



NEBOSH International General Certificate in Occupational Health and safety



Element 11

Electrical safety

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11.0 Learning outcomes

The learner should be able to:

- Do a general risk assessment in their own workplace – profiling and prioritising risks, inspecting the workplace, recognising a range of common hazards, evaluating risks (taking account of current controls), recommending further control measures, planning actions.

5-11 Produce a risk assessment of a workplace which considers a wide range of identified hazards (drawn from elements 5-11) and meets best practice standards (*'suitable and sufficient'*).

11.1 Hazards and Risks

Introduction

Electricity is energy made available by the flow of electrons through a conductor (a conductor is a material that allows electron flow – explained later).

To understand how electrons flow through a conductor it is necessary to understand the structure of atoms.

Everything is made up of atoms, they are the building blocks of all matter. Atoms consist of a central nucleus made up of protons and neutrons which is orbited by rings of electrons.

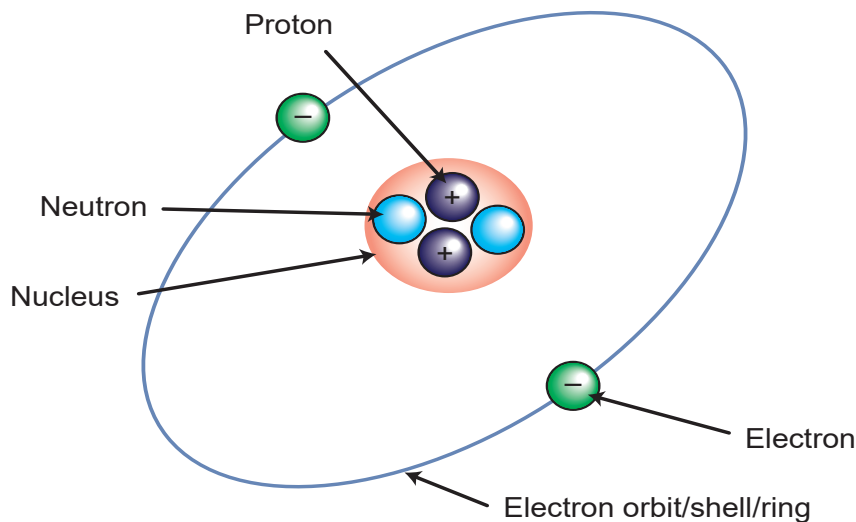


Figure 11.1: Atom

Protons and neutrons both have a mass, neutrons are electrically neutral and protons are positively charged, giving the nucleus a net positive charge. The number of protons and neutrons in a nucleus determines the atomic mass which is different for different elements.

Electrons have negligible mass and a negative charge. The natural state for an atom is to be electrically balanced, *i.e.* to have the same number of negative charges (electrons) as positive charges (protons).

The electrons orbit the nucleus in rings or orbits. Those closest to the nucleus are bound to it by strong electromagnetic attraction (positive attracts negative), but those in the outer ring (known as valence or free electrons) are less strongly attracted and are free to 'move' from atom to atom. This movement of electrons from atom to atom is known as electron flow.

Electron flow along a conductor is called a *current*. The current or rate of electron flow (numbers of electrons passing a point per second) is measured in amperes (amps) (symbol I).

For electrons to flow along a conductor a pressure must be applied, which comes from energy source (e.g. a battery) or mains power supply.

Conductor –

any material that easily allows electrons to flow
Insulator - any material that inhibits the flow of electrons

The power supply has the ability to pull electrons out of a circuit and push them back in the other side of the circuit. These negative and positive forces present at the terminals of the power supply give it the potential to do work.

The difference in positive and negative potential between the terminals of a power supply (potential difference) is measured in units of volts (symbol V).

Higher *voltage* results in greater current flow.

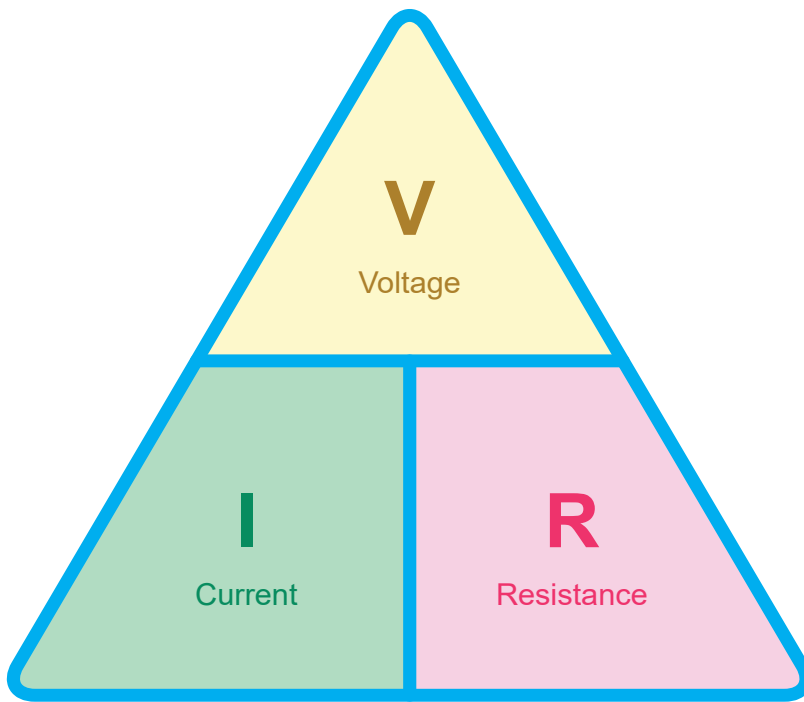
All materials, including conductors, will afford some resistance to the flow of electrons. *The resistance* of a conductor is measured in ohms (Ω) (symbol R).

The resistance of a circuit depends on a number of factors, namely:

- the length of a conductor – an increase in length results in an increase in resistance
- the cross-sectional area of the conductor – the greater the cross-sectional area, the lower the resistance
- the conductivity of the material used – some materials are better conductors than others (e.g., silver is a better conductor than copper)
- temperature – for most materials, the hotter the material, the greater its resistance
- physical condition – any damage to the conductor will increase its resistance.

There is a direct relationship between voltage, current and resistance. If a circuit has a resistance (R) of 1 ohm and a voltage (V) of 1 volt is applied a current (I) of 1 ampere will flow. This is known as Ohm's law which states that:

'The value of a current passing through a conductor is directly proportional to the potential difference between the ends of the conductor, and inversely proportional to the resistance of the conductor.'



$$V = I \times R$$

$$I = \frac{V}{R}$$

$$R = \frac{V}{I}$$

Figure 11.2: Ohms law

The water analogy

An analogy can be drawn between electricity flowing in a circuit and water flowing through a pipe.

- The water pressure equates to the voltage
- The water flow rate equates to the current
- The pipe will also offer resistance to the water flow depending on its bore (diameter)
- A water pump compares to a DC battery. Water leaves the pump under high pressure and returns to feed the pump at low pressure. The current leaving the positive terminal of the battery into the live or phase conductor is under high pressure and the current returning to the negative terminal through the neutral conductor is at low pressure.

Alternating and Direct Currents (AC and DC)

Direct Current (DC) is produced by batteries. When a circuit is completed the current flows in one direction only, at a specific, constant voltage.

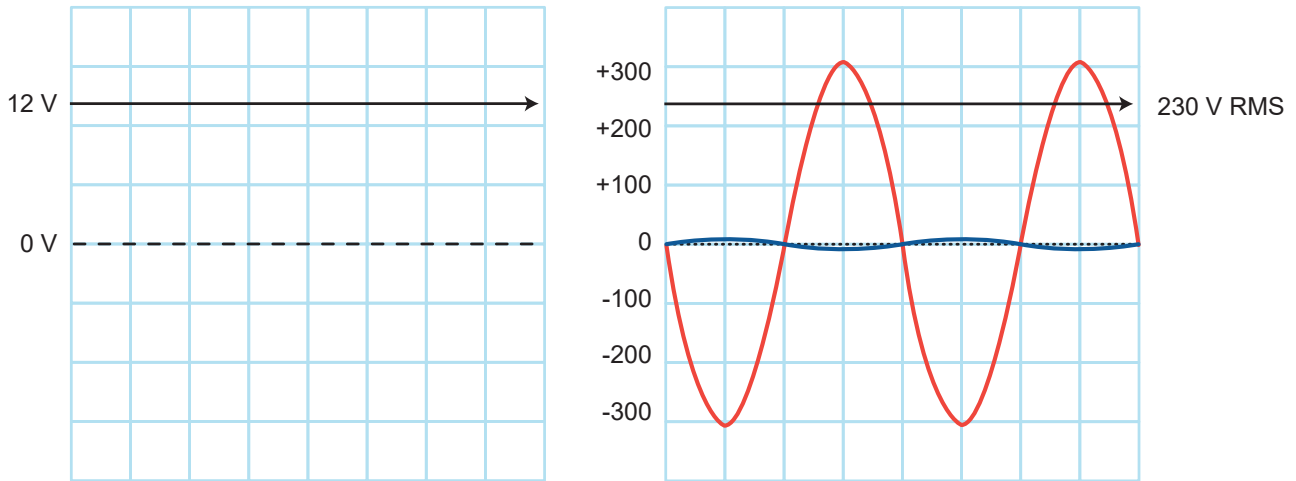


Figure 11.3: Direct and Alternate current

The European Union, and Australia mains supply is 230V at a frequency of 50 Hertz (Hz) ($\pm 6\%$). In the USA and Canada the standard mains supply is 120V at 60 Hz. ($\pm 5\%$). Some other examples are shown in table 11.1.

