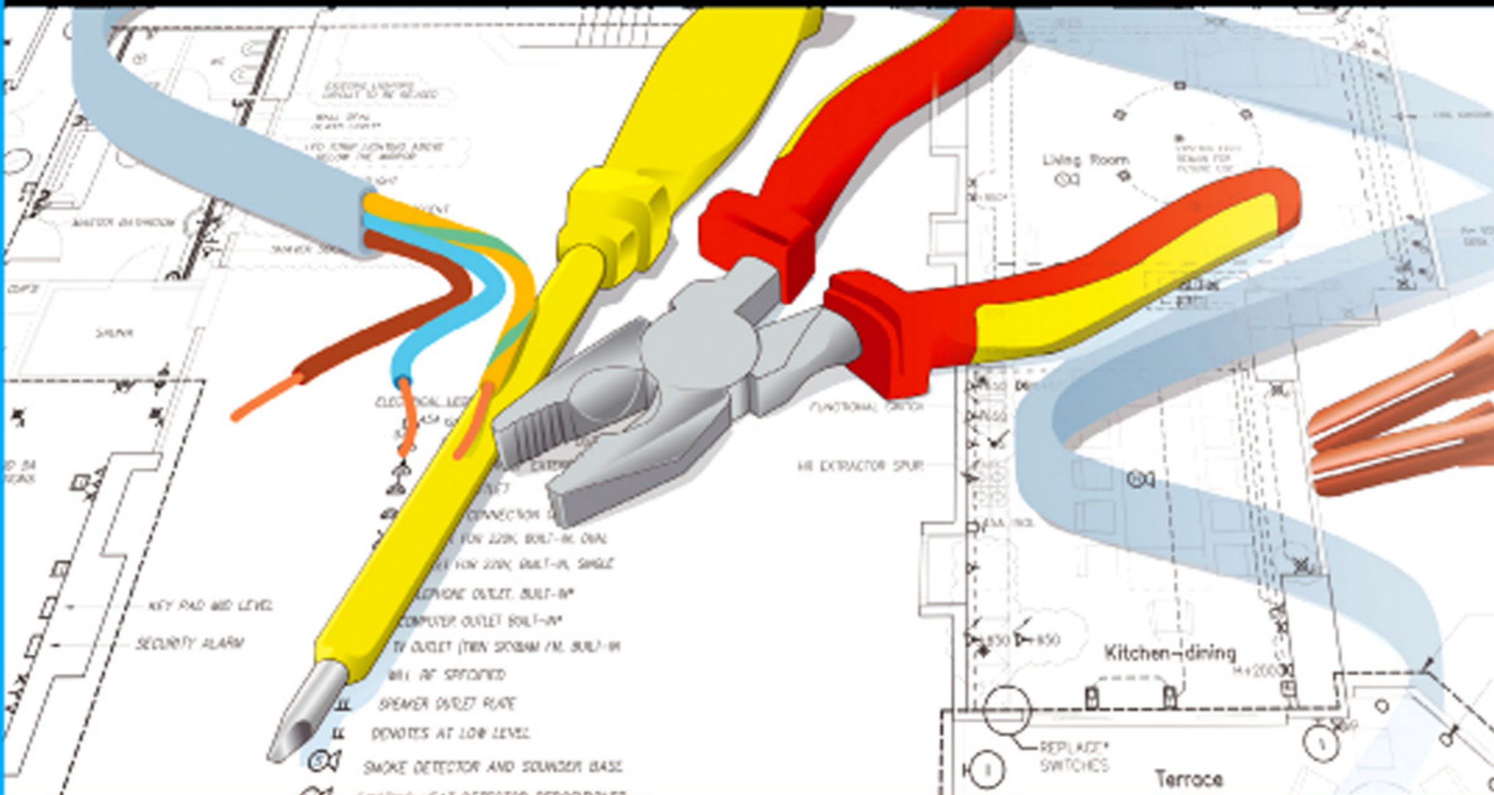
Advanced Electrical Installation Work

Sixth Edition

City & Guilds 2357 Diploma in Electrotechnical Technology



Trevor Linsley

Newnes

Advanced Electrical Installation Work

To Joyce, Samantha and Victoria

Advanced Electrical Installation Work

Sixth Edition

Trevor Linsley

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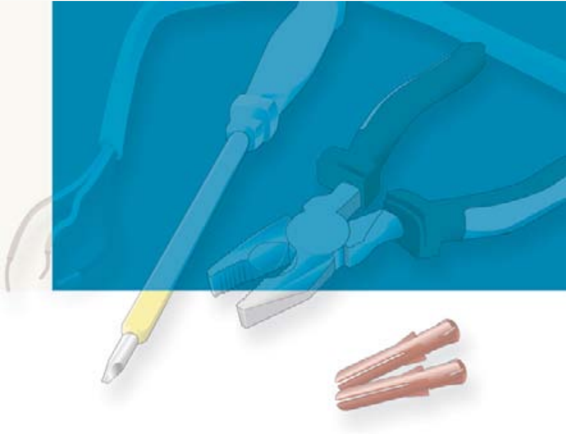

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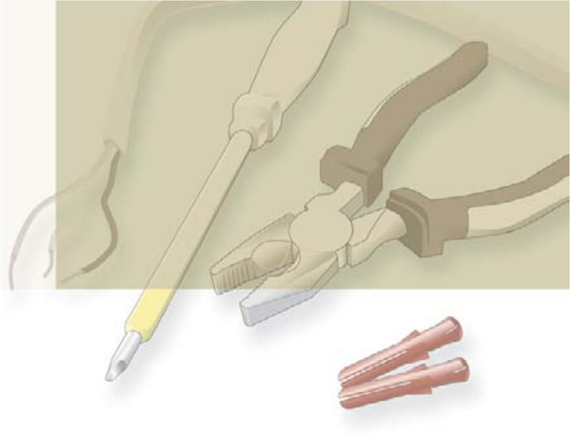

Preface

The 6th edition of *Advanced Electrical Installation Work* has been completely rewritten in Seven Chapters to closely match the Seven Performance Units of the City and Guilds 2357 qualification. The technical content has been revised and updated to the requirements of the new 17th edition of the IEE Regulations
BS 7671: 2008. Improved page design with new illustrations gives greater clarity to each topic.

This book of electrical installation theory and practice will be of value to the electrical trainee working towards:

- The City and Guilds 2357 Level 3 NVQ Diploma in Installing Electrotechnical Systems and Equipment.
- The City and Guilds 2399 series of Environmental Systems Qualification.
- The SCOTVEC and BTEC Electrical Utilization Units at Levels II and III.

Advanced Electrical Installation Work provides a sound basic knowledge of electrical theory and practice which other trades in the construction industry will find of value, particularly those involved in multi-skilled activities.

The book incorporates the requirements of the latest regulations, particularly:

- 17th edition IEE Wiring Regulations
- British Standards BS 7671: 2008
- Part P of the Building Regulations, Electrical Safety in Dwellings: 2006
- Hazardous Waste Regulations: 2005
- Work at Height Regulations: 2005.

Trevor Linsley

2011

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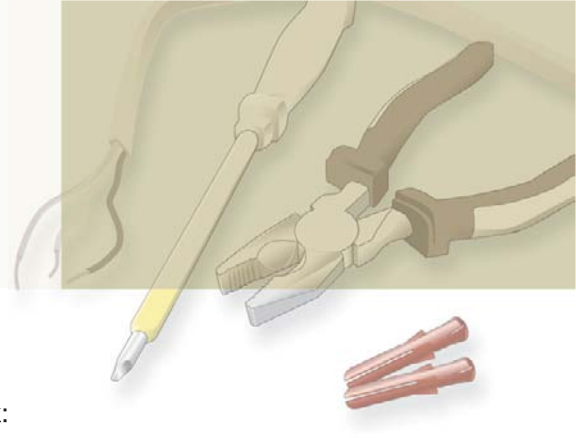

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- The Institution of Engineering and Technology for permission to reproduce regulations and tables from the 17th edition IEE Regulations
- The British Standards Institution for permission to reproduce material from BS 7671: 2008
- Crabtree Electrical Industries for technical information and data
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I would like to thank the many college lecturers who responded to the questionnaire from Elsevier, the publishers, regarding the proposed new edition of this book. Their recommendations have been taken into account in producing this improved 6th edition.

I would also like to thank the editorial and production staff at Elsevier, the publishers, for their enthusiasm and support. They were able to publish this 6th edition within the very short timescale created by the publication of the new City and Guilds 2357 qualification.

Finally I would like to thank Joyce, Samantha and Victoria for their support and encouragement.

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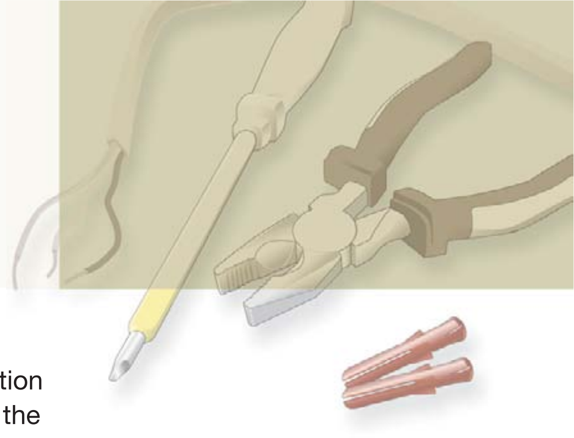

About this book

There are seven performance units in the new City and Guilds 2357 qualification Installing Electrotechnical Systems. Each chapter in this book covers one of the seven performance units 311 to 318.

Competence in the essential safety outcomes such as safe isolation and risk assessment must be demonstrated on more than one occasion and are therefore included in more than one performance unit and chapter in this book.

The performance units will be assessed by the observation of a task or outcome plus a portfolio of evidence or assignments related to the task or outcome.

This book will assist readers to assemble their portfolio of evidence and to complete the assignments required for each performance unit.

The portfolio of evidence will be assessed by City and Guilds approved assessors at your place of work or training centre. For this reason there are no multiple choice questions at the end of each chapter in this book, as there are in *Basic Electrical Installation Work* 6th edition.

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CHAPTER 1

Applying health and safety regulations and working practices

Unit 311 of the City and Guilds 2357 syllabus

Applying Health and Safety legislation and working practices (installing and maintaining electrotechnical systems and equipment)

When you have completed this chapter you should be able to:

1. Identify health and safety legislation and produce a risk assessment and method statement
2. Select and use appropriate PPE
3. Recognize warning signs and use access equipment correctly
4. Apply basic first aid procedures

Online Material WWW

This chapter has free associated content, including animations and instructional videos, to support your learning

When you see the logo, visit the website below to access this material:

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Identify health and safety legislation and produce a risk assessment and method statement (CGLI Outcome 1)

This first chapter of *Advanced Electrical Installation Work* covers the health and safety core skills required by the City and Guilds Level 3 Diploma in Installing Electrotechnical Systems and Equipment. That is, the Health and Safety laws and regulations that underpin the electrotechnical industry.

Let me begin by looking at the background to the modern Health and Safety Regulations and the electricity supply and wiring regulations.

Electricity generation as we know it today began when Michael Faraday conducted the famous ring experiment in 1831. This experiment, together

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with many other experiments of the time, made it possible for Lord Kelvin and Sebastian de Ferranti to patent in 1882 the designs for an electrical machine called the Ferranti–Thompson dynamo, which enabled the generation of electricity on a commercial scale.

In 1887 the London electric supply corporation was formed with Ferranti as chief engineer. This was one of the many privately owned electricity generating stations supplying the electrical needs of the United Kingdom. As the demand for electricity grew, more privately owned generating stations were built until eventually the government realized that electricity was a national asset which would benefit from nationalization.

In 1926 the Electricity Supply Act placed the responsibility for generation in the hands of the Central Electricity Board. In England and Wales the Central Electricity Generating Board (CEGB) had the responsibility for the generation and transmission of electricity on the supergrid. In Scotland, generation was the joint responsibility of the North of Scotland Hydro-Electricity Board and the South of Scotland Electricity Board. In Northern Ireland electricity generation was the responsibility of the Northern Ireland Electricity Service.

In 1988 Cecil Parkinson, the Secretary of State for Energy in the Conservative government, proposed the denationalization of the electricity supply industry; this became law in March 1991, thereby returning the responsibility for generation, transmission and distribution to the private sector. It was anticipated that this action, together with new legislation over the security of supplies, would lead to a guaranteed quality of provision, with increased competition leading eventually to cheaper electricity.

During the period of development of the electricity services, particularly in the early days, poor design and installation led to many buildings being damaged by fire and the electrocution of human beings and livestock. It was the insurance companies which originally drew up a set of rules and guidelines of good practice in the interest of reducing the number of claims made upon them. The first rules were made by the American Board of Fire Underwriters and were quickly followed by the Phoenix Rules of 1882. In the same year the first edition of the Rules and Regulations for the Prevention of Fire Risk arising from Electrical Lighting was issued by the Institute of Electrical Engineers.

The current edition of these regulations is called the Requirements for Electrical Installations, IEE Wiring Regulations (BS 7671: 2008), and since July 2008 we have been using the 17th edition. All the rules have been revised, updated and amended at regular intervals to take account of modern developments, and the 17th edition brought the UK Regulations into harmony with those of the rest of Europe.

The laws and regulations affecting the electrotechnical industry have steadily increased over the years. There is a huge amount of legislation from the European law-makers in Brussels. These laws and regulations will permeate each and every sector of the electrotechnical industry and reform and modify our future work patterns and behaviour.

In this section I want to deal with the laws and regulations that affect our industry and in particular I want to look at the laws concerned with health and safety at work, making the working environment safe.

The Health and Safety at Work Act 1974

Many governments have passed laws aimed at improving safety at work but the most important recent legislation has been the Health and Safety at Work Act

1974. The purpose of the Act is to provide the legal framework for stimulating and encouraging high standards of health and safety at work; the Act puts the responsibility for safety at work on both workers and managers.

The Health and Safety at Work Act is an 'Enabling Act' that allows the Secretary of State to make further laws, known as regulations, without the need to pass another Act of Parliament. Regulations are law, passed by Parliament and are usually made under the Health and Safety at Work Act 1974. This applies to regulations based on European directives as well as new UK regulations. The way it works is that the Health and Safety at Work Act established the Health and Safety Commission (HSC) and gave it the responsibility of drafting new regulations and enforcing them through its executive arm known as the Health and Safety Executive (HSE) or through the local Environmental Health Officers (EHO). The HSC has equal representation from employers, trade unions and special interest groups. Their role is to set out the regulations as goals to be achieved. They describe what must be achieved in the interests of safety, but not how it must be done.

Under the Health and Safety at Work Act an **employer** has a duty to care for the health and safety of employees (Section 2 of the Act). To do this he has a *responsibility* to ensure that:

- the working conditions and standard of hygiene are appropriate;
- the plant, tools and equipment are properly maintained;
- safe systems of work are in place;
- safe methods of handling, storing and transporting goods and materials are used;
- there is a system for reporting accidents in the workplace;
- the company has a written health & safety policy statement;
- the necessary safety equipment – such as personal protective equipment (PPE), dust and fume extractors and machine guards – are available and properly used;
- the workers are trained to use equipment and plant safely.

Employees have a duty to care for their own health and safety and that of others who may be affected by their actions (Section 7 of the Act). To do this they must:

- take reasonable care to avoid injury to themselves or others as a result of their work activity;
- co-operate with their employer, helping him or her to comply with the requirements of the act;
- not interfere with or misuse anything provided to protect their health and safety.

Failure to comply with the Health and Safety at Work Act is a criminal offence and any infringement of the law can result in heavy fines, a prison sentence or both.

Enforcement

Laws and rules must be enforced if they are to be effective. The system of control under the Health and Safety at Work Act comes from the HSE which is charged with enforcing the law. The HSE is divided into a number of specialist inspectorates or sections which operate from local offices throughout the United Kingdom. From the local offices the inspectors visit individual places of work.

Definition

Under the Health and Safety at Work Act an *employer* has a duty to care for the health and safety of employees.

Safety first

Laws

The Health and Safety at Work Act provides the legal framework for stimulating and encouraging health and safety at work. It is:

- the most important
- the most far reaching
- a single piece of legislation

Definition

Employees have a duty to care for their own health and safety and that of others who may be affected by their actions.

The HSE inspectors have been given wide-ranging powers to assist them in the enforcement of the law. They can:

1 enter premises unannounced and carry out investigations, take measurements or photographs;
2 take statements from individuals;
3 check the records and documents required by legislation;
4 give information and advice to an employee or employer about safety in the workplace;
5 demand the dismantling or destruction of any equipment, material or substance likely to cause immediate serious injury;
6 issue an improvement notice which will require an employer to put right, within a specified period of time, a minor infringement of the legislation;
7 issue a prohibition notice which will require an employer to stop immediately any activity likely to result in serious injury, and which will be enforced until the situation is corrected;
8 prosecute all persons who fail to comply with their safety duties, including employers, employees, designers, manufacturers, suppliers and the self-employed.

Safety documentation

Under the Health and Safety at Work Act, the employer is responsible for ensuring that adequate instruction and information is given to employees to make them safety-conscious. Part 1, Section 3 of the Act instructs all employers to prepare a written health and safety policy statement and to bring this to the notice of all employees. Your employer must let you know who your safety representatives are and the new health and safety poster shown in Fig. 1.1 has a blank section into which the names and contact information of your specific representatives can be added. This is a large laminated poster, 595 × 415 mm, suitable for wall or notice board display.

All workplaces employing five or more people had to display the type of poster shown in Fig. 1.1 after 30 June 2000.

To promote adequate health and safety measures the employer must consult with the employees' safety representatives. In companies which employ more than 20 people this is normally undertaken by forming a safety committee which is made up of a safety officer and employee representatives, usually nominated by a trade union. The safety officer is usually employed full-time in that role. Small companies might employ a safety supervisor, who will have other duties within the company, or alternatively they could join a 'safety group'. The safety group then shares the cost of employing a safety adviser or safety officer, who visits each company in rotation. An employee who identifies a dangerous situation should initially report to his site safety representative. The safety representative should then bring the dangerous situation to the notice of the safety committee for action which will remove the danger. This may mean changing company policy or procedures or making modifications to equipment. All actions of the safety committee should be documented and recorded as evidence that the company takes seriously its health and safety policy.

Safety first

Information

- Have you seen the new Health and Safety Law poster like Fig 1.1
  - in your place of work?
  - at the college?
- were the blank sections filled in?

The Management of Health and Safety at Work Regulations 1999

The Health and Safety at Work Act 1974 places responsibilities on employers to have robust health and safety systems and procedures in the workplace.

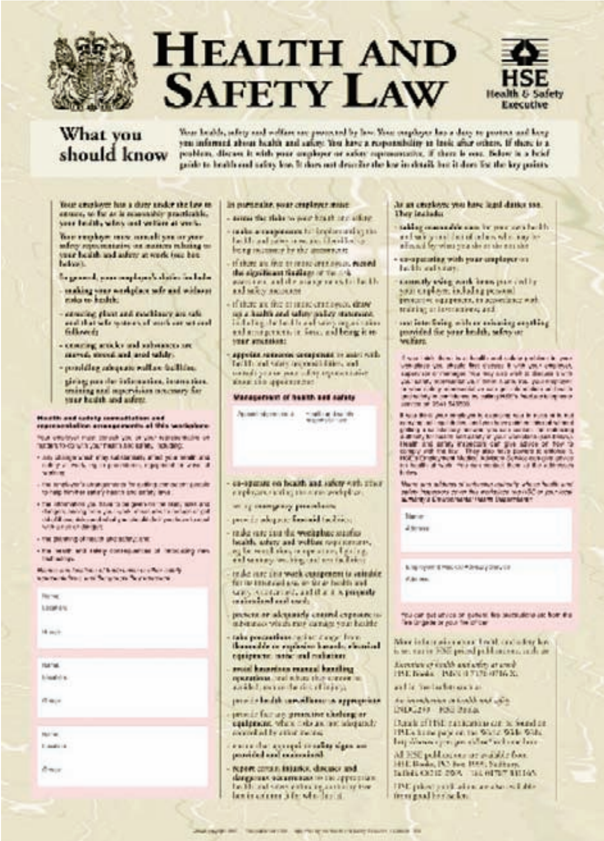

Figure 1.1 New Health and Safety Law poster. *Source*: HSE © Crown copyright material is reproduced with the permission of the Controller of HMSO and Her Majesty's Stationery Office, Norwich.

Directors and managers of any company who employ more than five employees can be held personally responsible for failures to control health and safety.

The Management of Health and Safety at Work Regulations 1999 tell us that employers must systematically examine the workplace, the work activity and the management of safety in the establishment through a process of '*risk assessments*'. A record of all significant risk assessment findings must be kept in a safe place and be available to an HSE inspector if required. Information based on these findings must be communicated to relevant staff and if changes in work behaviour patterns are recommended in the interests of safety, then they must be put in place. The process of risk assessment is considered in detail later in this chapter.

Risks which may require a formal assessment in the electrotechnical industry might be:

- working at heights;
- using electrical power tools;
- falling objects;
- working in confined places;
- electrocution and personal injury;
- working with 'live' equipment;
- using hire equipment;
- *manual handling*: pushing, pulling, lifting;
- *site conditions*: falling objects, dust, weather, water, accidents and injuries.

And any other risks which are particular to a specific type of work place or work activity.

Provision and Use of Work Equipment Regulations 1998

These regulations tidy up a number of existing requirements already in place under other regulations such as the Health and Safety at Work Act 1974, the Factories Act 1961 and the Offices, Shops and Railway Premises Act 1963.

The Provision and Use of Work Equipment Regulations 1998 places a general duty on employers to ensure minimum requirements of plant and equipment. If an employer has purchased good quality plant and equipment, which is well maintained, there is little else to do. Some older equipment may require modifications to bring it in line with modern standards of dust extraction, fume extraction or noise, but no assessments are required by the regulations other than those generally required by the Management Regulations 1999 discussed previously.

The Control of Substances Hazardous to Health Regulations 2002

The original Control of Substances Hazardous to Health (COSHH) Regulations were published in 1988 and came into force in October 1989. They were re-enacted in 1994 with modifications and improvements, and the latest modifications and additions came into force in 2002.

The COSHH Regulations control people's exposure to hazardous substances in the workplace. Regulation 6 requires employers to assess the risks to health from working with hazardous substances, to train employees in techniques which will reduce the risk and provide PPE so that employees will not endanger themselves or others through exposure to hazardous substances. Employees should also know what cleaning, storage and disposal procedures are required and what emergency procedures to follow. The necessary information must be available to anyone using hazardous substances as well as to visiting HSE inspectors.

Hazardous substances include:

1. any substance which gives off fumes causing headaches or respiratory irritation;
2. man-made fibres which might cause skin or eye irritation (e.g. loft insulation);
3. acids causing skin burns and breathing irritation (e.g. car batteries, which contain dilute sulphuric acid);
4. solvents causing skin and respiratory irritation (strong solvents are used to cement together PVC conduit fittings and tube);
5. fumes and gases causing asphyxiation (burning PVC gives off toxic fumes);
6. cement and wood dust causing breathing problems and eye irritation;
7. exposure to asbestos – although the supply and use of the most hazardous asbestos material is now prohibited, huge amounts were installed between 1950 and 1980 in the construction industry and much of it is still in place today. In their latest amendments the COSHH Regulations focus on giving advice and guidance to builders and contractors on the safe use and control of asbestos products. These can be found in Guidance Notes EH 71.

Where PPE is provided by an employer, employees have a duty to use it to safeguard themselves.

The Construction (Design and Management) Regulations 1994

The Construction (Design and Management) Regulations (CDM) are aimed at improving the overall management of health, safety and welfare throughout all stages of the construction project.

The person requesting that construction work commence, the client, must first of all appoint a '**duty holder**', someone who has a duty of care for health, safety and welfare matters on site. This person will be called a 'planning supervisor'. The planning supervisor must produce a 'pre-tender' health and safety plan and co-ordinate and manage this plan during the early stages of construction.

The client must also appoint a principal contractor who is then required to develop the health and safety plan made by the planning supervisor, and keep it up to date during the construction process to completion.

The degree of detail in the health and safety plan should be in proportion to the size of the construction project and recognize the health and safety risks involved on that particular project. Small projects will require simple straightforward plans; large projects, or those involving significant risk, will require more detail. The CDM Regulations will apply to most large construction projects but they do not apply to the following:

- Construction work, other than demolition work, that does not last longer than 30 days and does not involve more than four people.
- Construction work carried out inside commercial buildings such as shops and offices, which does not interrupt the normal activities carried out on those premises.
- Construction work carried out for a domestic client.
- The maintenance and removal of pipes or lagging which forms a part of a heating or water system within the building.

Definition

'Duty holder', someone who has a duty of care for health, safety and welfare matters on site. This phrase recognizes the level of responsibility which electricians are expected to take on as part of their job in order to control electrical safety in the work environment.

The Construction (Health, Safety and Welfare) Regulations 1996

An electrical contractor is a part of the construction team, usually as a sub-contractor, and therefore the regulations particularly aimed at the construction industry also influence the daily work procedures and environment of an electrician. The most important recent piece of legislation is the Construction Regulations.

The temporary nature of construction sites makes them one of the most dangerous places to work. These regulations are made under the Health and Safety at Work Act 1974 and are designed specifically to promote safety at work in the construction industry. Construction work is defined as any building or civil engineering work, including construction, assembly, alterations, conversions, repairs, upkeep, maintenance or dismantling of a structure.

The general provision sets out minimum standards to promote a good level of safety on site. Schedules specify the requirements for guardrails, working platforms, ladders, emergency procedures, lighting and welfare facilities. Welfare facilities set out minimum provisions for site accommodation: washing facilities, sanitary conveniences and protective clothing. There is now a duty for all those working on construction sites to wear head protection, and this includes electricians working on site as sub-contractors.

Safety first

Head protection

- the Construction Regulations require everyone working on a construction site to wear head protection
- this includes electricians

Safe working procedures

The principles which were laid down in the many Acts of Parliament and the regulations that we have already looked at in this chapter, control our working environment. They make our workplace safer, but despite all this legislation, workers continue to be injured and killed at work or die as a result of a work-related injury. The number of deaths has consistently averaged about 200 each year for the past 8 years. These figures only relate to employees. If you include the self-employed and members of the public killed in work-related accidents, the numbers almost double.

In addition to the deaths, about 28,000 people have major accidents at work and about 130,000 people each year, receive minor work-related injuries which keep them off work for more than 3 days.

It is a mistake to believe that these things only happen in dangerous occupations such as deep sea diving, mining and quarrying, fishing industry, tunnelling and fire-fighting or that it only happens in exceptional circumstances such as would never happen in your workplace. This is not the case. Some basic thinking and acting beforehand could have prevented most of these accident statistics from happening.

Definition

Human errors include behaving badly or foolishly, being careless and not paying attention to what you should be doing at work.

Definition

Environmental conditions include unguarded or faulty machinery.

Safety first

Safety procedures

- hazard risk assessment *is an essential part* of any health and safety management system
- the aim of the planning process is to minimize risk
- HSE publication HSG(65)

Causes of accidents

Most accidents are caused by either human error or environmental conditions. **Human errors** include behaving badly or foolishly, being careless and not paying attention to what you should be doing at work, doing things that you are not competent to do or have not been trained to do. You should not work when tired or fatigued and should never work when you have been drinking alcohol or taking drugs.

Environmental conditions include unguarded or faulty machinery, damaged or faulty tools and equipment, poorly illuminated or ventilated workplaces and untidy, dirty or overcrowded workplaces.

The most common causes of accidents

These are:

- slips, trips and falls;
- manual handling, that is moving objects by hand;
- using equipment, machinery or tools;
- storage of goods and materials which then become unstable;
- fire;
- electricity;
- mechanical handling.

Accident prevention measures

To control the risk of an accident we usually:

- eliminate the cause;
- substitute a procedure or product with less risk;
- enclose the dangerous situation;
- put guards around the hazard;
- use safe systems of work;

- supervise, train and give information to staff;
- if the hazard cannot be removed or minimized then provide PPE.

Let us now look at the application of one of the procedures that make the workplace a safer place to work but first of all I want to explain what I mean when I use the words hazard and risk.

Hazard and risk

A **hazard** is something with the 'potential' to cause harm, for example, chemicals, electricity or working above ground.

A **risk** is the 'likelihood'of harm actually being done.

Competent persons are often referred to in the Health and Safety at Work Regulations, but who is 'competent'? For the purposes of the Act, a competent person is anyone who has the necessary technical skills, training and expertise to safely carry out the particular activity. Therefore, a **competent person** dealing with a hazardous situation reduces the risk.

Think about your workplace and at each stage of what you do, think about what might go wrong. Some simple activities may be hazardous. Here are some typical activities where accidents might happen.

Typical activity	Potential hazard
Receiving materials	Lifting and carrying
Stacking and storing	Falling materials
Movement of people	Slips, trips and falls
Building maintenance	Working at heights or in confined spaces
Movement of vehicles	Collisions

How high are the risks? Think about what might be the worst result, is it a broken finger or someone suffering permanent lung damage or being killed? How likely is it to happen? How often is that type of work carried out and how close do people get to the hazard? How likely is it that something will go wrong?

How many people might be injured if things go wrong? Might this also include people who do not work for your company?

Employers of more than five people must document the risks at work and the process is known as hazard risk assessment.

Hazard risk assessment – the process

The Management of Health and Safety at Work Regulations 1999 tell us that employers must systematically examine the workplace, the work activity and the management of safety in the establishment through a process of risk assessments. A record of all significant risk assessment findings must be kept in a safe place and be made available to an HSE inspector if required. Information based on the risk assessment findings must be communicated to relevant staff and if changes in work behaviour patterns are recommended in the interests of safety, then they must be put in place.

So risk assessment must form a part of any employer's robust policy of health and safety. However, an employer only needs to 'formally' assess the significant risks. He is not expected to assess the trivial and minor types of household risks. Staff are expected to read and to act upon these formal risk assessments and they are unlikely to do so enthusiastically if the file is full of trivia. An assessment

Definitions

A *hazard* is something with the 'potential' to cause harm, for example, chemicals, electricity or working above ground.

A *risk* is the 'likelihood' of harm actually being done.

Definition

A *competent person* is anyone who has the necessary technical skills, training and expertise to safely carry out the particular activity.

of risk is nothing more than a careful examination of what, in your work, could cause harm to people. It is a record that shows whether sufficient precautions have been taken to prevent harm.

The HSE recommends five steps to any risk assessment.

Step 1

Look at what might reasonably be expected to cause harm. Ignore the trivial and concentrate only on significant hazards that could result in serious harm or injury. Manufacturers' data sheets or instructions can also help you spot hazards and put risks in their true perspective.

Step 2

Decide who might be harmed and how. Think about people who might not be in the workplace all the time – cleaners, visitors, contractors or maintenance personnel. Include members of the public or people who share the workplace. Is there a chance that they could be injured by activities taking place in the workplace?

Step 3

Evaluate what is the risk arising from an identified hazard. Is it adequately controlled or should more be done? Even after precautions have been put in place, some risk may remain. What you have to decide, for each significant hazard, is whether this remaining risk is low, medium or high. First of all, ask yourself if you have done all the things that the law says you have got to do. For example, there are legal requirements on the prevention of access to dangerous machinery. Then ask yourself whether generally accepted industry standards are in place, but do not stop there – think for yourself, because the law also says that you must do what is reasonably practicable to keep the workplace safe. Your real aim is to make all risks small by adding precautions, if necessary.

If you find that something needs to be done, ask yourself:

1 Can I get rid of this hazard altogether?
2 If not, how can I control the risk so that harm is unlikely?

Only use PPE when there is nothing else that you can reasonably do.

If the work that you do varies a lot, or if there is movement between one site and another, select those hazards which you can reasonably foresee, the ones that apply to most jobs and assess the risks for them. After that, if you spot any unusual hazards when you get on site, take what action seems necessary.

Step 4

Record your findings and say what you are going to do about risks that are not adequately controlled. If there are fewer than five employees you do not need to write anything down but if there are five or more employees, the significant findings of the risk assessment must be recorded. This means writing down the more significant hazards and assessing if they are adequately controlled and recording your most important conclusions. Most employers have a standard risk assessment form which they use such as that shown in Fig. 1.2 but any format is suitable. The important thing is to make a record.

There is no need to show how the assessment was made, providing you can show that:

1 a proper check was made,
2 you asked those who might be affected,
3 you dealt with all obvious and significant hazards,

HAZARD RISK ASSESSMENT	FLASH-BANG ELECTRICAL CO.
For Company name or site: ---------- Address: ---------- ----------	Assessment undertaken by: ---------- Signed: ---------- Date: ----------
STEP 5 Assessment review date: ----------	
STEP 1 List the hazards here	STEP 2 Decide who might be harmed
STEP 3 Evaluate (what is) the risk – is it adequately controlled? State risk level as low, medium or high	STEP 4 Further action – what else is required to control any risk identified as medium or high?

Figure 1.2 Hazard risk assessment standard form.

4 the precautions are reasonable and the remaining risk is low,
5 you informed your employees about your findings.

Risk assessments need to be *suitable* and *sufficient*, not perfect. The two main points are:

1 Are the precautions reasonable?
2 Is there a record to show that a proper check was made?

File away the written assessment in a dedicated file for future reference or use. It can help if an HSE inspector questions the company's precautions or if the company becomes involved in any legal action. It shows that the company has done what the law requires.

Step 5

Review the assessments from time to time and revise them if necessary.

Completing a risk assessment

When completing a risk assessment such as that shown in Fig. 1.3, do not be over complicated. In most firms in the commercial, service and light industrial sector, the hazards are few and simple. Checking them is common sense but necessary.

Step 1

List only hazards which you could reasonably expect to result in significant harm under the conditions prevailing in your workplace. Use the following examples as a guide:

- Slipping or tripping hazards (e.g. from poorly maintained or partly installed floors and stairs).
- Fire (e.g. from flammable materials you might be using, such as solvents).
- Chemicals (e.g. from battery acid).
- Moving parts of machinery (e.g. blades).
- Rotating parts of handtools (e.g. drills).
- Accidental discharge of cartridge operated tools.
- High pressure air from airlines (e.g. air powered tools).
- Pressure systems (e.g. steam boilers).
- Vehicles (e.g. fork lift trucks).
- Electricity (e.g. faulty tools and equipment).
- Dust (e.g. from grinding operations or thermal insulation).
- Fumes (e.g. from welding).
- Manual handling (e.g. lifting, moving or supporting loads).
- Noise levels too high (e.g. machinery).
- Poor lighting levels (e.g. working in temporary or enclosed spaces).
- Low temperatures (e.g. working outdoors or in refrigeration plants).
- High temperatures (e.g. working in boiler rooms or furnaces).

Step 2

Decide who might be harmed, do not list individuals by name. Just think about groups of people doing similar work or who might be affected by your work:

- Office staff
- Electricians
- Maintenance personnel
- Other contractors on site
- Operators of equipment
- Cleaners
- Members of the public.

Pay particular attention to those who may be more vulnerable, such as:

- staff with disabilities,
- visitors,

- young or inexperienced staff,
- people working in isolation or enclosed spaces.

Step 3

Calculate what is the risk – is it adequately controlled? Have you already taken precautions to protect against the hazards which you have listed in Step 1? For example:

- Have you provided adequate information to staff?
- Have you provided training or instruction?

Do the precautions already taken

- meet the legal standards required?
- comply with recognized industrial practice?
- represent good practice?
- reduce the risk as far as is reasonably practicable?

If you can answer 'yes' to the above points then the risks are adequately controlled, but you need to state the precautions you have put in place. You can refer to company procedures, company rules, company practices, etc., in giving this information. For example, if we consider there might be a risk of electric shock from using electrical power tools, then the risk of a shock will be *less* if the company policy is to PAT test all power tools each year and to fit a label to the tool showing that it has been tested for electrical safety. If the stated company procedure is to use battery drills whenever possible, or 110 V drills when this is not possible, and *never* to use 230 V drills, then this again will reduce the risk. If a policy such as this is written down in the company safety policy statement, then you can simply refer to the appropriate section of the safety policy statement and the level of risk will be low.

Step 4

Further action – what more could be done to reduce those risks which were found to be inadequately controlled?

You will need to give priority to those risks that affect large numbers of people or which could result in serious harm. Senior managers should apply the principles below when taking action, if possible in the following order:

1. Remove the risk completely.
2. Try a less risky option.
3. Prevent access to the hazard (e.g. by guarding).
4. Organize work differently in order to reduce exposure to the hazard.
5. Issue PPE.
6. Provide welfare facilities (e.g. washing facilities for removal of contamination and first aid).

Any hazard identified by a risk assessment as *high risk* must be brought to the attention of the person responsible for health and safety within the company. Ideally, in Step 4 of the risk assessment you should be writing, 'No further action is required. The risks are under control and identified as low risk'.

The assessor may use as many standard hazard risk assessment forms, such as that shown in Fig. 1.2, as the assessment requires. Upon completion they should be stapled together or placed in a plastic wallet and stored in the dedicated file.

Method statement

The Construction, Design and Management Regulations and Approved Codes of Practice define a method statement as a written document laying out the work procedure and sequence of operations to ensure health and safety.

If the method statement is written as a result of a risk assessment carried out for a task or operation, then following the prescribed method will reduce the risk. If the risk is low a verbal statement may be all that is required.

The safe isolation procedure described in Outcome 1 of Chapter 3 is a method statement. Following this method meets the requirements of the Electricity at Work Regulations, the IEE Regulations, and reduces the risk of electric shock to the operative and other people who might be affected by his actions.

To demonstrate that you understand this second CGLI Outcome your tutor/trainer/lecturer will assess your ability to produce a risk assessment and method statement.

Select and use PPE (CGLI Outcome 2)

We have already looked at the causes of accidents and safe working procedures in Outcome 1 so let us now look at reducing the risk by wearing appropriate PPE.

Where PPE is provided by an employer, employees have a duty to use it to safeguard themselves.

PPE at Work Regulations 1992

PPE is defined as all equipment designed to be worn, or held, to protect against a risk to health and safety. This includes most types of protective clothing, and equipment such as eye, foot and head protection, safety harnesses, life jackets and high-visibility clothing.

Under the Health and Safety at Work Act, employers must provide free of charge any PPE and employees must make full and proper use of it. Safety signs such as those shown in Fig. 1.3 are useful reminders of the type of PPE to be used in a particular area. The vulnerable parts of the body which may need protection are the head, eyes, ears, lungs, torso, hands and feet and, additionally, protection from falls may need to be considered. Objects falling from a height present the major hazard against which head protection is provided. Other hazards include striking the head against projections and hair becoming entangled in machinery. Typical methods of protection include helmets, light duty scalp protectors called 'bump caps' and hairnets.

Safety first

PPE

- what type of PPE do you use at work?
- make a list in the margin of the book

The eyes are very vulnerable to liquid splashes, flying particles and light emissions such as ultraviolet light, electric arcs and lasers. Types of eye protectors include safety spectacles, safety goggles and face shields. Screen based workstations are being used increasingly in industrial and commercial locations by all types of personnel. Working with VDUs (visual display units) can cause eye strain and fatigue and, therefore, work patterns should be varied and operators are entitled to free eye tests.

Noise is accepted as a problem in most industries and surprisingly there has been very little control legislation. The HSE have published a 'Code of Practice' and 'Guidance Notes' HSG 56 for reducing the exposure of employed persons to

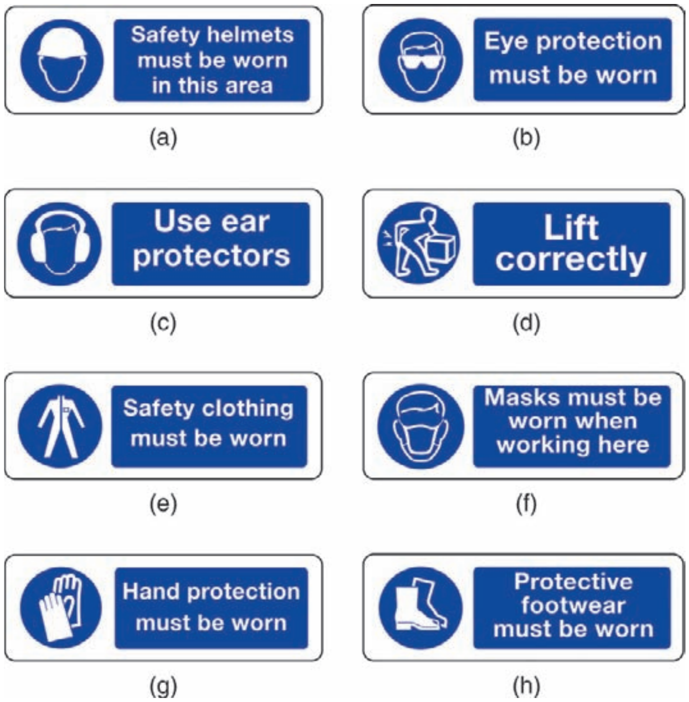

Figure 1.3 Safety signs showing type of PPE to be worn.

noise. A continuous exposure limit of below 90 dB for an 8-hour working day is recommended by the code.

Noise may be defined as any disagreeable or undesirable sound or sounds, generally of a random nature, which do not have clearly defined frequencies. The usual basis for measuring noise or sound level is the decibel scale. Whether noise of a particular level is harmful or not also depends upon the length of exposure to it. This is the basis of the widely accepted limit of 90 dB of continuous exposure to noise for 8 hours per day.

A peak sound pressure of above 200 pascals or about 120 dB is considered unacceptable and 130 dB is the threshold of pain for humans. If a person has to shout to be understood at 2 m, the background noise is about 85 dB. If the distance is only 1 m, the noise level is about 90 dB. Continuous noise at work causes deafness, makes people irritable, affects concentration, causes fatigue and accident proneness and may mask sounds which need to be heard in order to work efficiently and safely.

It may be possible to engineer out some of the noise, for example, by placing a generator in a separate sound-proofed building. Alternatively, it may be possible to provide job rotation, to rearrange work locations or provide acoustic refuges.

Where individuals must be subjected to some noise at work it may be reduced by ear protectors. These may be disposable ear plugs, reusable ear plugs or ear muffs. The chosen ear protector must be suited to the user and suitable for the type of noise and individual personnel should be trained in its correct use.

Breathing reasonably clean air is the right of every individual, particularly at work. Some industrial processes produce dust which may present a potentially serious hazard. The lung disease asbestosis is caused by the inhalation of asbestos dust or particles and the coal dust disease pneumoconiosis, suffered by many coal miners, has made people aware of the dangers of breathing in contaminated air.

Some people may prove to be allergic to quite innocent products such as flour dust in the food industry or wood dust in the construction industry. The main effect of inhaling dust is a measurable impairment of lung function. This can be avoided by wearing an appropriate mask, respirator or breathing apparatus as recommended by the company's health and safety policy and indicated by local safety signs.

A worker's body may need protection against heat or cold, bad weather, chemical or metal splash, impact or penetration and contaminated dust. Alternatively, there may be a risk of the worker's own clothes causing contamination of the product, as in the food industry. Appropriate clothing will be recommended in the company's health and safety policy. Ordinary working clothes and clothing provided for food hygiene purposes are not included in the PPE at Work Regulations.

Hands and feet may need protection from abrasion, temperature extremes, cuts and punctures, impact or skin infection. Gloves or gauntlets provide protection from most industrial processes but should not be worn when operating machinery because they may become entangled in it. Care in selecting the appropriate protective device is required; for example, barrier creams provide only a limited protection against infection.

Boots or shoes with in-built toe caps can give protection against impact or falling objects and, when fitted with a mild steel sole plate, can also provide protection from sharp objects penetrating through the sole. Special slip resistant soles can also be provided for employees working in wet areas.

Whatever the hazard to health and safety at work, the employer must be able to demonstrate that he or she has carried out a risk assessment, made recommendations which will reduce that risk and communicated these recommendations to the workforce. Where there is a need for PPE to protect against personal injury and to create a safe working environment, the employer must provide that equipment and any necessary training which might be required and the employee must make full and proper use of such equipment and training.

To demonstrate that you understand this second CGLI Outcome your tutor/trainer/lecturer will assess your ability to select and use appropriate PPE to ensure your health and safety.

Recognize warning signs and use access equipment safely (CGLI Outcome 3)

Your personal conduct at work and your attitude to safety are important to your own safety and the safety of others who might be affected by your actions.

Personal conduct

Remember that it is the customers who actually pay the wages of everyone employed in your company. You should always be polite and listen carefully to their wishes. They may be elderly or of a different religion or cultural background than you. In a domestic situation, the playing of loud music on a radio may not be approved of. Treat the property in which you are working with the utmost care. When working in houses, shops and offices use dust sheets to protect floor coverings and furnishings. Clean up periodically and make a special effort when the job is completed.

Dress appropriately: an unkempt or untidy appearance will encourage the customer to think that your work will be of poor quality.

Key fact

Customer relationships

Good customer relationships are important

- always be polite
- do not switch on a radio
- do not use a mobile phone during the 'customer's time'
- always be punctual
- always behave in a professional manner

The electrical installation in a building is often carried out alongside other trades. It makes good sense to help other trades where possible and to develop good working relationships with other employees. The customer will be most happy if the workers give an impression of working together as a team for the successful completion of the project.

Finally, remember that the customer will probably see more of the electrician and the electrical trainee than the managing director of your firm and, therefore, the image presented by you will be assumed to reflect the policy of the company. You are, therefore, your company's most important representative. Always give the impression of being capable and in command of the situation, because this gives customers confidence in the company's ability to meet their needs. However, if a problem does occur which is outside your previous experience and you do not feel confident to solve it successfully, then contact your supervisor for professional help and guidance. It is not unreasonable for a young member of the company's team to seek help and guidance from those employees with more experience. This approach would be preferred by most companies rather than having to meet the cost of an expensive blunder.

Safe working practice

If your career in the electrotechnical industry is to be a long, happy and safe one, you must always wear appropriate PPE such as footwear and head protection, and behave responsibly and sensibly in order to maintain a safe working environment. Before starting work, make a safety assessment. What is going to be hazardous, will you require PPE, do you need any special access equipment?

Construction sites can be hazardous because of the temporary nature of the construction process. The surroundings and systems are always changing as the construction process moves to its completion date when everything is finally in place.

Safe methods of working must be demonstrated by everyone at every stage. 'Employees have a duty of care to protect their own health and safety and that of others who might be affected by their work activities'.

To make the work area safe before starting work and during work activities, it may be necessary to:

- use barriers or tapes to screen off potential hazards,
- place warning signs as appropriate,
- inform those who may be affected by any potential hazard,
- use a safe isolation procedure before working on live equipment or circuits,
- obtain any necessary 'permits to work' before work begins.

Get into the habit of always working safely and being aware of the potential hazards around you when you are working.

Having chosen an appropriate wiring system which meets the intended use and structure of the building and satisfies the environmental conditions of the installation, you must install the system conductors, accessories and equipment in a safe and competent manner.

The structure of the building must be made good if it is damaged during the installation of the wiring system. For example, where conduits and trunking are run through walls and floors.

All connections in the wiring system must be both electrically and mechanically sound. All conductors must be chosen so that they will carry the design current under the installed conditions.

If the wiring system is damaged during installation it must be made good to prevent future corrosion. For example, where galvanized conduit trunking or tray is cut or damaged by pipe vices, it must be made good to prevent localized corrosion.

All tools must be used safely and sensibly. Cutting tools should be sharpened and screwdrivers ground to a sharp square end on a grindstone. Tools, plant and equipment must be locked away or in some other way made secure at the end of the working day.

It is particularly important to check that the plug top and cables of hand held electrically powered tools and extension leads are in good condition. Damaged plug tops and cables must be repaired before you use them. All electrical power tools of 110 and 230 V must be tested with a portable appliance tester (PAT) in accordance with the company's health and safety procedures, but probably at least once each year.

Tools and equipment that are left lying about in the workplace can become damaged or stolen and may also be the cause of people slipping, tripping or falling. Tidy up regularly and put power tools back in their boxes. You personally may have no control over the condition of the workplace in general, but keeping your own work area clean and tidy is the mark of a skilled and conscientious craftsman.

Finally, when the job is finished, clean up and dispose of all waste material responsibly and safety.

Safety signs

The rules and regulations of the working environment are communicated to employees by written instructions, signs and symbols. All signs in the working environment are intended to inform. They should give warning of possible dangers and must be obeyed. At first there were many different safety signs, but British Standard BS 5499 Part 1 and the Health and Safety (Signs and Signals) Regulations 1996 have introduced a standard system which gives health and safety information with the minimum use of words. The purpose of the regulations is to establish an internationally understood system of safety signs and colours which draw attention to equipment and situations that do, or could, affect health and safety. Text-only safety signs became illegal from 24 December 1998. From that date, all safety signs have had to contain a pictogram or symbol such as those shown in Fig. 1.4. Signs fall into four categories: prohibited activities; warnings; mandatory instructions and safe conditions.

Prohibition signs

These are *must not do* signs. These are circular white signs with a red border and red cross-bar, and are given in Fig. 1.5. They indicate an activity which *must not* be done.

Warning signs

Warning signs give safety information. These are triangular yellow signs with a black border and symbol, and are given in Fig. 1.6. They *give warning* of a hazard or danger.

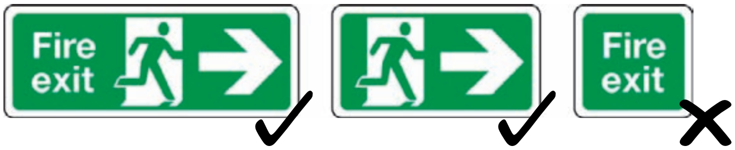

Figure 1.4 Text-only safety signs do not comply.

Figure 1.5 Prohibition signs. These are MUST NOT DO signs.

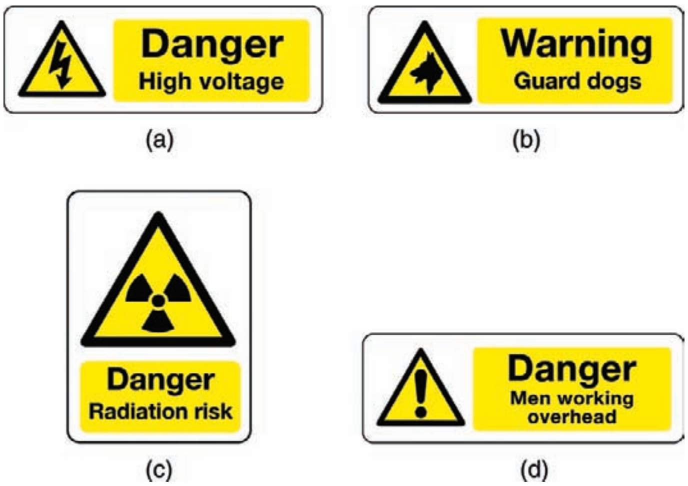

Figure 1.6 Warning signs. These give safety information.

Safety first

Safety signs

Which safety signs do you see around you

- when you are at work?
- when you are at college?

Mandatory signs

These are must do signs. These are circular blue signs with a white symbol, and are given in Fig. 1.7. They *give instructions* which must be obeyed.

Advisory or safe condition sign

These are square or rectangular green signs with a white symbol, and are given in Fig. 1.8. They *give information* about safety provision.

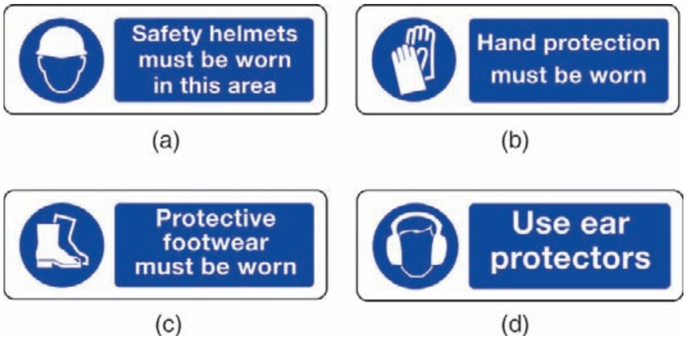

Figure 1.7 Mandatory signs. These are MUST DO signs.

Figure 1.8 Advisory or safe condition signs. These also give safety information.

Safety first

Working alone

Never work alone in:

- confined spaces
- storage tanks
- enclosed ductwork

Working alone

Some working situations are so potentially hazardous that not only must PPE be worn but you must also never work alone and safe working procedures must be in place before your work begins to reduce the risk.

It is unsafe to work in isolation in the following situations:

- when working above ground,
- when working below ground,
- when working in confined spaces,
- when working close to unguarded machinery,
- when a fire risk exists,
- when working close to toxic or corrosive substances.

Working above ground

We will look at this topic as it applies to electrotechnical personnel later in this chapter. The new Work at Height Regulations 2005 tell us that a person is at height if that person could be injured by falling from it. The regulations require that:

- We should avoid working at height if at all possible.
- No work should be done at height which can be done on the ground. For example, equipment can be assembled on the ground then taken up to height, perhaps for fixing.
- Ensure the work at height is properly planned.
- Take account of any risk assessments carried out under Regulation 3 of the Management of Health and Safety at Work Regulations.

Working below ground

Working below ground might be working in a cellar or an unventilated basement with only one entrance/exit. There is a risk that this entrance/exit might become blocked by materials, fumes or fire. When working in trenches there is always the risk of the sides collapsing if they are not adequately supported by temporary steel sheets. There is also the risk of falling objects so always:

- wear a hard hat,
- never go into an unsupported excavation,
- erect barriers around the excavation,
- provide good ladder access,
- ensure the work is properly planned,
- take account of the risk assessment before starting work.

Working in confined spaces

When working in confined spaces there is always the risk that you may become trapped or overcome by a lack of oxygen or by gas, fumes, heat or an accumulation of dust. Examples of confined spaces are:

- storage tanks and silos on farms,
- enclosed sewers and pumping stations,
- furnaces,
- ductwork.

In my experience, electricians spend a lot of time on their knees in confined spaces because many electrical cable systems run out of sight away from public areas of a building.

The Confined Spaces Regulations 1997 require that:

- A risk assessment is carried out before work commences.
- If there is a serious risk of injury in entering the confined space then the work should be done on the outside of the vessel.
- a safe working procedure, such as a ‘permit-to-work procedure’, is followed and adequate emergency arrangements put in place before work commences.

Working near unguarded machinery

There is an obvious risk in working close to unguarded machinery and indeed, most machinery will be guarded but in some production processes and with overhead travelling cranes, this is not always possible. To reduce the risks associated with these hazards:

- have the machinery stopped during your work activity if possible,
- put temporary barriers in place,

- make sure that the machine operator knows that you are working on the equipment,
- identify the location of emergency stop buttons,
- take account of the risk assessment before work commences.

A risk of fire

When working in locations containing stored flammable materials such as petrol, paraffin, diesel or bottled gas, there is always the risk of fire. To minimize the risk:

- take account of the risk assessment before work commences,
- keep the area well ventilated,
- locate the fire extinguishers,
- secure your exit from the area,
- locate the nearest fire alarm point,
- follow a safe working procedure and put adequate emergency arrangements in place before work commences.

Access equipment

Work at Height Regulations 2005

Working above ground level creates added dangers and slows down the work rate of the electrician. New Work at Height Regulations came into force on 6 April 2005. Every precaution should be taken to ensure that the working platform is appropriate for the purpose and in good condition.

Ladders

The term ladder is generally taken to include step-ladders and trestles. The use of ladders for working above ground level is only acceptable for access and work of short duration (Work at Height Regulations 2005).

It is advisable to inspect the ladder before climbing it. It should be straight and firm. All rungs and tie rods should be in position and there should be no cracks in the stiles. The ladder should not be painted since the paint may be hiding defects.

Extension ladders should be erected in the closed position and extended one section at a time. Each section should overlap by at least the number of rungs indicated below:

- Ladder up to 4.8 m length – 2 rungs overlap
- Ladder up to 6.0 m length – 3 rungs overlap
- Ladder over 6.0 m length – 4 rungs overlap.

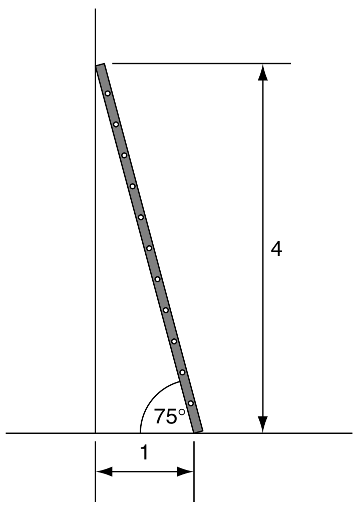

Figure 1.9 A correctly erected ladder.

The angle of the ladder to the building should be in the proportion 4 up to 1 out or 75° as shown in Fig. 1.9. The ladder should be lashed at the top and bottom when possible to prevent unwanted movement and placed on firm and level ground. Footing is only considered effective for ladders smaller than 6 m and manufactured securing devices should always be considered. When ladders provide access to a roof or working platform the ladder must extend at least 1.05 m or 5 rungs above the landing place.

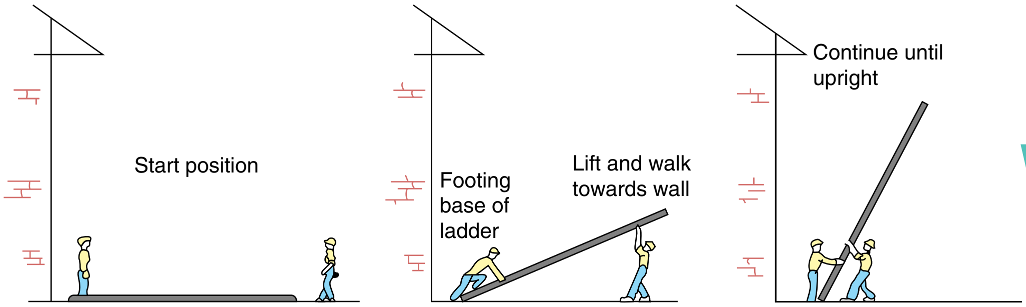

Figure 1.10 Correct procedure for erecting long or extension ladder.

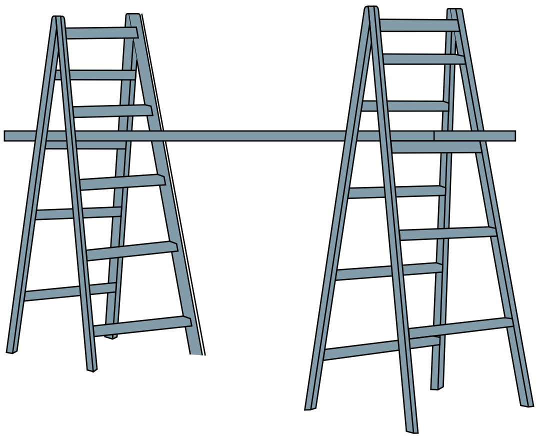

Figure 1.11 A trestle scaffold.

Short ladders may be carried by one person resting the ladder on the shoulder, but longer ladders should be carried by two people, one at each end, to avoid accidents when turning corners.

Long ladders or extension ladders should be erected by two people as shown in Fig. 1.10. One person stands on or 'foots' the ladder, while the other person lifts and walks under the ladder towards the wall. When the ladder is upright it can be positioned in the correct place, at the correct angle and secured before being climbed.

Trestle scaffold

Figure 1.11 shows a trestle scaffold. Two pairs of trestles spanned by scaffolding boards provide a simple working platform. The platform must be at least two boards or 450 mm wide. At least one-third of the trestle must be above the working platform. If the platform is more than 2 m above the ground, toeboards and guardrails must be fitted, and a separate ladder provided for access. The boards which form the working platform should be of equal length and not overhang the trestles by more than four times their own thickness. The maximum span of boards between trestles is:

- 1.3 m for boards 40 mm thick
- 2.5 m for boards 50 mm thick

Safety first

Ladders

New Working at Height Regulations tell us:

- ladders are only to be used for access
- must only be used for work of short duration

Safety first

Scaffold

Scaffolding or mobile towers are always safer than ladders for working above ground.

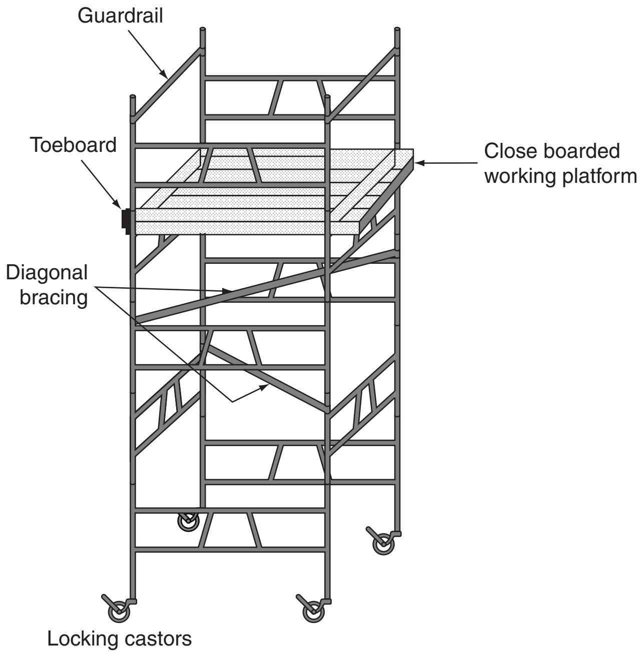

Figure 1.12 A mobile scaffold tower.

Trestles which are higher than 3.6 m must be tied to the building to give them stability. Where anyone can fall more than 4.5 m from the working platform, trestles may not be used.

Mobile scaffold towers

Mobile scaffold towers may be constructed of basic scaffold components or made from light alloy tube. The tower is built up by slotting the sections together until the required height is reached. A scaffold tower is shown in Fig. 1.12.

If the working platform is above 2 m from the ground it must be closed boarded and fitted with guardrails and toeboards. When the platform is being used, all four wheels must be locked. The platform must not be moved unless it is clear of tools, equipment and workers and should be pushed at the base of the tower and not at the top.

The stability of the tower depends upon the ratio of the base width to tower height. A ratio of base to height of 1:3 gives good stability. Outriggers can be used to increase stability by effectively increasing the base width. If outriggers are used then they must be fitted diagonally across all four corners of the tower and not on one side only. The tower must not be built more than 12 m high unless it has been specially designed for that purpose. Any tower higher than 9 m should be secured to the structure of the building to increase stability.

Access to the working platform of a scaffold tower should be by a ladder securely fastened vertically to the inside of the tower. Ladders must never be leaned against a tower since this might push the tower over.

To demonstrate that you understand this third CGLI Outcome your tutor/trainer/lecturer will assess your ability to recognize warning signs and use access equipment.

Safety first

Isolation

- never work 'live'
- isolate
- secure the isolation
- prove the supply 'dead' before starting work

Apply basic first aid procedures (CGLI Outcome 4)

First aid

Despite all the safety precautions taken on construction sites to prevent injury to the workforce, accidents do happen and *you* may be the only other person able to take action to assist a workmate. If you are not a qualified first aider limit your help to obvious common sense assistance and call for help, *but* do remember that if a workmate's heart or breathing has stopped as a result of an accident he has only minutes to live unless you act quickly. The Health and Safety (First Aid) Regulations 1981 and relevant approved codes of practice and guidance notes place a duty of care on all employers to provide *adequate* first aid facilities appropriate to the type of work being undertaken. Adequate facilities will relate to a number of factors such as:

- How many employees are employed?
- What type of work is being carried out?
- Are there any special or unusual hazards?
- Are employees working in scattered and/or isolated locations?
- Is there shift work or 'out of hours' work being undertaken?
- Is the workplace remote from emergency medical services?
- Are there inexperienced workers on site?
- What were the risks of injury and ill health identified by the company's hazard risk assessment?

