# University guidance for electrical safety

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# 1. University of St Andrews

**University Local Rules for Electrical Safety**

**Contents**

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## 1. Introduction

**The Electricity at Work Regulations 1989** made under the **Health and Safety at Work etc Act 1974** came into force on 1st April 1990. They apply to all places of work and to all work involving the use of electricity. The Regulations are primarily concerned with the prevention of *danger* and *injury* from electric shock, electrical burns, fires of electric origin, electrical arcing and explosions initiated or caused by electricity. Burns in this context include radiofrequency burns. Ultraviolet radiation due to arcing can also produce injury to which these Regulations apply. The Regulations are supported by the Health and Safety Executive (HSE) publication, '**Memorandum of Guidance on the Electricity at Work Regulations 1989**'.

All School/Units where work on electrical systems and/or electrical equipment forms a major part of the work activity should have a copy of the Memorandum and the HSE publication entitled, '**Electricity at Work *safe working practices' (HSG85)*** available for relevant staff to consult.

The Regulations apply equally to systems of different voltages and do not distinguish between high and low system voltages.

The Regulations impose different levels of duty. In certain cases the requirements are absolute whilst others are qualified by the well known phrase "so far as is reasonably practicable".

Electricity plays a part in almost everything we do and while it is a useful tool it must be treated, at all times, with great respect. Electrical equipment, which is under the control of this University, is in daily use both within and outwith University premises. The sensible use of such equipment will generally ensure that no person is exposed to a significant risk to health. Nevertheless it should be recognised that, under certain circumstances, the use of electrical equipment may become extremely hazardous to health.

The object of this guidance is to provide local rules for Schools/Units in order to ensure compliance with the requirements of the above legislation.

Where the word *must* is used in this booklet the requirements are mandatory and must be followed at all times. Other recommendations must not be disregarded without compelling reason.

## 2. Summary of the Electricity at Work Regulations 1989

There are 33 Regulations in all. Regulations 17 to 28 apply only to mines and will not be considered further here. The specific Regulations relating to electrical safety in all other work situations are contained in Regulations 4 to 16. Certain of these deal specifically with the components of electrical systems whilst others are concerned with electrical work and the competency of those undertaking the work. The remainder of this section is devoted to a consideration of the individual regulations.

Regulation 4

This is a general Regulation but acts as a catch-all in the same fashion as Regulation 1 of the 1908 Regulations. The first two parts of this Regulation impose a general requirement to ensure that all electrical systems are of such construction and maintained so as to prevent, so far as is reasonably practicable, danger. The supporting guidance to this Regulation makes it clear that the word 'construction' has a very wide meaning including matters such as the design of the system and selection of the equipment used on it. There is no detailed comment on the design of electrical systems but reference to the existence of other sources of authoritative guidance such as the IEE Wiring Regulations and British, European and International Standards.

Regulation 4(2)

This Regulation describes the maintenance of electrical systems stating that regular inspection and testing is necessary for all installations. This should also be applied to all equipment connected to the installation. Detailed up to date records of maintenance programmes are essential. The maintenance referred to is the maintenance required to ensure the safety of the system, not the actual activity of doing it.

The duty is set at the 'reasonably practicable' level. However, it is important to note that Regulation 4(4) dealing with protective equipment is set at the absolute level: "protective equipment shall be suitable for the purpose, suitably maintained, and properly used".

Regulation 5

This Regulation deals with the strength and capability of electrical equipment. There is an absolute duty to ensure that no electrical equipment is put into use where its strength and capability can be exceeded in such a way as may give rise to danger. There is thus a requirement to ensure that all equipment is properly selected according to its intended use and adequately rated for the required duty before it is put into service.