Country	Voltage	Frequency	Notes
Australia	230 V	50Hz	Historically 240V as per UK.
Brazil	110 / 220V	60Hz	*127 V found in states of Bahia, Paraná (including Curitiba), Rio de Janeiro, São Paulo and Minas Gerais (though 220 V may be found in some hotels). Other areas are 220 V only, with the exception of Fortaleza (240 V).
Canada	120V	60Hz	Smaller buildings (like houses) are supplied with 240/120V split-phase with 240V being used for large loads and 120V for all else.
European Union (EU)	230V	50Hz	Standardised to accommodate the range of 220V to 240V.
India	230V	50Hz	

Country	Voltage	Frequency	Notes
Kenya	240V	50Hz	
South Africa	220 / 230V	50Hz	250V in Grahamstad, Port Elizabeth, and King Williams.
United Arab Emirates (UAE)	220V	50Hz	
United Kingdom (UK)	230V	50Hz	The historical voltage in the UK was 240V. This is within tolerances and is still commonly found.
United States of America (USA)	120V	60Hz	Large residential buildings frequently have 120/208V 3-phase power, with large appliances being connected between two of the phases, giving a voltage of 208 volts.

Table 11.1: Examples of Mains Voltages and Frequencies

A frequency of 50 Hz means that the flow of electrons changes direction and back again 50 times per second. This is usually represented in a diagram (Figure 11.3) as a sine wave.

The wave peaking at around +/- 300 V represents the potential difference at the live terminal. The almost flat wave at around 0 V represents the potential difference at the neutral terminal.

The 230 V figure is an average voltage. The peak voltage is higher.

Hazards, risks and danger of electricity

Burns]	From contact with a live conductor.
Shock		NB mains electricity (230 V AC) can kill.
Arcing		Arcing occurs when electricity flows through the air from one conductor to another. Arcing may cause burns or shock if a person is the second conductor or is close to the arc. Arcing produces intense heat which may cause a fire or explosion.
Fire and Explosion]	Electricity could be the source of ignition in a potentially flammable or explosive atmosphere.

(These can be remembered as **B-SAFE**)

Electric burn

Electric burns are different from burns due to fire, arcing or explosion.

Electric burns are due to the heating effect caused by the passage of electric current through body tissues. They are most commonly associated with electric shock and often occur in and on the skin layers at the point of contact with the electrical conductors which gave rise to the electric shock.

Like electric shocks, burns can be caused by both direct and indirect contact. The term indirect contact refers specifically to contact with an exposed conductive part under fault conditions.

Due to the body's resistance to electricity, the current can cause extensive and deep burns. Voltage levels of 500 to 1000 volts tend to cause internal burns due to the large energy available from the source. In most cases of high-energy electrical trauma, heating in the deeper tissues along the extremity will reach damaging temperatures within a few seconds.

Electric burns are usually painful and very slow to heal. Permanent scarring is common.

Electric shock

The human body responds in several ways to electrical current flowing through it. The sensation of shock is only one such effect and this can be extremely painful. When a shock is received, the electric current may take multiple paths through the body and its intensity

at any one point is difficult or impossible to predict. The passage of electric current may cause muscular contractions, respiratory failure, and fibrillation of the heart, cardiac arrest or injury from internal burns. Any of these can be fatal.

The nature and severity of injury depends upon the magnitude, duration and path of the current through the body and, in the case of alternating current, on its frequency. It is not possible to identify precise thresholds for the existence of hazard because a judgement has to be made in each case taking all the circumstances into account such as body weight, physical condition of the victim and so forth. Quite low currents, of the order of only a few milliamps, can cause fatal electric shock.

Factors which mainly influence the likely effect of shock current are its voltage, frequency, duration and any impedance (or resistance) in the current path.

The higher the current, the more likely it is to be lethal. If the current pathway passes through the head or heart muscle, it increases the risk of death.

The longer the duration of the shock, the more likely it is to be fatal.

As current is proportional to voltage, when resistance is fixed (Ohm's Law – Figure 11.2), high voltage is an indirect risk for producing higher current. Very high frequency electric current causes tissue burning but is incapable of penetrating the body far enough to cause cardiac arrest, hence the use of high-frequency current devices in electro-surgery to prevent blood loss in hospital operating theatres and outpatient procedures.

The effects of electric shock are most acute at about the public electricity supply frequency of 50 hertz. Susceptibility to electric shock is increased if a person is in good electrical contact with earth, such as in damp or wet conditions or in conducting locations such as inside a metal tank. Hot environments where people may become damp due to perspiration or humidity, thus reducing the insulation protection offered by clothing, may present an increased risk from electric shock.

The conventional public electricity supply voltage of 230 volts 50 hertz a.c. should always be considered as potentially fatally dangerous. Many fatal electric shock accidents have occurred from contact with conductors live at this voltage and possibly the most dangerous situation is where contact is made with conductors by each hand, current then flowing '*hand to hand*' across the heart region.

Arcing

Arcing causes a particular type of burn injury which is distinct from other types. Arcing generates ultra violet radiation which causes damage akin to severe sunburn. Molten metal particles from the arc itself can penetrate, burn and lodge in the flesh. These effects are additional to any radiated heat damage caused by the arc.

On its own, ultra violet radiation can cause damage, sensitive skin and eyes are especially vulnerable to arc flash. ('Arc eye' is commonly encountered with electric arc welding if the proper precautions are not adopted.)

Arcing faults can occur if the energy available at a piece of electrical equipment is sufficient to maintain a conductive path through the air or insulation between two conductors which are at different potentials. Under fault flashover conditions, currents many times the nominal rating or setting of a protective device may flow before those devices operate to clear the fault.

Much energy is dissipated in the arc and depending on the electrical protection, may continue long enough to inflict very serious arcing burns or to initiate a fire in periods for example as short as 0.25 second, which is not an untypical minimum time for fault clearance. Arc flashovers caused during work on live circuit conductors are likely to be particularly hazardous because the worker is likely to be very near to or even enveloped by the arc. Such cases often lead to very serious, sometimes fatal, burn injuries.

Fires of an electrical origin

Fires may be started by electricity in a number of ways. The principal mechanisms are:

- a. overheating of cables and electrical equipment due to overloading of conductors
- b. leakage currents due to poor or inadequate insulation
- c. overheating of flammable materials placed too close to electrical equipment which is otherwise operating normally
- d. the ignition of flammable materials by arcing or sparking of electrical equipment, including the scattering of hot particles from electrical equipment.

Note:

overheating of portable devices, or their chargers, when charging is now a common fire ignition source

The injuries associated with fire are usually burns but may include other injuries such as smoke inhalation.

Explosion

In this category are those injuries caused by explosions either of an electrical nature or those whose source of ignition is electrical.

Electrical explosions include the violent and catastrophic rupture of any electrical equipment. Switchgear, motors and power cables are liable to explode if they are subjected to excessive currents, which release violent electromagnetic forces and dissipate heat energy, or if they suffer prolonged internal arcing faults.

Explosions whose source of ignition is electrical include ignition of flammable vapours, gases, liquids and dusts by electric sparks, arcs or the high surface temperature of electrical equipment.

High risks associated with electricity

The following activities are considered to be higher risk:

- a. use of poorly maintained equipment
- b. work near overhead power lines
- c. contact with underground power cables
- d. work on 230 V mains electricity supplies
- e. use of electrical equipment in wet environments.

a. Use of poorly maintained equipment

Nearly a quarter of all reportable electrical accidents involve portable equipment. The vast majority of these accidents result in electric shock.