The regulations state that:

> 'Employers are under a duty to provide such numbers of suitable persons as is adequate and appropriate in the circumstances for rendering first aid to his employees if they are injured or become ill at work. For this purpose a person shall not be suitable unless he or she has undergone such training and has such qualifications as the Health and Safety Executive may approve'.

This is typical of the way in which the health and safety regulations are written. The regulations and codes of practice do not specify numbers, but set out guidelines in respect of the number of first aiders needed, dependent upon the type of company, the hazards present and the number of people employed.

Let us now consider the questions 'what is first aid'? and 'who might become a first aider?' The regulations give the following definitions of first aid. 'First aid is the treatment of minor injuries which would otherwise receive no treatment or do not need treatment by a doctor or nurse' *or* 'In cases where a person will require help from a doctor or nurse, first aid is treatment for the purpose of preserving life and minimizing the consequences of an injury or illness until such help is obtained'. A more generally accepted definition of first aid might be as follows: **first aid** is the initial assistance or treatment given to a casualty for any injury or sudden illness before the arrival of an ambulance, doctor or other medically qualified person.

Now having defined first aid, who might become a first aider? A **first aider** is someone who has undergone a training course to administer first aid at work and holds a current first aid certificate. The training course and certification must be approved by the HSE. The aims of a first aider are to preserve life, to limit the worsening of the injury or illness and to promote recovery.

Definition

First aid is the initial assistance or treatment given to a casualty for any injury or sudden illness before the arrival of an ambulance, doctor or other medically qualified person.

Table 1.1 Suggested numbers of first aid personnel

Category of risk	Numbers employed at any location	Suggested number of first aid personnel
Lower risk For example, shops and offices, libraries	Fewer than 50 50–100 More than 100	At least one appointed person At least one first aider One additional first aider for every 100 employed
Medium risk For example, light engineering and assembly work, food processing, warehousing	Fewer than 20 20–100 More than 100	At least one appointed person At least one first aider for every 50 employed (or part thereof) One additional first aider for every 100 employed
Higher risk For example, most construction, slaughterhouses, chemical manufacture, extensive work with dangerous machinery or sharp instruments	Fewer than five 5–50 More than 50	At least one appointed person At least one first aider One additional first aider for every 50 employed

Definition

A *first aider* is someone who has undergone a training course to administer first aid at work and holds a current first aid certificate.

Definition

An *appointed person* is someone who is nominated to take charge when someone is injured or becomes ill, including calling an ambulance if required. The appointed person will also look after the first aid equipment, including re-stocking the first aid box.

A first aider may also undertake the duties of an appointed person. An **appointed person** is someone who is nominated to take charge when someone is injured or becomes ill, including calling an ambulance if required. The appointed person will also look after the first aid equipment, including re-stocking the first aid box.

Appointed persons should not attempt to give first aid for which they have not been trained but should limit their help to obvious common sense assistance and summon professional assistance as required. Suggested numbers of first aid personnel are given in Table 1.1. The actual number of first aid personnel must take into account any special circumstances such as remoteness from medical services, the use of several separate buildings and the company's hazard risk assessment. First aid personnel must be available at all times when people are at work, taking into account shift working patterns and providing cover for sickness absences.

Under the regulations, every company must have at least one first aid kit. The size and contents of the kit will depend upon the nature of the risks involved in the particular working environment and the number of employees. Table 1.2 gives a list of the contents of any first aid box to comply with the HSE regulations.

There now follows a description of some first aid procedures which should be practised under expert guidance before they are required in an emergency.

Bleeding

If the wound is dirty, rinse it under clean running water. Clean the skin around the wound and apply a plaster, pulling the skin together.

Table 1.2 Contents of first aid boxes

Item	Number of employees				
	1–5	6–10	11–50	51–100	101–150
Guidance card on general first aid	1	1	1	1	1
Individually wrapped sterile adhesive dressings	10	20	40	40	40
Sterile eye pads with attachment (Standard Dressing No. 16 BPC)	1	2	4	6	8
Triangular bandages	1	2	4	6	8
Sterile covering for serious wounds (where applicable)	1	2	4	6	8
Safety pins	6	6	12	12	12
Medium sized sterile unmedicated dressings (Standard Dressings No. 9 and No. 14 and the Ambulance Dressing No. 1)	3	6	8	10	12
Large sterile unmedicated dressings (Standard Dressings No. 9 and No. 14 and the Ambulance Dressing No. 1)	1	2	4	6	10
Extra large sterile unmedicated dressings (Ambulance Dressing No. 3)	1	2	4	6	8
Where tap water is not available, sterile water or sterile normal saline in disposable containers (each holding a minimum of 300 ml) must be kept near the first aid box. The following minimum quantities should be kept:					
Number of employees	1–10	11–50	51–100	101–150	
Quantity of sterile water	1 × 300 ml	3 × 300 ml	6 × 300 ml	6 × 300 ml	

If the bleeding is severe apply direct pressure to reduce the bleeding and raise the limb if possible. Apply a sterile dressing or pad and bandage firmly before obtaining professional advice.

To avoid possible contact with hepatitis or the AIDS virus, when dealing with open wounds first aiders should avoid contact with fresh blood by wearing plastic or rubber protective gloves, or by allowing the casualty to apply pressure to the bleeding wound.

Burns

Remove heat from the burn to relieve the pain by placing the injured part under clean cold water. Do not remove burnt clothing sticking to the skin. Do not apply lotions or ointments. Do not break blisters or attempt to remove loose skin. Cover the injured area with a clean dry dressing.

Broken bones

Make the casualty as comfortable as possible by supporting the broken limb either by hand or with padding. Do not move the casualty unless by remaining in that position he is likely to suffer further injury. Obtain professional help as soon as possible.

Contact with chemicals

Wash the affected area very thoroughly with clean cold water. Remove any contaminated clothing. Cover the affected area with a clean sterile dressing and seek expert advice. It is a wise precaution to treat all chemical substances as possibly harmful; even commonly used substances can be dangerous if contamination is from concentrated solutions. When handling dangerous substances, it is also good practice to have a neutralizing agent to hand.

Disposal of dangerous substances must not be into the main drains since this can give rise to an environmental hazard, but should be undertaken in accordance with Local Authority regulations.

Exposure to toxic fumes

Get the casualty into fresh air quickly and encourage deep breathing if conscious. Resuscitate if breathing has stopped. Obtain expert medical advice as fumes may cause irritation of the lungs.

Definition

Asphyxiation is a condition caused by lack of air in the lungs leading to suffocation. Suffocation may cause discomfort by making breathing difficult or it may kill by stopping the breathing.

Asphyxiation

Asphyxiation is a condition caused by lack of air in the lungs leading to suffocation. Suffocation may cause discomfort by making breathing difficult or it may kill by stopping the breathing. There is a risk of asphyxiation to workers when:

- working in confined spaces,
- working in poorly ventilated spaces,
- working in paint stores and spray booths,
- working in the petrochemical industry,
- working in any environment in which toxic fumes and gases are present.

Under the Management of Health and Safety at Work Regulations a risk assessment must be made if the environment may be considered hazardous to health. Safety procedures, including respiratory protective equipment, must be in place before work commences.

The treatment for fume inhalation or asphyxia is to get the patient into fresh air but only if you can do this without putting yourself at risk. If the patient is unconscious proceed with resuscitation as described below.

Sprains and bruising

A cold compress can help to relieve swelling and pain. Soak a towel or cloth in cold water, squeeze it out and place it on the injured part. Renew the compress every few minutes.

Breathing stopped – resuscitation

Remove any restrictions from the face and any vomit, loose or false teeth from the mouth. Loosen tight clothing around the neck, chest and waist. To ensure a good airway, lay the casualty on his back and support the shoulders on some padding. Tilt the head backwards and open the mouth. If the casualty is faintly breathing, lifting the tongue clear of the airway may be all that is necessary to restore normal breathing. However, if the casualty does not begin to breathe, open your mouth wide and take a deep breath, close the casualty's nose by pinching with your fingers, and, sealing your lips around his mouth, blow into his lungs until the chest rises. Remove your mouth and watch the casualty's chest fall. Continue this procedure at your natural breathing rate. If the mouth is damaged or you have difficulty making a seal around the casualty's mouth, close his mouth and inflate the lungs through his nostrils. Give artificial respiration until natural breathing is restored or until professional help arrives.

Heart stopped beating – chest compressions

This sometimes happens following a severe electric shock. If the casualty's lips are blue, the pupils of his eyes widely dilated and the pulse in his neck cannot be felt, then he may have gone into cardiac arrest. Act quickly and lay the casualty on his back. Kneel down beside him and place the heel of one hand in the centre of his chest. Cover this hand with your other hand and interlace the fingers. Straighten your arms and press down on his chest sharply with the heel of your hands and then release the pressure. Continue to do this 15 times at the rate of one push per second. Check the casualty's pulse. If none is felt, give two breaths of artificial respiration and then a further 15 chest compressions. Continue this procedure until the heartbeat is restored and the artificial respiration until normal breathing returns. Pay close attention to the condition of the casualty while giving heart massage. When a pulse is restored the blueness around the mouth will quickly go away and you should stop the heart massage. Look carefully at the rate of breathing. When this is also normal, stop giving artificial respiration. Treat the casualty for shock, place him in the recovery position and obtain professional help.

Shock

Everyone suffers from shock following an accident. The severity of the shock depends upon the nature and extent of the injury. In cases of severe shock the casualty will become pale and his skin becomes clammy from sweating. He may feel faint, have blurred vision, feel sick and complain of thirst. Reassure the casualty that everything that needs to be done is being done. Loosen tight clothing and keep him warm and dry until help arrives. *Do not* move him unnecessarily or give him anything to drink.

Every accident must be reported to an employer and minor accidents reported to a supervisor, safety officer or first aider. Details of the accident and treatment given must be suitably documented as described later in this book under the sub-heading 'Accident reports'.

If the accident results in death, serious injury or an injury that leads to an absence from work of more than 3 days, then your employer must report the accident to the local office of the HSE.

Emergency procedures – electric shock

Electric shock occurs when a person becomes part of the electrical circuit, as shown in Fig. 1.13. The level or intensity of the shock will depend upon many factors, such as age, fitness and the circumstances in which the shock is received. The lethal level is approximately 50 mA, above which muscles

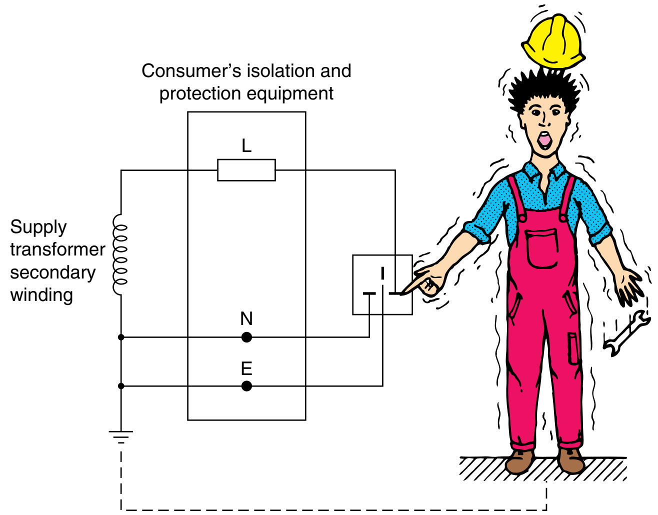

Figure 1.13 Touching live and earth or live and neutral makes a person part of the electrical circuit and can lead to an electric shock.

contract, the heart flutters and breathing stops. A shock above the 50 mA level is therefore fatal unless the person is quickly separated from the supply. Below 50 mA, only an unpleasant tingling sensation may be experienced or you may be thrown across a room, roof or ladder, but the resulting fall may lead to serious injury.

To prevent people receiving an electric shock accidentally, all circuits contain protective devices. All exposed metal is earthed, and fuses and MCBs are designed to trip under fault conditions.

Construction workers and particularly electricians do receive electric shocks, usually as a result of carelessness or unforeseen circumstances. When this happens it is necessary to act quickly to prevent the electric shock becoming fatal. Actions to be taken upon finding a workmate receiving an electric shock are as follows:

- Switch off the supply if possible.
- Alternatively, remove the person from the supply *without touching him*, for example, push him off with a piece of wood, pull him off with a scarf, dry towel or coat.
- If breathing or the heart has stopped, immediately call professional help by dialling 999 or 112 and asking for the ambulance service. Give precise directions to the scene of the accident. The casualty stands the best chance of survival if the emergency services can get a rapid-response paramedic team quickly to the scene. They have extensive training and will have specialist equipment with them.
- Only then should you treat for shock by applying resuscitation or cardiac massage until the patient recovers, or help arrives.

To reduce the risk of an electric shock at work we should:

- Avoid contact with live parts by insulating all live parts and placing them out of reach by using barriers or temporary barriers.
- Check and inspect all cables and equipment for damage before using them.
- PAT test all portable equipment.

Figure 1.14 First aid logbook/accident book with data protection compliant removable sheets.

- Use only low voltage or battery tools.
- Use a secure electrical isolation procedure before beginning work.

Accident reports

Every accident must be reported to an employer and minor accidents reported to a supervisor, safety officer or first aider and the details of the accident and treatment given suitably documented. A first aid logbook or accident book such as that shown in Fig. 1.14 containing first aid treatment record sheets could be used to effectively document accidents which occur in the workplace and the treatment given. Failure to do so may influence the payment of compensation at a later date if an injury leads to permanent disability. To comply with the Data Protection Regulations, from 31 December 2003 all first aid treatment logbooks or accident report books must contain perforated sheets which can be removed after completion and filed away for personal security.

If the accident results in death, serious injury or an injury that leads to an absence from work of more than 3 days, then your employer must report the accident to the local office of the HSE. The quickest way to do this is to call the Incident Control Centre on 0845 300 9923. They will require the following information:

- The name of the person injured.
- A summary of what happened.
- A summary of events prior to the accident.
- Information about the injury or loss sustained.
- Details of witnesses.
- Date and time of accident.
- Name of the person reporting the incident.

The Incident Control Centre will forward a copy of every report they complete to the employer for them to check and hold on record. However, good practice would recommend an employer or his representative make an extensive report of any serious accident that occurs in the workplace. In addition to recording the above information, the employer or his representative should:

- Sketch diagrams of how the accident occurred, where objects were before and after the accident, where the victim fell, etc.

- Take photographs or video that show how things were after the accident, for example, broken stepladders, damaged equipment, etc.
- Collect statements from witnesses. Ask them to write down what they saw.
- Record the circumstances surrounding the accident. Was the injured person working alone – in the dark – in some other adverse situation or condition – was PPE being worn – was PPE recommended in that area?

The above steps should be taken immediately after the accident has occurred and after the victim has been sent for medical attention. The area should be made safe and the senior management informed so that any actions to prevent a similar occurrence can be put in place. Taking photographs and obtaining witnesses' statements immediately after an accident happens means that evidence may still be around and memories still sharp.

To demonstrate that you understand this final Outcome in Unit 311 your tutor/trainer/lecturer will assess your ability to apply basic first aid procedures.

CHAPTER 2

Applying environmental legislation and environmental technology systems

Unit 312 of the City and Guilds 2357 syllabus

Applying environmental legislation, working practices and the principles of environmental technology systems

When you have completed this chapter you should be able to:

1. Apply environmental legislation
2. Apply work methods and procedures
3. Describe environmental technology systems

Apply environmental legislation and working practice to environmental technology systems (CGLI Outcomes 1 and 2)

Environmental laws and regulations

The environment describes the world in which we live, work and play; it relates to our neighbourhood and surroundings.

Environmental laws protect the environment in which we live by setting standards for the control of pollution to land, air and water.

If a wrong is identified in the area in which we now think of as 'environmental' it can be of two kinds:

1 An offence in common law which means damage to property, nuisance or negligence leading to a claim for damages.

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2 A statutory offence against one of the laws dealing with the protection of the environment. These offences are nearly always 'crimes' and punished by fines or imprisonment rather than by compensating any individual.

The legislation dealing with the environment has evolved for each part – air, water, land, noise, radioactive substances etc. Where an organization's activities impact upon the environmental laws they are increasingly adopting environmental management systems which comply with ISO 14001. Let us now look at some of the regulations and try to see the present picture at the beginning of the new millennium.

Environmental Protection Act 1990

In the context of environmental law, the Environmental Protection Act 1990 was a major piece of legislation. The main sections of the Act are:

Part 1 Integrated pollution control by HM Inspectorate of Pollution, and air pollution control by Local Authorities

Part 2 Wastes on land

Part 3 Statutory nuisances and clean air

Part 4 Litter

Part 5 Radioactive Substances Act 1960

Part 6 Genetically modified organisms

Part 7 Nature conservation

Part 8 Miscellaneous, including contaminated land.

The Royal Commission of 1976 identified that a reduction of pollutant to one medium, air, water or land, then led to an increase of pollutant to another. It therefore stressed the need to take an integrated approach to pollution control. The processes subject to an integrated pollution control are:

- Air emissions.
- Processes which give rise to significant quantities of special waste, that is, waste defined in law in terms of its toxicity or flammability.
- Processes giving rise to emissions to sewers or 'Red List' substances. These are 23 substances including mercury, cadmium and many pesticides, which are subject to discharge consent to the satisfaction of the Environment Agency.

Where a process is under integrated control the Inspectorate is empowered to set conditions to ensure that the best practicable environmental option (BPEO) is employed to control pollution. This is the cornerstone of the Environmental Protection Act.

Pollution Prevention and Control Regulations 2000

The system of pollution prevention and control is replacing that of integrated pollution control established by the Environmental Protection Act 1990, thus bringing environmental law into the new millennium and implementing European Directive (EC/96/61) on integrated pollution prevention and control. The new system was fully implemented in 2007.

Pollution prevention and control is a regime for controlling pollution from certain industrial activities. This regime introduces the concept of Best Available Technique (BAT) for reducing and preventing pollution to an acceptable level.

Industrial activities are graded according to their potential to pollute the environment:

- A(1) installations are regulated by the Environment Agency.
- A(2) installations are regulated by the Local Authorities.
- Part B installations are also regulated by the Local Authority.

All three systems require the operators of certain industrial installations to obtain a permit to operate. Once an operator has submitted a permit application, the regulator then decides whether to issue a permit. If one is issued it will include conditions aimed at reducing and preventing pollution to acceptable levels. A(1) installations are generally perceived as having the greatest potential to pollute the environment. A(2) installations and Part B installations would have the least potential to pollute.

The industries affected by these regulations are those dealing with petrol vapour recovery, incineration of waste, mercury emissions from crematoria, animal rendering, non-ferrous foundry processes, surface treating of metals and plastic materials by powder coating, galvanizing of metals and the manufacture of certain specified composite wood-based boards.

Clean Air Act 1993

We are all entitled to breathe clean air but until quite recently the only method of heating houses and workshops was by burning coal, wood or peat in open fires. The smoke from these fires created air pollution and the atmosphere in large towns and cities was of poor quality. On many occasions in the 1950s the burning of coal in London was banned because the city was grinding to a halt because of the combined effect of smoke and fog, called smog. Smog was a very dense fog in which you could barely see more than a metre in front of you and which created serious breathing difficulties. In the new millennium we are no longer dependent upon coal and wood to heat our buildings; smokeless coal has been created and the gaseous products of combustion are now diluted and dispersed by new chimney design regulations. Using well engineered combustion equipment together with the efficient arrestment of small particles in commercial chimneys of sufficient height, air pollution has been much reduced. This is what the Clean Air Act set out to achieve and it has been largely successful.

The **Clean Air Act** applies to all small and medium sized companies operating furnaces, boilers, or incinerators. Compliance with the Act does not require an application for authorization and so companies must make sure that they do not commit an offence. In general the emission of dark smoke from any chimney is unacceptable. The emission of dark smoke from any industrial premises is also unacceptable. This might be caused by, for example, the burning of old tyres or old cable.

In England, Scotland and Wales it is not necessary for the Local Authority to have witnessed the emission of dark smoke before taking legal action. Simply the evidence of burned materials, which potentially give rise to dark smoke when burned, is sufficient. In this way the law aims to stop people creating dark smoke under the cover of darkness.

A **public nuisance** is 'an act unwarranted by law or an omission to discharge a legal duty which materially affects the life, health, property, morals or reasonable comfort or convenience of Her Majesty's subjects'. This is a criminal offence and Local Authorities can prosecute, defend or appear in proceedings that affect the inhabitants of their area.

Definition

The *Clean Air Act* applies to all small and medium sized companies operating furnaces, boilers, or incinerators.

Definition

A *public nuisance* is 'an act unwarranted by law or an omission to discharge a legal duty which materially affects the life, health, property, morals or reasonable comfort or convenience of Her Majesty's subjects'.

Controlled Waste Regulations 1998

Under these regulations we have a 'Duty of Care to handle, recover and dispose of all waste responsibly'. This means that all waste must be handled, recovered and disposed of by individuals or businesses that are authorized to do so under a system of signed Waste Transfer Notes.

The Environmental Protection (Duty of Care) Regulations 1991 state that as a business you have a duty to ensure that any waste you produce is handled safely and in accordance with the law. This is the 'Duty of Care' and applies to anyone who produces, keeps, carries, treats or disposes of waste from business or industry.

You are responsible for the waste that you produce, even after you have passed it on to another party such as a skip hire company, a scrap metal merchant, recycling company or local council. The Duty of Care has no time limit and extends until the waste has either been finally and properly disposed of or fully recovered.

So what does this mean for your company?

- Make sure that waste is only transferred to an authorized company.
- Make sure that waste being transferred is accompanied by the appropriate paperwork showing what was taken, where it was to be taken and by whom.
- Segregate the different types of waste that your work creates.
- Label waste skips and waste containers so that it is clear to everyone what type of waste goes into that skip.
- Minimize the waste that you produce and do not leave waste behind for someone else to clear away. Remember there is no time limit on your Duty of Care for waste.

Definition

Special waste is covered by the Special Waste Regulations 1996 and is waste that is potentially hazardous or dangerous and which may, therefore, require special precautions during handling, storage, treatment or disposal. Examples of special waste are asbestos, lead-acid batteries, used engine oil, solvent-based paint, solvents, chemical waste and pesticides.

Occupiers of domestic properties are exempt from the Duty of Care for the household waste that they produce. However, they do have a Duty of Care for the waste produced by, for example, a tradesperson working at a domestic property.

Special waste is covered by the Special Waste Regulations 1996 and is waste that is potentially hazardous or dangerous and which may, therefore, require special precautions during handling, storage, treatment or disposal. Examples of special waste are asbestos, lead-acid batteries, used engine oil, solvent-based paint, solvents, chemical waste and pesticides. The disposal of special waste must be carried out by a competent person, with special equipment and a licence.

Hazardous Waste Regulations 2005

New Hazardous Waste Regulations were introduced in July 2005 and under these regulations electric discharge lamps and tubes such as fluorescent, sodium, metal halide and mercury vapour are classified as hazardous waste. While each lamp only contains a very small amount of mercury, vast numbers are used and disposed of each year, resulting in a significant environmental threat. The environmentally responsible way to dispose of lamps and tubes is to recycle them and this process is now available through the electrical wholesalers.

Electrotechnical companies produce relatively small amounts of waste and even smaller amounts of special waste. Most companies buy in the expertise of specialist waste companies these days and build these costs into the contract.

Packaging (Essential Requirements) Regulations 2003

The new Packaging Regulations were introduced on 25 August 2003 bringing the UK into harmony with Europe. The regulations deal with the essential requirements of packaging for the storage and transportation of goods. There are two essential elements to the regulations:

1. the packaging shall be designed and manufactured so that the volume and weight is to the minimum amount required to maintain the necessary level of safety for the packaged product, and
2. the packaging shall be designed and manufactured in such a way that the packaging used is either reusable or rerecyclable.

The regulations are enforced by the Weights and Measures Authority in Great Britain, the Department of Enterprise Trade and Investment in Northern Ireland and the Procurator-fiscal or Lord Advocate in Scotland.

Waste Electrical and Electronic Equipment EU Directive 2007

The Waste Electrical and Electronic Equipment (WEEE) Regulations will ensure that Britain complies with its EU obligation to recycle waste from electrical products. The regulation came into effect in July 2007 and from that date any company which makes, distributes or trades in electrical or electronic goods such as household appliances, sports equipment and even torches and toothbrushes will have to make arrangements for recycling these goods at the end of their useful life. Batteries will be covered separately by yet another forthcoming EU directive.

Some sectors are better prepared for the new regulations than others. Mobile phone operators, O2, Orange, Virgin and Vodafone, along with retailers such as Currys and Dixons, have already joined together to recycle their mobile phones collectively. In Holland the price of a new car now includes a charge for the recycling costs.

Further information is available on the DTI and DEFRA website under WEEE.

Radioactive Substances Act 1993

These regulations apply to the very low ionizing radiation sources used by specialized industrial contractors. The radioactive source may be sealed or unsealed. Unsealed sources are added to a liquid in order to trace the direction or rate of flow of that liquid. Sealed radioactive sources are used in radiography for the non-destructive testing of materials or in liquid level and density gauges.

This type of work is subject to the Ionising Radiations Regulations 1999 (IRR), which impose comprehensive duties on employers to protect people at work against exposure to ionizing radiation. These regulations are enforced by the HSE, while the Radioactive Substances Act (RSA) is enforced by the Environmental Agency.

The RSA 1993 regulates the keeping, use, accumulation and disposal of radioactive waste, while the IRR 1999 regulates the working and storage conditions when using radioactive sources. The requirements of RSA 1993 are in addition to and separate from IRR 1999 for any industry using radioactive sources. These regulations also apply to off shore installations and to work in connection with pipelines.

Dangerous Substances and Preparations and Chemicals Regulations 2000

Chemical substances that are classified as carcinogenic, mutagenic or toxic, or preparations which contain those substances, constitute a risk to the general public because they may cause cancer, genetic disorders and birth defects, respectively.

These regulations were introduced to prohibit the supply of these dangerous drugs to the general public, to protect consumers from contracting fatal diseases through their use.

The regulations require that new labels be attached to the containers of these drugs which identify the potential dangers and indicate that they are restricted to professional users only.

The regulations implement Commission Directive 99/43/EC, known as the 17th Amendment, which brings the whole of Europe to an agreement that these drugs must not be sold to the general public, this being the only way of offering the highest level of protection for consumers.

The regulations are enforced by the Local Authority Trading Standards Department.

Noise regulations

Before 1960 noise nuisance could only be dealt with by common law as a breach of the peace under various Acts or local by-laws. In contrast, today there are many statutes, government circulars, British Standards and EU Directives dealing with noise matters. Environmental noise problems have been around for many years. During the eighteenth century, in the vicinity of some London hospitals, straw was put on the roads to deaden the sound of horses' hooves and the wheels of carriages. Today we have come a long way from this self-regulatory situation.

Definition

'A *statutory nuisance* must materially interfere with the enjoyment of one's dwelling. It is more than just irritating or annoying and does not take account of the undue sensitivity of the receiver'.

In the context of the Environmental Protection Act 1990*,* noise or vibration is a **statutory nuisance** if it is prejudicial to health or is a nuisance. However, nuisance is not defined and has exercised the minds of lawyers, magistrates and judges since the concept of nuisance was first introduced in the 1936 Public Health Act. There is a wealth of case law but a good working definition might be 'A statutory nuisance must materially interfere with the enjoyment of one's dwelling. It is more than just irritating or annoying and does not take account of the undue sensitivity of the receiver'.

The line that separates nuisance from no nuisance is very fine and non-specific. Next door's intruder alarm going off at 3 a.m. for an hour or more is clearly a statutory nuisance, whereas one going off a long way from your home would not be a nuisance. Similarly, an all night party with loud speakers in the garden would be a nuisance, whereas an occasional party finishing at say midnight would not be a statutory nuisance.

At Stafford Crown Court on 1 November 2004, Alton Towers, one of the country's most popular theme parks, was ordered by a judge to reduce noise levels from its 'white knuckle' rides. In the first judgment of its kind, the judge told the Park's owners that neighbouring residents must not be interrupted by noise from rides such as Nemesis, Air, Corkscrew, Oblivion or from loudspeakers or fireworks.

The owners of Alton Towers, Tussauds Theme Parks Ltd, were fined the maximum sum of £5000 and served with a Noise Abatement Order for being guilty of breaching the 1990 Environmental Protection Act. Mr Richard Buxton, for the prosecution, said that the £5000 fine reflected the judge's view that Alton Towers had made little or no effort to reduce the noise nuisance.

Many nuisance complaints under the Act are domestic and are difficult to assess and investigate. Barking dogs, stereos turned up too loud, washing machines running at night to use 'low cost' electricity, television, DIY activities are all difficult to assess precisely as statutory nuisance. Similarly, sources of commercial noise complaints are also varied and include deliveries of goods during the night, general factory noises, refrigeration units, noise from public houses and clubs are all common complaints.

Industrial noise can be complex and complaints difficult to resolve both legally and technically. Industrial noise assessment is aided by BS 4142 but no guidance exists for other noise nuisance. The Local Authority has a duty to take reasonable steps to investigate all complaints and to take appropriate action.

The Noise and Statutory Nuisance Act 1993

This Act extended the statutory nuisance provision of the Environmental Protection Act 1990 to cover noise from vehicles, machinery or equipment in the streets. The definition of equipment includes musical instruments but the most common use of this power is to deal with car alarms and house intruder alarms being activated for no apparent reason and which then continue to cause a nuisance for more than 1 hour.

Noise at Work Regulations 1989

The Noise at Work Regulations, unlike the previous vague or limited provisions, apply to all work places and require employers to carry out assessments of the noise levels within their premises and to take appropriate action where necessary. The 1989 regulations came into force on 1 January 1990 implementing in the United Kingdom EC Directive 86/188/EEC 'The Protection of Workers from Noise'.

Three action levels are defined by the regulations:

1. The first action level is a daily personal noise exposure of 85 dB, expressed as 85 dB(A).
2. The second action level is a daily personal noise exposure of 90 dB(A).
3. The third defined level is a peak action level of 140 dB(A) or 200 Pa of pressure which is likely to be linked to the use of cartridge operated tools, shooting guns or similar loud explosive noises. This action level is likely to be most important where workers are subjected to a small number of loud impulses during an otherwise quiet day.

The Noise at Work Regulations are intended to reduce hearing damage caused by loud noise. So, what is a loud noise? If you cannot hear what someone is saying when they are 2 m away from you or if they have to shout to make themselves heard, then the noise level is probably above 85 dB and should be measured by a competent person.

At the first action level an employee must be provided with ear protection (ear muffs or ear plugs) on request. At the second action level the employer must reduce, so far as is reasonably practicable, other than by providing ear protection, the exposure to noise of that employee.

Hearing damage is cumulative; it builds up, leading eventually to a loss of hearing ability. Young people, in particular, should get into the routine of avoiding noise exposure before their hearing is permanently damaged. The damage can also take the form of permanent tinnitus (ringing noise in the ears) and an inability to distinguish words of similar sound such as bit and tip.

Vibration is also associated with noise. Direct vibration through vibrating floors or from vibrating tools, can lead to damage to the bones of the feet or hands. A condition known as ‘vibration white finger’ is caused by an impaired blood supply to the fingers, associated with vibrating hand tools.

Employers and employees should not rely too heavily on ear protectors. In practice, they reduce noise exposure far less than is often claimed, because they may be uncomfortable or inconvenient to wear. To be effective, ear protectors need to be worn all the time when in noisy places. If left off for even a short time, the best protectors cannot reduce noise exposure effectively.

Protection against noise is best achieved by controlling it at source. Wearing ear protection must be a last resort. Employers should:

- Design machinery and processes to reduce noise and vibration (mounting machines on shock absorbing materials can dampen out vibration).
- When buying new equipment, where possible, choose quiet machines. Ask the supplier to specify noise levels at the operator’s working position.
- Enclose noisy machines in sound absorbing panels.
- Fit silencers on exhaust systems.
- Install motor drives in a separate room away from the operator.
- Inform workers of the noise hazard and get them to wear ear protection.
- Reduce a worker’s exposure to noise by job rotation or provide a noise refuge.

New regulations introduced in 2006 reduced the first action level to 80 dB(A) and the second level to 85 dB(A) with a peak action level of 98 dB(A) or 140 Pa of pressure. Every employer must make a ‘noise’ assessment and provide workers with information about the risks to hearing if the noise level approaches the first action level. He must do all that is reasonably practicable to control the noise exposure of his employees and clearly mark ear protection zones. Employees must wear personal ear protection whilst in such a zone.

The EHO (Environmental Health Officer)

The responsibilities of the EHO are concerned with reducing risks and eliminating the dangers to human health associated with the living and working environment. EHOs are responsible for monitoring and ensuring the maintenance of standards of environmental and public health, including food safety, workplace health and safety, housing, noise, odour, industrial waste, pollution control and communicable diseases in accordance with the law. Although they have statutory powers with which to enforce the relevant regulations, the majority of their work involves advising and educating in order to implement public health policies.

The majority of EHOs are employed by Local Authorities, who are the agencies concerned with the protection of public health. Increasingly, however, officers are being employed by the private sector, particularly those concerned with food, such as large hotel chains, airlines and shipping companies.

Your Local Authority EHOs would typically have the responsibility of enforcing the environmental laws discussed above. Their typical work activities are to:

- ensure compliance with the Health and Safety at Work Act 1974, the Food Safety Act 1990 and the Environmental Protection Act 1990;
- carry out health and safety investigations, food hygiene inspections and food standards inspections;
- investigate public health complaints such as illegal dumping of rubbish, noise complaints and inspect contaminated land;
- investigate complaints from employees about their workplace and carry out accident investigations;
- investigate food poisoning outbreaks;
- obtain food samples for analysis where food is manufactured, processed or sold;
- visit housing and factory accommodation to deal with specific incidents such as vermin infestation and blocked drains;
- test recreational water, such as swimming pool water and private water supplies in rural areas;
- inspect and licence pet shops, animal boarding kennels, riding stables and zoos;
- monitor air pollution in heavy traffic areas and remove abandoned vehicles;
- work in both an advisory capacity and as enforcers of the law, educating managers of premises on issues which affect the safety of staff and members of the public.

In carrying out these duties, officers have the right to enter any workplace without giving notice, although notice may be given if they think it appropriate. They may also talk to employees, take photographs and samples and serve an Improvement Notice, detailing the work which must be carried out if they feel that there is a risk to health and safety that needs to be dealt with.

Enforcement law inspectors

If the laws relating to work, the environment and people are to be effective, they must be able to be enforced. The system of control under the Health and Safety at Work Act comes from the HSE or the Local Authority. Local Authorities are responsible for retail and service outlets such as shops, garages, offices, hotels, public houses and clubs. The HSE are responsible for all other work premises including the Local Authorities themselves. Both groups of inspectors have the same powers. They are allowed to:

- enter premises, accompanied by a police officer if necessary;
- examine, investigate and require the premises to be left undisturbed;
- take samples and photographs as necessary, dismantle and remove equipment;
- require the production of books or documents and information;
- seize, destroy or render harmless any substance or article;
- issue enforcement notices and initiate prosecutions.

There are two types of enforcement notices, an '**improvement notice**' and a '**prohibition notice**'.

Definition

An *improvement notice* identifies a contravention of the law and specifies a date by which the situation is to be put right.

Definition

A *prohibition notice* is used to stop an activity which the inspector feels may lead to serious injury.

An improvement notice identifies a contravention of the law and specifies a date by which the situation is to be put right. An appeal may be made to an Employment Tribunal within 21 days.

A prohibition notice is used to stop an activity which the inspector feels may lead to serious injury. The notice will identify which legal requirement is being contravened and the notice takes effect as soon as it is issued. An appeal may be made to the Employment Tribunal but the notice remains in place and work is stopped during the appeal process.

Cases may be heard in the Magistrates' or Crown Courts.

Magistrates' Court (Summary Offences) for health and safety offences: employers may be fined up to £20,000 and employees or individuals up to £5000. For failure to comply with an enforcement notice or a court order, anyone may be imprisoned for up to 6 months.

Crown Court (Indictable Offences) for failure to comply with an enforcement notice or a court order: fines are unlimited in the Crown Court and may result in imprisonment for up to 2 years.

Actions available to an inspector upon inspection of premises:

- Take no action – the law is being upheld.
- Give verbal advice – minor contraventions of the law identified.
- Give written advice – omissions have been identified and a follow up visit will be required to ensure that they have been corrected.
- Serve an improvement notice – a contravention of the law has, or is taking place and the situation must be remedied by a given date. A follow up visit will be required to ensure that the matter has been corrected.
- Serve a prohibition notice – an activity has been identified which may lead to serious injury. The law has been broken and the activity must stop immediately;
- Prosecute – the law has been broken and the employer prosecuted.

On any visit one or more of the above actions may be taken by the inspector.

Building Regulations – Part P 2006

The Building Regulations lay down the design and build standards for construction work in buildings in a series of Approved Documents. The scope of each Approved Document is given below:

Part A structure

Part B fire safety

Part C site preparation and resistance to moisture

Part D toxic substances

Part E resistance to the passage of sound

Part F ventilation

Part G hygiene

Part H drainage and waste disposal

Part J combustion appliances and fuel storage systems

Part K protection from falling, collision and impact

Part L conservation of fuel and power

Part M access and facilities for disabled people

Part N glazing – safety in relation to impact, opening and cleaning

Part P electrical safety.

The Building Regulations are one of the most important pieces of legislation controlling the installation of environmental technology systems.

Part P of the Building Regulations was published on 22 July 2004, bringing domestic electrical installations in England and Wales under building regulations control. This means that anyone carrying out domestic electrical installation work from 1 January 2005 must comply with Part P of the Building Regulations. An amended document was published in an attempt at greater clarity and this came into effect on 6 April 2006.

If the electrical installation meets the requirements of the IEE Regulations BS 7671, then it will also meet the requirements of Part P of the Building Regulations, so no change there. What is going to change under Part P is this new concept of 'notification' to carry out electrical work.

Notifiable electrical work

Any work to be undertaken by a firm or individual who is *not* registered under an 'approved competent person scheme' must be notified to the Local Authority Building Control Body before work commences. That is, work that involves:

- the provision of at least one new circuit,
- work carried out in kitchens,
- work carried out in bathrooms,
- work carried out in special locations such as swimming pools and hot air saunas.

Upon completion of the work, the Local Authority Building Control Body will test and inspect the electrical work for compliance with Part P of the Building Regulations.

Non-notifiable electrical work

Work carried out by a person or firm registered under an authorized Competent Persons Self-Certification Scheme or electrical installation work that does not include the provision of a new circuit. This includes work such as:

- replacing accessories such as socket outlets, control switches and ceiling roses;
- replacing a like for like cable for a single circuit which has become damaged by, for example, impact, fire or rodent;
- re-fixing or replacing the enclosure of an existing installation component provided the circuit's protective measures are unaffected;
- providing mechanical protection to existing fixed installations;
- adding lighting points (light fittings and switches) to an existing circuit, provided that the work is not in a kitchen, bathroom or special location;
- installing or upgrading the main or supplementary equipotential bonding provided that the work is not in a kitchen, bathroom or special location.

All replacement work is non-notifiable even when carried out in kitchens, bathrooms and special locations, but certain work carried out in kitchens, bathrooms and special locations may be notifiable, even when carried out by an authorized competent person. The IEE have published a guide called the *Electricians' Guide* to the Building Regulations which brings clarity to this subject. In specific cases the Local Authority Building Control Officer or an approved inspector will be able to confirm whether Building Regulations apply.

Failure to comply with the Building Regulations is a criminal offence and Local Authorities have the power to require the removal or alteration of work that does not comply with these requirements.

Electrical work carried out by DIY home-owners will still be permitted after the introduction of Part P. Those carrying out notifiable DIY work must first submit a building notice to the Local Authority before the work begins. The work must then be carried out to the standards set by the IEE Wiring Regulations BS 7671 and a building control fee paid for such work to be inspected and tested by the Local Authority.

Competent Persons Scheme

The Competent Persons Self-Certification Scheme is aimed at those who carry out electrical installation work as the primary activity of their business. The government has approved schemes to be operated by BRE Certification Ltd, British Standards Institution, ELECSA Ltd, NICEIC Certification Services Ltd, and Napit Certification Services Ltd. All the different bodies will operate the scheme to the same criteria and will be monitored by the Department for Communities and Local Government, formally called the Office of the Deputy Prime Minister. Installers of environmental technology systems must also be registered under the scheme.

Those individuals or firms wishing to join the Competent Persons Scheme will need to demonstrate their competence, if necessary, by first undergoing training. The work of members will then be inspected at least once each year. There will be an initial registration and assessment fee and then an annual membership and inspection fee.

To demonstrate that you understand the first and second CGLI Outcomes your tutor/trainer/lecturer will assess your ability to apply environmental legislation and working practice to environmental technology systems.

Describe environmental technology systems (CGLI Outcome 3)

Environmental energy generation

Most of the electrical energy generated in today's power stations is produced from coal and oil, both of which release a lot of CO_2 into the atmosphere, causing climate change. However, following the introduction of the Climate Change Act in 2008 the UK and Europe have agreed to reduce the CO_2 gas emissions from power generation by 20% by the year 2020 and by 60% by 2050. Meeting these targets will mean basing much of the new energy infrastructure around renewable energy, particularly offshore wind power and micro-generation systems.

Wind energy

The Department of Energy and Climate Change considers wind energy from offshore wind farms to be the most promising of all the renewable energy alternatives in meeting the 2020 and 2050 targets for reducing CO_2 emissions.

Wave energy

The UK is a small island surrounded by water. Surely we could harness some of the energy contained in the tides and waves to generate electrical energy! Well, all the research and development to date is at the prototype stage right now.

Micro-hydropower generation

The use of small hydropower is gaining popularity as an alternative to expensive diesel generation especially in remote off grid communities in Canada and China. In the UK in the Cumbrian Lake District and the Derbyshire Peak District local communities are using the energy from fast flowing rivers to support their local communities by generating electrical energy from water power.

Solar thermal

Solar thermal hot water heating systems are recognized as a reliable way to use the energy of the sun to heat water. The technology is straightforward: a solar panel is placed on the roof and water is pumped around the panel and a heat exchanger situated in the domestic water cylinder. This system heats the domestic hot water.

Solar photovoltaic

Photovoltaic cells in panels are placed upon the roof and turn sunlight directly into electricity. They can be 'stand alone' systems operating in remote areas, or operated in parallel with the a.c. mains supply. When connected to a 'smart meter', PV generators can be very profitable in domestic and commercial buildings.

Ground source heat pumps

Ground source heat pumps extract heat from the ground by circulating a fluid through pipes buried in the ground. A heat exchanger and pump extract heat from these pipes. The heat is then used to provide underfloor radiant heating or water heating.

Combined heat and power

CHP is the simultaneous generation of usable heat and power in a single process. That is, heat is produced as a by-product of the power generation process. The heat is then used to provide radiant heating in nearby buildings.

Water conservation

Conservation is the preservation of something important, especially of the natural environment. Available stored water is a scarce resource in England and Wales where there is only 1400 cubic meters per person per year—very little compared with France, which has 3100 cubic meters per person per year, Italy which has 2900 and Spain 2800. About a half of the water used by an average home is used to shower, bathe and wash the laundry; another third is used to flush the toilet.

At a time when most domestic and commercial properties have water meters installed it saves money to harvest and re-use water.

The City and Guilds have asked us to look at two methods of water conservation, by rainwater harvesting and grey water recycling.

Rainwater harvesting

Rainwater harvesting is the collection and storage of rainwater for future use. Rainwater has in the past been used for drinking, water for livestock and water for irrigation. It is now also being used to provide water for car cleaning and garden irrigation in domestic and commercial buildings.

Many gardeners already harvest rainwater for garden use by collecting run off from a roof or greenhouse and storing it in a water butt or water barrel. However a 200 litre water butt does not give much drought protection although garden plants much prefer rainwater to fluoridated tap water. To make a useful contribution the rainwater storage tank should be between 2,000 and 7,000 litre capacity. The rainwater collecting surfaces will be the roof of the building and any hard paved surfaces such as patios. Down pipes and drainage pipes then route the water to the storage tank situated, perhaps under the lawn. An electric pump lifts the water from the storage tank to the point of use, possibly a dedicated outdoor tap. The water is then distributed through a hose pipe or sprinkler system to the garden in the normal way.

With a little extra investment, rainwater can be filtered and used inside the house to supply washing machines and WCs. Installing domestic pipes and interior plumbing can be added to existing homes although it is more straightforward in a new build home.

With the move toward more sustainable homes UK architects are becoming more likely to specify rainwater harvesting in their design to support alternatives to a mains water supply. In Germany rainwater harvesting systems are now installed as standard in all new commercial buildings.

Grey water recycling

Grey water is tap water which has already performed one operation and is then made available to be used again instead of flushing it down the drain. Grey water recycling offers a way of getting double the use out of the world's most precious resource.

There are many products on the market such as the BRAC system which takes in water used in the shower, bath and laundry, cleans it by filtering and then reuses it for toilet flushing. It is only a matter of routeing the grey waste water drain-pipe from the bath, shower and laundry to the filter unit and then plumbing the sanitized grey water to the toilet tank.

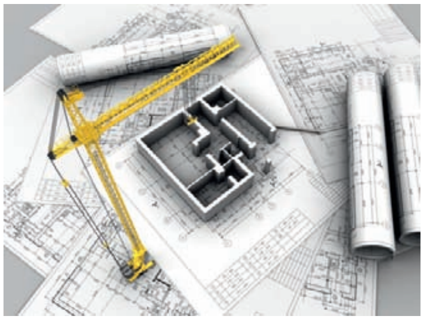
These systems are easy to install, particularly in a new build property. It is only a matter of re-routeing the drain-pipes. Another option for your grey water is to route it into the rainwater storage tank for further use in the garden.

All of the above environmental technology systems are considered in detail in Chapter 2 of Basic Electrical Installation Work 6th Edition.

To demonstrate that you understand this final Outcome of Unit 312 your tutor/trainer/ lecturer will assess your ability to describe environmental technology systems.

CHAPTER 3

Organizing the work environment



Unit 313 of the City and Guilds 2357 syllabus

Overseeing and organizing the work environment (electrical installation)

When you have completed this chapter you should be able to:

1. Identify relevant people and carry out safe isolation
2. Produce a risk assessment and method statement
3. Apply site communication techniques
4. Organize operatives
5. Produce programmes of work
6. Deal with effective delivery and storage of materials

Online Material WWW

This chapter has free associated content, including animations and instructional videos, to support your learning

When you see the logo, visit the website below to access this material:

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Identify relevant people involved with electrical systems and carry out safe isolation in case of emergencies (CGLI Outcome 1)

Relevant people involved with electrical systems

An electrician working for an electrical contracting company works as a part of the broader construction industry. This is a multi-million-pound industry carrying out all types of building work, from basic housing to hotels, factories, schools, shops, offices and airports. The construction industry is one of the UK's biggest employers, and carries out contracts to the value of about 10% of the UK's gross national product.

Although a major employer, the construction industry is also very fragmented. Firms vary widely in size, from the local builder employing two or three people to the big national companies employing thousands. Of the total workforce

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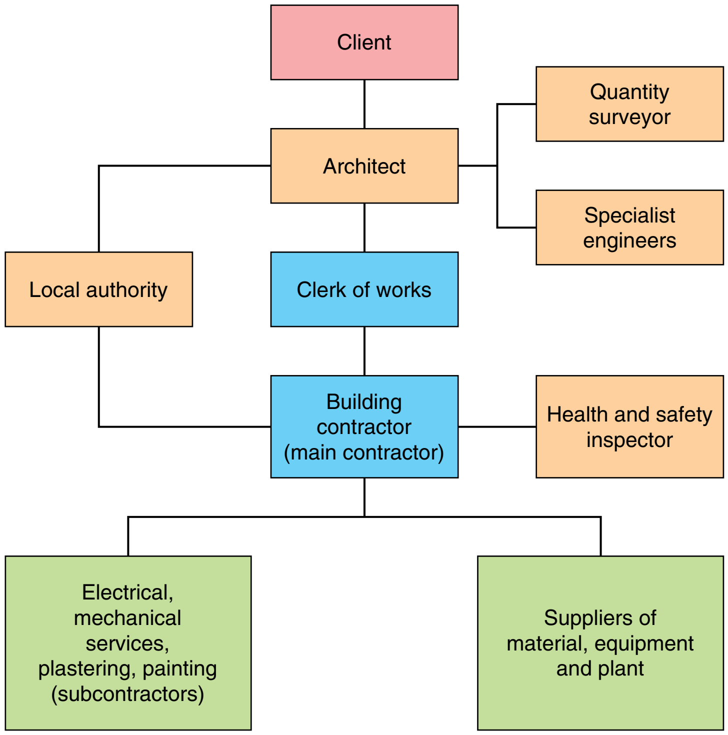

Figure 3.1 The building team.

of the construction industry, 92% are employed in small firms of less than 25 people.

The yearly turnover of the construction industry is about £35 billion. Of this total sum, about 60% is spent on new building projects and the remaining 40% on maintenance, renovation or restoration of mostly housing.

In all these various construction projects the electrotechnical industries play an important role, supplying essential electrical services to meet the needs of those who will use the completed building.

The building team

The construction of a new building is a complex process which requires a team of professionals working together to produce the desired results. We can call this team of professionals the building team, and their interrelationship can be expressed as in Fig. 3.1.

The client is the person or group of people with the actual need for the building, such as a new house, office or factory. The client is responsible for financing all the work and, therefore, in effect, employs the entire building team.

The architect is the client's agent and is considered to be the leader of the building team. The architect must interpret the client's requirements and produce working drawings. During the building process the architect will supervise all aspects of the work until the building is handed over to the client.

The quantity surveyor measures the quantities of labour and material necessary to complete the building work from drawings supplied by the architect.

Specialist engineers advise the architect during the design stage. They will prepare drawings and calculations on specialist areas of work.

The clerk of works is the architect's 'on-site' representative. He or she will make sure that the contractors carry out the work in accordance with the drawings and other contract documents. They can also agree general matters directly with the building contractor as the architect's representative.

The local authority will ensure that the proposed building conforms to the relevant planning and building legislation.

The health and safety inspectors will ensure that the government's legislation concerning health and safety is fully implemented by the building contractor.

The building contractor will enter into a contract with the client to carry out the construction work in accordance with contract documents. The building contractor is usually the main contractor and he or she, in turn, may engage sub-contractors to carry out specialist services such as electrical installation, mechanical services, plastering and painting.

The electrical team

The electrical contractor is the sub-contractor responsible for the installation of electrical equipment within the building.

Electrical installation activities include:

- installing electrical equipment and systems into new sites or locations;
- installing electrical equipment and systems into buildings that are being refurbished because of change of use;
- installing electrical equipment and systems into buildings that are being extended or updated;
- replacement, repairs and maintenance of existing electrical equipment and systems.

Try this

My Team

Sketch a block diagram, similar to those shown in Figs 3.1 and 3.2, that represents the team in which you work.

An electrical contracting firm is made up of a group of individuals with varying duties and responsibilities. There is often no clear distinction between the duties of the individuals, and the responsibilities carried by an employee will vary from one employer to another. If the firm is to be successful, the individuals must work together to meet the requirements of their customers. Good customer relationships are important for the success of the firm and the continuing employment of the employee.

The customer or his representatives will probably see more of the electrician and the electrical trainee than the managing director of the firm and, therefore, the image presented by them is very important. They should always be polite and seen to be capable and in command of the situation. This gives a customer confidence in the firm's ability to meet his or her needs. The electrician and his trainee should be appropriately dressed for the job in hand, which probably means an overall of some kind. Footwear is also important, but sometimes a difficult consideration for a journeyman electrician. For example, if working in a factory, the safety regulations may insist that protective footwear be worn, but rubber boots may be most appropriate for a building site. However, neither of these would be the most suitable footwear for an electrician fixing a new light fitting in the home of the managing director!

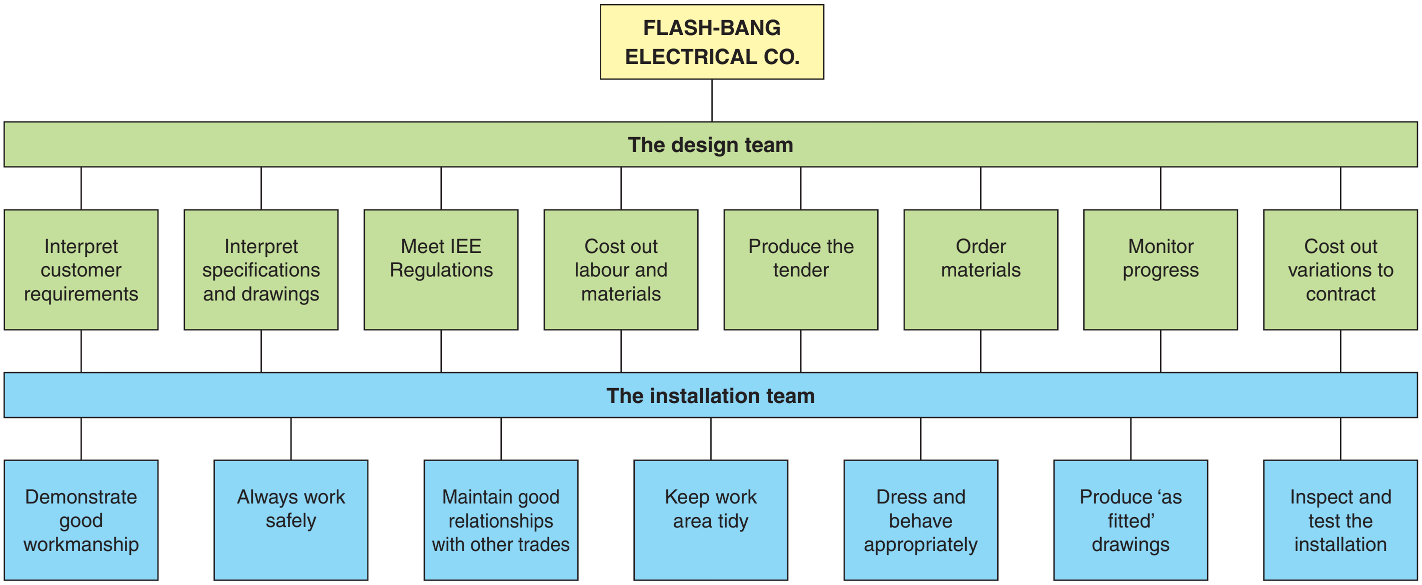

Figure 3.2 The electrical team.

The electrical installation in a building is often carried out alongside other trades. It makes sound sense to help other trades where possible and to develop good working relationships with other employees.

The employer has the responsibility of finding sufficient work for his employees, paying government taxes and meeting the requirements of the Health and Safety at Work Act described in Chapter 1. The rates of pay and conditions for electricians and trainees are determined by negotiation between the Joint Industry Board and the AMICUS Union, which will also represent their members in any disputes. Electricians are usually paid at a rate agreed for their grade as an electrician, approved electrician or technician electrician; movements through the grades are determined by a combination of academic achievement and practical experience.

The electrical team will consist of a group of professionals and their interrelationship can be expressed as shown in Fig. 3.2.

Designing an electrical installation

The designer of an electrical installation must ensure that the design meets the requirements of the IEE Wiring Regulations for electrical installations and any other regulations which may be relevant to a particular installation. The designer may be a professional technician or engineer whose job is to design electrical installations for a large contracting firm. In a smaller firm, the designer may also be the electrician who will carry out the installation to the customer's requirements. The **designer** of any electrical installation is the person who interprets the electrical requirements of the customer within the regulations, identifies the appropriate types of installation, the most suitable methods of protection and control and the size of cables to be used.

Definition

The *designer* of any electrical installation is the person who interprets the electrical requirements of the customer within the regulations.

A large electrical installation may require many meetings with the customer and his professional representatives in order to identify a specification of what is required. The designer can then identify the general characteristics of the electrical installation and its compatibility with other services and equipment, as indicated in Part 3 of the Regulations. The protection and safety of the installation, and of those who will use it, must be considered with due regard to Part 4 of the Regulations. An assessment of the frequency and quality of the maintenance to be expected will give an indication of the type of installation which is most appropriate.

The size and quantity of all the materials, cables, control equipment and accessories can then be determined. This is called a '**bill of quantities**'.

It is a common practice to ask a number of electrical contractors to tender or submit a price for work specified by the bill of quantities. The contractor must cost all the materials, assess the labour cost required to install the materials and add on profit and overhead costs in order to arrive at a final estimate for the work. The contractor tendering the lowest cost is usually, but not always, awarded the contract.

To complete the contract in the specified time the electrical contractor must use the management skills required by any business to ensure that men and materials are on site as and when they are required. If alterations or modifications are made to the electrical installation as the work proceeds which are outside the original specification, then a **variation order** must be issued so that the electrical contractor can be paid for the additional work.

The specification for the chosen wiring system will be largely determined by the building construction and the activities to be carried out in the completed building.

An industrial building, for example, will require an electrical installation which incorporates flexibility and mechanical protection. This can be achieved by a conduit, tray or trunking installation.

In a block of purpose-built flats, all the electrical connections must be accessible from one flat without intruding upon the surrounding flats. A loop-in conduit system, in which the only connections are at the light switch and outlet positions, would meet this requirement.

For a domestic electrical installation an appropriate lighting scheme and multiple socket outlets for the connection of domestic appliances, all at a reasonable cost, are important factors which can usually be met by a PVC insulated and sheathed wiring system.

The final choice of a wiring system must rest with those designing the installation and those ordering the work, but whatever system is employed, good workmanship by competent persons is essential for compliance with the regulations (IEE Regulation 134.1.1). The necessary skills can be acquired by an electrical trainee who has the correct attitude and dedication to his craft.

Definition

The size and quantity of all the materials, cables, control equipment and accessories can then be determined. This is called a '*bill of quantities*'.

Legal contracts

Before work commences, some form of legal contract should be agreed between the two parties, that is, those providing the work (e.g. the sub-contracting electrical company) and those asking for the work to be carried out (e.g. the main building company).

A contract is a formal document which sets out the terms of agreement between the two parties. A standard form of building contract typically contains four sections:

1 *The articles of agreement* – this names the parties, the proposed building and the date of the contract period.
2 *The contractual conditions* – this states the rights and obligations of the parties concerned, for example, whether there will be interim payments for work completed, or a penalty if work is not completed on time.

3 *The appendix* – this contains details of costings, for example, the rate to be paid for extras as daywork, who will be responsible for defects, how much of the contract tender will be retained upon completion and for how long.
4 *The supplementary agreement* – this allows the electrical contractor to recoup any value-added tax paid on materials at interim periods.

In signing the contract, the electrical contractor has agreed to carry out the work to the appropriate standards in the time stated and for the agreed cost. The other party, say the main building contractor, is agreeing to pay the price stated for that work upon completion of the installation.

If a dispute arises the contract provides written evidence of what was agreed and will form the basis for a solution.

For smaller electrical jobs, a verbal contract may be agreed, but if a dispute arises there is no written evidence of what was agreed and it then becomes a matter of one person's word against another's.

In this first Outcome of Unit 313 the City and Guilds tell us that operatives must be able to carry out a safe isolation procedure for products, equipment and systems in case of an emergency.

Test equipment and safe isolation procedures

The Health and Safety Executive (HSE) has published Guidance Notes (GS 38) which advise electricians and other electrically competent people on the selection of suitable test probes, voltage indicating devices and measuring instruments. This is because they consider suitably constructed test equipment to be as vital for personal safety as the training and practical skills of the electrician. In the past, unsatisfactory test probes and voltage indicators have frequently been the cause of accidents, and therefore all test probes must now incorporate the following features:

1 The probes must have finger barriers or be shaped so that the hand or fingers cannot make contact with the live conductors under test.
2 The probe tip must not protrude more than 2 mm, and preferably only 1 mm, be spring-loaded and screened.
3 The lead must be adequately insulated and coloured so that one lead is readily distinguished from the other.
4 The lead must be flexible and sufficiently robust.
5 The lead must be long enough to serve its purpose but not too long.
6 The lead must not have accessible exposed conductors even if it becomes detached from the probe or from the instrument.
7 Where the leads are to be used in conjunction with a voltage detector they must be protected by a fuse.

A suitable probe and lead is shown in Fig. 3.3.

GS 38 also tells us that where the test is being made simply to establish the presence or absence of a voltage, the preferred method is to use a proprietary test lamp or voltage indicator which is suitable for the working voltage, rather than a multimeter. Accident history has shown that incorrectly set multimeters or makeshift devices for voltage detection have frequently caused accidents. Fig. 3.4 shows a suitable voltage indicator. Test lamps and voltage indicators are not fail-safe, and therefore GS 38 recommends that they should be regularly proved, preferably before and after use, as described in the flowchart for a safe isolation procedure shown in Fig 3.7.

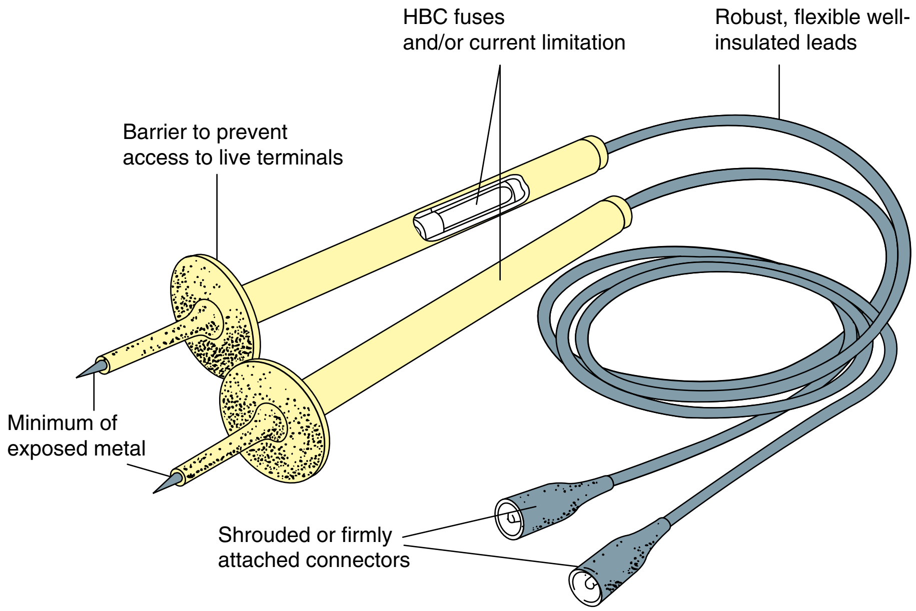

Figure 3.3 Recommended type of test probe and leads.

Figure 3.4 Typical voltage indicator.

