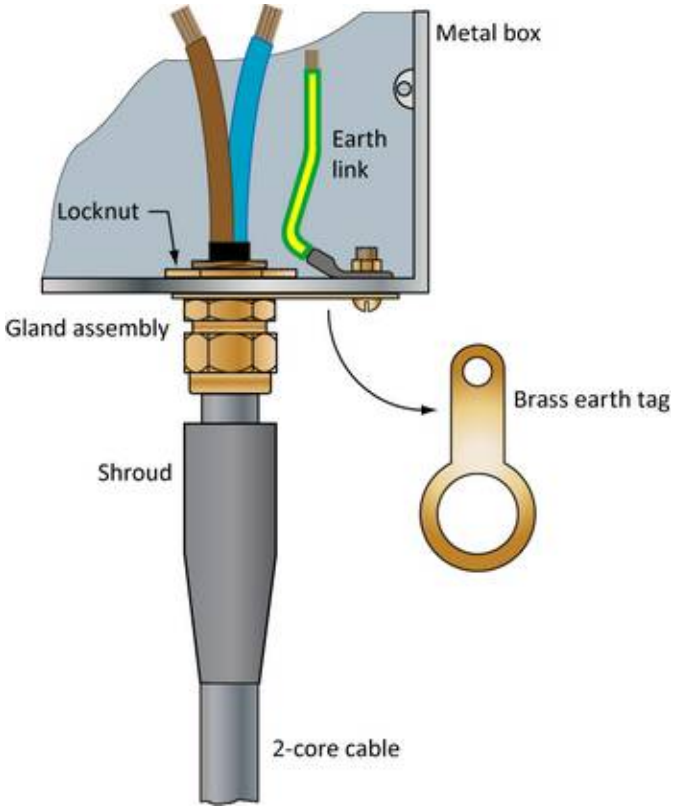
Notice that the cable has an outer layer of cross-linked polyethylene (XLPE); the next layer is made up of stranded steel wire, after which the inner conductors are insulated using pvc. So there are three main layers of covering. Sometimes there is also a further layer of pvc wrapping.

It is worthwhile noting that manufacturers no longer manufacture pvc sheathed and insulated cables. Manufacturers make use of XLPE insulated and sheathed cables.

This type of cable is not as common as the thermoplastic insulated and sheathed cable but it has a wide range of uses; main and distribution cables, control circuits etc. It can come in a wide variety of shapes and sizes, from multi-core (21 cores for some) and as large as 300 mm^2 and more.

You can see the advantages and disadvantages in the table below.

Advantages	Good mechanical strength. Wide variety of choice over type. Can use the armouring as a cpc.
Disadvantages	Expensive to buy. Expensive to install. Large and heavy at times. Require specialist terminations.



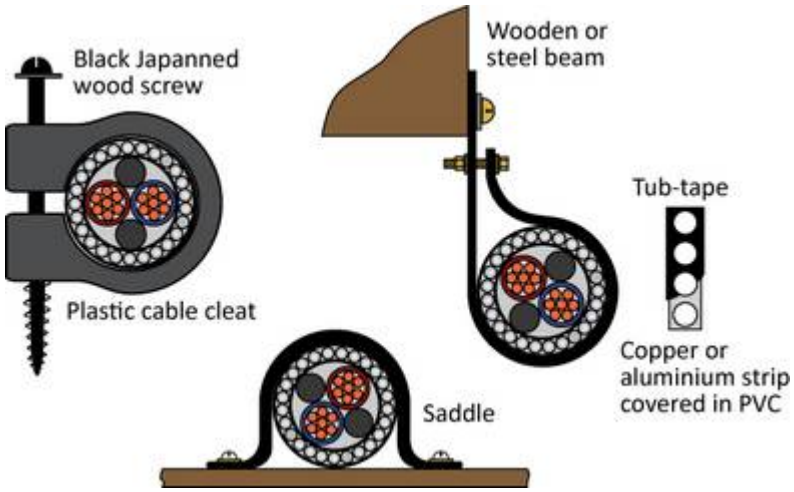
You can see that a swa cable requires a particular way of terminating it

Take care to make sure that everything is tight; you are using the armouring as a circuit protective conductor (cpc).

Clipping

SWA is usually much heavier than thermoplastic insulated and sheathed. This is not surprising with all the steel wire that there is around the conductors. What it does mean however is extra care must be taken when clipping it.

There are a variety of types of clip that you can use; tele-cleats, saddles, tub-tape (all round band). All of these are appropriate under a variety of conditions.



As you can see from the figure above, each of the clips looks different. Whatever happens the clipping must be secure and able to carry the full weight of the cable. If a large swa cable comes loose and falls it can rip down a wall, so be careful.

Using Appendix D of your On Site Guide, complete the table below which asks you to find the spacing's for clipping armoured cables.

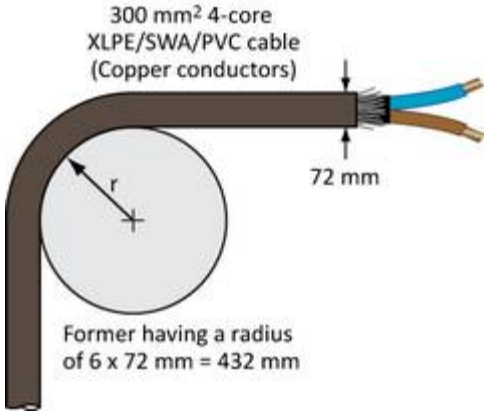
Cable diameter (mm)	Type of cable swa	Vertical Max. distance	Horizontal Max. distance
9 < d ≤ 15	1.5-2.5 mm^2 two core 1.5 mm^2 four core		
15 < d ≤ 20	4-6 mm^2 two core 2.5-6 mm^2 three core 2.5-4 mm^2 four core		
20 < d ≤ 40	10-16 mm^2 two core 10-16 mm^2 three core 6-16 mm^2 four core		

For the larger sized cables you will need to look up the manufacturer's details. Whatever happens, Regulations 522.8.4 and 522.8.5 must be complied with, just as they were with the thermoplastic insulated and sheathed cables.

Bending

The same rules apply to swa as for thermoplastic insulated and sheathed cables. Below is a table showing the ***minimum*** internal bending radii. Fill in the details.

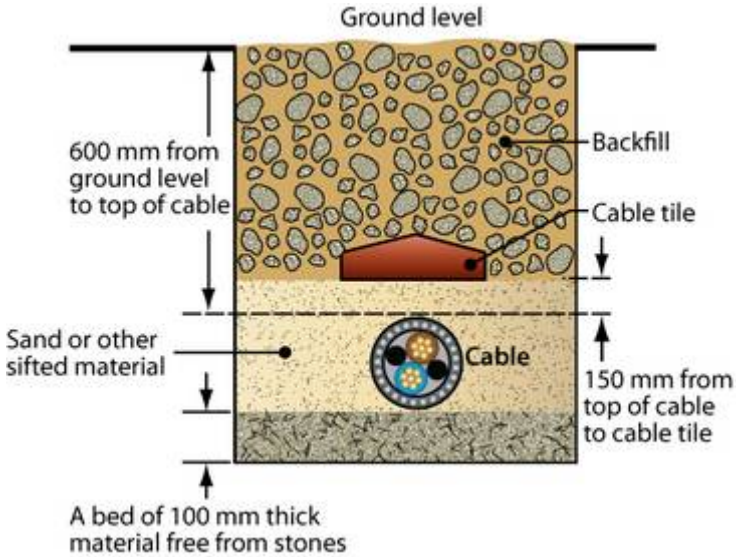
Conductor material	**Cable diameter ϕ**	**Minimum radii factor, n, (radius=n×ϕ)**
Copper/ Aluminium	ALL	
Copper/Alu minium	Shaped	



You can see from the table that if the conductors are shaped; that is they look like triangles, then the bending radii is larger.

Burying cables

Swa cables as stated earlier have good mechanical strength. This doesn't mean that you can go around hammering nails into them, but it does mean that you can get away with placing these cables in situations that could lead to bumps and bangs etc. It is more than reasonable therefore to allow them to be buried. This being the case, there are one or two points to be considered.

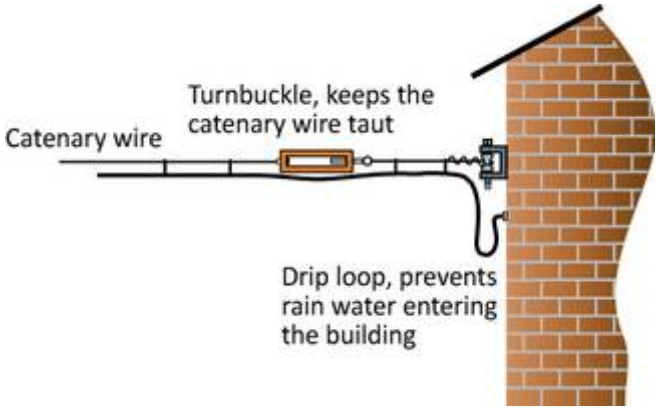


This phrasing used in this regulation; sufficient depth may mean any number of things, it all depends on what the ground is going to be used for. In the diagram shown certain figures are given, it is probably best to stick to them.

It is necessary when you have buried cables to record on a drawing the location of the cable route. If later someone with a JCB comes along a row of cable tiles will not be enough to prevent a ‘bang’.

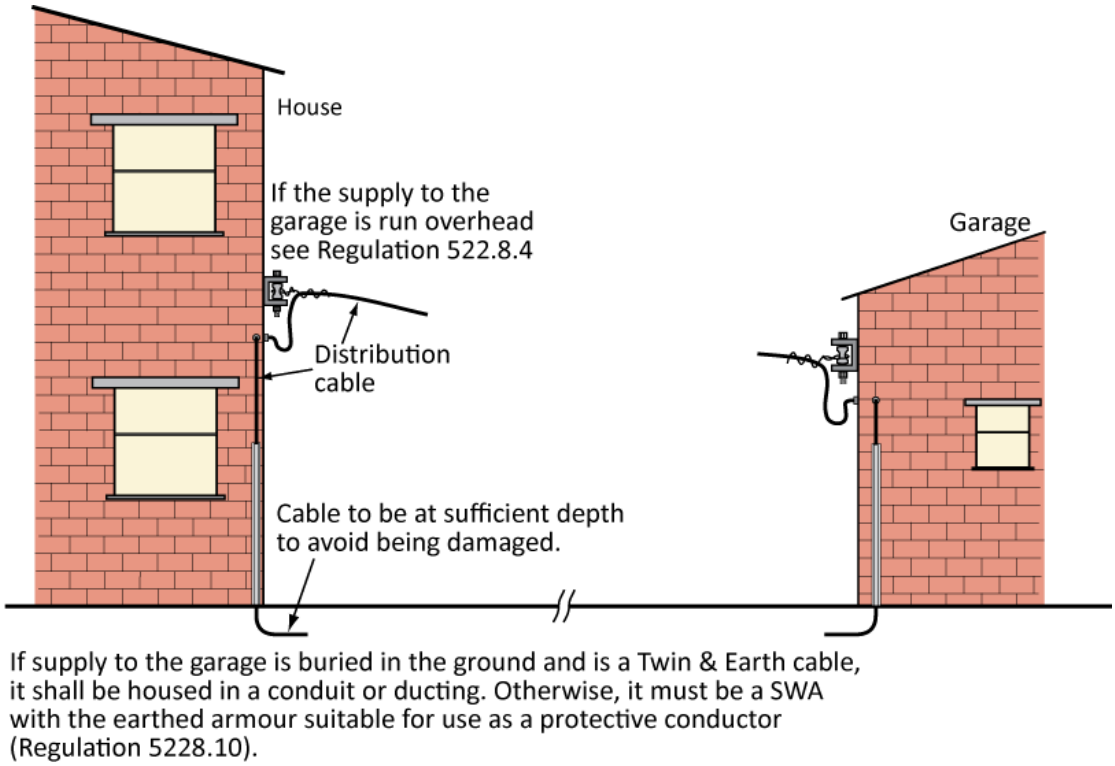
Catenary wiring

When cables enter an installation from outside, particularly where that cable comes in at high level, there is a chance that rain water could run down the cable and into the property or even a piece of equipment. This is obviously rather unsatisfactory. You can see in the picture below that a loop has been put into the cable. This loop allows the water to drip so no water enters the property or equipment.



Cable supports between buildings

It is allowed to run cables between buildings. Table D2 of the On-Site-Guide gives details on the maximum length of span, the maximum height of span to the wiring system used.



If supply to the garage is buried in the ground and is a Twin & Earth cable, it shall be housed in a conduit or ducting. Otherwise, it must be a SWA with the earthed armour suitable for use as a protective conductor (Regulation 5228.10).

MI Cable

MI is used in a variety of situations. It is particularly used where there is a likelihood of heat being present, such as fire alarm and emergency lighting circuits. It is also used in boiler houses and control circuits. It has an extra benefit in that it can withstand hammer blows. As long as the outer sheath remains undamaged then the cores inside the cable will deform in the same proportion as the outer sheath.

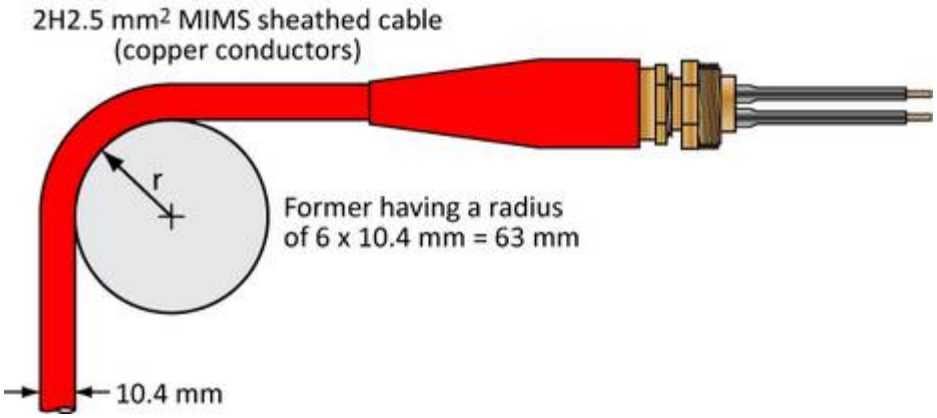
Advantages	Good mechanical strength. Wide variety of choice over type. Can use the sheath as a cpc. Good heat resistant qualities.
Disadvantages	Expensive to buy. Expensive to install. Insulation must not get damp Require specialist terminations.

Bending MI

The bending radius for MI is listed Appendix D of the OSG, complete the table below.

Conductor material	Cable diameter ϕ	Minimum radii factor, n, (radius=n×ϕ)
Bare copper	ALL	
Covered with pvc	All including pvc covering	

The idea behind reworking the cable (straightening and bending it again) is to reduce the chance of any breaks in the outer sheath.



The sheath, once damaged, becomes useless and the cable must be repaired or replaced.

Both of these options can prove to be expensive. If the bending and straightening of a cable can be eliminated then you can get away with a slightly tighter bend than you would normally be expected to get away with.

The use of a soft mallet to ‘dress’ the cable (tidy and straighten up) is recommended. There are few cables, when clipped properly, that look better than MI, and equally few that look quite so awful when they are installed badly. Take your time with it!

The bending radius of FP200 can be taken as being similar to that for MI. If FP200 is bent too sharply the conductors can damage very easily and then you have an insulation resistance problem.

Clipping

MI cable should never be left unclipped. If there is too much movement or vibration, it can damage the conductors or the outer sheath due to the copper work hardening.

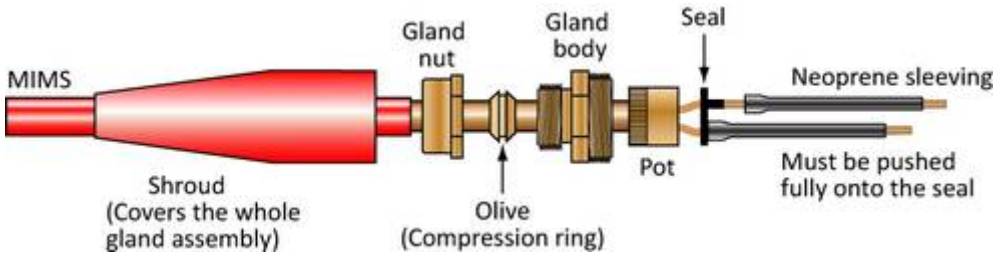
Complete the table below.

Cable diameter (mm)	Type of cable MICS	Vertical Max distance	Horizontal Max distance
9 ≤ d	1.0-2.5 mm2 four-core		
15 < d ≤ 20	2.5-10 mm2 two-core 1.0-2.5 mm2 seven-core		
20 < d ≤ 40	10-25 mm2 two-core <16 mm2 four-core		

You can see that the clip spacing's are much wider than those for swa and thermoplastic (pvc) insulated and sheathed cables. This is because the cable is very stiff.

Terminating

As with the swa cable, there is a particular way in which MI should be terminated.



Looking at the drawing above we can see what the termination is made up of. There is the gland body, the gland nut, the shroud and the 'olive'. The 'olive' is a brass sleeve that is shaped like an olive.

When the gland nut and the gland body are screwed together, the olive is forced out of shape and onto the sheath of the cable. This forms a good connection and the outer sheath can be used as the cpc.

FP range

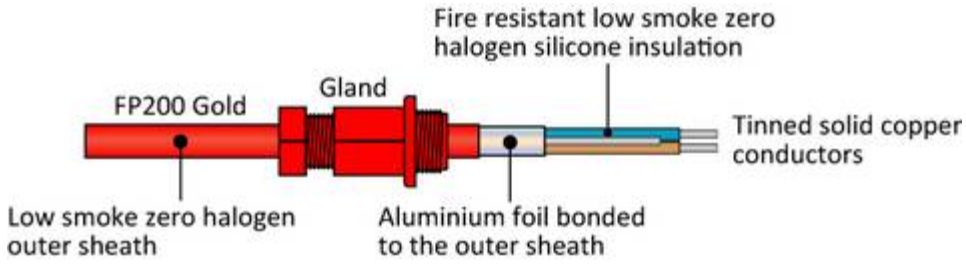
The final cables that we will consider briefly are the FP range of fire resistant alternatives to MICC.

If you take a look at the Prysmian website you will see that there is quite a range of cables to choose from; FP100, FP200 Gold, FP200 Flex; FP Plus; FP400 and FP600.

Have a visit to: http://www.fpcables.co.uk

The problem with MI is that, although it is an excellent cable with good mechanical strength and fire resistant qualities, it is expensive to install, and as far as its fire resistant qualities are concerned, what is the point in having a cable that can survive hours when everyone should have evacuated the building in minutes?

The FP ranges of cable were designed to reduce the costs of installation. The makeup of the range of cables is similar to the drawing below.



This cable has silicon-based insulation around the conductors surrounded by a thin aluminium foil which is bonded to the outer sheath.

Cable range.

FP100	Single-core fire resistant cable, used in metal conduit or trunking
FP200 Gold	Multi-core fire resistant cable, used extensively in alarm circuits
FP200 Flex	Similar to above but is more flexible
FP Plus	This is the enhanced variant with a stronger sheath which out performs the standard soft-silicone fire resistant cable
FP400	A tough armoured fire resistant cable which is suitable for projects where MICC has been approved.
FP600S	This is the ultimate fire resistant armoured cable suitable for power and control of fire safety circuits.

Exercise 15

1. State two advantages and two disadvantages of SWA cables.

2. What are the vertical and horizontal distances used when clipping SWA cable?

3. What is the bending radius of shaped SWA cable?

4. Draw two types of clip used when installing SWA cable.

5. A XLPE/SWA/PVC 240 mm four-core cable is to run for a length of 120 m. In one area it is to be fixed along a length of wall at a height of 4 m. In another area it is to drop from the wall to cross a driveway of length 8 m before rising once again to a height of 4 m for the rest of its run.
   - Explain how the cable would be supported along the length of its run.
   - Give reasons why you have chosen your options.
   - A second cable of size 120 mm at some time later is to be run with the existing cable. What would be the most efficient way for this to be installed?

6. A large single-storey shop is to have a refit. A mixture of thermoplastic (PVC) insulated and sheathed and MICS cables are to be run tidily above a suspended ceiling. What installation options are open to you?

7. Use the Internet or other sources and investigate the range of types and sizes of cable tray, ladder rack and basket tray that are available in the U.K.

8. What are the differences between xlpe/swa/pvc and pvc/swa/pvc cables? If you are running a cable through an area of increased temperature what cable type would you choose?

9. Give two advantages and two disadvantages when using MI cable.

10. What is the minimum bending radius for MI if it is:
    a) only bent once?
    b) bent a number of times?

11. What is the spacing used when clipping MI vertically?

12. What should you be careful of when stripping MI?

13. Why might you prefer to install FP200 Gold rather than MI?

14. What type of cables are installed in Grade 1 listed churches and why?

16: Wiring systems – cable and containment systems

In this session the student will:

- State the methods used to install conduit and trunking containment system.
- State the safety precautions inherent in the installation of metal containment systems.

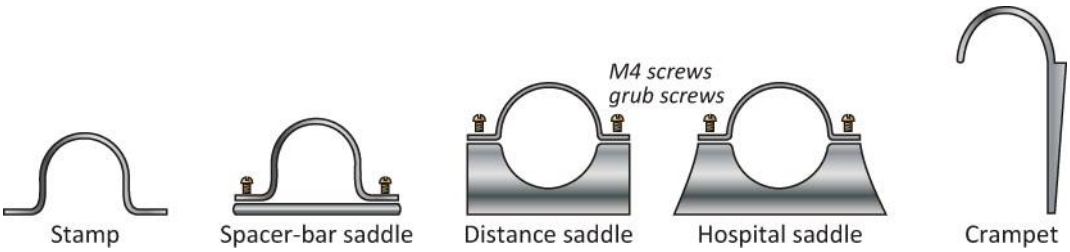
Conduit and trunking

As stated earlier there are many ways in which we can install the cables that provide power to the relevant parts of an installation.

In this session, we will look at the methods used in installing conduit and trunking and how it is supported.

Fixing

Steel conduit and plastic for that matter, can be fixed using a wide variety of '***saddles***'. The main types are, '***stamp***'; '***distance***', '***spacer-bar***' and '***hospital***'.



Stamp	Used in non-visible locations.
Distance	General use.
Spacer-bar	General use.
Hospital	General use and where it is necessary to clean behind the conduit. This type lifts the conduit away from the surface, and the sloping sides allows for easier cleaning.
Crampet	Used for fixing conduits to masonry or concrete prior to being plastered or floor screed.

The fixing spacing of conduit depends on whether it is being run vertically or horizontally and also on how large it is. Have a look at Appendix D of the On Site Guide and fill in the table below.

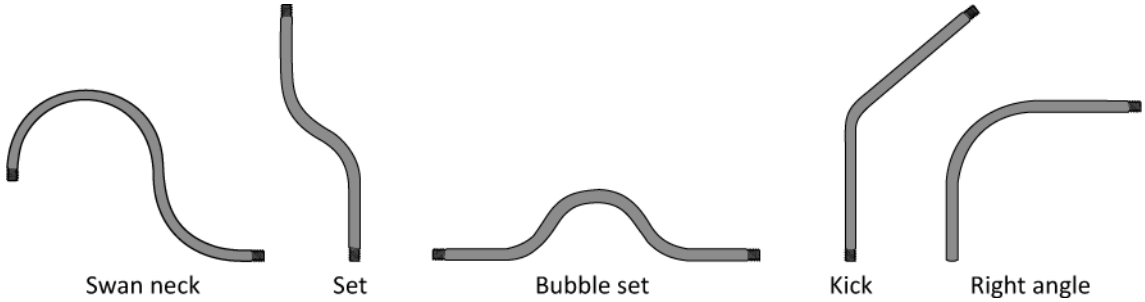
Conduit external diameter	**Maximum distance between supports**	
mm	Vertical (m)	Horizontal (m)
d ≤ 16		
16 < d ≤ 25		
25 < d ≤ 40		
d > 40		

These values are only valid for steel conduit; other types of conduit require other distances. The On-Site Guide provides guidance on the distances between supports.

Bending

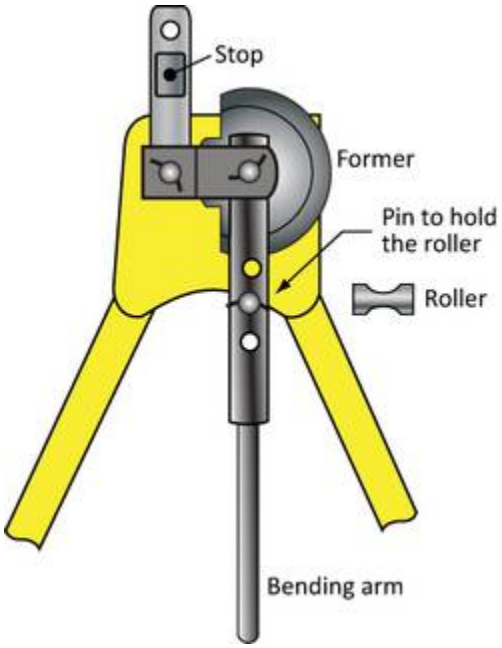
Steel conduit can be bent into any number of shapes, making it quite a flexible wiring system. There are precautions that need to be taken, and the bends must be made in certain ways, otherwise the conduit may end up being crushed.

There are five general bends that are made in conduit. These are the '***swan neck***', the '***right angle***', the '***kick***', the '***set***', and the '***bubble set***'. Have a look at their respective shapes below.



These five drawings show the most common types of bend. The main method of bending conduit is to use a bending machine. The techniques of bending conduit will be shown in the workshop or in the workplace.