Typical faults and bad practices that have been identified as causes of accidents involving portable electrical equipment include:

- failure to select the right equipment for the job and/or environment, inadequate checks on the equipment before use to ensure it was not damaged
- a lack of regular maintenance to keep equipment in safe working order
- unauthorised repairs leaving the equipment in a dangerous condition
- incorrect fuse rating
- poor earth protection
- failure to use residual current device
- overloading of sockets
- use of defective cables which were split, twisted, kinked or jointed
- poor cable management resulting in trailing cables
- the use of long unprotected cables that were damaged in use
- plugs with bent pins or broken cases.

b. Work near overhead power lines

Contact with live overhead lines kills people and causes serious injuries every year. A high proportion – about one third – of inadvertent line contacts prove fatal.

Contact with overhead electric lines can be lethal whether they are carrying a voltage as high as 400 000 V (400 kV) or as low as 230 V.

Overhead lines consist usually of uninsulated cables supported via insulators on wooden poles or metal towers.

If a crane jib, excavator, scaffold pole, ladder, or similar comes into contact with, or gets too close to the lines, an electric current can arc and/or flow with a risk of fatal or severe shock and burns. The risk of arcing (or flashover) increases with line voltage.

Insulating materials such as wood or plastic may also be capable of transmitting dangerous current to if dirty and damp.

Work on 230 V mains electricity supplies

Most electrical accidents occur because people are working on or near equipment that is:

- thought to be dead but which is live
- known to be live but those involved do not have adequate training or the appropriate equipment, or they have not taken adequate precautions.

c. Contact with underground power cables

Injuries are usually caused by the explosive effects of arcing current, and by any associated fire or flames which may result, when a live cable is penetrated by a sharp object or crushed severely enough to cause internal contact between the conductors.

Injuries are typically severe, potentially fatal, burns to the hands, face and body. Direct electric shock is less likely.

Other nearby services, such as plastic gas pipes, may also be at risk from damaged live electricity cables. This could result in explosions and a greater fire risk.

d. Use of electrical equipment in wet environments

Electrical equipment may be exposed to the elements, including rain and surface water in external workplaces such as construction sites or may be used in workplaces that are naturally wet or humid, e.g. laundries, slaughterhouses, kitchens, swimming pools.

Electrical equipment may also be used to apply water or steam under pressure (e.g. jet washing or steam cleaning).

11.2 Control measures

The legal framework for controlling the risks of working with electrical equipment and circuitry are contained within the Electricity at Work Regulations 1989 (EAWR).

The main duties are held by the employer, though employees have duties to cooperate with the employer and to comply directly with requirements for any matters under their control.

The general duties require the employer, so far as is reasonably practicable to ensure that:

- electrical systems are constructed so as not to give rise to danger
- electrical systems are maintained so as not to give rise to danger
- every work activity, including operation, use and maintenance of a system and work near a system, is carried so as not to give rise to danger
- protective equipment is suitable for the use for which it is provided, maintained in good condition and properly used.

The relationship between these general duties and the more specific requirements is shown in Figure 11.4. Some of the key requirements are discussed in detail later.

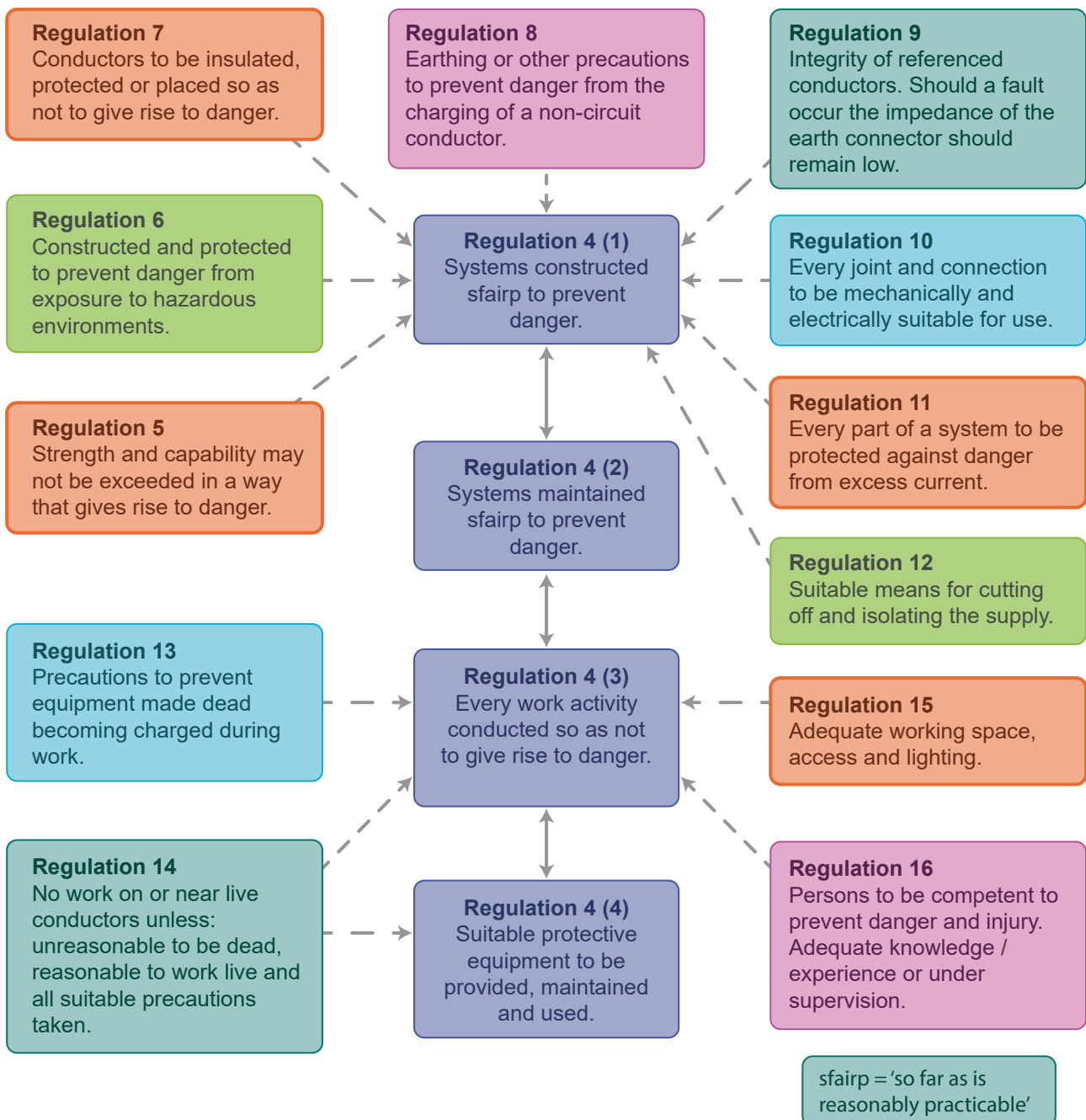


Figure 11.4: Key requirements of EAWR

Insulation, protection and placing of conductors

All conductors in a system should be:

- suitably covered with insulating material and otherwise protected so as to prevent danger
- be suitably placed or have other suitable precautions to prevent danger.

Suitable insulation of the conductors in an electrical system is typically the primary safeguard to prevent danger from electric shock. It will also prevent danger from fire and explosion arising from contact of conductors either with each other or with earth.

The insulation may require protection from mechanical damage. Such protection would include the use of steel trunking and conduits or the use of steel armoured cables.

Examples where bare conductors are used in conjunction with suitable precautions are to be found in many applications including overhead electric power lines and railway electrification.

Suitable placing of the conductors *e.g.* at such an overhead height that contact is not reasonably foreseeable or within a secure enclosure will go a considerable way towards preventing danger.

Strength and capability

The term '*strength and capability*' of electrical equipment refers to the ability of the equipment to withstand the thermal, electromagnetic and electro-chemical effects of the electrical currents which might be expected to flow through them.

These currents include typical load currents, transient overloads, and fault currents.

Insulation must be effective to enable the equipment to withstand the applied voltage and any likely transient over-voltages.

Most electrical equipment is only be able to withstand short-circuit currents safely for a short period so additional over-current protection will be required.

Protection against electric shock under fault conditions

Precautions are required to prevent danger when a conductor (other than a circuit conductor) becomes charged as a result of the use of a system, or a system fault.

Depending on the circumstances this may involve introducing precautions to:

- ensure that such conductors do not become charged
- ensure that if a conductor does become charged the values of voltage and current and the duration are such that danger will not arise.

A range of techniques may be used individually or in combinations, including:

- a. earthing
- b. fuses, mini circuit breakers (MCB) and residual current devices (RCD)
- c. double insulation
- d. use of safe voltages.