Test procedures

1. The circuits must be isolated using a 'safe isolation procedure', such as that described below, before beginning to test.
2. All test equipment must be 'approved' and connected to the test circuits by recommended test probes as described by the HSE Guidance Notes GS

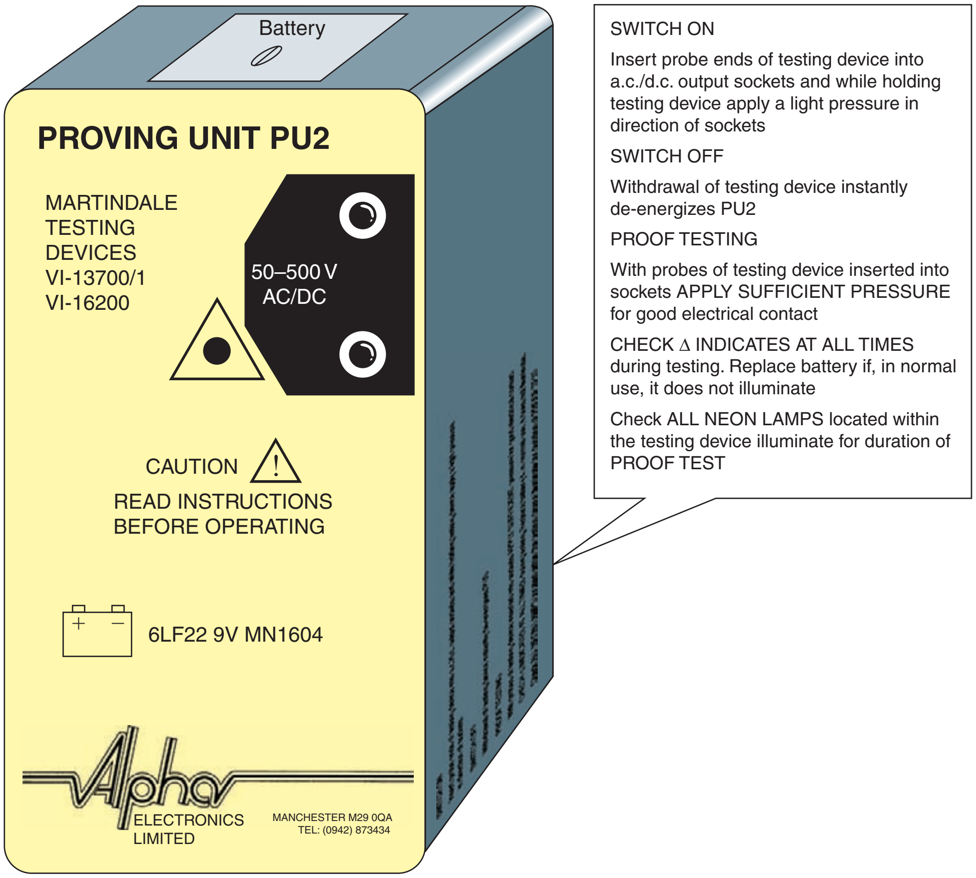

Figure 3.5 Voltage proving unit.

38. The test equipment used must also be ‘proved’ on a known supply or by means of a proving unit such as that shown in Fig. 3.5.

3 Isolation devices must be ‘secured’ in the ‘off’ position as shown in Fig. 3.6.

4 Warning notices must be posted.

5 All relevant safety and functional tests must be completed before restoring the supply.

Definition

The *Electricity at Work Act* tells us that it is ‘preferable’ that supplies be made dead before work commences (IEE Regulation 4(3)).

Definition

Note that while live testing may be required in order to find the fault, live repair work must not be carried out. The individual circuit or item of equipment must first be isolated.

Live testing

The **Electricity at Work Act** tells us that it is ‘preferable’ that supplies be made dead before work commences (IEE Regulation 4(3)). However, it does acknowledge that some work, such as fault-finding and testing, may require the electrical equipment to remain energized. Therefore, if the fault finding and testing can only be successfully carried out ‘live’, then the person carrying out the fault diagnosis must:

- be trained so that he understands the equipment and the potential hazards of working live and can, therefore, be deemed to be ‘competent’ to carry out the activity;
- only use approved test equipment;
- set up barriers and warning notices so that the work activity does not create a situation dangerous to others.

Note that while live testing may be required in order to find the fault, live repair work must not be carried out. The individual circuit or item of equipment must first be isolated.

Isolation of supply

The Electricity at Work Regulations are very specific in describing the procedure to be used for isolation of the electrical supply. Regulation 12(1) tells us that **isolation** means the disconnection and separation of the electrical equipment from every source of electrical energy in such a way that this disconnection and separation is secure. Regulation 4(3) tells us that we must also prove the conductor's dead before work commences and that the test instrument used for this purpose must itself be proved immediately before and immediately after testing the conductors. To isolate an individual circuit or item of equipment successfully, competently and safely we must follow a procedure such as that given by the flow diagram in Fig. 3.7. Start at the top and work your way down the flowchart. When you get to the heavy-outlined amber boxes, pause and ask yourself whether everything is satisfactory up to this point. If the answer is yes, move on. If no, go back as indicated by the diagram.

To demonstrate that you understand this first CGLI Outcome your tutor/trainer/ lecturer will assess your ability to identify relevant people involved with electrical systems and carry out a safe isolation procedure in case of emergencies.

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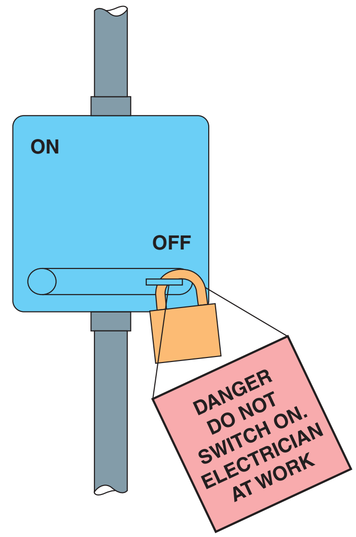


Figure 3.6 Secure isolation of a supply.

Produce a risk assessment and method statement (CGLI Outcome 2)

Hazard and risk

A **hazard** is something with the 'potential' to cause harm, for example, chemicals, electricity or working above ground.

A **risk** is the 'likelihood'of harm actually being done.

Competent persons are often referred to in the Health and Safety at Work Regulations, but who is 'competent'? For the purposes of the Act, a competent person is anyone who has the necessary technical skills, training and expertise to safely carry out the particular activity. Therefore, a **competent person** dealing with a hazardous situation reduces the risk.

Think about your workplace and at each stage of what you do, think about what might go wrong. Some simple activities may be hazardous. Here are some typical activities where accidents might happen.

Typical activity	Potential hazard
Receiving materials	Lifting and carrying
Stacking and storing	Falling materials
Movement of people	Slips, trips and falls
Building maintenance	Working at heights or in confined spaces
Movement of vehicles	Collisions

How high are the risks? Think about what might be the worst result, is it a broken finger or someone suffering permanent lung damage or being killed? How likely is it to happen? How often is that type of work carried out and how close do people get to the hazard? How likely is it that something will go wrong?

How many people might be injured if things go wrong? Might this also include people who do not work for your company?

Definition

Isolation means the disconnection and separation of the electrical equipment from every source of electrical energy in such a way that this disconnection and separation is secure.

Definitions

A *hazard* is something with the 'potential' to cause harm, for example, chemicals, electricity or working above ground.

A *risk* is the 'likelihood' of harm actually being done.

Definition

A *competent person* is anyone who has the necessary technical skills, training and expertise to safely carry out the particular activity.

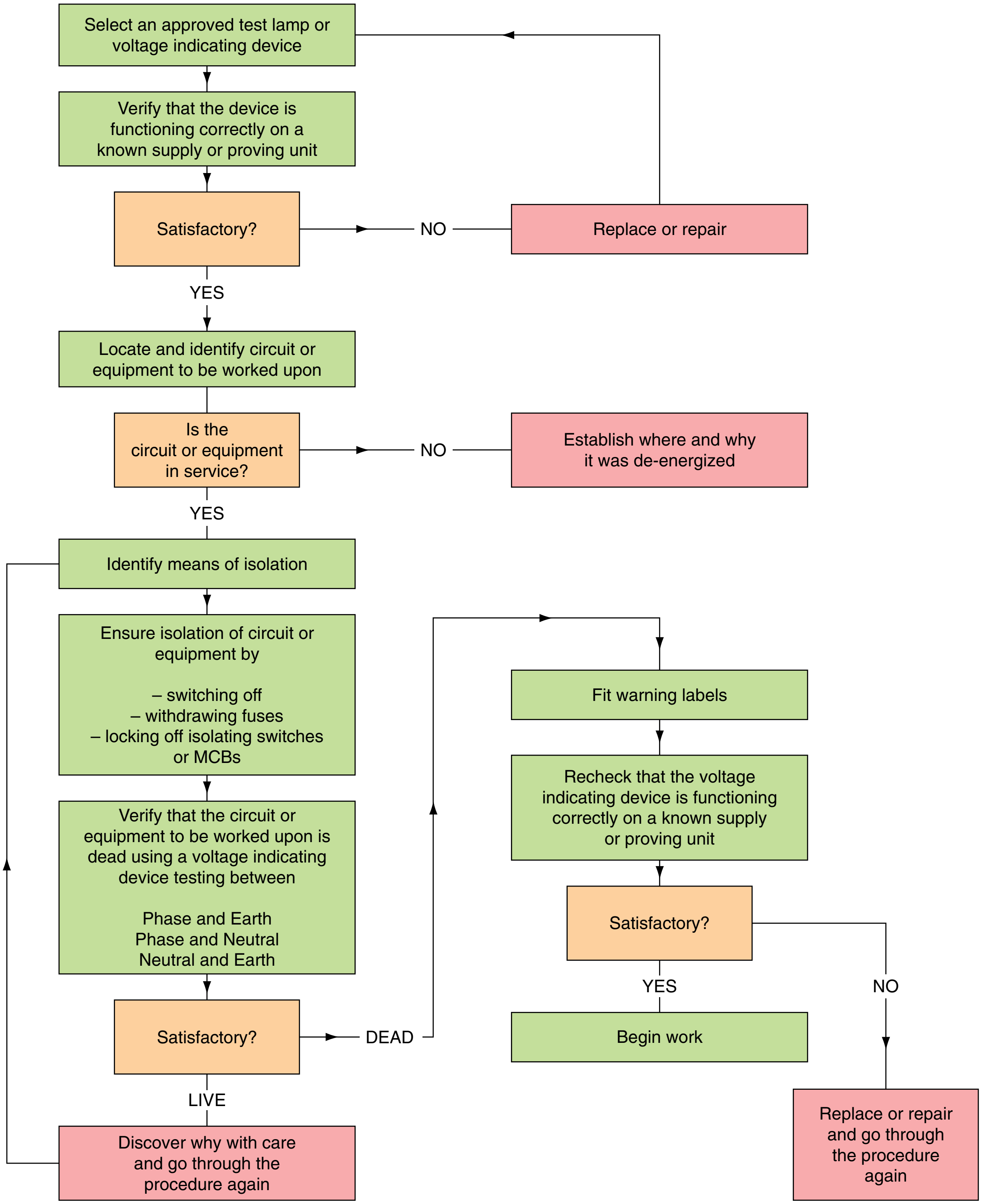


Figure 3.7 Flowchart for a secure isolation procedure.

WWW

Employers of more than five people must document the risks at work and the process is known as hazard risk assessment.

Hazard risk assessment – the process

The Management of Health and Safety at Work Regulations 1999 tell us that employers must systematically examine the workplace, the work activity and the management of safety in the establishment through a process of risk assessments. A record of all significant risk assessment findings must be kept in a safe place and be made available to an HSE inspector if required. Information based on the risk assessment findings must be communicated to relevant staff and if changes in work behaviour patterns are recommended in the interests of safety, then they must be put in place.

So risk assessment must form a part of any employer's robust policy of health and safety. However, an employer only needs to 'formally' assess the significant risks. He is not expected to assess the trivial and minor types of household risks. Staff are expected to read and to act upon these formal risk assessments and they are unlikely to do so enthusiastically if the file is full of trivia. An assessment of risk is nothing more than a careful examination of what, in your work, could cause harm to people. It is a record that shows whether sufficient precautions have been taken to prevent harm.

The HSE recommends five steps to any risk assessment.

Step 1

Look at what might reasonably be expected to cause harm. Ignore the trivial and concentrate only on significant hazards that could result in serious harm or injury. Manufacturers' data sheets or instructions can also help you spot hazards and put risks in their true perspective.

Step 2

Decide who might be harmed and how. Think about people who might not be in the workplace all the time – cleaners, visitors, contractors or maintenance personnel. Include members of the public or people who share the workplace. Is there a chance that they could be injured by activities taking place in the workplace?

Step 3

Evaluate what is the risk arising from an identified hazard. Is it adequately controlled or should more be done? Even after precautions have been put in place, some risk may remain. What you have to decide, for each significant hazard, is whether this remaining risk is low, medium or high. First of all, ask yourself if you have done all the things that the law says you have got to do. For example, there are legal requirements on the prevention of access to dangerous machinery. Then ask yourself whether generally accepted industry standards are in place, but do not stop there – think for yourself, because the law also says that you must do what is reasonably practicable to keep the workplace safe. Your real aim is to make all risks small by adding precautions, if necessary.

If you find that something needs to be done, ask yourself:

1. Can I get rid of this hazard altogether?
2. If not, how can I control the risk so that harm is unlikely?

Only use PPE when there is nothing else that you can reasonably do.

If the work that you do varies a lot, or if there is movement between one site and another, select those hazards which you can reasonably foresee, the ones that apply to most jobs and assess the risks for them. After that, if you spot any unusual hazards when you get on site, take what action seems necessary.

Step 4

Record your findings and say what you are going to do about risks that are not adequately controlled. If there are fewer than five employees you do not need to write anything down but if there are five or more employees, the significant findings of the risk assessment must be recorded. This means writing down the more significant hazards and assessing if they are adequately controlled and recording your most important conclusions. Most employers have a standard risk

HAZARD RISK ASSESSMENT	FLASH-BANG ELECTRICAL CO.
For Company name or site: ____________ Address: ____________ ____________	Assessment undertaken by: ____________ Signed: ____________ Date: ____________
STEP 5 Assessment review date: ____________	
STEP 1 List the hazards here	STEP 2 Decide who might be harmed
STEP 3 Evaluate (what is) the risk – is it adequately controlled? State risk level as low, medium or high	STEP 4 Further action – what else is required to control any risk identified as medium or high?

Figure 3.8 Hazard risk assessment standard form.

assessment form which they use such as that shown in Fig. 3.8 but any format is suitable. The important thing is to make a record.

There is no need to show how the assessment was made, providing you can show that:

1 a proper check was made,
2 you asked those who might be affected,

3 you dealt with all obvious and significant hazards,
4 the precautions are reasonable and the remaining risk is low,
5 you informed your employees about your findings.

Risk assessments need to be *suitable* and *sufficient*, not perfect. The two main points are:

1 Are the precautions reasonable?
2 Is there a record to show that a proper check was made?

File away the written assessment in a dedicated file for future reference or use. It can help if an HSE inspector questions the company's precautions or if the company becomes involved in any legal action. It shows that the company has done what the law requires.

Step 5

Review the assessments from time to time and revise them if necessary.

Completing a risk assessment

When completing a risk assessment such as that shown in Fig. 3.8, do not be over complicated. In most firms in the commercial, service and light industrial sector, the hazards are few and simple. Checking them is common sense but necessary.

Step 1

List only hazards which you could reasonably expect to result in significant harm under the conditions prevailing in your workplace. Use the following examples as a guide:

- Slipping or tripping hazards (e.g. from poorly maintained or partly installed floors and stairs).
- Fire (e.g. from flammable materials you might be using, such as solvents).
- Chemicals (e.g. from battery acid).
- Moving parts of machinery (e.g. blades).
- Rotating parts of handtools (e.g. drills).
- Accidental discharge of cartridge operated tools.
- High pressure air from airlines (e.g. air powered tools).
- Pressure systems (e.g. steam boilers).
- Vehicles (e.g. fork lift trucks).
- Electricity (e.g. faulty tools and equipment).
- Dust (e.g. from grinding operations or thermal insulation).
- Fumes (e.g. from welding).
- Manual handling (e.g. lifting, moving or supporting loads).
- Noise levels too high (e.g. machinery).
- Poor lighting levels (e.g. working in temporary or enclosed spaces).
- Low temperatures (e.g. working outdoors or in refrigeration plant).
- High temperatures (e.g. working in boiler rooms or furnaces).

Step 2

Decide who might be harmed, do not list individuals by name. Just think about groups of people doing similar work or who might be affected by your work:

- Office staff
- Electricians
- Maintenance personnel

- Other contractors on site
- Operators of equipment
- Cleaners
- Members of the public.

Pay particular attention to those who may be more vulnerable, such as:

- staff with disabilities,
- visitors,
- young or inexperienced staff,
- people working in isolation or enclosed spaces.

Step 3

Calculate what is the risk – is it adequately controlled? Have you already taken precautions to protect against the hazards which you have listed in Step 1? For example:

- Have you provided adequate information to staff?
- Have you provided training or instruction?

Do the precautions already taken

- meet the legal standards required?
- comply with recognized industrial practice?
- represent good practice?
- reduce the risk as far as is reasonably practicable?

If you can answer 'yes' to the above points then the risks are adequately controlled, but you need to state the precautions you have put in place. You can refer to company procedures, company rules, company practices, etc., in giving this information. For example, if we consider there might be a risk of electric shock from using electrical power tools, then the risk of a shock will be *less* if the company policy is to PAT test all power tools each year and to fit a label to the tool showing that it has been tested for electrical safety. If the stated company procedure is to use battery drills whenever possible, or 110 V drills when this is not possible, and *never* to use 230 V drills, then this again will reduce the risk. If a policy such as this is written down in the company safety policy statement, then you can simply refer to the appropriate section of the safety policy statement and the level of risk will be low.

Step 4

Further action – what more could be done to reduce those risks which were found to be inadequately controlled?

You will need to give priority to those risks that affect large numbers of people or which could result in serious harm. Senior managers should apply the principles below when taking action, if possible in the following order:

1. Remove the risk completely.
2. Try a less risky option.
3. Prevent access to the hazard (e.g. by guarding).
4. Organize work differently in order to reduce exposure to the hazard.
5. Issue PPE.
6. Provide welfare facilities (e.g. washing facilities for removal of contamination and first aid).

Any hazard identified by a risk assessment as *high risk* must be brought to the attention of the person responsible for health and safety within the company.

Ideally, in Step 4 of the risk assessment you should be writing, 'No further action is required. The risks are under control and identified as low risk'.

The assessor may use as many standard hazard risk assessment forms, such as that shown in Fig. 3.8, as the assessment requires. Upon completion they should be stapled together or placed in a plastic wallet and stored in the dedicated file.

Method statement

The Construction, Design and Management Regulations and Approved Codes of Practice define a method statement as a written document laying out the work procedure and sequence of operations to ensure health and safety.

If the method statement is written as a result of a risk assessment carried out for a task or operation then following the prescribed method will reduce the risk. If the risk is low a verbal statement may be all that is required.

The safe isolation procedure described in Outcome 2 of this chapter is a method statement. Following this method meets the requirements of the Electricity at Work Regulations, the IEE Regulations, and reduces the risk of electric shock to the operative and other people who might be affected by his actions.

To demonstrate that you understand this second CGLI Outcome your tutor/trainer/lecturer will assess your ability to produce a risk assessment and method statement.

Organizing and overseeing work activities (CGLI Outcomes 3, 4 and 5)

Effective and efficient management systems

Smaller electrical contracting firms will know where their employees are working and what they are doing from day to day because of the level of personal contact between the employer, employee and customer.

As a firm expands and becomes engaged on larger contracts, it becomes less likely that there is anyone in the firm with a complete knowledge of the firm's operations, and there arises an urgent need for sensible management and planning skills so that men and materials are on site when they are required and a healthy profit margin is maintained.

When the electrical contractor is told that he has been successful in tendering for a particular contract he is committed to carrying out the necessary work within the contract period. He must therefore consider:

- by what date the job must be finished;
- when the job must be started if the completion date is not to be delayed;
- how many men will be required to complete the contract;
- when certain materials will need to be ordered;
- when the supply authorities must be notified that a supply will be required;
- if it is necessary to obtain authorization from a statutory body for any work to commence.

In thinking ahead and planning the best method of completing the contract, the individual activities or jobs must be identified and consideration given to how the various jobs are interrelated. To help in this process a number of management

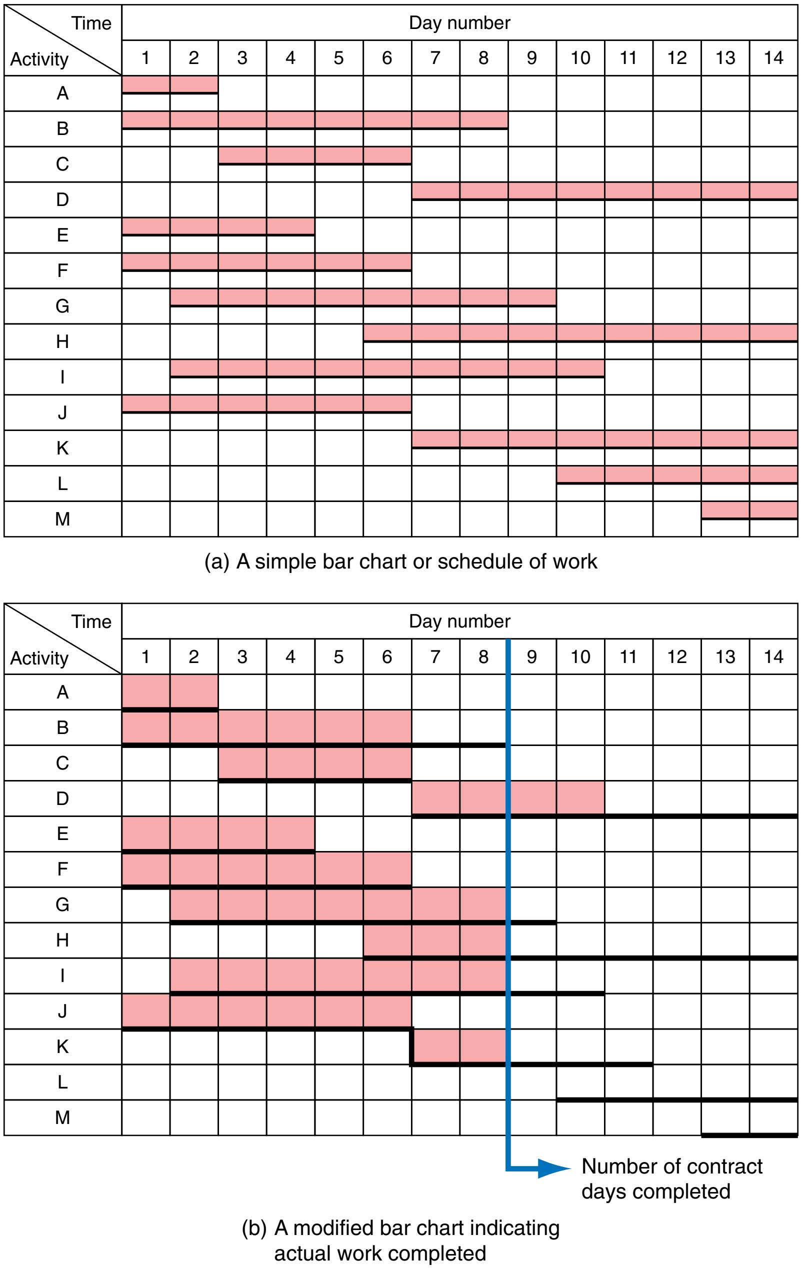


Figure 3.9 Bar charts: (a) a simple bar chart or schedule of work; (b) a modified bar chart indicating actual work completed.

techniques are available. In this chapter we will consider only two: bar charts and network analysis. The very preparation of a bar chart or network analysis forces the contractor to think deeply, carefully and logically about the particular contract, and it is therefore a very useful aid to the successful completion of the work.

Definition

There are many different types of bar chart used by companies but the *object of any bar chart* is to establish the sequence and timing of the various activities involved in the contract as a whole.

Bar charts

There are many different types of bar chart used by companies but the **object of any bar chart** is to establish the sequence and timing of the various activities involved in the contract as a whole. They are a visual aid in the process of communication. In order to be useful they must be clearly understood by the people involved in the management of a contract. The chart is constructed on a rectangular basis, as shown in Fig. 3.9.

All the individual jobs or activities which make up the contract are identified and listed separately down the vertical axis on the left-hand side, and time flows from left to right along the horizontal axis. The unit of time can be chosen to suit the length of the particular contract, but for most practical purposes either days or weeks are used.

The simple bar chart shown in Fig. 3.9(a) shows a particular activity A which is estimated to last 2 days, while activity B lasts 8 days. Activity C lasts 4 days and should be started on day 3. The remaining activities can be interpreted in the same way.

With the aid of colours, codes, symbols and a little imagination, much additional information can be included on this basic chart. For example, the actual work completed can be indicated by shading above the activity line as shown in Fig. 3.9(b) with a vertical line indicating the number of contract days completed; the activities which are on time, ahead of or behind time can easily be identified. Activity B in Fig. 3.9(b) is 2 days behind schedule, while activity D is 2 days ahead of schedule. All other activities are on time. Some activities must be completed before others can start. For example, all conduit work must be completely erected before the cables are drawn in. This is shown in Fig. 3.9(b) by activities J and K. The short vertical line between the two activities indicates that activity J must be completed before K can commence.

Useful and informative as the bar chart is, there is one aspect of the contract which it cannot display. It cannot indicate clearly the interdependence of the various activities upon each other, and it is unable to identify those activities which must strictly adhere to the time schedule if the overall contract is to be completed on time, and those activities in which some flexibility is acceptable. To overcome this limitation, in 1959 the Central Electricity Generating Board (CEGB) developed the critical path network diagram which we will now consider.

Network analysis

In large or complex contracts there are a large number of separate jobs or activities to be performed. Some can be completed at the same time, while others cannot be started until others are completed. A **network diagram** can be used to co-ordinate all the interrelated activities of the most complex project in such a way that all sequential relationships between the various activities, and the restraints imposed by one job on another, are allowed for. It also provides a method of calculating the time required to complete an individual activity and will identify those activities which are the key to meeting the completion date, called the critical path. Before considering the method of constructing a network diagram, let us define some of the terms and conventions we shall be using.

Definition

A *network diagram* can be used to co-ordinate all the interrelated activities of the most complex project.

Critical path

Critical path is the path taken from the start event to the end event which takes the longest time. This path denotes the time required for completion of the whole contract.

Definition

Critical path is the path taken from the start event to the end event which takes the longest time.

Float time

Float time, slack time or time in hand is the time remaining to complete the contract after completion of a particular activity.

$$\text{Float time} = \text{Critical path time} - \text{Activity time}$$

Definition

Float time, slack time or time in hand is the time remaining to complete the contract after completion of a particular activity.

> **Definition**
>
> *Activities* are represented by an arrow, the tail of which indicates the commencement, and the head the completion of the activity.

> **Definition**
>
> *Dummy activities* are represented by an arrow with a dashed line.

> **Definition**
>
> An *event* is a point in time, a milestone or stage in the contract when the preceding activities are finished.

The total float time for any activity is the total leeway available for all activities in the particular path of activities in which it appears. If the float time is used up by one of the early activities in the path, there will be no float left for the remaining activities and they will become critical.

Activities

Activities are represented by an arrow, the tail of which indicates the commencement, and the head the completion of the activity. The length and direction of the arrows have no significance: they are not vectors or phasors. Activities require time, manpower and facilities. They lead up to or emerge from events.

Dummy activities

Dummy activities are represented by an arrow with a dashed line. They signify a logical link only, require no time and denote no specific action or work.

Event

An **event** is a point in time, a milestone or stage in the contract when the preceding activities are finished. Each activity begins and ends in an event. An event has no time duration and is represented by a circle which sometimes includes an identifying number or letter.

Time may be recorded to a horizontal scale or shown on the activity arrows. For example, the activity from event A to B takes 9 hours in the network diagram shown in Fig. 3.10.

Example 1

Identify the three possible paths from the start event A to the finish event F for the contract shown by the network diagram in Fig. 3.10. Identify the critical path and the float time in each path.

The three possible paths are:

1 event A–B–D–F
2 event A–C–D–F
3 event A–C–E–F

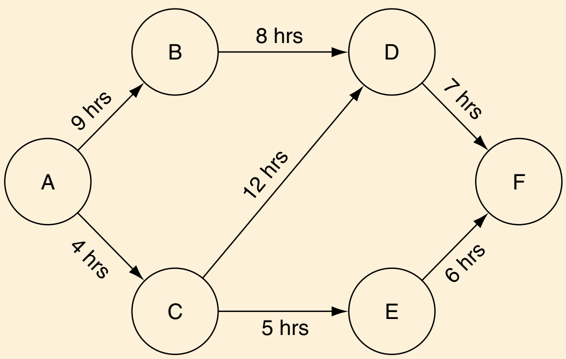


Figure 3.10 A network diagram for example 1.

(Continued)

Example 1 (Continued)

The times taken to complete these activities are:

1 path A–B–D–F = 9 + 8 + 7 = 24 hours
2 path A–C–D–F = 4 + 12 + 7 = 23 hours
3 path A–C–E–F = 4 + 5 + 6 = 15 hours

The longest time from the start event to the finish event is 24 hours, and therefore the critical path is A–B–D–F.

The float time is given by:

$$\text{Float time} = \text{Critical path} - \text{Activity time}$$

For path 1, A–B–D–F

$$\text{Float time} = 24\text{ hours} - 24\text{ hours} = 0\text{ hours}$$

There can be no float time in any of the activities which form a part of the critical path since a delay on any of these activities would delay completion of the contract. On the other two paths some delay could occur without affecting the overall contract time.

For path 2, A–C–D–F

$$\text{Float time} = 24\text{ hours} - 23\text{ hours} = 1\text{ hour}$$

For path 3, A–C–E–F

$$\text{Float time} = 24\text{ hours} - 15\text{ hours} = 9\text{ hours}$$

Example 2

Identify the time taken to complete each activity in the network diagram shown in Fig. 3.11. Identify the three possible paths from the start event A to the final event G and state which path is the critical path.

The time taken to complete each activity using the horizontal scale is:

activity A–B = 2 days
activity A–C = 3 days
activity A–D = 5 days
activity B–E = 5 days
activity C–F = 5 days
activity E–G = 3 days
activity D–G = 0 days
activity F–G = 0 days

Activities D–G and F–G are dummy activities which take no time to complete but indicate a logical link only. This means that in this case once the activities preceding events D and F have been completed, the contract will not be held up by work associated with these particular paths and they will progress naturally to the finish event.

(Continued)

Example 2 (Continued)

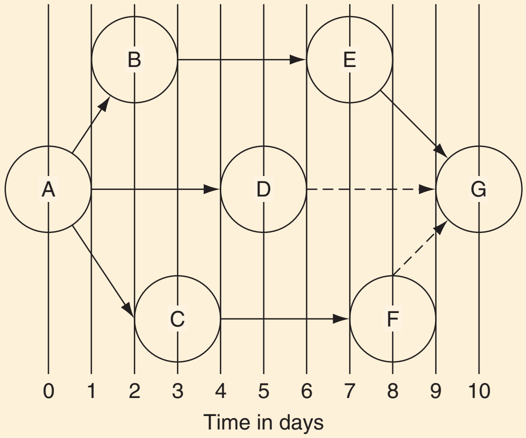


Figure 3.11 A network diagram for example 2.

The three possible paths are:

1 A–B–E–G
2 A–D–G
3 A–C–F–G

The times taken to complete the activities in each of the three paths are:

path 1, A–B–E–G = 2 + 5 + 3 = 10 days
path 2, A–D–G = 5 + 0 = 5 days
path 3, A–C–F–G = 3 + 5 + 0 = 8 days

The critical path is path 1, A–B–E–G

Constructing a network

The first step in constructing a network diagram is to identify and draw up a list of all the individual jobs, or activities, which require time for their completion and which must be completed to advance the contract from start to completion.

The next step is to build up the arrow network showing schematically the precise relationship of the various activities between the start and end event. The designer of the network must ask these questions:

1 Which activities must be completed before others can commence? These activities are then drawn in a similar way to a series circuit but with event circles instead of resistor symbols.
2 Which activities can proceed at the same time? These can be drawn in a similar way to parallel circuits but with event circles instead of resistor symbols.

Commencing with the start event at the left-hand side of a sheet of paper, the arrows representing the various activities are built up step by step until the final event is reached. A number of attempts may be necessary to achieve a well-balanced and symmetrical network diagram showing the best possible flow of work and information, but this time is well spent when it produces a diagram which can be easily understood by those involved in the management of the particular contract.

Example 3

A particular electrical contract is made up of activities A–F as described below:

A = an activity taking 2 weeks commencing in week 1
B = an activity taking 3 weeks commencing in week 1
C = an activity taking 3 weeks commencing in week 4
D = an activity taking 4 weeks commencing in week 7
E = an activity taking 6 weeks commencing in week 3
F = an activity taking 4 weeks commencing in week 1

Certain constraints are placed on some activities because of the availability of men and materials and because some work must be completed before other work can commence as follows:

Activity C can only commence when B is completed
Activity D can only commence when C is completed
Activity E can only commence when A is completed
Activity F does not restrict any other activity

(a) Produce a simple bar chart to display the activities of this particular contract.
(b) Produce a network diagram of the programme and describe each event.
(c) Identify the critical path and the total contract time.
(d) State the maximum delay which would be possible on activity E without delaying the completion of the contract.
(e) State the float time in activity F.

(a) A simple bar chart for this contract is shown in Fig. 3.12(a).
(b) The network diagram is shown in Fig. 3.12(b). The events may be described as follows:
Event 1 = the commencement of the contract
Event 2 = the completion of activity A and the commencement of activity E
Event 3 = the completion of activity B and the commencement of activity C
Event 4 = the completion of activity F
Event 5 = the completion of activity E
Event 6 = the completion of activity C
Event 7 = the completion of activity D and the whole contract.
(c) There are three possible paths:
1 via events 1–2–5–7
2 via events 1–4–7
3 via events 1–3–6–7

The time taken for each path is:

path 1 = 2 weeks + 6 weeks = 8 weeks
path 2 = 4 weeks = 4 weeks
path 3 = 3 weeks + 3 weeks + 4 weeks = 10 weeks

The critical path is therefore path 3, via events 1–3–6–7, and the total contract time is 10 weeks.

(*Continued*)

Example 3 (Continued)

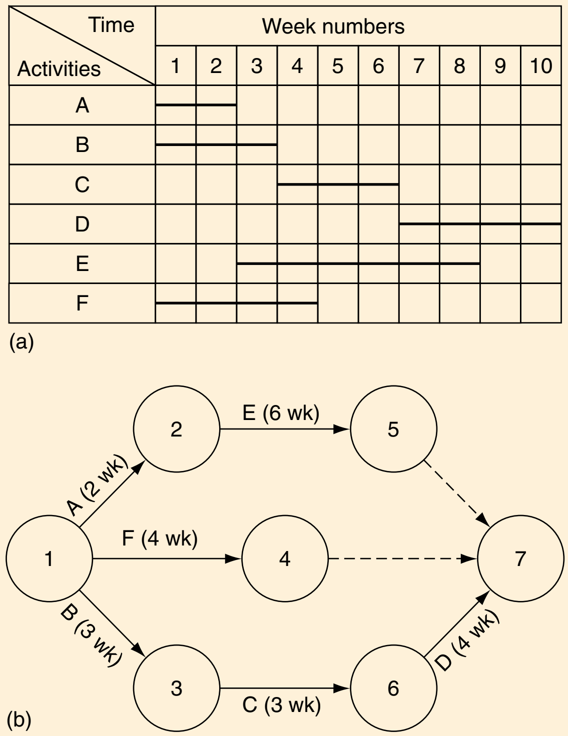


Figure 3.12 (a) Bar chart and (b) network diagram for example 3.

(d) We have that:

$$\text{Float time} = \text{Critical path time} - \text{Activity time}$$

Activity E is on path 1 via events 1–2–5–7 having a total activity time of 8 weeks

$$\text{Float time} = 10 \text{ weeks} - 8 \text{ weeks} = 2 \text{ weeks}$$

Activity E could be delayed for a maximum of 2 weeks without delaying the completion date of the whole contract

(e) Activity F is on path 2 via events 1–4–7 having a total activity time of 4 weeks

$$\text{Float time} = 10 \text{ weeks} - 4 \text{ weeks} = 6 \text{ weeks}$$

On-site communication techniques

Good communication is about transferring information from one person to another. Electricians and other professionals in the construction trades communicate with each other and the general public by means of drawings, sketches and symbols in addition to what we say and do.

Drawings and diagrams

Many different types of electrical drawing and diagram can be identified which give relevant information for the installation, termination and connection of conductors: layout, schematic, block, wiring and circuit diagrams. The type of diagram to be used in any particular application is the one which most clearly communicates the desired information.

Layout drawings or site plan

These are scale drawings based upon the architect's site plan of the building and show the positions of the electrical equipment which is to be installed. The electrical equipment is identified by a graphical symbol.

The standard symbols used by the electrical contracting industry are those recommended by the British Standard BS EN 60617, *Graphical Symbols for Electrical Power, Telecommunications and Electronic Diagrams.* Some of the more common electrical installation symbols are given in Fig. 3.13.

The site plan or layout drawing will be drawn to a scale smaller than the actual size of the building, so to find the actual measurements you must measure the distance on the drawing and then multiply by the scale.

For example, if the site plan is drawn to a scale of 1:100, then 10 mm on the site plan represents 1 m measured in the building.

A layout drawing is shown in Fig. 3.14 of a small domestic extension. It can be seen that the mains intake position, probably a consumer's unit, is situated in the store-room which also contains one light controlled by a switch at the door. The bathroom contains one lighting point controlled by a one-way switch at the door. The kitchen has two doors and a switch is installed at each door to control the fluorescent luminaire. There are also three double sockets situated around the kitchen. The sitting room has a two-way switch at each door controlling the centre lighting point. Two wall lights with built in switches are to be wired, one at each side of the window. Two double sockets and one switched socket are also to be installed in the sitting room. The bedroom has two lighting points controlled independently by two one-way switches at the door.

The wiring diagrams and installation procedures for all these circuits can be found in Chapter 14 of *Basic Electrical Installation Work,* 6th Edition.

Definition

Layout drawings are scale drawings based upon the architect's site plan of the building and show the positions of the electrical equipment which is to be installed.

As-fitted drawings

When the installation is completed a set of drawings should be produced which indicate the final positions of all the electrical equipment. As the building and electrical installation progresses, it is sometimes necessary to modify the positions of equipment indicated on the layout drawing because, for example, the position of a doorway has been changed. The layout drawings indicate the original intentions for the positions of equipment, while the 'as-fitted' drawing indicates the actual positions of equipment upon completion of the job.

Definition

When the installation is completed a set of drawings should be produced which indicate the final positions of all the electrical equipment.

Detail drawings and assembly drawings

These are additional drawings produced by the architect to clarify some point of detail. For example, a drawing might be produced to give a fuller description of the suspended ceiling arrangements.

Definition

Detail drawings are additional drawings produced by the architect to clarify some point of detail.

Schematic diagrams

A **schematic diagram** is a diagram in outline of, for example, a motor starter circuit. It uses graphical symbols to indicate the interrelationship of the electrical elements in a circuit. These help us to understand the working operation of the circuit.

Definition

A *schematic diagram* is a diagram in outline of, for example, a motor starter circuit.

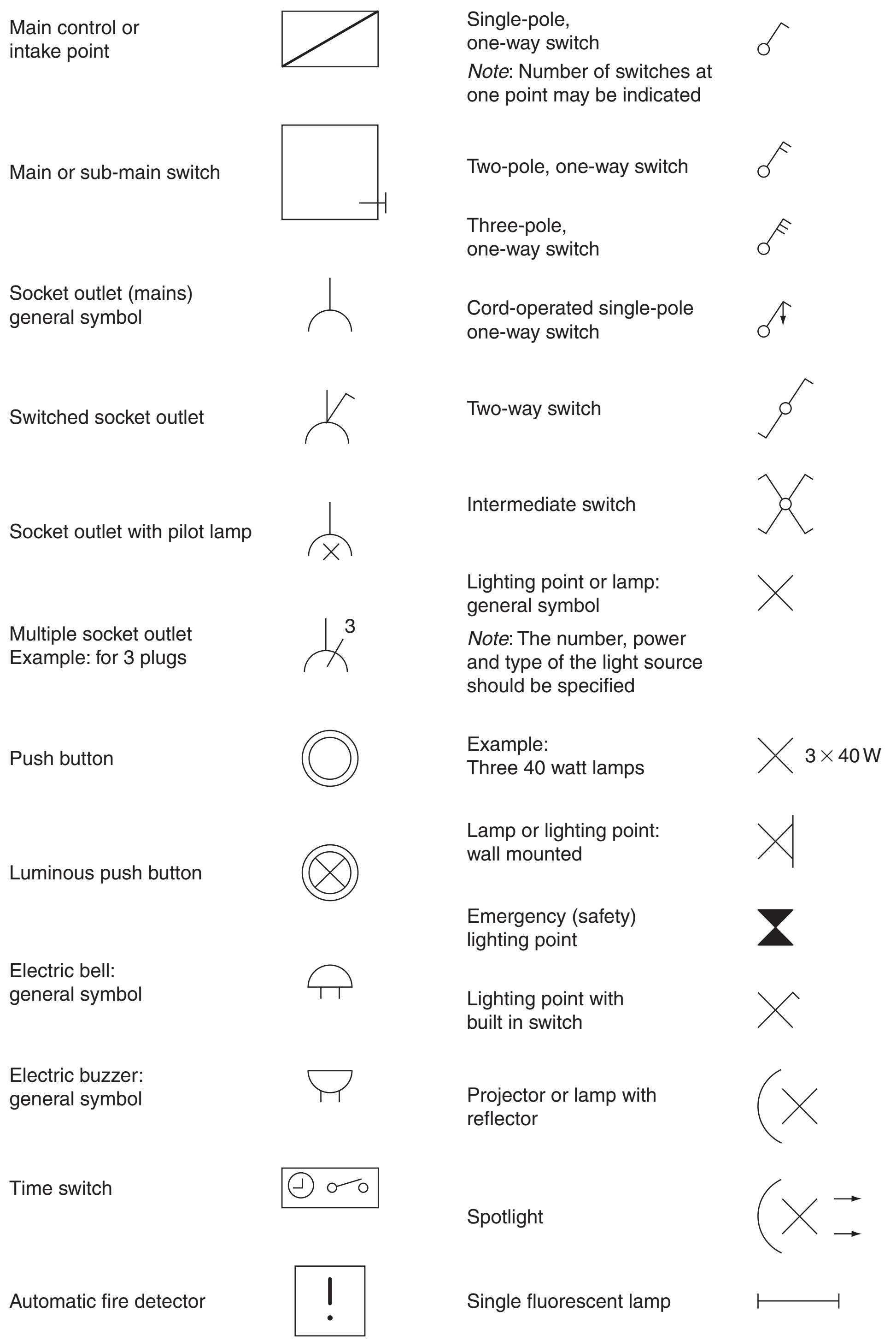


Figure 3.13 Some BS EN 60617 installation symbols.

An electrical schematic diagram looks very much like a circuit diagram. A mechanical schematic diagram gives a more complex description of the individual elements in the system, indicating, for example, acceleration, velocity, position, force sensing and viscous damping.

Definition

A *block diagram* is a very simple diagram in which the various items or pieces of equipment are represented by a square or rectangular box.

Block diagrams

A **block diagram** is a very simple diagram in which the various items or pieces of equipment are represented by a square or rectangular box. The purpose of the

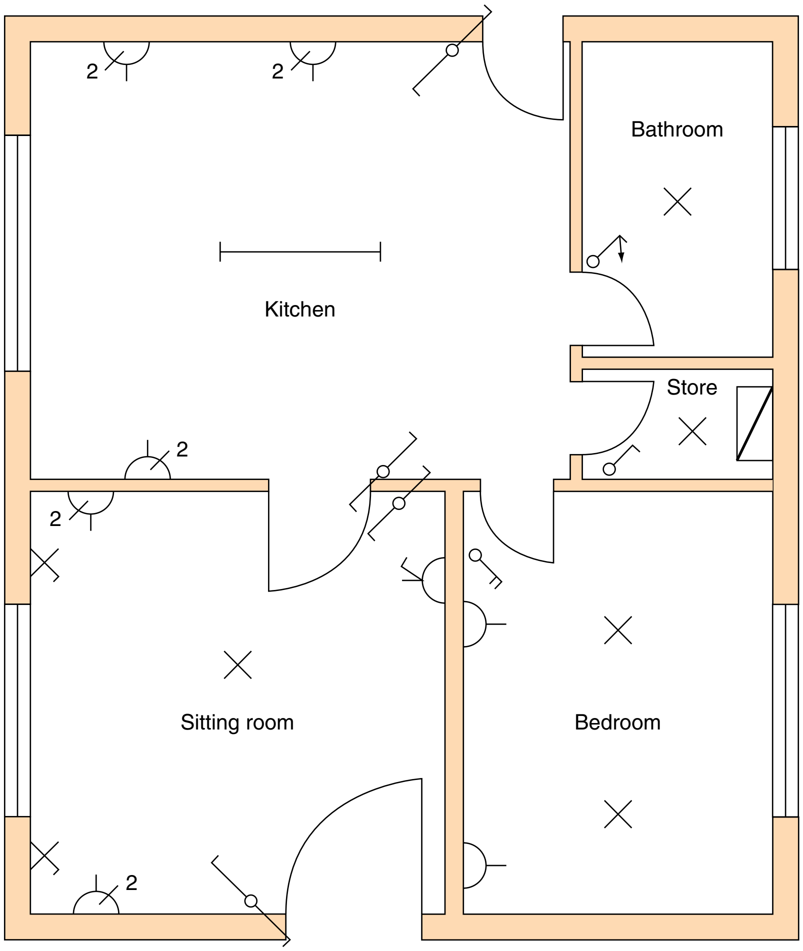


Figure 3.14 Layout drawing or site plan for electrical installation.

block diagram is to show how the components of the circuit relate to each other and therefore the individual circuit connections are not shown.

Wiring diagrams

A **wiring diagram** or connection diagram shows the detailed connections between components or items of equipment. They do not indicate how a piece of equipment or circuit works. The purpose of a wiring diagram is to help someone with the actual wiring of the circuit. Figure 3.15 shows the wiring diagram for a two-way lighting circuit.

Definition

A *wiring diagram* or connection diagram shows the detailed connections between components or items of equipment.

Try this

Drawing

The next time you are on site:

- ask your supervisor to show you the site plans
- ask him to show you how the scale works

Circuit diagrams

A **circuit diagram** shows most clearly how a circuit works. All the essential parts and connections are represented by their graphical symbols. The purpose of a circuit diagram is to help our understanding of the circuit. It will be laid

Definition

A *circuit diagram* shows most clearly how a circuit works.

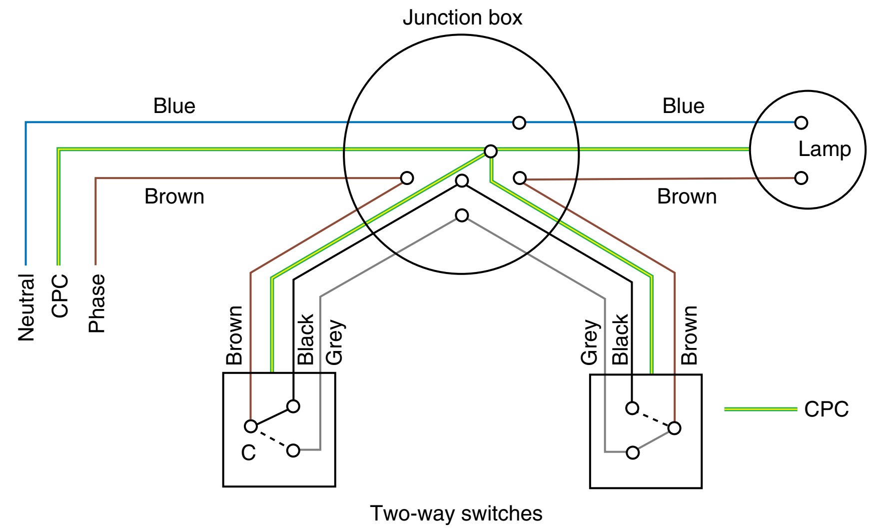


Figure 3.15 Wiring diagram of two-way switch control.

out as clearly as possible, without regard to the physical layout of the actual components, and therefore it may not indicate the most convenient way to wire the circuit.

Telephone communications

Telephones and mobile phones today play one of the most important roles in enabling people to communicate with each other. You are never alone when you have a telephone. If there is a problem, you can ring your supervisor or foreman for help. The advantage of a telephone message over a written message is its speed; the disadvantage is that no record is kept of an agreement made over the telephone. Therefore, business agreements made on the telephone are often followed up by written confirmation.

When *taking* a telephone call, remember that you cannot be seen and, therefore, gestures and facial expressions will not help to make you understood. Always be polite and helpful when answering your company's telephone – you are your company's most important representative at that moment. Speak clearly and loud enough to be heard without shouting, sound cheerful and write down messages if asked. Always read back what you have written down to make sure that you are passing on what the caller intended.

Many companies now use standard telephone message pads such as that shown in Fig. 3.16 because they prompt people to collect all the relevant information. In this case John Gall wants Dave Twem to pick up the Megger from Jim on Saturday and take it to the Bispham site on Monday. The person taking the call and relaying the message is Dave Low.

When *making* a telephone call, make sure you know what you want to say or ask. Make notes so that you have times, dates and any other relevant information ready before you make the call.

Definition

A lot of communications between and within larger organizations take place by completing standard forms or sending internal memos.

Written messages

A lot of communications between and within larger organizations take place by completing standard forms or sending internal memos. Written messages have the advantage of being 'auditable'. An auditor can follow the paperwork trail to see, for example, who was responsible for ordering certain materials.

FLASH-BANG ELECTRICAL TELEPHONE MESSAGES

Date *Thurs 11 Aug. 10* Time *09.30*

Message to *Dave Twem*

Message from (Name) *John Gall*

(Address) *Bispham Site*

Blackpool.

(Telephone No.) *(01253) 123456*

Message *Pick up Megger*

from Jim on Saturday and take to Bispham

site on Monday.

Thanks

Message taken by *Dave Low*

Figure 3.16 Typical standard telephone message pad.

When completing standard forms, follow the instructions given and ensure that your writing is legible. Do not leave blank spaces on the form, always specifying 'not applicable' or 'N/A' whenever necessary. Sign or give your name and the date as asked for on the form. Finally, read through the form again to make sure you have answered all the relevant sections correctly.

Internal memos are forms of written communication used within an organization; they are not normally used for communicating with customers or suppliers. Figure 3.17 shows the layout of a typical standard memo form used by Dave Twem to notify John Gall that he has ordered the hammer drill.

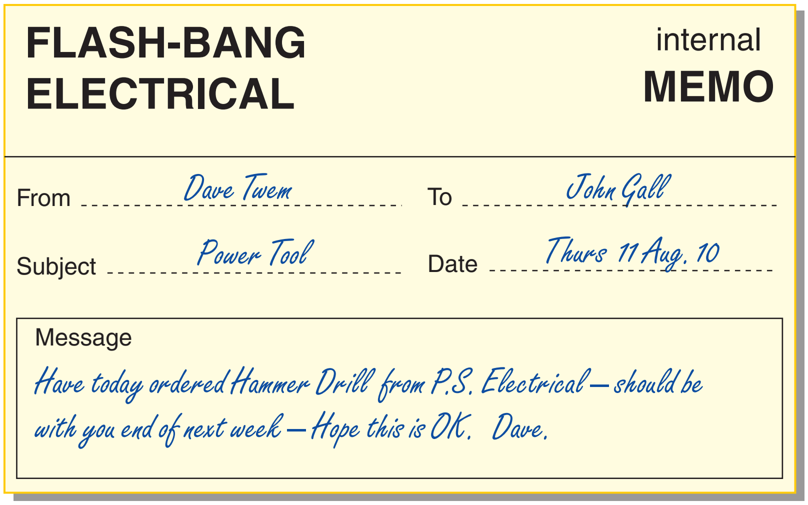
Letters provide a permanent record of communications between organizations and individuals. They may be handwritten, but formal business letters give a better impression of the organization if they are typewritten. A letter should be written using simple concise language, and the tone of the letter should always be polite even if it is one of complaint. Always include the date of the correspondence. The greeting on a formal letter should be 'Dear Sir/Madam' and concluded with 'Yours faithfully'. A less formal greeting would be 'Dear Mr Smith' and concluded 'Yours sincerely'. Your name and status should be typed below your signature.

Time sheets

A **time sheet** is a standard form completed by each employee to inform the employer of the actual time spent working on a particular contract or site. This helps the employer to bill the hours of work to an individual job. It is usually a weekly document and includes the number of hours worked, the name of the job

Definition

A *time sheet* is a standard form completed by each employee to inform the employer of the actual time spent working on a particular contract or site.



FLASH-BANG ELECTRICAL

internal **MEMO**

From Dave Twem To John Gall

Subject Power Tool Date Thurs 11 Aug. 10

Message

Have today ordered Hammer Drill from P.S. Electrical – should be with you end of next week – Hope this is OK. Dave.

Figure 3.17 Typical standard memo form.

and any travelling expenses claimed. Office personnel require time sheets so that wages can be made up.

Definition

A *job sheet* or *job card* such as that shown in Fig. 3.18 carries information about a job which needs to be done, usually a small job.

Job sheets

A **job sheet** or **job card** such as that shown in Fig. 3.18 carries information about a job which needs to be done, usually a small job. It gives the name and address of the customer, contact telephone numbers, often a job reference number and a brief description of the work to be carried out. A typical job sheet work description might be:

- Job 1: Upstairs lights not working.
- Job 2: Funny fishy smell from kettle socket in kitchen.

An electrician might typically have a ‘jobbing day’ where he picks up a number of job sheets from the office and carries out the work specified.

Job 1, for example, might be the result of a blown fuse which is easily rectified, but the electrician must search a little further for the fault which caused the fuse to blow in the first place. The actual fault might, for example, be a decayed flex on a pendant drop which has become shorted out, blowing the fuse. The pendant drop would be re-flexed or replaced, along with any others in poor condition. The installation would then be tested for correct operation and the customer given an account of what has been done to correct the fault. General information and assurances about the condition of the installation as a whole might be requested and given before setting off to job 2.

The kettle socket outlet at job 2 is probably getting warm and, therefore, giving off that ‘fishy’ bakelite smell because loose connections are causing the bakelite socket to burn locally. A visual inspection would confirm the diagnosis.
A typical solution would be to replace the socket and repair any damage to the conductors inside the socket box. Check the kettle plug top for damage and loose connections. Make sure all connections are tight before reassuring the customer that all is well; then, off to the next job or back to the office.

The time spent on each job and the materials used are sometimes recorded on the job sheet, but alternatively a daywork sheet can be used. This will depend upon what is normal practice for the particular electrical company. This information can then be used to ‘bill’ the customer for work carried out.

JOB SHEET

Job Number ----------------

FLASH-BANG ELECTRICAL

Customer name --

Address of job --

Contact telephone number ------------------------------------

Work to be carried out --

Any special instructions/conditions/materials used

Figure 3.18 Typical time sheet.

Daywork sheets or variation order

Daywork is one way of recording variations to a contract, that is, work done which is outside the scope of the original contract. It is *extra* work. If daywork is to be carried out, the site supervisor must first obtain a signature from the client's representative, for example, the architect, to **authorize the extra work**. A careful record must then be kept on the daywork sheets of all extra time and materials used so that the client can be billed for the extra work. A typical daywork sheet is shown in Fig. 3.19.

Definition

Daywork is one way of recording *variations to a contract*, that is, work done which is outside the scope of the original contract. It is *extra* work.

Reports

On large jobs, the foreman or supervisor is often required to keep a report of the relevant events which happen on the site for example, how many people from your company are working on site each day, what goods were delivered, whether there were any breakages or accidents, and records of site meetings attended. Some firms have two separate documents, a site diary to record daily events and a weekly report which is a summary of the week's events extracted from the site diary. The site diary remains on site and the weekly report is sent to head office to keep managers informed of the work's progress.

Personal conduct

Remember that it is the customers who actually pay the wages of everyone employed in your company. You should always be polite and listen carefully to their wishes. They may be elderly or of a different religion or cultural background

FLASH-BANG ELECTRICAL

VARIATION ORDER OR DAYWORK SHEET

Client name ....

Job number/ref. ....

Date	Labour	Start time	Finish time	Total hours	Office use

Materials quantity	Description	Office use

Site supervisor or Flash-Bang Electrical representative responsible for carrying out work ....

Signature of person approving work and status e.g.

Client ☐ Architect ☐ Q.S. ☐ Main contractor ☐ Clerk of works ☐

Signature ....

Figure 3.19 Typical daywork sheet or variation order.

than you. In a domestic situation, the playing of loud music on a radio may not be approved of. Treat the property in which you are working with the utmost care. When working in houses, shops and offices use dust sheets to protect floor coverings and furnishings. Clean up periodically and make a special effort when the job is completed.

Dress appropriately: an unkempt or untidy appearance will encourage the customer to think that your work will be of poor quality.

The electrical installation in a building is often carried out alongside other trades. It makes good sense to help other trades where possible and to develop good working relationships with other employees. The customer will be most happy if the workers give an impression of working together as a team for the successful completion of the project.

Finally, remember that the customer will probably see more of the electrician and the electrical trainee than the managing director of your firm and, therefore, the image presented by you will be assumed to reflect the policy of the company. You are, therefore, your company's most important representative. Always give the impression of being capable and in command of the situation, because this gives customers confidence in the company's ability to meet their needs. However, if a problem does occur which is outside your previous experience and you do not feel confident to solve it successfully, then contact your supervisor for professional help and guidance. It is not unreasonable for a young member of the company's team to seek help and guidance from those employees with more experience. This approach would be preferred by most companies rather than having to meet the cost of an expensive blunder.

Construction site – safe working practice

In Chapter 1 we looked at some of the laws and regulations that affect our working environment. We looked at safety signs and personal protective equipment (PPE). The structure of companies within the electrotechnical industry and the ways in which they communicate information by drawings, symbols and standard forms was discussed earlier in this chapter.

If your career in the electrotechnical industry is to be a long, happy and safe one, you must always wear appropriate PPE such as footwear and head protection, and behave responsibly and sensibly in order to maintain a safe working environment. Before starting work, make a safety assessment. What is going to be hazardous, will you require PPE, do you need any special access equipment?

Construction sites can be hazardous because of the temporary nature of the construction process. The surroundings and systems are always changing as the construction process moves to its completion date when everything is finally in place.

Safe methods of working must be demonstrated by everyone at every stage. 'Employees have a duty of care to protect their own health and safety and that of others who might be affected by their work activities'.

To make the work area safe before starting work and during work activities, it may be necessary to:

- use barriers or tapes to screen off potential hazards,
- place warning signs as appropriate,
- inform those who may be affected by any potential hazard,
- use a safe isolation procedure before working on live equipment or circuits,
- obtain any necessary 'permits to work' before work begins.

Try this

Communications

Make a list of all the different types of standard forms which your employer uses. Let me start the list for you with 'time sheets'.

Get into the habit of always working safely and being aware of the potential hazards around you when you are working.

Having chosen an appropriate wiring system which meets the intended use and structure of the building and satisfies the environmental conditions of the installation, you must install the system conductors, accessories and equipment in a safe and competent manner.

The structure of the building must be made good if it is damaged during the installation of the wiring system. For example, where conduits and trunking are run through walls and floors.

All connections in the wiring system must be both electrically and mechanically sound. All conductors must be chosen so that they will carry the design current under the installed conditions.

If the wiring system is damaged during installation it must be made good to prevent future corrosion. For example, where galvanized conduit trunking or tray is cut or damaged by pipe vices, it must be made good to prevent localized corrosion.

All tools must be used safely and sensibly. Cutting tools should be sharpened and screwdrivers ground to a sharp square end on a grindstone.

It is particularly important to check that the plug and cables of hand held electrically powered tools and extension leads are in good condition. Damaged plugs and cables must be repaired before you use them. All electrical power tools of 110 and 230 V must be tested with a portable appliance tester (PAT) in accordance with the company's health and safety procedures, but probably at least once each year.

Tools and equipment that are left lying about in the workplace can become damaged or stolen and may also be the cause of people slipping, tripping or falling. Tidy up regularly and put power tools back in their boxes. You personally may have no control over the condition of the workplace in general, but keeping your own work area clean and tidy is the mark of a skilled and conscientious craftsman.

Finally, when the job is finished, clean up and dispose of all waste material responsibly as described in Chapter 1 of *Basic Electrical Installation Work*, 6th edition under the heading 'Disposing of waste'.

To demonstrate that you understand the third, fourth and fifth CGLI Outcomes, your tutor/trainer/lecturer will assess your ability to communicate effectively, organize operatives and produce programmes of work.

Delivery and storage of equipment (CGLI Outcome 6)

Delivery notes

When materials are delivered to site, the person receiving the goods is required to sign the driver's 'delivery note'. This record is used to confirm that goods have been delivered by the supplier, who will then send out an invoice requesting payment, usually at the end of the month.

The person receiving the goods must carefully check that all the items stated on the delivery note have been delivered in good condition and are:

- the correct type
- fit for purpose
- in the correct quantity

Any missing or damaged items must be clearly indicated on the **delivery note** before signing, because, by signing the delivery note the person is saying ‘yes, these items were delivered to me as my company’s representative on that date and in good condition and I am now responsible for these goods’. Suppliers will replace materials damaged in transit provided that they are notified within a set time period, usually 3 days. The person receiving the goods should try to quickly determine their condition. Has the packaging been damaged, does the container ‘sound’ like it might contain broken items? It is best to check at the time of delivery if possible, or as soon as possible after delivery and within the notifiable period. Electrical goods delivered to site should be handled carefully and stored securely until they are installed. Electrical accessories, cable and equipment are expensive items and attractive to the opportunist thief. Do not leave deliveries unattended. The goods must be locked away securely and only brought out of the store when they are installed. Copies of delivery notes are sent to head office so that payment can be made for the goods received.

To demonstrate that you understand this final CGLI Outcome in Unit 313 your tutor/trainer/lecturer will assess your ability to deal with the delivery and storage of materials on site.

Definition

By signing the *delivery note* the person is saying ‘yes, these items were delivered to me as my company’s representative on that date and in good condition and I am now responsible for these goods’.

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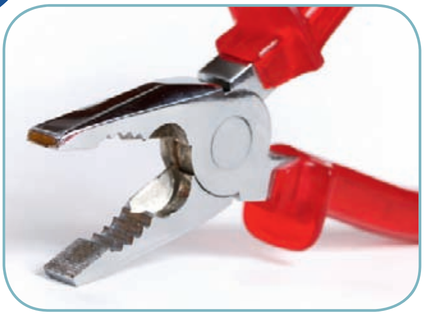
CHAPTER 4

Planning, preparing and installing wiring systems



Unit 315 of the City and Guilds 2357 syllabus

Planning, preparing and installing mandatory wiring systems and associated equipment in buildings, structures and the environment

When you have completed this chapter you should be able to:

1. Prepare the work environment for the installation of wiring systems
2. Interpret work activities
3. Monitor work progress
4. Identify electrical supplies and earthing arrangements
5. Measure and mark out wiring systems
6. Fix cable and wiring systems, calculate conduit and trunking capacities
7. Confirm contract variations

Online Material WWW

This chapter has free associated content, including animations and instructional videos, to support your learning

When you see the logo, visit the website below to access this material:

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Prepare the working environment for the installation of wiring systems (CGLI Outcome 1)

Construction sites can be hazardous because of the temporary nature of the construction process. The surroundings and systems are always changing as the construction process moves to its completion date when everything is finally in place.