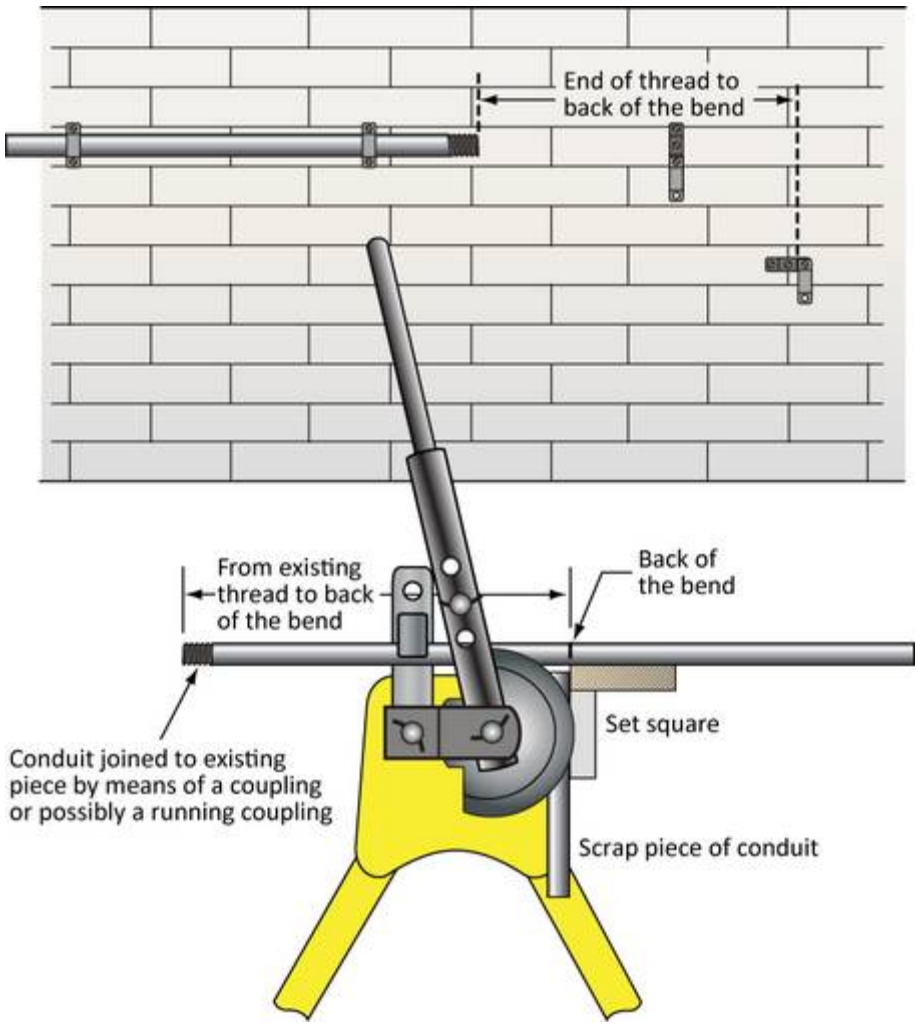
Typical bending machine



The figure here shows a side view of a conduit bending machine. These machines are made up of a frame, a bending arm, a stop and a former. The former allows the conduit to be bent without being forced out of shape.

The techniques used to bend the conduit at just the right point are best practised either at work or in the workshop. There are a number of techniques, each one being appropriate and reasonable.

One technique measures the conduit from the back of one bend, or the end of the conduit, to the back of the next bend. Follow this with me.



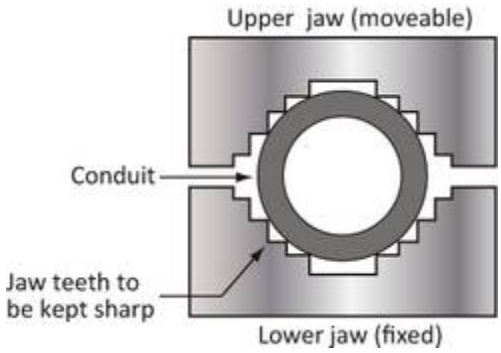
To measure accurately you need to mark the conduit to the 'back of the bend'. You can see from the diagram above that the end that has been measured from is placed into the machine.

It does matter which way that you place the conduit into the machine. If you place the conduit end that you have not measured from into the machine, then you will be about 50 mm out.

There are a number of tools that are required when you are going to be using steel conduit, many of which are needed when using trunking or cable tray.

No doubt you will already have most of these tools and know what they look like. If you don't, you are sure to build up the amount of tools you require over a period of time.

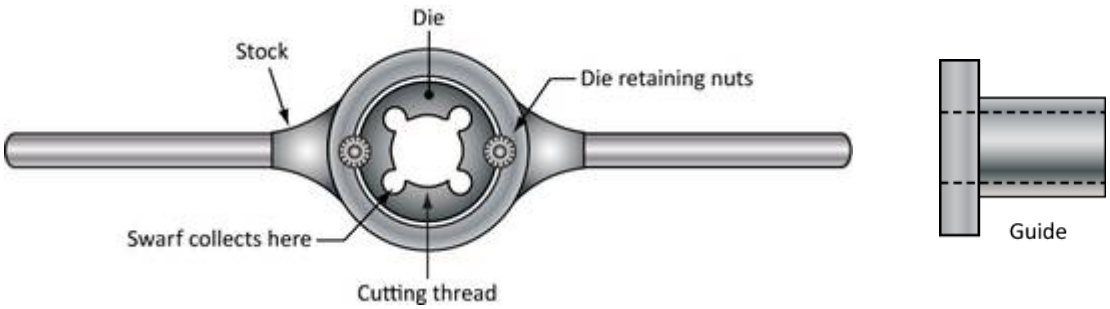
When steel conduit is terminated into a box or some other fixture then it has to be '***threaded***'. To thread an end on a piece of conduit requires a reasonable vice, one which clamps the conduit from four sides, not just two.



You can see that the conduit is clamped from four sides. This stops the conduit from being flattened when too much force is applied.

You still should be careful how tight you clamp it down just to make sure that the vice doesn't leave any 'teeth' marks on the conduit.

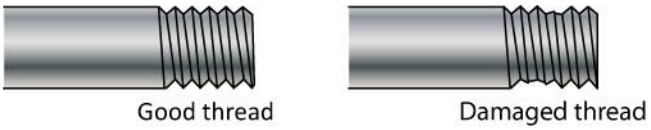
To make the thread you need a set of '***stocks and dies***'. The '***stock***' is the part that holds the '***die***' in place. It is the die that cuts the thread into the metalwork.



You should be able to see what the stock and die looks like. The guide, shown here, controls how straight you are relative to the conduit when you begin to thread.

Again you should pick up the relevant skills from work or from in the workshop. However, there are a couple of points worth noting.

The length of a normal thread should be about 15 mm long. You should clean out the die every time you use it, and even while you are using it. If too much '***swarf***' (excess metal cuttings) sticks inside the die, the thread becomes ragged and can lead to problems when joining lengths together.



The thread on the right has been damaged by worn dies or not cleaning the swarf from the dies.

It is important to highlight just a couple of extra points:

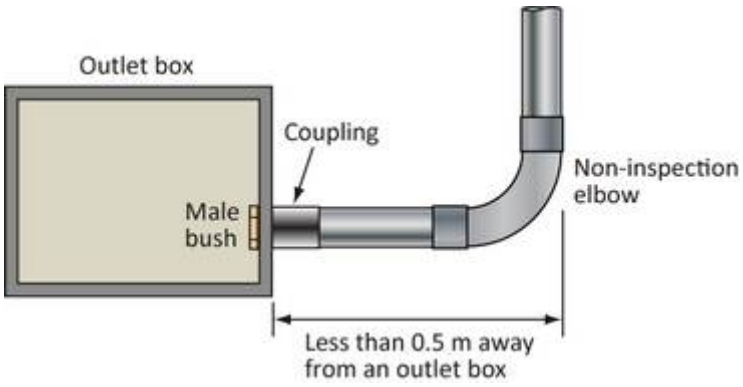
- the use of cutting compound is essential to ensure threads are undamaged. However, cutting compound may cause dermatitis (skin disease) and therefore hand care is important
- damage to the enamelling of the conduit should be made good by painting over the scratched areas.

There are a number of other fittings that are used. These are:

Coupler	This is a length of tube threaded internally and is used for joining lengths of conduit together.
Male bush	This is made of brass and has an external thread that fits into a coupler or a spout.
Female bush	This is also made of brass and fits on the outside of a threaded piece of conduit. They are used to reduce the chance of damage to cables as they leave the end of conduit.
Reducers	These enable conduits of different sizes to be joined together.
Adapters	Adapters allow a metric piece of conduit to be connected to an older imperial length of conduit.
Inspection elbows	These are the same as the inspection bends but have a much tighter bend.

Inspection tee Inspection tees are like a small tee box, still with the lid though.

Non-inspection joints. These fittings are limited in their use, because they do not allow for access for maintenance (Regulation 529.3 refers).



Although there are no stated figures given in BS 7671 the generally accepted practise is that a solid non-inspection elbow, must be placed within 0.5 m of the outlet box.

The advantage to their use is that it is possible to get a right angled bend into a tight space.

The minimum required length of conduit to use a bending machine is 200 mm, anything less the arm will skid of the end before the conduit bend is formed.

Terminations

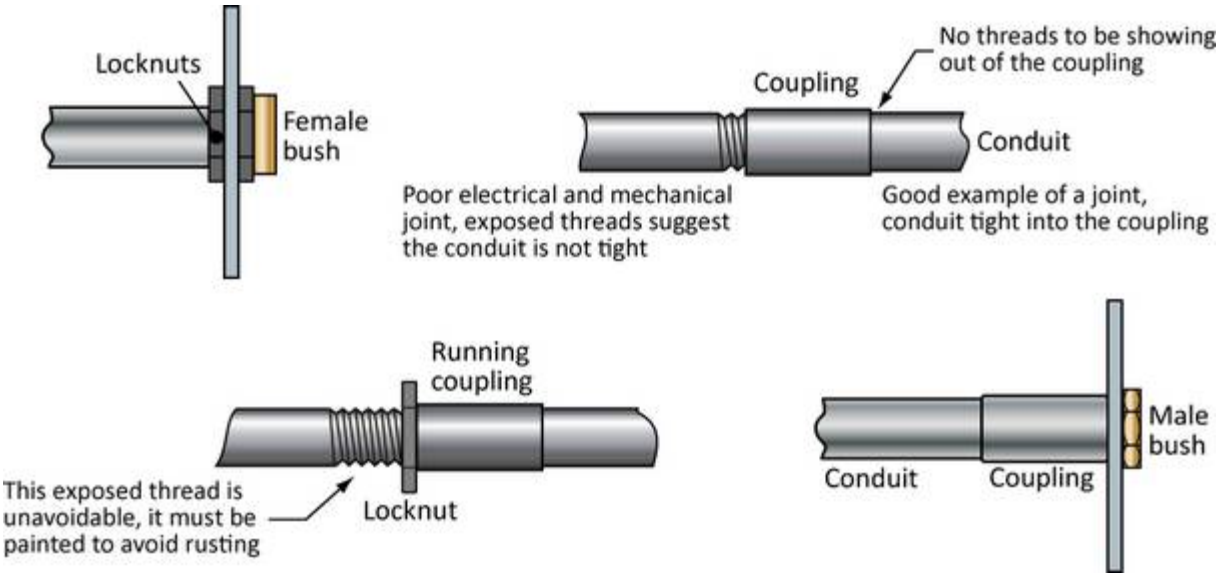
The four most common joints in conduit are:

Coupler Couplers are used when joining two lengths of conduit.

Running coupler These are used when joining two lengths of conduit that are unable to twist.

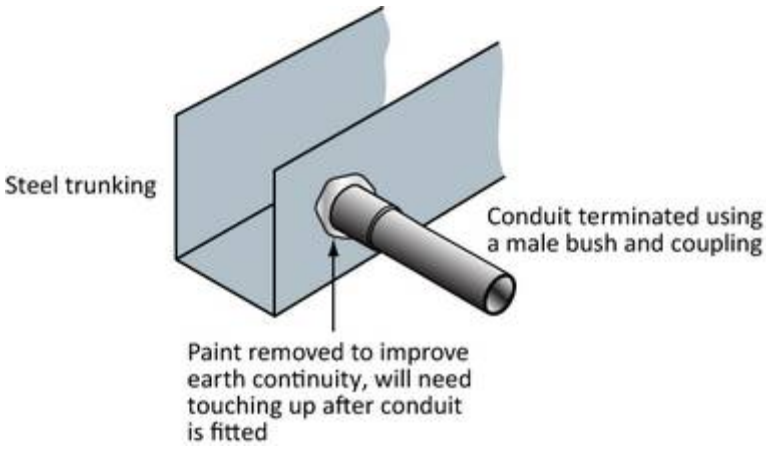
Female bush and locknut These are used when terminating a conduit into a box or trunking.

Male bush and coupler These are used when terminating a conduit into a box or trunking.



Inside the couplings, the conduit ends should be positioned very close to each other. You should not try to shorten the thread and leave a gap between the conduit ends inside the coupler. This can lead to damage to conductors as they are drawn into the conduit. It also makes the use of a draw easier, otherwise it tends to snag in the gap between the conduit ends, you then need to tap the conduit to make it spring out.

Remember that the paint on the box should be removed to make sure that there is a good connection. The conduit can be used as a protective conductor, so anything that could cause a problem with continuity should be eliminated.

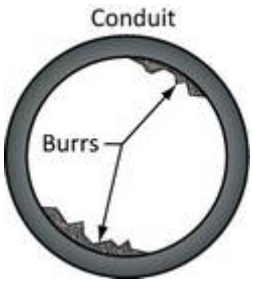


Before we move on to look at specific requirements in BS 7671, it is important to remember that it is no good simply trying to '***throw in***' as much conduit as you can as quickly as you can. If joints are not tight, or connections come loose all sorts of problems can occur. Joints could overheat, cables could get damaged and time and money be lost, just because you weren't prepared to take a little bit of time to get things right, particularly when the steel conduit is being used as a cpc.

There are one or two points that need to be noted as far as BS 7671 is concerned however.

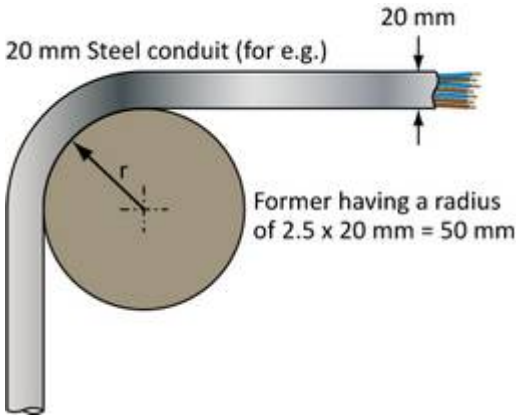
Regulation group 522.8 details the specific requirements of BS 7671 for protection against mechanical stresses. These requirements cover the need to ensure that anything that may damage conductors or their sheaths is removed, and about the need for the conduit installation to be completed before cables are drawn in, and that there is enough room for people to both pull the cables in and out of the system without causing damage.

With conduit, when a cut has been made, there is an edge formed on the inside of the conduit. This is called a '***burr***'. These burrs should be removed using a tool such as a reamer, otherwise the cable will be damaged, particularly when being drawn into the conduit.



Bends in conduit

The requirement states the need to be careful how tight the bend of the conduit is, so that the cables won't get damaged when they are in the system.



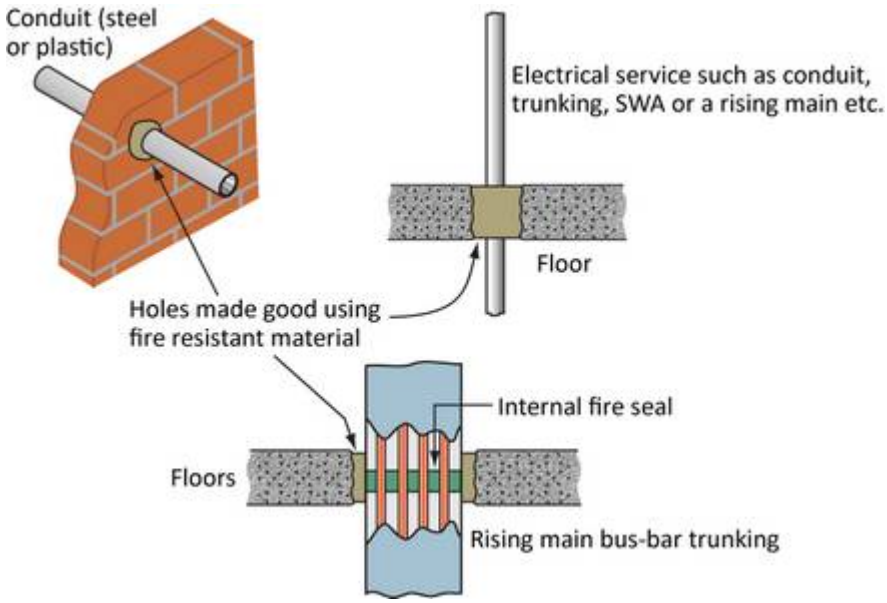
It used to be the case, in the 14th and 15th Editions of the Wiring Regulations, that there was a stated figure, and that was that the bending radius of the conduit should not be less than 2.5 times the diameter of the conduit. This is still true but the figure is now only quoted in the OSG as a note (Note 3) to Table D3. The idea is similar to that used when bending cables. This figure is still a reasonable one to work to. The main criterion though is the need to eliminate the damage to the cables.

These requirements state that if there are amounts of water that can collect in the conduit, there should be drainage points provided so that the water can drain out harmlessly and about the need to make sure that all joints are good and strong. Grip-conduit is not acceptable, especially when the conduit is being used as a protective conductor.

The final point that needs to be raised is common, not just for steel conduit, but to any conduit or trunking that passes through a wall, particularly a wall that has fire retardant qualities that need to be maintained

Section 527 deals with the precautions to be taken within fire-segregated compartments and the sealing of wiring system penetrations.

Rather than write out quite so much of the requirements, make a note of the figure below.



Notice that the sealing must take place both internally and externally, the wall and the conduit if the conduit has an area greater than 710 mm^2. This equates to anything greater than about 32 mm conduit. However a consideration of Regulation 527.2.3 may allow no special precautions to be taken.

As you can see there are so many regulations. It would be good practise for you to keep thumbing through BS 7671 just to become familiar with them. There are no real short cuts, although the use of the index is strongly recommended if you're not sure where things are!

These requirements are common to both steel and PVC conduit so they won't be stated again, although they will be referred to.

PVC conduit

Pvc conduit has been around for a number of years, and has proved to be a flexible and robust wiring system. As with the steel conduit it is more of a delivery system within which cables are drawn in and carried to where they are needed. PVC conduit comes in bundles of 25, and the length of it is slightly longer than steel conduit at 4 m. There are a number of types of PVC conduit just as there are a number of types of steel conduit.

Fixing

PVC conduit can be fixed using the same type of saddles as steel conduit, **stamp**; **block**; **spacer-bar** and **hospital**, and for the same type of reasons. Obviously, there isn't a plastic crampit!

The fixing spacing of PVC conduit is not the same as for steel conduit, although it still depends on whether it is being run vertically or horizontally and also on how large it is. Fill in the gaps.

Conduit external diameter	**Maximum distance between supports**	
mm	Vertical (m)	Horizontal (m)
d ≤ 16		
16 < d ≤ 25		
25 < d ≤ 40		
d > 40		

The reason why pvc conduit requires fixing at shorter intervals than steel is because it is flexible, and to have the conduit sag somewhere in the middle is unacceptable. As with the steel conduit, these figures can be found in Table D3 of your OSG.

Bending PVC conduit

As with steel conduit, PVC conduit can be bent into any number of shapes, making it quite a flexible wiring system. There are precautions that need to be taken, and the bends must be made in certain ways, otherwise the conduit may end up being crushed.

So far this is exactly the same as for steel conduit. The real difference between the two occurs when we try to bend the stuff. PVC conduit doesn't require a bending machine, and I haven't seen many people who can bend steel conduit without one!

Although pvc conduit does not need a bending machine and a former to keep it in shape, it does need to have something to keep the conduit in shapes whilst it is bent.

The normal method used to put a bend into plastic conduit is to use a spring. These springs are about 450 mm long and fill the conduit completely. The conduit is then bent around the same knee (still not recommended) or thigh. As long as the spring is positioned just where the conduit is being bent then the conduit will be fine, if the spring is incorrectly positioned then the conduit will crush and be useless.

The reason why it isn't recommended that you bend the conduit around your knee is that the kneecap is not the strongest of bones in the body and you could well end up dislodging it, a somewhat uncomfortable experience.

There are a number of types of spring, depending on whether the conduit is light or heavy gauge. The ways of differentiating between the types of spring is that they have their ends painted either red or green.

The exact techniques you use have to be practised, and there is no substitute for experience. Make sure that you have access to a workshop or work.

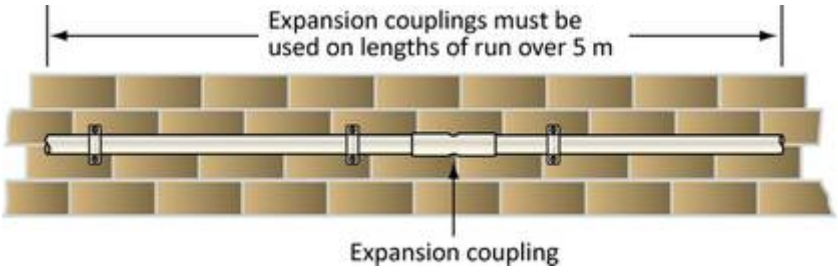
The final point that needs to be made when you are bending PVC conduit is that it will 'creep' back. Normally when you bend this type of conduit you bend it more than you need (almost double) and then wait for it to creep back a bit before fixing it to a surface. Do not bend it too tight though. If you do you will see the colour of the conduit change, and then you will see the spring outline begin to show. You are still required to make sure that the cables that run in the conduit remain undamaged and are not being stressed.

Fixtures and fittings

PVC conduit is not usually threaded, but glued. The type of glue used is very powerful and effectively welds the pvc conduit to any accessory in comes into contact with. There are a number of items that it can be attached to. Many of these are the same as for steel conduit.

It must always be remembered when installing pvc conduit that it does not manage extremes of temperature very well. In cold conditions it can, when being worked, shatter. This can be dangerous, particularly if it is being bent close to your face and eyes. In hot conditions the pvc becomes very soft and can end up being permanently damaged and distorted. In addition pvc may be affected by direct sunlight. This is called '***solar gain***'. If the conduit is going to be in direct sunlight then the black pvc withstands this process better than the white pvc conduit.

Within the two extremes of temperature pvc conduit may be used in many areas. It is particularly useful on farms where its' ability to withstand mechanical damage is important. More importantly its non-conducting properties allows for earth faults to be limited to certain areas limiting the risk to animals.



Three points need to be raised here. The first is that when you are using an expansion coupler you will also need to use a non-setting adhesive (glue). The normal type will not allow the conduit to move within the coupler, and putting no adhesive on will allow water to get in.

The second point is that this adhesive is strong. It must be used in well-ventilated areas. If you don't, you could end up with a feeling of sickness and light-headedness (you are glue sniffing). Be careful with it, and always replace the lid when it is not in use.

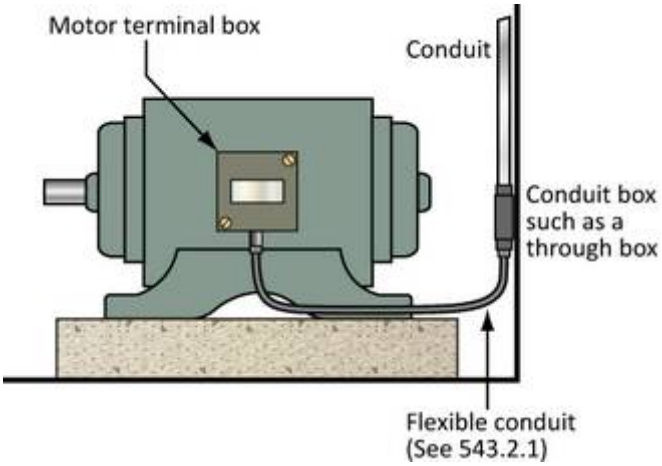
The final point to mention when dealing with pvc conduit is that because of its excellent insulating properties you cannot use it as a protective conductor. Any circuits installed in the conduit need to have a circuit protective conductor run with them.

The requirements that apply to steel conduit apply predominantly to pvc conduit, although where they talk about protective conductors they become redundant.

Flexible conduit

Imagine that a machine or something that can vibrate or moved has been installed. It is to be wired from a distribution board via steel or pvc conduit, which the constant movement of the machine would eventually damage; they are too rigid. It therefore becomes necessary to use some other means of connecting the load to the rest of the wiring system.

There are two possible options, either to use some form of flex, although this is limited in size and strength, or to use flexible conduit. This conduit has a pvc outer sheath and an inner layer made up of thin spiral of steel or pvc.



This type of conduit is more robust than flex, although it is not acceptable to use it as a protective conductor. Special glands must be used that clamp the conduit to the gland.

The only fixtures and fittings that are used are the special glands used for terminating. The saddles used by steel and pvc conduit can be used for this conduit, although only short lengths are commonly used.

Below is a table showing how often flexible conduit should be fixed. Take a look in Appendix D of OSG and fill in the gaps.

Conduit external diameter	**Maximum distance between supports**	
mm	Vertical (m)	Horizontal (m)
d ≤ 16		
16 < d ≤ 25		
25 < d ≤ 40		
d > 40		

It is worthwhile having a brief recap on some of the qualities of the different types of conduit and their relative advantages and disadvantages. Below is a table listing some of them.