Earthing

Earthing the exposed metal parts of an appliance (which should not normally carry a current) provides a low resistance path to earth for any fault current. An electric current will always try to find the path of least resistance to earth (zero potential) and the earth wire is designed to provide a more efficient route than a human being.

Many 230/400 V power installations are so designed so that an earth fault triggers the automatic interruption of the supply by fuses or automatic circuit breakers. Such installations will require regular testing to ensure that the protective devices will work in the event of an earth fault.

Fuses, MCBs and RCDs

Fuse

A fuse is a method of overcurrent protection and contains a piece of wire that melts easily. If a fault in an appliance causes too much current flow through the fuse the wire heats up until it melts and breaks the circuit.

The fuse is designed to protect the wiring and the appliance if a fault occurs.



Fuses operate too slowly to provide protection against electric shock and are easy to replace with incorrectly rated fuses or other metal ‘bridges’ such as nails, screws or bolts.

MCB

An MCB is another method of overcurrent protection and does the same job as a fuse, but works in a different way. A spring-loaded push switch is held in the closed position by a spring-loaded soft iron bolt. An electromagnet is arranged so that it can pull the bolt away from the switch if the current increases beyond a set limit. This releases the push switch into the open position and breaks the circuit.

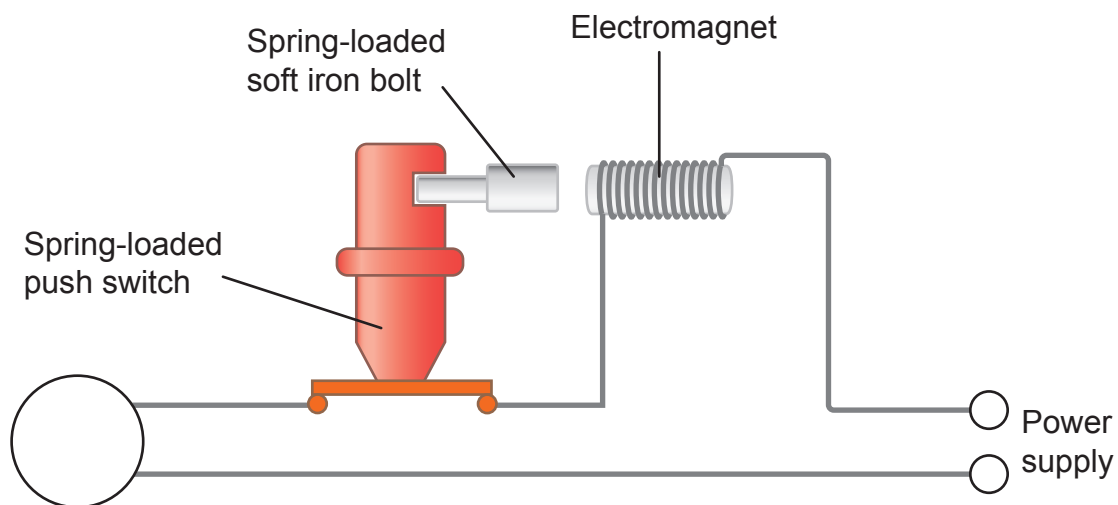


Figure 11.5: MCB

RCD

RCD is a generic term which embraces a range of related devices. An RCD works by constantly monitoring the current flowing in the live and neutral wires supplying a circuit or piece of equipment. Under normal circumstances, the current flowing in the live and neutral wires is equal. When an earth leakage occurs due to a fault an imbalance occurs. The imbalance is detected by the RCD, which automatically cuts off the power before injury or damage can result.

RCD'S for protecting people have a rated tripping current (sensitivity) of not more than 30 milliamps (mA) and a non-adjustable rated operating time of 200 milliseconds (ms) at a test current of 30 mA, and 40 ms at 150 mA.

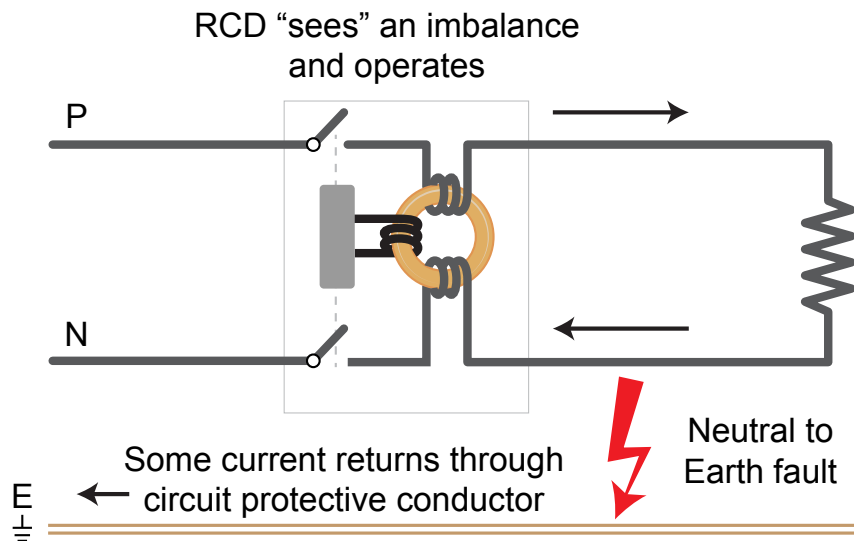


Figure 11.6: RCD

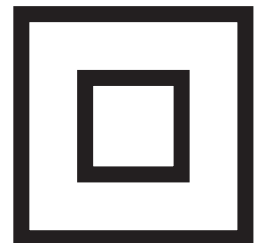
Double insulation

'Double insulation' covers the live conductors of electrical equipment with two discrete layers of insulation. Each layer would adequately insulate the conductor but together greatly reduces the probability of danger arising from insulation failure.

Double insulation eliminates the need for an earthing protective conductor and has been found to be useful for portable electric motor driven tools.

Double insulated equipment is labelled as Class II or double insulated and marked with the double insulation symbol of a box within a box.

The integrity of the protection depends on the layers of insulation remaining in sound condition and that the equipment is properly constructed, used and maintained.



Safe voltages

Reduced voltage systems are particularly appropriate for portable equipment in the following circumstances:

- highly conducting locations e.g. boilers and tunnels
- high risk of mechanical damage to equipment and trailing cables
- where the body may be damp and have large areas of contact with the conductor.

Keeping the supply voltage as low as is able to do the job combats risk at source and provides a safer solution.

The use of 110 V CTE (Centre Tapped to Earth) supply (Reduced Low Voltage) is advocated in the UK for harsh environments such as construction sites. The centre tap to earth ensures that in a single phase system the maximum voltage to earth is only 55 V.

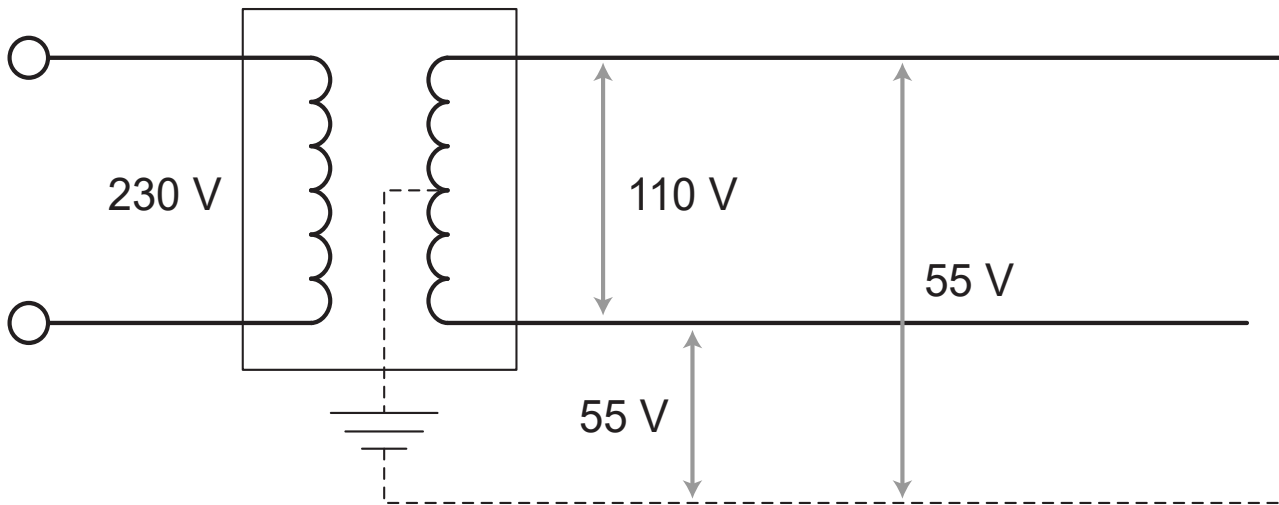


Figure 11.7: Step down transformer and 110 V CTE Supply

SELV systems (Safety or Separated Extra Low Voltage) are separated from earth and have a limited voltage of 50 V. SELV is typically used for lighting systems on construction sites. SELV would be impractical for most power tools especially those with motors or requiring long cables.