Regulation 6

This Regulation deals with the siting of electrical equipment in adverse or hazardous environments. Such environments include mechanical damage, the effects of weather, temperature or pressure, wet, dirty, dusty or corrosive conditions or the presence of any flammable or explosive substance including dust, vapours and gases. Electrical equipment which may reasonably foreseeably be exposed to these conditions must be of such construction or as necessary protected to prevent, so far as is reasonably practicable, danger arising from such exposure. The onus is now on the user and specifier who knows the activities undertaken and the environment concerned, to select the appropriate equipment. This Regulation is of particular significance in building work (and in fieldwork or outdoor work generally) where by its very nature extremely adverse conditions may prevail especially in the use of portable electrical equipment.

Regulation 7

This Regulation is concerned with the insulation, protection and placing of conductors. It sets out the basic principles to prevent danger from conductors. Live conductors must either be suitably covered by insulating material or be placed so as to minimise danger. The former includes not only the need to provide electrical insulation but also to provide further protection as required against mechanical damage and other adverse conditions thus reinforcing the duties imposed by Regulation 6. The second alternative includes not only placement out of reach but also the use of siting live conductors inside enclosures and the institution of safe working practices, instruction and warning notices, etc.

This Regulation gives guidance on situations where it is not always possible to insulate a live conductor. Where live conductors are not insulated to prevent danger the alternative is not necessarily simply to place them out of reach. This is only one option and in fact may form only one part of the alternative set of precautions required to achieve safety.

Regulation 8

This Regulation deals with the requirements for earthing or other suitable precautions which are necessary to avoid the risk of shock from conductors which may inadvertently become charged due to a fault in the system. Although the requirement is absolute it is again subject to the defence provided for by Regulation 29.

While the main emphasis of this Regulation is on earthing, it provides for the adoption of other safety measures such as residual current devices, all-insulated or double insulated equipment, reduced voltage systems and earth free systems where appropriate.

Regulation 9

This Regulation seeks to preserve the integrity of 'referenced' conductors i.e. conductors connected to earth or any other reference point. If a circuit conductor is connected to earth or to any other reference point, nothing which might reasonably be expected to give

rise to danger by breaking the electrical continuity or introducing high impedance shall be placed in that conductor unless suitable precautions are taken to prevent danger.

Regulation 10

This Regulation requires that all joints and connections in a system are mechanically and electrically suitable for use. The duty is absolute but again subject to the defence provided for by Regulation 29 . Particular attention must be paid to plugs and sockets containing a protective conductor, portable equipment and possible damage from electrolytic action. The requirement applies equally to both temporary and permanent connections.

Regulation 11

This Regulation is concerned with the provision of excess current protection. The duty is absolute but again subject to the defence provided for by Regulation 29. The Regulation requires the installation of protective devices to guard against overload, short circuit and earth fault currents. The protection devices will include fuses and circuit breakers. An overload may be long term condition which can exist for several hours before danger arises, whilst short circuits and earth faults present danger immediately and therefore require prompt disconnection from the supply. The objective of any protective device is to detect abnormal current flows in any of these situations and to interrupt safely the fault current before danger arises.

Regulation 12

This Regulation deals with the means for cutting off the supply and for 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. There is thus need for a positive air gap between the source of electrical energy and the electrical system, the positive identification of the on/off switch, the prevention of unauthorised operation, accessible location and for the switch to be clearly marked and labelled.

Regulation 13

This Regulation covers the preferred method of working on electrical systems, namely that it is de-energised before work commences. Adequate precautions must be taken to ensure that this is so. This requires satisfactory arrangements not only for the disconnection of the system but also procedures to ensure that the de-energised plant cannot become live again inadvertently, either through reconnecting to the supply or as a result of electromagnetic induction, mutual capacitance or stored electrical energy.