Conduit Type	Advantages	Disadvantages	Where used
Steel	Mechanically strong; Can be used as protective conductor.	Expensive to install; Difficult to change once installed.	Factories, garages, workshops etc.
PVC	Mechanically Strong; Doesn't introduce an earth; Easier than steel to install.	Doesn't like extremes of temperature; Can be affected by oils; Requires a protective conductor.	Farms, workshops, schools etc.
Flexible	Flexible; Isn't damaged by vibration.	Should only be used for short lengths-not very mechanically strong; Requires a protective conductor.	Short links to machines and appliances.

Trunking

As with conduit, cable trunking comes in all types and sizes. The three most common types are:

- sheet steel
- galvanised or enamelled steel-covered with an extra coating
- pvc.

Trunking is commonly installed in the same types of installation as conduit, although there are one or two variations.

Pick up any appropriate catalogue and you will come across an almost infinite variety of trunking types. However, we are only interested at the moment on how it is installed.

Trunking comes in many shapes and sizes and even comes with a separating strip. This separating of trunking is called '***segregation***'.

Circuits that fall into a variety of types or '***voltage bands***' have to be separated from each other.

These voltage bands are split into two parts:

- **Voltage band I**

  Installations where protection against electric shock is provided under certain conditions by the value of voltage;

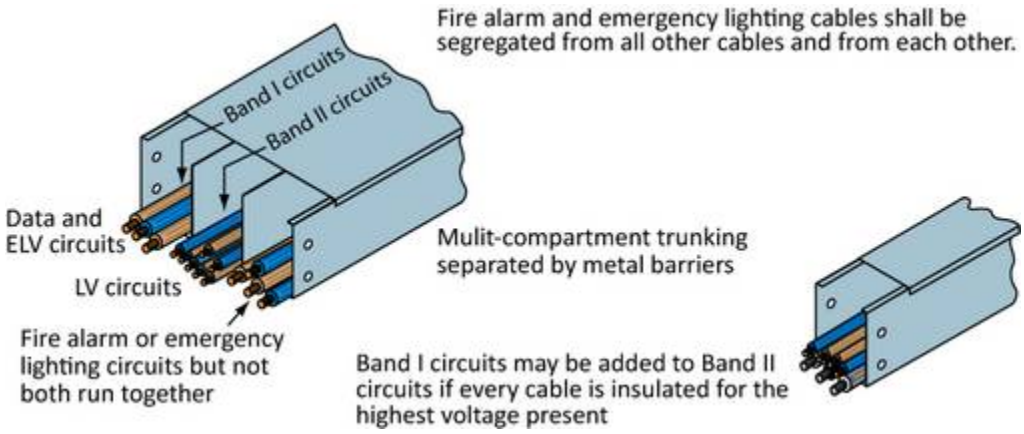
  Installations where the voltage is limited for operational reasons (telecommunications etc.).

  ELV is normally Band I.

- **Voltage band II**
- Contains the voltages for supplies to household, and most commercial and industrial installations.

  LV will normally be Band II.

- **Fire alarms and Emergency lighting**
- A fire alarm circuit or an emergency lighting circuit.



You should remember what makes up low and extra low voltages. The table below should help. Fill in the gaps.

Voltage	**d.c.(ripple free)**		**a.c.**	
	Lowest	Highest	Lowest	Highest
Extra-low				
Low				

Section 528 deals with all aspects concerning the running of cables together.

The general rules are to segregate voltage band I and II circuits unless the insulation value of the band II circuit is of the same value as the band I circuit. If you are using MICS cable for the fire alarm or emergency lighting circuits then you are able to get away without segregating, as the MIC sheath is adequate segregation. Have a look at the requirements of BS 7671.

Support for trunking

Any form of trunking has to be effectively fixed to something, whether it be a wall or, ceiling or bench. The amount of fixings depends on whether the trunking is metal or plastic, and also on whether it is fixed vertically or horizontally.

Complete the table below using your On Site Guide.

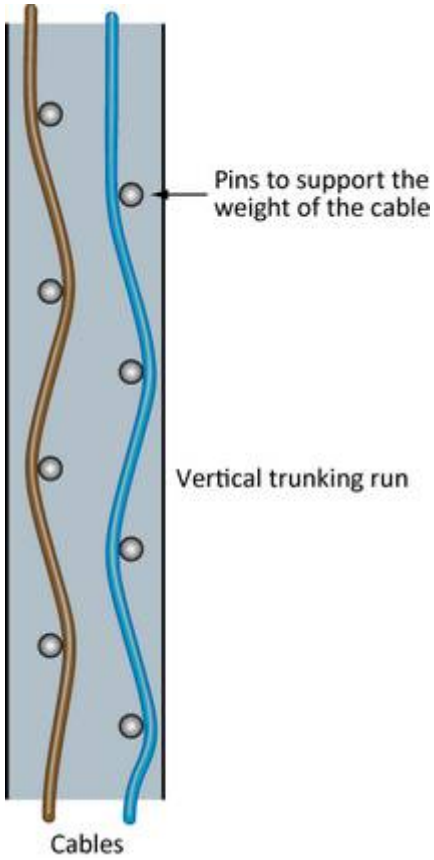
Trunking area	**Trunking sizes**	**Maximum distance between supports (Horizontal) (m)**		**Maximum distance between supports (Vertical) (m)**	
mm^2	**mm**	**Plastic**	**Metal**	**Plastic**	**Metal**
Less than 700	25×25				
700-1500	38×38				
1500-2500	50×50				
2500-5000	100×50				
5000+	100×75				

Notice that plastic trunking requires more regular fixing and that although there is less support needed for vertical trunking, there is relatively little difference between horizontal and vertical fixing.

Cable support in trunking

You may think that cables in trunking don't need any extra support. However, you would be wrong. Cables have weight and therefore require support at appropriate intervals. Regulation 522.8.4 requires that cables are supported at suitable distances to ensure cables are not damaged by having to support their own weight.

If you have looked up the requirement, you can see there is no stated figure, however it is recommended (a recommendation is not law – if in doubt ask the manufacturer of the cable) that if the cable is likely to rise for more than 5 m it would be advisable to provide some means of support. The support comes in the form of pins inserted into the trunking with the cables laced around them.



Notice that the cable is not wrapped around the pins, but woven in and out. This process gives sufficient support to the cables.

If the cable is run in trunking that hangs from a ceiling, the cables are held in using short strips of '***trunking lid***', until all the cables are installed. Once they are installed, the main lid acts as the means of supporting the cables in the trunking. Care must be taken to ensure that the lid doesn't trap any of the cables however.

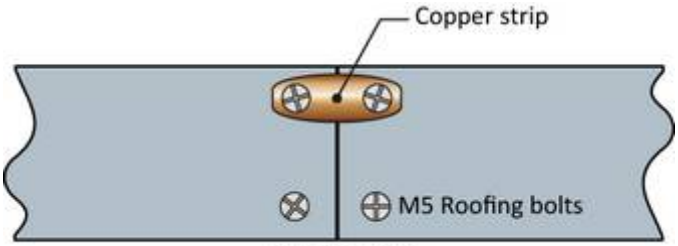
Installing trunking

As with conduit, trunking comes with any number of accessories to help with the installation process. If you look in any trunking manufacturer's catalogue, you will see a wide variety of accessories for joining, bending, changing size and the types of trunking. There are too many to list here, however you will no doubt come across many of them.

Even if they were listed, many would be left out.

Care must be taken however when installing trunking. Some of the points should be familiar from when we looked at conduit:

- edges should be filed smooth so that cables don't get damaged
- if cables enter the trunking then grommets or grommet strip should be used
- make sure that appropriate bushes (male and female) are used when necessary
- make sure that all connections are strong and secure. Joints should be tight and fit for use
- whenever there is a joint in metal trunking, make sure that an ***earth strap*** is used to link the pieces together. There is no need for this in plastic trunking, obviously, as protective conductors have to be run. With metal trunking, there may be no need to run protective conductors, as the trunking itself is often sufficient as a protective conductor.



Trunking joint

Notice that the straps should have at least the same effective size as the trunking. It is not sufficient to unthinkingly attach, say, a piece of 1.0 mm^2 green and yellow singles.

A solid reliable connection needs to be made. If the connection is not good then the resistance of the joint can build up, and under earth fault conditions lead to an increased fire and shock risk.

Exercise 16

1. List the common types of steel and PVC conduit.

2. List the common sizes of conduit.

3. What problems are there with flexible conduit?

4. Where would you expect to use steel conduit, and why?

5. List the tools required when working with steel conduit.

6. When you make off a conduit end what precautions should you take?

7. Where would you expect to use pvc conduit, and why?

8. An engineering workshop in a college is being refitted. What type/s of conduit might you use and why?

9. List three types of trunking available.

10. When and where should fire barriers be installed?

11. Where would you expect to use under floor trunking and why?

12. How would you protect cables from damage in trunking?

13. How are cables supported in long lengths of vertical steel trunking?

14. An open-plan office has a number of desks situated at a variety of locations throughout the room. What types of trunking might you use and what reasons can you give for your choice/s?

15. Under what conditions would you want to use cable tray? Give examples of the type of installation you would use it for.

16. Where would you try to avoid installing pvc conduit? Give reasons for your answer.

17. How do we allow for any alterations in the length of pvc conduit?

18. What does the adhesive used for connecting pvc conduit do to the conduit?

17: Wiring systems – installing components

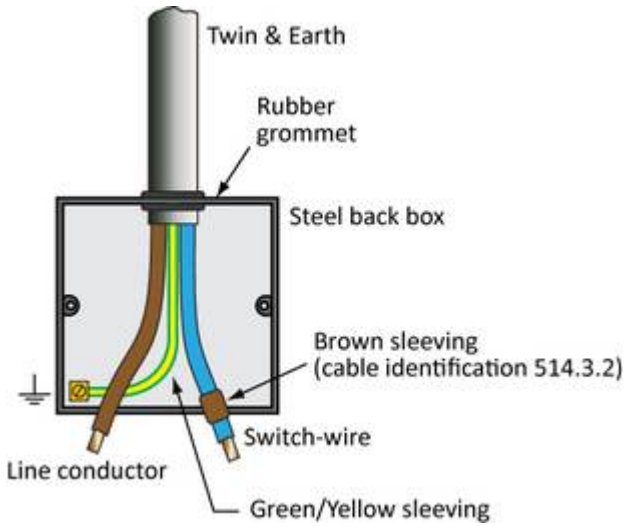
In this session the student will:

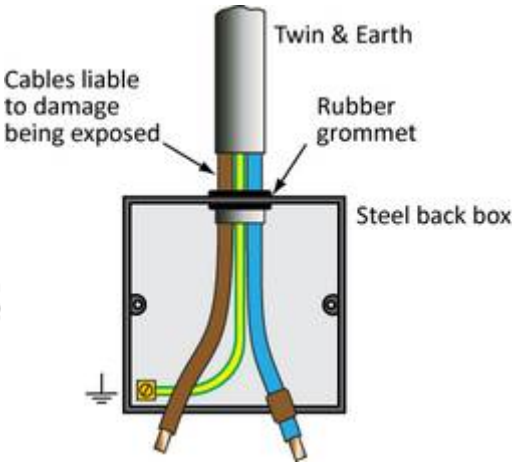
- State the methods used to install wiring accessories
- Have an understanding of IP codes

When initially installing an electrical accessory there will commonly be two elements; the box – used to contain the cabling and connections, and the accessory itself.

The box used to house the cables and connections will vary according to the size of cable as well as the quantity of cables and the depth and size of the accessory.

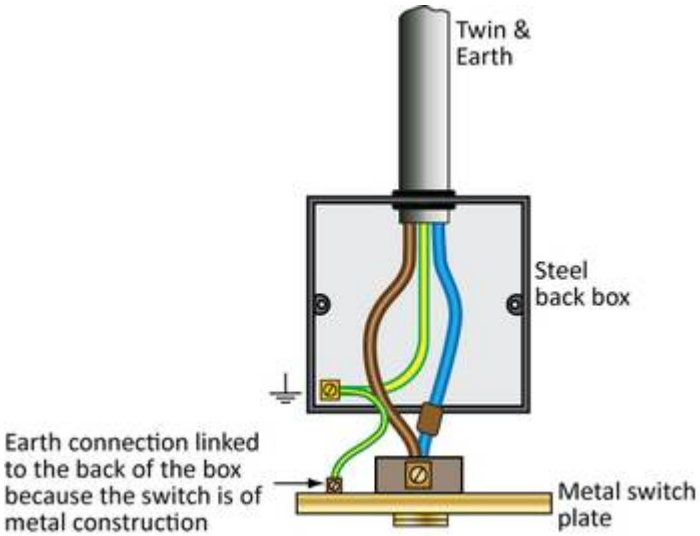
All cables should enter the box without any of the internal insulation being left outside of the box. At least 10 mm of grey/white outer insulation should remain inside the box and no brown or blue should be seen other than inside the box.





Notice the brown sleeving on the blue conductor, it is going to be used as a live conductor (switch-wire), and needs to show this.

Where a metallic accessory box has two adjustable lugs, a link should be made to the back of the box with a short length of earth wire. This links the box to the accessory. Where the box has at least one solid fixing lug then no link is required.



The bare copper cpc should be insulated with a length of greensleeving, and where necessary may be twisted together. The twisting of conductors is not a requirement of BS 7671; however you are expected to ensure that all connections of both electrically and mechanically sound. This requires us to ensure that the conductors will neither work loose or, if connected too tightly, will not break loose. Both are a significant problem. The thinner the conductor the greater the problems and for this reason many refuse to use 1.0 mm conductors.

For cables of 2.5 mm or less, and where only one conductor is entering a connection it is common for the conductor to be doubled over. This allows the connection to be ‘filled’ with the conductor giving less chance of anything working loose or breaking.

Where a recessed luminaire is installed in a ceiling void it is recommended that either a downlighter with integral fire protection is installed or a firehood is installed over the back of the downlighter.

Firehood fitted to a downlighter

Downlighter with integral fire protection

Connections likely to cause a fire

When installing accessories and components it is important to consider the environment so that the correct components and/or enclosures are chosen. One way of doing this is to consider their IP rating.

IP codes

If you have been looking up the particular sections of BS 7671, you will have seen IP (Index of Protection) numbers.

The object of BS EN 60529 Degrees of protection provided by enclosures (IP codes) is to give definitions for degrees of protection provided by enclosures of electrical equipment as regards:

- protection of persons against access to hazardous parts inside the enclosure;
- protection of equipment inside the enclosure against ingress of solid foreign objects;
- protection of the equipment inside the enclosure against harmful effects due to the ingress of water.

Below is a table that should explain this.

First Number	Degree of protection from solid objects	Second Number	Degree of protection from moisture
0	No protection.	0	No protection.
1	Protection against solid foreign objects of 50 mm and greater diameter	1	Protection against vertically falling water drops
2	Protection against solid foreign objects of 12.5 mm diameter and greater	2	Protection against vertically falling water drops when enclosure tilted up to 15˚
3	Protection against solid foreign objects of 2.5 mm diameter and greater	3	Protection against spraying water
4	Protection against solid foreign objects of 1 mm diameter and greater	4	Protection against splashing water
5	Protection against dust. Dust may enter but it does not affect operation.	5	Protection against water jets.
6	Protection against all dust. Dust tight.	6	Protection from powerful water jets.
		7	Protection against the effects of temporary immersion in water.
		8	Protection against the effects of continuous immersion in water.

The additional letter that the standard uses, generally in the third column, (A, B, C, or D) refer to the protection offered to a person against contact with dangerous parts within an enclosure, and are at a higher rating than that offered by the first number column.

Letter	Description
A	The back of the hand is protected against touching dangerous parts within an enclosure. The access probe (50 mm diameter sphere) shall have adequate clearance from hazardous parts.
B	Protected against access with a finger. A jointed test finger (12 mm × 80 mm) shall have adequate clearance from hazardous parts.
C	Protected against access with a tool. The access probe (2.5 mm × 100 mm) shall have adequate clearance from hazardous parts.
D	Protected against access with wire. The access probe (1.0 mm × 100 mm) shall have adequate clearance from hazardous parts.

The last column provides more information on the degree of protection.

Letter	Description
H	High voltage apparatus.
M	Tested against the ingress of water having harmful effects when the moving parts of the equipment are in motion.
S	Tested against the ingress of water having harmful effects when the moving parts of the machinery are stationary.
W	Suitable with specified weather conditions and provided with additional protection for such conditions.

There is an additional set of numbers that are used sometimes.
These relate to the impact (hit with a hammer) that a piece of equipment can withstand. This additional row of numbers is not part of BS EN 60529 but part of a French standard.

The letter ‘X’ just means that particular column has no protection specified. It does not mean that there is no protection at all, but rather that the protection is not considered. It is important that you are familiar with the numbers and letters listed on the previous pages. Have a look at a couple of examples.

It is important that you are familiar with the numbers and letters listed on the previous pages.

Have a look at a couple of examples.

IPXXB

X	X	B
No protection.	No protection.	Protected with adequate clearance from dangerous parts, against a 12 mm × 80 mm long standard test finger from touching dangerous parts.

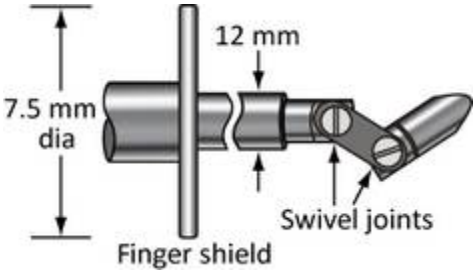
And another one.

IPX4D

X	4	D
No protection.	Protected against water splashed from any direction.	Protected against access with wire. The access probe (1.0 mm × 100 mm) shall have adequate clearance from hazardous parts.

If you see for e.g. a socket saying it is protected to IP22, means that it is protected against insertion of fingers, and will not be damaged or become unsafe if it was exposed to having vertically falling water drops if the enclosure was tilted up to 15˚.

So, what does a test finger look like?



Exercise 17

1. A client doesn't want you to chop a wall out, but would rather you ran a cable inside the cavity. What would you say to them?

2. Steel conduit is to be held down before the screed is poured on it. How will it be held in place?

3. PVC cables are to be clipped to a solid concrete surface. How might this be sensibly done?

4. Why would you choose to install pvc twin and earth cable inside oval tubing?

5. What method would you use to fix a motor to a wall?

6. A garage set at a distance from the house by 5 m is to have a supply installed. How would you run the cable? What type of cable would you use? What precautions would you take?

7. A socket-outlet is to be installed in a greenhouse. What factors would you need to consider?

8. A ring circuit is to be installed in a kitchen. What factors would affect how you wired the circuit? What type of cable would you use?

9. A recessed luminaire is to be installed. What factors will you consider?

10. An outside light is to be installed on the corner of a house. Comment on:
    i) The height of installation
    ii) The means of control and maintenance
    iii) IP rating.

18: Making good

In this session the student will:

- Have an understanding on how to make good the fabric of the building

Making good

For a variety of walls, there will be a variety of skills required to make them good. It isn't your job to build the wall, but you should be aware of what you can do.

Chases

When a wall is chopped out to make room for a cable, there are a number of factors that you need to take into account.

- Make sure that you have placed a dustsheet down where necessary
- Always wear appropriate safety equipment such as goggles, facemask and good shoes.
- Only chop out what you need to cover the cable and whatever is protecting the cable, such as channel (casing), conduit, or oval tubing
- Make the cuts clean. Don't wander all over the place.

To make a neat cut it is common practice nowadays to use an electric chaser such as the ones shown below.

Wear appropriate PPE and make sure the tools have some form of dust extraction otherwise the dust goes everywhere.

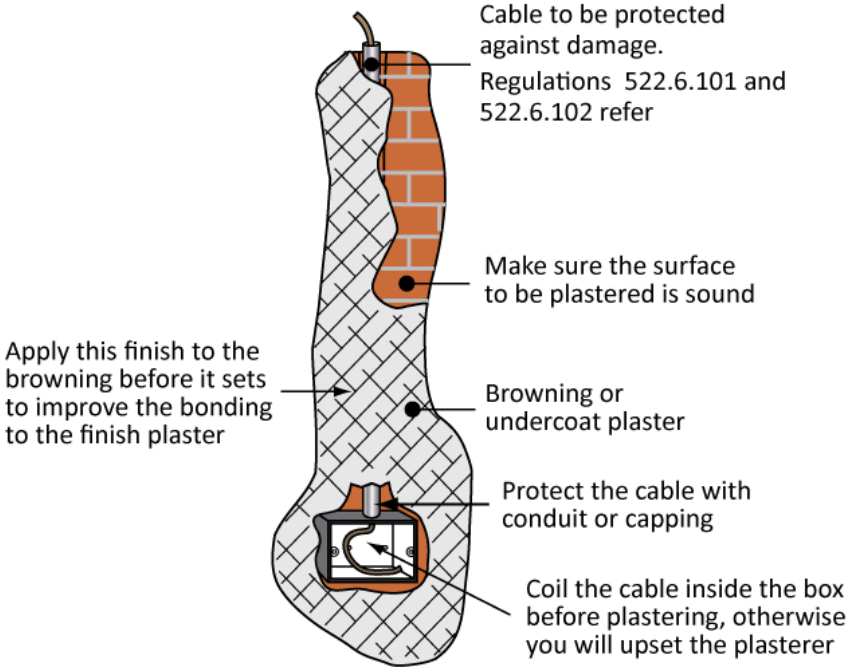
The examples show chases made into brick but it is similar for walls covered in plaster.

Prior to start preparing the wall for your cables you need to consider a few things.

- Check for hidden cables
- Remove objects to a safe place, take down paintings etc. Remember, making a chase into a wall sets up a vibration, the client will not be happy if damage their Renoir or break their Ming vase!
- Check the rear of the wall you are chasing to make sure there is no potential for damage.
- Place dust sheets on the furniture in the vicinity of where the chasing is going to take place, dust goes everywhere, especially if you intend using a powered chasing tool.
- It is a good idea to place newspaper of some firmer on the floor under your chase to collect the debris and to protect the clients Axminster carpet or their polished parquet floor.
- Do clean up the mess regularly, this prevents it being trampled everywhere, the practice used on a construction site does not work inside people's homes.
- Do liaise with other trades, this makes for harmony at work and quite often it stops the same job being done twice.
- Try and keep the householders children out of the way, they would not like to be covered in brick dust or get hit with a lump hammer when you are in full swing!

Plastering

When you come to make good, consider what the original wall is covered with. If the wall is cement rendered then you should mix something similar and vice-versa for plastered walls.



If the chase is in a plastered wall, create a channel for the new topcoat plaster or polyfilla to go in.

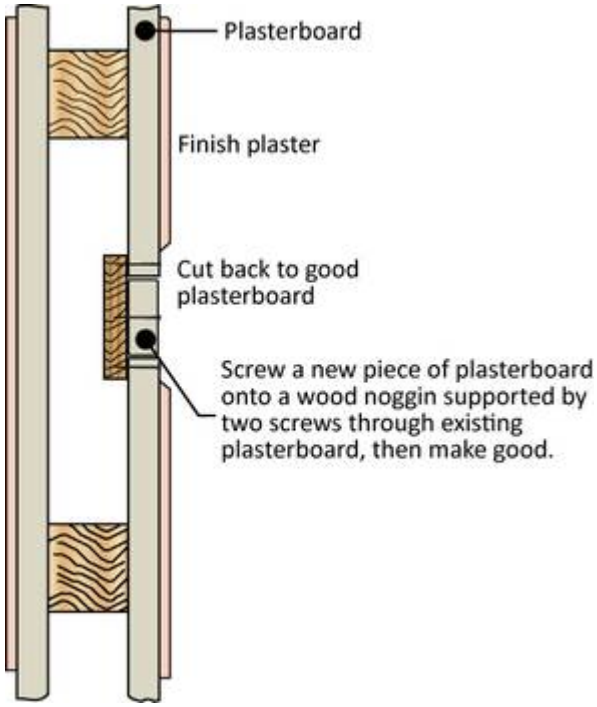
This stops cracks appearing down the length of the chase.

When plastering walls:

- wet the chase that you are going to plaster. This allows the new plaster to combine with the old
- mix some filling plaster. Most often this will be browning, although some walls require a type of plaster called bonding plaster, which holds things together better
- this mixture should be pushed into the entire chase and should be left 1 mm-2 mm lower than the surface. This makes room for the skimming plaster
- mix the skimming plaster when the filler has ‘gone off’. You shouldn’t leave plaster standing around, as it will harden. Skim up to the old surface and try not to go proud, you may end up having to sand it down.

Although plastering can cover a multitude of sins, be aware that you should not be using it to cover your mistakes. In the end, you may end up having to redo everything. A common problem is not having the chase deep enough then finding that the cable and/or channelling sits proud of the surface. Don’t think that you can cover over your mistake by forming a neat little hump. It will be noticed!