Battery powered tools are available with 12 V, 25 V and 36 V DC battery packs. These may be considered the safest option as in addition to the low voltage they are not encumbered by power cables. The trade-off is that the power available may not be sufficient for the job.

Competent persons

Electrical work should only be undertaken by persons with sufficient technical knowledge or experience to prevent danger or injury, or should be undertaken with an appropriate level of supervision having regard to the nature of the work.

No one should be placed at risk due to a lack of skills on their own part or on the part of others dealing with electrical equipment.

The scope of *'technical knowledge or experience'* may include:

- a. adequate knowledge of electricity
- b. adequate experience of electrical work
- c. adequate understanding and practical experience of the type of system to be worked on

- d. understanding of the hazards which may arise during the work and the corresponding precautions
- e. ability to recognise whether it is safe for work to continue.

Employees should be trained and instructed to ensure that they understand the safety procedures which are relevant to their work and should work in accordance with those procedures.

Where a person's technical knowledge or experience is not sufficient to ensure that they can undertake the work safely the work should be conducted under supervision.

Supervision does not necessarily require continual attendance at the work site, but the level and manner of supervision should be sufficient to prevent danger.

The responsibilities of the supervisor should be clearly defined. Where the risks are low, verbal instructions may be adequate but as the risk or complexity increases written procedures will be required.

Safe working practices

Most electrical accidents occur because people are working on or near equipment that is:

- thought to be dead but which is live
- known to be live but those involved do not have adequate training or appropriate equipment, or they have not taken adequate precautions.

The appropriate safe working practice can be determined by establishing whether to work dead or work live and planning and preparing appropriate procedures for the work.

Work on or near live conductors

Work on or near live conductors should be the exception to the rule. Live working should only be permitted if:

- *It is unreasonable in all the circumstances for the conductor to be dead.* Examples might include commissioning a complex control cabinet, fault finding or where a Distribution Network Operator (DNO) connects a new low-voltage service to an existing main.
- *It is reasonable in all the circumstances for the person to be at work on or near that conductor while it is live* – This decision should not be taken lightly. The economic and operational factors should be evaluated against the risks involved, bearing in mind that the risk of shock or burns from working live is high.
- *Suitable precautions (including, where necessary, the provision of personal protective equipment) have been taken to prevent injury* – this would include:
 - temporary insulation or protective barriers should be installed
 - for work that is ‘near’ rather than ‘on’ live equipment suitable safety clearances should be established and maintained
 - only competent people should be involved in undertaking the work
 - adequate working space should be assured
 - adequate lighting should be provided
 - properly insulated tools should be used
 - suitable protective clothing and equipment should be provided and used e.g. a cable joiner would need insulating gloves and insulating rubber matting
 - not working alone, the worker should be accompanied by someone who is in a safe position, and is competent to avoid injury, help disconnect the supply and render first aid or contact emergency assistance.

Planning, preparation and procedures

1. Identify the electrical system and the work to be done

Adequate information should be available about the electrical system and the work to be done.

In the case of a newly constructed system, or newly installed equipment, there should be up to date drawings and schedules as provided by the installers.

With old installations it may be necessary to update information through a combination of surveying, testing and labelling of the installation.

It may be unwise to rely solely on one source of information, e.g. a label.

When the equipment and work to be done has been identified, it is necessary to decide whether to work dead or work live, although it must be stressed that working dead should be the norm.

2. Plan the work

Planning requires a disciplined way of thinking by the person in charge of the work and demands that five important factors are considered:

- the work to be done
- the hazards of the system or equipment to be worked on
- the people doing the work and the level of supervision necessary
- the precautions to be taken
- the system of work to be employed.

3. Specify correct system of work

A system of written procedures is required whenever electrical work is to be carried out. The amount of detail necessary will depend on the circumstances, for simple work a brief policy statement (specifying always switching off, working dead and never working on live equipment) backed up by a set of simple instructions would be appropriate.

If something unexpected occurs during the job procedures are required to review of the work, modify systems of work and communicate to appropriate colleagues and managers.

4. Select and instruct competent workers

The degree of competence of individual workers should be judged against the specific type of work to be done and related to their knowledge, training and experience.

The instructions should also be specific to each job and in many cases will require emphasis on and elaboration of the safe system of work.

5. Ensure correct working methods

Workers should understand:

- the correct working methods for the specific work in hand
- the limits of the work they are to do and the constraints put upon them in how they carry out the work
- how to deal with any contingencies that may arise.

6. Provide and ensure use of appropriate protective equipment

Protective equipment provided for people at work on or near electrical equipment must be:

- suitable for the use for which it is provided
- maintained in a condition suitable for that use
- used properly.

7. Provide information, tools and instruments and ensure workers are fully instructed

Appropriate information includes drawings and diagrams of the equipment or circuit, as well as manufacturers and installer's information and instructions.

Appropriate tools may include suitably insulated tools which have been maintained in good condition and which have been regularly inspected and tested.

8. Arrangements for management checks and supervision

The only effective way of management knowing that the Regulations are being complied with is by carrying out regular checks of the work. This is particularly important if the work is being done in the field, on another occupier's premises or by peripatetic workers.

Supervision should be proportionate to the danger and the competence of the people doing the work.

There will be a greater need for supervision when working live as opposed to working dead.

If there is more than one group at work, the supervisor should ensure that the activities of the various groups are effectively co-ordinated.

Dead working

1. Identify circuit or equipment to be worked on	Actual physical identification of the circuit may be required. Drawings, diagrams and other written information may be useful. Factors that may affect the safe system of work should be taken into account.
2. Cut off supply, isolate and secure isolation	The equipment should be disconnected from every source of electrical energy before working on, or near, any part which has been live or is likely to be live. The disconnecting device should have an isolating gap sufficient for the voltage levels present or likely to occur. Switches should be locked in the OFF position using a suitable ' <i>safety</i> ' lock.
3. Retain keys. Post '<i>caution</i>' and '<i>danger</i>' notices	Caution notices should be posted near the disconnection point to warn of the danger of re-energising and danger notices should be placed adjacent to the place of work indicating equipment and circuitry that is still live.
4. Prove circuit or equipment dead	Checks should be made at the point of work to prove that the parts to be worked on or near really are dead. The device used for proving dead should itself be proved immediately before and after testing.
5. Apply circuit main earth(s) where necessary	To minimise the risk to workers properly designed earthing devices or earthing leads should be applied to all points where the circuit or equipment is isolated from the supply.
6. Take precautions against adjacent live parts where necessary	Physical barriers and/or temporary insulation should be used where necessary to protect against inadvertent contact with other live parts nearby.
7. Issue permit-to-work where necessary	An electrical permit-to-work should clearly state that the circuit or item of equipment is safe to work on. It should never be issued on equipment that is still live. The information given should be precise, detailed and accurate. It should state which equipment etc. has been made safe, the steps by which this safety has been achieved and exactly what work is to be done.

8. Apply local earth(s) where necessary

Additional local earths at the point of work may also be necessary if this is remote from the point of isolation, but these should be applied only after proving dead at the point of work.

Table 11.2: Dead working

Safe isolation practice

When working with electrical systems, hazard elimination at source is clearly the best strategy.

It is important to ensure that:

- the correct point of isolation is identified
- an appropriate means of isolation is used and the supply cannot inadvertently be reinstated while the work is in progress
- caution notices are provided at the point(s) of isolation
- the conductors are proved to be dead at the point of work before they are touched.

For work on low voltage (LV) electrical equipment or circuits, the means of isolation may be an adjacent local isolation device such as a plug and socket, switch-disconnector, circuit breaker, fuse etc., as appropriate – providing it is under the direct control of the person doing the work.

When there is no such local means of isolation and/or there is a risk of reinstatement of the supply, the circuit or equipment to be worked on must be securely isolated by one of the following methods:

Isolation using a main switch or distribution board (DB) switch-disconnector – this is the preferred method.