Safe methods of working must be demonstrated by everyone at every stage. 'Employees have a duty of care to protect their own health and safety and that of others who might be affected by their work activities'.

Advanced Electrical Installation Work. 978-0-08-097042-4

To make the work area safe before starting work and during work activities, it may be necessary to:

- use barriers or tapes to screen off potential hazards,
- place warning signs as appropriate,
- inform those who may be affected by any potential hazard,
- use a safe isolation procedure before working on live equipment or circuits,
- obtain any necessary 'permits to work' before work begins.

Try this

Communications

Make a list of all the different types of PPE signs which you see at work and college.

Get into the habit of always working safely and being aware of the potential hazards around you when you are working.

Having chosen an appropriate wiring system which meets the intended use and structure of the building and satisfies the environmental conditions of the installation, you must install the system conductors, accessories and equipment in a safe and competent manner.

The structure of the building must be made good if it is damaged during the installation of the wiring system. For example, where conduits and trunking are run through walls and floors.

All connections in the wiring system must be both electrically and mechanically sound and we will discuss this elsewhere. All conductors must be chosen so that they will carry the design current under the installed conditions.

If the wiring system is damaged during installation it must be made good to prevent future corrosion. For example, where galvanized conduit trunking or tray is cut or damaged by pipe vices, it must be made good to prevent localized corrosion.

All tools must be used safely and sensibly. Cutting tools should be sharpened and screwdrivers ground to a sharp square end on a grindstone.

It is particularly important to check that the plug and cables of hand held electrically powered tools and extension leads are in good condition. Damaged plugs and cables must be repaired before you use them. All electrical power tools of 110 and 230 V must be tested with a portable appliance tester (PAT) in accordance with the company's health and safety procedures, but probably at least once each year.

Tools and equipment that are left lying about in the workplace can become damaged or stolen and may also be the cause of people slipping, tripping or falling. Tidy up regularly and put power tools back in their boxes. You personally may have no control over the condition of the workplace in general, but keeping your own work area clean and tidy is the mark of a skilled and conscientious craftsman.

Where PPE is provided by an employer, employees have a duty to use it to safeguard themselves.

PPE at Work Regulations 1992

PPE is defined as all equipment designed to be worn, or held, to protect against a risk to health and safety. This includes most types of protective clothing, and

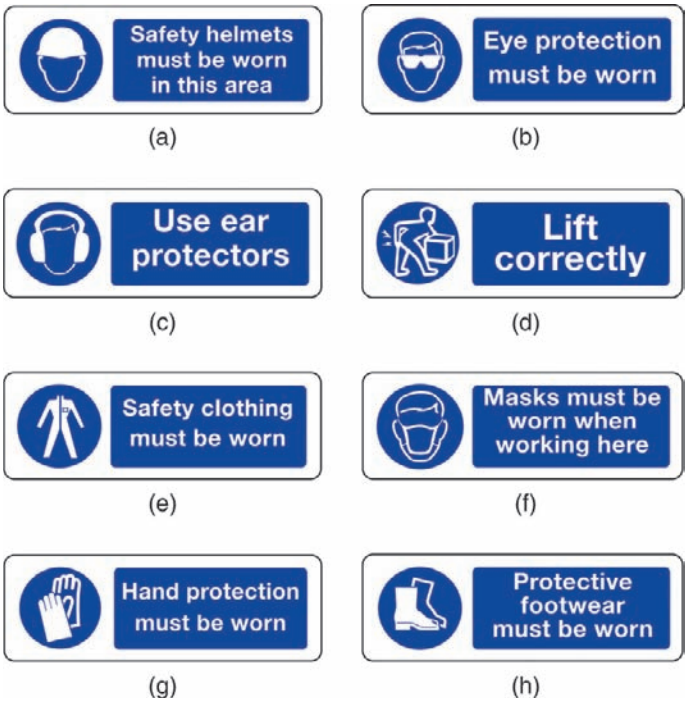

Figure 4.1 Safety signs showing type of PPE to be worn.

equipment such as eye, foot and head protection, safety harnesses, life jackets and high-visibility clothing.

Under the Health and Safety at Work Act, employers must provide free of charge any PPE and employees must make full and proper use of it. Safety signs such as those shown in Fig. 4.1 are useful reminders of the type of PPE to be used in a particular area. The vulnerable parts of the body which may need protection are the head, eyes, ears, lungs, torso, hands and feet and, additionally, protection from falls may need to be considered. Objects falling from a height present the major hazard against which head protection is provided. Other hazards include striking the head against projections and hair becoming entangled in machinery. Typical methods of protection include helmets, light duty scalp protectors called 'bump caps' and hairnets.

The eyes are very vulnerable to liquid splashes, flying particles and light emissions such as ultraviolet light, electric arcs and lasers. Types of eye protectors include safety spectacles, safety goggles and face shields. Screen based workstations are being used increasingly in industrial and commercial locations by all types of personnel. Working with VDUs (visual display units) can cause eye strain and fatigue and, therefore, work patterns should be varied and operators are entitled to free eye tests.

Noise is accepted as a problem in most industries and surprisingly there has been very little control legislation. The HSE have published a 'Code of Practice' and 'Guidance Notes' HSG 56 for reducing the exposure of employed persons to noise. A continuous exposure limit of below 90 dB for an 8-hour working day is recommended by the code.

Noise may be defined as any disagreeable or undesirable sound or sounds, generally of a random nature, which do not have clearly defined frequencies. The usual basis for measuring noise or sound level is the decibel scale. Whether

Safety first

PPE

- What type of PPE do you use at work?
- Make a list in the margin of the book

noise of a particular level is harmful or not also depends upon the length of exposure to it. This is the basis of the widely accepted limit of 90 dB of continuous exposure to noise for 8 hours per day.

A peak sound pressure of above 200 pascals or about 120 dB is considered unacceptable and 130 dB is the threshold of pain for humans. If a person has to shout to be understood at 2 m, the background noise is about 85 dB. If the distance is only 1 m, the noise level is about 90 dB. Continuous noise at work causes deafness, makes people irritable, affects concentration, causes fatigue and accident proneness and may mask sounds which need to be heard in order to work efficiently and safely.

It may be possible to engineer out some of the noise, for example, by placing a generator in a separate sound-proofed building. Alternatively, it may be possible to provide job rotation, to rearrange work locations or provide acoustic refuges.

Where individuals must be subjected to some noise at work it may be reduced by ear protectors. These may be disposable ear plugs, reusable ear plugs or ear muffs. The chosen ear protector must be suited to the user and suitable for the type of noise and individual personnel should be trained in its correct use.

Breathing reasonably clean air is the right of every individual, particularly at work. Some industrial processes produce dust which may present a potentially serious hazard. The lung disease asbestosis is caused by the inhalation of asbestos dust or particles and the coal dust disease pneumoconiosis, suffered by many coal miners, has made people aware of the dangers of breathing in contaminated air.

Some people may prove to be allergic to quite innocent products such as flour dust in the food industry or wood dust in the construction industry. The main effect of inhaling dust is a measurable impairment of lung function. This can be avoided by wearing an appropriate mask, respirator or breathing apparatus as recommended by the company's health and safety policy and indicated by local safety signs.

A worker's body may need protection against heat or cold, bad weather, chemical or metal splash, impact or penetration and contaminated dust. Alternatively, there may be a risk of the worker's own clothes causing contamination of the product, as in the food industry. Appropriate clothing will be recommended in the company's health and safety policy. Ordinary working clothes and clothing provided for food hygiene purposes are not included in the PPE at Work Regulations.

Hands and feet may need protection from abrasion, temperature extremes, cuts and punctures, impact or skin infection. Gloves or gauntlets provide protection from most industrial processes but should not be worn when operating machinery because they may become entangled in it. Care in selecting the appropriate protective device is required; for example, barrier creams provide only a limited protection against infection.

Boots or shoes with in-built toe caps can give protection against impact or falling objects and, when fitted with a mild steel sole plate, can also provide protection from sharp objects penetrating through the sole. Special slip resistant soles can also be provided for employees working in wet areas.

Whatever the hazard to health and safety at work, the employer must be able to demonstrate that he or she has carried out a risk assessment, made recommendations which will reduce that risk and communicated these recommendations to the workforce. Where there is a need for PPE to protect against personal injury and to create a safe working environment, the employer must provide that equipment and any necessary training which might be required and the employee must make full and proper use of such equipment and training.

Causes of accidents

Most accidents are caused by either human error or environmental conditions. **Human errors** include behaving badly or foolishly, being careless and not paying attention to what you should be doing at work, doing things that you are not competent to do or have not been trained to do. You should not work when tired or fatigued and should never work when you have been drinking alcohol or taking drugs.

Environmental conditions include unguarded or faulty machinery, damaged or faulty tools and equipment, poorly illuminated or ventilated workplaces and untidy, dirty or overcrowded workplaces.

The most common causes of accidents

These are:

- slips, trips and falls;
- manual handling, that is moving objects by hand;
- using equipment, machinery or tools;
- storage of goods and materials which then become unstable;
- fire;
- electricity;
- mechanical handling.

Accident prevention measures

To control the risk of an accident we usually:

- eliminate the cause;
- substitute a procedure or product with less risk;
- enclose the dangerous situation;
- put guards around the hazard;
- use safe systems of work;
- supervise, train and give information to staff;
- if the hazard cannot be removed or minimized then provide PPE.

Let us now look at the application of one of the procedures that make the workplace a safer place to work but first of all I want to explain what I mean when I use the words hazard and risk.

Hazard and risk

A **hazard** is something with the 'potential' to cause harm, for example, chemicals, electricity or working above ground.

A **risk** is the 'likelihood'of harm actually being done.

Competent persons are often referred to in the Health and Safety at Work Regulations, but who is 'competent'? For the purposes of the Act, a competent person is anyone who has the necessary technical skills, training and expertise to safely carry out the particular activity. Therefore, a **competent person** dealing with a hazardous situation reduces the risk.

Definition

Human errors include behaving badly or foolishly, being careless and not paying attention to what you should be doing at work.

Definition

Environmental conditions include unguarded or faulty machinery.

Safety first

Safety Procedures

- hazard risk assessment is an essential part of any health and safety management system
- The aim of the planning process is to minimize risk
- HSE publication HSG (65)

Definitions

A *hazard* is something with the 'potential' to cause harm, for example, chemicals, electricity or working above ground.

A *risk* is the 'likelihood' of harm actually being done.

Definition

A *competent person* is anyone who has the necessary technical skills, training and expertise to safely carry out the particular activity.

Think about your workplace and at each stage of what you do, think about what might go wrong. Some simple activities may be hazardous. Here are some typical activities where accidents might happen.

Typical activity	Potential hazard
Receiving materials	Lifting and carrying
Stacking and storing	Falling materials
Movement of people	Slips, trips and falls
Building maintenance	Working at heights or in confined spaces
Movement of vehicles	Collisions

How high are the risks? Think about what might be the worst result, is it a broken finger or someone suffering permanent lung damage or being killed? How likely is it to happen? How often is that type of work carried out and how close do people get to the hazard? How likely is it that something will go wrong?

How many people might be injured if things go wrong? Might this also include people who do not work for your company?

Employers of more than five people must document the risks at work and the process is known as hazard risk assessment.

Hazard risk assessment – the process

The Management of Health and Safety at Work Regulations 1999 tell us that employers must systematically examine the workplace, the work activity and the management of safety in the establishment through a process of risk assessments. A record of all significant risk assessment findings must be kept in a safe place and be made available to an HSE inspector if required. Information based on the risk assessment findings must be communicated to relevant staff and if changes in work behaviour patterns are recommended in the interests of safety, then they must be put in place.

So risk assessment must form a part of any employer's robust policy of health and safety. However, an employer only needs to 'formally' assess the significant risks. He is not expected to assess the trivial and minor types of household risks. Staff are expected to read and to act upon these formal risk assessments and they are unlikely to do so enthusiastically if the file is full of trivia. An assessment of risk is nothing more than a careful examination of what, in your work, could cause harm to people. It is a record that shows whether sufficient precautions have been taken to prevent harm.

The HSE recommends five steps to any risk assessment.

Step 1

Look at what might reasonably be expected to cause harm. Ignore the trivial and concentrate only on significant hazards that could result in serious harm or injury. Manufacturers' data sheets or instructions can also help you spot hazards and put risks in their true perspective.

Step 2

Decide who might be harmed and how. Think about people who might not be in the workplace all the time – cleaners, visitors, contractors or maintenance personnel. Include members of the public or people who share the workplace.

Is there a chance that they could be injured by activities taking place in the workplace?

Step 3

Evaluate what is the risk arising from an identified hazard. Is it adequately controlled or should more be done? Even after precautions have been put in place, some risk may remain. What you have to decide, for each significant hazard, is whether this remaining risk is low, medium or high. First of all, ask yourself if you have done all the things that the law says you have got to do. For example, there are legal requirements on the prevention of access to dangerous machinery. Then ask yourself whether generally accepted industry standards are in place, but do not stop there – think for yourself, because the law also says that you must do what is reasonably practicable to keep the workplace safe. Your real aim is to make all risks small by adding precautions, if necessary.

If you find that something needs to be done, ask yourself:

1 Can I get rid of this hazard altogether?
2 If not, how can I control the risk so that harm is unlikely?

Only use PPE when there is nothing else that you can reasonably do.

If the work that you do varies a lot, or if there is movement between one site and another, select those hazards which you can reasonably foresee, the ones that apply to most jobs and assess the risks for them. After that, if you spot any unusual hazards when you get on site, take what action seems necessary.

Step 4

Record your findings and say what you are going to do about risks that are not adequately controlled. If there are fewer than five employees you do not need to write anything down but if there are five or more employees, the significant findings of the risk assessment must be recorded. This means writing down the more significant hazards and assessing if they are adequately controlled and recording your most important conclusions. Most employers have a standard risk assessment form which they use such as that shown in Fig. 4.2 but any format is suitable. The important thing is to make a record.

There is no need to show how the assessment was made, providing you can show that:

1 a proper check was made,
2 you asked those who might be affected,
3 you dealt with all obvious and significant hazards,
4 the precautions are reasonable and the remaining risk is low,
5 you informed your employees about your findings.

Risk assessments need to be *suitable* and *sufficient*, not perfect. The two main points are:

1 Are the precautions reasonable?
2 Is there a record to show that a proper check was made?

File away the written assessment in a dedicated file for future reference or use. It can help if an HSE inspector questions the company's precautions or if the company becomes involved in any legal action. It shows that the company has done what the law requires.

HAZARD RISK ASSESSMENT	FLASH-BANG ELECTRICAL CO.
For Company name or site: ____________ Address: ____________ ____________	Assessment undertaken by: ____________ Signed: ____________ Date: ____________
STEP 5 Assessment review date: ____________	
STEP 1 List the hazards here	STEP 2 Decide who might be harmed
STEP 3 Evaluate (what is) the risk – is it adequately controlled? State risk level as low, medium or high	STEP 4 Further action – what else is required to control any risk identified as medium or high?

Figure 4.2 Hazard risk assessment standard form.

Step 5

Review the assessments from time to time and revise them if necessary.

Completing a risk assessment

When completing a risk assessment such as that shown in Fig. 4.2, do not be over complicated. In most firms in the commercial, service and light industrial sector, the hazards are few and simple. Checking them is common sense but necessary.

Step 1

List only hazards which you could reasonably expect to result in significant harm under the conditions prevailing in your workplace. Use the following examples as a guide:

- Slipping or tripping hazards (e.g. from poorly maintained or partly installed floors and stairs).
- Fire (e.g. from flammable materials you might be using, such as solvents).
- Chemicals (e.g. from battery acid).
- Moving parts of machinery (e.g. blades).
- Rotating parts of handtools (e.g. drills).
- Accidental discharge of cartridge operated tools.
- High pressure air from airlines (e.g. air powered tools).
- Pressure systems (e.g. steam boilers).
- Vehicles (e.g. fork lift trucks).
- Electricity (e.g. faulty tools and equipment).
- Dust (e.g. from grinding operations or thermal insulation).
- Fumes (e.g. from welding).
- Manual handling (e.g. lifting, moving or supporting loads).
- Noise levels too high (e.g. machinery).
- Poor lighting levels (e.g. working in temporary or enclosed spaces).
- Low temperatures (e.g. working outdoors or in refrigeration plants).
- High temperatures (e.g. working in boiler rooms or furnaces).

Step 2

Decide who might be harmed, do not list individuals by name. Just think about groups of people doing similar work or who might be affected by your work:

- Office staff
- Electricians
- Maintenance personnel
- Other contractors on site
- Operators of equipment
- Cleaners
- Members of the public.

Pay particular attention to those who may be more vulnerable, such as:

- staff with disabilities,
- visitors,
- young or inexperienced staff,
- people working in isolation or enclosed spaces.

Step 3

Calculate what is the risk – is it adequately controlled? Have you already taken precautions to protect against the hazards which you have listed in Step 1? For example:

- Have you provided adequate information to staff?
- Have you provided training or instruction?

Do the precautions already taken

- meet the legal standards required?
- comply with recognized industrial practice?
- represent good practice?
- reduce the risk as far as is reasonably practicable?

If you can answer 'yes' to the above points then the risks are adequately controlled, but you need to state the precautions you have put in place. You can refer to company procedures, company rules, company practices, etc., in giving this information. For example, if we consider there might be a risk of electric shock from using electrical power tools, then the risk of a shock will be *less* if the company policy is to PAT test all power tools each year and to fit a label to the tool showing that it has been tested for electrical safety. If the stated company procedure is to use battery drills whenever possible, or 110 V drills when this is not possible, and *never* to use 230 V drills, then this again will reduce the risk. If a policy such as this is written down in the company safety policy statement, then you can simply refer to the appropriate section of the safety policy statement and the level of risk will be low.

Step 4

Further action – what more could be done to reduce those risks which were found to be inadequately controlled?

You will need to give priority to those risks that affect large numbers of people or which could result in serious harm. Senior managers should apply the principles below when taking action, if possible in the following order:

1. Remove the risk completely.
2. Try a less risky option.
3. Prevent access to the hazard (e.g. by guarding).
4. Organize work differently in order to reduce exposure to the hazard.
5. Issue PPE.
6. Provide welfare facilities (e.g. washing facilities for removal of contamination and first aid).

Any hazard identified by a risk assessment as *high risk* must be brought to the attention of the person responsible for health and safety within the company. Ideally, in Step 4 of the risk assessment you should be writing, 'No further action is required. The risks are under control and identified as low risk'.

The assessor may use as many standard hazard risk assessment forms, such as that shown in Fig. 4.2, as the assessment requires. Upon completion they should be stapled together or placed in a plastic wallet and stored in the dedicated file.

Method statement

The Construction, Design and Management Regulations and Approved Codes of Practice define a method statement as a written document laying out the work procedure and sequence of operations to ensure health and safety.

If the method statement is written as a result of a risk assessment carried out for a task or operation then following the prescribed method will reduce the risk. If the risk is low a verbal statement may be all that is required.

The safe isolation procedure described next in this chapter is a method statement. Following this method meets the requirements of the Electricity at Work Regulations, the IEE Regulations, and reduces the risk of electric shock to the operative and other people who might be affected by his actions.

Test equipment and safe isolation procedures

The Health and Safety Executive (HSE) has published Guidance Notes (GS 38) which advise electricians and other electrically competent people on the selection of suitable test probes, voltage indicating devices and measuring instruments. This is because they consider suitably constructed test equipment to be as vital for personal safety as the training and practical skills of the electrician. In the past, unsatisfactory test probes and voltage indicators have frequently been the cause of accidents, and therefore all test probes must now incorporate the following features:

1. The probes must have finger barriers or be shaped so that the hand or fingers cannot make contact with the live conductors under test.
2. The probe tip must not protrude more than 2 mm, and preferably only 1 mm, be spring-loaded and screened.
3. The lead must be adequately insulated and coloured so that one lead is readily distinguished from the other.
4. The lead must be flexible and sufficiently robust.
5. The lead must be long enough to serve its purpose but not too long.
6. The lead must not have accessible exposed conductors even if it becomes detached from the probe or from the instrument.
7. Where the leads are to be used in conjunction with a voltage detector they must be protected by a fuse.

A suitable probe and lead is shown in Fig. 4.3.

GS 38 also tells us that where the test is being made simply to establish the presence or absence of a voltage, the preferred method is to use a proprietary

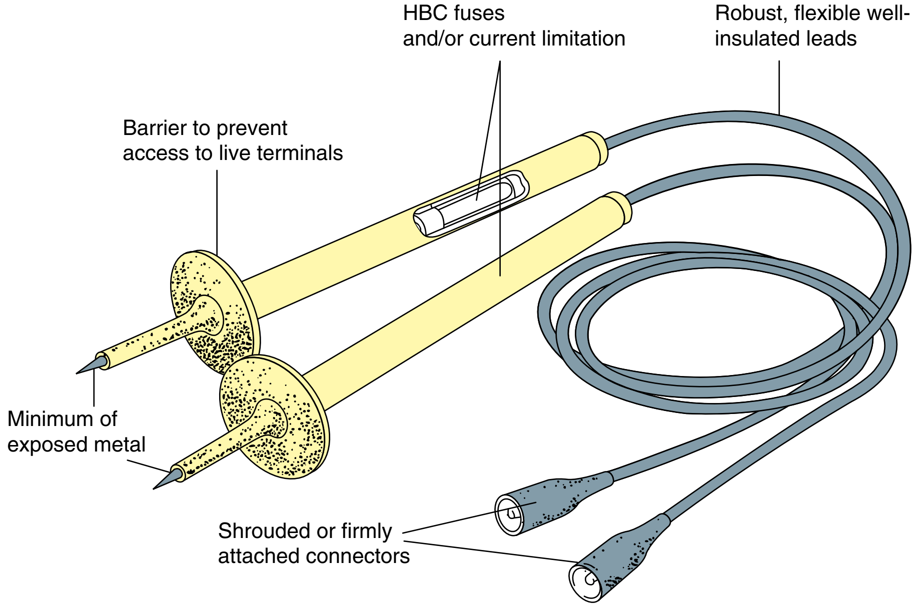

Figure 4.3 Recommended type of test probe and leads.

Figure 4.4 Typical voltage indicator.

test lamp or voltage indicator which is suitable for the working voltage, rather than a multimeter. Accident history has shown that incorrectly set multimeters or makeshift devices for voltage detection have frequently caused accidents. Fig. 4.4 shows a suitable voltage indicator. Test lamps and voltage indicators are not fail-safe, and therefore GS 38 recommends that they should be regularly proved, preferably before and after use, as described in the flowchart for a safe isolation procedure shown in Fig 4.7.

Test procedures

1. The circuits must be isolated using a 'safe isolation procedure', such as that described below, before beginning to test.
2. All test equipment must be 'approved' and connected to the test circuits by recommended test probes as described by the HSE Guidance Notes GS 38. The test equipment used must also be 'proved' on a known supply or by means of a proving unit such as that shown in Fig. 4.5.
3. Isolation devices must be 'secured' in the 'off' position as shown in Fig. 4.6.
4. Warning notices must be posted.
5. All relevant safety and functional tests must be completed before restoring the supply.

Live testing

The **Electricity at Work Act** tells us that it is 'preferable' that supplies be made dead before work commences (Regulation 4(3)). However, it does acknowledge that some work, such as fault-finding and testing, may require the electrical

Definition

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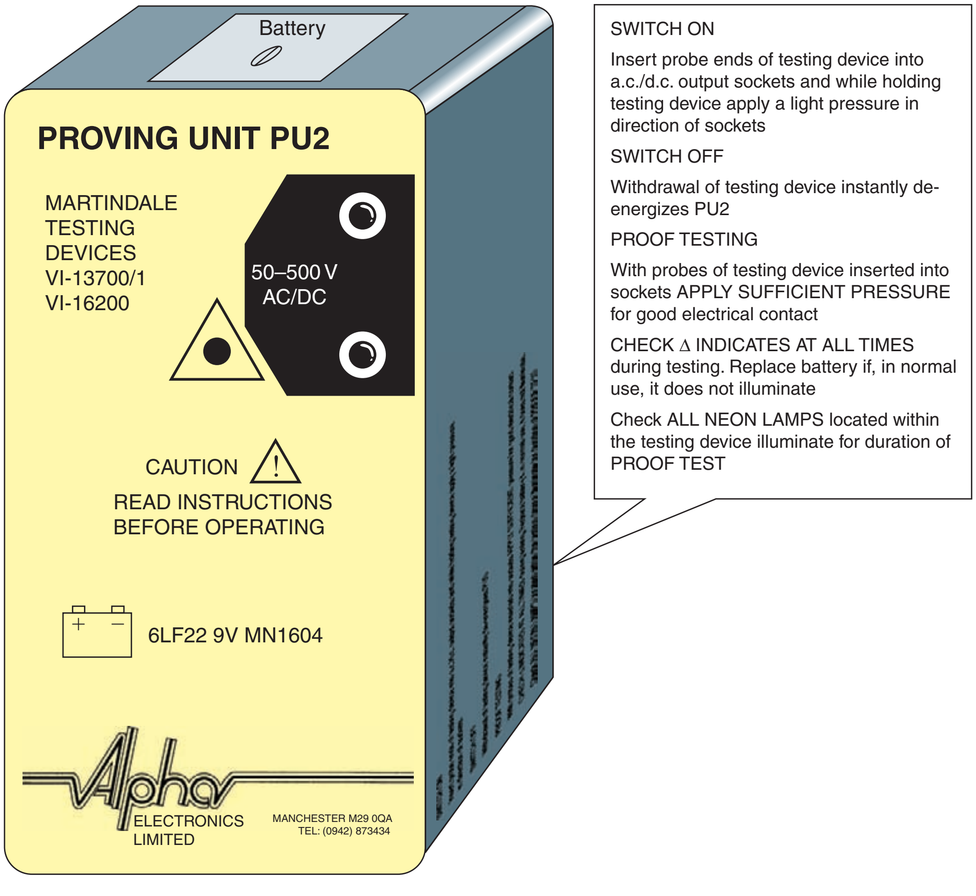

Figure 4.5 Voltage proving unit.

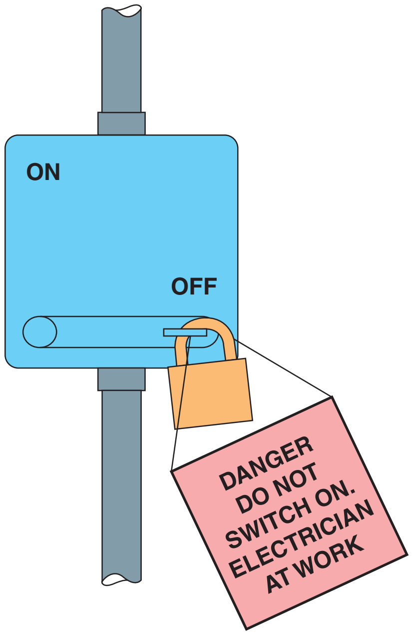

Figure 4.6 Secure isolation of a supply.

equipment to remain energized. Therefore, if the fault finding and testing can only be successfully carried out 'live', then the person carrying out the fault diagnosis must:

- be trained so that he understands the equipment and the potential hazards of working live and can, therefore, be deemed to be 'competent' to carry out the activity;
- only use approved test equipment;
- set up barriers and warning notices so that the work activity does not create a situation dangerous to others.

Note that while live testing may be required in order to find the fault, live repair work must not be carried out. The individual circuit or item of equipment must first be isolated.

Definition

Note that while live testing may be required in order to find the fault, live repair work must not be carried out. The individual circuit or item of equipment must first be isolated.

Isolation of supply

The Electricity at Work Regulations are very specific in describing the procedure to be used for isolation of the electrical supply. IEE Regulation 12(1) tells us that **isolation** means the disconnection and separation of the electrical equipment from every source of electrical energy in such a way that this disconnection and separation is secure. IEE Regulation 4(3) tells us that we must also prove the conductors are dead before work commences and that the test instrument used for this purpose must itself be proved immediately before and immediately after testing the conductors. To isolate an individual circuit or item of equipment

Definition

Isolation means the disconnection and separation of the electrical equipment from every source of electrical energy in such a way that this disconnection and separation is secure.

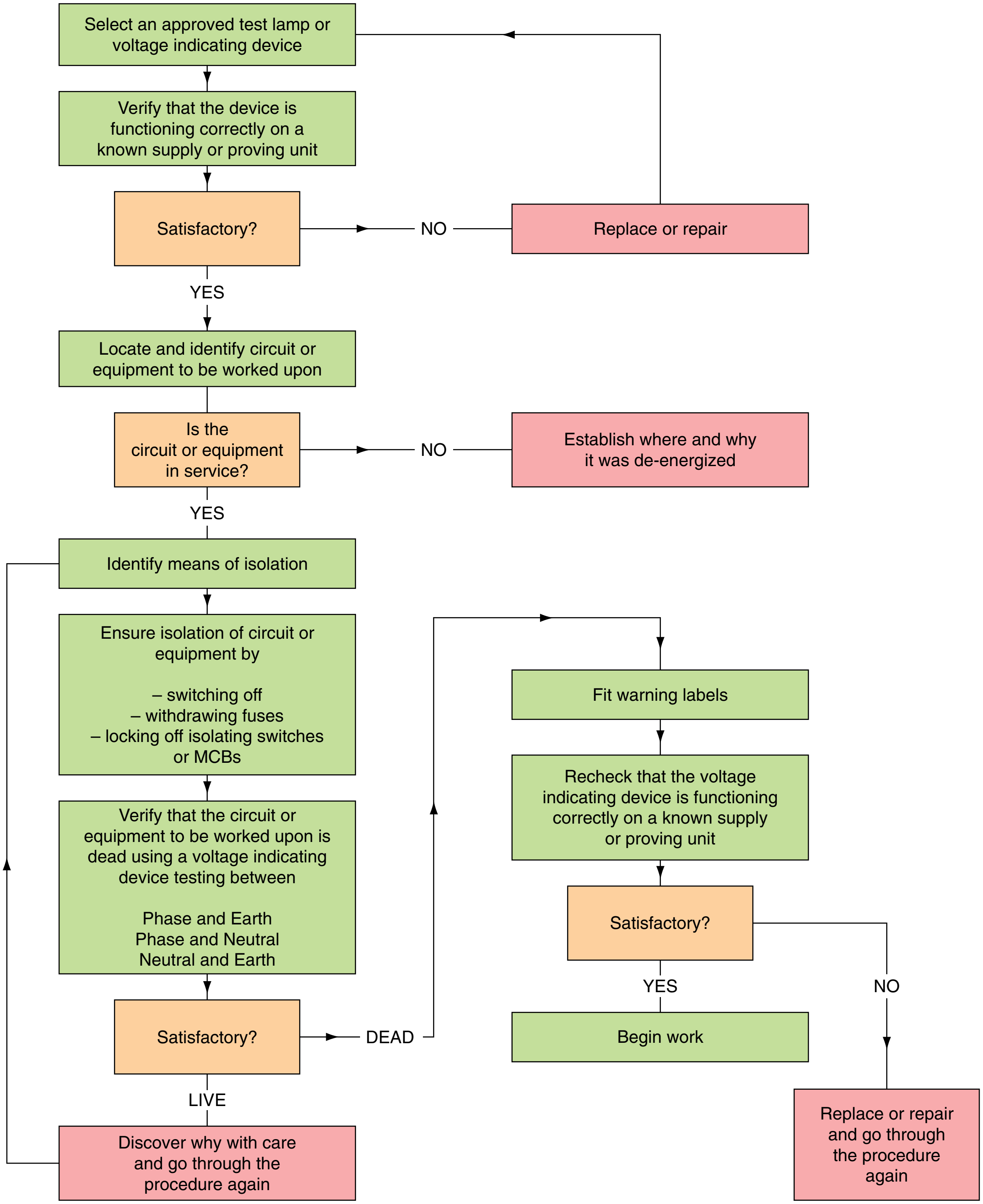

Figure 4.7 Flowchart for a secure isolation procedure.

successfully, competently and safely we must follow a procedure such as that given by the flow diagram in Fig. 4.7. Start at the top and work your way down the flowchart. When you get to the heavy-outlined amber boxes, pause and ask yourself whether everything is satisfactory up to this point. If the answer is yes, move on. If no, go back as indicated by the diagram.

Secure site storage

The ability to resolve a technical practical problem using tools and equipment is a part of what those of us in the electrotechnical industry are about, and so tools are very important to us. As a safety precaution it makes sense not to leave them unattended on site and to keep them in the back of your locked vehicle when not being used. Power tools are expensive, make your working life less difficult and are very easy to be carried away so they too should leave with you at the end of the working day. However, some pieces of equipment are too big to take home such as access equipment, generators and other electrical equipment brought in or hired specifically for a particular job. At the end of the working day these larger pieces of equipment must be made secure. On large construction sites the main contractors often make secure storage, in the shape of metal containers available to their sub-contractors and this may be a good solution in some situations. However, the security of a store can be put at risk if there is more than one key-holder. One of the other key-holders might leave the store unlocked and your material and equipment could be stolen through no fault of your own. So what are the alternatives? You could put your materials and equipment inside a large locked box that has been bolted to the wall or floor inside the main contractor's locked store or, you could use motorcycle locks to secure your plant inside the main contractor's locked store. The storage of materials which are to be installed at some later date also require secure storage. Electrical contractors these days often work out of an industrial unit which may also be their Head Office incorporating facilities for 'office work' and will therefore be occupied during the working day. Materials could probably be delivered and stored at this industrial unit and only small quantities taken to site each day by the installing electricians. Alternatively, if you have a good relationship with your local wholesalers, they too will deliver smaller quantities to site so that there is no requirement for storage. You may think that I am painting a rather bleak picture of secure site storage but electrical goods and equipment are very expensive and most desirable to a thief and you must, therefore, give serious consideration to how you will securely store goods on site if you have no other alternative.

To demonstrate that you understand this first CGL1 Outcome your tutor/trainer/lecturer will assess your ability to choose appropriate PPE, complete a risk assessment and method statement, carry out safe isolation and identify a secure site storage facility.

Monitoring and interpreting work activities (CGLI Outcomes 2 and 3)

Electrical installation design

The designer of an electrical installation must ensure that the design meets the requirements of the IEE Wiring Regulations for electrical installations and any other regulations which may be relevant to a particular installation. The designer may be a professional technician or engineer whose job is to design electrical installations for a large contracting firm. In a smaller firm, the designer may also be the electrician who will carry out the installation to the customer's requirements. The **designer** of any electrical installation is the person who interprets the electrical requirements of the customer within the regulations, identifies the appropriate types of installation, the most suitable methods of protection and control and the size of cables to be used.

Definition

The *designer* of any electrical installation is the person who interprets the electrical requirements of the customer within the regulations.

A large electrical installation may require many meetings with the customer and his professional representatives in order to identify a specification of what is required. The designer can then identify the general characteristics of the electrical installation and its compatibility with other services and equipment, as indicated in Part 3 of the Regulations. The protection and safety of the installation, and of those who will use it, must be considered, with due regard to Part 4 of the Regulations. An assessment of the frequency and quality of the maintenance to be expected will give an indication of the type of installation which is most appropriate.

Definition

The size and quantity of all the materials, cables, control equipment and accessories can then be determined. This is called a '*bill of quantities*'.

The size and quantity of all the materials, cables, control equipment and accessories can then be determined. This is called a '**bill of quantities**'.

It is a common practice to ask a number of electrical contractors to tender or submit a price for work specified by the bill of quantities. The contractor must cost all the materials, assess the labour cost required to install the materials and add on profit and overhead costs in order to arrive at a final estimate for the work. The contractor tendering the lowest cost is usually, but not always, awarded the contract.

To complete the contract in the specified time the electrical contractor must use the management skills required by any business to ensure that men and materials are on site as and when they are required. If alterations or modifications are made to the electrical installation as the work proceeds which are outside the original specification, then a **variation order** must be issued so that the electrical contractor can be paid for the additional work.

The specification for the chosen wiring system will be largely determined by the building construction and the activities to be carried out in the completed building.

An industrial building, for example, will require an electrical installation which incorporates flexibility and mechanical protection. This can be achieved by a conduit, tray or trunking installation.

In a block of purpose-built flats, all the electrical connections must be accessible from one flat without intruding upon the surrounding flats. A loop-in conduit system, in which the only connections are at the light switch and outlet positions, would meet this requirement.

For a domestic electrical installation an appropriate lighting scheme and multiple socket outlets for the connection of domestic appliances, all at a reasonable cost, are important factors which can usually be met by a PVC insulated and sheathed wiring system.

The final choice of a wiring system must rest with those designing the installation and those ordering the work, but whatever system is employed, good workmanship by competent persons is essential for compliance with the regulations (IEE Regulation 134.1.1). The necessary skills can be acquired by an electrical trainee who has the correct attitude and dedication to his craft.

Legal contracts

Before work commences, some form of legal contract should be agreed between the two parties, that is, those providing the work (e.g. the sub-contracting electrical company) and those asking for the work to be carried out (e.g. the main building company).

A contract is a formal document which sets out the terms of agreement between the two parties. A standard form of building contract typically contains four sections:

1. *The articles of agreement* – this names the parties, the proposed building and the date of the contract period.
2. *The contractual conditions* – this states the rights and obligations of the parties concerned, for example, whether there will be interim payments for work completed, or a penalty if work is not completed on time.
3. *The appendix* – this contains details of costings, for example, the rate to be paid for extras as daywork, who will be responsible for defects, how much of the contract tender will be retained upon completion and for how long.
4. *The supplementary agreement* – this allows the electrical contractor to recoup any value-added tax paid on materials at interim periods.

In signing the contract, the electrical contractor has agreed to carry out the work to the appropriate standards in the time stated and for the agreed cost. The other party, say the main building contractor, is agreeing to pay the price stated for that work upon completion of the installation.

If a dispute arises the contract provides written evidence of what was agreed and will form the basis for a solution.

For smaller electrical jobs, a verbal contract may be agreed, but if a dispute arises there is no written evidence of what was agreed and it then becomes a matter of one person's word against another's.

Management systems

Smaller electrical contracting firms will know where their employees are working and what they are doing from day to day because of the level of personal contact between the employer, employee and customer.

As a firm expands and becomes engaged on larger contracts, it becomes less likely that there is anyone in the firm with a complete knowledge of the firm's operations, and there arises an urgent need for sensible management and planning skills so that men and materials are on site when they are required and a healthy profit margin is maintained.

When the electrical contractor is told that he has been successful in tendering for a particular contract he is committed to carrying out the necessary work within the contract period. He must therefore consider:

- by what date the job must be finished;
- when the job must be started if the completion date is not to be delayed;
- how many men will be required to complete the contract;
- when certain materials will need to be ordered;
- when the supply authorities must be notified that a supply will be required;
- if it is necessary to obtain authorization from a statutory body for any work to commence.

In thinking ahead and planning the best method of completing the contract, the individual activities or jobs must be identified and consideration given to how the various jobs are interrelated. To help in this process a number of management techniques are available. In this chapter we will consider only two: bar charts and work schedules. The very preparation of a bar chart or work schedule forces the

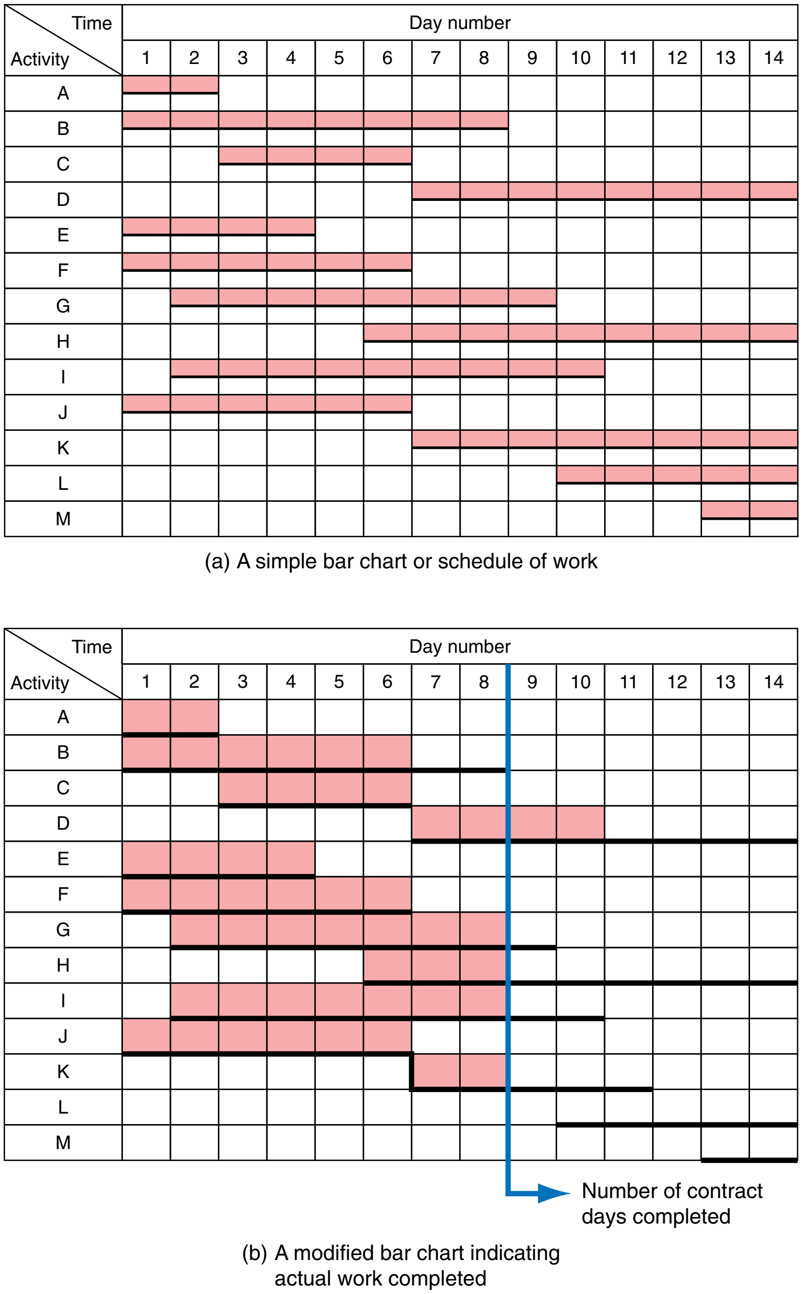

Figure 4.8 Bar charts: (a) a simple bar chart or schedule of work; (b) a modified bar chart indicating actual work completed.

Definition

There are many different types of bar chart used by companies but the *object of* any *bar chart* is to establish the sequence and timing of the various activities involved in the contract as a whole.

contractor to think deeply, carefully and logically about the particular contract, and are therefore a very useful aids to the successful completion of the work.

Bar charts

There are many different types of bar chart used by companies but the **object of any bar chart** is to establish the sequence and timing of the various activities involved in the contract as a whole. They are a visual aid in the process of communication. In order to be useful they must be clearly understood by the people involved in the management of a contract. The chart is constructed on a rectangular basis, as shown in Fig. 4.8.

All the individual jobs or activities which make up the contract are identified and listed separately down the vertical axis on the left-hand side, and time flows from left to right along the horizontal axis. The unit of time can be chosen to suit the length of the particular contract, but for most practical purposes either days or weeks are used.

The simple bar chart shown in Fig. 4.8(a) shows a particular activity A which is estimated to last 2 days, while activity B lasts 8 days. Activity C lasts 4 days and should be started on day 3. The remaining activities can be interpreted in the same way.

With the aid of colours, codes, symbols and a little imagination, much additional information can be included on this basic chart. For example, the actual work completed can be indicated by shading above the activity line as shown in Fig. 4.8(b) with a vertical line indicating the number of contract days completed; the activities which are on time, ahead of or behind time can easily be identified. Activity B in Fig. 4.8(b) is 2 days behind schedule, while activity D is 2 days ahead of schedule. All other activities are on time. Some activities must be completed before others can start. For example, all conduit work must be completely erected before the cables are drawn in. This is shown in Fig. 4.8(b) by activities J and K. The short vertical line between the two activities indicates that activity J must be completed before K can commence.

Work schedules

If an electrical contract is to be completed successfully, safely and efficiently it will require some planning. A schedule of work is a part of the planning process. It might be a list of what is to be done. It might indicate when certain events need to take place. In drawing up a schedule of work we might:

- check the drawing and specifications and produce a list of what has to be done
- create a logical sequence for what has to be done
- make a list of special tools and equipment required for the project
- identify how many operatives or those with special skills are required to complete the project
- identify key dates in the installation process and perhaps put these on a bar chart to ensure jobs are completed on time

On a large project the contracts manager, project engineer, safety officer and site supervisors may all be involved in the process. If the project is small it may fall to the electrician on site to do it all.

A schedule of test results is a written record of the results obtained when carrying out the electrical tests required by Part 6 of the IEE Regulations. The schedule brings together all the detailed information about the testing of a particular installation.

In the same way, a work schedule brings together the detail of the project.

Daywork sheets or variation orders

Daywork is one way of recording **variations to a contract**, that is, work done which is outside the scope of the original contract. It is *extra* work. If daywork is to be carried out, the site supervisor must first obtain a signature from the client's representative, for example, the architect, to **authorize the extra work**. A careful record must then be kept on the daywork sheets of all extra time and materials used so that the client can be billed for the extra work. A typical daywork sheet is shown in Fig. 4.9.

Definition

Daywork is one way of recording *variations to a contract*, that is, work done which is outside the scope of the original contract. It is *extra* work.

FLASH-BANG ELECTRICAL

VARIATION ORDER OR DAYWORK SHEET

Client name --

Job number/ref. --

Date	Labour	Start time	Finish time	Total hours	Office use

Materials quantity	Description	Office use

Site supervisor or Flash-Bang Electrical representative responsible for carrying out work ----------

Signature of person approving work and status e.g.

Client ☐ Architect ☐ Q.S. ☐ Main contractor ☐ Clerk of works ☐

Signature --

Figure 4.9 Typical daywork sheet or variation order.

Site reports

On large jobs, the foreman or supervisor is often required to keep a report of the relevant events which happen on the site for example, how many people from your company are working on site each day, what goods were delivered, whether there were any breakages or accidents, and records of site meetings attended. Some firms have two separate documents, a site diary to record daily events and a weekly report which is a summary of the week's events extracted from the site diary. The site diary remains on site and the weekly report is sent to head office to keep managers informed of the work's progress.

To demonstrate that you understand this second and third CGLI Outcome your tutor/trainer/lecturer will assess your ability to monitor and interpret work activities.

Safe electrical supplies and earthing arrangements (CGLI Outcome 4)

Safe electrical supplies

We know from earlier chapters in this book that using electricity is one of the causes of accidents in the workplace. Using electricity is a hazard because it has the potential to cause harm. Therefore, the provision of protective devices in an electrical installation is fundamental to the whole concept of the safe use of electricity in buildings. The electrical installation as a whole must be protected against overload or short circuit, and the people using the building must be protected against the risk of shock, fire or other risks arising from their own misuse of the installation or from a fault. The installation and maintenance of adequate and appropriate protective measures is a vital part of the safe use of electrical energy. I want to look at protection against an electric shock by both basic and fault protection, at protection by equipotential bonding and automatic disconnection of the supply, and protection against excess current.

Let us first define some of the words we will be using. Chapter 54 of the IEE Regulations describes the earthing arrangements for an electrical installation. It gives the following definitions:

Earth – the conductive mass of the earth whose electrical potential is taken as zero.

Earthing – the act of connecting the exposed conductive parts of an installation to the main protective earthing terminal of the installation.

Bonding conductor – a protective conductor providing equipotential bonding.

Bonding – the linking together of the exposed or extraneous metal parts of an electrical installation.

Circuit protective conductor (CPC) – a protective conductor connecting exposed conductive parts of equipment to the main earthing terminal. This is the green and yellow insulated conductor in twin and earth cable.

Exposed conductive parts – this is the metalwork of an electrical appliance or the trunking and conduit of an electrical system which can be touched because they are not normally live, but which may become live under fault conditions.

Extraneous conductive parts – this is the structural steelwork of a building and other service pipes such as gas, water, radiators and sinks. They do not form a part of the electrical installation but may introduce a potential, generally earth potential, to the electrical installation.

Shock protection – protection from electric shock is provided by basic protection and fault protection.

Basic protection – this is provided by the insulation of live parts in accordance with Section 416 of the IEE Regulations.

Fault protection – this is provided by protective equipotential bonding and automatic disconnection of the supply (by a fuse or MCB) in accordance with IEE Regulations 411.3–6.

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Definition

Protective equipotential bonding: This is equipotential bonding for the purpose of safety.

Protective equipotential bonding – this is equipotential bonding for the purpose of safety and shown in Figs 4.11–4.13.

Basic protection and fault protection

The human body's movements are controlled by the nervous system. Very tiny electrical signals travel between the central nervous system and the muscles, stimulating operation of the muscles, which enable us to walk, talk and run and remember that the heart is also a muscle.

If the body becomes part of a more powerful external circuit, such as the electrical mains, and current flows through it, the body's normal electrical operations are disrupted. The shock current causes unnatural operation of the muscles and the result may be that the person is unable to release the live conductor causing the shock, or the person may be thrown across the room. The current which flows through the body is determined by the resistance of the human body and the surface resistance of the skin on the hands and feet.

This leads to the consideration of exceptional precautions where people with wet skin or wet surfaces are involved, and the need for special consideration in bathroom installations.

Two types of contact will result in a person receiving an electric shock. Direct contact with live parts which involves touching a terminal or line conductor that is actually live. The regulations call this **basic protection** (131.2.1). Indirect contact results from contact with an exposed conductive part such as the metal structure of a piece of equipment that has become live as a result of a fault. The regulations call this **fault protection** (131.2.2).

The touch voltage curve in Fig. 4.10 shows that a person in contact with 230 V must be released from this danger in 40 ms if harmful effects are to be avoided. Similarly, a person in contact with 400 V must be released in 15 ms to avoid being harmed.

In installations operating at normal mains voltage, the primary method of protection against direct contact (basic protection) is by insulation. All live parts are enclosed in insulating material such as rubber or plastic, which prevent contact with those parts. The insulating material must, of course, be suitable for the circumstances in which they will be used and the stresses to which they will be subjected.

Other methods of basic protection include the provision of barriers or enclosures which can only be opened by the use of a tool, or when the supply is first disconnected. Protection can also be provided by fixed obstacles such as a guardrail around an open switchboard or by placing live parts out of reach as with overhead lines.

Fault protection

Protection against indirect contact, called fault protection (IEE Regulation 131.2.2) is achieved by connecting exposed conductive parts of equipment to the main protective earthing terminal as shown in Figs 4.11–4.13.

In Chapter 13 of the IEE Regulations we are told that where the metalwork of electrical equipment may become charged with electricity in such a manner as to cause danger, that metalwork will be connected with earth so as to discharge the electrical energy without danger.

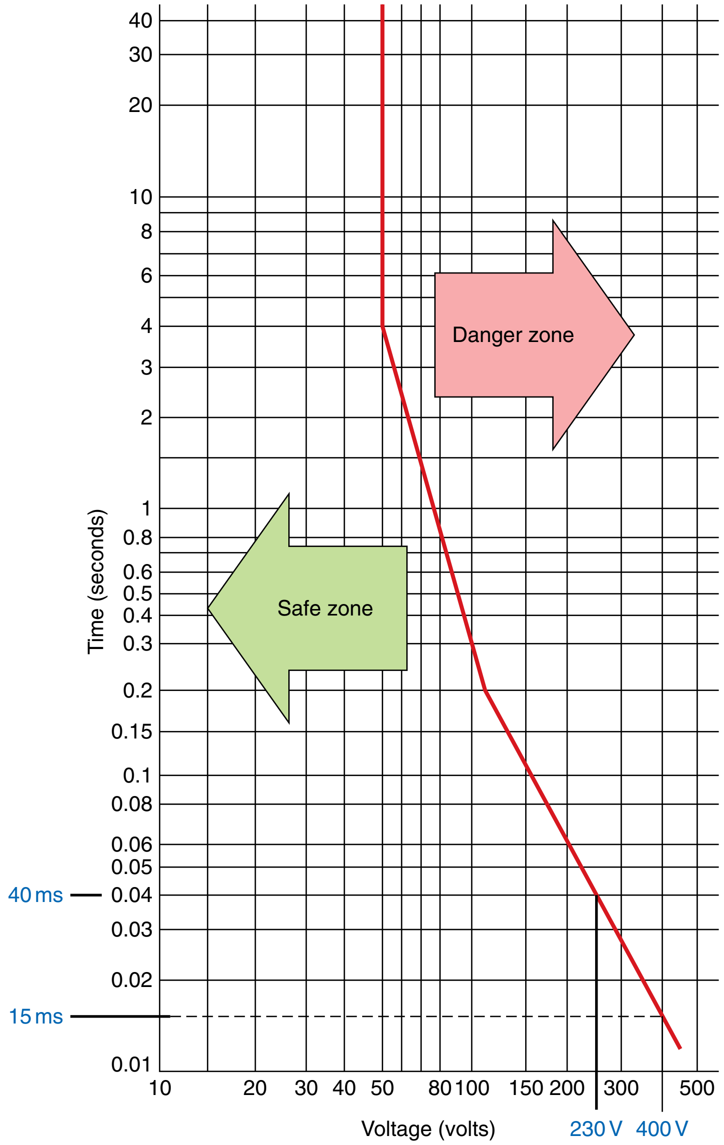

Figure 4.10 Touch voltage curve.

In connection with fault protection, equipotential bonding is one of the important principles for safety.

There are five methods of protection against contact with metalwork which has become unintentionally live, that is, indirect contact with exposed conductive parts recognized by the IEE Regulations. These are:

1. Protective equipotential bonding coupled with automatic disconnection of the supply.
2. The use of Class II (double insulated) equipment.
3. The provision of a non-conducting location.
4. The use of earth free equipotential bonding.
5. Electrical separation.

Methods 3 and 4 are limited to special situations under the effective supervision of trained personnel.

Method 5, electrical separation, is little used but does find an application in the domestic electric shaver supply unit which incorporates an isolating transformer.

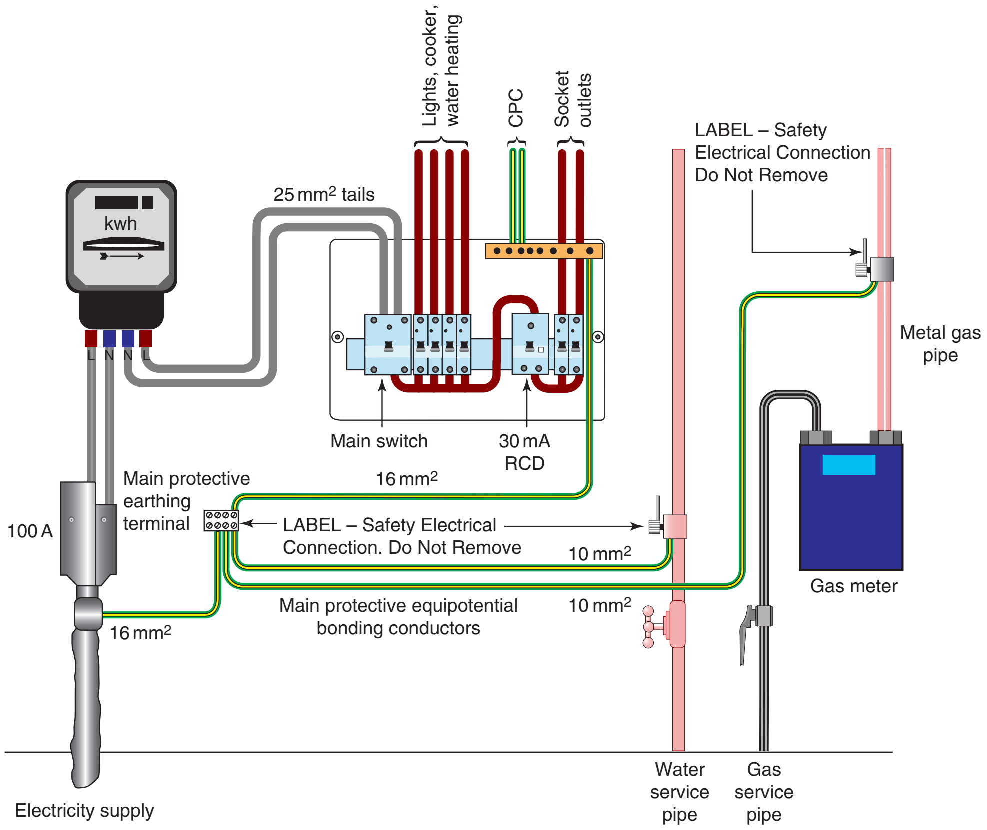

Figure 4.11 Cable sheath earth supply (TN-S system) showing earthing and bonding arrangements.

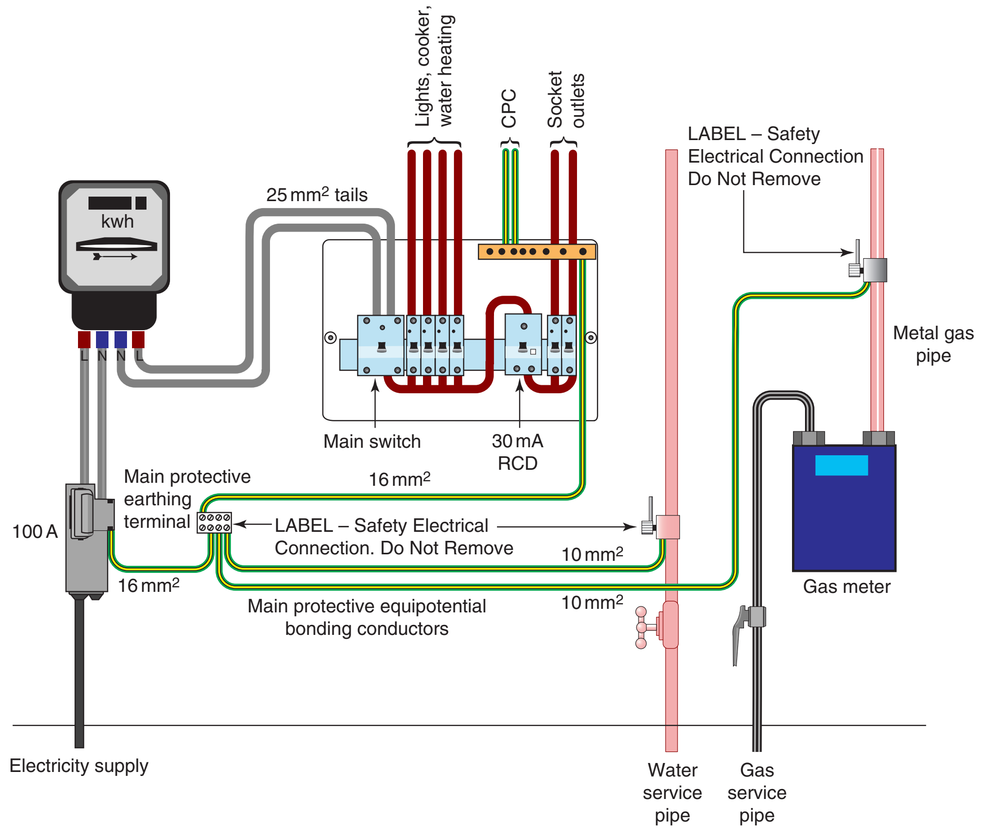

Figure 4.12 Protective multiple earth supply (TN-C-S system) showing earthing and bonding arrangements.

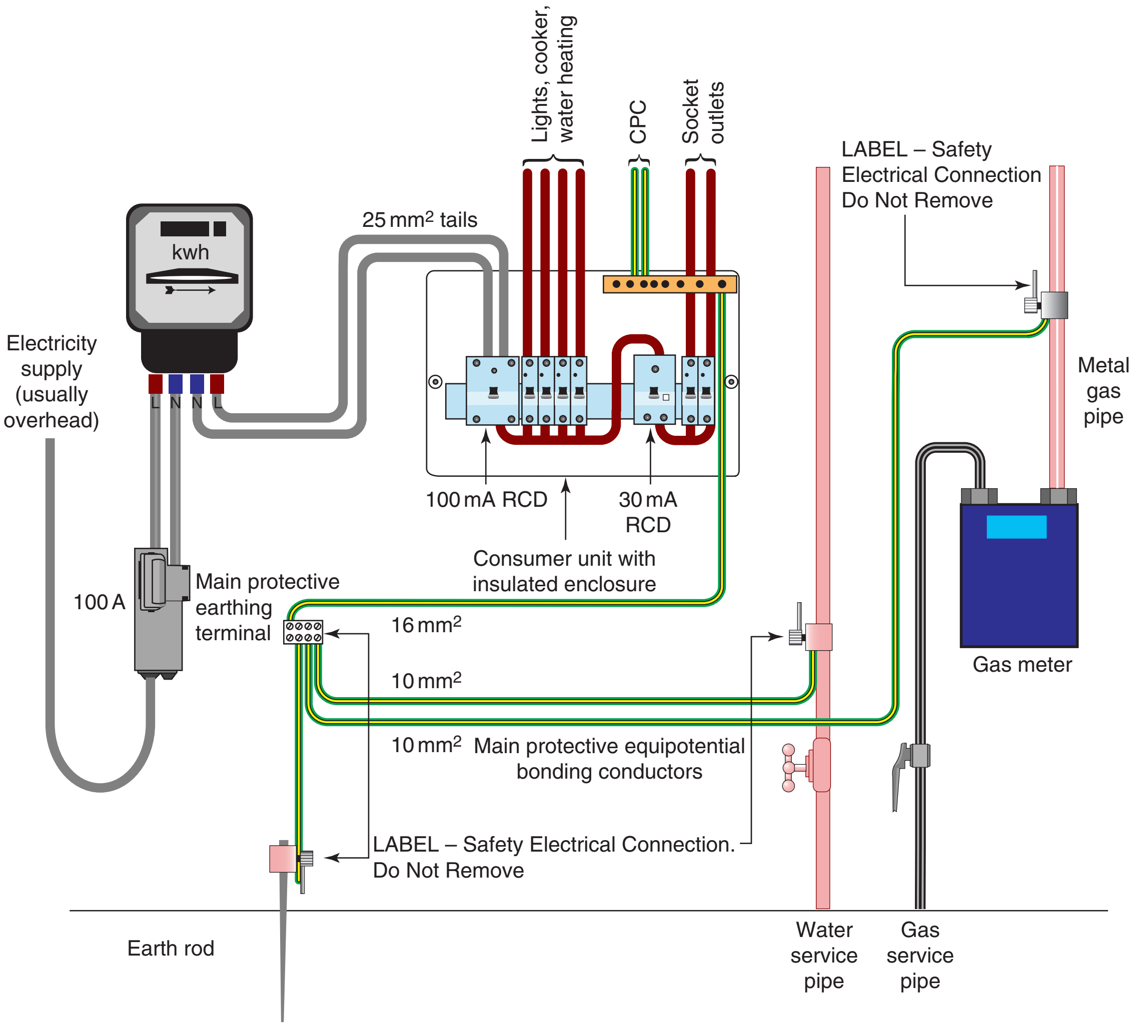

Figure 4.13 No earth provided supply (TT systems) showing earthing and bonding arrangements.