Hollow walls



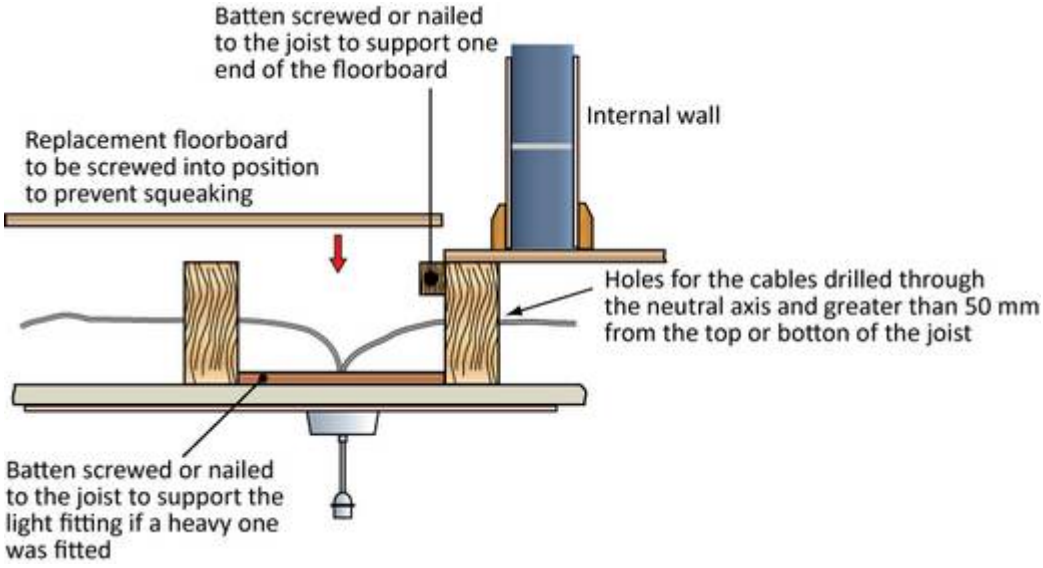
When a wall is made up of plasterboard, there may well be occasions when you have to repair the wall. Obviously, it is no good merely filling up the hole with plaster. You will have to think through what you are doing much more carefully.

Some try to stick in screwed up soaked newspaper and then filling with plaster; certainly not the best of choices.

A better option may be to use some of the plasterboard that has been cut out, to fill the hole and then to plaster up to that. Other options could be to use blank plates to cover over where electrical equipment once was situated.

Replacing floorboards

Ideally, when taking up floorboards it is best to cut the board half way across a joist. Sometimes this is not always possible, especially when the boards run under a wall. When this happens, cut the board flush with the joist, and then put a batten across the width of the joist to support the floorboard.



It is considered bad practice to leave your rubbish under the floorboards.

It is always best to screw the boards down when re-fitting them. This prevents the horrible floorboard creaking noise that happens when nails are re-used in existing holes.

There are also times when you may have to replaces ceramic tiles. It is possible to use plaster to stick tiles down with but remember, tile adhesive is mould resistant and waterproof which plaster isn't.

Use

Do not use

There are tools to use with ceramic tiles and these include; tile cutters, an abro file (tile file), and a smoothing block.

When drilling into ceramic tiles, the glaze part is the hardest, once through that, the rest of the tile is soft. Remember, tiles are brittle and snap easily so try and not push too hard when drilling. Do not use the hammer setting!!

Exercise 18

1. A luminaire has a mass of 3kg and there is no joist near to the place where you need to fix it. What are your options?

2. A row of floorboards have been lifted. What precautions will you take?

3. A chase has been chopped out and it is discovered that the wall behind the plaster is crumbling. The chase varies in depth from 25 mm deep to 75 mm deep. How will you repair the wall after the cable is installed?

4. A house has been rewired and the old lead cable has been replaced with thermoplastic cabling. All switch drops and socket outlets have been chased out with oval tubing used to enable rewiring to take place. What will you do with the waste? What precautions will you take (e.g. PPE)?

5. A wall is to have a 50 mm wide chase chopped in it. What precautions will you take?

6. A trainee has slipped and pushed his foot through the plasterboard ceiling. What will you do?

19: Regulatory requirements – Selection and erection

In this session the student will:

- Understand how the IET Wiring Regulations impact upon the installation of wiring systems, associated equipment and enclosures. In particular when selecting and erecting wiring systems.

This is the last outcome in 305 and looks at which Regulations are important to the installation of wiring systems, associated equipment and enclosures.

In previous sessions you have learnt of the different wiring systems and why you would select one type over another. Also, you have learnt how to think about the environmental factors that may affect your choices. How to support the systems and then how to make good any alterations you made to the fabric of the building.

We now need to consider the Regulations which will reinforce any choices you make with regard to the following list.

- selection and erection of wiring systems, associated equipment and enclosures
- isolation and switching
- protection against fire
- protection against electric shock
- special locations
- segregation
- flammable/explosive atmospheres

Before we can use the Regulations, we need to understand the numbering system and how the current edition is arranged.

BS 7671:2008 incorporating Amendment No. 1:2011

The 'Regs' have had a long history. The first edition was published in the nineteenth century and has undertaken a wide variety of changes over the years.

In 1981, there was a radical shift in the way in which the Wiring Regulations were structured. All the previous editions had effectively been a book setting out a series of do's and don'ts. If you were in doubt, you would go and look at the 'Regs' and they would lay out what was required.

When the 15th Edition came out there was a move away from the list of do's and don'ts. What was suddenly brought in was a framework document. The electrician was suddenly required to apply judgement.

This shift has continued with the introduction of the 16th Edition in 1992 and now the 17th Edition in 2008. The 'Regs' have also undertaken a name change. We no longer have a numbered edition, but a British Standard number. We now have BS 7671: 2008 (2011) which includes the first set of amendments introduced, and they are now called 'requirements' as opposed to 'regulations'. Additionally, each set of requirements is amended at different times.

Recently, we have had a complete overhaul and many areas have been harmonised with the rest of Europe (CENELEC Harmonisation Documents HD); we are to use BS 7671: 2008 (2011) (Green cover).

The eight areas of BS 7671 are:

- Scope, object and fundamental principles (Part 1)
- Definitions (Part 2)
- Assessment of general characteristics (Part 3)
- Protection for safety (Part 4)
- Selection and erection of equipment (Part 5)
- Inspection and testing (Part 6)
- Special installations and locations. (Part 7)
- Appendices

Numbering

The numbering system helps you find the requirement you want fairly quickly.

Consider the Regulation number 531.2.

Part	5	Selection & Erection of equipment
Chapter	53	Switchgear
Section	531	Devices for fault protection by automatic disconnection of supply
Group	531.2	RCDs
Identifying No. of Regulation	531.2.1	An RCD shall be capable of disconnecting all the line conductors of the circuit at substantially the same time.

The first number details the Part that you are happening to look at; in this instance Part 5.
The next number details the Chapter that you are looking at; in this instance Chapter 53.
At each level, you can see that more and more detail is added until you get to the Regulation that you require.

Although BS 7671 is a harmonised document, there are certain requirements that are unique to the UK. These requirements are identified by having the number 100.

For example, look at Section 522 and in particular requirement 522.2.100; cables within an accessory shall be suitable for the temperatures likely to be encountered.

Have a look at 522.6.100 to 522.6.103 which deals with cables embedded in walls and under the floor. These are all examples of UK specific requirements.

Selection and erection of wiring systems (Part 5)

A wiring system is defined as, *'an assembly made up of cable or busbars and parts which secure and, if necessary, enclose the cable or busbars.'*

Go to page 110 of BS 7671 and look at the sub headings under Part 5. We need to be looking at selection and erection of wiring systems which points us to Chapter 52, so now turn to page 121.

Section 521 directs you to look at Appendix 4, in particular Table 4A1 which deals with installation methods on how cables and conductors can be installed, and Table 4A2 which gives a range of installation methods which is to be used when determining the current carrying capacity of conductors/cables. Spend a few moments having a look at Appendix 4 now.

Answer the following.

1. What are the permitted installation methods for non-sheathed cables?

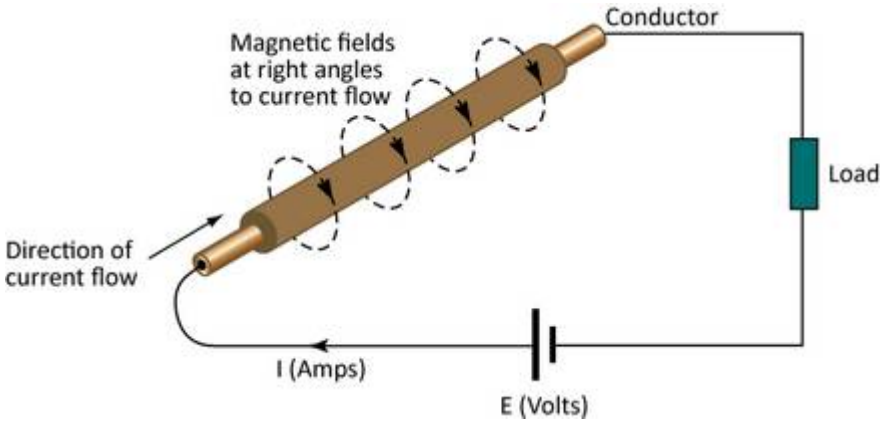
2. What is the installation method for multi-core cables on a ladder rack?

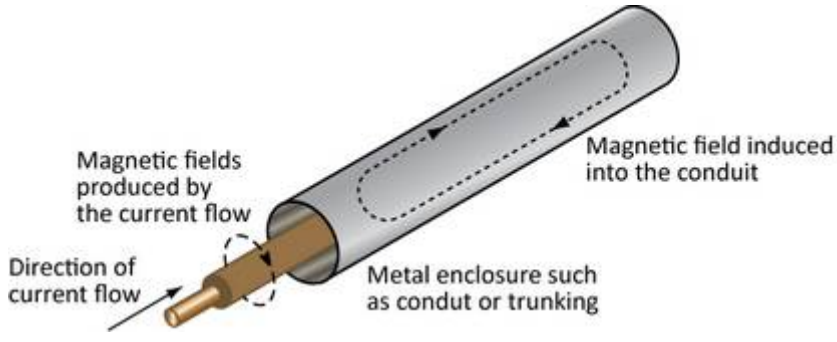
3. What is the table to be used for determining the current carrying capacity of flat twin and earth cables installed in thermal insulation?

521.5.1 Ferromagnetic enclosures.

When installing conductors of a.c. circuits it is imperative that all line and neutral conductors are contained within the same enclosure. Failure to do this creates a lot of heat being generated by electromagnetic induction which can be very large.

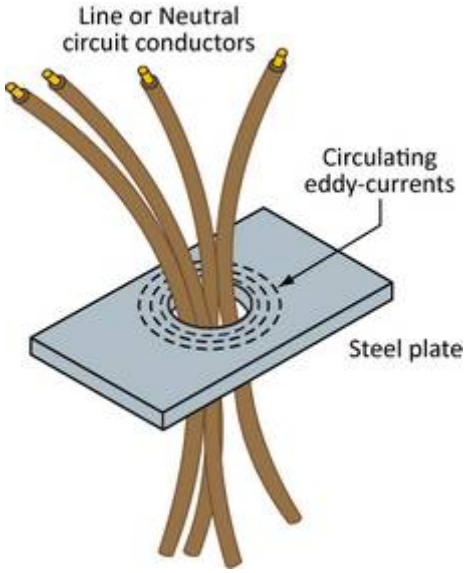
Induction is produced when a conductor has current passing through it. As the current flows then a magnetic field is produced around the cable. Whenever a magnetic field cuts a conductor such as metal conduit or trunking, then an emf will be set up which produces a current. This current will heat the conduit or trunking.





If the numbers of conductors were to be increased and the current continued to come from the same direction, then the strength of the magnetic field would increase. In effect, the inductance has increased. If this took place near any ferrous material, then the effect would be increased.

This effect can occur in an installation if conductors that are all of one type (all line conductors or neutral conductors) are run in anything made of a ferrous material (iron or steel) or, if they pass through a hole in ferrous material. When this happens, what are called 'eddy currents' can be set up. These eddy currents can lead to increased temperatures in the cable, which affects their current-carrying capacity, or they can lead to voltages appearing between two points.

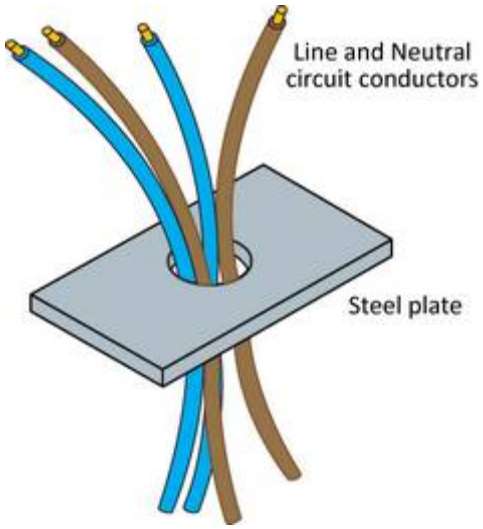


You can see that the cables pass through a metal plate. This effect is dealt with by Regulation 521.5.2 of BS 7671.

This effect can be reduced in one of two ways.

- Don't use anything made with iron or steel. This is not always achievable.
- Make sure that all line and neutral conductors pass through the same hole. This cancels out the effect because the direction of the magnetic field around the line and neutral conductors cancel each other out

This will cancel out the effect. It is worth noting that protective conductors should also pass through the same hole.



The only other electromagnetic effect is produced when there are large fault currents flowing.

If large fault currents flow, very large magnetic fields are produced and these can cause the cables to move, or the bars to bend and buckle in busbar trunking.

These effects are difficult to remove as they are caused by a fault that should not be there.

We need to ensure that the fault can be cleared quickly by choosing appropriate protective devices (fuses/circuit breakers etc.).

521.5.2 Single-core SWA cable are not to be used for an a.c. circuit, you now know the reason why.

521.6 Two or more circuits can be installed in the same conduit, ducting or trunking, this is fairly obvious, since that is the whole purpose of using that type of containment system.

521.7 Two or more circuits are allowed in the same cable. This is useful for multi-core cables for control circuits and the like.

This is providing the requirements of Section 528 are met. Have a look at 528 now.

521.8.1 Each part of a circuit shall be arranged such that they are not distributed far and wide. This makes perfect sense; keep all parts of a circuit together. This aids testing and any fault finding that may take place in the future.

521.8.2 The line and neutral conductors of each final circuit shall be electrically separate from those of any other final circuit. This is really talking about borrowing line and/or neutral conductors for an adjacent circuit. For example; you have run a twin & earth (line and switch-wire) to a room thermostat, but later on learn that it requires a neutral. There is a lighting point very close, what do you do? The right thing to do is inform your employer that you need some three-core and earth and replace the original cable.

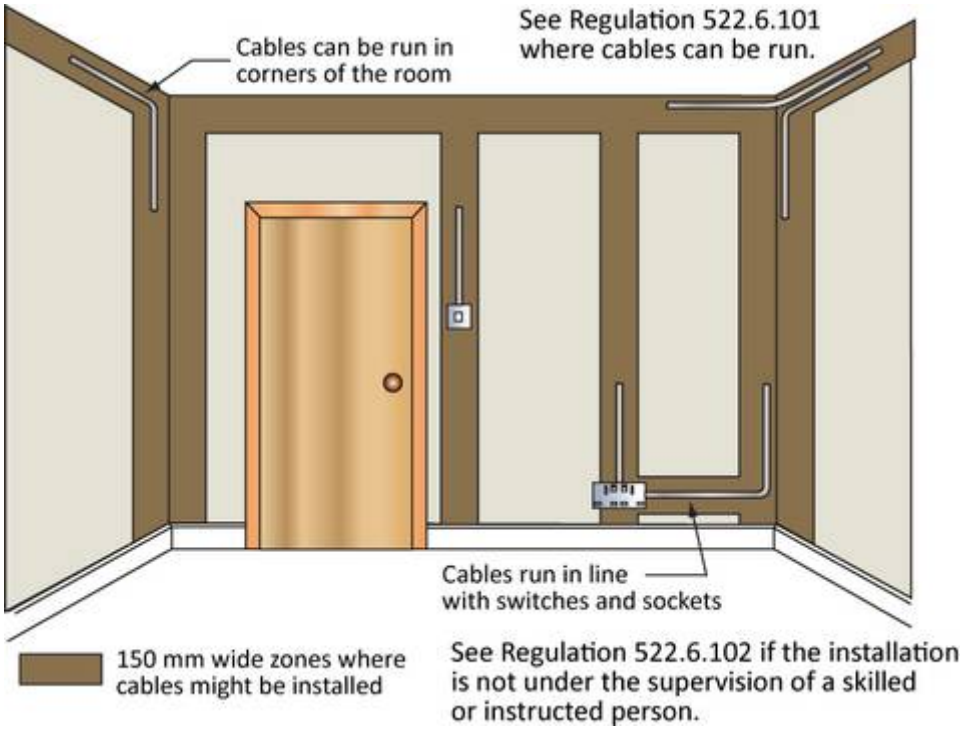
521.10.1 Non-sheathed cables for fixed wiring shall be enclosed in a containment system. You read this when you looked at table 4A1

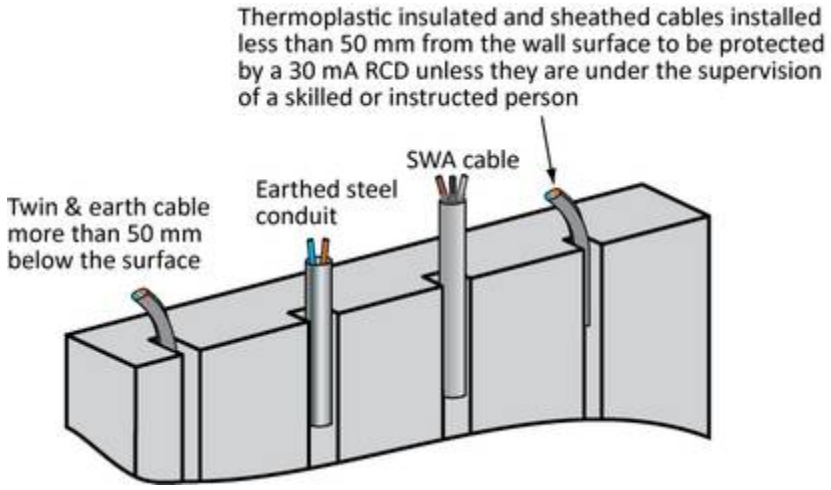
522 This section looks at the selection and erection of wiring systems in relation to external influences. This has been covered earlier in outcome 4, take time and have another read of it.

522.6.100 to 522.6.103 These requirements deal with how cables are installed under a floor or above ceiling where they are not liable to damage.

They also look at how cables are installed in a wall or partition and look at the depth they can be placed and the precautions to be taken to prevent damage.

They also describe the situation if the installation is under the supervision of a skilled or instructed person.





523.9 This discusses that any cable run where it is likely to be surrounded by thermal insulation should be avoided. It draws your attention to Table 52.2 which gives derating factors per depth of thermal insulation.

Selection and erection to minimise the spread of fire

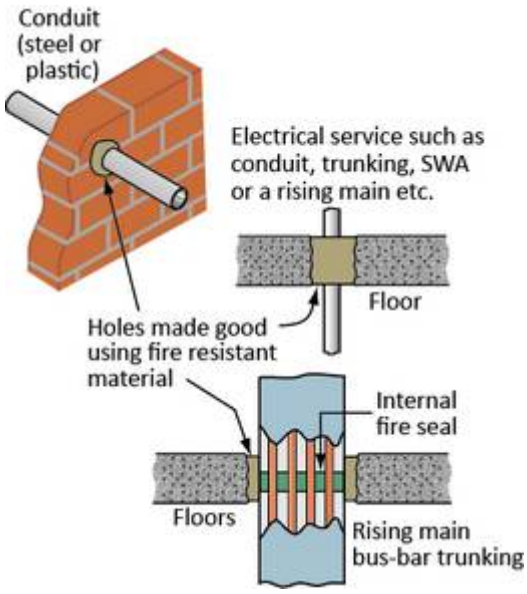
Fire is such a damaging effect to life and property that the impact of wiring systems on an installation must be minimised (refer Regulation 527.1.1).

An architect and his/her design team will have designed a building with a certain level of structural integrity. When, through the effects of fire, that structural integrity is reduced then a fire can, and will, cause a building to collapse. Section 527 of *BS 7671* details many of the requirements to reduce the impact of the wiring system on the structural integrity of the building (refer Regulation 527.1.2).

Regulation Group 527.1 details the requirements for cable types within installations. It is Regulation Group 527.2 and other British Standards, such as BS 5839-1 (relating to fire alarm systems) that detail the requirements for those instances where a wiring system penetrates an element of building construction, such as a floor, wall or ceiling.

Approved document B gives guidance on fire safety. A useful booklet for the electrician to own is the Electrical Installers Guide to the Building Regulations.

Regulations 527.1.1 and 527.2.2



Where a wiring system penetrates an element of building construction then it must be sealed. This is usually done with an intumescent seal. An intumescent material expands as it is heated up and therefore blocks access to both smoke and flame. The seals should be in place not only for permanent wiring systems, but also those that are a more temporary nature (refer Regulation 527.2.1 and Regulation 527.2.2).

Because of the ability of trunking and conduit systems to behave as access points for smoke and flame, Regulation 527.2.3 limits the cross-sectional area after which point the non-flame propagating conduit or trunking must be internally sealed.

The maximum permitted internal cross-sectional area before which an internal seal must be provided is 710 mm^2. This translates to a maximum conduit size of 32 mm diameter and trunking dimension of $25mm \times 25mm$.

Fire seals

It is not only the fabric of the building that needs sealing if cables have penetrated through walls or floors. Consideration needs to be given to accessories installed in cavity walls, particularly those made from wood and plasterboard.

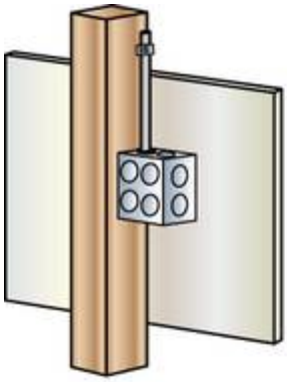
The problem is the ability of hot gases to get inside the partition and cause fires.

Cutting an electrical socket opening in a drywall partition can reduce its acoustic performance and resistance to fire which could therefore result in non-compliance with Part E and Part B Building Regulations.

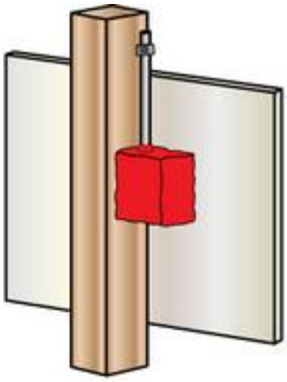
One way to overcome this is to fit an intumescent seal around the accessory such as the type shown. They are available as a roll or a putty pad.

Intumescent putty pad

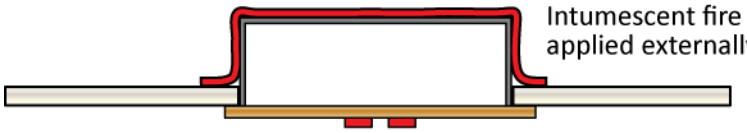
They are simply cut to shape.



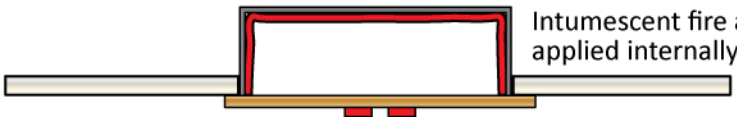
Back box mounted in a partition wall



Intumescent fire acoustic putty pad applied externally to an accessory



Intumescent fire acoustic putty pad applied externally to an accessory box



Intumescent fire acoustic putty pad applied internally to an accessory box

The mouldable pads fit easily into socket boxes to reduce sound travelling through the walls whilst providing flexibility when fitting avoiding accidental tearing or puncturing.

These seals are not needed if the accessory box area is less 103 cm^2 or if they are mounted greater than 600 mm apart.

Another version has a seal moulded into the shape of the mounting box such as the one shown.

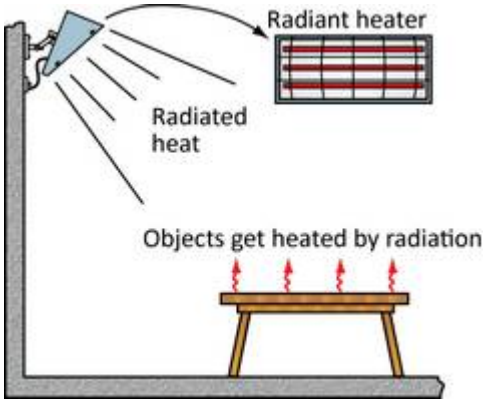
This offers a cost effective and simple solution for protecting electrical switch and socket boxes when fitted in fire rated walls.

Photo courtesy of Tenmat Ltd

421.1.2 Fixed electrical equipment must be selected and erected in such a way that its temperature in normal operations will not cause a fire. This looks at things such fluorescents where the choke gets very hot in normal use.

421.1.3 Where arcs, sparks or particles at high temperature may be emitted by fixed equipment, the equipment shall be screened or mounted in such a way that there is no hazard resulting from its use. The type of equipment that springs to mind is electric arc welders.

421.1.4 Fixed equipment causing heat when in their normal operating mode shall be at a sufficient distance so that there is little chance of adjacent fixed equipment or material reaching combustion temperatures.



422.3.1 Luminaires shall be kept at an adequate distance from combustible materials. A small spotlight shall be installed at a minimum distance from combustible materials.

(i)	Rated up to a 100 W	0.5 m
(ii)	Over 100 W up to 300 W	0.8 m
(iii)	Over 300 W and up to 500 W	1.0 m

Exercise 19

1. Every cable installed shall be so constructed
   a) as to withstand any forces caused by the current it may have to carry in normal service.
   b) be strong enough to withstand the forces on it when being pulled into conduit or trunking.
   c) to give many years of service without degradation.
   d) to comply with all statutory regulations.

2. Every part of a circuit shall be so arranged
   a) that the conductors are spread across different conduits to prevent exceeding the space factor.
   b) that the conductors are not contained in different multi-core cables or conduits.
   c) that each accessory is colour coded for easy identification.
   d) that highest current using equipment is mounted nearest to the consumer unit.