To be effective, each person carrying out work on the system should have control of their own point(s) of isolation and not rely on others to prevent inadvertent energisation, *i.e.*:

- the point of isolation should be locked off using a unique key or combination retained by the person undertaking the work
- where there are multiple isolations on a DB, a multi-lock hasp can be used to prevent access to a main isolator until such time that all persons working on a system have completed their work and removed their padlocks from the hasp

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

Isolation of individual circuits – Where it is not practical to isolate a distribution board, individual circuits supplied from it can be isolated by one of the following methods:

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

Isolation of individual circuits protected by fuses

Where fuses are used, the simple removal of the fuse is an acceptable means of disconnection.

If removal of the fuse exposes live terminals that can be touched, the incoming supply to the fuse will need to be isolated.

Note:

The practice of placing PVC insulating tape over a circuit breaker to prevent inadvertent switch-on is not a safe means of isolation!:

To prevent the fuse being replaced by others, the fuse should be retained by the person undertaking the work, and a lockable fuse insert with a padlock should be fitted as above. A caution notice should also be used to deter inadvertent replacement of a spare fuse. The HSE also recommends that the enclosure is locked to prevent access.

Electrical permits-to-work

An electrical permit-to-work must be used for work on high voltage (HV) systems that have been made dead, and can be useful in certain situations for LV work. These permits are primarily a statement that a circuit or item of equipment is isolated and safe to work on.

Caution notices

In all instances where there is a foreseeable risk that the electrical supply could be reinstated, an appropriate ‘*caution*’ notice should be placed at the point of isolation such as that shown in Figure 11.8.

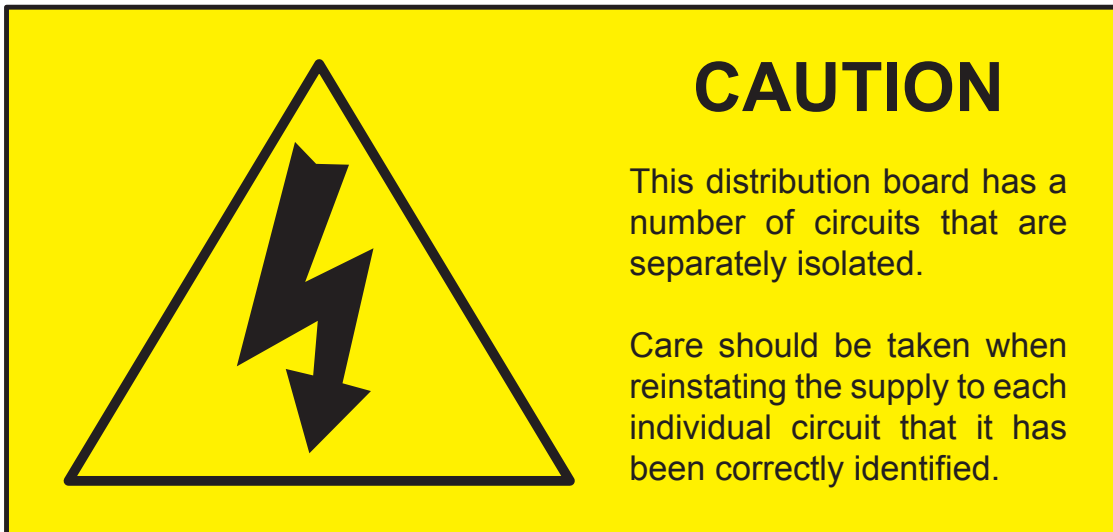


Figure 11.8: Example of a caution notice

Proving dead isolated equipment or circuits

Following isolation of equipment or circuits and before starting work it should be proved that the parts to be worked on and those nearby are dead. It should never be assumed that equipment is dead because a particular isolation device has been placed in the off position.

The procedure for proving dead should be by use of a proprietary test lamp or other device as recommended in HSE Guidance Note GS38. The test instrument should be proved to be working on a known live source or proprietary proving unit before and after use. All phases of the supply and the neutral should be tested and proved dead.

Underground cables

A safe system of work for working near buried services has four basic elements:

- planning the work
- plans
- cable-locating devices
- safe digging practices.

Planning the work

Many dangers can be avoided by careful planning before the work starts. Project planning will involve:

- liaison with service owners or operators and other interested parties such as landowners and other utility providers
- eliminating or reducing hazards at the design stage
- a site specific risk assessment taking local circumstances into account
- effective segregation of the work site
- the use of permits to work for particularly hazardous work
- instructing and training employees in correct procedures and the precautions to be taken
- appropriate supervision to ensure that the work is being carried out according plan and that all precautions are in place.

If there is a need to make dead for work to proceed safely the electricity company will require at least a weeks' notice, as customers whose supply is to be disconnected must be given at least five days' notice.

Plans

Plans or other suitable information about all buried services in the area should be obtained before excavation work starts, when the work is being planned.

Plans can only give an indication of the location, configuration and number of underground services at a particular site. They are rarely drawn accurately to scale, and scales can be changed during copying. Plans should be used as a guide to help tracing by locating devices.

If plans and information are not available (e.g. emergency work) the work should be planned on the assumption that there are buried services in the area.

Locating devices

Modern cable avoidance tools (CAT) have three modes of operation:

- power mode (Hum detection)
- radio mode (RF detection)
- generator mode (Genny) (transmitter-receiver).

Power mode – Detects the magnetic field radiated by electricity cables which have a current flowing through them. They do not respond to:

- cables where there is little or no current flowing, e.g. service connection cables to unoccupied premises or street lighting cables in the daytime
- Direct Current (DC) cables, e.g. on railways
- some well-balanced high-voltage cables
- deep cables (> 3 metres deep) (*Note:* Most cables are laid in trenches between 450 mm and 1 m deep, though some high-voltage (HV) cables will be deeper).

Radio mode – Detects low-frequency radio signals, which may be picked up and re-emitted by long metallic pipes and cables. If radio frequency detection is used, other metallic objects may re-radiate the signal and results may vary appreciably according to locality, length of the buried cable or pipe and distance from the termination and geographical orientation.

Generator mode – Detects conductors radiating a signal applied by the signal generator (genny). The genny sends a known signal along buried metallic services either by direct connection to the service or by signal induction.

Detecting the signal enables the service carrying it to be located, traced and identified.

Safe digging practice

Excavation work should be carried out carefully and follow recognised safe digging practices. Once a locating device has been used to determine position and route, excavation may proceed, with trial holes dug using suitable hand tools as necessary to confirm the position of any buried services.

- Hand-held power tools and mechanical excavators should not be used too close to underground services.
- Excavations should run alongside the service rather than directly over it.
- Horizontal digging is recommended for final exposure of the service, as hand tools can be controlled more effectively.
- Once exposed, services may need to be supported and should never be used as hand- or footholds for climbing out of excavations.
- All services should be assumed to be live until disconnected and proven safe at the point of work.

Identifying exposed services

Most electricity cables are coloured black, though some high voltage cables are red. Where ducts are used they are normally coloured black if of modern plastic construction. Protection tiles made out of concrete clay or plastic may be placed in the ground above a cable. Where marker tapes are present, they are usually coloured yellow with a black legend, but the absence of these must not be regarded as indicating that no cables are present. Marker tapes or tiles should not be removed or displaced.

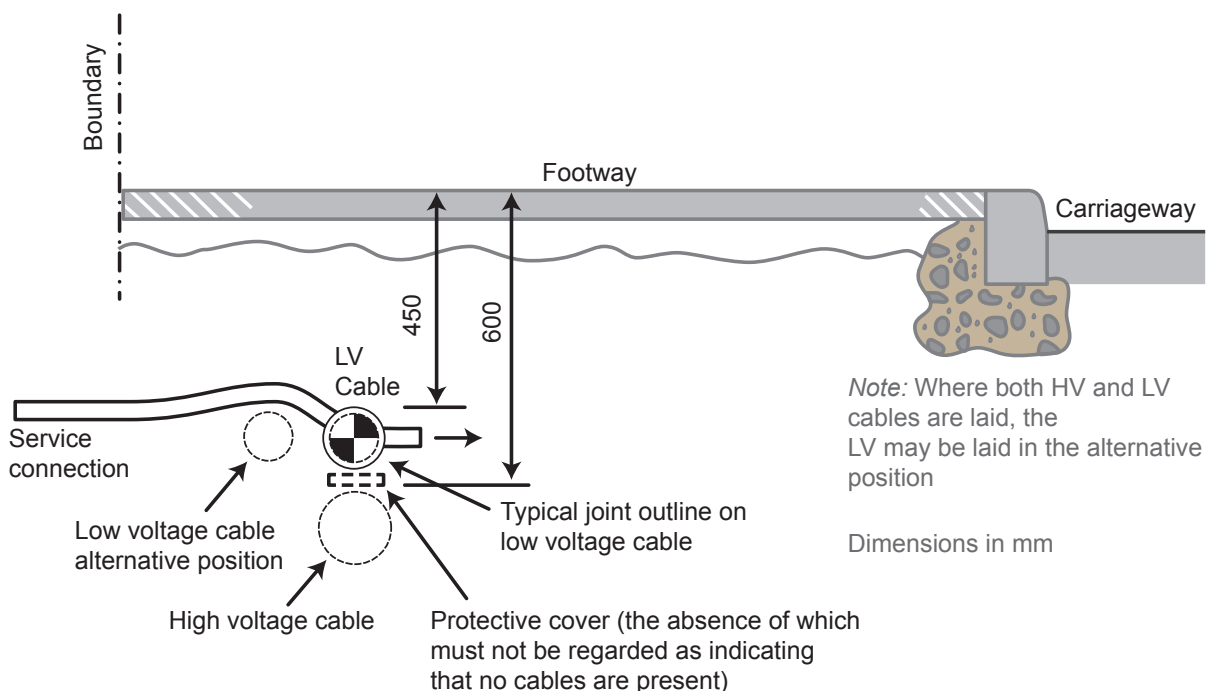


Figure 11.9: Electricity position in a 2 metre footway

Overhead cables

The following hierarchy of precautions should be applied to work at or near overhead power lines:

- avoid working under or near overhead lines
- divert overhead lines clear of the work area
- make lines dead while the work is in progress
- work around the live overhead lines using appropriate precautions.

In some cases it may be necessary to use suitable combinations of these measures, particularly where overhead lines pass over permanent work areas.

Precautions depend on the nature of the work – there are three broad categories of work:

1. No scheduled work or passage of plant under the lines	Use barriers to prevent close approach
2. Plant will pass under the lines	Defined passageways should be made
3. Work will be carried out beneath the lines	Further precautions are required, in addition to the erection of barriers with passageways

Table 11.3: Categories of work beneath overhead power lines

No work or passage of plant under the lines

Ground level barriers should be erected 6 meters away from and parallel to the overhead line to prevent any part of mobile plant approaching too close to the line. Additional clearance will be required for plant with long jibs or booms.

A line of coloured plastic flags or ‘*bunting*’, mounted at a height of from 3 to 6 metres above ground level immediately over the barriers, could be used to give plant operators an additional indication of proximity to the line.

The supports for the bunting should be sited at least 9 metres from the position of the nearest conductor to the barrier when projected vertically onto the ground. Care is necessary when erecting bunting and flags to avoid contact or approach near to the conductors.

Where there will only be access on one side of the line, a barrier on this side only will suffice.

Fences, posts, oil drums etc. should be made as visible as possible, for example by being painted with red and white stripes. Alternate red and white plastic warning flags may be hung on or immediately above any fence line to improve their visibility.

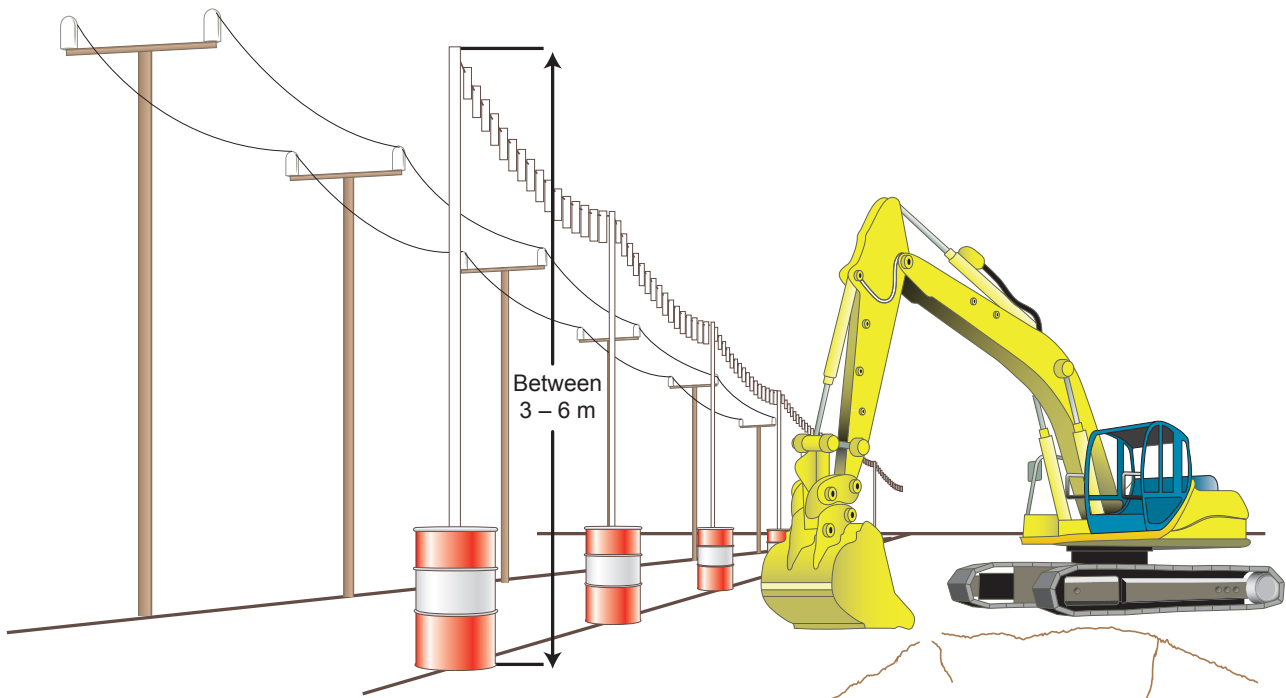


Figure 11.10: Ground level barriers

Plant will pass under lines

The following precautions should be followed to provide safe passage under the overhead line either along an access road or from one part of the work area to another:

- the width of the passageway should be restricted to the minimum needed for the safe crossing of plant
- the surface of the passageway should be levelled, firmed up and well maintained to ensure smooth passage of the equipment passing under the overhead line
- the passageway should cross the route of the line at right angles
- the number of passageways should be kept to a minimum
- the passageway should be fenced to define its route with goal posts erected at each end to act as gateways in the barriers running parallel to the overhead line
- the goal posts should be constructed from rigid, non-conducting material (timber or plastic pipe) and be marked in red and white stripes
- warning notices should be displayed at either side of the passageway, on or near the goal posts

- where work continues after dark the notices and cross-bars should be lit
- additional warning notices should be erected on the approaches to the crossing, say about 30 metres away.