Method 2, the use of Class II insulated equipment is limited to single pieces of equipment such as tools used on construction sites, because it relies upon effective supervision to ensure that no metallic equipment or extraneous earthed metalwork enters the area of the installation.

The method which is most universally used in the United Kingdom is, therefore, Method 1 – protective equipotential bonding coupled with automatic disconnection of the supply.

This method relies upon all exposed metalwork being electrically connected together to an effective earth connection. Not only must all the metalwork associated with the electrical installation be so connected, that is, conduits, trunking, metal switches and the metalwork of electrical appliances, but also IEE Regulation 411.3.1.2 tells us to connect the extraneous metalwork of water service pipes, gas and other service pipes and ducting, central heating and air conditioning systems, exposed metallic structural parts of the building and lightning protective systems to the main protective earthing terminal. In this way the possibility of a voltage appearing between two exposed metal parts is removed. Protective equipotential bonding is shown in Figs 4.11–4.13.

Key fact

Bonding

When carrying out earthing and bonding activities:

- use a suitable bonding clamp
- connect to a cleaned pipe
- make sure all connections are tight
- fix a label 'Safety Electrical Connection' close to the connection
- IEE Regulation 514.13

The second element of this protection method is the provision of a means of automatic disconnection of the supply in the event of a fault occurring that causes the exposed metalwork to become live. IEE Regulation 411.3.2 tells us that for final circuits not exceeding 32 A, the maximum disconnection time shall not exceed 0.4 seconds.

The achievement of these disconnection times is dependent upon the type of protective device used, fuse or circuit breaker, the resistance of the circuit conductors to the fault and the provision of adequate protective equipotential bonding. The resistance, or we call it the impedance, of the earth fault loop must be less than the values given in Tables 41.2–41.4 of the IEE Regulations. (Table 4.1 shows the maximum value of the earth fault loop impedance for circuits protected by miniature circuit breakers – MCBs to BS EN 60898.) Chapter 54 of the IEE Regulations gives details of the earthing arrangements to be incorporated in the supply system to meet these regulations and these are described below.

Supply system earthing arrangements

The British government agreed on 1 January 1995 that the electricity supplies in the United Kingdom would be harmonized with those of the rest of Europe. Thus the voltages used previously in low-voltage supply systems of 415 and 240 V have become 400 V for three-phase supplies and 230 V for single-phase supplies. The Electricity Supply Regulations 1988 have also been amended to permit a range of variation from the newly declared nominal voltage. From January 1995 the permitted tolerance is the nominal voltage +10% or −6%. Previously it was ±6%. This gives a voltage range of 216–253 V for a nominal voltage of 230 V and 376–440 V for a nominal voltage of 400 V (IEE Regulations Appendix 2).

It is further proposed that the tolerance levels will be adjusted to ±10% of the declared nominal voltage. All EU countries will have to adjust their voltages to comply with a nominal voltage of 230 V single-phase and 400 V three-phase.

The supply to a domestic, commercial or small industrial consumer's installation is usually protected at the incoming service cable position with a 100 A high breaking capacity (HBC) fuse. Other items of equipment at this position are the energy meter and the consumer's distribution unit, providing the protection for the final circuits and the earthing arrangements for the installation.

An efficient and effective earthing system is essential to allow protective devices to operate. The limiting values of earth fault loop impedance are given in Tables 41.2–41.4 of the IEE Regulations. Table 4.1 in this chapter gives the maximum Z_Z values for a Type B MCB. Chapter 54 and the wiring systems of Part 2 of

Table 4.1 Maximum earth fault loop impedance *Z*. Adapted from the IEE *On Site Guide* by kind permission of the Institution of Electrical Engineers

Type B MCB								
Maximum measured earth fault loop impedance (in ohms) overcurrent protective device is type B MCB to BSEN 60898								
	MCB rating (amperes)							
	6	10	16	20	25	32	40	50
For 0.4 second disconnection Z_S (ohms)	7.67	4.6	2.87	2.3	1.84	1.44	1.15	0.92

the regulations give details of the earthing arrangements to be incorporated in the supply system to meet the requirements of the regulations. Five systems are described in the definitions but only the TN-S, TN-C-S and TT systems are suitable for public supplies.

A system consists of an electrical installation connected to a supply. Systems are classified by a capital letter designation.

The supply earthing

The supply earthing arrangements are indicated by the first letter, where T means one or more points of the supply are directly connected to earth and I means the supply is not earthed or one point is earthed through a fault-limiting impedance.

The installation earthing

The installation earthing arrangements are indicated by the second letter, where T means the exposed conductive parts are connected directly to earth and N means the exposed conductive parts are connected directly to the earthed point of the source of the electrical supply.

The earthed supply conductor

The earthed supply conductor arrangements are indicated by the third letter, where S means a separate neutral and protective conductor and C means that the neutral and protective conductors are combined in a single conductor.

Cable sheath earth supply (TN-S system)

This is one of the most common types of supply system to be found in the United Kingdom where the electricity companies' supply is provided by underground cables. The neutral and protective conductors are separate throughout the system. The protective earth conductor (PE) is the metal sheath and armour of the underground cable, and this is connected to the consumer's main earthing terminal. All exposed conductive parts of the installation, gas pipes, water pipes and any lightning protective system are connected to the protective conductor via the main earthing terminal of the installation. The arrangement is shown in Fig. 4.11.

Protective multiple earthing supply (TN-C-S system)

This type of underground supply is becoming increasingly popular to supply new installations in the United Kingdom. It is more commonly referred to as protective multiple earthing (PME). The supply cable uses a combined protective earth and neutral (PEN) conductor. At the supply intake point a consumer's main earthing terminal is formed by connecting the earthing terminal to the neutral conductor. All exposed conductive parts of the installation, gas pipes, water pipes and any lightning protective system are then connected to the main earthing terminals. Thus phase to earth faults are effectively converted into phase to neutral faults. The arrangement is shown in Fig. 4.12.

No earth provided supply (TT system)

This is the type of supply more often found when the installation is fed from overhead cables. The supply authorities do not provide an earth terminal and the installation's CPCs must be connected to earth via an earth electrode provided by the consumer. An effective earth connection is sometimes difficult to obtain

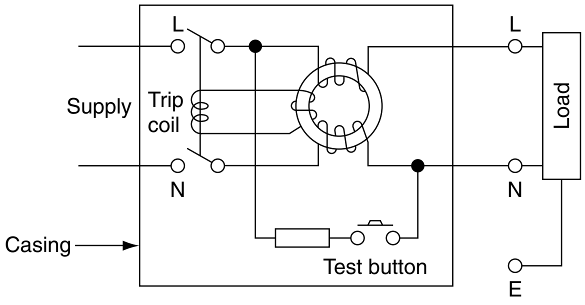

Figure 4.14 Construction of an RCD.

and in most cases a residual current device (RCD) is provided when this type of supply is used. The arrangement is shown in Fig. 4.13.

Figures 4.11–4.13 shows the layout of a typical domestic service position for these three supply systems. The TN-C and IT systems of supply do not comply with the supply regulations and therefore cannot be used for public supplies. Their use is restricted to private generating plants and for this reason I shall not include them here, but they can be seen in Part 2 of the IEE Regulations.

Residual current protection

The IEE Regulations recognize the particular problems created when electrical equipment such as lawnmowers, hedge-trimmers, drills and lights are used outside buildings. In these circumstances the availability of an adequate earth return path is a matter of chance. The regulations, therefore, require that any socket outlet with a rated current not exceeding 20 A for use by ordinary people and intended for general use, shall have the additional protection of an RCD, which has a rated operating current of not more than 30 milliamperes (mA) (IEE Regulation 411.3.3).

Definition

An *RCD* is a type of circuit breaker that continuously compares the current in the line and neutral conductors of the circuit.

An **RCD** is a type of circuit breaker that continuously compares the current in the line and neutral conductors of the circuit. The currents in a healthy circuit will be equal, but in a circuit that develops a fault, some current will flow to earth and the line and neutral currents will no longer balance. The RCD detects the imbalance and disconnects the circuit. Figure 4.14 shows an RCD.

The regulations recognize RCDs as 'additional protection' in the event of a failure of the provision for basic protection, fault protection or the carelessness by the users of the installation (IEE Regulation 415.1.1).

To demonstrate that you understand this fourth CGLI Outcome your tutor/trainer/lecturer will assess your ability to identify the earthing arrangements of a given supply.

Definition

Most cables can be considered to be constructed in three parts: the *conductor*, which must be of a suitable cross-section to carry the load current; the *insulation*, which has a colour or number code for identification and the *outer sheath*, which may contain some means of providing protection from mechanical damage.

Fitting and fixing cables and wiring systems (CGLI Outcomes 5 and 6)

Cables

Most cables can be considered to be constructed in three parts: the **conductor**, which must be of a suitable cross-section to carry the load current; the **insulation**, which has a colour or number code for identification and the **outer sheath**, which may contain some means of providing protection from mechanical damage.

The conductors of a cable are made of either copper or aluminium and may be stranded or solid. Solid conductors are only used in fixed wiring installations and may be shaped in larger cables. Stranded conductors are more flexible and conductor sizes from 4.0 to 25 mm^2 contain seven strands. A 10 mm^2 conductor, for example, has seven 1.35 mm diameter strands which collectively make up the 10 mm^2 cross-sectional area of the cable. Conductors above 25 mm^2 have more than seven strands, depending upon the size of the cable. Flexible cords have multiple strands of very fine wire, as fine as one strand of human hair. This gives the cable its very flexible quality.

New wiring colours

Twenty-eight years ago the United Kingdom agreed to adopt the European colour code for flexible cords, that is, brown for live or line conductor, blue for the neutral conductor and green combined with yellow for earth conductors. However, no similar harmonization was proposed for non-flexible cables used for fixed wiring. These were to remain as red for live or line conductor, black for the neutral conductor and green combined with yellow for earth conductors.

On 31 March 2004 the IEE published Amendment No. 2 to BS 7671: 2001 which specified new cable core colours for all fixed wiring in UK electrical installations. These new core colours will 'harmonize' the United Kingdom with the practice in mainland Europe.

Fixed cable core colours up to 2006

Single-phase supplies – red line conductors, black neutral conductors and green combined with yellow for earth conductors.

Three-phase supplies – red, yellow and blue line conductors, black neutral conductors and green combined with yellow for earth conductors.

These core colours must *not* be used after 31 March 2006.

New (harmonized) fixed cable core colours

Single-phase supplies – brown line conductors, blue neutral conductors and green combined with yellow for earth conductors (just like the existing flexible cords).

Three-phase supplies – brown, black and grey line conductors, blue neutral conductors and green combined with yellow for earth conductors.

These are the cable core colours to be used from 31 March 2004 onwards.

Extensions or alterations to existing ***single-phase*** installations do not require marking at the interface between the old and new fixed wiring colours. However, a warning notice must be fixed at the consumer unit or distribution fuse board which states:

> *Caution – This installation has wiring colours to two versions of BS 7671. Great care should be taken before undertaking extensions, alterations or repair that all conductors are correctly identified.*

Alterations to ***three-phase*** installations must be marked at the interface L1, L2, L3 for the lines and N for the neutral. Both new and old cables must be marked. These markings are preferred to coloured tape and a caution notice is again required at the distribution board (see Appendix 7 of the IEE Regulations).

PVC insulated and sheathed cables

Domestic and commercial installations use this cable, which may be clipped direct to a surface, sunk in plaster or installed in conduit or trunking. It is the

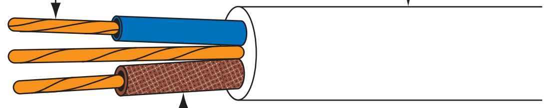

Figure 4.15 A twin and earth PVC insulated and sheathed cable.

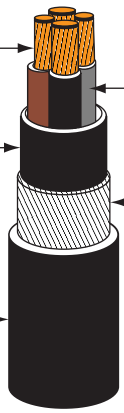

Figure 4.16 A four-core PVC/SWA cable.

simplest and least expensive cable. Figure 4.15 shows a sketch of a twin and earth cable.

The conductors are covered with a colour-coded PVC insulation and then contained singly or with others in a PVC outer sheath.

Definition

PVC insulated steel wire armour cables are used for wiring underground between buildings, for main supplies to dwellings, rising sub-mains and industrial installations. They are used where some mechanical protection of the cable conductors is required.

PVC/SWA cable

PVC insulated steel wire armour cables are used for wiring underground between buildings, for main supplies to dwellings, rising sub-mains and industrial installations. They are used where some mechanical protection of the cable conductors is required.

The conductors are covered with colour-coded PVC insulation and then contained either singly or with others in a PVC sheath (see Fig. 4.16). Around this sheath is placed an armour protection of steel wires twisted along the length of the cable, and a final PVC sheath covering the steel wires protects them from corrosion. The armour sheath also provides the circuit protective conductor (CPC) and the cable is simply terminated using a compression gland.

Definition

An *MI cable* has a seamless copper sheath which makes it waterproof and fire and corrosion-resistant. These characteristics often make it the only cable choice for hazardous or high-temperature installations.

MI cable

An **MI cable** has a seamless copper sheath which makes it waterproof and fire and corrosion-resistant. These characteristics often make it the only cable choice for hazardous or high-temperature installations such as oil refineries and chemical works, boiler-houses and furnaces, petrol pump and fire alarm installations.

The cable has a small overall diameter when compared to alternative cables and may be supplied as bare copper or with a PVC oversheath. It is colour-coded

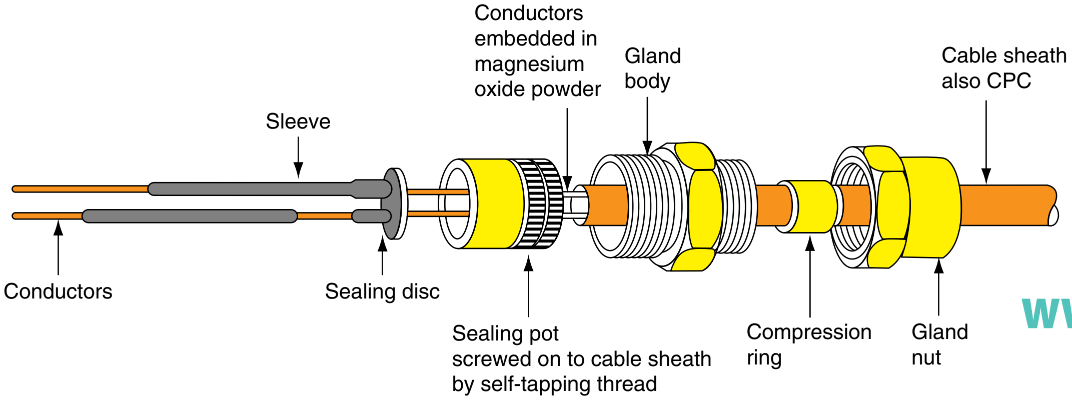

Figure 4.17 MI cable with terminating seal and gland.

orange for general electrical wiring, white for emergency lighting or red for fire alarm wiring. The copper outer sheath provides the CPC, and the cable is terminated with a pot and sealed with compound and a compression gland (see Fig. 4.17).

The copper conductors are embedded in a white powder, magnesium oxide, which is non-ageing and non-combustible, but which is hygroscopic, which means that it readily absorbs moisture from the surrounding air, unless adequately terminated. The termination of an MI cable is a complicated process requiring the electrician to demonstrate a high level of practical skill and expertise for the termination to be successful.

FP 200 cable

FP 200 cable is similar in appearance to an MI cable in that it is a circular tube, or the shape of a pencil, and is available with a red or white sheath. However, it is much simpler to use and terminate than an MI cable.

The cable is available with either solid or stranded conductors that are insulated with 'insudite' a fire resistant insulation material. The conductors are then screened by wrapping an aluminium tape around the insulated conductors, that is, between the insulated conductors and the outer sheath. This aluminium tape screen is applied metal side down and in contact with the bare CPC.

The sheath is circular and made of a robust thermoplastic low smoke, zero halogen material.

FP 200 is available in 2, 3, 4, 7, 12 and 19 cores with a conductor size range from 1.0 mm to 4.0 mm. The core colours are: two core, brown and blue; three core, brown, black and grey and four core, brown, black grey and blue.

The cable is as easy to use as a PVC insulated and sheathed cable. No special terminations are required; the cable may be terminated through a grommet into a knock out box or terminated through a simple compression gland.

The cable is a fire resistant cable, primarily intended for use in fire alarms and emergency lighting installations or it may be embedded in plaster.

LSF cables

Low smoke and fume (LSF) cables give off very low smoke and fumes if they are burned in a burning building. Most standard cable types are available as LSF cables.

Safety first

PVC cables

- At low temperatures PVC cable insulation can become brittle when handled
- PVC cables must not be installed when the ambient temperature is 0°C (IEE Reg 522.1.2)

Definition

FP 200 cable is similar in appearance to an MI cable in that it is a circular tube, or the shape of a pencil, and is available with a red or white sheath. However, it is much simpler to use and terminate than an MI cable.

Definition

Low smoke and fume cables give off very low smoke and fumes if they are burned in a burning building. Most standard cable types are available as LSF cables.

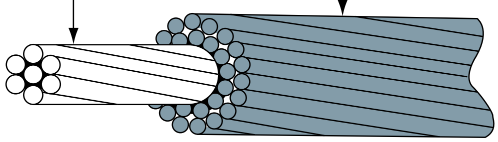

Figure 4.18 132 kV overhead cable construction.

High-voltage power cables

The cables used for high-voltage power distribution require termination and installation expertise beyond the normal experience of a contracting electrician. The regulations covering high-voltage distribution are beyond the scope of the IEE Regulations for electrical installations. Operating at voltages in excess of 33 kV and delivering thousands of kilowatts, these cables are either suspended out of reach on pylons or buried in the ground in carefully constructed trenches.

High-voltage overhead cables

Suspended from cable towers or pylons, overhead cables must be light, flexible and strong.

The cable is constructed of stranded aluminium conductors formed around a core of steel stranded conductors (see Fig. 4.18). The aluminium conductors carry the current and the steel core provides the tensile strength required to suspend the cable between pylons. The cable is not insulated since it is placed out of reach and insulation would only add to the weight of the cable.

Definition

Paper insulated lead covered steel wire armour cables are only used in systems above 11 kV. Very high-voltage cables are only buried underground in special circumstances when overhead cables would be unsuitable, for example, because they might spoil a view of natural beauty.

High-voltage underground cables – PILCSWA

Paper insulated lead covered steel wire armour (PILCSWA) cables are only used in systems above 11 kV. Very high-voltage cables are only buried underground in special circumstances when overhead cables would be unsuitable, for example, because they might spoil a view of natural beauty. Underground cables are very expensive because they are much more complicated to manufacture than overhead cables. In transporting vast quantities of power, heat is generated within the cable. This heat is removed by passing oil through the cable to expansion points, where the oil is cooled. The system is similar to the water cooling of an internal combustion engine. Figure 4.19 shows a typical high-voltage cable construction.

The conductors may be aluminium or copper, solid or stranded. They are insulated with oil-impregnated brown paper wrapped in layers around the conductors. The oil ducts allow the oil to flow through the cable, removing excess heat. The whole cable within the lead sheath is saturated with oil, which is a good insulator. The lead sheath keeps the oil in and moisture out of the cable, and this is supported by the copper-woven fabric tape. The cable is protected by steel wire armouring, which has bitumen or PVC serving over it to protect the armour sheath from corrosion. The termination and installation of these cables is a very specialized job, undertaken by the supply authorities only.

Installing cables and wiring systems

When installing wiring systems using cables, conduit, trunking or tray they must be installed horizontally or vertically and fixed securely to the fabric of the

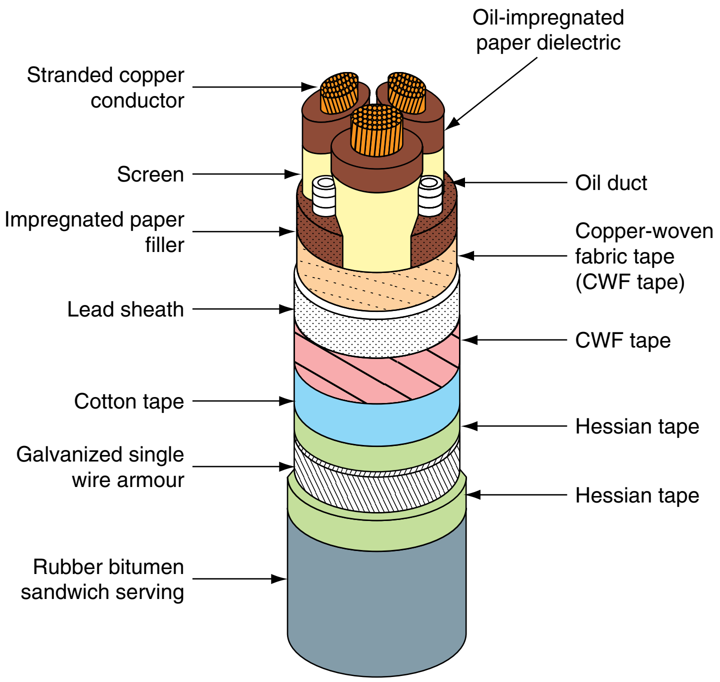

Figure 4.19 132 kV underground cable construction.

building. Fixing devises are considered in detail in *Basic Electrical Installation Work* 6th edition and shown in Figs 5.38 to 5.54.

Cable runs must be carefully planned and marked out to avoid one cable having to cross over another.

The tools required for measuring and marking out are:

- steel tape measures which provide a convenient way to measure a few inches or a few metres.
- spirit levels can be used to check that something is horizontal or vertical.
- plumb bobs or chalk lines can be used to check or verify verticals. They consist of a weight on a length of string . When the weight stops moving the string is a true vertical.
- pencil or piece of chalk can used to mark fixing positions.

The final choice of a wiring system must rest with those designing the installation and those ordering the work, but whatever system is employed, good workmanship by competent persons and the use of proper materials is essential for compliance with the IEE Regulation 134.1.1. The necessary skills can be acquired by an electrical trainee who has the correct attitude and dedication to his craft.

PVC insulated and sheathed wiring systems are used extensively for lighting and socket installations in domestic dwellings. Mechanical damage to the cable caused by impact, abrasion, penetration, compression or tension must be minimized during installation (IEE Regulation 522.6.1). The cables are generally fixed using plastic clips incorporating a masonry nail, which means the cables can be fixed to wood, plaster or brick with almost equal ease. Cables should be run horizontally or vertically, not diagonally, down a wall. All kinks should be removed so that the cable is run straight and neatly between clips fixed at equal distances providing adequate support for the cable so that it does not become damaged by its own weight (IEE Regulation 522.8.4 and Table 4A of the *On Site Guide*). Where cables are bent, the radius of the bend should not cause the conductors to be damaged (IEE Regulation 522.8.3 and Table 4E of the *On Site Guide*).

Terminations or joints in the cable may be made in ceiling roses, junction boxes, or behind sockets or switches, provided that they are enclosed in a non-ignitable material, are properly insulated and are mechanically and electrically secure (IEE Regulation 526). All joints must be accessible for inspection testing and maintenance when the installation is completed (IEE Regulation 526.3).

Try this

Definition

What do we mean by a 'competent person'?

Where PVC insulated and sheathed cables are concealed in walls, floors or partitions, they must be provided with a box incorporating an earth terminal at each outlet position. PVC cables do not react chemically with plaster, as do some cables, and consequently PVC cables may be buried under plaster. Further protection by channel or conduit is only necessary outside of designated zones if mechanical protection from nails or screws is required, or to protect them from the plasterer's trowel. However, IEE Regulation 522.6.6 now tells us that where PVC cables are to be embedded in a wall or partition at a depth of less than 50 mm they should be run along one of the permitted routes. To identify the most probable cable routes, IEE Regulation 522.6.6 tells us that outside a zone formed by a 150 mm border all around a wall edge, cables can only be run horizontally or vertically to a point or accessory unless they are contained in a substantial earthed enclosure, such as a conduit, which can withstand nail penetration. This is shown in Fig. 5.28 in Chapter 5 of *Basic Electrical Installation Work*, 6th edition.

Where the accessory or cable is fixed to a wall which is less than 100 mm thick, protection must also be extended to the reverse side of the wall if a position can be determined.

Where none of this protection can be complied with and the installation is to be used by ordinary people, then the cable must be given additional protection with a 30 mA residual current device (RCD) (IEE Regulation 522.6.7).

Try this

Definitions

What do we mean by an 'ordinary person'. Perhaps you could write a definition in the margin.

Key fact

Conduit

Burrs must be removed from the cut ends of conduit so that the cable sheath will not become damaged when drawn into the conduit (IEE Regulation 522.8.1).

Where cables and wiring systems pass through walls, floors and ceilings the hole should be made good with incombustible material such as mortar or plaster to prevent the spread of fire (IEE Regulation 527.2.1). Cables passing through metal boxes should be bushed with a rubber grommet to prevent abrasion of the cable. Holes drilled in floor joists through which cables are run should be 50 mm below the top or 50 mm above the bottom of the joist to prevent damage to the cable by nail penetration (IEE Regulation 522.6.5). PVC cables should not be installed when the surrounding temperature is below 0°C or when the cable temperature has been below 0°C for the previous 24 hours because the insulation becomes brittle at low temperatures and may be damaged during installation (IEE Regulation 522.1.2).

Conduit installations

A **conduit** is a tube, channel or pipe in which insulated conductors are contained. The conduit, in effect, replaces the PVC outer sheath of a cable, providing mechanical protection for the insulated conductors. A conduit installation can be rewired easily or altered at any time, and this flexibility, coupled with mechanical protection, makes conduit installations popular for commercial and industrial applications. There are three types of conduit used in electrical installation work: steel, PVC and flexible.

Definition

A *conduit* is a tube, channel or pipe in which insulated conductors are contained.

Steel conduit

Steel conduits are made to a specification defined by BS 4568 and are either heavy gauge welded or solid drawn. Heavy gauge is made from a sheet of steel welded along the seam to form a tube and is used for most electrical installation work. Solid drawn conduit is a seamless tube which is much more expensive and only used for special gas-tight, explosion-proof or flame-proof installations.

Conduit is supplied in 3.75 m lengths and typical sizes are 16, 20, 25 and 32 mm. Conduit tubing and fittings are supplied in a black enamel finish for internal use or hot galvanized finish for use on external or damp installations. A wide range of fittings is available and the conduit is fixed using saddles or pipe hooks, as shown in Fig. 4.20.

Metal conduits are threaded with stocks and dies and bent using special bending machines. The metal conduit is also utilized as the CPC and, therefore, all connections must be screwed up tightly and all burrs removed so that cables will not be damaged as they are drawn into the conduit. Metal conduits containing a.c. circuits must contain phase and neutral conductors in the same conduit to prevent eddy currents flowing, which would result in the metal conduit becoming hot (IEE Regulations 521.5.2, 522.8.1 and 522.8.11).

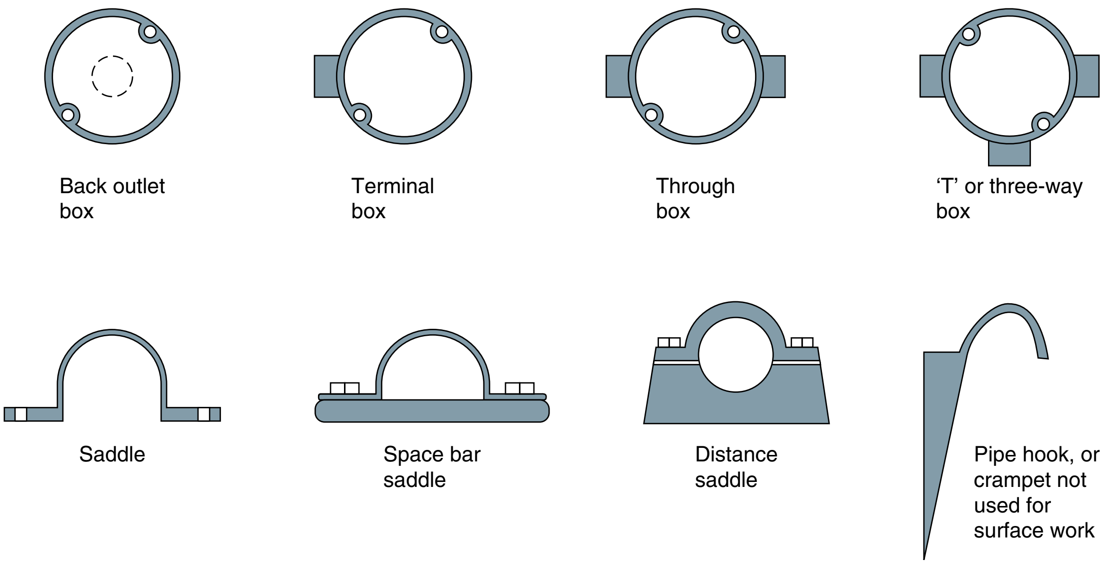

Figure 4.20 Conduit fittings and saddles.

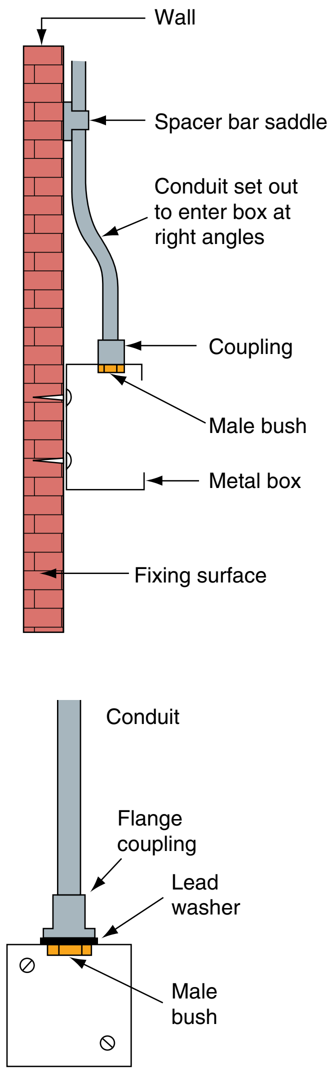

Figure 4.21 Terminating conduits.

PVC conduit

PVC conduit used on typical electrical installations is heavy gauge standard impact tube manufactured to BS 4607. The conduit size and range of fittings are the same as those available for metal conduit. PVC conduit is most often joined by placing the end of the conduit into the appropriate fitting and fixing with a PVC solvent adhesive. PVC conduit can be bent by hand using a bending spring of the same diameter as the inside of the conduit. The spring is pushed into the conduit to the point of the intended bend and the conduit then bent over the knee. The spring ensures that the conduit keeps its circular shape. In cold weather, a little warmth applied to the point of the intended bend often helps to achieve a more successful bend.

The advantages of a PVC conduit system are that it may be installed much more quickly than steel conduit and is non-corrosive, but it does not have the mechanical strength of steel conduit. Since PVC conduit is an insulator it cannot be used as the CPC and a separate earth conductor must be run to every outlet. It is not suitable for installations subjected to temperatures below 25°C or above 60°C. Where luminaires are suspended from PVC conduit boxes, precautions must be taken to ensure that the lamp does not raise the box temperature or that the mass of the luminaire supported by each box does not exceed the maximum recommended by the manufacturer (IEE Regulations 522.1 and 522.2). PVC conduit also expands much more than metal conduit and so long runs require an expansion coupling to allow for conduit movement and help to prevent distortion during temperature changes.

All conduit installations must be erected first before any wiring is installed (IEE Regulation 522.8.2). The radius of all bends in conduit must not cause the cables to suffer damage, and therefore the minimum radius of bends given in Table 4E of the *On Site Guide* applies (IEE Regulation 522.8.3). All conduits should terminate in a box or fitting and meet the boxes or fittings at right angles, as shown in Fig. 4.21. Any unused conduit box entries should be blanked off and all boxes covered with a box lid, fitting or accessory to provide complete enclosure of the conduit system. Conduit runs should be separate from other services, unless intentionally bonded, to prevent arcing occurring from a faulty circuit within the conduit, which might cause the pipe of another service to become punctured.

When drawing cables into conduit they must first be *run off* the cable drum. That is, the drum must be rotated as shown in Fig. 4.22 and not allowed to *spiral off*, which will cause the cable to twist.

Cables should be fed into the conduit in a manner which prevents any cable crossing over and becoming twisted inside the conduit. The cable insulation must not be damaged on the metal edges of the draw-in box. Cables can be pulled in on a draw wire if the run is a long one. The draw wire itself may be drawn in on a fish tape, which is a thin spring steel or plastic tape.

A limit must be placed on the number of bends between boxes in a conduit run and the number of cables which may be drawn into a conduit to prevent the cables being strained during wiring. Appendix 5 of the *On Site Guide* gives a guide to the cable capacities of conduits and trunking.

Definition

Flexible conduit is made of interlinked metal spirals often covered with a PVC sleeving.

Flexible conduit

Flexible conduit is made of interlinked metal spirals often covered with a PVC sleeving. The tubing must not be relied upon to provide a continuous earth path and, consequently, a separate CPC must be run either inside or outside the flexible tube (IEE Regulation 543.2.1).

Flexible conduit is used for the final connection to motors so that the vibrations of the motor are not transmitted throughout the electrical installation and to allow for modifications to be made to the final motor position and drive belt adjustments.

Conduit capacities

Single PVC insulated conductors are usually drawn into the installed conduit to complete the installation. Having decided upon the type, size and number of cables required for a final circuit, it is then necessary to select the appropriate size of conduit to accommodate those cables.

The tables in Appendix 5 of the *On Site Guide* describe a 'factor system' for determining the size of conduit required to enclose a number of conductors. The tables are shown in Tables 4.2 and 4.3. The method is as follows:

- Identify the cable factor for the particular size of conductor (Table 4.2)
- Multiply the cable factor by the number of conductors to give the sum of the cable factors.
- Identify the appropriate part of the conduit factor table given by the length of run and number of bends. (For straight runs of conduit less than 3 m in length, the conduit factors are given in Table 5B. For conduit runs in excess of 3 m or incorporating bends, the conduit factors are given in Table 5D, see Table 4.3)
- The correct size of conduit to accommodate the cables is that conduit which has a factor equal to or greater than the sum of the cable factors.

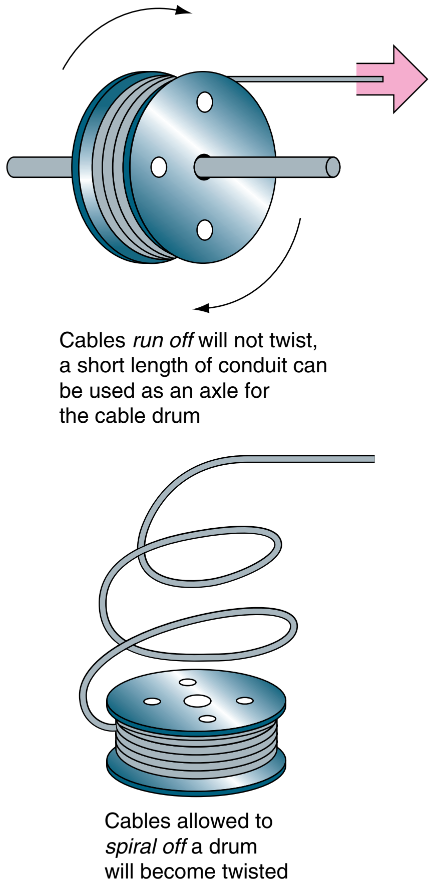

Figure 4.22 Running off cable from a drum.

Definition

Single PVC insulated conductors are usually drawn into the installed conduit to complete the installation.

Table 4.2 Conduit cable factors. Adapted from the *IEE On Site Guide* by kind permission of the Institution of Electrical Engineers

Cable factors for use in conduit in long straight runs over 3 m, or runs of any length incorporating bends		
Type of conductor	**Conductor cross-sectional area (mm²)**	**Cable factor**
Solid or stranded	1	16
	1.5	22
	2.5	30
	4	43
	6	58
	10	105
	16	145
	25	217
The inner radius of a conduit bend should be not less than 2.5 times the outside diameter of the conduit		

Table 4.3 Conduit cable factors for bends and long straight runs. Adapted from the *IEE On Site Guide* by kind permission of the Institution of Electrical Engineers

Cable factors for runs incorporating bends and long straight runs

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

Additional factors: For 38 mm diameter use ...... 1.4 × (32 mm factor)
For 50 mm diameter use ...... 2.6 × (32 mm factor)
For 63 mm diameter use ...... 4.2 × (32 mm factor)

Example 1

Six 2.5 mm^2 PVC insulated cables are to be run in a conduit containing two bends between boxes 10 m apart. Determine the minimum size of conduit to contain these cables.

From Table 4.2

$$\begin{aligned} \text{The factor for one } 2.5\,\text{mm}^2 \text{ cable} &= 30 \\ \text{The sum of the cable factors} &= 6 \times 30 \\ &= 180 \end{aligned}$$

From Table 4.3, a 25 mm conduit, 10 m long and containing two bends, has a factor of 260. A 20 mm conduit containing two bends only has a factor of 141 which is less than 180, the sum of the cable factors and, therefore, 25 mm conduit is the minimum size to contain these cables.

Example 2

Ten 1.0 mm^2 PVC insulated cables are to be drawn into a plastic conduit which is 6 m long between boxes and contains one bend. A 4.0 mm PVC insulated CPC is also included. Determine the minimum size of conduit to contain these conductors.

From Table 4.2

$$\begin{aligned} \text{The factor for one 1.0 mm cable} &= 16 \\ \text{The factor for one 4.0 mm cable} &= 43 \\ \text{The sum of the cable factors} &= (10 \times 16) + (1 \times 43) = 203 \end{aligned}$$

From Table 4.3, a 20 mm conduit, 6 m long and containing one bend, has a factor of 233. A 16 mm conduit containing one bend only has a factor of 143 which is less than 203, the sum of the cable factors and, therefore, 20 mm conduit is the minimum size to contain these cables.

Trunking installations

A **trunking** is an enclosure provided for the protection of cables which is normally square or rectangular in cross-section, having one removable side. Trunking may be thought of as a more accessible conduit system and for industrial and commercial installations it is replacing the larger conduit sizes. A trunking system can have great flexibility when used in conjunction with conduit; the trunking forms the background or framework for the installation, with conduits running from the trunking to the point controlling the current using apparatus. When an alteration or extension is required it is easy to drill a hole in the side of the trunking and run a conduit to the new point. The new wiring can then be drawn through the new conduit and the existing trunking to the supply point.

Trunking is supplied in 3 m lengths and various cross-sections are measured in millimetres from 50 × 50 up to 300 × 150. Most trunking is available in either steel or plastic.

Definition

A *trunking* is an enclosure provided for the protection of cables which is normally square or rectangular in cross-section, having one removable side. Trunking may be thought of as a more accessible conduit system.

Definition

Metallic trunking is formed from mild steel sheet, coated with grey or silver enamel paint for internal use or a hot-dipped galvanized coating where damp conditions might be encountered.

Metallic trunking

Metallic trunking is formed from mild steel sheet, coated with grey or silver enamel paint for internal use or a hot-dipped galvanized coating where damp conditions might be encountered and made to a specification defined by BS EN 50085. A wide range of accessories is available, such as 45° bends, 90° bends, tee and four-way junctions, for speedy on-site assembly. Alternatively, bends may be fabricated in lengths of trunking, as shown in Fig. 4.23. This may be necessary or more convenient if a bend or set is non-standard, but it does take more time to fabricate bends than merely to bolt on standard accessories.

When fabricating bends the trunking should be supported with wooden blocks for sawing and filing, in order to prevent the sheet-steel vibrating or becoming deformed. Fish plates must be made and riveted or bolted to the trunking to form a solid and secure bend. When manufactured bends are used, the continuity of the earth path must be ensured across the joint by making all fixing screw connections very tight, or fitting a separate copper strap between the trunking and the standard bend. If an earth continuity test on the trunking is found to be unsatisfactory, an insulated CPC must be installed inside the trunking. The size of the protective conductor will be determined by the largest cable contained in the trunking, as described by Table 54.7 of the IEE Regulations. If the circuit conductors are less than 16 mm^2, then a 16 mm^2 CPC will be required.

Non-metallic trunking

Trunking and trunking accessories are also available in high-impact PVC. The accessories are usually secured to the lengths of trunking with a PVC solvent adhesive. PVC trunking, like PVC conduit, is easy to install and is non-corrosive. A separate CPC will need to be installed and non-metallic trunking may

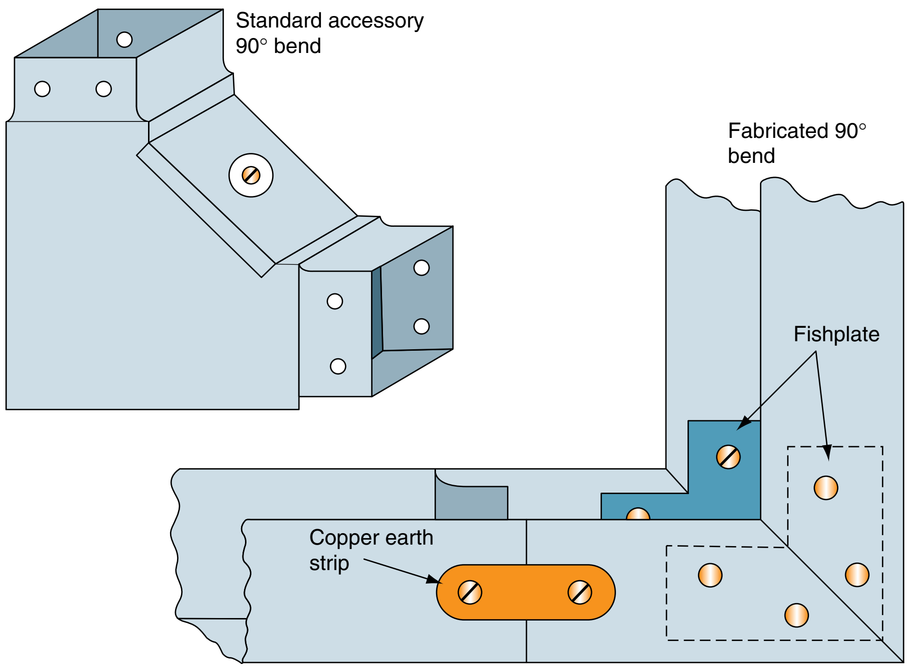

Figure 4.23 Alternative trunking bends.

require more frequent fixings because it is less rigid than metallic trunking. All trunking fixings should use round-headed screws to prevent damage to cables since the thin sheet construction makes it impossible to countersink screw heads.

Mini-trunking

Mini-trunking is very small PVC trunking, ideal for surface wiring in domestic and commercial installations such as offices. The trunking has a cross-section of 16 × 16 mm, 25 × 16 mm, 38 × 16 mm or 38 × 25 mm and is ideal for switch drops or for housing auxiliary circuits such as telephone or audio equipment wiring. The modern square look in switches and sockets is complemented by the mini-trunking which is very easy to install (see Fig. 4.24).

Definition

Mini-trunking is very small PVC trunking, ideal for surface wiring in domestic and commercial installations such as offices.

Skirting trunking

A **trunking manufactured from PVC or steel** and in the shape of a skirting board is frequently used in commercial buildings such as hospitals, laboratories and offices. The trunking is fitted around the walls of a room and contains the wiring for socket outlets and telephone points which are mounted on the lid, as shown in Fig. 4.24.

Definition

A *trunking manufactured from PVC or steel* and in the shape of a skirting board is frequently used in commercial buildings such as hospitals, laboratories and offices.

Where any trunking passes through walls, partitions, ceilings or floors, short lengths of lid should be fitted so that the remainder of the lid may be removed later without difficulty. Any damage to the structure of the buildings must be made good with mortar, plaster or concrete in order to prevent the spread of fire. Fire barriers must be fitted inside the trunking every 5 m, or at every floor level or room dividing wall, if this is a shorter distance, as shown in Fig. 4.25(a).

Key fact

Fire Safety

Where the wiring system passes through elements of building construction such as floors and walls, any damage must be made good (IEE Regulation 527.2).

Where trunking is installed vertically, the installed conductors must be supported so that the maximum unsupported length of non-sheathed cable does not exceed 5 m. Figure 4.25(b) shows cables woven through insulated pin supports, which is one method of supporting vertical cables.

PVC insulated cables are usually drawn into an erected conduit installation or laid into an erected trunking installation. Table 5D of the *On Site Guide* only gives factors for conduits up to 32 mm in diameter, which would indicate that conduits larger than this are not in frequent or common use. Where a cable enclosure greater than 32 mm is required because of the number or size of the conductors, it is generally more economical and convenient to use trunking.

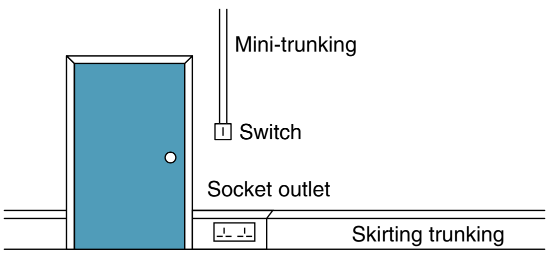

Figure 4.24 Typical installation of skirting trunking and mini-trunking.

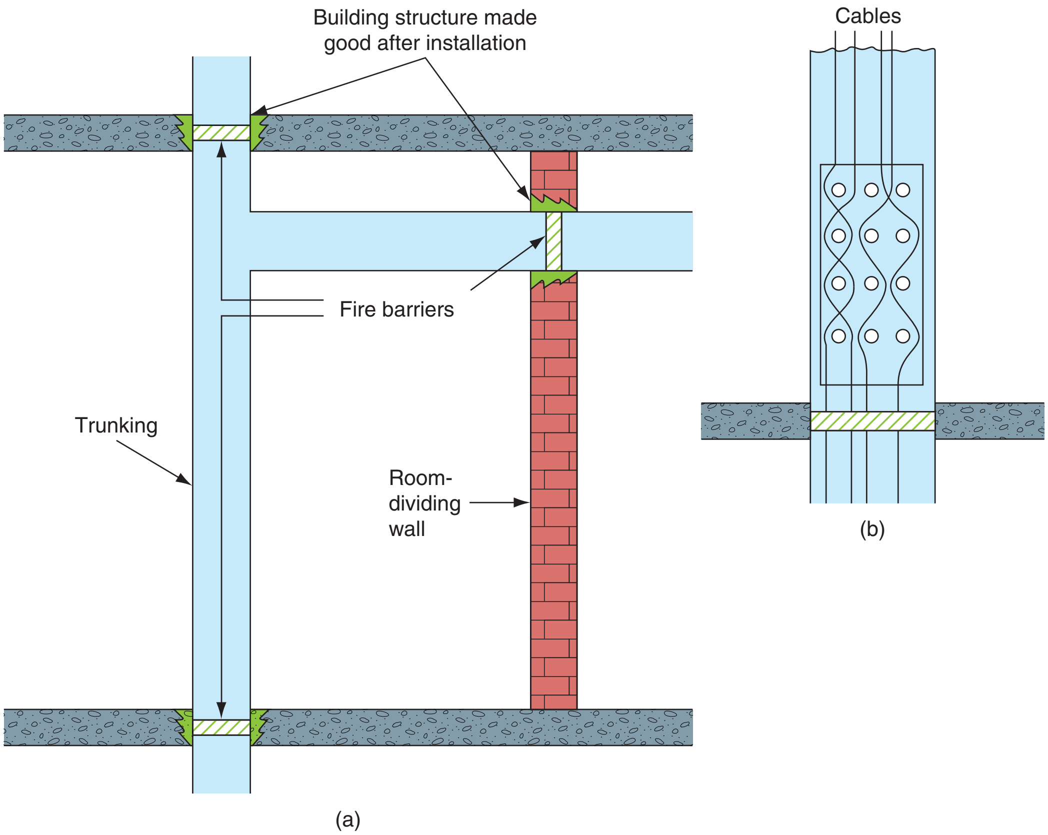

Figure 4.25 Installation of trunking.

Table 4.4 Trunking cable factors. Adopted from the IEE *On Site Guide* by kind permission of the Institution of Electrical Engineers

Type of conductor	Cable factors for trunking		
	Conductor cross-sectional area (mm^2)	PVC, BS 6004 cable factor	Thermosetting BS 7211 cable factor
Solid	1.5	8.0	8.6
	2.5	11.9	11.9
Stranded	1.5	8.6	9.6
	2.5	12.6	13.9
	4	16.6	18.1
	6	21.2	22.9
	10	35.3	36.3
	16	47.8	50.3
	25	73.9	75.4

Note: (i) These factors are for metal trunking and may be optimistic for plastic trunking where the cross-sectional area available may be significantly reduced from the nominal by the thickness of the wall material. (ii) The provision of spare space is advisable; however, any circuits added at a later date must take into account grouping (Appendix 4, BS 7671)

Trunking capacities

The ratio of the space occupied by all the cables in a conduit or trunking to the whole space enclosed by the conduit or trunking is known as the **space factor**. Where sizes and types of cable and trunking are not covered by the tables in Appendix 5 of the *On Site Guide* a space factor of 45% must not be exceeded. This means that the cables must not fill more than 45% of the space enclosed by the trunking. The tables of Appendix 5 take this factor into account.

To calculate the size of trunking required to enclose a number of cables:

- Identify the cable factor for the particular size of conductor (See Table 4.4)
- Multiply the cable factor by the number of conductors to give the sum of the cable factors
- Consider the factors for trunking shown in Table 4.5. The correct size of trunking to accommodate the cables is that trunking which has a factor equal to or greater than the sum of the cable factors

Definition

The ratio of the space occupied by all the cables in a conduit or trunking to the whole space enclosed by the conduit or trunking is known as the *space factor*.

Table 4.5 Trunking cable factors. Adopted from the *IEE On Site Guide* by kind permission of the Institution of Electrical Engineers

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

Space factor – 45% with trunking thickness taken into account

Example

Calculate the minimum size of trunking required to accommodate the following single-core PVC cables:

20 × 1.5 mm solid conductors
20 × 2.5 mm solid conductors
21 × 4.0 mm stranded conductors
16 × 6.0 mm stranded conductors

From Table 4.4, the cable factors are:

for 1.5 mm solid cable	–	8.0
for 2.5 mm solid cable	–	11.9
for 4.0 mm stranded cable	–	16.6
for 6.0 mm stranded cable	–	21.2

The sum of the cable terms is:

$$(20 \times 8.0) + (20 \times 11.9) + (21 \times 16.6) + (16 \times 21.2) = 1085.8$$

From Table 4.5, 75 × 38 mm trunking has a factor of 1146 and, therefore, the minimum size of trunking to accommodate these cables is 75 × 38 mm, although a larger size, say 75 × 50 mm would be equally acceptable if this was more readily available as a standard stock item.

Segregation of circuits

Where an installation comprises a mixture of low-voltage and very low-voltage circuits such as mains lighting and power, fire alarm and telecommunication circuits, they must be separated or *segregated* to prevent electrical contact (IEE Regulation 528.1).

For the purpose of these regulations various circuits are identified by one of two bands as follows:

Band I telephone, radio, bell, call and intruder alarm circuits, emergency circuits for fire alarm and emergency lighting

Band II mains voltage circuits

When Band I circuits are insulated to the same voltage as Band II circuits, they may be drawn into the same compartment.

When trunking contains rigidly fixed metal barriers along its length, the same trunking may be used to enclose cables of the separate bands without further precautions, provided that each band is separated by a barrier, as shown in Fig. 4.26.

Multi-compartment PVC trunking cannot provide band segregations since there is no metal screen between the bands. This can only be provided in PVC trunking if screened cables are drawn into the trunking.

Cable tray installations

Cable tray is a sheet-steel channel with multiple holes. The most common finish is hot-dipped galvanized but PVC-coated tray is also available. It is used

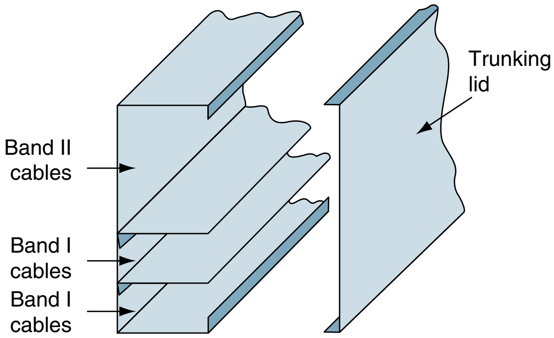

Figure 4.26 Segregation of cables in trunking.

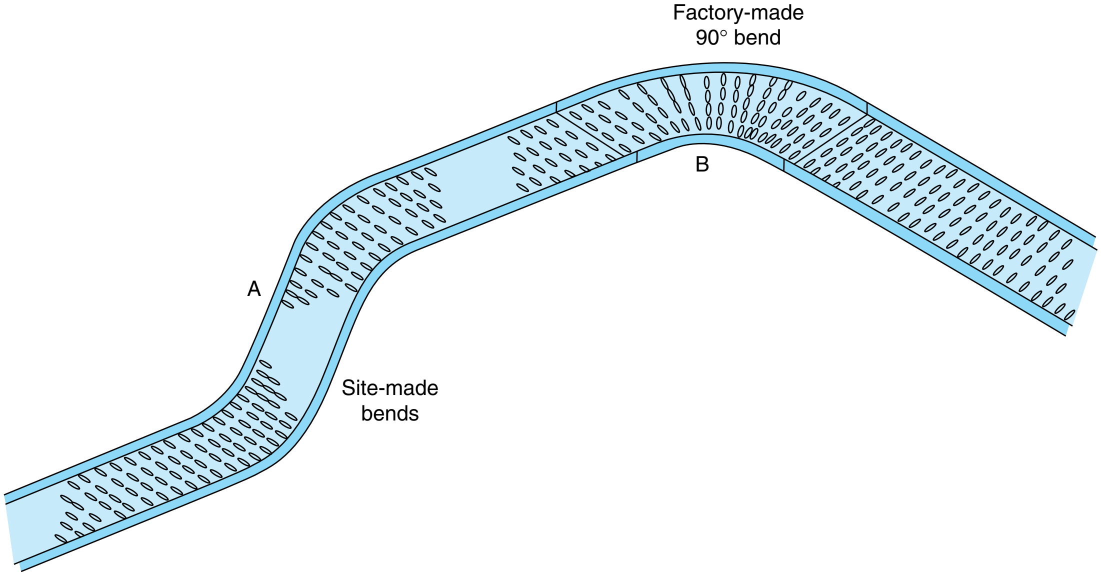

Figure 4.27 Cable tray with bends.

extensively on large industrial and commercial installations for supporting MI and SWA cables which are laid on the cable tray and secured with cable ties through the tray holes.

Cable tray should be adequately supported during installation by brackets which are appropriate for the particular installation. The tray should be bolted to the brackets with round-headed bolts and nuts, with the round head inside the tray so that cables drawn along the tray are not damaged.

The tray is supplied in standard widths from 50 to 900 mm, and a wide range of bends, tees and reducers is available. Figure 4.27 shows a factory-made 90° bend at B. The tray can also be bent using a cable tray bending machine to create bends such as that shown at A in Fig. 4.27. The installed tray should be securely bolted with round-headed bolts where lengths or accessories are attached, so that there is a continuous earth path which may be bonded to an electrical earth. The whole tray should provide a firm support for the cables and therefore the tray fixings must be capable of supporting the weight of both the tray and cables.

Cable basket installations

Cable basket is becoming very popular for industrial installations. It is made from steel wire into a basket channel with sides.

Definition

Cable tray is a sheet-steel channel with multiple holes. The most common finish is hot-dipped galvanized but PVC-coated tray is also available. It is used extensively on large industrial and commercial installations for supporting MI and SWA cables which are laid on the cable tray and secured with cable ties through the tray holes.

Cable basket allows maximum airflow around the cables which are laid into the basket without fixing.

Cable basket requires similar installation techniques to cable tray and should be adequately supported.

PVC/SWA cable installations

Steel wire armoured PVC insulated cables are now extensively used on industrial installations and often laid on cable tray. This type of installation has the advantage of flexibility, allowing modifications to be made speedily as the need arises. The cable has a steel wire armouring giving mechanical protection and permitting it to be laid directly in the ground or in ducts, or it may be fixed directly or laid on a cable tray or basket. Figure 4.16 shows a PVC/SWA cable.

Definition

Steel wire armoured PVC insulated cables are now extensively used on industrial installations and often laid on cable tray.

It should be remembered that when several cables are grouped together the current rating will be reduced according to the correction factors given in Appendix 4 Table 4C1 of the IEE Regulations and Table 6C of the *On Site Guide.*

The cable is easy to handle during installation, is pliable and may be bent to a radius of eight times the cable diameter. The PVC insulation would be damaged if installed in ambient temperatures over 70°C or below 0°C, but once installed the cable can operate at low temperatures.

The cable is terminated with a simple gland which compresses a compression ring onto the steel wire armouring to provide the earth continuity between the switchgear and the cable.

MI cable installations

MI cables are available for general wiring as:

- light-duty MI cables for voltages up to 600 V and sizes from 1.0 to 10 mm^2, and
- heavy-duty MI cables for voltages up to 1000 V and sizes from 1.0 to 150 mm^2.

Figure 4.17 shows an MI cable and termination. The cables are available with bare sheaths or with a PVC oversheath. The cable sheath provides sufficient mechanical protection for all but the most severe situations, where it may be necessary to fit a steel sheath or conduit over the cable to give extra protection, particularly near floor level in some industrial situations.

The cable may be laid directly in the ground, in ducts, on cable tray or clipped directly to a structure. It is not affected by water, oil or the cutting fluids used in engineering and can withstand very high temperature or even fire. The cable diameter is small in relation to its current carrying capacity and it should last indefinitely if correctly installed because it is made from inorganic materials. These characteristics make the cable ideal for Band I emergency circuits, boiler-houses, furnaces, petrol stations and chemical plant installations.

The cable is supplied in coils and should be run off during installation and not spiralled off, as described in Fig. 4.22 for conduit. The cable can be work-hardened if over-handled or over-manipulated. This makes the copper outer sheath stiff and may result in fracture. The outer sheath of the cable must not be penetrated, otherwise moisture will enter the magnesium oxide insulation and lower its resistance. To reduce the risk of damage to the outer sheath during installation, cables should be straightened and formed by hammering with a hide hammer or a block of wood and a steel hammer. When bending MI cables the radius of the bend should not cause the cable to become damaged and clips should provide adequate support (IEE Regulation 522.8.5).

The cable must be prepared for termination by removing the outer copper sheath to reveal the copper conductors. This can be achieved by using a rotary stripper tool or, if only a few cables are to be terminated, the outer sheath can be removed with side cutters, peeling off the cable in a similar way to peeling the skin from a piece of fruit with a knife. When enough conductor has been revealed, the outer sheath must be cut off square to facilitate the fitting of the sealing pot, and this can be done with a ringing tool. All excess magnesium oxide powder must be wiped from the conductors with a clean cloth. This is to prevent moisture from penetrating the seal by capillary action.

Cable ends must be terminated with a special seal to prevent the entry of moisture. Figure 4.17 shows a brass screw-on seal and gland assembly, which allows termination of the MI cables to standard switchgear and conduit fittings. The sealing pot is filled with a sealing compound, which is pressed in from one side only to prevent air pockets forming, and the pot closed by crimping home the sealing disc. Such an assembly is suitable for working temperatures up to 105°C. Other compounds or powdered glass can increase the working temperature up to 250°C.

The conductors are not identified during the manufacturing process and so it is necessary to identify them after the ends have been sealed. A simple continuity or polarity test, as described in Chapter 6 of this book can identify the conductors which are then sleeved or identified with coloured markers.

Connection of MI cables can be made directly to motors, but to absorb the vibrations a 360° loop should be made in the cable just before the termination. If excessive vibration is to be expected the MI cable should be terminated in a conduit through-box and the final connection made by flexible conduit.

Copper MI cables may develop a green incrustation or patina on the surface, even when exposed to normal atmospheres. This is not harmful and should not be removed. However, if the cable is exposed to an environment which might encourage corrosion, an MI cable with an overall PVC sheath should be used.

Restoration of the building structure

If the structure, or we sometimes call it the fabric of the building, has been damaged as a result of your electrical repair work, it must be made good before you hand the installation, system or equipment back to the client.

Where a wiring system passes through elements of the building construction such as floors, walls, roofs, ceilings, partitions or cavity barriers, the openings remaining after the passage of the wiring system must be sealed according to the degree of fire resistance demonstrated by the original building material (IEE Regulation 527.2).

You should always make good the structure of the building using appropriate materials ***before*** you leave the job so that the general building structural performance and fire safety are not reduced. If additionally, there is a little cosmetic plastering and decorating to be done, then who actually will carry out this work is a matter of negotiation between the client and the electrical contractor.

Disposal of waste

Having completed any work in the electrotechnical industry, we come to the final practical task, leaving the site in a safe and clean condition and the removal of

Safety first

Fire

If your electrical activities cause damage to the fabric of the building then:

- the openings remaining must be sealed according to the degree of fire resistance demonstrated by the original building material
- IEE Regulation 527.2

any waste material. This is an important part of your company's 'good customer relationships' with the client. We also know that we have a 'duty of care' for the waste that we produce as an electrical company.

We have also said many times in this book that having a good attitude to health and safety, working conscientiously and neatly, keeping passage ways clear and regularly tidying up the workplace is the sign of a good and competent craftsman. But what do you do with the rubbish that the working environment produces? Well:

- All the packaging material for electrical fittings and accessories usually goes into either your employer's skip or the skip on site designated for that purpose.
- All the off-cuts of conduit, trunking and tray also go into the skip.
- In fact, most of the general site debris will probably go into the skip and the waste disposal company will take the skip contents to a designated local council land fill area for safe disposal.
- The part coils of cable and any other reusable leftover lengths of conduit, trunking or tray will be taken back to your employer's stores area. Here it will be stored for future use and the returned quantities deducted from the costs allocated to that job.
- What goes into the skip for normal disposal into a land fill site is usually a matter of common sense. However, some substances require special consideration and disposal. We will now look at asbestos and large quantities of used fluorescent tubes which are classified as 'special waste' or 'hazardous waste'.

Asbestos is a mineral found in many rock formations. When separated it becomes a fluffy, fibrous material with many uses. It was used extensively in the construction industry during the 1960s and 1970s for roofing material, ceiling and floor tiles, fire resistant board for doors and partitions, for thermal insulation and commercial and industrial pipe lagging.

In the buildings where it was installed some 40 years ago, when left alone, it does not represent a health hazard, but those buildings are increasingly becoming in need of renovation and modernization. It is in the dismantling and breaking up of these asbestos materials that the health hazard increases. Asbestos is a serious health hazard if the dust is inhaled. The tiny asbestos particles find their way into delicate lung tissue and remain embedded for life, causing constant irritation and eventually, serious lung disease.

Working with asbestos materials is not a job for anyone in the electrotechnical industry. If asbestos is present in situations or buildings where you are expected to work, it should be removed by a specialist contractor before your work commences. Specialist contractors, who will wear fully protective suits and use breathing apparatus, are the only people who can safely and responsibly carry out the removal of asbestos. They will wrap the asbestos in thick plastic bags and store them temporarily in a covered and locked skip. This material is then disposed of in a special land fill site with other toxic industrial waste materials and the site monitored by the Local Authority for the foreseeable future.