3. The line and neutral conductors of each final circuit shall be
   a) wired separately to prevent damage when they are being drawn in.
   b) easily accessible for inspection.
   c) covered with basic insulation.
   d) electrically separate from those of every other final circuit.

4. Equipment that is intended to be moved in normal use shall be
   a) operated only by skilled persons.
   b) operated using battery power.
   c) connected using flexible cables.
   d) connected via a router on a wireless system.

5. According to BS 7671, which one of the following types of cable may not be used for a.c.?
   a) Twin cables armoured with steel wire.
   b) Single-core cables armoured with steel wire.
   c) Single-core MI copper sheathed cable.
   d) Paper insulated lead sheathed cables.

6. A material which can be reshaped when heated is called
   a) ferrous
   b) alloy
   c) thermosetting
   d) thermoplastic

7. An expansion coupling designed to allow for longitudinal expansion is most likely to be installed
   a) in a pvc conduit wiring system.
   b) in a steel conduit wiring system.
   c) in a steel trunking wiring system.
   d) in a wiring system using cable tray.

8. The schedule of Installation Methods of cables describes single-core non-sheathed in conduit on a wooden or masonry wall or spaced less than 0.3 x conduit diameter from it as being
   a) Reference method A.
   b) Reference method B.
   c) Reference method C.
   d) Reference method E of F.

9. What is the width of the 'safe zone' that cables can be run in horizontally and vertically?
   a) 75 mm
   b) 100 mm
   c) 125 mm
   d) 150 mm

10. In an installation not supervised by skilled or instructed persons, cables installed in walls or partitions at a depth less than 50 mm from the surface, shall be protected by a 30 mA RCD when they are
   a) run horizontally or vertically to accessories
   b) enclosed in earthed conduit
   c) wired in mineral insulated cable
   d) mechanically protected against damage

11. Where a rising main busbar system within a steel trunking is installed high rise buildings, fire barriers must be fitted
   a) every 3 m of height.
   b) at the top and bottom of the riser.
   c) midway between each floor.
   d) where the trunking passes through floors.

12. The main function of a cable sheath is to
   a) provide secure termination
   b) improve heat dissipation from the cable
   c) protect the cable from mechanical damage
   d) provide an extra layer of insulation

13. Cables passing through joists under floorboards must be at least how far from the surface?
   a) 50 mm
   b) 40 mm
   c) 30 mm
   d) 60 mm

14. Two 20 mm conduits are to be terminated through a concrete floor to a lighting outlet. A suitable accessory for termination would be a
   a) tangent elbow box
   b) loop-in box
   c) through box
   d) branch U box

15. An installation method which reduces building work when modernising existing property is
   a) MI buried in walls
   b) PVC sheathed cables buried in walls
   c) pre-wired flexible conduit
   d) the use of skirting trunking

16. After a period of storage at a temperature of 0° C, a pvc cable should be
   a) warmed slowly before installation
   b) warmed slowly before installation
   c) returned to the supplier
   d) installed whilst cold to prevent insulation cracking

17. The manufacturers code ref 6491X refers to which type of cable?
   a) Steel wired armoured
   b) Mineral insulated
   c) Multi-core pvc
   d) single-core pvc

18. What is the maximum continuous operating temperature for XLPE type cable?
    a) 70 ° C
    b) 80° C
    c) 90° C
    d) 100° C

19. At what depth should XPLE/SWA be buried in order to prevent mechanical damage?
    a) 1 metre
    b) 600 mm
    c) 300 mm
    d) At a sufficient depth to avoid being damaged in the foreseeable future

20. When should cables be drawn into a conduit system?
    a) Half way through the installation
    b) In sections as you progress through the installation
    c) At the end of the installation
    d) At each successive floor level or room connection

20: Regulatory requirements – Isolation & Switching

In this session the student will:

- Understand how the IET Wiring Regulations impact upon the installation of wiring systems, associated equipment and enclosures. In particular when considering Isolation and switching

In this session we are going to look at isolation and switching and what that means for the electrician.

Firstly it would be useful to define the terms that we are going to use so that we can eliminate any confusion in our terminology.

Isolation

Isolation is defined as:

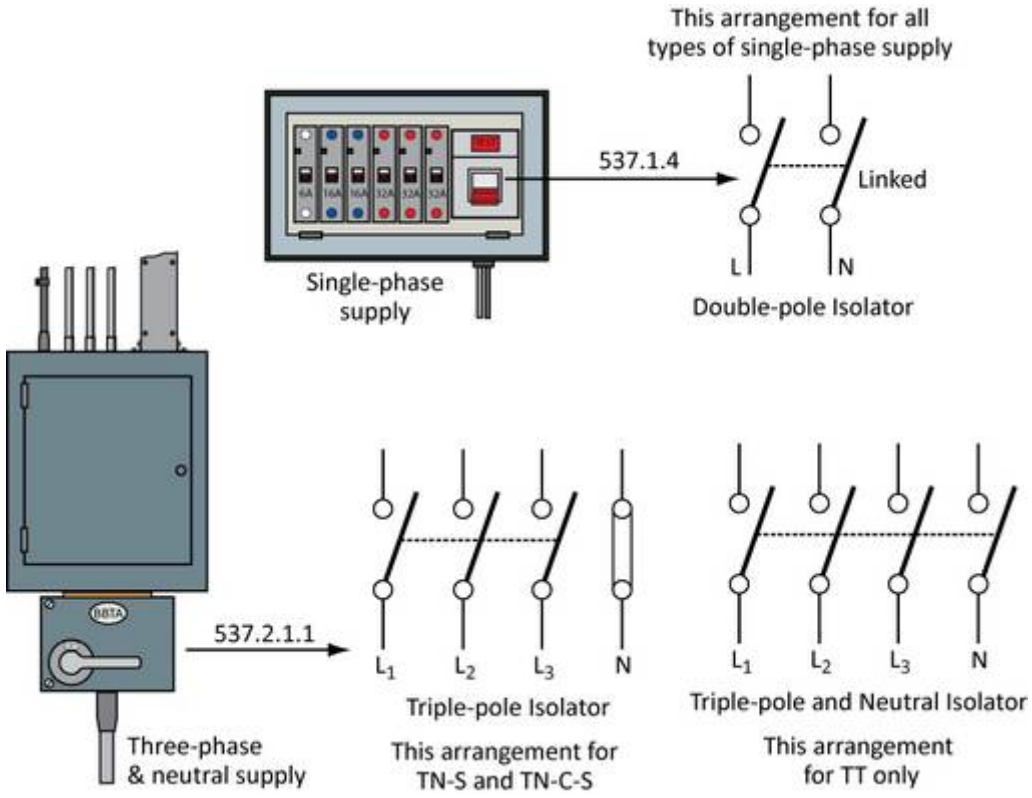
'A function intended to cut off for reasons of safety the supply from all, or a discrete section, of the installation by separating the installation or section from every source of electrical energy'.

There must always be isolation and it should be designed into the system. An isolator is often described as a disconnector, although it is not the only means of providing isolation, and it is essential that the isolator can be safely secured (padlocked) or kept under constant supervision of the person at risk.

Every installation must have a main switch or circuit-breaker that is capable of switching the whole of the installation.

The number of poles that need to be isolated varies depending on the type of earthing arrangements that have been provided. Have a look at the table below.

Location	*Single Phase*	*Three Phase*	*Regulation*
Main Switch			
TN-S	All live conductors	Line conductors only	537.1.4
TN-C-S	(Line and Neutral)	(Brown, Black and Grey lines)	
Other Isolators			
TN-S	Line conductor only		537.2.1.1
TN-C-S	(Brown, Black and Grey Lines)		
All Locations			
TT	All live conductors		537.2.1.1
	(Brown, Black, Grey Lines and Neutral)		



In effect, isolation is the means of cutting off the electrical supply to enable skilled people to work on or near live parts.

Typical isolators could be a plug and socket-outlet, a protective device, a fused connection unit or a disconnector. For most intake positions in a domestic setting the main switch is a disconnector: it is an off-load device.

Many commercial and industrial installations have switchgear such as switch-fuses or fused-switches, air circuit-breakers, moulded case circuit-breakers and the like. Many of these can operate as on-load devices

There are a series of regulations found in BS 7671 that deal with the requirements for isolation. However, Table 53.2 in BS 7671 is particularly useful in stating what can and cannot be used for isolation, emergency switching and functional switching.

The table below provides a brief review of the circuits where isolation is required.

Isolation	***Commentary***	***Regulations***
At the origin of an installation.	This is usually a main switch or circuit-breaker and is located as near as possible to the origin of the installation.	537.1.2, 537.1.3, 531.1.4, 537.1.5, 537.1.6, 537.2.1.1
For every circuit or group of circuits.	Group isolation is allowed where appropriate. If the isolation device is remote from the equipment then it must be lockable in the off position.	537.2.1.1, 537.2.1.2
For every motor (fixed) and their associated control gear.	If the isolator is remote then it must be capable of being lockable in the off position.	132.15.2, 537.2.1.5 Also see *BS EN 60204-1: 2006 Safety of machinery - Electrical equipment of machines - Part 1: General requirements*
For discharge lighting at high voltage.	Isolation must be provided to the low voltage circuit, and if remote, it must be lockable in the off position.	537.2.1.6, 537.2.1.5
For all distribution boards.	Where the isolating device is remote from the board then it must be capable of being locked off.	537.2.1.3, 537.2.1.5
For every switchboard.	If the isolating device is used in conjunction with a circuit breaker, they must be interlocked. If the isolator is remote then it should be capable of being locked off.	537.2.1.3, 537.2.1.5

Switching off for mechanical maintenance

Switching off for mechanical maintenance is defined as switching off for:

> '*the replacement, refurbishment or cleaning of lamps and non electrical parts of equipment, plant and machinery*'.

In most circumstances, the isolator acts as the means for this type of switching.

Regulation 537.3.1.1 requires switching off for mechanical maintenance to be provided where mechanical maintenance may involve the risk of physical injury. This device can be used by non-electrically trained people and so it must be capable of on-load and off-load switching (refer Regulation 537.3.2.5).

Live parts should not be accessible when switching off for mechanical maintenance. If live parts are open then isolation must take place. Remember that we are dealing with non-electrical people. The table below states the main requirements for the switching off for mechanical maintenance.

Switching	***Commentary***	***Regulation***
To be inserted in the main supply circuit	This can be a multi-pole switch, circuit-breaker, plug and socket-outlet	537.3.2.1
Devices permitted should be manually operated	An operator is required as control must be maintained.	537.3.2.2
Open position of the device to be clearly visible	This can be either by showing the contacts themselves or by clear indication.	537.3.2.2
Identifiable	Both by position and labelling this should be seen to be used as the means of switching off for mechanical maintenance.	537.3.2.4
Plug and socket-outlet may be used	Not greater than 16 A.	537.3.2.1, 537.3.2.6

These are the key points that switching off for mechanical maintenance raises. However, once again, where we are dealing with an electric machine then, as with isolation, the requirements of BS EN 60204 apply.

If there are any concerns about this type of switching arrangement than you should move towards the safe end and provide for isolation, with all that isolation entails.

Emergency switching

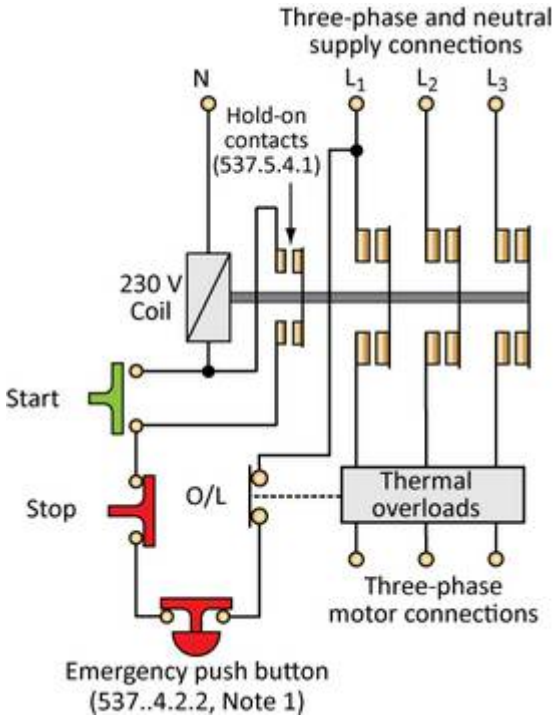
Emergency switching is defined as:

> '*An operation intended to remove, as quickly as possible, danger, which may have occurred unexpectedly*.

Emergency switching is to be able to be used by any person and should disconnect all live conductors in a TT system and all line conductors in a TN system (Regulation 537.4.1.2 and Regulation 537.1.2 refer).

Location	***Single Phase***	***Three Phase***	***Regulation***
Main Switch			
TN-S	All live conductors (Line and Neutral)	Line conductors only (Brown, Black and Grey lines)	537.4.1.2 537.1.2
TN-C-S			
TT	All live conductors (Brown, Black, Grey Lines and Neutral)		537.4.1.2 537.1.2

Examples of emergency switching would be emergency stop buttons on motor control gear, escalators etc. It should be noted once again however, that BS EN 60204 details the requirements for emergency switching of circuits supplying electrical machinery.



It must not be possible to restart machinery until all emergency stop commands have been reset (see also Regulation 537.4.2.6). The diagram to the left demonstrates a simple application of this.

The table below states the main requirements for emergency switching.

Switching	***Demand***	***Regulation***
To act as directly as possible on the appropriate supply conductors	To avoid any bypassing of the stop mechanism	537.4.1.3
Single action	No fiddling around	537.4.1.3
Capable of breaking full-load current	Must be able to operate under all normal conditions as by its nature an emergency is likely to occur whilst the circuit is in operation	537.4.2.1
Hand-operated where practicable	Hand/eye coordination is better than foot/eye coordination	537.4.2.3
Stop button should be red	High visibility colour	537.4.2.4
Readily accessible	If it's hidden what is its purpose?	537.4.2.5
Latched in the open position	To comply with the requirements of *BS EN 60204*	537.4.2.6
Readily identifiable	It's got to be seen	537.4.2.7
Pug and socket-outlet not selected as a device for emergency switching	Not selected does not mean not used.	537.4.2.8

Functional switching

Functional switching is defined as:

> '*An operation intended to switch 'on' or 'off' or vary the supply of electrical energy to all or part of an installation for normal operating purposes*.

Limit switches

Relays

Switches

Starters/Contactors

Examples of functional switching would be plate switches, grid switches, contactors, relays, electronic devices, machine limit switches, dimmer switches etc. The list is almost endless.

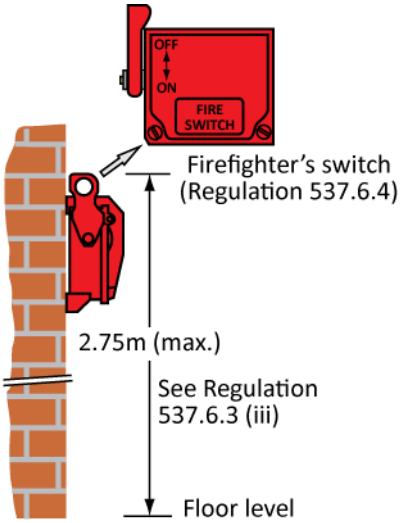
You use functional switching every day. It must be capable of switching the full load current and can switch a variety of devices or circuits.

Switching	***Demand***	***Regulation***
Need not control all live conductors	A functional switching device does not need to be a multi-pole device as switching a line conductor of a single phase supply will cause the circuit to cease to operate	537.5.1.2, 537.5.2.2
Can control more than one item	For example, two lights can be controlled via one switch	537.5.1.3
Suitable for their intended operation	Chosen in the light of the intended load. This will include inductive switching etc.	537.5.2.1
Off-load devices should not be used	Disconnectors are not designed for full-load operation.	537.5.2.3

You should have noticed that the duties have become less onerous with each type of switching. Isolation has the highest levels of safety for working on a particular circuit or device, whilst all other means of switching are to do with non-electrical people and control.

It is probably necessary to just consider one special type of switch which acts as a functional switch, but generally only in an emergency situation.

Firefighter's switch



The firefighter's switch is a particular form of functional/control switch which must be provided for:

- interior discharge lighting installations operating at a voltage exceeding low voltage, and
- exterior installations operating at a voltage exceeding low voltage.

Switching	***Demand***	***Regulation***
Single firefighter's switch	Where practicable one switch should control all loads	537.6.2
Conspicuous position at not more than 2.75 m	It has to be seen and usable	537.6.3 (iii)
Coloured red	Obvious for its purpose	537.6.4 (i)
Nameplate	'FIREFIGHTER'S SWITCH 150 mm by 100 mm lettering at 36 point (0.5 inch)	537.6.4 (i)
'ON' and 'OFF' labelled	Must be able to be seen by someone on the floor	537.6.4 (ii)
Prevent switch being turned on accidentally	Interlock is set such that a button is held in whilst the switch is turned back on.	537.6.4 (iii)

Exercise 20 Isolation & switching

1. Which one of the following is not permitted as means of isolation in a circuit?
   a) Double-pole switch fuse
   b) 13 A plug and socket
   c) Semi-conductor device
   d) Linked switch

2. A means of isolation must be provided in an electrical installation. This is required to be
   a) clearly identified
   b) always placed next to the equipment it isolates
   c) automatic in operation
   d) available for emergency switching

3. The means of isolation for a particular item of equipment may be installed in a position remote from that equipment, providing that it
   a) can be locked in the off position using a lock and key common to all other such isolators
   b) can be locked in the off position using a lock and key that are unique to that isolator
   c) is located so as to be in full view of persons working on the equipment
   d) is manually operated and a visual display is located next to the equipment

4. Which one of following may be used to provide emergency switching for an electric motor?
   a) a key switch latched in the on position
   b) a plug and socket
   c) a switch fuse with a removable handle
   d) a device which latches in the off position

5. A section of a factory requires urgent non-electrical repairs to a machine. The type of switching provided to allow for this work to proceed would be switching for
   a) mechanical movement
   b) mechanical maintenance
   c) emergency
   d) safe operation

6. A device intended, for reasons of safety, to cut off all or part of an installation from every source of electrical energy provides
   a) functional switching
   b) isolation
   c) switching off for mechanical maintenance
   d) emergency switching

7. A switch fitted in a lighting circuit to enable lamp replacement to be carried out on one luminaire with the remainder of the circuit energised provides
   a) isolation
   b) functional switching
   c) emergency switching
   d) switching off for mechanical maintenance

8. Which one of the arrangements complies with the IET Wiring Requirements?
   a) The fire-fighter's switch is fixed 4 m above the ground and the off is at the top
   b) The fire-fighter's switch is coloured red and the off position is at the bottom
   c) The fire-fighter's switch is coloured red and fixed 2.75 m above the floor
   d) The fire-fighter's switch is fixed 2 m above the floor and off at the bottom

9. A fire-fighter's emergency switch should be provided for
   a) Exterior discharge lighting installations exceeding low voltage
   b) Interior low voltage discharge lighting installation
   c) Emergency lighting systems operating at low voltage
   d) Multi-storey office block via alarm circuits operating above low voltage

10. BS 7671 details the requirements of devices for emergency switching. Which of the following devices would **not** satisfy these requirements?
    a) An emergency stop button which breaks the control circuit of a contactor
    b) A switch which breaks the control circuit of a contactor
    c) A switch which breaks all live conductors
    d) A 32 A plug and socket-outlet

11. Provision shall be made for securing off-load switching devices
    a) against unauthorised opening
    b) to break inductive loads quickly
    c) not to be used on low current loads
    d) to be solely used on discharge lighting circuit

12. A main switch intended for use by ordinary persons shall
    a) be located where inadvertent opening of the contacts cannot take place
    b) break the live conductors only of a single-phase supply
    c) be constructed of a non-conducting and durable material
    d) interrupt both live conductors of a single-phase supply

21: Regulatory requirements – special locations

In this session the student will:

- understand the principle regulations that apply to special locations

In all instances the general requirements of BS 7671 apply to all electrical installations. Special locations are those that require additional precautions to the general requirements of BS 7671 to be taken. These are due to the increase in risk that they pose. Starting at Section 701 and ending at Section 753 BS 7671 details these extra requirements.

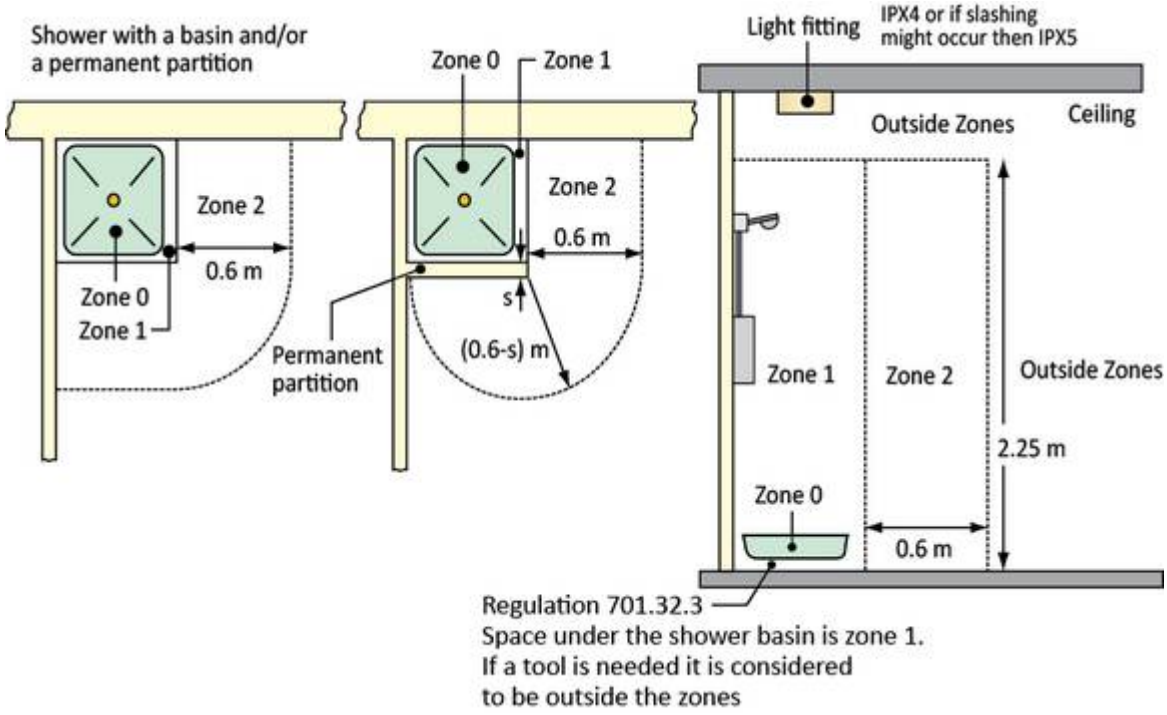
Locations containing a bath or shower (Section 701)

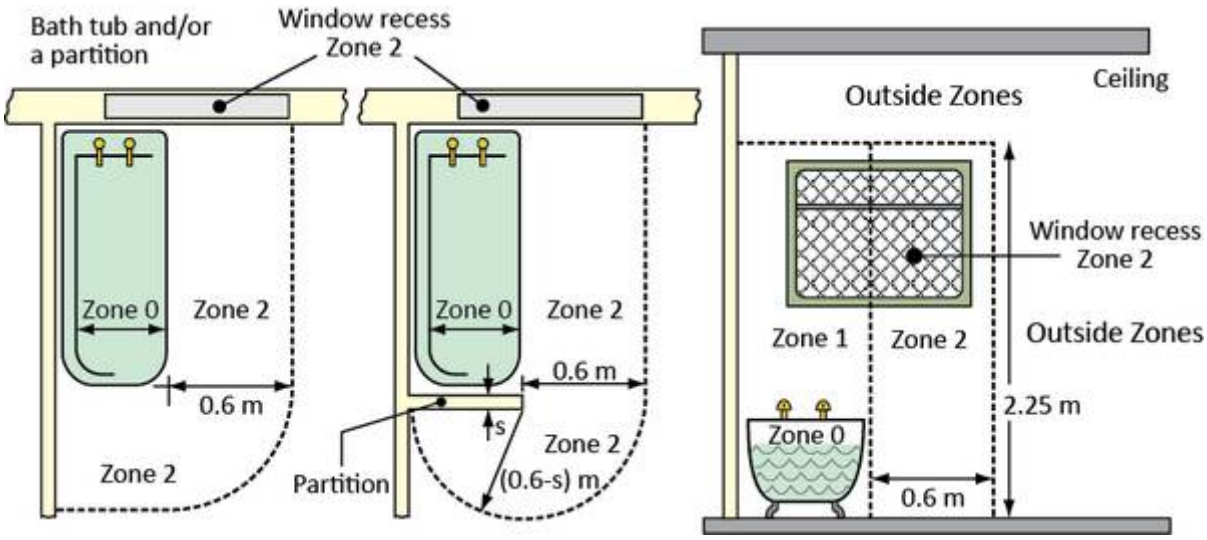
If we look at Section 701, Bathrooms have now been sectioned into different zones, there are three zones:

Zone	Description
0	The interior of the bath or shower. Where a shower has no basin, then zone 0 extends to a height of 0.10 m above the drain.
1	Limited by i) the finished floor level and the horizontal plane corresponding to the highest fixed shower head of water outlet or the horizontal plane lying 2.25 m above the finished floor level, whichever is the higher ii) the vertical surface circumscribing the bath tub or shower basin iii) the vertical surface at a distance of 1.20 m from the centre point of the fixed water outlet on the wall or ceiling for showers without a basin *The space under a bath tub or shower basin is considered to be zone 1. However, if the space under the bath tub or shower basin is only accessible with a tool, it is considered to be outside the zones.*
2	Limited by i) the finished floor level and the horizontal plane corresponding to the highest fixed shower head or water outlet or the horizontal plane lying 2.25 m above the finished floor level, whichever is higher ii) the vertical surface at the boundary of zone 1 and the parallel vertical surface at a distance of 0.60 m from the zone 1 border *For showers without a basin there is no zone 2 but an increased zone 1 is provided by the horizontal dimension of 1.20 m mentioned in Regulation 701.32.3(ii)b.*

Now that bathrooms are zoned, there is a greater need to think about what can be installed within certain areas. From Section 701.5 and following, we have the detail of the degree of protection against water ingress to consider, the switchgear required and the requirements of fixed current using equipment.