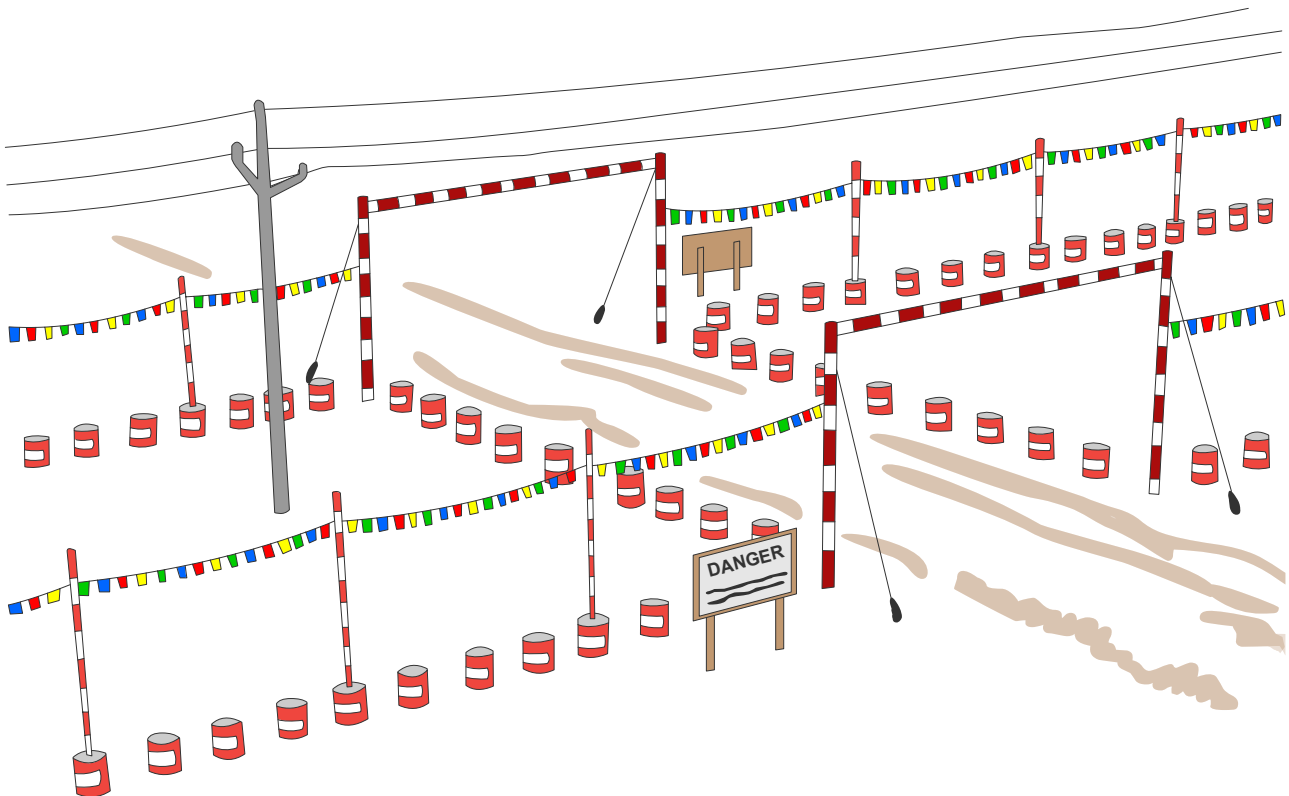


Figure 11.12: Passage beneath overhead line

Work will be done beneath the line

If work beneath live overhead lines cannot be avoided, barriers, goal posts and warning notices should be provided. However, they will not prevent danger from upward movements of cranes, excavators or other appliances, nor will they prevent direct contact by workers where buildings or structures are being erected beneath the lines.

The following additional precautions are recommended:

- the safe clearance required beneath the overhead lines should be established
- plant, equipment or tools that could reach beyond the safe clearance limit should not be taken under the line
- cranes and excavators should be modified by the addition of suitable physical restraints so that it cannot reach beyond the safe clearance limit
- access for plant and materials and the working of plant should be under the direct supervision of a suitable person.

In cases where buildings or structures are to be erected under overhead lines (and for those occasions when work has to be done at or from an existing building) increased risks will arise because of the chance of safe clearances being reduced by the proximity of the works and by provision of the required access above ground level.

In such cases a horizontal barrier of timber or other insulating material or earthed steel net should be erected beneath the live conductors to form a roof over the construction area.

Emergency response and first aid

In any accident involving electricity the first priority is to isolate the power supply. If this is not possible the contact between the victim and the conductor must be broken. This must never be attempted with bare hands. The rescuer should wear rubber gloves or use an insulator such as a long handled wooden broom and stand on an insulating material such as rubber matting or a timber pallet.

Once the victim has been safely isolated from the supply help should be summoned (first aider and emergency medical response), and first aid should be administered:

- cardio-pulmonary resuscitation (CPR)
- treatment of burns and other injuries
- remaining with the casualty until medical help arrives.



Inspection and testing

All systems including fixed, portable and transportable equipment must be maintained, so far as reasonably practicable, to prevent danger.

Fixed installations

The frequency of periodic inspection and testing of fixed installations is determined taking into account:

- the type of installation
- its use and operation
- the frequency and quality of maintenance
- the external influences to which it is subjected.

Guidance from the Institution of Engineering and Technology (IET) recommends the following frequencies of routine checks and formal inspection and testing in commercial and industrial premises with routine installations.

Type of premises	Routine check	Maximum period between formal inspections
Commercial	Annual	5 years or on change of occupancy
Industrial	Annual	3 years

Table 11.4: Recommended frequencies for fixed installation inspection and testing

Different frequencies are for other routine installations, external installations and buildings open to the public.

Portable appliances

A system of periodic inspection and testing is necessary to demonstrate that this duty is being fulfilled. The system would typically involve the following levels of checks:

- checks by the user
- formal visual inspections by a person trained and appointed to carry them out
- combined inspection and tests by an electrically competent person.

User checks (visual)

Users should be encouraged to look at equipment and associated plugs and sockets critically before each use, to check for signs of damage e.g.:

- damage to the cable sheath
- damage to the plug (e.g. cracked casing or bent pins)
- inadequate joints in the cable (e.g. taped joints)
- the cable outer sheath is not at the entry to the plug or the equipment (e.g. coloured insulation of core cables visible)
- the equipment has been subjected to:
 - damage from inappropriate use (e.g. wet or excessively contaminated)
 - damaged external casing (e.g. loose parts or screws)
 - evidence of overheating (e.g. burn marks or discoloration).

Formal visual inspections

The most important component of a maintenance regime is usually the formal visual inspection, carried out routinely by a trained person.

A basic visual inspection as outlined above should be undertaken, but in a more formal and systematic manner. It will also include removal of the plug top to visually check the fuse, the cord grip is tight, cable terminations are secure and there are no signs of internal damage.

The formal visual inspections should be carried out at regular intervals. The period between inspections can vary considerably based on risk factors such as the type of equipment, the conditions of use and the environment.

Combined inspection and tests

Visual inspections will, if carried out properly, reveal most (but not all) potentially dangerous faults.

Some faults, such as loss of earth integrity (e.g. broken earth wire within a flexible cable), or deterioration of insulation integrity, or contamination of internal and external surfaces, cannot be detected by visual inspection alone.

Periodic combined inspection and testing is the only reliable way of detecting such faults, and should be carried out to back up the checks and inspection regime. Testing is likely to be justified:

- whenever there is reason to suppose the equipment may be defective (but this cannot be confirmed by visual inspection)
- after any repair, modification or similar work
- at periods appropriate to the equipment, the manner and frequency of use and the environment.

The Electricity at Work Regulations 1989 does not specify what needs to be done, by whom or how frequently (for example, they do not make it a legal requirement to test all portable electrical appliances every year). This allows the duty holder to select precautions appropriate to the risk rather than having precautions imposed that may not be relevant to a particular work activity.

The inspection carried out in conjunction with testing should usually include checking:

- the correct polarity of supply cables
- correct fusing, effective termination of cables and cores
- that the equipment is suitable for its environment.

Combined inspection and testing requires an appropriate degree of competence to interpret test results. Basically, there are two levels of competence:

- a person who is not skilled in electrical work may routinely use a simple *'pass/fail'* type of portable appliance tester
- a person with appropriate electrical skills uses a more sophisticated instrument that gives actual readings requiring interpretation.

Maintenance and test records

- although there is no requirement in the EAW Regulations to keep maintenance logs for portable and transportable electrical equipment, the EAW Memorandum⁵ does refer to the benefits of recording maintenance, including test results
- a suitable log is useful as a management tool for monitoring and reviewing the effectiveness of the maintenance scheme and also to demonstrate that a scheme exists
- it can also be used as an inventory of equipment and a check on the use of unauthorised equipment (e.g. domestic kettles or electric heaters brought to work by employees)
- the log can include faults found during inspection, which may be a useful indicator of places of use, or types of equipment, that are subject to a higher than average level of wear or damage
- this will help monitor whether suitable equipment has been selected. Entries in a test log

can also highlight any adverse trends in test readings that may affect the safety of the equipment, thus enabling remedial action to be taken

- be careful when interpreting trends where a subsequent test may be done with a different instrument to that used for an earlier test, as differences in the results may be due to difference in the instruments rather than deterioration in the equipment being tested.

Type of business	User checks	Formal visual inspection	Combined inspection and test
Equipment hire	N/A	Before issue/after return	Before issue
Construction	110 V-Weekly 230 V mains – Daily/every shift	110 V-Monthly 230 V mains – weekly	110 V – Before first use on site then 3-monthly, 230 V mains – Before first use on site then monthly
Light industrial	Yes	Before initial use then 6-monthly	6-12 months
Heavy industrial/high risk of equipment damage	Daily	Weekly	6-12 months
Office information technology, e.g. computers, photocopiers, fax machines	No	2-4 years	None if double-insulated, otherwise up to 5 years
Double-insulated equipment not hand-held, e.g. fans, table lamps	No	2-4 years	No
Hand-held, double-insulated (Class II) equipment, e.g. some floor cleaners and irons	Yes	6 months-1 year	No

Type of business	User checks	Formal visual inspection	Combined inspection and test
Earthed (Class I) equipment, e.g. electric kettles, some floor cleaners	Yes	6 months-1 year	1-2 years
Cables, leads and plugs connected to Class I equipment, extension leads and battery chargers	Yes	6 months-4 years depending on type of equipment it is connected to	1-5 years depending on type of equipment it is connected to
Equipment used by the public, e.g. in hotels	Formal visual inspection, done much more frequently by a member of staff. After the first few inspections, information obtained can be used to revise the intervals between future inspections. The same is true for combined inspection and testing.		

Table 11.5: Suggested inspection and testing intervals (HSG 107)

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