There is a lot of work for electrical contractors in many parts of the country updating and improving the lighting in government buildings and schools. This work often involves removing the old fluorescent fittings hanging on chains or fixed to beams, and installing a suspended ceiling and an appropriate number of recessed modular fluorescent fittings. So what do we do with the old fittings? Well, the fittings are made of sheet steel, a couple of plastic lampholders, a little cable, a starter and ballast. All of these materials can go into the ordinary skip. However, the fluorescent tubes contain a little mercury and fluorescent powder with toxic elements, which cannot be disposed of in the normal land fill sites. New Hazardous Waste Regulations were introduced in July 2005 and under these regulations lamps and tubes are classified as hazardous. While each lamp contains only a small amount of mercury, vast numbers of lamps and tubes are disposed of in the United Kingdom every year resulting in a significant environmental threat.

The environmentally responsible way to dispose of fluorescent lamps and tubes is to recycle them.

To demonstrate that you understand the fifth and sixth CGLI Outcomes your tutor/trainer/lecturer will assess your ability to measure, mark out, fit and fix wiring systems.

Confirm variations to the installation specification (CGL1 Outcome 7)

The final outcome of City and Guilds Unit 315 asks you to confirm variations to the electrical installation specification. You should go back to the beginning of this chapter to Outcomes 2 and 3 and Fig. 4.9 and read the section on daywork sheets or variation Orders. Your tutor/trainer/lecturer will then assess you on this topic.

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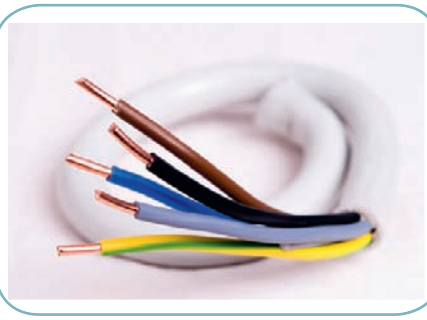
CHAPTER 5

Terminating and connecting conductors



Unit 316 of the City and Guilds 2357 syllabus

Terminating and connecting conductors, cables and flexible cords in electrical systems

When you have completed this chapter you should be able to:

1. Confirm the safety of the work environment before terminating and connecting conductors
2. Terminate and connect conductors, cables and cords
3. Identify conductors and confirm terminations are safe

Online Material WWW

This chapter has free associated content, including animations and instructional videos, to support your learning

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Confirm the safety of the work environment before terminating and connecting conductors (CGLI Outcome 1)

If your career in the electrotechnical industry is to be a long, happy and safe one, you must always wear appropriate PPE such as footwear, and head protection and behave responsibly and sensibly in order to maintain a safe working environment. Before starting work, make a safety assessment: what is going to be hazardous, will you require PPE, do you need any special access equipment?

Safe methods of working must be demonstrated by everyone at every stage. 'Employees have a duty of care to protect their own health and safety and that of others who might be affected by their work activities'.

Advanced Electrical Installation Work. 978-0-08-097042-4

To make the work area safe before starting work and during work activities, it may be necessary to:

- use barriers or tapes to screen off potential hazards,
- place warning signs as appropriate,
- inform those who may be affected by any potential hazard,
- use a safe isolation procedure before working on live equipment or circuits,
- obtain any necessary 'permits to work' before work begins.

Get into the habit of always working safely and being aware of the potential hazards around you when you are working.

Having chosen an appropriate wiring system which meets the intended use and structure of the building and satisfies the environmental conditions of the installation, you must install the system conductors, accessories and equipment and terminate and connect conductors, cables and flexible cords in a safe and competent manner.

The structure of the building must be made good if it is damaged during the installation of the wiring system. For example, where conduits and trunking are run through walls and floors.

All connections in the wiring system must be both electrically and mechanically sound. All conductors must be chosen so that they will carry the design current under the installed conditions.

If the wiring system is damaged during installation it must be made good to prevent future corrosion. For example, where galvanized conduit trunking or tray is cut or damaged by pipe vices, it must be made good to prevent localized corrosion.

All tools must be used safely and sensibly. Cutting tools should be sharpened and screwdrivers ground to a sharp square end on a grindstone.

It is particularly important to check that the plug and cables of hand held electrically powered tools and extension leads are in good condition. Damaged plugs and cables must be repaired before you use them. All electrical power tools of 110 and 230 V must be tested with a portable appliance tester (PAT) in accordance with the company's health and safety procedures, but probably at least once each year.

Tools and equipment that are left lying about in the workplace can become damaged or stolen and may also be the cause of people slipping, tripping or falling. Tidy up regularly and put power tools back in their boxes. You personally may have no control over the condition of the workplace in general, but keeping your own work area clean and tidy is the mark of a skilled and conscientious craftsman.

Finally, when the job is finished, clean up and dispose of all waste material responsibly.

We know from earlier chapters in this book that using electricity is one of the causes of accidents in the workplace. Using electricity is a hazard because it has the potential, the possibility to cause harm. Therefore, the provision of protective devices in an electrical installation is fundamental to the whole concept of the safe use of electricity in buildings.

Where PPE is provided by an employer, employees have a duty to use it to safeguard themselves.

PPE at Work Regulations 1992

PPE is defined as all equipment designed to be worn, or held, to protect against a risk to health and safety. This includes most types of protective clothing, and

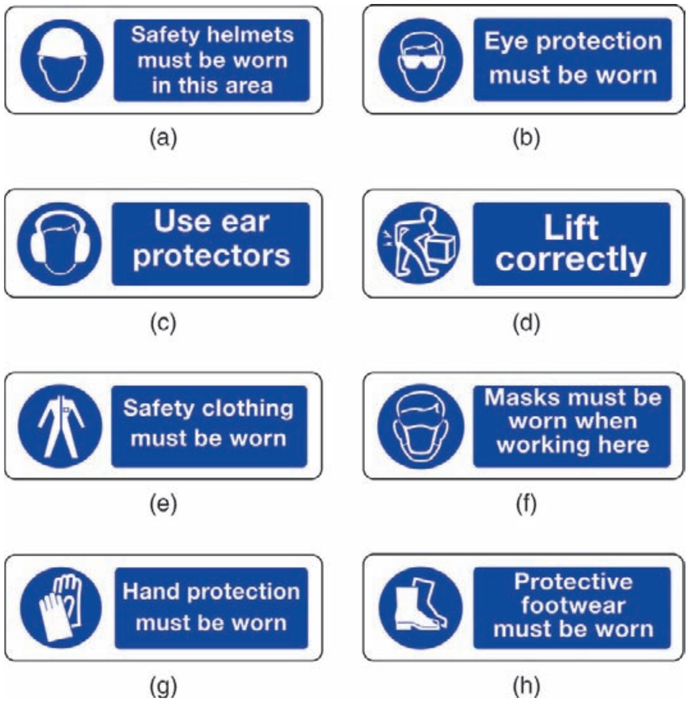

Figure 5.1 Safety signs showing type of PPE to be worn.

equipment such as eye, foot and head protection, safety harnesses, life jackets and high-visibility clothing.

Under the Health and Safety at Work Act, employers must provide free of charge any PPE and employees must make full and proper use of it. Safety signs such as those shown in Fig. 5.1 are useful reminders of the type of PPE to be used in a particular area. The vulnerable parts of the body which may need protection are the head, eyes, ears, lungs, torso, hands and feet and, additionally, protection from falls may need to be considered. Objects falling from a height present the major hazard against which head protection is provided. Other hazards include striking the head against projections and hair becoming entangled in machinery. Typical methods of protection include helmets, light duty scalp protectors called 'bump caps' and hairnets.

The eyes are very vulnerable to liquid splashes, flying particles and light emissions such as ultraviolet light, electric arcs and lasers. Types of eye protectors include safety spectacles, safety goggles and face shields. Screen based workstations are being used increasingly in industrial and commercial locations by all types of personnel. Working with VDUs (visual display units) can cause eye strain and fatigue and, therefore, work patterns should be varied and operators are entitled to free eye tests.

Noise is accepted as a problem in most industries and surprisingly there has been very little control legislation. The HSE have published a 'Code of Practice' and 'Guidance Notes' HSG 56 for reducing the exposure of employed persons to noise. A continuous exposure limit of below 90 dB for an 8-hour working day is recommended by the code.

Noise may be defined as any disagreeable or undesirable sound or sounds, generally of a random nature, which do not have clearly defined frequencies. The usual basis for measuring noise or sound level is the decibel scale. Whether noise of a particular level is harmful or not also depends upon the length

Safety first

PPE

- What type of PPE do you use at work?
- Make a list in the margin of the book

of exposure to it. This is the basis of the widely accepted limit of 90 dB of continuous exposure to noise for 8 hours per day.

A peak sound pressure of above 200 pascals or about 120 dB is considered unacceptable and 130 dB is the threshold of pain for humans. If a person has to shout to be understood at 2 m, the background noise is about 85 dB. If the distance is only 1 m, the noise level is about 90 dB. Continuous noise at work causes deafness, makes people irritable, affects concentration, causes fatigue and accident proneness and may mask sounds which need to be heard in order to work efficiently and safely.

It may be possible to engineer out some of the noise, for example, by placing a generator in a separate sound-proofed building. Alternatively, it may be possible to provide job rotation, to rearrange work locations or provide acoustic refuges.

Where individuals must be subjected to some noise at work it may be reduced by ear protectors. These may be disposable ear plugs, reusable ear plugs or ear muffs. The chosen ear protector must be suited to the user and suitable for the type of noise and individual personnel should be trained in its correct use.

Breathing reasonably clean air is the right of every individual, particularly at work. Some industrial processes produce dust which may present a potentially serious hazard. The lung disease asbestosis is caused by the inhalation of asbestos dust or particles and the coal dust disease pneumoconiosis, suffered by many coal miners, has made people aware of the dangers of breathing in contaminated air.

Some people may prove to be allergic to quite innocent products such as flour dust in the food industry or wood dust in the construction industry. The main effect of inhaling dust is a measurable impairment of lung function. This can be avoided by wearing an appropriate mask, respirator or breathing apparatus as recommended by the company's health and safety policy and indicated by local safety signs.

A worker's body may need protection against heat or cold, bad weather, chemical or metal splash, impact or penetration and contaminated dust. Alternatively, there may be a risk of the worker's own clothes causing contamination of the product, as in the food industry. Appropriate clothing will be recommended in the company's health and safety policy. Ordinary working clothes and clothing provided for food hygiene purposes are not included in the PPE at Work Regulations.

Hands and feet may need protection from abrasion, temperature extremes, cuts and punctures, impact or skin infection. Gloves or gauntlets provide protection from most industrial processes but should not be worn when operating machinery because they may become entangled in it. Care in selecting the appropriate protective device is required; for example, barrier creams provide only a limited protection against infection.

Boots or shoes with in-built toe caps can give protection against impact or falling objects and, when fitted with a mild steel sole plate, can also provide protection from sharp objects penetrating through the sole. Special slip resistant soles can also be provided for employees working in wet areas.

Whatever the hazard to health and safety at work, the employer must be able to demonstrate that he or she has carried out a risk assessment, made recommendations which will reduce that risk and communicated these recommendations to the workforce. Where there is a need for PPE to protect against personal injury and to create a safe working environment, the employer must provide that equipment and any necessary training which might be required and the employee must make full and proper use of such equipment and training.

Causes of accidents

Most accidents are caused by either human error or environmental conditions. **Human errors** include behaving badly or foolishly, being careless and not paying attention to what you should be doing at work, doing things that you are not competent to do or have not been trained to do. You should not work when tired or fatigued and should never work when you have been drinking alcohol or taking drugs.

Environmental conditions include unguarded or faulty machinery, damaged or faulty tools and equipment, poorly illuminated or ventilated workplaces and untidy, dirty or overcrowded workplaces.

The most common causes of accidents

These are:

- slips, trips and falls;
- manual handling, that is moving objects by hand;
- using equipment, machinery or tools;
- storage of goods and materials which then become unstable;
- fire;
- electricity;
- mechanical handling.

Accident prevention measures

To control the risk of an accident we usually:

- eliminate the cause;
- substitute a procedure or product with less risk;
- enclose the dangerous situation;
- put guards around the hazard;
- use safe systems of work;
- supervise, train and give information to staff;
- if the hazard cannot be removed or minimized then provide PPE.

Let us now look at the application of one of the procedures that make the workplace a safer place to work but first of all I want to explain what I mean when I use the words hazard and risk.

Hazard and risk

A **hazard** is something with the 'potential' to cause harm, for example, chemicals, electricity or working above ground.

A **risk** is the 'likelihood'of harm actually being done.

Competent persons are often referred to in the Health and Safety at Work Regulations, but who is 'competent'? For the purposes of the Act, a competent person is anyone who has the necessary technical skills, training and expertise to safely carry out the particular activity. Therefore, a **competent person** dealing with a hazardous situation reduces the risk.

Definition

Human errors include behaving badly or foolishly, being careless and not paying attention to what you should be doing at work.

Definition

Environmental conditions include unguarded or faulty machinery.

Safety first

Safety Procedures

- Hazard risk assessment is an essential part of any health and safety management system
- The aim of the planning process is to minimize risk
- HSE publication HSG (65)

Definitions

A *hazard* is something with the 'potential' to cause harm, for example, chemicals, electricity or working above ground.

A *risk* is the 'likelihood' of harm actually being done.

Definition

A *competent person* is anyone who has the necessary technical skills, training and expertise to safely carry out the particular activity.

Think about your workplace and at each stage of what you do, think about what might go wrong. Some simple activities may be hazardous. Here are some typical activities where accidents might happen.

Typical activity	Potential hazard
Receiving materials	Lifting and carrying
Stacking and storing	Falling materials
Movement of people	Slips, trips and falls
Building maintenance	Working at heights or in confined spaces
Movement of vehicles	Collisions

How high are the risks? Think about what might be the worst result, is it a broken finger or someone suffering permanent lung damage or being killed? How likely is it to happen? How often is that type of work carried out and how close do people get to the hazard? How likely is it that something will go wrong?

How many people might be injured if things go wrong? Might this also include people who do not work for your company?

Employers of more than five people must document the risks at work and the process is known as hazard risk assessment.

Hazard risk assessment – the process

The Management of Health and Safety at Work Regulations 1999 tell us that employers must systematically examine the workplace, the work activity and the management of safety in the establishment through a process of risk assessments. A record of all significant risk assessment findings must be kept in a safe place and be made available to an HSE inspector if required. Information based on the risk assessment findings must be communicated to relevant staff and if changes in work behaviour patterns are recommended in the interests of safety, then they must be put in place.

So risk assessment must form a part of any employer's robust policy of health and safety. However, an employer only needs to 'formally' assess the significant risks. He is not expected to assess the trivial and minor types of household risks. Staff are expected to read and to act upon these formal risk assessments and they are unlikely to do so enthusiastically if the file is full of trivia. An assessment of risk is nothing more than a careful examination of what, in your work, could cause harm to people. It is a record that shows whether sufficient precautions have been taken to prevent harm.

The HSE recommends five steps to any risk assessment.

Step 1

Look at what might reasonably be expected to cause harm. Ignore the trivial and concentrate only on significant hazards that could result in serious harm or injury. Manufacturers' data sheets or instructions can also help you spot hazards and put risks in their true perspective.

Step 2

Decide who might be harmed and how. Think about people who might not be in the workplace all the time – cleaners, visitors, contractors or maintenance personnel. Include members of the public or people who share the workplace. Is there a chance that they could be injured by activities taking place in the workplace?

Step 3

Evaluate what is the risk arising from an identified hazard. Is it adequately controlled or should more be done? Even after precautions have been put in place, some risk may remain. What you have to decide, for each significant hazard, is whether this remaining risk is low, medium or high. First of all, ask yourself if you have done all the things that the law says you have got to do. For example, there are legal requirements on the prevention of access to dangerous machinery. Then ask yourself whether generally accepted industry standards are in place, but do not stop there – think for yourself, because the law also says that you must do what is reasonably practicable to keep the workplace safe. Your real aim is to make all risks small by adding precautions, if necessary.

If you find that something needs to be done, ask yourself:

1. Can I get rid of this hazard altogether?
2. If not, how can I control the risk so that harm is unlikely?

Only use PPE when there is nothing else that you can reasonably do.

If the work that you do varies a lot, or if there is movement between one site and another, select those hazards which you can reasonably foresee, the ones that apply to most jobs and assess the risks for them. After that, if you spot any unusual hazards when you get on site, take what action seems necessary.

Step 4

Record your findings and say what you are going to do about risks that are not adequately controlled. If there are fewer than five employees you do not need to write anything down but if there are five or more employees, the significant findings of the risk assessment must be recorded. This means writing down the more significant hazards and assessing if they are adequately controlled and recording your most important conclusions. Most employers have a standard risk assessment form which they use such as that shown in Fig. 5.2 but any format is suitable. The important thing is to make a record.

There is no need to show how the assessment was made, providing you can show that:

1. a proper check was made,
2. you asked those who might be affected,
3. you dealt with all obvious and significant hazards,
4. the precautions are reasonable and the remaining risk is low,
5. you informed your employees about your findings.

Risk assessments need to be *suitable* and *sufficient*, not perfect. The two main points are:

1. Are the precautions reasonable?
2. Is there a record to show that a proper check was made?

File away the written assessment in a dedicated file for future reference or use. It can help if an HSE inspector questions the company's precautions or if the company becomes involved in any legal action. It shows that the company has done what the law requires.

Step 5

Review the assessments from time to time and revise them if necessary.

HAZARD RISK ASSESSMENT	FLASH-BANG ELECTRICAL CO.
For Company name or site: ---------------------- Address: ---------------------- ----------------------	Assessment undertaken by: ---------------------- Signed: ---------------------- Date: ----------------------
STEP 5 Assessment review date: ----------------------	
STEP 1 List the hazards here	STEP 2 Decide who might be harmed
STEP 3 Evaluate (what is) the risk – is it adequately controlled? State risk level as low, medium or high	STEP 4 Further action – what else is required to control any risk identified as medium or high?

Figure 5.2 Hazard risk assessment standard form.

Completing a risk assessment

When completing a risk assessment such as that shown in Fig. 5.2, do not be over complicated. In most firms in the commercial, service and light industrial sector, the hazards are few and simple. Checking them is common sense but necessary.

Step 1

List only hazards which you could reasonably expect to result in significant harm under the conditions prevailing in your workplace. Use the following examples as a guide:

- Slipping or tripping hazards (e.g. from poorly maintained or partly installed floors and stairs).
- Fire (e.g. from flammable materials you might be using, such as solvents).
- Chemicals (e.g. from battery acid).
- Moving parts of machinery (e.g. blades).
- Rotating parts of handtools (e.g. drills).
- Accidental discharge of cartridge operated tools.
- High pressure air from airlines (e.g. air powered tools).
- Pressure systems (e.g. steam boilers).
- Vehicles (e.g. fork lift trucks).
- Electricity (e.g. faulty tools and equipment).
- Dust (e.g. from grinding operations or thermal insulation).
- Fumes (e.g. from welding).
- Manual handling (e.g. lifting, moving or supporting loads).
- Noise levels too high (e.g. machinery).
- Poor lighting levels (e.g. working in temporary or enclosed spaces).
- Low temperatures (e.g. working outdoors or in refrigeration plants).
- High temperatures (e.g. working in boiler rooms or furnaces).

Step 2

Decide who might be harmed, do not list individuals by name. Just think about groups of people doing similar work or who might be affected by your work:

- Office staff
- Electricians
- Maintenance personnel
- Other contractors on site
- Operators of equipment
- Cleaners
- Members of the public.

Pay particular attention to those who may be more vulnerable, such as:

- staff with disabilities,
- visitors,
- young or inexperienced staff,
- people working in isolation or enclosed spaces.

Step 3

Calculate what is the risk – is it adequately controlled? Have you already taken precautions to protect against the hazards which you have listed in Step 1? For example:

- Have you provided adequate information to staff?
- Have you provided training or instruction?

Do the precautions already taken

- meet the legal standards required?
- comply with recognized industrial practice?
- represent good practice?
- reduce the risk as far as is reasonably practicable?

If you can answer 'yes' to the above points then the risks are adequately controlled, but you need to state the precautions you have put in place. You can refer to company procedures, company rules, company practices, etc., in giving this information. For example, if we consider there might be a risk of electric shock from using electrical power tools, then the risk of a shock will be *less* if the company policy is to PAT test all power tools each year and to fit a label to the tool showing that it has been tested for electrical safety. If the stated company procedure is to use battery drills whenever possible, or 110 V drills when this is not possible, and *never* to use 230 V drills, then this again will reduce the risk. If a policy such as this is written down in the company safety policy statement, then you can simply refer to the appropriate section of the safety policy statement and the level of risk will be low.

Step 4

Further action – what more could be done to reduce those risks which were found to be inadequately controlled?

You will need to give priority to those risks that affect large numbers of people or which could result in serious harm. Senior managers should apply the principles below when taking action, if possible in the following order:

1. Remove the risk completely.
2. Try a less risky option.
3. Prevent access to the hazard (e.g. by guarding).
4. Organize work differently in order to reduce exposure to the hazard.
5. Issue PPE.
6. Provide welfare facilities (e.g. washing facilities for removal of contamination and first aid).

Any hazard identified by a risk assessment as *high risk* must be brought to the attention of the person responsible for health and safety within the company. Ideally, in Step 4 of the risk assessment you should be writing, 'No further action is required. The risks are under control and identified as low risk'.

The assessor may use as many standard hazard risk assessment forms, such as that shown in Fig. 5.2, as the assessment requires. Upon completion they should be stapled together or placed in a plastic wallet and stored in the dedicated file.

Test equipment and safe isolation procedures

The Health and Safety Executive (HSE) has published Guidance Notes (GS 38) which advise electricians and other electrically competent people on the selection of suitable test probes, voltage indicating devices and measuring instruments. This is because they consider suitably constructed test equipment to be as vital for personal safety as the training and practical skills of the electrician. In the past, unsatisfactory test probes and voltage indicators have

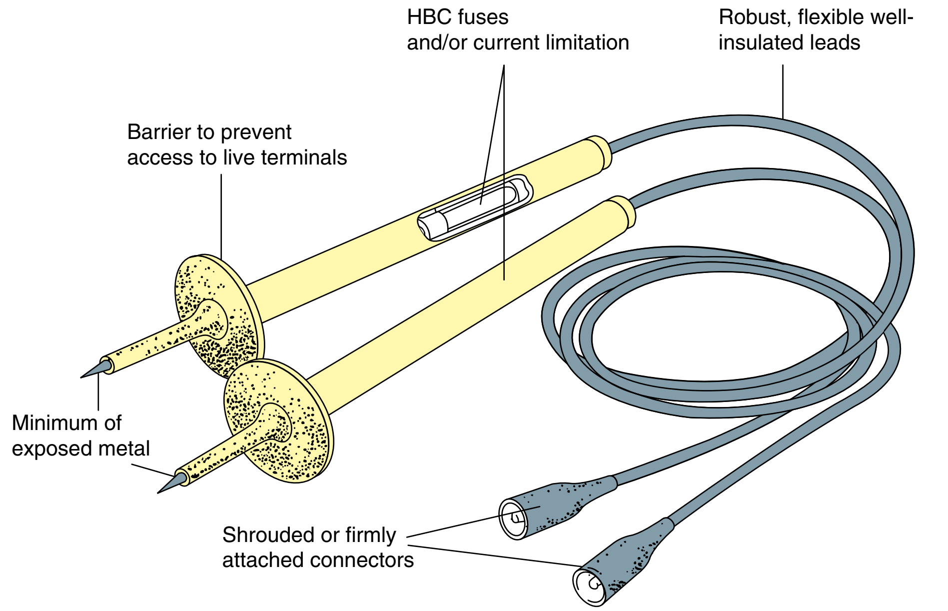

Figure 5.3 Recommended type of test probe and leads.

frequently been the cause of accidents, and therefore all test probes must now incorporate the following features:

1 The probes must have finger barriers or be shaped so that the hand or fingers cannot make contact with the live conductors under test.
2 The probe tip must not protrude more than 2 mm, and preferably only 1 mm, be spring-loaded and screened.
3 The lead must be adequately insulated and coloured so that one lead is readily distinguished from the other.
4 The lead must be flexible and sufficiently robust.
5 The lead must be long enough to serve its purpose but not too long.
6 The lead must not have accessible exposed conductors even if it becomes detached from the probe or from the instrument.
7 Where the leads are to be used in conjunction with a voltage detector they must be protected by a fuse.

A suitable probe and lead is shown in Fig. 5.3.

GS 38 also tells us that where the test is being made simply to establish the presence or absence of a voltage, the preferred method is to use a proprietary test lamp or voltage indicator which is suitable for the working voltage, rather than a multimeter. Accident history has shown that incorrectly set multimeters or makeshift devices for voltage detection have frequently caused accidents. Fig. 5.4 shows a suitable voltage indicator. Test lamps and voltage indicators are not fail-safe, and therefore GS 38 recommends that they should be regularly proved, preferably before and after use, as described in the flowchart for a safe isolation procedure shown in Fig 5.7.

Test procedures

1 The circuits must be isolated using a 'safe isolation procedure', such as that described below, before beginning to test.

Figure 5.4 Typical voltage indicator.

2 All test equipment must be 'approved' and connected to the test circuits by recommended test probes as described by the HSE Guidance Notes GS 38. The test equipment used must also be 'proved' on a known supply or by means of a proving unit such as that shown in Fig. 5.5.
3 Isolation devices must be 'secured' in the 'off' position as shown in Fig. 5.6.
4 Warning notices must be posted.
5 All relevant safety and functional tests must be completed before restoring the supply.

Live testing

The **Electricity at Work Act** tells us that it is 'preferable' that supplies be made dead before work commences (Regulation 4(3)). However, it does acknowledge that some work, such as fault-finding and testing, may require the electrical equipment to remain energized. Therefore, if the fault finding and testing can only be successfully carried out 'live', then the person carrying out the fault diagnosis must:

- be trained so that he understands the equipment and the potential hazards of working live and can, therefore, be deemed to be 'competent' to carry out the activity;
- only use approved test equipment;
- set up barriers and warning notices so that the work activity does not create a situation dangerous to others.

Definition

The *Electricity at Work Act* tells us that it is 'preferable' that supplies be made dead before work commences (IEE Regulation 4(3)).

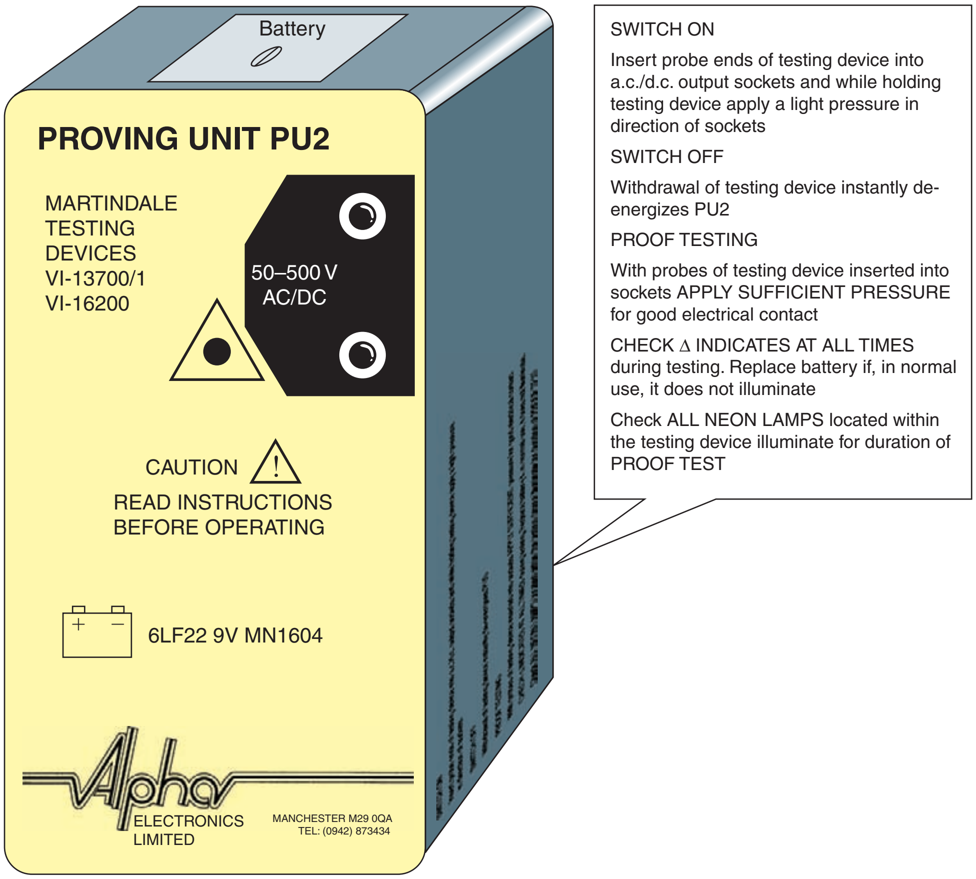

Figure 5.5 Voltage proving unit.

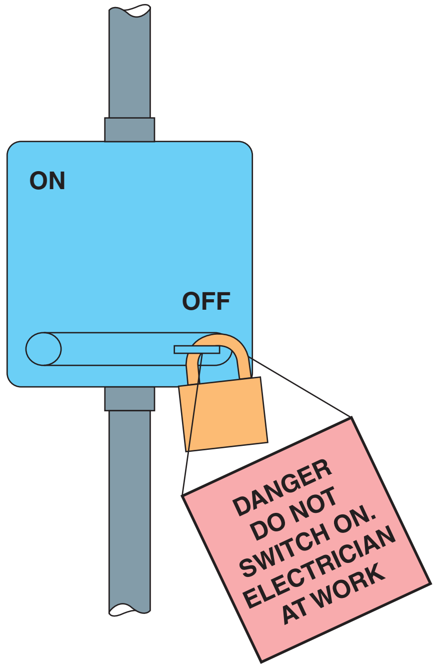

Figure 5.6 Secure isolation of a supply.

Note that while live testing may be required in order to find the fault, live repair work must not be carried out. The individual circuit or item of equipment must first be isolated.

Definition

Note that while live testing may be required in order to find the fault, live repair work must not be carried out. The individual circuit or item of equipment must first be isolated.

Isolation of supply

The Electricity at Work Regulations are very specific in describing the procedure to be used for isolation of the electrical supply. IEE Regulation 12(1) tells us that **isolation** means the disconnection and separation of the electrical equipment from every source of electrical energy in such a way that this disconnection and separation is secure. IEE Regulation 4(3) tells us that we must also prove the conductors are dead before work commences and that the test instrument used for this purpose must itself be proved immediately before and immediately after testing the conductors. To isolate an individual circuit or item of equipment successfully, competently and safely we must follow a procedure such as that given by the flow diagram in Fig. 5.7. Start at the top and work your way down the flowchart. When you get to the heavy-outlined amber boxes, pause and ask yourself whether everything is satisfactory up to this point. If the answer is yes, move on. If no, go back as indicated by the diagram.

To demonstrate that you understand this first CGLI Outcome your tutor/trainer/lecturer will assess your ability to choose appropriate PPE, complete a risk assessment and carry out a safe isolation procedure.

Definition

Isolation means the disconnection and separation of the electrical equipment from every source of electrical energy in such a way that this disconnection and separation is secure.

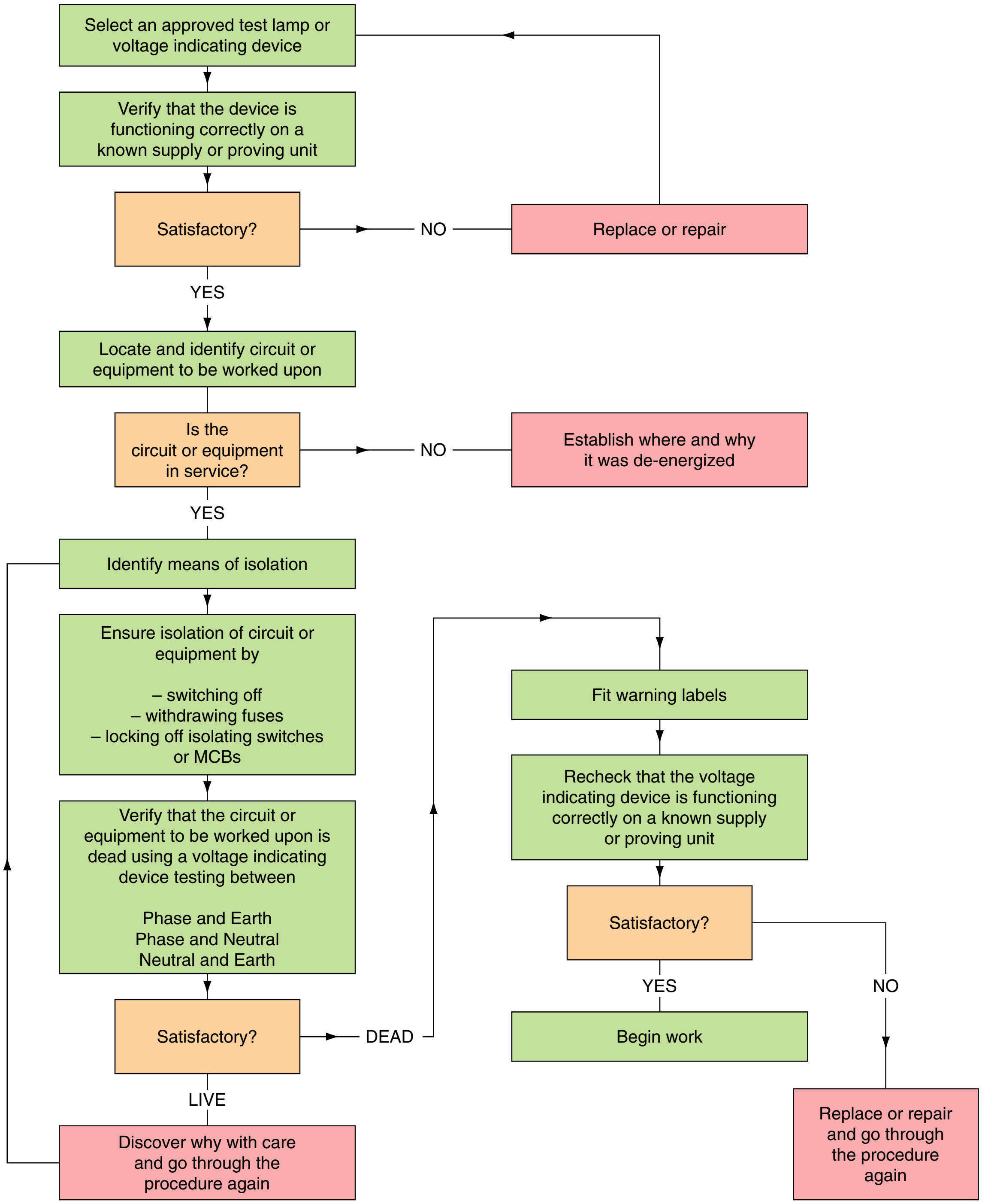

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Figure 5.7 Flowchart for a secure isolation procedure.

Definition

The entry of a cable end into an accessory, enclosure or piece of equipment is what we call a termination.

Terminating and connecting conductors (CGLI Outcome 2)

The entry of a cable end into an accessory, enclosure or piece of equipment is what we call a termination. Section 526 of the IEE Regulations tells us that:

1 every connection between conductors and equipment shall be durable, provide electrical continuity and mechanical strength and protection.

2 every termination and joint in a live conductor shall be made within a suitable accessory, piece of equipment or enclosure that complies with the appropriate product standard.
3 every connection shall be accessible for inspection, testing and maintenance.
4 the means of connection shall take account of the number and shape of the wires forming the conductor.
5 the connection shall take account of the cross-section of the conductor and the number of conductors to be connected.
6 the means of connection shall take account of the temperature attained in normal service.
7 there must be no mechanical strain on the conductor connections.

There is a wide range of suitable means of connecting conductors and we shall look at these in a moment. Whatever method is used to connect live conductors, the connection must be contained in an enclosed compartment such as an accessory, for example, a switch or socket box or a junction box. Alternatively, an equipment enclosure may be used, for example, a motor enclosure or an enclosure partly formed by non-combustible building material (IEE Regulation 526.5). This is because faulty joints and terminations in live conductors can attain very high temperatures due to the effects of resistive heating. They might also emit arcs, sparks or hot particles with the consequent risk of fire to adjacent materials.

Types of terminal connections

Junction boxes

Junction boxes are probably the most popular method of making connections in domestic properties. Brass terminals are fixed inside a bakelite container. The two important factors to consider when choosing a junction box are the number of terminals required and the current rating. Socket outlet junction boxes have larger brass terminals than lighting junction boxes.

Key fact

Junction boxes are probably the most popular method of making connections in domestic properties.

Strip connectors

Strip connectors or a chocolate block is a very common method of connecting conductors. The connectors are mounted in a moulded plastic block in strips of 10 or 12. The conductors are inserted into the block and secured with the grub-screw. In order that the conductors do not become damaged the screw connection must be firm but not overtightened. The size used should relate to the current rating of the circuit. Figure 5.8 shows a strip connector.

Key fact

Strip connectors or a chocolate block is a very common method of connecting conductors.

Pillar terminal

A pillar terminal is a brass pillar with a hole through the side into which the conductor is inserted and secured with a set-screw. If the conductor is small in relation to the hole it should be doubled back. In order that the conductor does not become damaged the screw connection should be tight but not overtightened. Figure 5.8 shows a pillar terminal.

Screwhead, nut and washer terminals

The conductor being terminated is formed into an eye as shown in Fig. 5.8. The eye should be slightly larger than the screw shank but smaller than the outside diameter of the screwhead, nut or washer. The eye should be placed on the screw shank in such a way that the rotation of the screwhead or nut will tend to close the joint in the eye.

Key fact

Screwhead and claw washer terminal connections are a good way to connect flexible cords.

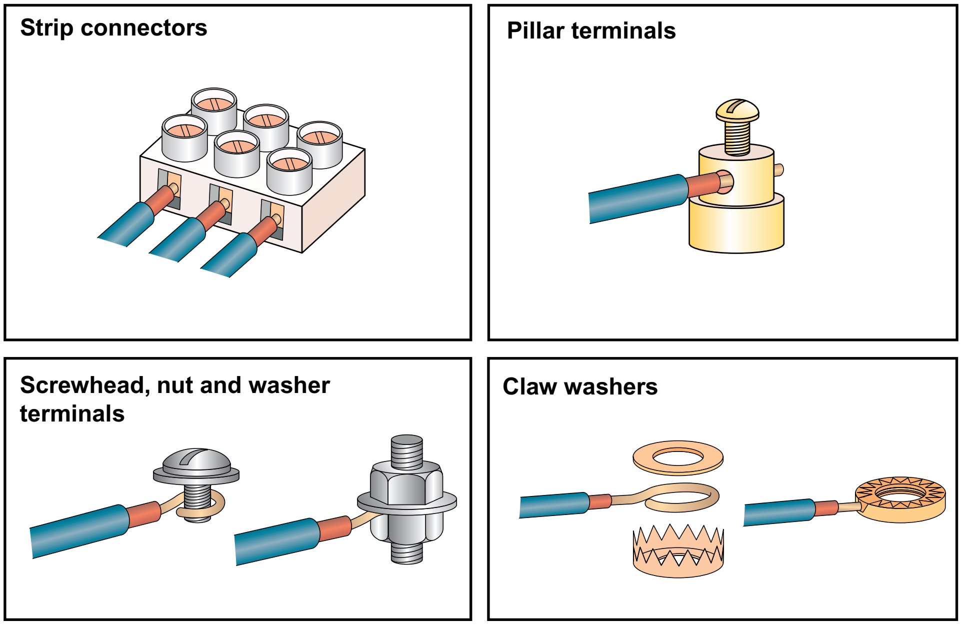

Figure 5.8 Types of terminal connections.

Claw washers

In order to avoid inappropriate separation or spreading of individual wires of multiwire, claw washers are used to obtain a good sound connection. The looped conductor is laid in the pressing as shown in Fig. 5.8, a plain washer is placed on top of the conductor and the metal points folded over the washer.

Crimp terminals

Crimp terminals are made of tinned sheet copper. The chosen crimp terminal is slipped over the end of the conductor and crimped with the special crimping tool. This type of connection is very effective for connecting equipotential bonding conductors to approved earth clamps.

Key fact

Whatever method is used to make the connection it must be both electrically and mechanically sound.

Soldered joints or compression joints

Although the soldering of large underground cables is still common today, joints up to about 100 amperes are now usually joined with a compression joint. This uses the same principle as for the crimp termination above, it is just a little larger.

Whatever method is used to make the connection is conductors the connection must be both electrically and mechanically sound if we are to avoid high resistance joints, corrosion and erosion at the point of termination.

Definition

Cables can be considered to be constructed in three parts: the *conductor* which must be of a suitable cross-section to carry the load current; the *insulation*, which has a colour or number code for identification; and the *outer sheath* which may contain some means of providing protection from mechanical damage.

Conductors and cables

Most cables can be considered to be constructed in three parts: the ***conductor*** which must be of a suitable cross-section to carry the load current; the ***insulation***, which has a colour or number code for identification; and the ***outer sheath*** which may contain some means of providing protection from mechanical damage.

The conductors of a cable are made of either copper or aluminium and may be stranded or solid. Solid conductors are only used in fixed wiring installations and may be shaped in larger cables. Stranded conductors are more flexible and

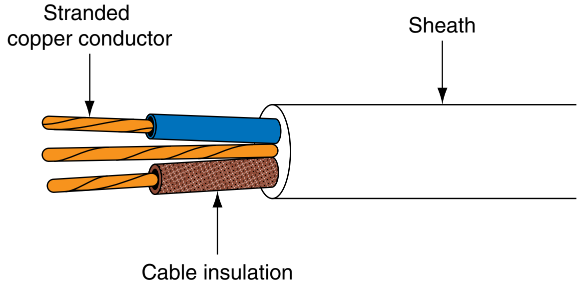

Figure 5.9 A twin and earth PVC insulated and sheathed cable.

conductor sizes from 4.0 to 25 mm^2 contain seven strands. A 10 mm^2 conductor, for example, has seven 1.35 mm diameter strands which collectively make up the 10 mm^2 cross-sectional area of the cable. Conductors above 25 mm^2 have more than seven strands, depending upon the size of the cable. Flexible cords have multiple strands of very fine wire, as fine as one strand of human hair. This gives the cable its very flexible quality.

PVC insulated and sheathed cables

Domestic and commercial installations use this cable, which may be clipped direct to a surface, sunk in plaster or installed in conduit or trunking. It is the simplest and least expensive cable. Figure 5.9 shows a sketch of a twin and earth cable.

The conductors are covered with a colour-coded PVC insulation and then contained singly or with others in a PVC outer sheath.

PVC/SWA cable

PVC insulated steel wire armour cables are used for wiring underground between buildings, for main supplies to dwellings, rising sub-mains and industrial installations. They are used where some mechanical protection of the cable conductors is required.

The conductors are covered with colour-coded PVC insulation and then contained either singly or with others in a PVC sheath (see Fig. 5.10). Around this sheath is placed an armour protection of steel wires twisted along the length of the cable, and a final PVC sheath covering the steel wires protects them from corrosion. The armour sheath also provides the circuit protective conductor (CPC) and the cable is simply terminated using a compression gland.

MI cable

A mineral insulated (MI) cable has a seamless copper sheath which makes it waterproof and fire- and corrosion-resistant. These characteristics often make it the only cable choice for hazardous or high-temperature installations such as oil refineries and chemical works, boiler houses and furnaces, petrol pump and fire alarm installations.

The cable has a small overall diameter when compared to alternative cables and may be supplied as bare copper or with a PVC oversheath. It is colour-coded orange for general electrical wiring, white for emergency lighting or red for fire alarm wiring.

Safety first

PVC cables

- PVC cables should not be installed when the surrounding temperature is below 0°C
- The PVC insulation becomes brittle at low temperatures and may be damaged during installation
- IEE Regulation 522.1.2

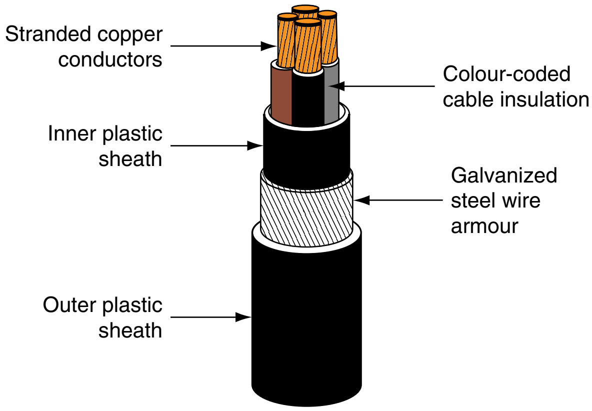

Figure 5.10 A four-core PVC/SWA cable.

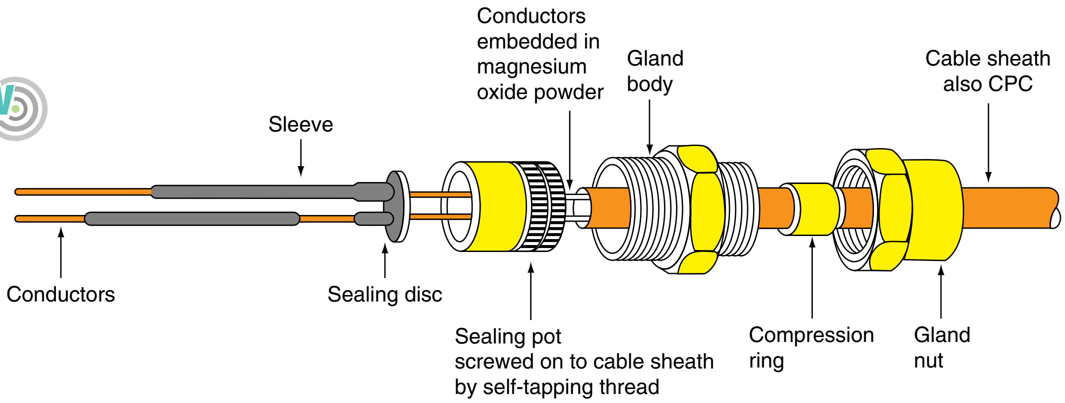

Figure 5.11 MI cable with terminating seal and gland.

The copper outer sheath provides the CPC, and the cable is terminated with a pot and sealed with compound and a compression gland (see Fig. 5.11).

The copper conductors are embedded in a white powder, magnesium oxide, which is non-ageing and non-combustible, but which is hygroscopic, which means that it readily absorbs moisture from the surrounding air, unless adequately terminated. The termination of an MI cable is a complicated process requiring the electrician to demonstrate a high level of practical skill and expertise for the termination to be successful.

FP 200 cable

FP 200 cable is similar in appearance to an MI cable in that it is a circular tube, or the shape of a pencil, and is available with a red or white sheath. However, it is much simpler to use and terminate than an MI cable.

The cable is available with either solid or stranded conductors that are insulated with 'insudite' a fire resistant insulation material. The conductors are then screened, by wrapping an aluminium tape around the insulated conductors, that is, between the insulated conductors and the outer sheath. This aluminium tape screen is applied metal side down and in contact with the bare CPC.

The sheath is circular and made of a robust thermoplastic low smoke, zero halogen material.

FP 200 is available in 2, 3, 4, 7, 12 and 19 cores with a conductor size range from 1.0 to 4.0 mm. The core colours are: two core, brown and blue, three core, brown, black and grey and four core, brown, black, grey and blue.

The cable is as easy to use as a PVC insulated and sheathed cable. No special terminations are required, the cable may be terminated through a grommet into a knock out box or terminated through a simple compression gland.

The cable is a fire resistant cable, primarily intended for use in fire alarms and emergency lighting installations or it may be embedded in plaster.

Data cables

The cable used for data transmissions and computer networks are Category 5 cables or Cat 5 cables. These are high integrity signal cables usually containing four UTP (universal twisted pair) cables within the cable jacket. New Cat5E (enhanced) cables are capable of transmission speeds up to one gigabit per second.

Optical fibre cables

The introduction of fibre-optic cable systems and digital transmissions will undoubtedly affect future cabling arrangements and the work of the electrician. Networks based on the digital technology currently being used so successfully by the telecommunications industry are very likely to become the long-term standard for computer systems. Fibre-optic systems dramatically reduce the number of cables required for control and communications systems, and this will in turn reduce the physical room required for these systems. Fibre-optic cables are also immune to electrical noise when run parallel to mains cables and, therefore, the present rules of segregation and screening may change in the future. There is no spark risk if the cable is accidentally cut and, therefore, such circuits are intrinsically safe. Intrinsic safety is described in Chapter 13 under the heading 'Hazardous area installations'.

Optical fibre cables are communication cables made from optical-quality plastic, the same material from which spectacle lenses are manufactured. The energy is transferred down the cable as digital pulses of laser light as against current flowing down a copper conductor in electrical installation terms. The light pulses stay within the fibre-optic cable because of a scientific principle known as 'total internal refraction' which means that the laser light bounces down the cable and when it strikes the outer wall it is always deflected inwards and, therefore, does not escape out of the cable, as shown in Fig. 5.12.

Definition

Optical fibre cables are communication cables made from optical-quality plastic, the same material from which spectacle lenses are manufactured. The energy is transferred down the cable as digital pulses of laser light as against current flowing down a copper conductor in electrical installation terms.

The cables are very small because the optical quality of the conductor is very high and signals can be transmitted over great distances. They are cheap to produce and lightweight because these new cables are made from high-quality plastic and not high-quality copper. Single-sheathed cables are often called 'simplex' cables and twin sheathed cables 'duplex', that is, two simplex cables together in one sheath. Multi-core cables are available containing up to 24 single fibres.

Fibre-optic cables look like steel wire armour cables (but of course are lighter) and should be installed in the same way and given the same level of protection as SWA cables. Avoid tight-radius bends if possible and kinks at all costs. Cables are terminated in special joint boxes which ensure cable ends are cleanly cut and butted together to ensure the continuity of the light pulses. Fibre-optic cables are Band I circuits when used for data transmission and must therefore be segregated from other mains cables to satisfy the IEE Regulations.

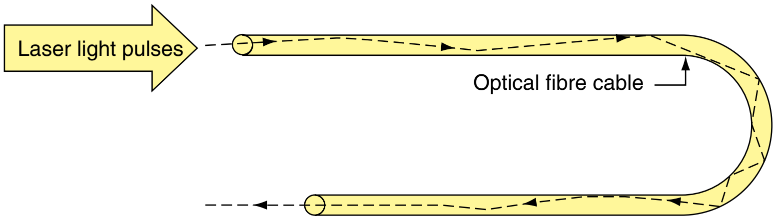

Figure 5.12 Digital pulses of laser light down an optical fibre cable.

The testing of fibre-optic cables requires that special instruments be used to measure the light attenuation (i.e. light loss) down the cable. Finally, when working with fibre-optic cables, electricians should avoid direct eye contact with the low-energy laser light transmitted down the conductors.

High-voltage power cables

The cables used for high-voltage power distribution require termination and installation expertise beyond the normal experience of a contracting electrician. The regulations covering high-voltage distribution are beyond the scope of the IEE Regulations for electrical installations. Operating at voltages in excess of 33 kV and delivering thousands of kilowatts, these cables are either suspended out of reach on pylons or buried in the ground in carefully constructed trenches.

To demonstrate that you understand this second CGLI Outcome your tutor/trainer/lecturer will assess your ability to terminate and connect conductors, cables and cords.

Identify conductors and confirm terminations are safe (CGLI Outcome 3)

New wiring colours

Twenty-eight years ago the United Kingdom agreed to adopt the European colour code for flexible cords, that is, brown for live or phase conductor, blue for the neutral conductor and green combined with yellow for earth conductors. However, no similar harmonization was proposed for non-flexible cables used for fixed wiring. These were to remain as red for live or phase conductor, black for the neutral conductor and green combined with yellow for earth conductors.

On 31 March 2004, the IEE published Amendment No. 2 to BS 7671: 2001 which specified new cable core colours for all fixed wiring in UK electrical installations. These new core colours will ‘harmonize’ the United Kingdom with the practice in mainland Europe from that date onwards.

Fixed cable core colours up to 2006

- *Single-phase* supplies red line conductors, black neutral conductors, and green combined with yellow for earth conductors.
- *Three-phase* supplies red, yellow and blue line conductors, black neutral conductors and green combined with yellow for earth conductors.

- These core colours could be used up to 31 March 2006. So there was a period of transition to the new colours from March 2004 to March 2006 so that electrical installations under construction could be completed.

New (harmonized) fixed cable core colours

- *Single-phase* supplies brown line conductors, blue neutral conductors and green combined with yellow for earth conductors.
- *Three-phase* supplies brown, black and grey line conductors, blue neutral conductors and green combined with yellow for earth conductors.
- These are the cable core colours which must be used on all new installations from 31 March 2004 onwards.

Extensions or alterations to existing *single-phase* installations do not require marking at the interface between the old and new fixed wiring colours. However, a warning notice must be fixed at the consumer unit or distribution fuse board which states:

> *Caution – this installation has wiring colours to two versions of BS 7671. Great care should be taken before undertaking extensions, alterations or repair that all conductors are correctly identified.*

Alterations to *three-phase* installations must be marked at the interface L1, L2, L3 for the lines and N for the neutral. Both new and old cables must be marked. These markings are preferred to coloured tape and a caution notice is again required at the distribution board. Appendix 7 of BS 7671: 2008 deals with harmonized cable core colours and Table 5.1 shows a comparison of the old and new colours.

Safe terminations and connections

To ensure that all electrical terminations and connections are safe, the installing electrician should give consideration to the following good practice points:

- all connections must be both electrically and mechanically secure
- all connections must be long lasting and not fail quickly
- the method of connection must take account of:
  (i) The size of conductor and, therefore, the current carrying capacity of that conductor

Table 5.1 Example of conductor marking at the interface for additions and alterations to an a.c. installation identified with the old cable colours

Function	Old conductor		New conductor	
	Colour	Marking	Marking	Colour
Phase 1 of a.c.	Red	L1	L1	Brown[1]
Phase 2 of a.c.	Yellow	L2	L2	Black[1]
Phase 3 of a.c.	Blue	L3	L3	Grey[1]
Neutral of a.c.	Black	N	N	Blue
Protective conductor	Green and yellow			Green and yellow

[1]Three single-core cables with insulation of the same colour may be used if identified at the terminations

  (ii) the material of the conductor; copper is a soft metal but aluminium is softer
  (iii) the number of conductors being connected
  (iv) the temperature to be attained at the point of connection in normal service
  (v) the provision of adequate locking arrangements in situations subject to vibration
- every connection must remain accessible for inspection and testing
- every connection in a live conductor must be made within:
  (i) a suitable accessory such as a switch, socket ceiling rose or joint box, or
  (ii) an equipment enclosure such as a luminaire, or
  (iii) a non-combustible enclosure designed for this purpose
- there must be no mechanical strain put on the conductors or connections

Section 526 of the IEE Regulations deals with electrical connections.

Disposal of waste

Having completed any work in the electrotechnical industry, we come to the final practical task, leaving the site in a safe and clean condition and the removal of any waste material. This is an important part of your company's 'good customer relationships' with the client. We also know that we have a 'duty of care' for the waste that we produce as an electrical company.

We have also said many times in this book that having a good attitude to health and safety, working conscientiously and neatly, keeping passageways clear and regularly tidying up the workplace is the sign of a good and competent craftsman. But what do you do with the rubbish that the working environment produces? Well:

- All the packaging material for electrical fittings and accessories usually goes into either your employer's skip or the skip on site designated for that purpose.
- All the off-cuts of conduit, trunking and tray also go into the skip.
- In fact, most of the general site debris will probably go into the skip and the waste disposal company will take the skip contents to a designated local council land fill area for safe disposal.
- The part coils of cable and any other reusable leftover lengths of conduit, trunking or tray will be taken back to your employer's stores area. Here it will be stored for future use and the returned quantities deducted from the costs allocated to that job.
- What goes into the skip for normal disposal into a land fill site is usually a matter of common sense. However, some substances require special consideration and disposal. We looked at asbestos and large quantities of used fluorescent tubes which are classified as 'special waste' or 'hazardous waste' in Chapter 5 of *Basic Electrical Installation Work* 6th edition.

To demonstrate that you understand this final Outcome of Unit 316 your tutor/trainer/lecturer will assess your ability to identify conductors and confirm terminations are safe.

CHAPTER 6

Inspection, testing and commissioning electrical systems

Unit 317 of the City and Guilds 2357 syllabus

Inspecting, testing, commissioning and certifying electro-technical systems and equipment in buildings, structures and the environment

When you have completed this chapter you should be able to:

1. Confirm safety checks before electrical testing begins
2. Carry out a visual inspection of an electrotechnical system
3. Test electrotechnical systems
4. Commission electrotechnical systems

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Safety checks before electrical testing begins (CGLI Outcome 1)

The electrical contractor is charged with a responsibility to carry out a number of tests on an electrical installation and electrical equipment. The individual tests are dealt with in Part 6 of the IEE Regulations and described later in this chapter.

The reasons for testing the installation are:

- to ensure that the installation complies with the regulations,
- to ensure that the installation meets the specification,
- to ensure that the installation is safe to use.

Those who are to carry out the electrical tests must first consider the following safety factors:

- An assessment of safe working practice must be made before testing begins.

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- All safety precautions must be put in place before testing begins.
- You may be required to carry out a formal risk assessment before testing begins and I will describe this process below. Alternatively an informal assessment may be all that is required. It is the process of identifying hazards and reducing risk which is important.
- Everyone must be notified that the test process is about to take place, for example the client and other workers who may be affected by the tests.
- 'permits to work' must be obtained where relevant.
- All sources of information relevant to the tests have been obtained.
- The relevant circuits and equipment have been identified.
- Safe isolation procedures have been carried out – care must be exercised here, in occupied premises, not to switch off computer systems without first obtaining permission.
- Those who are to carry out the tests are competent to do so.

Definitions

A *hazard* is something with the 'potential' to cause harm, for example, chemicals, electricity or working above ground.

A *risk* is the 'likelihood' of harm actually being done.

Definition

A *competent person* is anyone who has the necessary technical skills, training and expertise to safely carry out the particular activity.

Hazard and risk

Before I describe the hazard risk assessment process, I want to explain what we mean by the words hazard and risk.

A **hazard** is something with the 'potential' to cause harm, for example, chemicals, electricity or working above ground.

A **risk** is the 'likelihood'of harm actually being done.

Competent persons are often referred to in the Health and Safety at Work Regulations, but who is 'competent'? For the purposes of the Act, a competent person is anyone who has the necessary technical skills, training and expertise to safely carry out the particular activity. Therefore, a **competent person** dealing with a hazardous situation reduces the risk.

Think about your workplace and at each stage of what you do, think about what might go wrong. Some simple activities may be hazardous. Here are some typical activities where accidents might happen.

Typical activity	Potential hazard
Receiving materials	Lifting and carrying
Stacking and storing	Falling materials
Movement of people	Slips, trips and falls
Building maintenance	Working at heights or in confined spaces
Movement of vehicles	Collisions

How high are the risks? Think about what might be the worst result, is it a broken finger or someone suffering permanent lung damage or being killed? How likely is it to happen? How often is that type of work carried out and how close do people get to the hazard? How likely is it that something will go wrong?

How many people might be injured if things go wrong? Might this also include people who do not work for your company?

Employers of more than five people must document the risks at work and the process is known as hazard risk assessment.

Hazard risk assessment – the process

The Management of Health and Safety at Work Regulations 1999 tell us that employers must systematically examine the workplace, the work activity and the management of safety in the establishment through a process of risk assessments. A record of all significant risk assessment findings must be kept in a safe place and be made available to an HSE Inspector if required. Information based on the risk assessment findings must be communicated to relevant staff and if changes in work behaviour patterns are recommended in the interests of safety, then they must be put in place.

So risk assessment must form a part of any employer's robust policy of health and safety. However, an employer only needs to 'formally' assess the significant risks. He is not expected to assess the trivial and minor types of household risks. Staff are expected to read and to act upon these formal risk assessments and they are unlikely to do so enthusiastically if the file is full of trivia. An assessment of risk is nothing more than a careful examination of what, in your work, could cause harm to people. It is a record that shows whether sufficient precautions have been taken to prevent harm.

The HSE recommends five steps to any risk assessment.

Step 1

Look at what might reasonably be expected to cause harm. Ignore the trivial and concentrate only on significant hazards that could result in serious harm or injury. Manufacturers' data sheets or instructions can also help you spot hazards and put risks in their true perspective.

Step 2

Decide who might be harmed and how. Think about people who might not be in the workplace all the time – cleaners, visitors, contractors or maintenance personnel. Include members of the public or people who share the workplace. Is there a chance that they could be injured by activities taking place in the workplace?

Step 3

Evaluate what is the risk arising from an identified hazard. Is it adequately controlled or should more be done? Even after precautions have been put in place, some risk may remain. What you have to decide, for each significant hazard, is whether this remaining risk is low, medium or high. First of all, ask yourself if you have done all the things that the law says you have got to do. For example, there are legal requirements on the prevention of access to dangerous machinery. Then ask yourself whether generally accepted industry standards are in place, but do not stop there – think for yourself, because the law also says that you must do what is reasonably practicable to keep the workplace safe. Your real aim is to make all risks small by adding precautions, if necessary.

If you find that something needs to be done, ask yourself:

1 Can I get rid of this hazard altogether?
2 If not, how can I control the risk so that harm is unlikely?

Only use PPE when there is nothing else that you can reasonably do.

If the work that you do varies a lot, or if there is movement between one site and another, select those hazards which you can reasonably foresee, the ones that apply to most jobs and assess the risks for them. After that, if you spot any unusual hazards when you get on site, take what action seems necessary.

Step 4

Record your findings and say what you are going to do about risks that are not adequately controlled. If there are fewer than five employees you do not need

HAZARD RISK ASSESSMENT	FLASH-BANG ELECTRICAL CO.
For Company name or site: .... Address:	Assessment undertaken by: .... Signed: .... Date: ....
STEP 5 Assessment review date:	
STEP 1 List the hazards here	STEP 2 Decide who might be harmed ....
STEP 3 Evaluate (what is) the risk – is it adequately controlled? State risk level as low, medium or high	STEP 4 Further action – what else is required to control any risk identified as medium or high? ....

Figure 6.1 Hazard risk assessment standard form.

to write anything down but if there are five or more employees, the significant findings of the risk assessment must be recorded. This means writing down the more significant hazards and assessing if they are adequately controlled and recording your most important conclusions. Most employers have a standard risk assessment form which they use such as that shown in Fig. 6.1 but any format is suitable. The important thing is to make a record.

There is no need to show how the assessment was made, providing you can show that:

1. a proper check was made,
2. you asked those who might be affected,
3. you dealt with all obvious and significant hazards,
4. the precautions are reasonable and the remaining risk is low,
5. you informed your employees about your findings.

Risk assessments need to be *suitable* and *sufficient*, not perfect. The two main points are:

1. Are the precautions reasonable?
2. Is there a record to show that a proper check was made?

File away the written assessment in a dedicated file for future reference or use. It can help if an HSE inspector questions the company's precautions or if the company becomes involved in any legal action. It shows that the company has done what the law requires.

Step 5

Review the assessments from time to time and revise them if necessary.

Completing a risk assessment

When completing a risk assessment such as that shown in Fig. 6.1, do not be over complicated. In most firms in the commercial, service and light industrial sector, the hazards are few and simple. Checking them is common sense but necessary.