Regulation 701.512.3 provides details on switchgear and controlgear. Again, the zoning is key. Pull cords are permitted in zones 1 and 2, but socket-outlets are not permitted within 3 m of the boundary of zone 1.



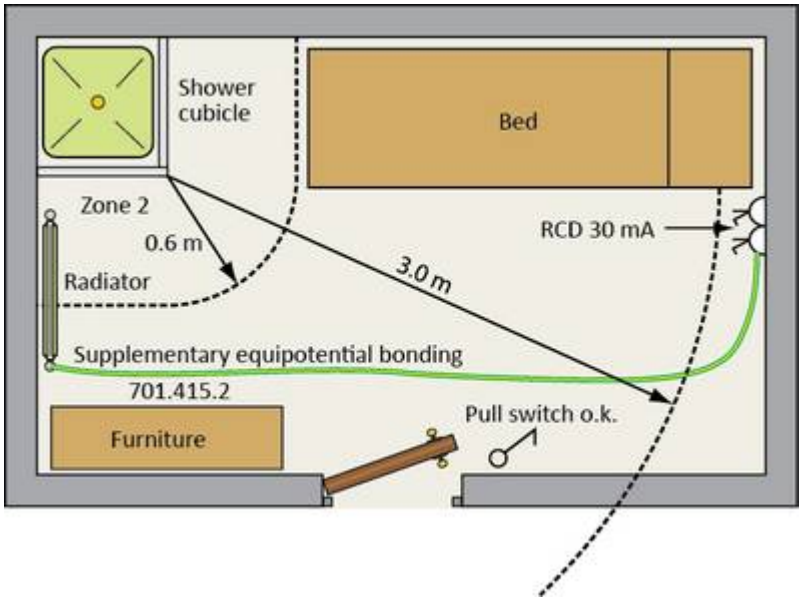


In practice, you will need to carefully consider the zoning of a bathroom. You will appreciate that many bathrooms are quite small, and as such, it will often be the case that there will be no areas outside these zones.

As with switch- and control-gear the connection of fixed current using equipment is strictly limited by Regulation 701.55.

Rooms containing a bath or shower

A main requirement for a room containing a bath or shower is the requirements for all circuits to have additional protection by RCDs having a rated residual operating current no greater than 30 mA and a maximum operating time of 40 ms at $5I_{\Delta n}$.



Linked into this requirement is that of supplementary equipotential bonding. Where three specific conditions are met there is no further need to install supplementary bonding. These three requirements are listed in Regulation 701.415.2, where:

i) all final circuits of the location comply with the disconnection time requirements of Regulation 411.3.2, and

ii) all final circuits of the location are protected by an RCD having a rated residual operating current not greater than 30 mA and a maximum operating time of 40 ms at $5I_{\Delta n}$ and

iii) all extraneous-conductive-parts of the location are effectively connected to the protective equipotential bonding in accordance with Regulation 411.3.1.2.

In new installations these requirements are relatively easy to comply with. In existing installations the designer will have to consider the options that are open to him/her. In particular, if a new circuit is installed then it must have an RCD fitted.

However, existing circuits will either have to have RCDs installed or the new circuit will have to be connected into the supplementary bonding of the existing circuits.

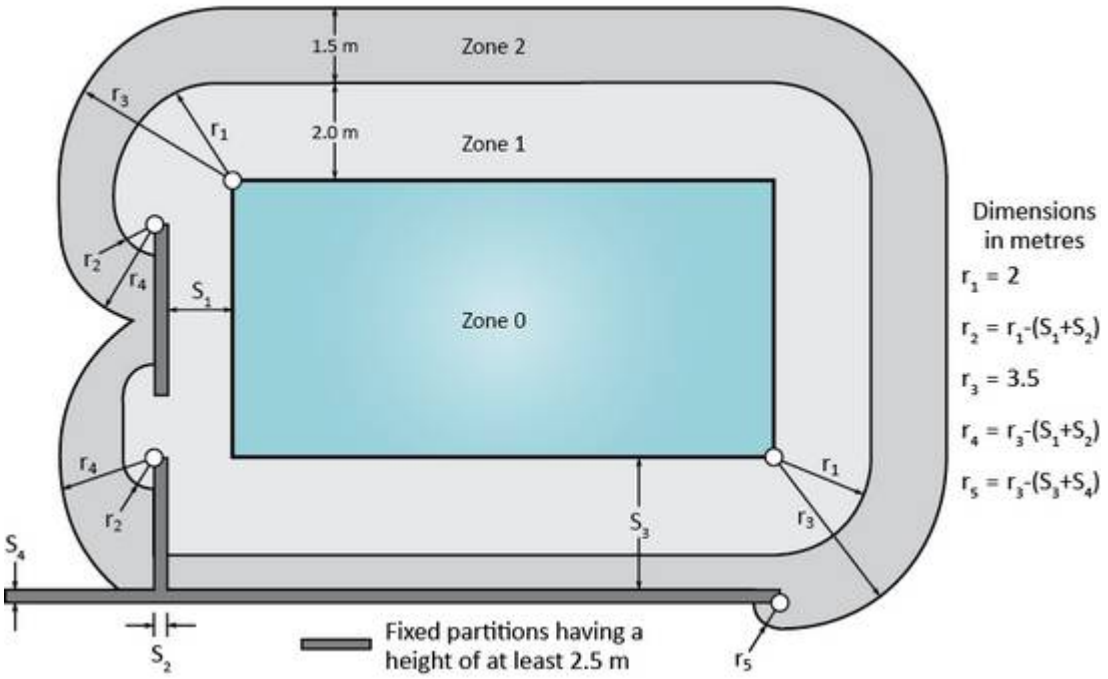
Swimming pools and other basins (Section 702)

The section on swimming pools deals with not only swimming pools, but also paddling pools and any such type of place that reduces the body's resistance. Regulation 702.11 details the scope of this section.

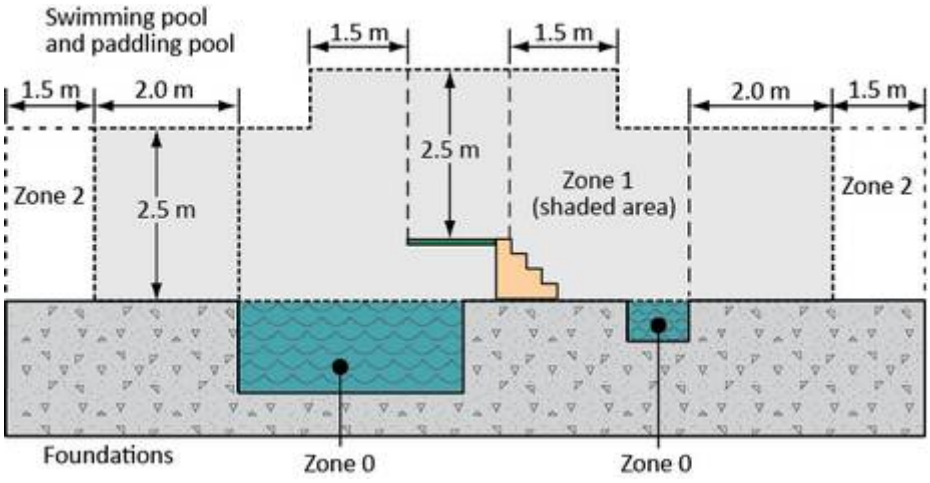
We need to be aware of the variety of 'zones' that apply with this type of installation.

Zone	Description
0	The interior of the basin of the swimming pool or fountain including any recesses in its walls or floors, basins for foot cleansing and water jets or waterfalls and the space below them.
1	Limited by - zone 0 - a vertical plane 2 m from the rim of the basin - the floor or surface expected to be occupied by persons - the horizontal plane 2.5 m above the floor or the surface expected to be occupied by persons Where the swimming pool or fountain contains diving boards, spring boards, starting blocks, chutes or other components expected to be occupied by persons, zone 1 comprises the zone limited by: - a vertical plane situated 1.5 m from the periphery of the diving boards, spring boards, starting blocks, chutes and other components such as accessible sculptures, viewing bays and decorative basins - the horizontal plane 2.5 m above the highest surface expected to be occupied by persons.
2	Limited by - the vertical plane external to zone 1 and a parallel plane 1.5 m from the former - the floor or surface expected to be occupied by persons - the horizontal plane 2.5 m above the floor or surface expected to be occupied by persons. There is no zone 2 for fountains.

Have a look at the following diagrams.



Regulation Group 702.410.3.4 details the protective measures available for use in each of the zones. It should be highlighted that there is an increased use of RCDs and, unlike a room containing a bath or shower, there is a requirement for supplementary equipotential bonding to be installed connecting together extraneous-conductive-parts in zones 0, 1 and 2 to exposed-conductive-parts of equipment situated in those zones.



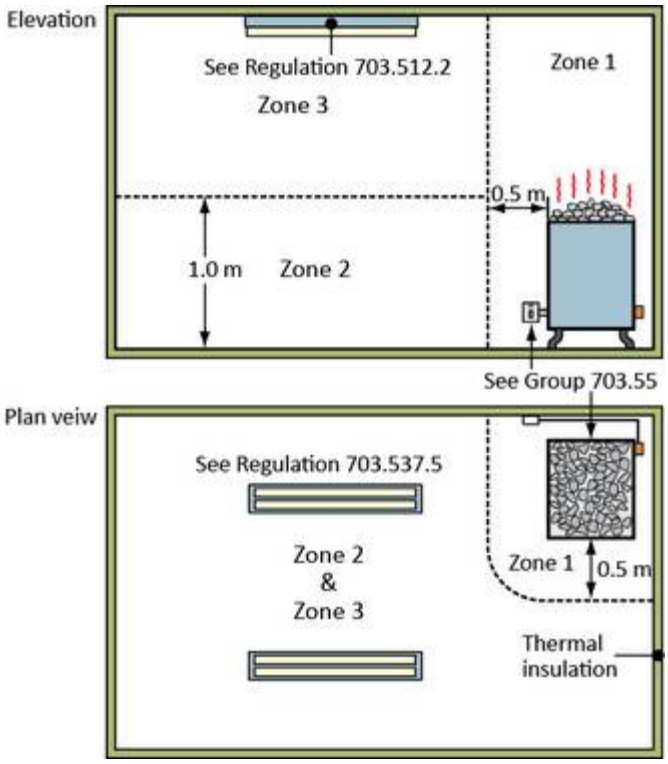
There is a preference for cables to be installed in pvc conduits rather than metallic conduits. Additionally, Regulation 702.522.22 requires that a wiring system is limited to that required for the supply of equipment inside zones 0 and 1. Regulation Group 702.55 details the specific requirements for current-using equipment in swimming pools, fountains and other basins.

Rooms and cabins containing sauna heaters (section 703)

As with swimming pools, hot air saunas are divided into zones. These zones however do not relate to water but temperature. Look at Section 703.

Zone	Description
1	The volume containing the sauna heater, limited by the floor, the cold side of the thermal insulation of the ceiling and a vertical surface circumscribing the sauna heater at a distance 0.5 m from the surface of the heater. If the sauna heater is located closer than 0.5 m to a wall, then zone 1 is limited by the cold side of the thermal insulation of that wall.
2	The volume outside zone 1, limited by the floor, the cold side of the thermal insulation of the walls and a horizontal surface located 1.0 m above the floor.
3	The volume outside zone 1, limited by the cold side of the thermal insulation of the ceiling and walls and a horizontal surface located 1.0 m above the floor.

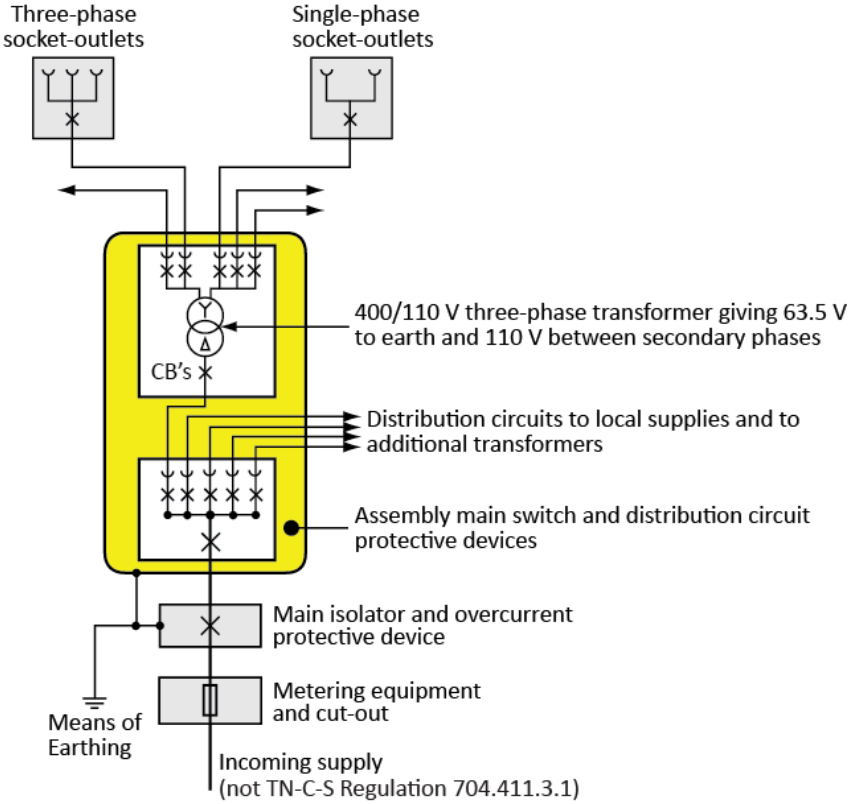
What is noticeable is that any means of protection against electric shock are permitted, except for the protective measures of obstacles and placing out of reach and non-conducting locations and earth-free local equipotential bonding (refer Regulations 703.410.3.5 and 710.410.3.6.



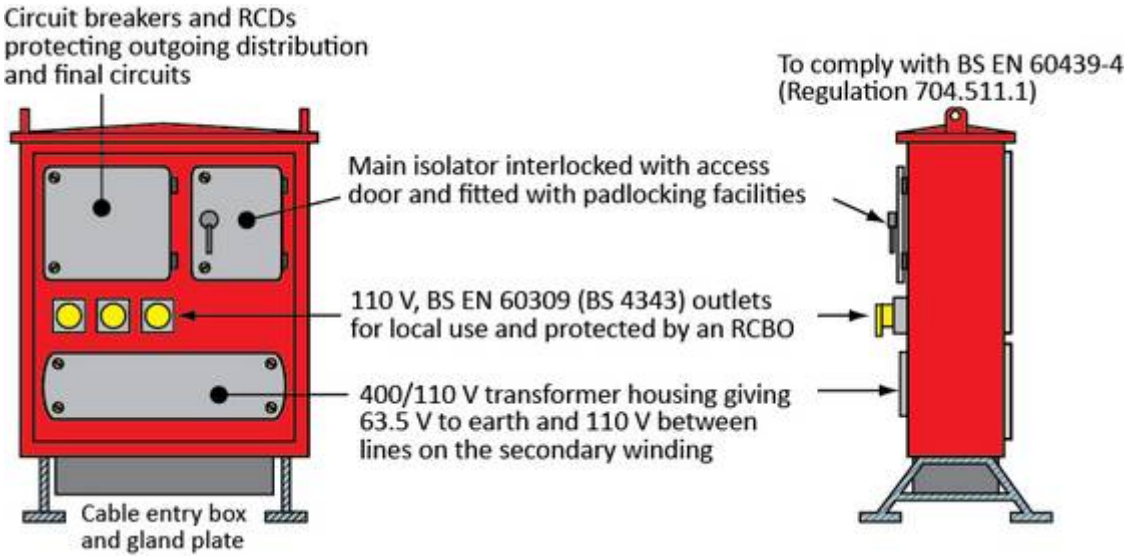
Installed equipment must have an IP rating of at least IPX4 and where cleaning is by jets then IPX5. Additionally, Regulation 703.512.2 details the requirements for equipment installed in each zone, in particular zone 1 and zone 3.

Construction and demolition site installations (Section 704)

Section 704 relates to the particular requirements for temporary installations for construction and demolition sites, during the period of construction or demolition. It does not relate to site offices; cloakrooms, meeting rooms, canteens etc (refer Regulation 704.1.1(vii).



It should also be noted that this Section should be read in conjunction with BS 7375: 1996 Code of practice for Distribution of electricity on construction and building sites.



Session 21 special locations; Bathrooms, Swimming pools, saunas etc

1. Electrical equipment installed in Zone 1 of a swimming pool must have a minimum degree of protection in accordance with
   a) IPX8
   b) IP4X
   c) IP2X
   d) IPX4

2. Construction site regulations apply to
   a) all site offices
   b) earthworks
   c) site canteens
   d) site toilets

3. Electrical equipment installed above a swimming pool diving board should not be fixed at a height less than
   a) 1.5 m
   b) 2.0 m
   c) 2.5 m
   d) 3.0 m

4. Equipment fitted in Zone 1 of a bathroom must
   a) be rated at a voltage not exceeding 12 V
   b) have a minimum IP rating of IPX5
   c) have a minimum IP rating of IPX4
   d) be fed from a plug and socket-outlet

5. Which one of the following may be installed inside Zone 1 of a hot air sauna?
   a) A ceiling mounted cord operated light switch
   b) A shaver socket to BS 3535
   c) A thermostat attached to the side of the sauna
   d) Any equipment to IP2X

6. In a swimming pool which of the following protective measures is **not** applicable to equipment installed in Zone 2?
   a) Protection by earth free local equipotential bonding
   b) Individual protection by electrical separation
   c) SELV
   d) Protection by an RCD in accordance with regulation 415.1.1

7. Which one of the following classifications of external influences would be appropriate for an item electrical equipment installed where it would be subject to “splashes of water”?
   a) AB
   b) BC1
   c) AD4
   d) AG1

8. In a location that contains a shower cubicle (other than a bathroom or shower room), a 13 A socket-outlet to BS 1363, backed up by an RCD, must be sited
   a) 0.6 m from the shower cubicle
   b) 3.0 m from the shower cubicle
   c) outside Zone 2
   d) in a safe area outside the location

9. An electric heater embedded in the floor of a bathroom should be
   a) supplied from an autotransformer
   b) covered with at least 50 mm of screed
   c) surrounded with thermal insulating material
   d) covered with an earthed metallic grid

10. In a bathroom where the space under the bath is accessible without the use of a tool, this space is classified as Zone
   a) 0
   b) 1
   c) 2
   d) 3

22: Regulatory requirements – special locations

In this session the student will:

- understand the principle regulations that apply to special locations

Agricultural and horticultural premises (Section 705)

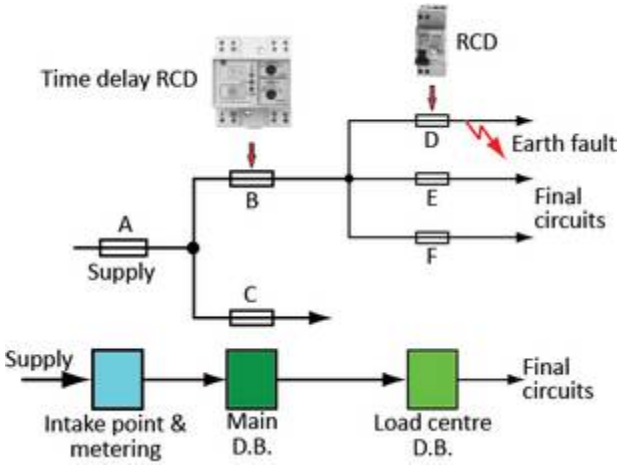
We have now moved on to Section 705, agricultural and horticultural premises.

This Section covers indoor and outdoor installations in agricultural and horticultural premises, but not houses, which are covered by the general requirements of BS 7671.

Extra care must be taken due to the increased risk for animals, and the variations in temperature, humidity and moisture. In addition, thought needs to be applied when considering rats etc.

Regulation 705.411.1 details the general requirements for the use of RCDs. Three specific aspects are considered:

- final circuits supplying socket-outlets with a rated current not exceeding 32 A should be protected by an RCD having a rated residual operating current of not greater than 30 mA
- final circuits supplying socket-outlets exceeding 32 A should be protected by an RCD having a rated residual operating current of not greater than 100 mA
- all other circuits should be protected by an RCD having a rated residual operating current of not greater than 300 mA.



The need to make use of a number of RCDs may lead to problems of discrimination. This may lead to a requirement for time delay RCDs etc.

Supplementary equipotential bonding is required in locations intended for livestock.

This supplementary bonding should connect all extraneous-conductive-parts and exposed-conductive-parts that can be touched by livestock, including the metal grid in the floor.

For the purpose of protection against fire Regulation Group 705.422 requires electrical heating appliances to comply with BS EN 60335-2-71 and that radiant heater are sited at least 0.5 m from livestock or combustible material. Additionally, an RCD having a rated residual operating current not exceeding 300 mA must be installed which will disconnect all live conductors. This means for a single-phase supply a double-pole device needs to be installed.

All electrical equipment must have a minimum degree of protection of IP44, and where this is not possible it must be installed in an enclosure with minimum protection of IP44. The designer must also account for all other external influences that exist (refer Regulation 705.512.3).

The requirement for documentation has increased since *BS 7671: 2001*. Specifically, the following documentation must be provided to the user of the installation:

- a plan indicating the location of all electrical equipment.
- the routing of all concealed cables.
- a single-line distribution diagram.
- an equipotential bonding diagram indicating locations of bonding conductors.

Regulation Group 705.52 details the requirements for wiring systems. In particular, wiring systems should be installed at a height that is inaccessible to livestock and, where vehicles are likely to be present; cables should be buried at a minimum depth of 0.6 m and have additional mechanical protection. Where cables are installed under arable (ploughed) ground then the minimum depth should be 1 m. In addition, Regulation 705.522.10 requires that special thought is given to the problems of fauna, such as rats and mice.

Regulation Group 705.537 details the requirements for isolation and switching.

Regulation Group 705.544 details the additional protection to be provided for supplementary bonding conductors. This is due to the increased mechanical and corrosive properties that exist in such locations.

Regulation Group705.55 details the requirements for socket-outlets and luminaire and lighting installations.

Regulation Group 705.56 details the requirements for the automatic life support for high density livestock rearing, such as might occur in poultry farms and the like. Notice particularly the requirement for strict discrimination under earth fault and short-circuit conditions for circuits supplying the ventilation.

Now move on and look at restrictive conductive locations.

Conducting locations with restricted movement (Section 706)

We are dealing here with an installation where movement for the operative is restricted and where he or she is surrounded by conductive material. You could be working inside a shaft or ducting.

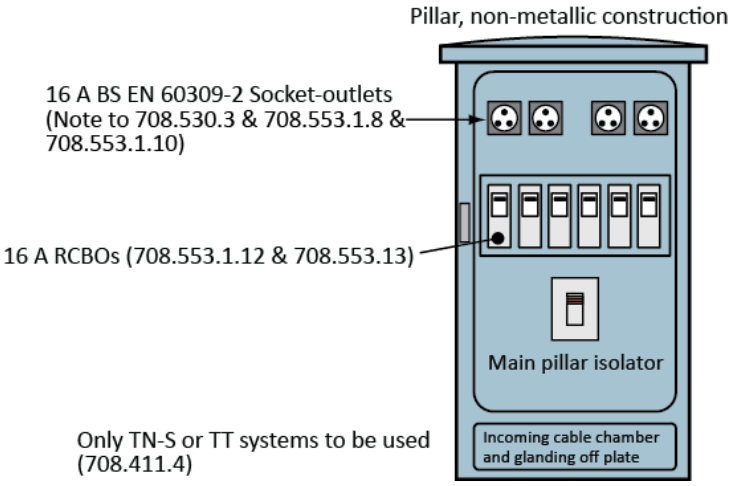
Care has to be taken. The person working there cannot pull away from the area with ease and therefore the degree of risk increases.

For protection against electric shock, Regulation 706.410.3.10 details the requirements for three types of equipment:

- hand-held tools or an item of mobile equipment - supplied only via SELV or electrical separation
- handlamps - supplied only by SELV
- supplies to fixed equipment - supplied by ADS with additional protection by supplementary equipotential bonding, or Class II equipment having additional protection by an RCD, or electrical separation, or SELV, or PELV.

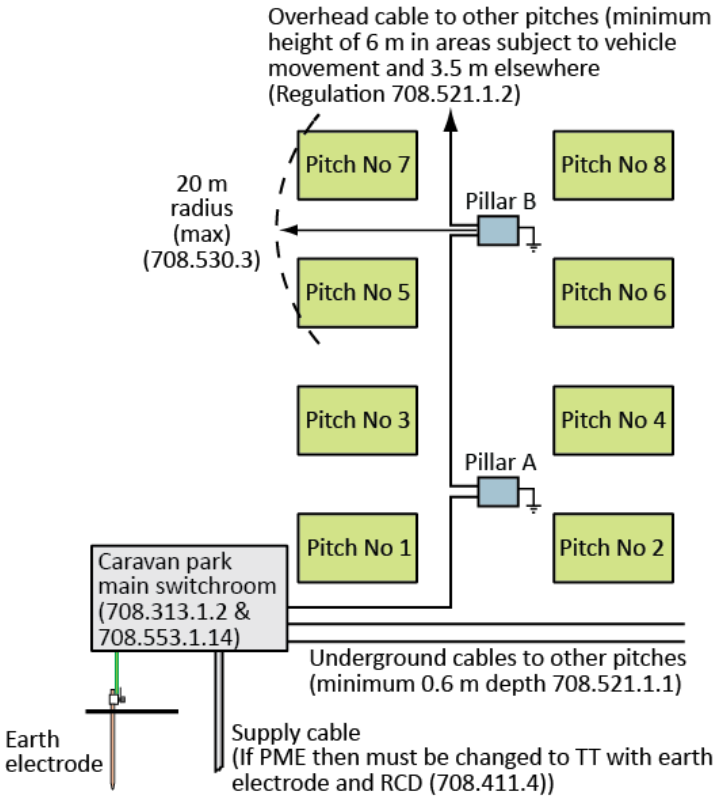
Electrical installations in caravan/camping parks and similar locations (Section 708)

Section 708 details the requirements for those places where caravans and the like park. It does not detail the requirements for caravans themselves, which is dealt with in Section 721.



The figure here details some of the specific requirements for a pitch supply. Consider very carefully Regulation Group 708.55.

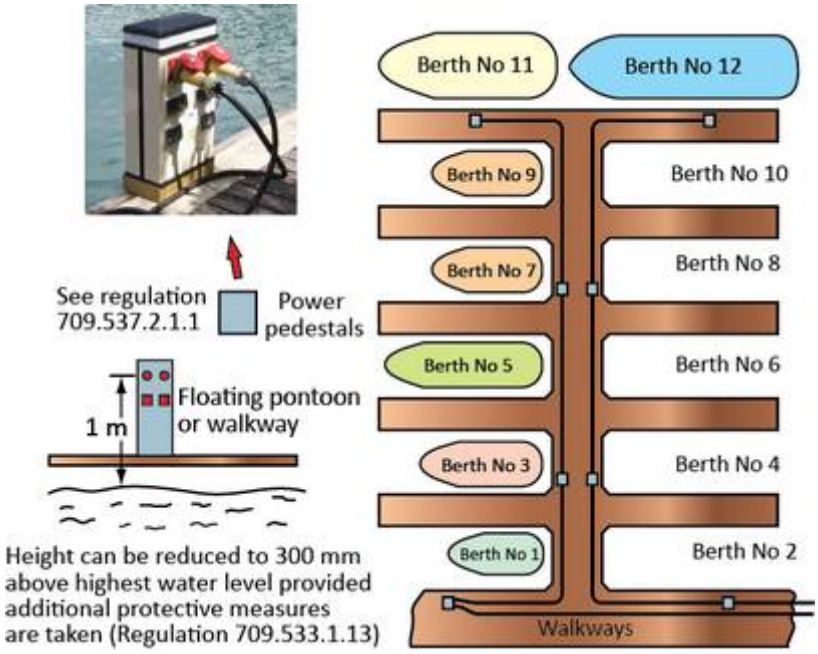
The figure here details many of the requirements for the supplies on a caravan or camping site.



Marinas and similar locations (Section 709)

This section details the requirements for circuits supplying pleasure craft or houseboats in marinas and similar locations.

Many of the basic requirements of the supply are similar to that required for caravan site supplies. Voltage levels are set at 230 V/400 V and there is a need to avoid the use of a TN-C-S system (Regulation 709.411.4 refers).



The particular external influences are obvious, and include the presence of water, a reduction in the body resistance of an individual, a corrosive atmosphere, the presence of flammable fuel and the contact of an individual with Earth potential.

The types of wiring system that are considered suitable are listed in Regulation 709.521.1.4, and include:

- underground cables
- overhead cables
- thermoplastic insulated and sheathed cables installed in pvc or steel conduit or trunking
- pvc sheathed MI cable
- armoured cables.

Regulation 709.521.1.5 details those wiring systems that are not to be used, which include:

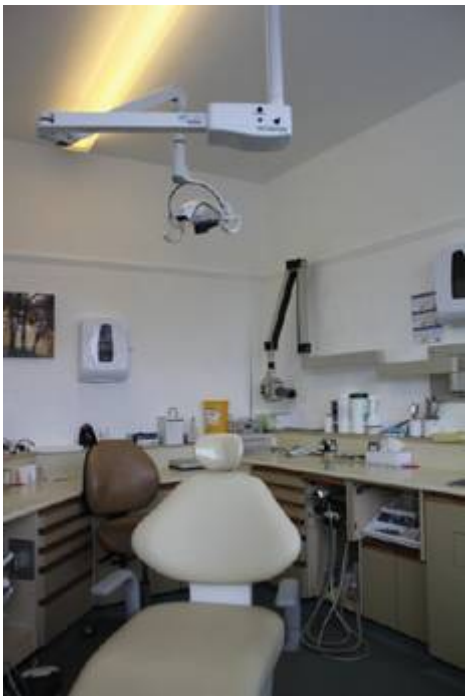
- cables in free air suspended from or incorporating catenary wire
- non-sheathed cables installed in conduit or trunking
- cables with aluminium conductors
- non-sheathed MI cables.

All socket-outlets must be protected by an RCD, and must comply with BS EN 60309-1 for current ratings greater than 63 A or BS EN 60309-2 for current ratings up to 63 A.

The minimum IP rating of every socket-outlet should be a minimum of IP44, but may need to be increased to IPX5 or IPX6 where appropriate. An instruction notice must also be positioned in a marina as required by Note 2 attached to Regulation 709.553.1.13.

Medical locations (Section 710)

This is another new section within BS 7671:2008 (2011) and covers the specific requirements for installations within medical locations.

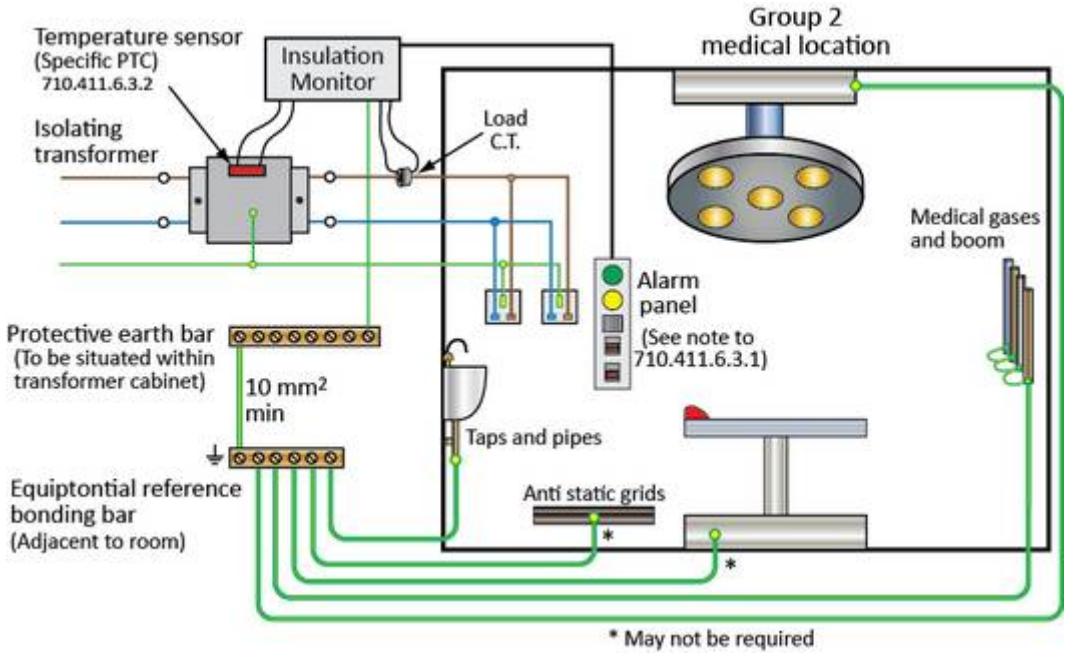


Annex A710 of Section 710 details a list of examples of typical medical locations and their associated Group and Class.

A designer must, in discussion with the client, decide on the Group and Class of the medical location as part of the assessment of general characteristics (Regulation 710.3 refers).

The nature of medical locations is such that there is an increased risk to patients from electricity. This may be due in part to their reduced ability to withstand electric shock and also to their decreased body resistance due to certain medical procedures and the like.

However, it is also essential in certain medical locations that power is not lost under almost any circumstances. For example, it would be catastrophic for a supply to fail in the middle of a difficult operation.



The requirements for fault protection acknowledge this twofold aspect. For example, Regulation 710.411.3.2.1 requires care to be taken to ensure that unwanted operation of an RCD does not lead to necessary equipment failing. Indeed, where the medical location falls under the Group 2 category, RCDs are to be used only for certain circuits (Regulation 710.411.4 refers). Regulation 710.531.2.4 also expects the designer to take into account those circuits having excessive protective conductor currents and the effect they may have on the unwanted operation of RCDs.

Regulation 710.411.3.2.5 limits the touch voltage that may appear for TT, TN and IT earthing systems to not more than 25 V a.c. Furthermore, the maximum disconnection times for protective devices is further reduced from that required by Table 41.1 of the Standard.

Final circuits supplying equipment intended for life support and the like in Group 2 medical locations should have an IT earthing system (refer Regulation 710.411.6.3.1).

Supplementary equipotential bonding should be installed for all Group 1 and Group 2 medical locations. This bonding should not be installed in a loop but each leg should be run back to an equipotential bonding busbar (refer Regulation 710.415.2.1 and Fig. 73.12).

Exercise 22 Special locations; Farms, caravan parks, medical etc

1. In agricultural premises, heating appliances shall be fixed so as to maintain an appropriate distance from the livestock. In the absence of manufacturers guidance, a radiant heater used in the vicinity of livestock should be placed at a distance not less than
   a) 0.5 m
   b) 1.5 m
   c) 2.0 m
   d) 2.5 m

2. The socket-outlet and its enclosure, forming part of a pitch supply equipment for a caravan park, must comply with BS EN 60309-2 and have a minimum index protection
   a) IP40
   b) IP55
   c) IP54
   d) IP44

3. In agricultural premises, an RCD may be used for protection against fire providing the operating current does not exceed
   a) 30 mA
   b) 100 mA
   c) 300 mA
   d) 500 mA

4. For all caravans using a mains electricity supply, an instruction notice must be fixed
   a) at or near the distribution point
   b) under the cover of the caravan electricity inlet box
   c) near the main electrical isolating switch inside the caravan
   d) inside the main door of the caravan

5. In a conduit system on an agricultural installation where livestock are kept, the external influence shall be classified as
   a) AF4
   b) AG3
   c) AF3
   d) AG1

6. Where socket-outlets are used in a caravan park, each socket-outlet forming part of the caravan pitch supply equipment shall be individually
   a) protected by an overcurrent device
   b) marked to indicate the voltage
   c) colour coded for identification
   d) supplied from a consumer unit

7. In a caravan park, the maximum socket-outlets which can be protected by an RCD
   a) 2
   b) 3
   c) 6
   d) 1

8. In a medical location which has been categorised as group 1, the disconnection time for a 400 V a.c. circuit supplied from TN-S system is
   a) 0.05 s
   b) 0.3 s
   c) 0.5 s
   d) 0.06 s

9. In a marina, every socket-outlet shall be located
   a) as near as possible to the berth and in an enclosure
   b) on a steel wired flexible cable for ease of use
   c) at least 0.5 m above the water level
   d) in a locked steel cabinet with the key held by the harbour master

10. If no additional protective measures are taken, socket-outlets for use in marinas shall be mounted at a height not less than
    a) 1 m above the highest water level
    b) 600 mm on a wooden pontoon
    c) 300 mm on a flexible raft
    d) 1 m above the mean water level

23: Regulatory requirements – special locations

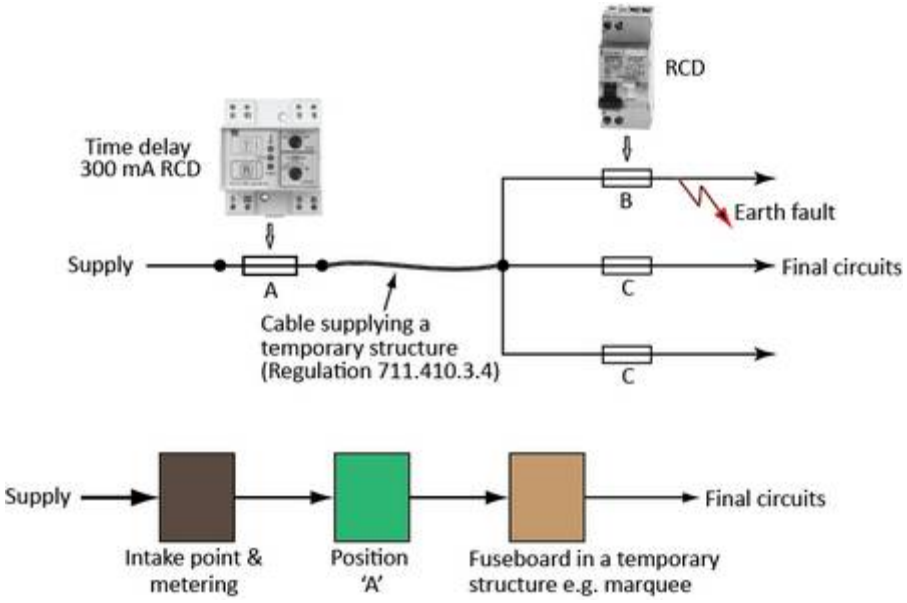
In this session the student will:

- understand the principle regulations that apply to special locations

Exhibition shows and stands (Section 711)

This section details the requirements for temporary electrical installation in exhibitions, shows and stands (including portable and mobile displays and equipment). Section 711 does not apply to fixed installations.

As with caravan sites and marinas a TN-C-S system is not permitted to be used except where the installation is under the continuous supervision of a skilled or instructed person and the suitability and effectiveness of the means of earthing has been confirmed prior to any connection being made. Generally however, only TT or TN-S systems are appropriate (refer Regulation 711.411.4).



A cable that is used to supply a temporary structure must be protected at its origin by an RCD having a rated residual operating current not exceeding 300 mA and be of a time delay type to ensure discrimination with downstream RCDs providing protection on final circuits.

The current rating of all socket-outlets circuits not exceeding 32 A and all final circuits other than for emergency lighting must be protected by a 30 mA RCD in accordance with Regulation 415.1.1.

Regulation 711.422.4.2 details the requirements for protection against fire. Particular thought should be given to the positioning of incandescent lamps and the like, where there are high temperature surfaces.

Regulation Group 711.5 details the requirements for the selection and erection of equipment. Wiring systems should be of armoured cable where there is a risk of mechanical damage (Regulation 711.52 refers) and all cables should have a minimum cross-sectional area of 1.5 mm^2 (Regulation 711.521 refers).

Where there is no fire alarm system, Regulation 711.521 requires that specific cable types are used, which include amongst others cables which are flame retardant to BS EN 60331-1-2.

Joints in cables should be avoided where practicable, however where they are made then they should use connectors complying with a relevant standard or in an enclosure to IP4X or IPXXD.

Isolation is required for every individual temporary structure, and each means of isolation should be readily accessible and appropriately identified (refer regulation 711.537.2).

Regulation Group 711.55 details the requirements for electric motors, ELV transformers, socket-outlets, luminaires and other lighting installations and inspection and testing.

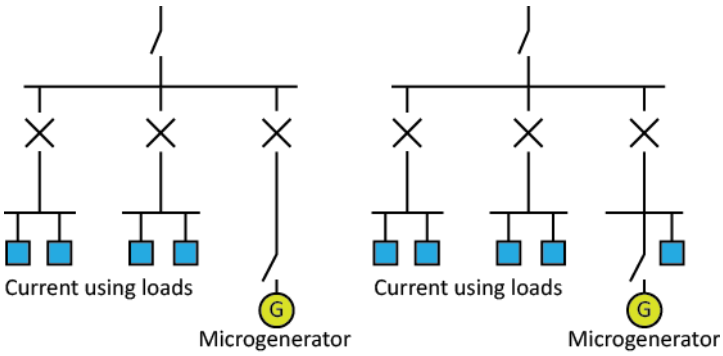
Solar photovoltaic (pv) power supply systems (Section 712)

The Electrical Safety Council has produced a Best Practice Guide on connecting a microgeneration system to a domestic or similar electrical installation, which can be found at http://www.esc.org.uk/industry/industry-guidance/best-practice-guides/.

Section 712 of BS 7671 details the specific requirements for solar photovoltaic (pv) power supply systems.

The designer should recognise that a PV system is a means of generation and as such is a live source in the same way that a normal supply is a live source.

The type of earthing arrangement may consist of at least one live conductor of the d.c. source being earthed if there is simple separation between the a.c. side and the d.c. side.

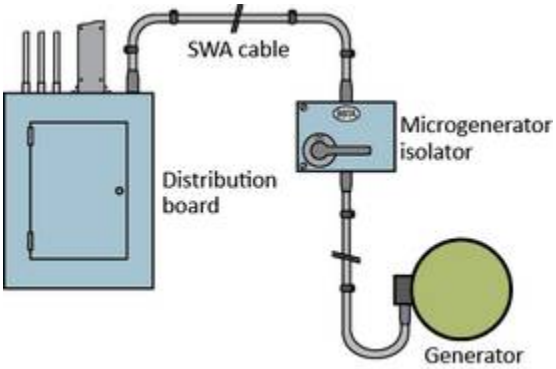


The figure here details two possible means of connecting a microgenerator to a dedicated circuit and to an existing final circuit.

Regulation 712.411.3.2.1.2 requires that where a PV supply does not have even simple separation between the a.c. and d.c. side then a Type B RCD to IEC 60755 Amendment 2 is installed. Generally double or reinforced insulation is preferred on the d.c. side.

Regulation Group 712.5 details the requirements for the selection and erection of equipment. PV module must comply with the requirements of the relevant standards such as BS EN 61215.

The PV string cables, array cables and d.c. main cables must be selected and erected to minimise the risk of earth faults and short-circuits. This may be achieved by reinforcing the cables by sheathing. External influences must be taken account of such as; wind, rain, ice and solar radiation.



Regulation Group 712.53 details the requirements for isolation and switching. The diagram shows an example of how a micro-generation system might be connected.

Mobile or transportable units (Section 717)

Mobile or transportable units include a vehicle and/or mobile or transportable structure in which all or part of an electrical installation is contained, which is provided with a temporary supply by means of, for example, a plug and socket-outlet. Examples of such units might include mobile trailers for displays in schools etc.

Section 717 details the particular requirements for mobile or transportable units.

The circuit supplying the unit must be protected by means of an RCD. This RCD does not have to be rated at 30 mA (Regulation 717.411.1 refers).

Protective equipotential bonding must be made via a finely stranded conductor and accessible conductive parts of the unit must be connected to the MET within the unit (Regulation 717.411.3.1.2 refers).

Careful thought needs to be given to the earthing system. A TN-C-S system is not permitted unless the installation is under the constant supervision of a skilled or instructed person, and the suitability and effectiveness of the means of earthing has been confirmed.

BS 7671 details examples of connections to mobile or transportable units in Figs 717.1 through 717.4.

Every socket-outlet, other than those supplied from circuits protected by means of SELV, PELV or electrical separation, must have additional protection by means of an RCD in accordance with Regulation 415.1.1. There must be a notice detailing:

i) the type of supply which may be connected to the unit
ii) the voltage rating of the unit
iii) the number of supplies, phases and their configuration
iv) the on-board earthing arrangements
v) the maximum power requirement of the unit.

Wiring systems are covered by Regulation Group 717.52.

To connect the unit to the supply, flexible cables in accordance with H07RN-F (BS 7919), or equivalent, having a minimum cross-sectional area of 2.5 mm^2 must be used.

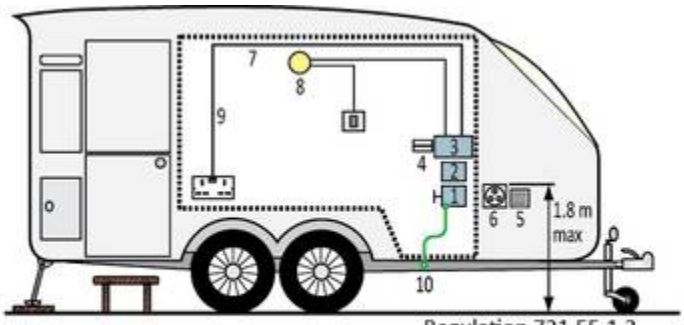
The internal wiring of the unit may be carried out with typical cables, such as thermoplastic insulated and sheathed (BS 6004), as long as measures are taken to avoid damage caused by sharp edges etc.

Wiring systems and electrical equipment should not be installed in locations that are likely to store gas cylinders, except for ELV equipment for gas supply control.

The connection to the unit must be made via a BS EN 60309-2 plug and socket-outlet. In addition plugs must be enclosed in insulating material, have a degree of protection of IP44 if located outside, and the plug part shall be situated in the unit.

Electrical installations in caravans and motor caravans (Section 721)

Section 721 details the particular requirements for caravans and motor caravans but not caravan sites, which are dealt with in Section 708 (refer Electrical installations in caravan/camping parks and similar locations), or the automotive aspects.



Regulation 721.55.1.2

Legend

Description		Regulation
1	D.P. main isolating switch	721.537.2.1.1
2	RCD (30 mA) and capable of interrupting all live conductors	721.411.1
3	Overcurrent protective devices	721.43.1
4	Periodic inspection and test notices	721.514.1 & Fig 721
5	Power inlet notice	721.514.1 & Fig 721
6	Power inlet (16 A 2-pole&E)	721.55.1.1
7	Cables supported correctly	721.522.7.1 & 721.522.8.1.3
8	Luminaire fixed to directly to lining or structure	721.55.2.4
9	Cable run to socket outlet	721.55.2.1 & 721.55.2.2
10	Main bonding conductor to chassis	721.411.3.1.2
	In general, all cables to meet the requirements of BS EN 60331-1-2	721.521.2

The figure here shows the installation in a typical caravan. The regulations that relate to each aspect are shown alongside.

Regulation 721.524.1 requires that every conductor must have a cross-sectional area of at least 1.5mm^2.

Regulation 721.543.2.3 requires that all protective conductors are incorporated in a multicore cable or in conduit together with the live conductors. This implies that they cannot be run independently.

The length and cross-sectional area (csa) of the cable used to connect the caravan to the pitch supply is stated in Regulation 721.55.2.6. The length of cable should be between 23-27m long and the csa must comply with Table 721.

Complete the table below.

Rated current A	Minimum cross-sectional area mm^2
16	
25	
32	
63	
100	

It should be stressed once again that a TN-C-S earthing system is not permitted to be used to supply a caravan. This is a requirement of legislation.

Annex A of BS 7671 provides guidance for extra low voltage d.c. installations. These requirements are in addition to those required by Section 721.

Operating and maintenance gangways (Section 729)

Section 729 is a new Section within the Standard. This section applies to the operation or maintenance of switchgear and control gear within areas, including gangways, where access is restricted to skilled or instructed persons (Regulation 729.1 refers).

The section details the specific distances that are required where protection is provided by barriers and/or enclosures (refer Regulation 729.513.2.1 refers), obstacles (Regulation 729.513.2.2 refers) and access to gangways (Regulation 729.513.2.3 refers).

Temporary electrical installations for structures, amusement devices and booths at fairgrounds, amusement parks and circuses (Section 740)

In many ways Section 740 is similar to Section 711 that dealt with exhibitions stands etc. This section details the requirements for electrical installations at fairgrounds and the like.

The risks are associated with wind, rain, solar radiations and the like, as well as the many visitors that will attend such events.

Supplies to stands etc are not to exceed 230 V/400 V a.c. or 440 V d.c. On large fairground sites it may be the case that there are a number of public supplies. These supplies must not be interconnected at stands etc (refer Regulation 740.313.3).

A TN-C-S is not permitted to be used, therefore only TT or TN-S systems are appropriate (refer Regulation 740.411.4.1).

A cable that is used to supply a temporary structure must be protected at its origin by an RCD having a rated residual operating current not exceeding 300 mA and be of a time delay type to ensure discrimination with downstream RCDs providing protection on final circuits (Regulation 740.410.3 refers).

All socket-outlet circuits not exceeding 32 A and all final circuits other than for circuits protected by SELV, PELV or electrical separation, or lighting circuits placed out of reach and not supplied from a socket-outlet, must be protected by a 30 mA RCD in accordance with Regulation 415.1.1 (Regulation 740.415.1 refers).

Where livestock are present, for example in certain circuses, supplementary equipotential bonding shall connect exposed-conductive-parts and extraneous-conductive-parts which can be touched by the livestock. This includes any metal grid in the floor (Regulation 740.415.2.1 refers).

Regulation 740.422.3 requires that a motor that is not continuously supervised must be fitted with a manually reset protective device against excessive temperature. Additionally, where there is a fire risk from a luminaire or floodlight, Regulation 740.55.1.5 requires that they are set up in such a way that they are unlikely to cause ignition of material.

Regulation Group 740.5 details the requirements for the selection and erection of equipment. Wiring systems should be of armoured cable where there is a risk of mechanical damage (Regulation 740.521.1 refers).

Joints in cables should be avoided where practicable, however where they are made then they should use connectors complying with a relevant standard or in an enclosure to IP4X or IPXXD.

All booths, stands and amusement devices must have its own means of isolation, which should be readily accessible and properly identified (refer Regulations 740.537.1 and 740.537.2.1.1). All isolation devices must disconnect all live conductors: two-pole for single-phase supplies and four-pole for three-phase supplies (refer Regulation 740.537.2.2).