Step 1

List only hazards which you could reasonably expect to result in significant harm under the conditions prevailing in your workplace. Use the following examples as a guide:

- Slipping or tripping hazards (e.g. from poorly maintained or partly installed floors and stairs).
- Fire (e.g. from flammable materials you might be using, such as solvents).
- Chemicals (e.g. from battery acid).
- Moving parts of machinery (e.g. blades).
- Rotating parts of handtools (e.g. drills).
- Accidental discharge of cartridge operated tools.
- High pressure air from airlines (e.g. air powered tools).
- Pressure systems (e.g. steam boilers).
- Vehicles (e.g. fork lift trucks).
- Electricity (e.g. faulty tools and equipment).
- Dust (e.g. from grinding operations or thermal insulation).
- Fumes (e.g. from welding).
- Manual handling (e.g. lifting, moving or supporting loads).
- Noise levels too high (e.g. machinery).
- Poor lighting levels (e.g. working in temporary or enclosed spaces).
- Low temperatures (e.g. working outdoors or in refrigeration plants).
- High temperatures (e.g. working in boiler rooms or furnaces).

Step 2

Decide who might be harmed, do not list individuals by name. Just think about groups of people doing similar work or who might be affected by your work:

- Office staff
- Electricians
- Maintenance personnel
- Other contractors on site
- Operators of equipment
- Cleaners
- Members of the public.

Pay particular attention to those who may be more vulnerable, such as:

- staff with disabilities,
- visitors,
- young or inexperienced staff,
- people working in isolation or enclosed spaces.

Step 3

Calculate what is the risk – is it adequately controlled? Have you already taken precautions to protect against the hazards which you have listed in Step 1? For example:

- Have you provided adequate information to staff?
- Have you provided training or instruction?

Do the precautions already taken

- meet the legal standards required?
- comply with recognized industrial practice?
- represent good practice?
- reduce the risk as far as is reasonably practicable?

If you can answer 'yes' to the above points then the risks are adequately controlled, but you need to state the precautions you have put in place. You can refer to company procedures, company rules, company practices, etc., in giving this information. For example, if we consider there might be a risk of electric shock from using electrical power tools, then the risk of a shock will be *less* if the company policy is to PAT test all power tools each year and to fit a label to the tool showing that it has been tested for electrical safety. If the stated company procedure is to use battery drills whenever possible, or 110 V drills when this is not possible, and *never* to use 230 V drills, then this again will reduce the risk. If a policy such as this is written down in the company safety policy statement, then you can simply refer to the appropriate section of the safety policy statement and the level of risk will be low.

Step 4

Further action – what more could be done to reduce those risks which were found to be inadequately controlled?

You will need to give priority to those risks that affect large numbers of people or which could result in serious harm. Senior managers should apply the principles below when taking action, if possible in the following order:

1. Remove the risk completely.
2. Try a less risky option.

3 Prevent access to the hazard (e.g. by guarding).
4 Organize work differently in order to reduce exposure to the hazard.
5 Issue PPE.
6 Provide welfare facilities (e.g. washing facilities for removal of contamination and first aid).

Any hazard identified by a risk assessment as *high risk* must be brought to the attention of the person responsible for health and safety within the company. Ideally, in Step 4 of the risk assessment you should be writing, 'No further action is required. The risks are under control and identified as low risk'.

The assessor may use as many standard hazard risk assessment forms, such as that shown in Fig. 6.1, as the assessment requires. Upon completion they should be stapled together or placed in a plastic wallet and stored in the dedicated file.

Test equipment and safe isolation procedures

The Health and Safety Executive (HSE) has published Guidance Notes (GS 38) which advise electricians and other electrically competent people on the selection of suitable test probes, voltage indicating devices and measuring instruments. This is because they consider suitably constructed test equipment to be as vital for personal safety as the training and practical skills of the electrician. In the past, unsatisfactory test probes and voltage indicators have frequently been the cause of accidents, and therefore all test probes must now incorporate the following features:

1 The probes must have finger barriers or be shaped so that the hand or fingers cannot make contact with the live conductors under test.
2 The probe tip must not protrude more than 2 mm, and preferably only 1 mm, be spring-loaded and screened.
3 The lead must be adequately insulated and coloured so that one lead is readily distinguished from the other.
4 The lead must be flexible and sufficiently robust.
5 The lead must be long enough to serve its purpose but not too long.
6 The lead must not have accessible exposed conductors even if it becomes detached from the probe or from the instrument.
7 Where the leads are to be used in conjunction with a voltage detector they must be protected by a fuse.

A suitable probe and lead is shown in Fig. 6.2.

GS 38 also tells us that where the test is being made simply to establish the presence or absence of a voltage, the preferred method is to use a proprietary test lamp or voltage indicator which is suitable for the working voltage, rather than a multimeter. Accident history has shown that incorrectly set multimeters or makeshift devices for voltage detection have frequently caused accidents. Figure 6.3 shows a suitable voltage indicator. Test lamps and voltage indicators are not fail-safe, and therefore GS 38 recommends that they should be regularly proved, preferably before and after use, as described in the flowchart for a safe isolation procedure shown in Fig. 6.6.

Test procedures

1 The circuits must be isolated using a 'safe isolation procedure', such as that described below, before beginning to test.

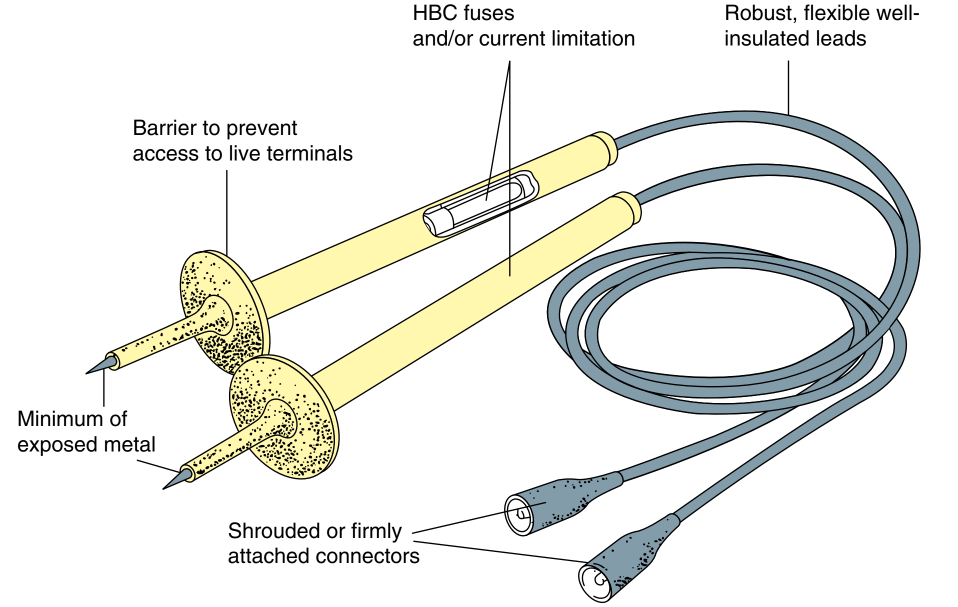

Figure 6.2 Recommended type of test probe and leads.

Figure 6.3 Typical voltage indicator.

2 All test equipment must be 'approved' and connected to the test circuits by recommended test probes as described by the HSE Guidance Notes GS 38. The test equipment used must also be 'proved' on a known supply or by means of a proving unit such as that shown in Fig. 6.4.
3 Isolation devices must be 'secured' in the 'off' position as shown in Fig. 6.5.
4 Warning notices must be posted.

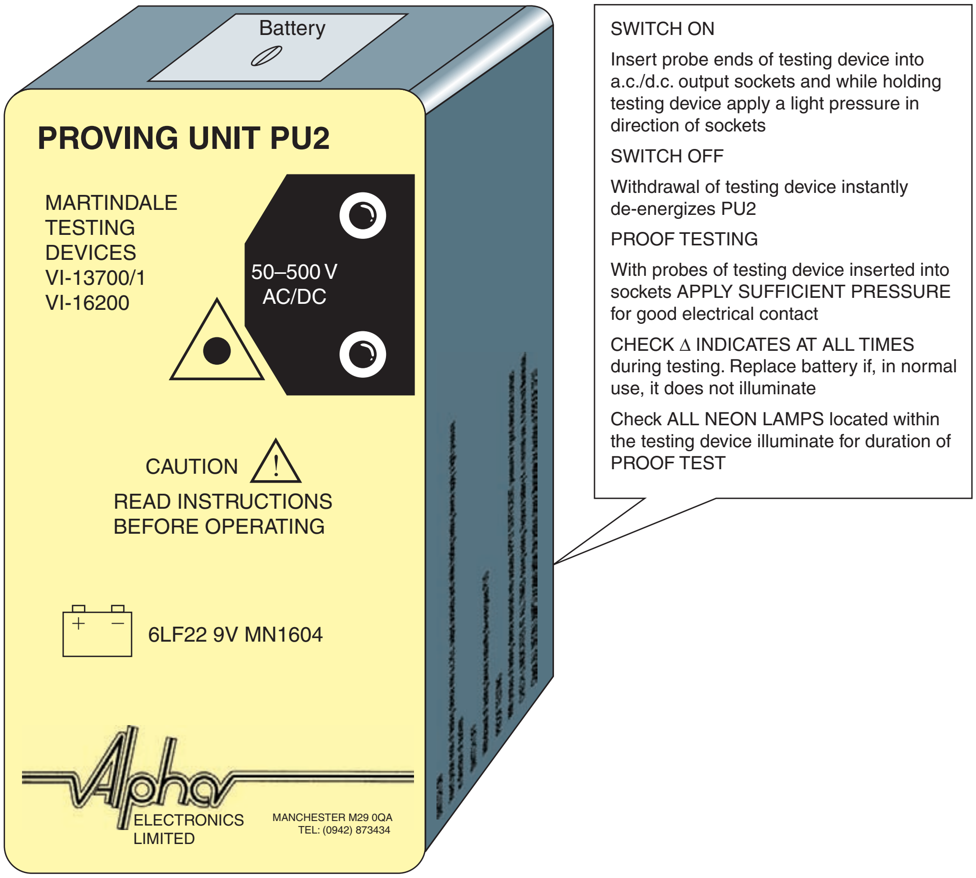

Figure 6.4 Voltage proving unit.

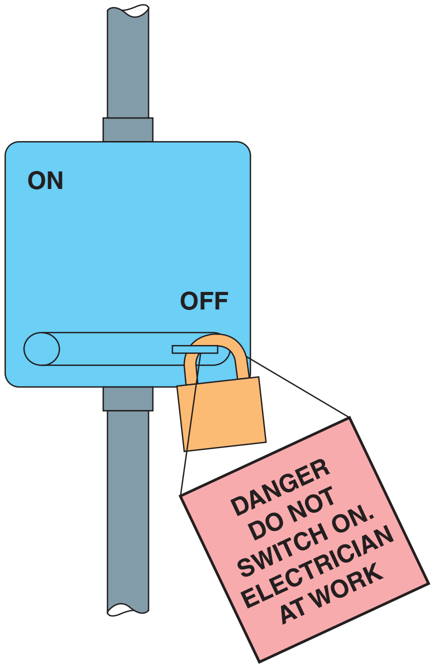

Figure 6.5 Secure isolation of a supply.

5 All relevant safety and functional tests must be completed before restoring the supply.

Live testing

The **Electricity at Work Act** tells us that it is 'preferable' that supplies be made dead before work commences (IEE Regulation 4(3)). However, it does acknowledge that some work, such as fault-finding and testing, may require the electrical equipment to remain energized. Therefore, if the fault finding and testing can only be successfully carried out 'live', then the person carrying out the fault diagnosis must:

- be trained so that he understands the equipment and the potential hazards of working live and can, therefore, be deemed to be 'competent' to carry out the activity;
- only use approved test equipment;
- set up barriers and warning notices so that the work activity does not create a situation dangerous to others.

Note that while live testing may be required in order to find the fault, live repair work must not be carried out. The individual circuit or item of equipment must first be isolated.

Definition

The *Electricity at Work Act* tells us that it is 'preferable' that supplies be made dead before work commences (IEE Regulation 4(3)).

Definition

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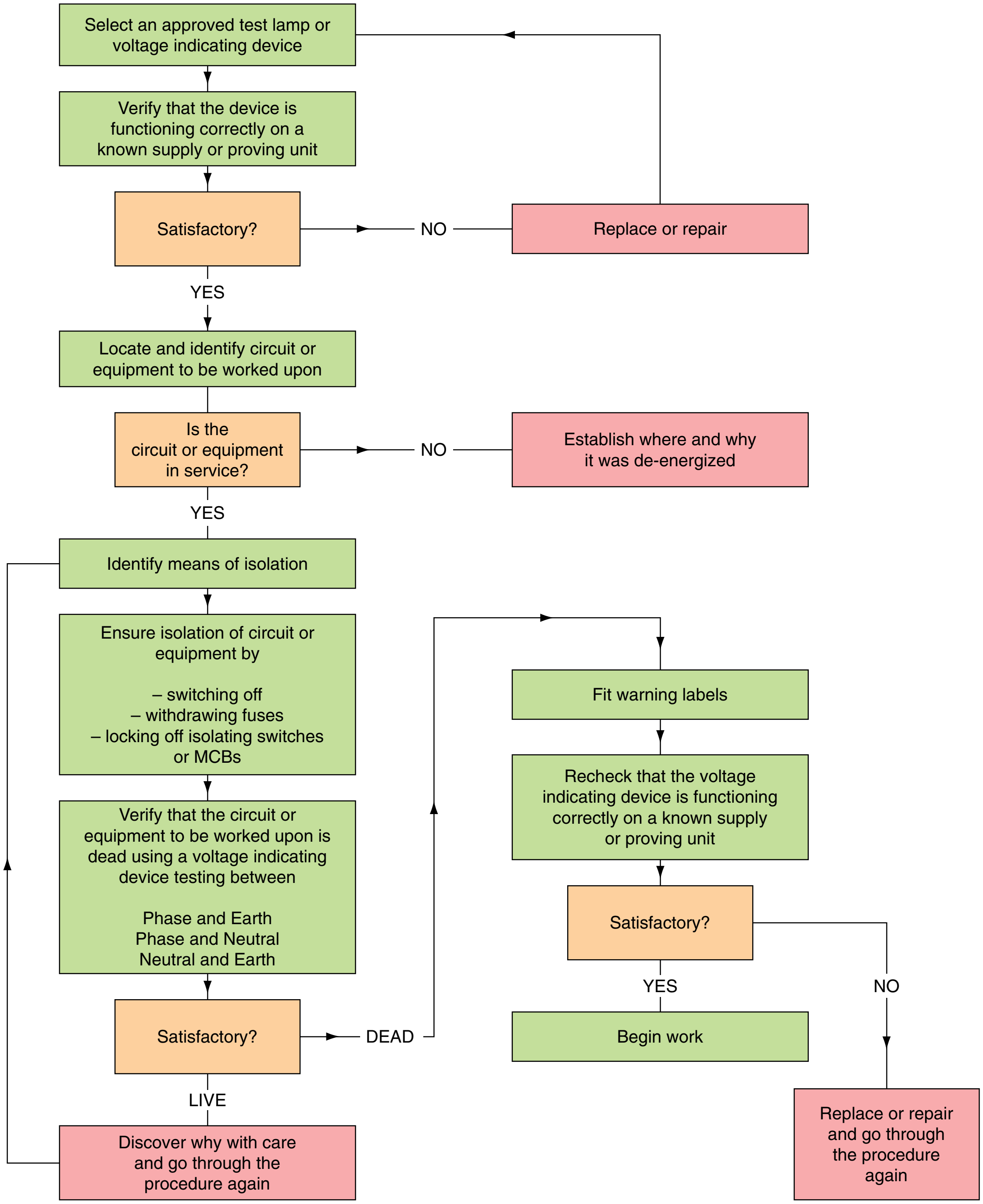

Figure 6.6 Flowchart for a secure isolation procedure.

Definition

Isolation means the disconnection and separation of the electrical equipment from every source of electrical energy in such a way that this disconnection and separation is secure.

Isolation of supply

The Electricity at Work Regulations are very specific in describing the procedure to be used for isolation of the electrical supply. IEE Regulation 12(1) tells us that **isolation** means the disconnection and separation of the electrical equipment from every source of electrical energy in such a way that this disconnection and separation is secure. IEE Regulation 4(3) tells us that we must also prove the conductor's dead before work commences and that the test instrument used for this purpose must itself be proved immediately before and immediately after testing the conductors. To isolate an individual circuit or item of equipment successfully, competently and safely we must follow a procedure such as that given by the flow diagram in Fig. 6.6. Start at the top and work your way down the flowchart. When you get to the heavy-outlined amber boxes, pause and ask yourself whether everything is satisfactory up to this point. If the answer is yes, move on. If no, go back as indicated by the diagram.

To demonstrate that you understand this first CGLI Outcome your tutor/trainer/lecturer will assess your ability to carry out safety checks and a safe isolation procedure before electrical testing begins.

Carry out a visual inspection of an electrotechnical system (CGLI Outcome 2)

Inspection and testing techniques

The testing of an installation implies the use of instruments to obtain readings. However, a test is unlikely to identify a cracked socket outlet, a chipped or loose switch plate, or a missing conduit-box lid or saddle, so it is also necessary to make a visual inspection of the installation.

All new installations must be inspected and tested during erection and upon completion before being put into service. All existing installations should be periodically inspected and tested to ensure that they are safe and meet the regulations of the IEE (Regulations 610–634).

The method used to test an installation may inject a current into the system. This current must not cause danger to any person or equipment in contact with the installation, even if the circuit being tested is faulty. The test results must be compared with any relevant data, including the IEE Regulation tables, and the test procedures must be followed carefully and in the correct sequence, as indicated by IEE Regulation 612.1. This ensures that the protective conductors are correctly connected and secure before the circuit is energized.

Visual inspection

The installation must be visually inspected before testing begins. The aim of the **visual inspection** is to confirm that all equipment and accessories are undamaged and comply with the relevant British and European Standards, and also that the installation has been securely and correctly erected. IEE Regulation 611.3 gives a checklist for the initial visual inspection of an installation, including:

- connection of conductors;
- identification of conductors;
- routeing of cables in safe zones;
- selection of conductors for current carrying capacity and volt drop;
- connection of single-pole devices for protection or switching in-phase conductors only;
- correct connection of socket outlets, lampholders, accessories and equipment;
- presence of fire barriers, suitable seals and protection against thermal effects;
- methods of 'basic protection' against electric shock, including the insulation of live parts and placement of live parts out of reach by fitting appropriate barriers and enclosures;

Definition

The aim of the *visual inspection* is to confirm that all equipment and accessories are undamaged and comply with the relevant British and European Standards, and also that the installation has been securely and correctly erected.

- methods of 'fault protection' against electric shock including the presence of earthing conductors for both protective bonding and supplementary bonding.
- prevention of detrimental influences (e.g. corrosion);
- presence of appropriate devices for isolation and switching;
- presence of undervoltage protection devices;
- choice and setting of protective devices;
- labelling of circuits, fuses, switches and terminals;
- selection of equipment and protective measures appropriate to external influences;
- adequate access to switchgear and equipment;
- presence of danger notices and other warning notices;
- presence of diagrams, instructions and similar information;
- appropriate erection method.

The checklist is a guide, it is not exhaustive or detailed, and should be used to identify relevant items for inspection, which can then be expanded upon. For example, the first item on the checklist, connection of conductors, might be further expanded to include the following:

- Are connections secure?
- Are connections correct (conductor identification)?
- Is the cable adequately supported so that no strain is placed on the connections?
- Does the outer sheath enter the accessory?
- Is the insulation undamaged?
- Does the insulation proceed up to but not *into* the connection?

This is repeated for each appropriate item on the checklist.

Those tests which are relevant to the installation must then be carried out in the sequence given in IEE Regulation 612.1 for reasons of safety and accuracy. These tests are described in the next Outcome of this chapter.

To demonstrate that you understand this second CGLI Outcome your tutor/trainer/lecturer will assess your ability to carry out a visual inspection of an electrotechnical system.

Testing electrotechnical systems (CGLI Outcome 3)

Those tests which are relevant to the installation must be carried out in the sequence given in IEE Regulation 612.1 and the *On Site Guide* for reasons of safety and accuracy. These tests are as follows:

Before the supply is connected

1. Test for continuity of protective conductors, including protective equipotential and supplementary bonding.
2. Test the continuity of all ring final circuit conductors.
3. Test for insulation resistance.
4. Test for polarity using the continuity method.
5. Test the earth electrode resistance.

With the supply connected

6. Recheck polarity using a voltmeter or approved test lamp.
7. Test the earth fault loop impedance.

8 Carry out functional testing (e.g. operation of RCDs).

If any test fails to comply with the regulations, then *all* the preceding tests must be repeated after the fault has been rectified. This is because the earlier test results may have been influenced by the fault (IEE Regulation 612.1).

There is an increased use of electronic devices in electrical installation work, for example, in dimmer switches and ignitor circuits of discharge lamps. These devices should temporarily be disconnected so that they are not damaged by the test voltage of, for example, the insulation resistance test (IEE Regulation 612.3).

Approved test instruments

The **test instruments** and **test leads** used by the electrician for testing an electrical installation must meet all the requirements of the relevant regulations. The Health and Safety Executive has published Guidance Notes GS 38 for test equipment used by electricians. The IEE Regulations (BS 7671) also specify the test voltage or current required to carry out particular tests satisfactorily. All test equipment must be chosen in accordance with the relevant parts of BS EN 61557. *All testing must, therefore, be carried out using an 'approved' test instrument if the test results are to be valid. The test instrument must also carry a calibration certificate, otherwise the recorded results may be void.* **Calibration certificates** usually last for a year. Test instruments must, therefore, be tested and recalibrated each year by an approved supplier. This will maintain the accuracy of the instrument to an acceptable level, usually within 2% of the true value.

Modern digital test instruments are reasonably robust, but to maintain them in good working order they must be treated with care. An approved test instrument costs equally as much as a good-quality camera; it should, therefore, receive the same care and consideration.

Let us look at the requirements of four often used test meters.

Continuity tester

To measure accurately the resistance of the conductors in an electrical installation we must use an instrument which is capable of producing an open circuit voltage of between 4 and 24 V a.c. or d.c., and deliver a short-circuit current of not less than 200 mA (IEE Regulation 612.2.1). The functions of continuity testing and insulation resistance testing are usually combined in one test instrument.

Insulation resistance tester

The test instrument must be capable of detecting insulation leakage between live conductors and between live conductors and earth. To do this and comply with IEE Regulation 612.3 the test instrument must be capable of producing a test voltage of 250 V, 500 V or 1000 V and deliver an output current of not less than 1 mA at its normal voltage.

Earth fault loop impedance tester

The test instrument must be capable of delivering fault currents as high as 25 A for up to 40 ms using the supply voltage. During the test, the instrument does an Ohm's law calculation and displays the test result as a resistance reading.

RCD Tester

Where circuits are protected by an RCD we must carry out a test to ensure that the device will operate very quickly under fault conditions and within the time limits set by the IEE Regulations. The instrument must, therefore, simulate a fault and measure

Definition

The *test instruments* and *test leads* used by the electrician for testing an electrical installation must meet all the requirements of the relevant regulations.

Definition

Calibration certificates usually last for a year. Test instruments must, therefore, be tested and recalibrated each year by an approved supplier.

Key fact

Testing

- A new installation must be inspected and tested during erection and upon completion
- All existing installations must be inspected and tested periodically
- IEE Regulations 610–634

Safety first

Live working

- NEVER work LIVE
- Some 'live testing' is allowed by 'competent persons'
- Otherwise, isolate and secure the isolation
- Prove the supply dead before starting work

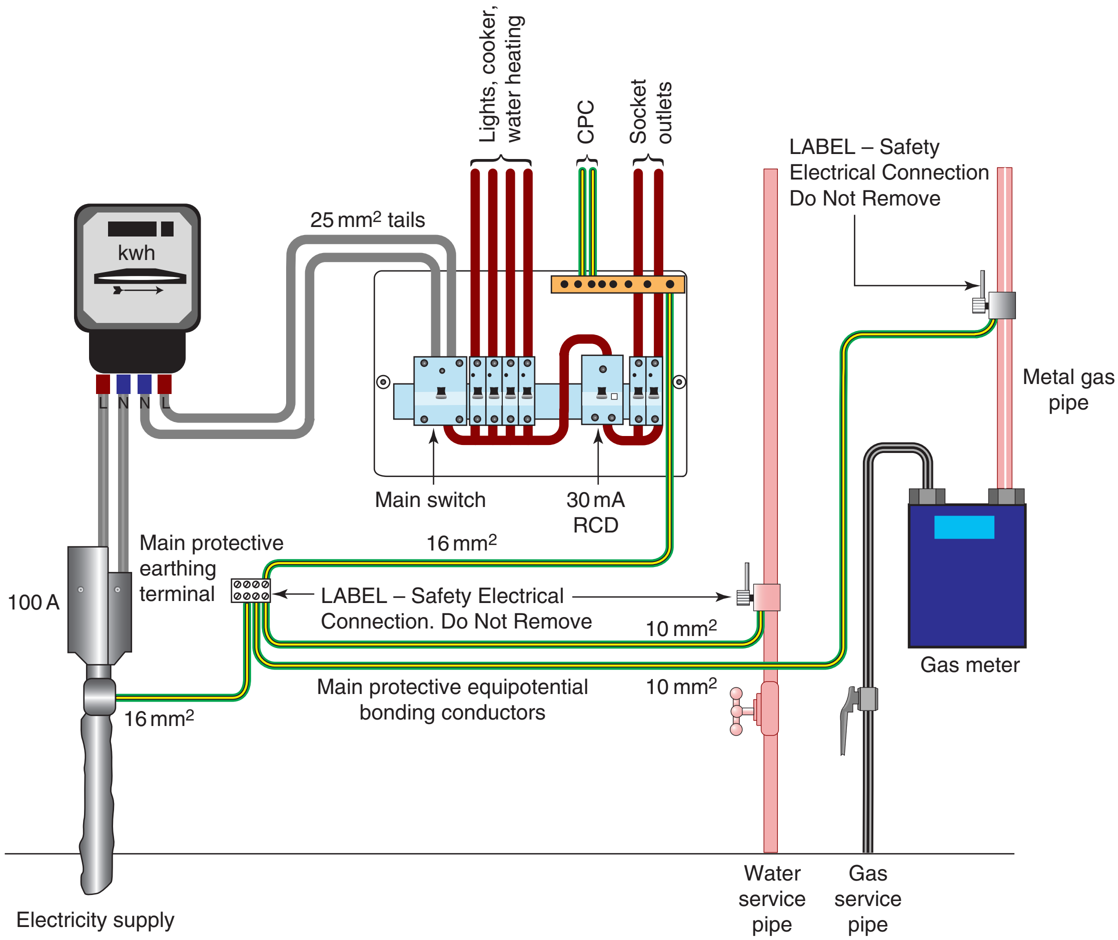

Figure 6.7 Cable sheath earth supply (TN-S system) showing earthing and main protective equipotential bonding arrangements.

Definition

A 'competent person' is someone who has the necessary technical skills, training and expertise to safely carry out a particular activity.

the time taken for the RCD to operate. The instrument is, therefore, calibrated to give a reading measured in milliseconds to an in-service accuracy of 10%.

If you purchase good-quality 'approved' test instruments and leads from specialist manufacturers they will meet all the regulations and standards and therefore give valid test results. However, to carry out all the tests required by the IEE Regulations will require a number of test instruments and this will represent a major capital investment in the region of £1000.

Let us now consider the individual tests.

1 Testing the continuity of protective conductors (612.2.1) including main and supplementary equipotential bonding

The object of the test is to ensure that the CPC is correctly connected, is electrically sound and has a total resistance which is low enough to permit the overcurrent protective device to operate within the disconnection time requirements of IEE Regulation 411.4.6, should an earth fault occur. Every protective conductor must be separately tested from the consumer's main protective earthing terminal to verify that it is electrically sound and correctly connected, including the protective equipotential bonding conductors and supplementary bonding conductors as shown in Fig. 6.7.

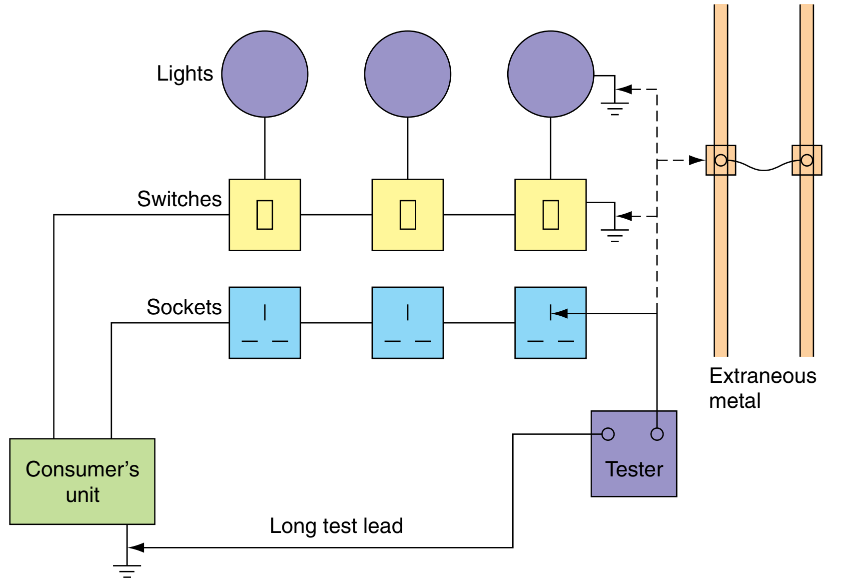

Figure 6.8 Testing continuity of protective conductors.

A d.c. test using an ohmmeter continuity tester is suitable where the protective conductors are of copper or aluminium up to 35 mm^2. The test is made with the supply disconnected, measuring from the consumer's main protective earthing terminal to the far end of each CPC, as shown in Fig. 6.8. The resistance of the long test lead is subtracted from these readings to give the resistance value of the CPC. The result is recorded on an installation schedule such as that given in Appendix 6 of the IEE Regulations.

A satisfactory test result for the bonding conductors will be in the order of 0.05 Ω or less (IEE Guidance Note 3).

Where steel conduit or trunking forms the protective conductor, the standard test described above may be used, but additionally the enclosure must be visually checked along its length to verify the integrity of all the joints.

If the inspecting engineer has grounds to question the soundness and quality of these joints then the phase–earth loop impedance test described later in this chapter should be carried out.

If, after carrying out this further test, the inspecting engineer still questions the quality and soundness of the protective conductor formed by the metallic conduit or trunking then a further test can be done using an a.c. voltage not greater than 50 V at the frequency of the installation and a current approaching 1.5 times the design current of the circuit, but not greater than 25 A.

This test can be done using a low-voltage transformer and suitably connected ammeters and voltmeters, but a number of commercial instruments are available such as the Clare tester, which give a direct reading in ohms.

Because fault currents will flow around the earth fault loop path, the measured resistance values must be low enough to allow the overcurrent protective device to operate quickly. For a satisfactory test result, the resistance of the protective conductor should be consistent with those values calculated for a line conductor of similar length and cross-sectional area. Values of resistance per metre for copper and aluminium conductors are shown in Table 6.1. The resistances of some other metallic containers are given in Table 6.2.

Table 6.1 This shows resistance values per metre. Adapted from the IEE *On Site Guide* by kind permission of the Institution of Electrical Engineers

Cross-sectional area (mm^2)		Resistance/metre or ($R_1 + R_2$)/metre (mΩ/m)	
Phase conductor	**Protective conductor**	**Copper**	**Aluminium**
1	—	18.10	
1	1	36.20	
1.5	—	12.10	
1.5	1	30.20	
1.5	1.5	24.20	
2.5	—	7.41	
2.5	1	25.51	
2.5	1.5	19.51	
2.5	2.5	14.82	
4	—	4.61	
4	1.5	16.71	
4	2.5	12.02	
4	4	9.22	
6	—	3.08	
6	2.5	10.49	
6	4	7.69	
6	6	6.16	
10	—	1.83	
10	4	6.44	
10	6	4.91	
10	10	3.66	
16	—	1.15	1.91
16	6	4.23	—
16	10	2.98	—
16	16	2.30	3.82
25	—	0.727	1.20
25	10	2.557	—
25	16	1.877	—
25	25	1.454	2.40
35	—	0.524	0.87
35	16	1.674	2.78
35	25	1.251	2.07
35	35	1.048	1.74
50	—	0.387	0.64
50	25	1.114	1.84
50	35	0.911	1.51
50	50	0.774	1.28

Table 6.2 Resistance values of some metallic containers

Metallic sheath	Size (mm)	Resistance at 20°C (mΩ/m)
Conduit	20 25 32	1.25 1.14 0.85
Trunking	50 × 50 75 × 75 100 × 100	0.949 0.526 0.337

Example

The CPC for a ring final circuit is formed by a 1.5 mm^2 copper conductor of 50 m approximate length. Determine a satisfactory continuity test value for the CPC using the value given in Table 6.1.

$$\text{Resistance/metre for a } 1.5\,\text{mm}^2 \text{ copper conductor} = 12.10\,\text{m}\Omega/\text{m}$$

$$\text{Therefore, the resistance of } 50\,\text{m} = 50 \times 12.10 \times 10^{-3}$$

$$= 0.605\,\Omega$$

The protective conductor resistance values calculated by this method can only be an approximation since the length of the CPC can only be estimated. Therefore, in this case, a satisfactory test result would be obtained if the resistance of the protective conductor was about 0.6 Ω. A more precise result is indicated by the earth fault loop impedance test which is carried out later in the sequence of tests.

2 Testing for continuity of ring final circuit conductors (612.2.2)

The object of the test is to ensure that all ring circuit cables are continuous around the ring, that is, that there are no breaks and no interconnections in the ring, and that all connections are electrically and mechanically sound. This test also verifies the polarity of each socket outlet.

The test is made with the supply disconnected, using an ohmmeter as follows.

Disconnect and separate the conductors of both legs of the ring at the main fuse. There are three steps to this test:

Step 1

Measure the resistance of the line conductors (L_1 and L_2), the neutral conductors (N_1 and N_2) and the protective conductors (E_1 and E_2) at the mains position as shown in Fig. 6.9. End-to-end live and neutral conductor readings should be approximately the same (i.e. within 0.05 Ω) if the ring is continuous. The protective conductor reading will be 1.67 times as great as these readings if 2.5/1.5 mm cable is used. Record the results on a table such as that shown in Table 6.3.

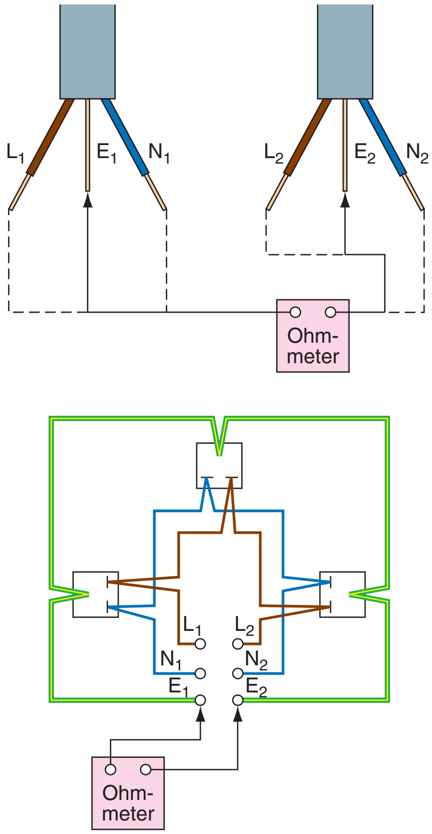

Figure 6.9 Step 1 test: measuring the resistance of phase, neutral and protective conductors.

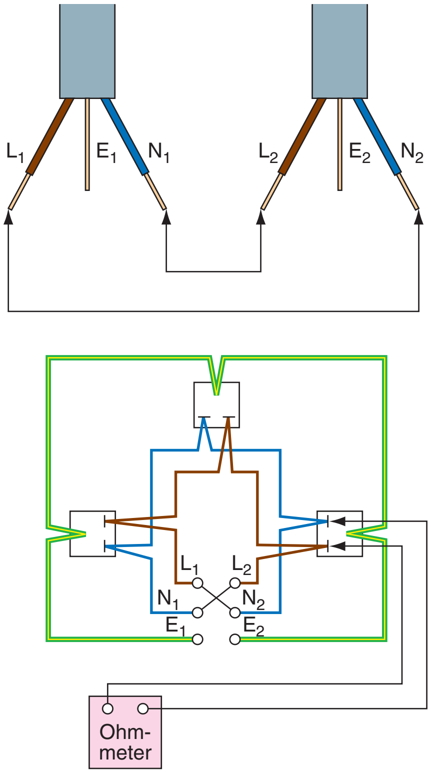

Figure 6.10 Step 2 test: connection of mains conductors and test circuit conditions.

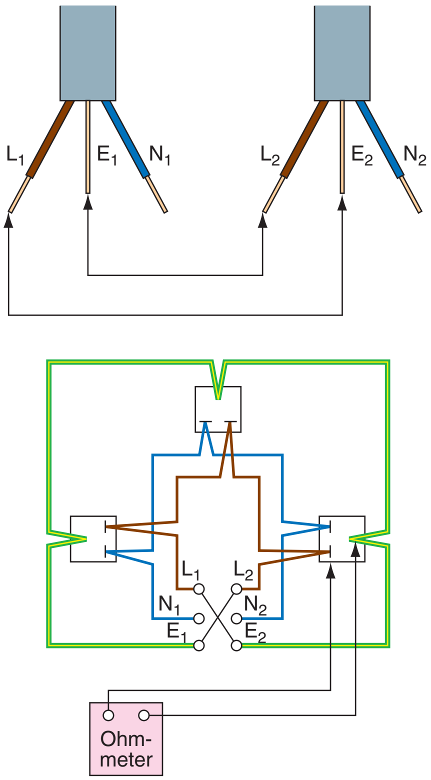

Figure 6.11 Step 3 test: connection of mains conductors and test circuit conditions.

Table 6.3 Table which may be used to record the readings taken when carrying out the continuity of ring final circuit conductors tests according to IEE Regulation 612.2.2

Test	Ohmmeter connected to	Ohmmeter readings	This gives a value for
Step 1	L_1 and L_2 N_1 and N_2 E_1 and E_2		r_1 r_2
Step 2	Live and neutral at each socket		
Step 3	Live and earth at each socket		$R_1 + R_2$
As a check $(R_1 + R_2)$ value should equal $(r_1 + r_2)/4$			

Step 2

The live and neutral conductors should now be temporarily joined together as shown in Fig. 6.10. An ohmmeter reading should then be taken between live and neutral at *every* socket outlet on the ring circuit. The readings obtained should be substantially the same, provided that there are no breaks or multiple loops in the ring. Each reading should have a value of approximately half the live and neutral ohmmeter readings measured in Step 1 of this test. Sockets connected as a spur will have a slightly higher value of resistance because they are fed by only one cable, while each socket on the ring is fed by two cables. Record the results on a table such as that shown in Table 6.3.

Step 3

Where the CPC is wired as a ring, for example where twin and earth cables or plastic conduit is used to wire the ring, temporarily join the live and CPCs together as shown in Fig. 6.11. An ohmmeter reading should then be taken between live and earth at *every* socket outlet on the ring. The readings obtained should be substantially the same provided that there are no breaks or multiple loops in the ring. This value is equal to $R_1 + R_2$ for the circuit. Record the results on an installation schedule such as that given in Appendix 6 of the IEE Regulations or a table such as that shown in Table 6.3. The Step 3 value of $R_1 + R_2$ should be equal to $(r_1 + r_2)/4$, where r_1 and r_2 are the ohmmeter readings from Step 1 of this test (see Table 6.3).

3 Testing insulation resistance (612.3)

The object of the test is to verify that the quality of the insulation is satisfactory and has not deteriorated or short-circuited. The test should be made at the consumer's unit with the mains switch off, all fuses in place and all switches closed. Neon lamps, capacitors and electronic circuits should be disconnected, since they will respectively glow, charge up or be damaged by the test.

There are two tests to be carried out using an insulation resistance tester which must have a test voltage of 500 V d.c. for 230 V and 400 V installations. These

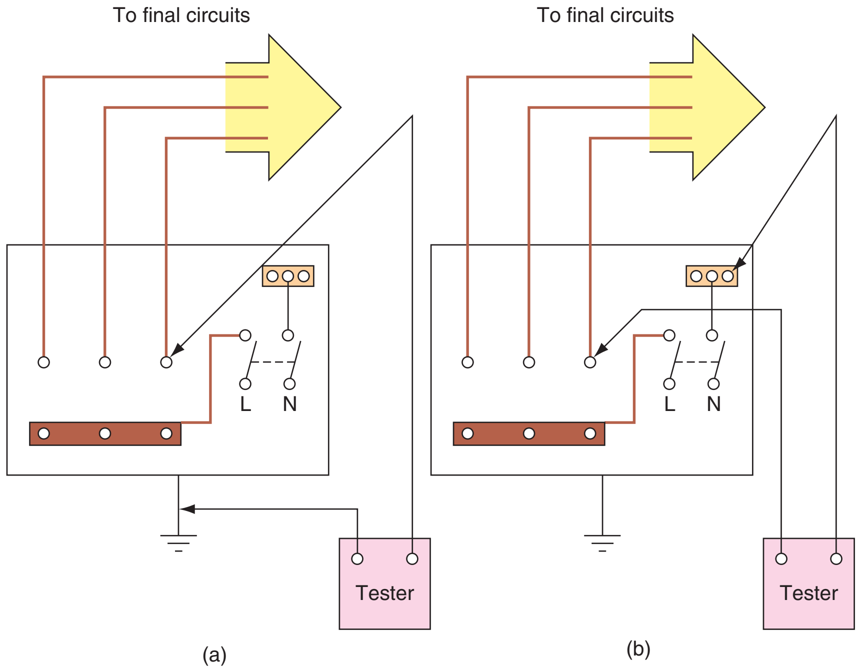

Figure 6.12 Insulation resistance test.

are line and neutral conductors to earth and between line conductors. The procedures are:

Line and neutral conductors to earth

1. Remove all lamps.
2. Close all switches and circuit breakers.
3. Disconnect appliances.
4. Test separately between the line conductor and earth, *and* between the neutral conductor and earth, for *every* distribution circuit at the consumer's unit as shown in Fig. 6.12. Record the results on a schedule of test results such as that given in Appendix 6 of the IEE Regulations.

Between line conductors

1. Remove all lamps.
2. Close all switches and circuit breakers.
3. Disconnect appliances.
4. Test between line and neutral conductors of *every* distribution circuit at the consumer's unit as shown in Fig. 6.12 and record the result.

The insulation resistance readings for each test must be not less than 1.0 MΩ for a satisfactory result (IEE Regulation 612.3.2).

Where the circuit includes electronic equipment which might be damaged by the insulation resistance test, a measurement between all live conductors (i.e. live and neutral conductors connected together) and the earthing arrangements may be made. The insulation resistance of these tests should be not less than 1.0 MΩ (IEE Regulation 612.3.3).

Although an insulation resistance reading of 1.0 MΩ complies with the regulations, the IEE Guidance Notes tell us that much higher values than this can be expected and that a reading of less than 2 MΩ might indicate a latent

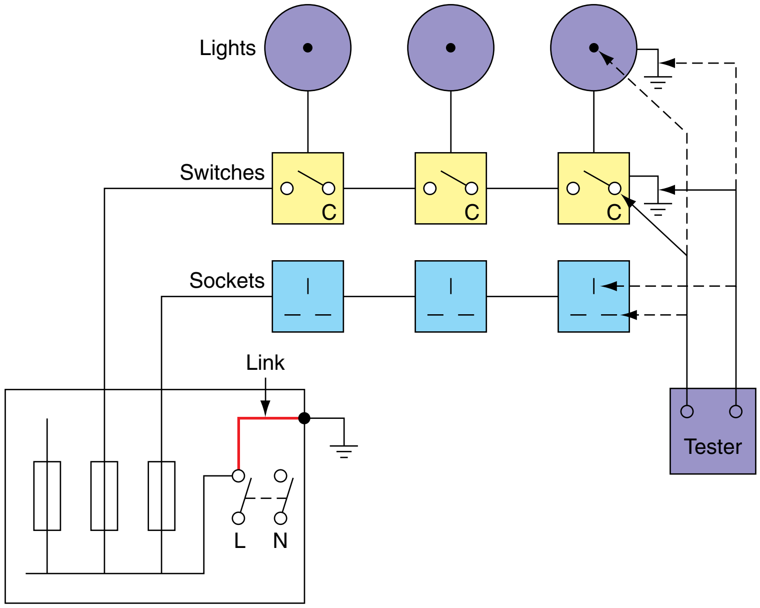

Figure 6.13 Polarity test.

but not yet visible fault in the installation. In these cases each circuit should be separately tested to obtain a reading greater than 2 MΩ.

4 Testing polarity (612.6)

The object of this test is to verify that all fuses, circuit breakers and switches are connected in the line or live conductor only, and that all socket outlets are correctly wired and Edison screw-type lampholders have the centre contact connected to the live conductor. It is important to make a polarity test on the installation since a visual inspection will only indicate conductor identification.

The test is done with the supply disconnected using an ohmmeter or continuity tester as follows:

1 Switch off the supply at the main switch.
2 Remove all lamps and appliances.
3 *Fix a temporary link* between the line and earth connections on the consumer's side of the main switch.
4 Test between the 'common' terminal and earth at each switch position.
5 Test between the centre pin of any Edison screw lampholders and any convenient earth connection.
6 Test between the live pin (i.e. the pin to the right of earth) and earth at each socket outlet as shown in Fig. 6.13.

For a satisfactory test result the ohmmeter or continuity meter should read very close to zero for each test.

Remove the test link and record the results on a schedule of test results such as that given in Appendix 6 of the IEE Regulations.

5 Testing earth electrode resistance (612.7)

When an earth electrode has been sunk into the general mass of earth, it is necessary to verify the resistance of the electrode. The general mass of earth can

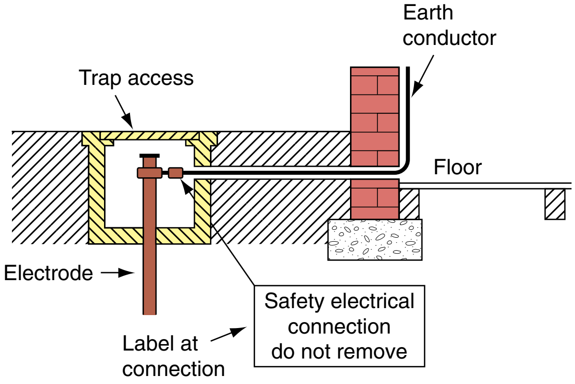

Figure 6.14 Termination of an earth electrode.

be considered as a large conductor which is at zero potential. Connection to this mass through earth electrodes provides a reference point from which all other voltage levels can be measured. This is a technique which has been used for a long time in power distribution systems.

The resistance to earth of an electrode will depend upon its shape, size and the resistance of the soil. Earth rods form the most efficient electrodes. A rod of about 1 m will have an earth electrode resistance of between 10 and 200 Ω. Even in bad earthing conditions a rod of about 2 m will normally have an earth electrode resistance which is less than 500 Ω in the United Kingdom. In countries which experience long dry periods of weather the earth electrode resistance may be thousands of ohms.

In the past, electrical engineers used the metal pipes of water mains as an earth electrode, but the recent increase in the use of PVC pipe for water mains now prevents the use of water pipes as the means of earthing in the United Kingdom, although this practice is still permitted in some countries. The IEE Regulation 542.2.1 recognizes the use of the following types of earth electrodes:

- earth rods or pipes
- earth tapes or wires
- earth plates
- earth electrodes embedded in foundations
- welded metallic reinforcement of concrete structures
- other suitable underground metalwork
- lead sheaths or other metallic coverings of cables.

The earth electrode is sunk into the ground, but the point of connection should remain accessible (IEE Regulation 542.4.2). The connection of the earthing conductor to the earth electrode must be securely made with a copper conductor complying with Table 54.1 and IEE Regulation 542.3.2 as shown in Fig. 6.14.

The installation site must be chosen so that the resistance of the earth electrode does not increase above the required value due to climatic conditions such as the soil drying out or freezing, or from the effects of corrosion (IEE Regulations 542.2.2 and 3).

Under fault conditions the voltage appearing at the earth electrode will radiate away from the electrode like the ripples radiating away from a pebble thrown into a pond. The voltage will fall to a safe level in the first 2 or 3 m away from the point of the earth electrode.

The basic method of measuring earth electrode resistance is to pass a current into the soil through the electrode and to measure the voltage required to produce this current.

IEE Regulation 612.9 demands that where earth electrodes are used they should be tested.

If the electrode under test forms part of the earth return for a TT installation in conjunction with an RCD, Guidance Note 3 of the IEE Regulations describes the following method:

1. Disconnect the installation protective equipotential bonding from the earth electrode to ensure that the test current passes only through the earth electrode.
2. Switch off the consumer's unit to isolate the installation.
3. Using a line earth loop impedance tester, test between the incoming line conductor and the earth electrode.
4. Reconnect the protective bonding conductors when the test is completed.

Record the result on a schedule of test results such as that given in Appendix 6 of the IEE Regulations.

The IEE Guidance Note 3 tells us that an acceptable value for the measurement of the earth electrode resistance would be less than 200 Ω.

Providing the first five tests were satisfactory, the supply may now be switched on and the final tests completed with the supply connected.

6 Testing polarity – supply connected

Using an approved voltage indicator such as that shown at Fig. 6.3 or test lamp and probes which comply with the HSE Guidance Note GS 38, again carry out a polarity test to verify that all fuses, circuit breakers and switches are connected in the live conductor. Test from the common terminal of switches to earth, the live pin of each socket outlet to earth and the centre pin of any Edison screw lampholders to earth. In each case the voltmeter or test lamp should indicate the supply voltage for a satisfactory result.

7 Testing earth fault loop impedance (supply connected) (612.9)

The object of this test is to verify that the impedance of the whole earth fault current loop line to earth is low enough to allow the over current protective device to operate within the disconnection time requirements of IEE Regulations 411.3.2.2, 411.4.6 and 411.4.7, should a fault occur.

The whole earth fault current loop examined by this test is comprised of all the installation protective conductors, the main protective earthing terminal and protective earth conductors, the earthed neutral point and the secondary winding of the supply transformer and the line conductor from the transformer to the point of the fault in the installation.

The test will, in most cases, be done with a purpose-made line earth loop impedance tester which circulates a current in excess of 10 A around the loop for a very short time, so reducing the danger of a faulty circuit. The test is made with the supply switched on, and carried out from the furthest point of *every* final circuit, including lighting, socket outlets and any fixed appliances. Record the results on a schedule of test results.

Purpose-built testers give a read-out in ohms and a satisfactory result is obtained when the loop impedance does not exceed the appropriate values given in Tables 41.2 and 41.3 of the IEE Regulations. For example, the maximum earth fault loop impedance for a socket circuit having a 0.4 s disconnection time and protected by a 32A Type B MCB is 1.44 ohms.

8 Additional protection: testing of RCD – supply connected (612.10)

The object of the test is to verify the effectiveness of the RCD, that it is operating with the correct sensitivity and proving the integrity of the electrical and mechanical elements. The test must simulate an appropriate fault condition and be independent of any test facility incorporated in the device.

When carrying out the test, all loads normally supplied through the device are disconnected.

The testing of a ring circuit protected by a general-purpose RCD to BS EN 61008 in a split-board consumer unit is carried out as follows:

1. Using the standard lead supplied with the test instrument, disconnect all other loads and plug in the test lead to the socket at the centre of the ring (i.e. the socket at the furthest point from the source of supply).
2. Set the test instrument to the tripping current of the device and at a phase angle of 0°.
3. Press the test button – the RCD should trip and disconnect the supply within 200 ms.
4. Change the phase angle from 0° to 180° and press the test button once again. The RCD should again trip within 200 ms. Record the highest value of these two results on a schedule of test results such as that given in Appendix 6 of the IEE Regulations.
5. Now set the test instrument to 50% of the rated tripping current of the RCD and press the test button. The RCD should *not trip* within 2 s. This test is testing the RCD for inconvenience *or* nuisance tripping.
6. Finally, the effective operation of the test button incorporated within the RCD should be tested to prove the integrity of the mechanical elements in the tripping device. This test should be repeated every 3 months.

If the RCD fails any of the above tests it should be changed for a new one.

Where the RCD has a rated tripping current not exceeding 30 mA and has been installed to reduce the risk associated with ‘basic’ and or ‘fault’ protection, as indicated in IEE Regulation 411.1, a residual current of 150 mA should cause the circuit breaker to open within 40 ms.

9 Check of phase sequence (612.12)

The phase sequence of three phase supplies must be verified with a phase sequence tester.

The phase sequence for a three phase supply is brown, black, grey.

10 Functional testing (612.13)

All RCD test buttons must be activated to verify the effectiveness of the RCD. Switchgear and control gear must be operated to show that they are securely mounted and operate correctly in accordance with the Regulations.

Certification and reporting

Following the completion of all new electrical work or additional work to an existing installation, the installation must be inspected and tested and an installation certificate issued and signed by a competent person. The 'competent person' must have a sound knowledge of the type of work undertaken, be fully versed in the inspection and testing procedures contained in the IEE Regulations (BS 7671) and employ adequate testing equipment.

A certificate and test results should be issued to those ordering the work in the format given in Appendix 6 of the IEE Regulations.

All installations must be periodically tested and inspected, and for this purpose a periodic inspection report should be issued (IEE Regulation 631.2). The standard format is again shown in Appendix 6 of the IEE Regulations.

In both cases the certificate must include the test values which verify that the installation complies with the IEE Regulations at the time of testing.

Suggested frequency of periodic inspection intervals are given below:

- Domestic installations – 10 years
- Commercial installations – 5 years
- Industrial installations – 3 years
- Agricultural installations – 3 years
- Caravan site installations – 1 year
- Caravans – 3 years
- Temporary installations on construction sites – 3 months.

Safe working procedures when testing

Whether you are carrying out the test procedure (i) as a part of a new installation, (ii) upon the completion of an extension to an existing installation, (iii) because you are trying to discover the cause of a fault on an installation, or (iv) because you are carrying out a periodic test and inspection of a building, you must always be aware of your safety, the safety of others using the building and the possible damage which your testing might cause to other systems in the building.

For your own safety:

- Always use 'approved' test instruments and probes.
- Ensure that the test instrument carries a valid calibration certificate otherwise the results may be invalid.
- Secure all isolation devices in the 'off' position.
- Put up warning notices so that other workers will know what is happening.
- Notify everyone in the building that testing is about to start and for approximately how long it will continue.
- Obtain a 'permit-to-work' if this is relevant.
- Obtain approval to have systems shut down which might be damaged by your testing activities. For example, computer systems may 'crash' when supplies

are switched off. Ventilation and fume extraction systems will stop working when you disconnect the supplies.

For the safety of other people:

- Fix warning notices around your work area.
- Use cones and highly visible warning tape to screen off your work area.
- Make an effort to let everyone in the building know that testing is about to begin. You might be able to do this while you carry out the initial inspection of the installation.
- Obtain verbal or written authorization to shut down information technology, emergency operation or stand-by circuits.

To safeguard other systems:

- Computer systems can be severely damaged by a loss of supply or the injection of a high test voltage from, for example, an insulation resistance test. Computer systems would normally be disconnected during the test period but this will generally require some organization before the testing begins. Commercial organizations may be unable to continue to work without their computer systems and, in these circumstances, it may be necessary to test outside the normal working day.
- Any resistance measurements made on electronic equipment or electronic circuits must be achieved with a battery operated ohmmeter in order to avoid damaging the electronic circuits.
- Farm animals are creatures of habit and may become very grumpy to find you testing their milking parlour equipment at milking time.
- Hospitals and factories may have emergency stand-by generators which re-energize essential circuits in the event of a mains failure. Your isolation of the circuit for testing may cause the emergency systems to operate. Discuss any special systems with the person authorizing the work before testing begins.

To demonstrate that you understand this third CGLI Outcome your tutor/trainer/lecturer will assess your ability to test electrotechnical systems.

Commissioning electrotechnical systems (CGLI Outcome 4)

Commissioning electrical systems

The commissioning of the electrical and mechanical systems within a building is a part of the 'handing-over' process of the new building by the architect and main contractor to the client or customer in readiness for its occupation and intended use. To 'commission' means to give authority to someone to check that everything is in working order. If it is out of commission, it is not in working order.

Following the completion, inspection and testing of the new electrical installation, the functional operation of all the electrical systems must be tested before they are handed over to the customer. It is during the commissioning period that any design or equipment failures become apparent, and this testing is one of the few quality controls possible on a building services installation.

This is the role of the commissioning engineer, who must assure himself that all the systems are in working order and that they work as they were designed to work. He must also instruct the client's representative, or the staff who will use the equipment, in the correct operation of the systems, as part of the handover arrangements.

The commissioning engineer must test the operation of all the electrical systems, including the motor controls, the fan and air conditioning systems, the fire alarm and emergency lighting systems. However, before testing the emergency systems, he must first notify everyone in the building of his intentions so that alarms may be ignored during the period of testing.

Commissioning has become one of the most important functions within the building project's completion sequence. The commissioning engineer will therefore have access to all relevant contract documents, including the building specifications and the electrical installation certificates as required by the IEE Regulations (BS 7671), and have a knowledge of the requirements of the Electricity at Work Act and the Health and Safety at Work Act.

The building will only be handed over to the client if the commissioning engineer is satisfied that all the building services meet the design specification in the contract documents.

To demonstrate that you understand this final CGLI Outcome your tutor/trainer/lecturer will assess your ability to commission electrotechnical systems.

CHAPTER 7

Fault diagnosis and repair

Unit 318 of the City and Guilds 2357 syllabus

Diagnosing and correcting electrical faults in electrical systems and equipment in buildings, structures and the environment

When you have completed this chapter you should be able to:

1. Select and use warning notices and barriers and carry out a safe isolation procedure
2. Identify faults on electrical systems
3. Correct faults on electrical systems

This chapter has free associated content, including animations and instructional videos, to support your learning

When you see the logo, visit the website below to access this material:

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Select and use warning notices and barriers and carry out a safe isolation procedure (CGLI Outcome 1)

Carry out safe working procedures

The principles which were laid down in the many Acts of Parliament and the regulations that we have already looked at, control our working environment. They make our workplace safer, but despite all this legislation, workers continue to be injured and killed at work or die as a result of a work-related injury. The number of deaths has consistently averaged about 200 each year for the past 8 years. These figures only relate to employees. If you include the self-employed and members of the public killed in work-related accidents, the numbers almost double.

In addition to the deaths, about 28,000 people have major accidents at work and about 130,000 people each year, receive minor work-related injuries which keep them off work for more than 3 days.

It is a mistake to believe that these things only happen in dangerous occupations such as deep sea diving, mining and quarrying, fishing industry, tunnelling and fire-fighting or that it only happens in exceptional circumstances

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such as would never happen in your workplace. This is not the case. Some basic thinking and acting beforehand could have prevented most of these accident statistics from happening.

Causes of accidents

Most accidents are caused by either human error or environmental conditions. **Human errors** include behaving badly or foolishly, being careless and not paying attention to what you should be doing at work, doing things that you are not competent to do or have not been trained to do. You should not work when tired or fatigued and should never work when you have been drinking alcohol or taking drugs.

Environmental conditions include unguarded or faulty machinery, damaged or faulty tools and equipment, poorly illuminated or ventilated workplaces and untidy, dirty or overcrowded workplaces.

Definition

Human errors include behaving badly or foolishly, being careless and not paying attention to what you should be doing at work.

Definition

Environmental conditions include unguarded or faulty machinery.

Safety first

Safety Procedures

- hazard risk assessment *is an essential part* of any health and safety management system
- the aim of the planning process is to minimize risk
- HSE publication HSG(65)

The most common causes of accidents

These are:

- slips, trips and falls;
- manual handling, that is moving objects by hand;
- using equipment, machinery or tools;
- storage of goods and materials which then become unstable;
- fire;
- electricity;
- mechanical handling.

Accident prevention measures

To control the risk of an accident we usually:

- eliminate the cause;
- substitute a procedure or product with less risk;
- enclose the dangerous situation;
- put guards around the hazard;
- use safe systems of work;
- supervise, train and give information to staff;
- if the hazard cannot be removed or minimized then provide PPE.

Before starting your work, you must get into the habit of carrying out a risk assessment, not a formal written assessment, but an informal one. Look at the hazards and consider the risk, then make the area safe.

Safety information

The rules and regulations of the working environment are communicated to employees by written instructions, signs and symbols. All signs in the working environment are intended to inform. They should give warning of possible dangers and must be obeyed. At first there were many different safety signs but British Standard BS 5499 Part 1 and the Health and Safety (Signs and Signals) Regulations 1996 have introduced a standard system which gives health and safety information with the minimum use of words. The purpose of the

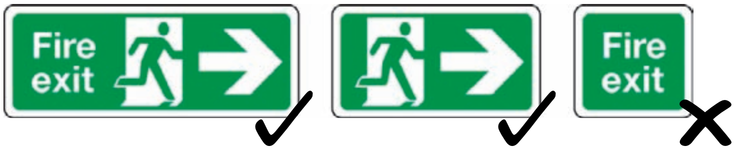

Figure 7.1 Text-only safety signs do not comply.

Figure 7.2 Prohibition signs. These are MUST NOT DO signs.

regulations is to establish an internationally understood system of safety signs and colours which draw attention to equipment and situations that do, or could, affect health and safety. Text-only safety signs became illegal from 24 December 1998. From that date, all safety signs have had to contain a pictogram or symbol such as those shown in Fig. 7.1. Signs fall into four categories: prohibited activities; warnings; mandatory instructions and safe conditions.

Prohibition signs

These are must not do signs. These are circular white signs with a red border and red cross bar, and are given in Fig. 7.2. They indicate an activity which *must not* be done.

Warning signs

Warning signs give safety information. These are triangular yellow signs with a black border and symbol, and are given in Fig. 7.3. They *give warning* of a hazard or danger.

Mandatory signs

These are must do signs. These are circular blue signs with a white symbol, and are given in Fig. 7.4. They *give instructions* which must be obeyed.

Advisory or safe condition signs

These are square or rectangular green signs with a white symbol, and are given in Fig. 7.5. They *give information* about safety provision.

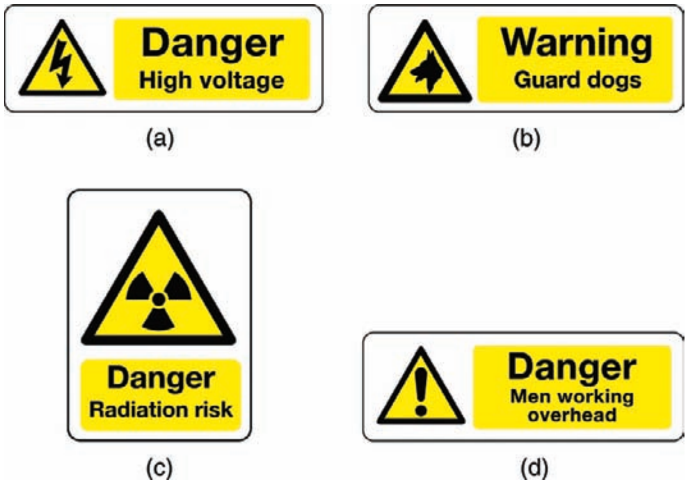

Figure 7.3 Warning signs. These give safety information.