Regulation Group 740.55 details the requirements for electric dodgems, ELV transformers, socket-outlets, luminaires and other lighting installations and inspection and testing.

It is worth highlighting the particular issues that relate to luminaires. Luminaires should have appropriate IP ratings and installed in such a way that the supply cable is not used to support them, unless that is what they are designed for.

Lamps in shooting galleries should be suitably protected against accidental damage!

A separate circuit supplying luminous tubes, signs or lamps must be controlled by an emergency switch. This switch must be easily accessible and marked in accordance with the requirements of the local authority.

An adequate number of socket-outlets must be installed for the user's requirements to be met safely. The note to Regulation 740.55.7 suggests one socket-outlet per square metre is appropriate for a stand or booth.

Dodgems must not be supplied at a voltage in excess of extra-low voltage and the circuit must be electrically separate from the mains supply by means of a transformer complying with BS EN 61558-2-4.

The electrical installation between its origin and any electrical equipment must be inspected and tested after each assembly on site. This does not include the internal wiring of the ride.

Floor and ceiling heating systems (Section 753)

Heating conductors and cables on page 156 has already covered much of the requirements of Section 753.

Section 753 details the requirements for electric floor and ceiling heating systems. It does not apply to external systems or systems installed in walls.

RCDs having a rated residual operating current not exceeding 30 mA must be installed to be used as disconnecting devices. Where there are no exposed-conductive-parts on the equipment, a grid must be provided on site above the floor heating elements or under the ceiling heating elements. To reduce the risk of unwanted operation of the RCD due to capacitance, limiting the rated heating power to 7.5 kW for 230 V supplies or 13 kW for 400 V supplies may be used. However, guidance from the manufacturer should be sought.

Heating units in ceilings must have an IP rating of not less than IPX1. Heating units in floors constructed with concrete or similar material must have an IP rating not less than IPX7.

Exercise 23 Special locations; Exhibitions, Solar, Amusements etc

1. Floor and heating systems in section753 apply to
   a) outdoor use
   b) wall fittings
   c) thermal storage or direct heating systems
   d) night storage heaters

2. To avoid overheating of a floor heating system in buildings, the temperature should be limited to
   a) 80° C
   b) 20° C
   c) 10° C
   d) 100° C

3. When installing heating units, there shall be heat free areas, what is the purpose of these?
   a) To prevent the unit overheating
   b) To allow nails or fixing devices to be safely used
   c) To allow the unit to be serviced whilst in use
   d) To allow rugs and carpets to placed in these spots

4. Section 721 applies to
   a) caravans used as homes
   b) caravan parks
   c) installations in caravans and motor homes
   d) transportable units

5. In caravans and motor homes the nominal voltage should not exceed
   a) 110/230 V a.c., 12 V d.c.
   b) 12/24 V d.c., 50 V a.c.
   c) 55/110 V a.c., 12/24 V d.c.
   d) 230/400 V a.c., 48 V d.c.

6. In a caravan, structural metallic parts which are accessible from within the caravan, shall be connected through the main protective bonding conductor to
   a) an earthing electrode adjacent to the caravan
   b) the main earthing terminal within the caravan
   c) the hook-up point via the plug and socket
   d) a crocodile clip at the end of a flexible lead from the consumer unit

7. PV equipment on the d.c. side shall be considered to energised even when the system is disconnected from
   a) the battery
   b) the a.c. side
   c) the d.c. inverter
   d) the isolation switch

8. Overload protection may be omitted to the PV main cable when the continuous current carrying capacity of the cable is equal to or greater than
   a) 1.25 times the short-circuit current of the PV generator
   b) 1.25 times the d.c. load current of the PV array
   c) the full-load current of the PV generator
   d) 120 V d.c. divided by the resistance of the PV array

9. Which of the following will apply to gangways having a restricted access?
   a) They should be marked with signs giving dimensions
   b) No unauthorised persons allowed unless accompanied
   c) Gangways must allow for easy evacuation at all times
   d) Doors must allow easy evacuation without the use of a key

10. The width of gangways shall be
   a) single person width
   b) wide enough for emergency evacuation
   c) wide enough for vehicular access
   d) wide enough for wheelchair users

11. Over what length must gangways be accessible from both ends?
   a) 10 m
   b) 15 m
   c) 2 m
   d) 5 m

12. The nominal voltage of temporary electrical installations in booths, stands and amusement devices shall not exceed
   a) 230 V a.c., 12 V d.c.
   b) 230 V a.c., 440 V d.c.
   c) 110 V a.c., 24 V d.c.
   d) 55 V a.c., 120 V d.c.

13. Switch gear and control gear on fairgrounds etc shall be accessible by
    a) emergency personnel only
    b) ordinary persons
    c) a key or authorised persons
    d) the ride/stand operator

14. Joints made as a connection into a circuit on an amusement park or fairground must be made into a connection with a degree of protection of at least
    a) IP2XA or IP4X
    b) IPXXD or IP4X
    c) IP54D or IP8X
    d) IPXXC or IP2X

15. The electrical installation on a fairground or similar shall be tested and inspected
    a) after each day
    b) after each ride/use
    c) after each assembly on site
    d) after each season

24: Statutory & Regulatory requirements – special locations

In this session the student will:

- understand the principle regulations that apply to special locations

This part of the outcome encourages us to look at Appendix 2 section 5.

In particular you need to be aware of the following Statutory Regulations:

(i) Electricity at Work Regulations 1989

(ii) Dangerous Substances and Explosive Atmospheres Regulations 2002

(iii) The Petroleum Act 1928

(iv) The Equipment and Protective Systems intended for use in Potentially Explosive Atmospheres Regulations 1996

Electricity at Work Regulations 1989

Electricity is a major hazard - not only can it kill directly, through shocks, it can also cause fires and explosions.

These regulations aim to impose duties to limit the risks involved in using electricity at work.

Definitions

Electrical equipment includes anything used, intended to be used or installed for use, to generate, provide, transmit, transform, rectify, convert, conduct, distribute, control, store, measure or use electrical energy.

This definition is extremely wide and includes everything from very high voltage overhead supply cables to battery-powered equipment.

System covers all and any electrical equipment which is, or may be, connected to an electrical energy source, and includes that source.

Danger means risk of injury.

Injury covers death or personal injury from electric shock, electric burn, electrical explosion or arcing, or from fire or explosion initiated by electrical energy, where any such death or injury is associated with the generation, provision, transmission, transformation, rectification, conversion, conduction, distribution, control, storage, measurement or use of electrical energy.

Regulation 3 places duties on:

- Employers, employees and the self-employed - to comply with the regulations as far as matters are under their control
- Employees -to co-operate with their employer

Regulation 6 requires all electrical equipment that may be exposed to:

- mechanical damage
- the effects of the weather, natural hazards temperature or pressure
- the effects of wet, dirty, dusty or corrosive conditions
- flammable or explosive substances including dusts, vapours or gases

Must be constructed or protected so that danger doesn't arise.

Regulation 16 requires that anyone working on electrical systems where technical knowledge or experience is necessary must have the required knowledge and/or experience or be under suitable supervision.

Defence

Any person who has a duty under regulations 4(4), 5 and 8-16 can, in any criminal proceedings, use the defence that they had taken all reasonable steps and exercised all due diligence to avoid the offence.

Dangerous Substances and Explosive Atmospheres Regulations 2002. (DSEAR)

Dangerous substances can put peoples' safety at risk from fire and explosion. DSEAR puts duties on employers and the self-employed to protect people from risks to their safety from fires, explosions and similar events in the workplace, this includes members of the public who may be put at risk by work activity.

What are dangerous substances?

Dangerous substances are any substances used or present at work that could, if not properly controlled, cause harm to people as a result of a fire or explosion. They can be found in nearly all workplaces and include such things as solvents, paints, varnishes, flammable gases, such as liquid petroleum gas (LPG), dusts from machining and sanding operations and dusts from foodstuffs.

Ignition sources

Ignition sources may be; flames, cigarettes, matches, cutting and welding flames, hot surfaces, mechanical machinery, friction or sparks, sparks from electrical equipment, electrostatic discharge, impact sparks, electrical equipment, lights etc.

Controlling sources of ignition

Ignition sources can be controlled in a number of ways;

- prohibition of smoking/use of matches
- Using only equipment classified for the zone
- Correct earthing of all plant and equipment
- Control of maintenance

The key requirements in DSEAR are that risks from dangerous substances are assessed and eliminated or reduced.

DSEAR defines;

A dangerous substance as

- a substance or preparation which is explosive, oxidising, extremely flammable, highly flammable or flammable,
- a substance or preparation which because of its chemical properties and the way it is used or is present at the workplace creates a risk
- any dust, whether in the form of solid particles or fibrous materials or otherwise, which can form an explosive mixture with air or an explosive atmosphere

"Explosive atmosphere"

- a mixture, under atmospheric conditions, of air and one or more dangerous substances in the form of gases, vapours, mists or dusts in which, after ignition has occurred, combustion spreads to the entire unburned mixture;

"Hazard"

- the chemical property of a dangerous substance which has the potential to give rise to fire, explosion, or other events which can result in harmful physical effects of a kind similar to those which can be caused by fire or explosion, affecting the safety of a person

"Risk"

- the likelihood of a person's safety being affected by harmful physical effects being caused to him from fire, explosion or other events arising from the hazardous properties of a dangerous substance in connection with work and also the extent of that harm*;*

"Work processes"

- means all technical aspects of work involving dangerous substances

Classification of hazardous places

Hazardous places are classified in terms of zones on the basis of the frequency and duration of the occurrence of an explosive atmosphere.

Zone 0

A place in which an explosive atmosphere consisting of a mixture with air of dangerous substances in the form of gas, vapour or mist is present continuously or for long periods or frequently.

Zone 1

A place in which an explosive atmosphere consisting of a mixture with air of dangerous substances in the form of gas, vapour or mist is likely to occur in normal operation occasionally.

Zone 2

A place in which an explosive atmosphere consisting of a mixture with air of dangerous substances in the form of gas, vapour or mist is not likely to occur in normal operation but, if it does occur, will persist for a short period only.

Health and Safety Executive state a Warning sign should be in place where explosive atmospheres may occur

Selection of equipment

The Equipment and Protective Systems for Use in Potentially Explosive Atmosphere Regulations

The general requirements of equipment are;

- Equipment must be so designed and constructed that sources of ignition do not become active, even in the event of rare incidents relating to equipment.
- Equipment must be equipped with means of protection such that:
  - either, in the event of failure of one means of protection, at least an independent second means provides the requisite level of protection; or
  - the requisite level of protection is ensured in the event of two faults occurring independently of each other.
- Where necessary, this equipment must be equipped with additional special means of protection.
- It must remain functional with an explosive atmosphere present.
- Where necessary, equipment must be so constructed that no dust can penetrate it.

- The surface temperatures of equipment parts must be kept clearly below the ignition temperature of the foreseeable air/dust mixtures in order to prevent the ignition of suspended dust.

The correct selection of equipment for a hazardous area requires, the temperature class or ignition temperature of the gas or vapour involved i.e. T1, T2 etc, and the classification of the zone

The Petroleum Act 1928

The Petroleum Act requires anyone who keeps petrol to obtain a licence from the local Petroleum licensing Authority. These licenses vary from area to area.

Installations within petrol stations are covered by BS EN 60079

BS EN 60079

The IEC standard BS EN 60079 covers areas not included in BS 7671.

BS EN 60079 part 10 - Classification of hazardous areas

BS EN 60079 Part 14 - Electrical apparatus for explosive gas atmospheres

BS EN 60079 part 17 - Inspection /maintenance of electrical installations in hazardous areas

ATEX is a European directive which addresses safety, where there is a risk from potentially explosive atmospheres.

Segregation

Section 528 Proximity of wiring systems to other services

This section discusses voltage bands; there it is essential that we first have an understanding of what these Voltage Bands are.

These voltage bands are split into two parts:

Voltage band I

- Installations where protection against electric shock is provided under certain conditions by the value of voltage;
- Installations where the voltage is limited for operational reasons (telecommunications, signalling, bell circuits, control and alarm installations).

ELV is normally Band I.

Voltage band II

Contains the voltages for supplies to household and most commercial and industrial installations.

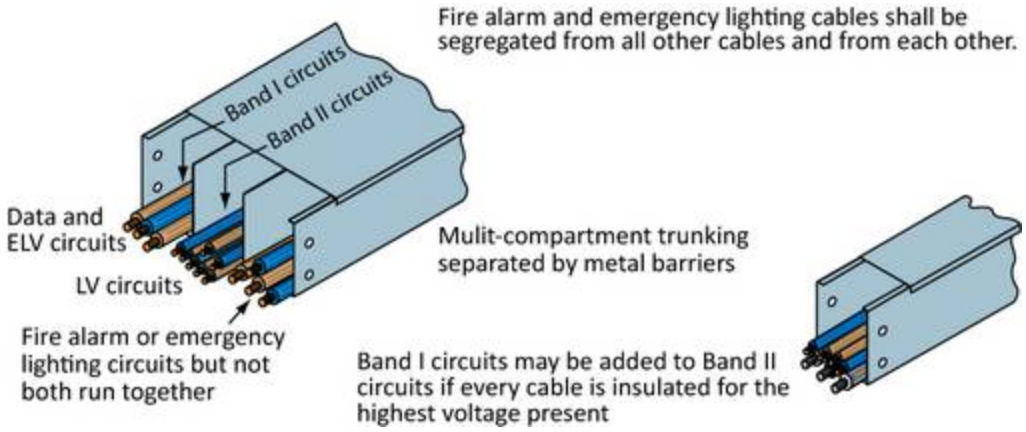
LV will normally be Band II.

Let us remind ourselves on what these voltages are. Complete the table below.

Voltage	d.c.(ripple free)		a.c.	
	Lowest	Highest	Lowest	Highest
Extra-low				
Low				

Circuits that fall into a variety of types or '***voltage bands***' have to be separated from each other.

A good example of how this can be achieved is by using multi-compartment trunking. Other options would be to install separate runs of conduit.



Group 528.1 deals with all aspects concerning the running of cables together. The general rules are to segregate voltage band I and II circuits unless the insulation value of the band II circuit is of the same value as the band I circuit. If you are using MICS cable for the fire alarm or emergency lighting circuits then you are able to get away without segregating, as the MIC sheath is adequate segregation. Have a look at the requirements of BS 7671.

Group 528.2 deals with the proximity of communication cables. There needs to be wide clearance given to power circuits where there is usually fluctuating loads, high transient inductances being created by the switching in and out of motor circuits and communication circuits, which could easily be subject to magnetic interference which is termed noise. There are times when communication circuits need to cross power circuits in multi-compartment trunking, when this happens, barriers have to be fitted to maintain the segregation.

Group 328.3 Proximity to non-electrical services

I believe this Group of Regulations need to be considered under the general heading of segregation as the electrician needs to bear in mind where he/she can install their wiring systems.

528.3.1 & 528.3.2 If there is likely to detrimental effects to your wiring system from non-electrical services that create smoke, heat etc, then suitable precautions need to be taken. This could be re-routing your cables in a different location or by effective screening. Move your system away from gas, steam lines and the like. However, this is generally solved for you at the design stage. If not, site liaisons with heating engineers will help.

528.3.3 & 528.3.4 Where it is unavoidable to install wiring systems in close proximity to non-electrical services which produce harmful effects, any work on the services shall not affect the normal operation of the electrical system. Precautions shall be taken at all times to protection the electrical system. This could be achieved by suitable spacing between the services or by enhanced shielding.

528.3.5 No cables shall be installed in lift shafts unless they form part of that installation.

Protection against Electric Shock

For this topic we need to turn to Part 4 Chapter 41.

This area of study was introduced in Unit 301; we need to take it a bit further to consider how we can prevent receiving an electric shock.

As you have previously learnt, the effects on the body vary, what is known however is that the heart can be seriously affected by an electric shock, which can cause it to beat irregularly leading to death. You can also receive very severe burns to parts of your body, after all when you are connected in a circuit; you have just become a resistor!

Below is a table showing the levels at which current can be perceived and the possible damage done.

Current in mA	Effect
0.5-2	Threshold of perception
2-10	Painful sensation, increasing with current
10-25	Cramp and inability to let go. Increase in blood pressure. Breathing difficulties caused by muscular contraction of the lungs
10 mA is taken as the current value, above which, were there to be hand to foot contact there would be a significant risk of fibrillation (irregular heartbeat) and death. A current of 25 mA hand to hand has the equivalent effect to a 10 mA hand to foot shock.	
25-80	Severe muscular contraction sometimes with bone fractures. Increased blood pressure. Loss of consciousness from heart or breathing failure.
80+	Burns at point of contact. Deep seated burns causing the internal cells to die from the effects of very high current leading to the destruction of flesh. Death from heart failure

Below and over the next few pages are a series of drawings highlighting what the different levels of current can do!

Sensation and effect	Diagram
Threshold of perception Current is usually 0.5 mA to 2 mA. This is not very much at all.	
Let go level Current ranges up to approximately 10 mA. This level of current is likely to hurt. This pain increases with an increase in current.	
Hold on level The point at which you are likely to find it difficult to let go of the object ranges from 10 mA to 25 mA. Your blood pressure will rise and you may experience difficulty breathing.	
Throwing level At currents in excess of 25 mA you are at risk from being thrown by the electric shock that you are receiving. Bones may be broken, blood pressure rises and there may be a loss of consciousness	

The purpose of the cartoons above is to show just what little current can do so much damage.

The Regulations state the aspect of electric shock quite clearly.

The fundamental rule of protection against electric shock is that hazardous-live-parts shall not be accessible and accessible conductive parts shall not be hazardous-live, either in use without a fault or in single fault conditions.

How is this achieved in practice?

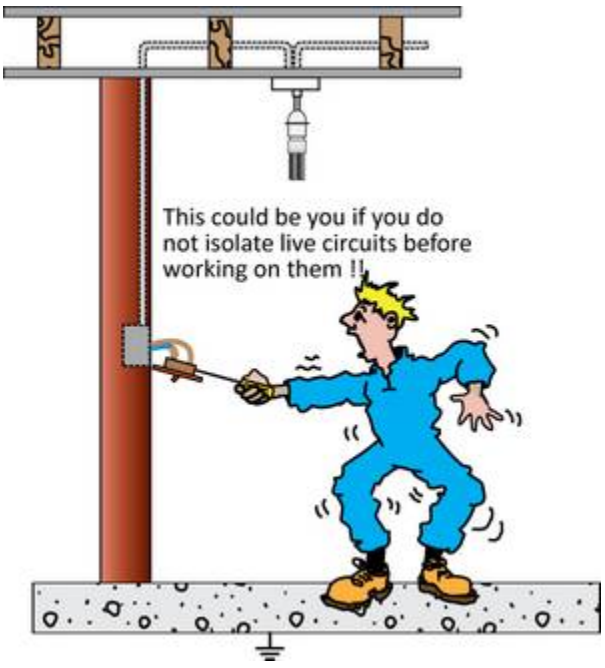
410.3.2 The protective measures are

i) An appropriate combination of basic protection and an independent provision for fault protection, or

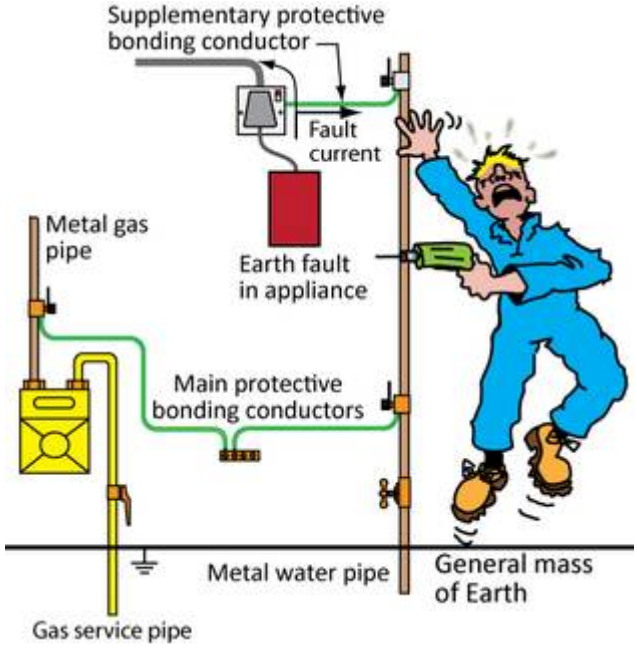
ii) An enhanced protective provision which provides both basic protection and fault protection.

Option ii) directs you to 414.2 and in practice is not common. Therefore we will concentrate on option i).

What is meant by basic protection and fault protection?



Basic protection is the insulation of live parts



Fault protection is the earthing of all metalwork

416.1 Live parts shall be completely covered with insulation that can only be removed with a tool such as a knife, side cutters, pliers or wire strippers etc.

416.2 Barriers or enclosures shall prevent contact with live parts. Access will require the use of a tool. Barriers and enclosures are typically found in fuseboards where all live parts are covered with a shield.

416.2.1 The degree of protection for live parts inside an enclosure or behind a barrier shall be to IPXXB or IP2X.

416.2.2 A horizontal top surface of a barrier or enclosure which is readily accessible is more stringent and requires protection to IPXXD or IP4X.

As an electrician the protective measure you will be working to is; Automatic Disconnection of Supply, commonly shortened to ADS. This protective measure is made up of two parts.

411.1 i) basic protection

ii) fault protection

From the above you have learnt that basic protection is the preventative measures taken to prevent touching live parts.

Fault protection is provided by protective earthing, protective equipotential bonding and automatic disconnection in the case of a fault. This is the part that relates to accessible conductive parts shall not be hazardous-live under fault conditions mentioned above.

411.3.1.1 Exposed conductive parts shall be connected to a circuit protective conductor. This conductor shall be run to and connected at each accessory. Simultaneously accessible exposed-conductive-parts shall be connected to the same earthing system. All that means is that where it is possible to simultaneously touch water of gas metal pipe work and the metalwork belonging to the electrical installation, it shall all be bonded and connected to the same earthing system.

411.3.1.2 In each installation, all extraneous metalwork shall be connected using protective bonding conductors the following items to the main earthing terminal.

i) Incoming water main at the point of entry, just after the stop cock

ii) Gas installation pipe work at the point of entry after the meter but before any branches, ideally with 600 mm of the meter.

iii) Other metal pipe work that comes out of the ground

Iv) Structural steel work of the building.

If there are out buildings that have elements of the list above then they too must be bonded.

411.3.2.1 A protective device shall automatically disconnect the supply in the event of a fault within the disconnection times required by 411.3.2.2, 411.3.2.3, and 411.3.2.4.

411.3.2.2 The disconnections times given in Table 41.1 are for final circuits not exceeding 32 A.

Complete the table below.

Syste	50 V <U_0 ≤ 120 V seconds		120 V < U_0 ≤ 230 V seconds		230 V < U_0 ≤ 400 V seconds		U_0 > 400 V seconds	
	a.c.	**d.c.**	**a.c.**	**d.c.**	**a.c.**	**d.c.**	**a.c.**	**d.c.**
TN								
TT								

411.3.2.3 For a circuit in a TN earthing system which exceeds 32 A, a disconnection time not exceeding 5 s is permitted.

411.3.2.4 For a circuit in a TT earthing system which exceeds 32 A, a disconnection time not exceeding 1 s is permitted.

In summary, protection against electric shock is achieved when the accessible live parts are insulated or protected by barriers or enclosures, and in the event of a fault, sufficient fault current needs to flow to cause automatic disconnection of the supply. This is achieved by bonding together to the same earthing system all accessible exposed and extraneous conductive parts.

(See Part 2 for the definitions on exposed and extraneous conductive parts)

Exercise 24 Dangerous substances, electric shock

1. Which one of the following is recognised as a means of providing fault protection?
   a) Protection by insulation of live parts
   b) Protection by automatic disconnection
   c) Protection by placing out of reach
   d) Protection by obstacles

2. The term 'basic protection' refers to
   a) protection against electric shock under fault free conditions
   b) extra low voltage terminals
   c) protection against electric shock under a single-fault condition
   d) live parts within an appliance

3. Within a 230 V single-phase, metal-clad fuse board, access to the line and neutral busbars are protected by insulation and by secured intermediate barriers. The fuse board may be
   a) opened without the use of a key or tool
   b) left unearthed
   c) used to accommodate SELV circuits
   d) used to accommodate ELV circuit conductors

4. A socket-outlet use for a SELV system should
   a) not have a protective conductor contact
   b) be of a 2-pin type
   c) be marked SELV
   d) have a protective conductor contact

5. Where SELV is used in normally dry conditions basic protection is unnecessary where the nominal voltage does not exceed
   a) 12 V a.c.
   b) 25 V a.c.
   c) 50 V a.c.
   d) 60 V a.c.

6. Obstacles may be used to provide basic protection providing
   a) the circuit voltage does not exceed 250 V
   b) the installation is under the control a skilled person
   c) the installation is contained within steel conduit
   d) an RCBO is fitted to all final circuits

7. Basic protection protects persons and/or livestock from contact with
   a) class II enclosures
   b) extra low voltage terminals
   c) exposed conductive parts made live by a fault
   d) live parts

8. The requirements regarding basic protection have not been applied if livestock comes into contact with
   a) exposed conductive parts made live by a fault
   b) an exposed terminal within a faulty enclosure
   c) a protective conductor carrying fault current
   d) extraneous conductive parts made live by an earth fault

9. In a location where a risk of danger from fire exists due to the manufacture or storage of combustible materials, enclosures of heaters shall not attain a surface temperature under normal working conditions exceeding
   a) 70° C
   b) 90° C
   c) 100° C
   d) 115° C

10. A 12 V control alarm circuit is classified by BS 7671 as
   a) a Band I circuit
   b) a Band II circuit
   c) a Band III circuit
   d) an unclassified circuit