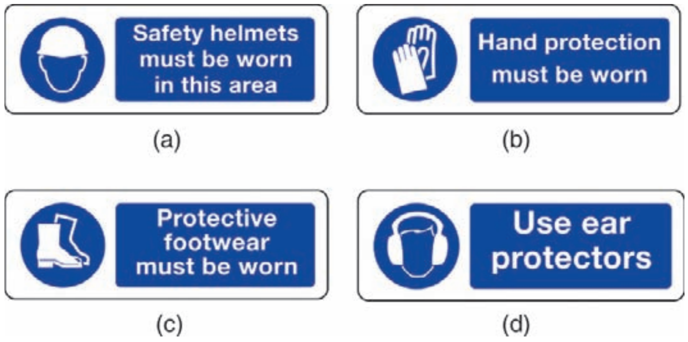

Figure 7.4 Mandatory signs. These are MUST DO signs.

Figure 7.5 Advisory or safe condition signs. These also give safety information.

Test equipment and safe isolation procedures

The Health and Safety Executive (HSE) has published Guidance Notes (GS 38) which advise electricians and other electrically competent people on the selection of suitable test probes, voltage indicating devices and measuring instruments. This is because they consider suitably constructed test equipment to be as vital for personal safety as the training and practical skills of the electrician. In the past, unsatisfactory test probes and voltage indicators have frequently been the cause of accidents, and therefore all test probes must now incorporate the following features:

1 The probes must have finger barriers or be shaped so that the hand or fingers cannot make contact with the live conductors under test.
2 The probe tip must not protrude more than 2 mm, and preferably only 1 mm, be spring-loaded and screened.
3 The lead must be adequately insulated and coloured so that one lead is readily distinguished from the other.
4 The lead must be flexible and sufficiently robust.
5 The lead must be long enough to serve its purpose but not too long.
6 The lead must not have accessible exposed conductors even if it becomes detached from the probe or from the instrument.
7 Where the leads are to be used in conjunction with a voltage detector they must be protected by a fuse.

A suitable probe and lead is shown in Fig. 7.6.

GS 38 also tells us that where the test is being made simply to establish the presence or absence of a voltage, the preferred method is to use a proprietary test lamp or voltage indicator which is suitable for the working voltage, rather than a multimeter. Accident history has shown that incorrectly set multimeters or makeshift devices for voltage detection have frequently caused accidents. Fig. 7.7 shows a suitable voltage indicator. Test lamps and voltage indicators

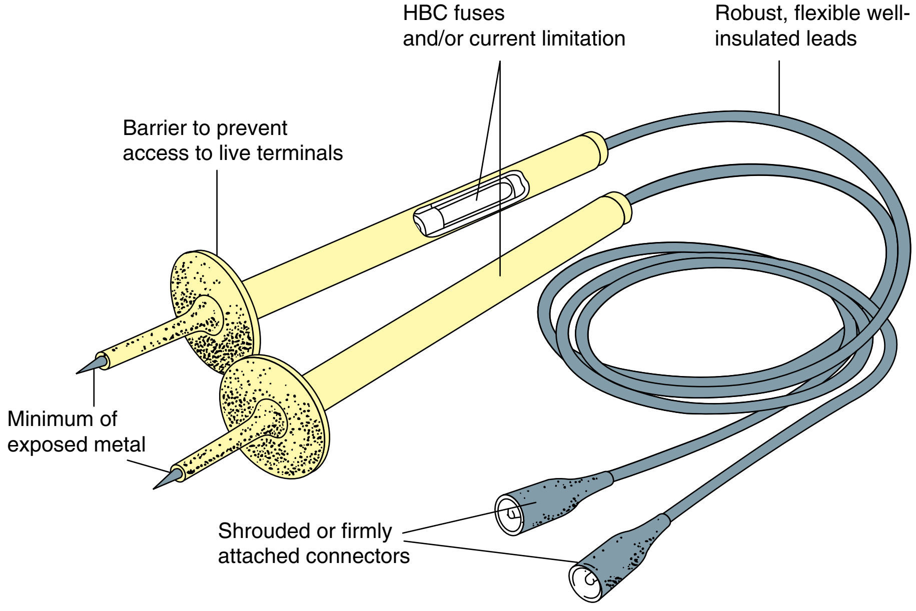

Figure 7.6 Recommended type of test probe and leads.

Figure 7.7 Typical voltage indicator.

are not fail-safe, and therefore GS 38 recommends that they should be regularly proved, preferably before and after use, as described in the flowchart for a safe isolation procedure shown in Fig 7.10.

Test procedures

1 The circuits must be isolated using a ‘safe isolation procedure’, such as that described below, before beginning to test.
2 All test equipment must be ‘approved’ and connected to the test circuits by recommended test probes as described by the HSE Guidance Notes GS 38. The test equipment used must also be ‘proved’ on a known supply or by means of a proving unit such as that shown in Fig. 7.8.
3 Isolation devices must be ‘secured’ in the ‘off’ position as shown in Fig. 7.9.
4 Warning notices must be posted.
5 All relevant safety and functional tests must be completed before restoring the supply.

Live testing

Definition

The *Electricity at Work Act* tells us that it is ‘preferable’ that supplies be made dead before work commences (IEE Regulation 4(3)).

The **Electricity at Work Act** tells us that it is ‘preferable’ that supplies be made dead before work commences (IEE Regulation 4(3)). However, it does acknowledge that some work, such as fault-finding and testing, may require the electrical equipment to remain energized. Therefore, if the fault finding and testing can only be successfully carried out ‘live’, then the person carrying out the fault diagnosis must:

- be trained so that he understands the equipment and the potential hazards of working live and can, therefore, be deemed to be ‘competent’ to carry out the activity;

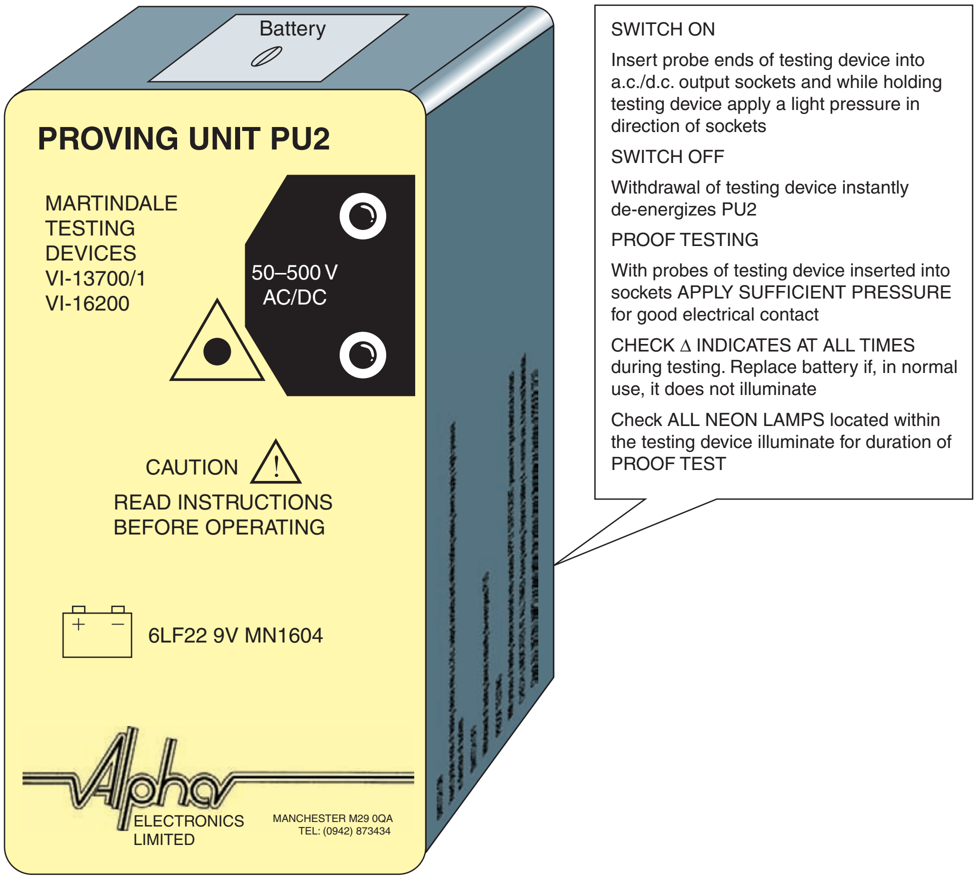

Figure 7.8 Voltage proving unit.

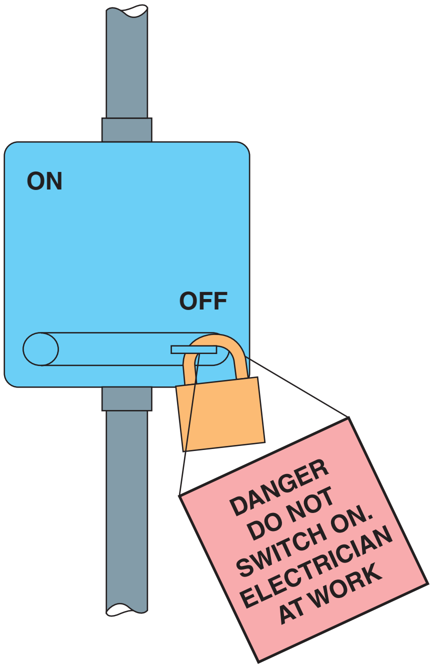

Figure 7.9 Secure isolation of a supply.

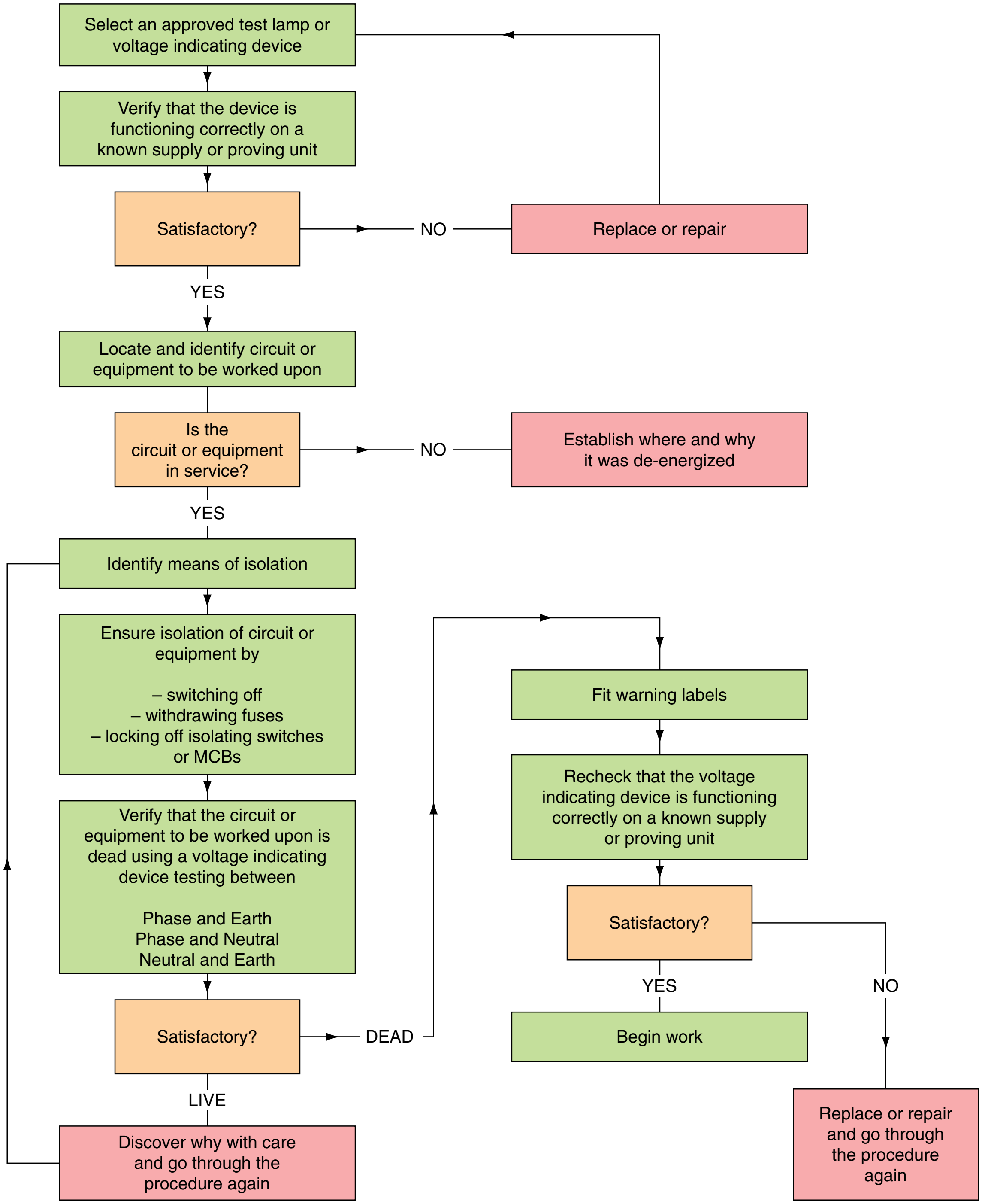

Figure 7.10 Flowchart for a secure isolation procedure.

Definition

Note that while live testing may be required in order to find the fault, live repair work must not be carried out. The individual circuit or item of equipment must first be isolated.

- only use approved test equipment;
- set up barriers and warning notices so that the work activity does not create a situation dangerous to others.

Note that while live testing may be required in order to find the fault, live repair work must not be carried out. The individual circuit or item of equipment must first be isolated.

Isolation of supply

The Electricity at Work Regulations are very specific in describing the procedure to be used for isolation of the electrical supply. Regulation 12(1) tells us that **isolation** means the disconnection and separation of the electrical equipment from every source of electrical energy in such a way that this disconnection and separation is secure. Regulation 4(3) tells us that we must also prove the conductor's dead before work commences and that the test instrument used for this purpose must itself be proved immediately before and immediately after testing the conductors. To isolate an individual circuit or item of equipment successfully, competently and safely we must follow a procedure such as that given by the flow diagram in Fig. 7.10. Start at the top and work your way down the flowchart. When you get to the heavy-outlined amber boxes, pause and ask yourself whether everything is satisfactory up to this point. If the answer is yes, move on. If no, go back as indicated by the diagram.

To demonstrate that you understand this first CGLI Outcome your tutor/trainer/lecturer will assess your ability to recognise warning notices and carry out a safe isolation procedure.

Definition

Isolation means the disconnection and separation of the electrical equipment from every source of electrical energy in such a way that this disconnection and separation is secure.

Identify Faults on electrical systems (CGLI Outcome 2)

To diagnose and find faults in electrical installations and equipment is probably one of the most difficult tasks undertaken by an electrician. The knowledge of fault finding and the diagnosis of faults can never be completely 'learned' because no two fault situations are exactly the same. As the systems we install become more complex, then the faults developed on these systems become more complicated to solve. To be successful the individual must have a thorough knowledge of the installation or piece of equipment and have a broad range of the skills and competences associated with the electrotechnical industries.

The ideal person will tackle the problem using a reasoned and logical approach, recognize his own limitations and seek help and guidance where necessary.

The tests recommended by the IEE Regulations can be used as a diagnostic tool but the safe working practices described by the Electricity at Work Act and elsewhere must always be observed during the fault-finding procedures.

If possible, fault finding should be planned ahead to avoid inconvenience to other workers and to avoid disruption of the normal working routine. **However, a faulty piece of equipment or a fault in the installation is not normally a planned event and usually occurs at the most inconvenient time.** The diagnosis and rectification of a fault is therefore often carried out in very stressful circumstances.

Symptoms of an electrical fault

The basic symptoms of an electrical fault may be described in one or a combination of the following ways:

1 There is a complete loss of power.
2 There is partial or localized loss of power.

3 The installation or piece of equipment is failing because of the following:
  - an individual component is failing;
  - the whole plant or piece of equipment is failing;
  - the insulation resistance is low;
  - the overload or protective devices operate frequently;
  - electromagnetic relays will not latch, giving an indication of undervoltage.

Causes of electrical faults

Definition

A *fault* is not a natural occurrence; it is an unplanned event which occurs unexpectedly.

A ***fault*** *is not a natural occurrence; it is an unplanned event which occurs unexpectedly.* The fault in an electrical installation or piece of equipment may be caused by:

- negligence – that is, lack of proper care and attention;
- misuse – that is, not using the equipment properly or correctly;
- abuse – that is, deliberate ill-treatment of the equipment.

If the installation was properly designed in the first instance to perform the tasks required of it by the user, then the *negligence, misuse or abuse* must be the fault of the user. However, if the installation does not perform the tasks required of it by the user then the negligence is due to the electrical contractor in not designing the installation to meet the needs of the user.

Negligence on the part of the user may be due to insufficient maintenance or lack of general care and attention, such as not repairing broken equipment or removing covers or enclosures which were designed to prevent the ingress of dust or moisture.

Misuse of an installation or pieces of equipment may occur because the installation is being asked to do more than it was originally designed to do, because of expansion of a company, for example. Circuits are sometimes overloaded because a company grows and a greater demand is placed on the existing installation by the introduction of new or additional machinery and equipment.

Where do electrical faults occur?

1 Faults occur in wiring systems, but not usually along the length of the cable, unless it has been damaged by a recent event such as an object being driven through it or a JCB digger pulling up an underground cable. Cable faults usually occur at each end, where the human hand has been at work at the point of cable inter-connections. This might result in broken conductors, trapped conductors or loose connections in joint boxes, accessories or luminaires.

All cable connections must be made mechanically and electrically secure. They must also remain accessible for future inspection, testing and maintenance (IEE Regulation 526.3). The only exceptions to this rule are when:
  - underground cables are connected in a compound filled or encapsulated joint;
  - floor warming or ceiling warming heating systems are connected to a cold tail;
  - a joint is made by welding, brazing, soldering or compression tool.

Since they are accessible, cable inter-connections are an obvious point of investigation when searching out the cause of a fault.

2 Faults also occur at cable terminations. The IEE Regulations require that a cable termination of any kind must securely anchor all conductors to reduce mechanical stresses on the terminal connections. All conductors of flexible cords must be terminated within the terminal connection otherwise the current carrying capacity of the conductor is reduced, which may cause local heating. Flexible cords are delicate – has the terminal screw been over-tightened, thus breaking the connection as the conductors flex or vibrate? Cables and flexible cords must be suitable for the temperature to be encountered at the point of termination or must be provided with additional insulation sleeves to make them suitable for the surrounding temperatures (IEE Regulation 522.2).

3 Faults also occur at accessories such as switches, sockets, control gear, motor contactors or at the point of connection with electronic equipment. The source of a possible fault is again at the point of human contact with the electrical system and again the connections must be checked as described in the first two points above. Contacts that make and break a circuit are another source of wear and possible failure, so switches and motor contactors may fail after extensive use. Socket outlets that have been used extensively and loaded to capacity in say kitchens, are another source of fault due to overheating or loose connections. Electronic equipment can be damaged by the standard tests described in the IEE Regulations and must, therefore, be disconnected before testing begins.

4 Faults occur on instrumentation panels either as a result of a faulty instrument or as a result of a faulty monitoring probe connected to the instrument. Many panel instruments are standard sizes connected to CTs or VTs and this is another source of possible faults of the types described in points 1–3.

5 Faults occur in protective devices for the reasons given in points 1–3 above but also because they may have been badly selected for the job in hand and do not offer adequate protection or discrimination as described in Chapter 4 of Basic Electrical Installation Work 6th Ed.

6 Faults often occur in luminaires (light fittings) because the lamp has expired. Discharge lighting (fluorescent fittings) also require a ‘starter’ to be in good condition, although many fluorescent luminaires these days use starter-less electronic control gear. The points made in 1–3 about cable and flexible cord connections are also relevant to luminaire faults.

7 Faults occur when terminating flexible cords as a result of the flexible cable being of a smaller cross-section than the load demands, because it is not adequately anchored to reduce mechanical stresses on the connection or because the flexible cord is not suitable for the ambient temperature to be encountered at the point of connection. When terminating flexible cords, the insulation should be carefully removed without cutting out any flexible cord strands of wire because this effectively reduces the cross-section of the conductor. The conductor strands should be twisted together and then doubled over, if possible, and terminated in the appropriate connection. The connection screws should be opened fully so that they will not snag the flexible cord as it is eased into the connection. The insulation should go up to, but not into, the termination. The terminal screws should then be tightened.

8 Faults occur in electrical components, equipment and accessories such as motors, starters, switch gear, control gear, distribution panels, switches, sockets and luminaires because these all have points at which electrical connections are made. It is unusual for an electrical component to become faulty when it is relatively new because it will have been manufactured and tested to comply with the appropriate British Standard. Through overuse or misuse components and equipment do become faulty but most faults are caused by poor installation techniques.

Safety first

Cable fault

- faults do occur in wiring systems
- but not usually along the cable length
- faults usually occur at each end
- where the human hand has been at work making connections.

Safety first

Isolation

- NEVER work 'LIVE'
- isolate
- secure the isolation
- prove the supply 'dead' before starting work.

Safety first

Socket outlets

All socket outlets used by ordinary persons intended for general use must have:

- 30 mA RCD protection
- Regulations 411.3.3 and 415.1.1.

Modern electrical installations using new materials can now last longer than fifty years. Therefore, they must be properly installed. Good design, good workmanship and the use of proper materials are essential if the installation is to comply with the relevant regulations (IEE Regulations 133.1.1 and 134.1.1).

Fault finding

Before an electrician can begin to diagnose the cause of a fault he must:

- have a thorough knowledge and understanding of the electrical installation or electrical equipment;
- collect information about the fault and the events occurring at or about the time of the fault from the people who were in the area at the time;
- begin to predict the probable cause of the fault using his own and other people's skills and expertise;
- test some of the predictions using a logical approach to identify the cause of the fault.
- be aware of the potential disruption to the electrical systems, in particular computer systems and safety systems.

Most importantly, electricians must use their detailed knowledge of electrical circuits and equipment learned through training and experience and then apply this knowledge to look for a solution to the fault.

Designing out faults

The designer of the installation cannot entirely design out the possibility of a fault occurring but he can design in 'damage limitation' should a fault occur.

For example designing in two, three or four lighting and power circuits will reduce the damaging effect of any one circuit failing because not all lighting and power will be lost as a result of a fault. Limiting faults to only one of many circuits is good practice because it limits the disruption caused by a fault. IEE Regulation 314 tells us to divide an installation into circuits as necessary so as to:

1. avoid danger and minimize inconvenience in the event of a fault occurring,
2. facilitate safe operation, inspection testing and maintenance.

Requirements for successful electrical fault finding

The steps involved in successfully finding a fault can be summarized as follows:

1. Gather *information* by talking to people and looking at relevant sources of information such as manufacturer's data, circuit diagrams, charts and schedules.
2. *Analyse* the evidence and use standard tests and a visual inspection to predict the cause of the fault.
3. *Interpret* test results and diagnose the cause of the fault.
4. *Rectify* the fault.
5. *Carry out* functional tests to verify that the installation or piece of equipment is working correctly and that the fault has been rectified.

Requirements for safe working procedures

The following five safe working procedures must be applied before undertaking the fault diagnosis.

1 The circuits must be isolated using a 'safe isolation procedure', such as that described in Outcome 1 of this chapter before beginning to repair the fault.
2 All test equipment must be 'approved' and connected to the test circuits by recommended test probes as described by the Health and Safety Executive (HSE) Guidance Note GS 38 and shown in Fig 7.6. The test equipment used must also be 'proved' on a known supply or by means of a proving unit such as that shown in Fig. 7.8.
3 Isolation devices must be 'secured' in the 'off' position as shown in Fig. 7.9. The key is retained by the person working on the isolated equipment.
4 Warning notices must be posted.
5 All relevant safety and functional tests must be completed before restoring the supply.

Live testing

The Electricity at Work Act tells us that it is 'preferable' that supplies be made dead before work commences (IEE Regulation 4(3)). However, it does acknowledge that some work, such as fault finding and testing, may require the electrical equipment to remain energized. Therefore, if the fault finding and testing can only be successfully carried out 'live', then the person carrying out the fault diagnosis must:

- be trained so that he understands the equipment and the potential hazards of working live and can, therefore, be deemed to be 'competent' to carry out the activity;
- only use approved test equipment;
- set up barriers and warning notices so that the work activity does not create a situation dangerous to others.

Note that while live testing may be required in order to find the fault, live repair work must not be carried out. The individual circuit or item of equipment must first be isolated.

Definition

Isolation means the disconnection and separation of the electrical equipment from every source of electrical energy in such a way that this disconnection and separation is secure.

Selecting test instruments

The HSE has published Guidance Notes (GS 38) which advise electricians and other electrically competent people on the selection of suitable test probes, voltage indicating devices and measuring instruments. This is because they consider suitably constructed test equipment to be as vital for personal safety as the training and practical skills of the electrician. In the past, unsatisfactory test probes and voltage indicators have frequently been the cause of accidents, and therefore all test probes must now incorporate the following features:

1 The probes must have finger barriers or be shaped so that the hand or fingers cannot make contact with the live conductors under test.
2 The probe tip must not protrude more than 2 mm, and preferably only 1 mm, be spring-loaded and screened.
3 The lead must be adequately insulated and coloured so that one lead is readily distinguished from the other.
4 The lead must be flexible and sufficiently robust.

Figure 7.11 Digital multimeter suitable for testing electrical and electronic circuits.

Definition

Analogue meters have a pointer moving across a calibrated scale.

Definition

Digital meters provide the same functions as analogue meters but they display the indicated value using a seven-segment LED to give a numerical value of the measurement.

5 The lead must be long enough to serve its purpose but not too long.
6 The lead must not have accessible exposed conductors even if it becomes detached from the probe or from the instrument.
7 Where the leads are to be used in conjunction with a voltage detector they must be protected by a fuse.

A suitable probe and lead is shown in Fig. 7.6.

GS 38 also tells us that where the test is being made simply to establish the presence or absence of a voltage, the preferred method is to use a proprietary test lamp or voltage indicator which is suitable for the working voltage, rather than a multimeter. Accident history has shown that incorrectly set multimeters or makeshift devices for voltage detection have frequently caused accidents. Figure 7.7 shows a suitable voltage indicator. Test lamps and voltage indicators are not fail-safe, and therefore GS 38 recommends that they should be regularly proved, preferably before and after use, as described previously in the flowchart for a safe isolation procedure.

The IEE Regulations (BS 7671) also specify the test voltage or current required to carry out particular tests satisfactorily. All testing must, therefore, be carried out using an 'approved' test instrument if the test results are to be valid. **The test instrument must also carry a calibration certificate, otherwise the recorded results may be void.** Calibration certificates usually last for a year. Test instruments must, therefore, be tested and recalibrated each year by an approved supplier. This will maintain the accuracy of the instrument to an acceptable level, usually within 2% of the true value.

Modern digital test instruments are reasonably robust, but to maintain them in good working order they must be treated with care. An approved test instrument costs equally as much as a good-quality camera; it should, therefore, receive the same care and consideration. Figure 7.11 shows a digital multimeter.

Continuity tester

To measure accurately the resistance of the conductors in an electrical installation we must use an instrument which is capable of producing an open circuit voltage of between 4 and 24 V a.c. or d.c., and deliver a short-circuit current of not less than 200 mA (IEE Regulation 612.2.1). The functions of continuity testing and insulation resistance testing are usually combined in one test instrument.

Insulation resistance tester

The test instrument must be capable of detecting insulation leakage between live conductors and between live conductors and earth. To do this and comply with IEE Regulation 612.3 the test instrument must be capable of producing a test voltage of 250, 500 or 1000 V and deliver an output current of not less than 1 mA at its normal voltage.

Earth fault loop impedance tester

The test instrument must be capable of delivering fault currents as high as 25 A for up to 40 ms using the supply voltage. During the test, the instrument does an Ohm's law calculation and displays the test result as a resistance reading.

RCD tester

Where circuits are protected by an RCD we must carry out a test to ensure that the device will operate very quickly under fault conditions and within the time limits set by the IEE Regulations. The instrument must, therefore, simulate a fault and measure the time taken for the RCD to operate. The instrument is, therefore, calibrated to give a reading measured in milliseconds to an in-service accuracy of 10%.

Figure 7.12 Tong tester or clip-on ammeter.

Tong tester

The tong tester or clip-on ammeter works on the same principle as the transformer. The laminated core of the transformer can be opened and passed over the busbar or single-core cable. In this way a measurement of the current being carried can be made without disconnection of the supply. The construction is shown in Fig. 7.12.

Phase sequence testers

Phase sequence is the order in which each phase of a three-phase supply reaches its maximum value. The normal phase sequence for a three-phase supply is brown–black–grey, which means that first brown, then black and finally the grey phase reaches its maximum value.

Phase sequence has an important application in the connection of three-phase transformers. The secondary terminals of a three-phase transformer must not be connected in parallel until the phase sequence is the same.

A phase sequence tester can be an indicator which is, in effect, a miniature induction motor, with three clearly colour-coded connection leads. A rotating disc with a pointed arrow shows the normal rotation for phase sequence brown–black–grey. If the sequence is reversed the disc rotates in the opposite direction to the arrow.

If you purchase good-quality 'approved' test instruments and leads from specialist manufacturers they will meet all the regulations and standards and therefore give valid test results. However, to carry out all the tests required by the IEE Regulations will require a number of test instruments and this will represent a major capital investment in the region of £1000.

The specific tests required by the IEE Regulations: BS 7671 are described in detail in Chapter 6 of this book under the sub-heading 'Inspection and testing techniques'.

Electrical installation circuits usually carry in excess of 1 A and often carry hundreds of amperes. Electronic circuits operate in the milliampere or even microampere range. The test instruments used on electronic circuits must have a *high impedance* so that they do not damage the circuit when connected to take readings. All instruments cause some disturbance when connected into a circuit because they consume some power in order to provide the torque required to move the pointer. In power applications these small disturbances seldom give rise to obvious errors, but in electronic circuits, a small disturbance can completely invalidate any readings taken. We must, therefore, choose our electronic test equipment with great care.

Figure 7.11 shows a digital multimeter which is suitable for testing electrical and electronic circuit.

To demonstrate that you understand this second CGLI Outcome your tutor/trainer/lecturer will assess your ability to identify faults on electrical systems.

Correcting faults on electrical systems (CGLI Outcome 3)

When the fault has been identified and repaired, the circuit, system or equipment must be inspected, tested and functional checks carried out as required by IEE Regulations Chapter 61.

The purpose of inspecting and testing the repaired circuit, system or equipment is to confirm the electrical integrity of the system before it is re-energized.

The tests recommended by Part 6 of the IEE Regulations are:

1 Test the continuity of the protective conductors including the protective equipotential and supplementary bonding conductors.
2 Test the continuity of all ring final circuit conductors.
3 Test the insulation resistance between live conductors and earth.
4 Test the polarity to verify that single pole control and protective devices are connected in the line conductor only.
5 Test the earth electrode resistance where the installation incorporates an earth electrode as a part of the earthing system.

The supply may now be connected and the following tests carried out:

6 Test the polarity using an approved test lamp or voltage indicator.
7 Test the earth fault loop impedance where the protective measures used require a knowledge of earth fault loop impedance.

These tests *where relevant* must be carried out in the order given above to comply with IEE Regulation 612.1.

If any test indicates a failure, that test and any preceding test must be repeated after the fault has been rectified. This is because the earlier tests may have been influenced by the fault.

The above tests are described in Chapter 6 of this book, in Part 6 of the IEE Regulations, and in Guidance Note 3 published by the IEE.

Safety first

Testing

The tests indicated in Part 6 of the regulations:

- must be carried out in the order given so that essential safety features are proved first
- IEE Regulations 612.1

Functional testing (IEE Regulation 612.13)

Following the carrying out of the relevant tests described above we must carry out functional testing to ensure that:

- the circuit, system or equipment works correctly;
- it works as it did before the fault occurred;
- it continues to comply with the original specification;
- it is electrically safe;
- it is mechanically safe;
- it meets all the relevant regulations in particular the IEE Regulations (BS 7671).

IEE Regulation 612.13 tells us to check the effectiveness of the following assemblies to show that they are properly mounted, adjusted and installed:

- Residual current devices (RCDs)
- Switchgear
- Control gear
- Controls and interlocks.

If a part of the fault cannot be corrected immediatly because, for example, a suitable replacement is not immediatly available, then that part of the system must be made safe and isolated as described earlier in this chapter.

Record the test results and details of the fault and hand these documents to the customer's representative.

Restoration of the building structure

If the structure, or we sometimes call it the fabric of the building, has been damaged as a result of your electrical repair work, it must be made good before you hand the installation, system or equipment back to the client.

Where a wiring system passes through elements of the building construction such as floors, walls, roofs, ceilings, partitions or cavity barriers, the openings remaining after the passage of the wiring system must be sealed according to the degree of fire resistance demonstrated by the original building material (IEE Regulation 527.2).

You should always make good the structure of the building using appropriate materials ***before*** you leave the job so that the general building structural performance and fire safety are not reduced. If additionally, there is a little cosmetic plastering and decorating to be done, then who actually will carry out this work is a matter of negotiation between the client and the electrical contractor.

Disposal of waste

Having successfully diagnosed the electrical fault and carried out the necessary repairs OR having completed any work in the electrotechnical industry, we come to the final practical task, leaving the site in a safe and clean condition and the removal of any waste material. This is an important part of your company's 'good customer relationships' with the client. We also know that we have a 'duty of care' for the waste that we produce as an electrical company.

We have also said many times in this book that having a good attitude to health and safety, working conscientiously and neatly, keeping passage ways clear and regularly tidying up the workplace is the sign of a good and competent craftsman. But what do you do with the rubbish that the working environment produces? Well:

- All the packaging material for electrical fittings and accessories usually goes into either your employer's skip or the skip on site designated for that purpose.
- All the off-cuts of conduit, trunking and tray also go into the skip.
- In fact, most of the general site debris will probably go into the skip and the waste disposal company will take the skip contents to a designated local council land fill area for safe disposal.
- The part coils of cable and any other reusable leftover lengths of conduit, trunking or tray will be taken back to your employer's stores area. Here it will be stored for future use and the returned quantities deducted from the costs allocated to that job.
- What goes into the skip for normal disposal into a land fill site is usually a matter of common sense. However, some substances require special consideration and disposal. We looked at asbestos and large quantities of used fluorescent tubes which are classified as 'special waste' or 'hazardous waste' in Chapter 5 of *Basic Electrical Installation Work* 6th edition.

To demonstrate that you understand this final Outcome in Unit 318 your tutor/trainer/lecturer will assess your ability to correct faults on electrical systems.

Safety first

Fire

If your electrical activities cause damage to the fabric of the building then:

- the openings remaining must be sealed according to the degree of fire resistance demonstrated by the original building material
- IEE Regulation 527.2

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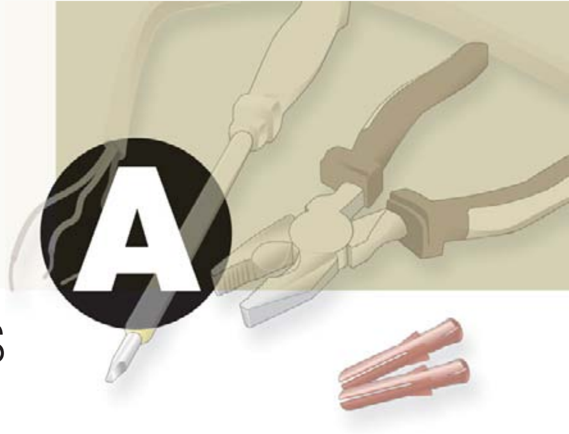
APPENDIX
Environmental organizations



The Department of Energy and Climate Change (DECC) for grants

BS 7671:2008 Engineering Recommendations G 83/1 and G 59/1 published by the Energy Network Association and the Department for Business, Enterprise and Regulatory Reform (BERR) for technical specifications

Building Regulations England and Wales: the Department of Communities and Local Government at www.communities.gov.uk and, for Scotland, The Scottish Building Standards Agency at www.sbsa.gov.uk

The Labour government's 'Feed in Tariff' was introduced by The Climate Secretary Ed Miliband to encourage green electricity producers by paying a subsidy for every kWh of electricity generated by renewable energy fed back to the national grid. The Coalition government, which came to power in 2010, are committed to supporting this policy

For information on the Feed in Tariff Scheme see the Office of the Gas and Electricity Markets (OFGEM) website at www.ofgem.gov.uk/fits

Energy Saving Trust at 020 7222 0101 and www.energysavingtrust.org.uk for advice on grants and products

Micro-generation product advice and their own certification scheme at 01752 823 600 and www.microgeneration.com

The Carbon Trust at www.carbontrust.co.uk/energy offers free advice on loans to businesses who are upgrading to more energy efficient equipment. The size of the loan will depend upon the CO_2 savings

Planning Guide for solar, PV and wind turbine installations can be found at www.planningportal.gov.uk/uploads/hhg/houseguide.html

Best practice guide for installing micro-generation systems can be found on the Electrical Safety Council website at www.esc.org.uk/bestpracticeguides.html

Rainwater harvesting guidance and products can be found in abundance by Googling 'rainwater-harvesting'

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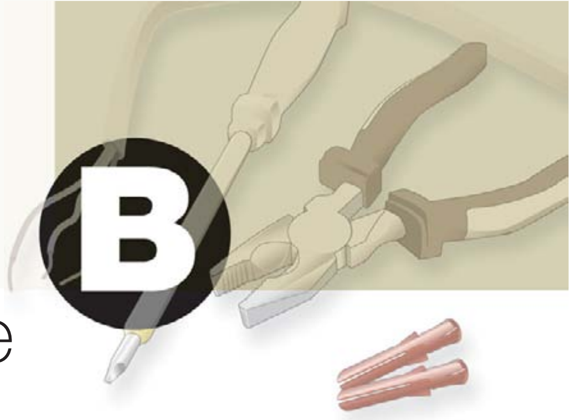


APPENDIX

Health and Safety Executive (HSE) publications and information

HSE Books information leaflets and guides may be obtained from
HSE Books, P.O. Box 1999, Sudbury, Suffolk CO10 6FS

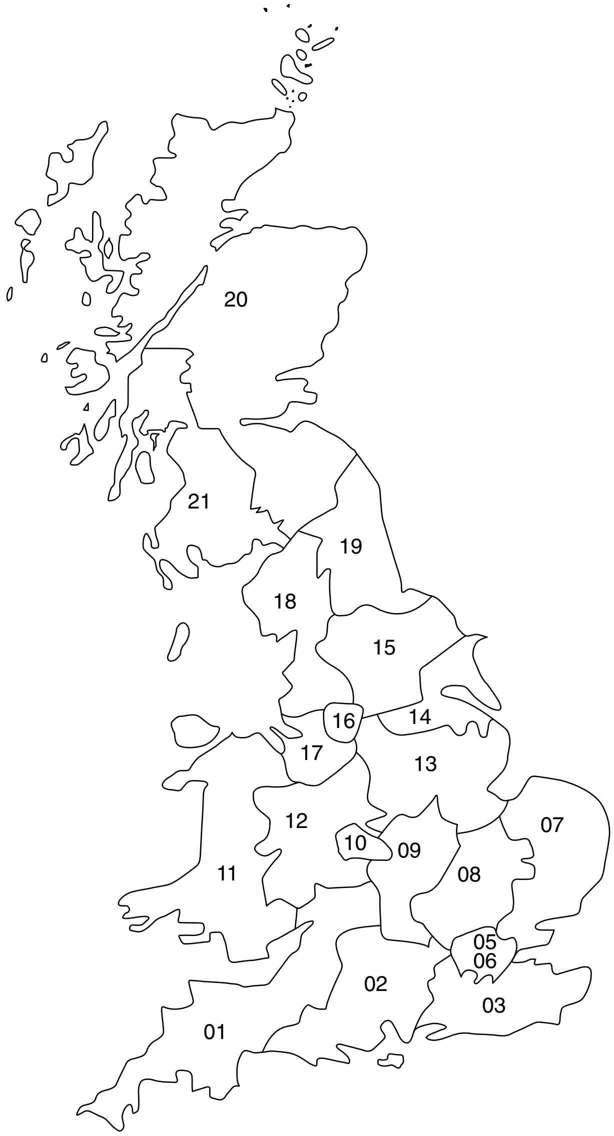
HSE Infoline – telephone no 01541 545500 or write to HSE Information Centre, Broad Lane, Sheffield S3 7HO

HSE home page on the World Wide Web
http://www.open.gov.uk/hse/hsehome.htm

The Health and Safety Poster and other HSE publications are available from www.hsebooks.com

Environmental Health Department of the Local Authority: look in the local telephone directory under the name of the authority

HSE AREA OFFICES



01 **South West**
Inter City House, Mitchell Lane, Victoria Street, Bristol BS1 6AN
Telephone: 01171 290681

02 **South**
Priestley House, Priestley Road, Basingstoke RG24 9NW
Telephone: 01256 473181

03 **South East**
3 East Grinstead House, London Road,
East Grinstead, West Sussex RH19 1RR
Telephone: 01342 326922

05 **London North**
Maritime House, 1 Linton Road, Barking,
Essex IG11 8HF
Telephone: 0208 594 5522

06 **London South**
1 Long Lane, London SE1 4PG
Telephone: 0207 407 8911

07 **East Anglia**
39 Baddow Road, Chelmsford, Essex CM2 OHL
Telephone: 0207 407 8911

08 **Northern Home Counties**
14 Cardiff Road, Luton, Beds LU1 1PP
Telephone: 01 582 34121

09 **East Midlands**
Belgrave House, 1 Greyfriars, Northampton NN1 2BS
Telephone: 01604 21233

10 **West Midlands**
McLaren Building, 2 Masshouse Circus, Queensway,
Birmingham B4 7NP
Telephone: 0121 200 2299

11 **Wales**
Brunel House, Nizalan Road, Cardiff CF2 1SH
Telephone: 02920 473777

12 **Marches**
The Marches House, Midway, Newcastle-under-Lyme,
Staffs ST5 1DT
Telephone: 01782 717181

13 **North Midlands**
Birkbeck House, Trinity Square, Nottingham NG1 4AU
Telephone: 0115 470712

14 **South Yorkshire**
Sovereign House, 40 Silver Street, Sheffield S1 2ES
Telephone: 0114 739081

15 **West and North Yorkshire**
8 St Paul's Street, Leeds LS1 2LE
Telephone: 0113 446191

16 **Greater Manchester**
Quay House, Quay Street, Manchester M3 3JB
Telephone: 0161 831 7111

17 **Merseyside**
The Triad, Stanley Road, Bootle L20 3PG
Telephone: 01229 922 7211

18 **North West**
Victoria House, Ormskirk Road, Preston PR1 1HH
Telephone: 01772 59321

19 **North East**
Arden House, Regent Centre, Gosforth, Newcastle upon Tyne NE3 3JN
Telephone: 0191 284 8448

20 **Scotland East**
Belford House, 59 Belford Road, Edinburgh EH4 3UE
Telephone: 0181 225 1313

21 **Scotland West**
314 St Vincent Street, Glasgow G3 8XG
Telephone: 0141 204 2646

Check the Health and Safety Executive Website: www.hse.gov.uk for the most up-to-date office addresses as they do change occasionally.

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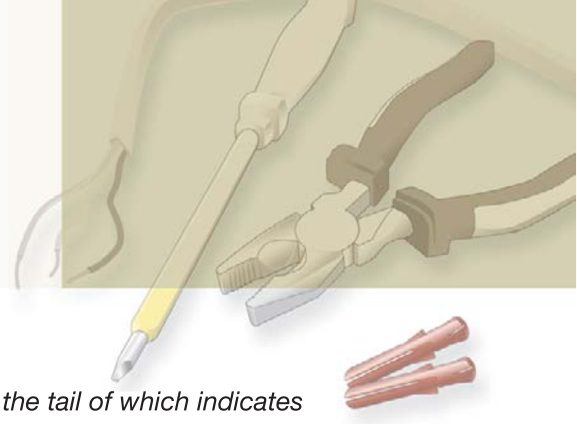
Glossary of terms



Activities *Activities are represented by an arrow, the tail of which indicates the commencement, and the head the completion of the activity*

Advantages of a d.c. machine *One of the advantages of a d.c. machine is the ease with which the speed may be controlled.*

Appointed person *An appointed person is someone who is nominated to take charge when someone is injured or becomes ill, including calling an ambulance if required. The appointed person will also look after the first aid equipment, including re-stocking the first aid box.*

As-fitted drawings *When the installation is completed a set of drawings should be produced which indicate the final positions of all the electrical equipment.*

Asphyxiation *Asphyxiation is a condition caused by lack of air in the lungs leading to suffocation. Suffocation may cause discomfort by making breathing difficult or it may kill by stopping the breathing.*

Assembly point *The purpose of an assembly point is to get you away from danger to a place of safety where you will not be in the way of the emergency services.*

Bar chart *There are many different types of bar chart used by companies but the object of any bar chart is to establish the sequence and timing of the various activities involved in the contract as a whole.*

Basic protection *Basic protection is provided by the insulation of live parts in accordance with Section 416 of the IEE Regulations.*

Bill of quantities *The size and quantity of all the materials, cables, control equipment and accessories. This is called a 'bill of quantities'.*

Block diagram *A block diagram is a very simple diagram in which the various items or pieces of equipment are represented by a square or rectangular box.*

Bonding *The linking together of the exposed or extraneous metal parts of an electrical installation.*

Bonding conductor *A protective conductor providing equipotential bonding.*

BS 5750/ISO 9000 certificate *A BS 5750/ISO 9000 certificate provides a framework for a company to establish quality procedures and identify ways of improving its particular product or service. An essential part of any quality system is accurate record-keeping and detailed documentation which ensures that procedures are being followed and producing the desired results.*

Cables *Most cables can be considered to be constructed in three parts: the* conductor*, which must be of a suitable cross-section to carry the load current; the* insulation*, which has a colour or number code for identification; and the* outer sheath *which may contain some means of providing protection from mechanical damage.*

Cable tray *Cable tray is a sheet-steel channel with multiple holes. The most common finish is hot-dipped galvanized but PVC-coated tray is also available. It is used extensively on large industrial and* *commercial installations for supporting MI and SWA cables which are laid on the cable tray and secured with cable ties through the tray holes.*

Cage rotor *The solid construction of the cage rotor used in many a.c. machines makes them almost indestructible.*

Calibration certificates *Calibration certificates usually last for a year. Test instruments must, therefore, be tested and recalibrated each year by an approved supplier.*

Capacitance *The property of a pair of plates to store an electric charge is called its* capacitance.

Capacitive reactance (X_C) Capacitive reactance (X_C) *is the opposition to an a.c. current in a capacitive circuit. It causes the current in the circuit to lead ahead of the voltage.*

Capacitor *By definition, a capacitor has a capacitance (C) of one farad (symbol F) when a p.d. of one volt maintains a charge of one coulomb on that capacitor.*

Cartridge fuse *The cartridge fuse breaks a faulty circuit in the same way as a semi-enclosed fuse, but its construction eliminates some of the disadvantages experienced with an open-fuse element.*

CFLs *CFLs (compact fluorescent lamps) are miniature fluorescent lamps designed to replace ordinary GLS lamps.*

Circuit diagram *A circuit diagram shows most clearly how a circuit works.*

Circuit Protective Conductor (CPC) *A protective conductor connecting exposed conductive parts of equipment to the main earthing terminal.*

Clean Air Act *The Clean Air Act applies to all small and medium sized companies operating furnaces, boilers, or incinerators.*

Competent person *A competent person is anyone who has the necessary technical skills, training and expertise to safely carry out the particular activity.*

Conductor *A* conductor *is a material in which the electrons are loosely bound to the central nucleus and are, therefore, free to drift around the material at random from one atom to another.*

Conduit *A conduit is a tube, channel or pipe in which insulated conductors are contained.*

Copper losses *Copper losses occur because of the small internal resistance of the windings.*

Copper losses and iron losses *As they have no moving parts causing frictional losses, most transformers have a very high efficiency, usually better than 90%. However, the losses which do occur in a transformer can be grouped under two general headings: copper losses and iron losses.*

Critical path *Critical path is the path taken from the start event to the end event which takes the longest time.*

Dangerous occurrence *Dangerous occurrence is a 'near miss' that could easily have led to serious injury or loss of life. Near miss accidents occur much more frequently than injury accidents and are, therefore, a good indicator of hazard, which is why the HSE collects this data.*

Daywork *Daywork is one way of recording* variations to a contract, *that is, work done which is outside the scope of the original contract. It is* extra work.

Delivery note *By signing the delivery note the person is saying 'yes, these items were delivered to me as my company's representative on that date and in good condition and I am now responsible for these goods'.*

Designer *The designer of any electrical installation is the person who interprets the electrical requirements of the customer within the regulations.*

Detail drawings and assembly drawings *These are additional drawings produced by the architect to clarify some point of detail.*

Direct current motors *Direct current motors are classified by the way in which the field and armature windings are connected, which may be in series or in parallel.*

Discharge lamps *Discharge lamps do not produce light by means of an incandescent filament but by the excitation of a gas or metallic vapour contained within a glass envelope.*

Disconnection and separation *We must ensure the disconnection and separation of electrical equipment from every source of supply and that this disconnection and separation is secure.*

Dummy activities *Dummy activities are represented by an arrow with a dashed line.*

Duty holder *Duty holder is someone who has a duty of care for health, safety and welfare matters on site.*

Duty of care *Everyone has a* duty of care *but not everyone is a* duty holder. *The person who exercises 'control over the whole system, equipment and conductors' and is the electrical company's representative on site is* the duty holder.

Earth *The conductive mass of the Earth whose electrical potential is taken as zero.*

Earthing *The act of connecting the exposed conductive parts of an installation to the main protective earthing terminal of the installation.*

Eddy currents *Eddy currents are circulating currents created in the core material by the changing magnetic flux. These are reduced by building up the core of thin slices or laminations of iron and insulating the separate laminations from each other.*

Efficacy *The performance of a lamp is quoted as a ratio of the number of lumens of light flux which it emits to the electrical energy input which it consumes. Thus* efficacy *is measured in lumens per watt; the greater the efficacy the better is the lamp's performance in converting electrical energy into light energy.*

Electricity At Work Act *The Electricity at Work Act tells us that it is 'preferable' that supplies be made dead before work commences (IEE Regulation 4(3)).*

Emergency lighting *Since an emergency occurring in a building may cause the mains supply to fail, the emergency lighting should be supplied from a source which is independent from the main supply.*

Emergency switching *Emergency switching involves the rapid disconnection of the electrical supply by a single action to remove or prevent danger.*

Employees *Employees have a duty to care for their own health and safety and that of others who may be affected by their actions.*

Employer *Under the Health and Safety at Work Act an employer has a duty to care for the health and safety of employees.*

Environmental conditions *Environmental conditions include unguarded or faulty machinery.*

Event *An event is a point in time, a milestone or stage in the contract when the preceding activities are finished.*

Exit routes *Exit routes are usually indicated by a green and white 'running man' symbol. Evacuation should be orderly; do not run but walk purposefully to your designated assembly point.*

Exposed conductive parts *This is the metalwork of an electrical appliance or the trunking and conduit of an electrical system.*

Extraneous conductive parts *This is the structural steelwork of a building and other service pipes such as gas, water, radiators and sinks.*

Fault *A fault is not a natural occurrence; it is an unplanned event which occurs unexpectedly.*

Fault protection Fault protection *is provided by protective equipotential bonding and automatic disconnection of the supply (by a fuse or MCB) in accordance with IEE Regulations 411.3 to 6.*

Fire extinguishers *Fire extinguishers remove heat from a fire and are a first response for small fires.*

Fire *Fire is a chemical reaction which will continue if fuel, oxygen and heat are present.*

First aid *First aid is the initial assistance or treatment given to a casualty for any injury or sudden illness before the arrival of an ambulance, doctor or other medically qualified person.*

First aider *A first aider is someone who has undergone a training course to administer first aid at work and holds a current first aid certificate.*

Flexible conduit *Flexible conduit is made of interlinked metal spirals often covered with a PVC sleeving.*

Float time, slack time or time in hand *Float time, slack time or time in hand is the time remaining to complete the contract after completion of a particular activity.*

Fluorescent lamp *A fluorescent lamp is a linear arc tube, internally coated with a fluorescent powder, containing a low-pressure mercury vapour discharge.*

FP 200 cable *FP 200 cable is similar in appearance to an MI cable in that it is a circular tube, or the shape of a pencil, and is available with a red or white sheath. However, it is much simpler to use and terminate than an MI cable.*

Functional switching *Functional switching involves the switching on or off or varying the supply of electrically operated equipment in normal service.*

Fuse element *The fuse element is encased in a glass or ceramic tube and secured to end-caps which are firmly attached to the body of the fuse so that they do not blow off when the fuse operates.*

GLS lamps *GLS lamps produce light as a result of the heating effect of an electrical current. Most of the electricity goes to producing heat and a little to producing light. A fine tungsten wire is first coiled and coiled again to form the incandescent filament of the GLS lamp.*

Hazardous malfunction *If a piece of equipment was to fail in its function, that is fail to do what it is supposed to do and, as a result of this failure have the potential to cause harm, then this would be defined as a hazardous malfunction.*

HBC cartridge fuses *As the name might imply, these HBC (high breaking capacity) cartridge fuses are for protecting circuits where extremely high fault currents may develop such as on industrial installations or distribution systems.*

Human errors *Human errors include behaving badly or foolishly, being careless and not paying attention to what you should be doing at work.*

Hysteresis loops *Some materials magnetize easily, and some are difficult to magnetize. Some materials retain their magnetism, while others lose it.*

Impedance *The total opposition to current flow in an a.c. circuit is called impedance and given the symbol Z.*

Improvement notice *An* improvement notice *identifies a contravention of the law and specifies a date by which the situation is to be put right.*

Induction heating processes *Induction heating processes use high-frequency power to provide very focused heating in industrial processes.*

Induction motor rotor *There are two types of induction motor rotor – the wound rotor and the cage rotor.*

Inductive reactance (X_L) Inductive reactance (X_L) *is the opposition to an a.c. current in an inductive circuit. It causes the current in the circuit to lag behind the applied voltage.*

Insulator *An* insulator *is a material in which the outer electrons are tightly bound to the nucleus and so there are no free electrons to move around the material.*

Inverse square law *The illumination of a surface follows the* inverse square law, *where* $E = \frac{I}{d^2}$ (lx)

Investors in people *Investors in People is a national quality standard that focuses on the needs of the people working within an organization. It recognizes that a company or business is investing some of its profits in its workforce in order to improve the efficiency and performance of the organization. The objective is to create an environment where what people can do and are motivated to do, matches what the company needs them to do to improve.*

Iron losses *Iron losses are made up of* hysteresis loss *and* eddy current loss*. The hysteresis loss depends upon the type of iron used to construct the core and consequently core materials are carefully chosen.*

Isolation *Isolation means the disconnection and separation of the electrical equipment from every source of electrical energy in such a way that this disconnection and separation is secure.*

Isolator *An isolator is a mechanical device that is operated manually and is provided so that the whole of the installation, one circuit or one piece of equipment, may be cut off from the live supply.*

Job sheet or job card *A job sheet or job card carries information about a job which needs to be done, usually a small job.*

Layout drawings or site plan *These are scale drawings based upon the architect's site plan of the building and show the positions of the electrical equipment which is to be installed.*

Low smoke and fume cables *Low smoke and fume cables give off very low smoke and fumes if they are burned in a burning building. Most standard cable types are available as LSF cables.*

Lumen method *When designing interior lighting schemes the method most frequently used depends upon a determination of the total flux required to provide a given value of illuminance at the working place. This method is generally known as the* lumen method*.*

Manual handling *Manual handling is lifting, transporting or supporting loads by hand or by bodily force.*

Metallic trunking *Metallic trunking is formed from mild steel sheet, coated with grey or silver enamel paint for internal use or a hot-dipped galvanized coating where damp conditions might be encountered.*

Michael Faraday *Michael Faraday demonstrated on 29 August 1831 that electricity could be produced by magnetism. He stated that* 'When a conductor cuts or is cut by a magnetic field an e.m.f. is induced in that conductor. The amount of induced e.m.f. is proportional to the rate or speed at which the magnetic field cuts the conductor'*.*

MI cable *An MI cable has a seamless copper sheath which makes it waterproof and fire- and corrosion-resistant. These characteristics often make it the only cable choice for hazardous or high-temperature installations.*

Mini-trunking *Mini-trunking is very small PVC trunking, ideal for surface wiring in domestic and commercial installations such as offices.*

Motor starter *The purpose of the motor starter is not to start the machine, as the name implies, but to reduce heavy starting currents and provide overload and no-volt protection in accordance with the requirements of Regulation 552.*

Mutual inductance *A mutual inductance of 1 H exists between two coils when a uniformly varying current of 1 A/s in one coil produces an e.m.f. of 1 V in the other coil.*

Network diagram *A network diagram can be used to co-ordinate all the interrelated activities of the most complex project.*

Ohm's law *Ohm's law, which says that the current passing through a conductor under constant temperature conditions is proportional to the potential difference across the conductor.*

Overload current *An overload current can be defined as a current which exceeds the rated value in an otherwise healthy circuit.*

Paper insulated lead covered steel wire armour cables *Paper insulated lead covered steel wire armour cables are only used in systems above 11 kV. Very high-voltage cables are only buried underground in special circumstances when overhead cables would be unsuitable, for example, because they might spoil a view of natural beauty.*

Permit-to-work procedure *The permit-to-work procedure is a type of 'safe system to work' procedure used in specialized and potentially dangerous plant process situations.*

Power factor *The power factor of the consumer is governed entirely by the electrical plant and equipment that is installed and operated within the consumer's buildings.*

Power factor improvement *Power factor improvement of most industrial loads is achieved by connecting capacitors to either:*

- *individual items of equipment or,*
- *banks of capacitors*

PPE *PPE is defined as all equipment designed to be worn, or held, to protect against a risk to health and safety.*

Prohibition notice *A* prohibition notice *is used to stop an activity which the inspector feels may lead to serious injury.*

Protective equipotential bonding *This is equipotential bonding for the purpose of safety.*

Public nuisance *A public nuisance is 'an act unwarranted by law or an omission to discharge a legal duty which materially affects the life, health, property, morals or reasonable comfort or convenience of Her Majesty's subjects'.*

Pulsating field *Once rotation is established, the pulsating field in the run winding is sufficient to maintain rotation and the start winding is disconnected by a centrifugal switch which operates when the motor has reached about 80% of the full load speed.*

PVC insulated steel wire armour cables *PVC insulated steel wire armour cables are used for wiring underground between buildings, for main supplies to dwellings, rising sub-mains and industrial installations. They are used where some mechanical protection of the cable conductors is required.*

Quality *Quality generally refers to the level of excellence, but in the business sense it means meeting the customer's expectations regarding performance, reliability and durability.*

RCD *An RCD is a type of circuit breaker that continuously compares the current in the line and neutral conductors of the circuit.*

Rectification *Rectification is the conversion of an a.c. supply into a unidirectional or d.c. supply.*

Resistance *In any circuit,* resistance *is defined as opposition to current flow.*

Resistivity *The* resistivity *(symbol ρ – the Greek letter 'rho') of a material is defined as the resistance of a sample of unit length and unit cross-section.*

Resistor *All materials have some resistance to the flow of an electric current but, in general, the term* resistor *describes a conductor specially chosen for its resistive properties.*

Safety Officer The Safety Officer *will be the specialist member of staff, having responsibility for health and safety within the company. He or she will report to the senior manager responsible for health and safety.*

Schematic diagrams *A schematic diagram is a diagram in outline of, for example, a motor starter circuit.*

Semi-enclosed fuse *The semi-enclosed fuse consists of a fuse wire, called the fuse element, secured between two screw terminals in a fuse carrier.*

Shock protection _Protection from electric shock is provided by basic protection and fault protection._

Short circuit _A short circuit is an overcurrent resulting from a fault of negligible impedance connected between conductors._

Single PVC insulated conductors _Single PVC insulated conductors are usually drawn into the installed conduit to complete the installation._

Skirting trunking _A trunking manufactured from PVC or steel and in the shape of a skirting board is frequently used in commercial buildings such as hospitals, laboratories and offices._

Socket outlets _Socket outlets provide an easy and convenient method of connecting portable electrical appliances to a source of supply._

Space factor _The ratio of the space occupied by all the cables in a conduit or trunking to the whole space enclosed by the conduit or trunking is known as the_ space factor.

Special waste _Special waste is covered by the Special Waste Regulations 1996 and is waste that is potentially hazardous or dangerous and which may, therefore, require special precautions during handling, storage, treatment or disposal. Examples of special waste are asbestos, lead-acid batteries, used engine oil, solvent-based paint, solvents, chemical waste and pesticides._

Static charge _Static charge builds up between any two insulating surfaces or between an insulating surface and a conducting surface, but it is not apparent between two conducting surfaces._

Static electricity _Static electricity is a voltage charge which builds up to many thousands of volts between two surfaces when they rub together._

Statutory nuisance _'A statutory nuisance must materially interfere with the enjoyment of one's dwelling. It is more than just irritating or annoying and does not take account of the undue sensitivity of the receiver'._

Steel wire armoured _Steel wire armoured PVC insulated cables are now extensively used on industrial installations and often laid on cable tray._

Switching for mechanical maintenance _The switching for mechanical maintenance requirements is similar to those for isolation except that the control switch must be capable of switching the full load current of the circuit or piece of equipment._

Team working _Team working is about working with other people._

Test instruments and test leads _The test instruments and test leads used by the electrician for testing an electrical installation must meet all the requirements of the relevant regulations._

The safety representative The safety representative _will be the person who represents a small section of the workforce on the Safety Committee. The role of the safety representative will be to bring to the Safety Committee the health and safety concerns of colleagues and to take back to colleagues information from the Committee._

Three-phase supply _If a three-phase supply is connected to three separate windings equally distributed around the stationary part or stator of an electrical machine, an alternating current circulates in the coils and establishes a magnetic flux._

Time sheet _A time sheet is a standard form completed by each employee to inform the employer of the actual time spent working on a particular contract or site._

Transformer _A transformer is an electrical machine which is used to change the value of an alternating voltage. Transformers vary in size from miniature units used in electronics to huge power transformers used in power stations._

Transformers rating _Transformers are rated in kVA (kilovolt-amps) rather than power in watts because the output current and power factor will be affected by the load connected to the transformer._

Trunking *Trunking is an enclosure provided for the protection of cables which is normally square or rectangular in cross-section, having one removable side. Trunking may be thought of as a more accessible conduit system.*

Universal motor *A series motor will run on both a.c. or d.c. and is, therefore, sometimes referred to as a 'universal' motor.*

UPS *A UPS is essentially a battery supply, electronically modified to provide a clean and secure a.c. supply.*

Visual inspection *The aim of the visual inspection is to confirm that all equipment and accessories are undamaged and comply with the relevant British and European standards, and also that the installation has been securely and correctly erected.*

Wiring diagram *A wiring diagram or connection diagram shows the detailed connections between components or items of equipment.*

Written messages *A lot of communications between and within larger organizations take place by completing standard forms or sending internal memos.*

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