The Memorandum of guidance on the Electricity at Work Regulations 1989 describes the precautions which can be taken:-

1. Isolation from all points of supply.

2. Securing each point of isolation.

3. Earthing where appropriate.

4. Proving dead at point of work.

5. Demarcation of safe zone of work.

6. Where necessary, safeguarding from adjacent live conductors.

7. Release for work by the issue of a safety document e.g. a Permit to Work

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Regulation 14

This Regulation sets out the limited circumstances where live working is permitted and prescribes the precautions then required. The circumstances permitting live working centre around the question of 'reasonableness'. In all the circumstances must the plant be dead or is it reasonable in some circumstances for the worker to be at work or near it when it is live if suitable precautions are taken to prevent injury? These duties are absolute but subject to the defence provided for by Regulation 29. Live work is justified only: (a) if it is impracticable to carry out the work with the conductor dead, (b) the work creates other hazards such as to users of the system by making the conductors dead, (c) there is a need to comply with other statutory requirements, or (d) the level of risk and effectiveness of the precautions is low when set against economic need.

The types of precautions that would be considered appropriate include:

1. employing trained and competent staff;

2. the provision of adequate information for such staff;

3. using suitably insulated tools, equipment and protective clothing;

4. using suitable insulated barriers or screens;

5. using suitable instruments and test probes;

6. accompaniment by another person if their presence can contribute significantly to ensuring that injury is prevented;

7. effectively controlling the work area where there is danger from live conductors such as through restricting access and the use of special precautions such as free work areas.

<u>Regulation 14(c)</u>

This section reinforces Regulation 4(4) in that where the provision of protective equipment forms part of the suitable precautions required to be taken, then such equipment must be suitable for the use for which it is provided, be maintained in a condition suitable for that use and be properly used. Thus, the written procedures for live working need to state clearly what protective equipment is required and thereby forms part of the safe system of work. A need also arises for the introduction of management systems for the routine inspection, maintenance, repair and replacement of such equipment.

Although Regulation 14 does not automatically require accompaniment for live work, where danger may arise the necessity for accompaniment will need to be considered in terms of what other safeguards are adopted as part of the total package of measures specified to achieve the required level of safety. Equally important is that where a second person is present he must clearly understand his role in the operation of the safe system of work.

<u>Regulation 15</u>

This Regulation deals with a number of miscellaneous matters relevant to the safe operation of electrical equipment namely working spaces, access and lighting. The duty is to prevent injury occurring in dangerous circumstances.

In common with the overall style and approach of the Regulations, the duties of this Regulation are only in general terms. An appendix to the Memorandum to the Regulations includes a note on working space dimensions in front of exposed live conductors.

<u>Regulation 16</u>

This Regulation requires that no person shall be engaged in any work activity where technical knowledge or experience is necessary to prevent danger or, where appropriate, injury, unless he possesses such knowledge or experience, or is under such degree of supervision as may be appropriate.

The Regulation also covers those circumstances where danger is present, ie where there is a risk of injury, as for example where work is being done on live or charged equipment using special techniques and under the terms of regulation 14. In these circumstances persons must possess sufficient technical knowledge or experience or be so supervised etc, to be capable of ensuring that injury is prevented.

The object of this Regulation is to ensure that persons are not placed at risk due to a lack of skills on the part of themselves or others in dealing with electrical equipment.

**3. Aministrative Procedures for Dealing with the Safe Use of Electrical Equipment**

The University Court is responsible for determining policy to be adopted for implementing all relevant legislation including the Electricity at Work Regulations. This responsibility derives from the Health and Safety at Work, etc., Act, 1974.

It is the duty of all Heads of Schools/Units to ensure that all aspects of the Court's Health and Safety Policy are complied with, within the areas under their control.

Each Head must take appropriate measures to ensure that all electrical equipment is safe and suitable for the purpose intended. All relevant persons should be made aware of the hazards associated with electricity and of the requirement to adopt working procedures designed to keep the risks to themselves and others as low as is reasonably achievable.

The guidance given in this publication must, wherever necessary, be supplemented by local School/Unit Rules relating to the specific activities of the School/Unit, so that when read in conjunction with these University Rules, the two documents form an effective means of securing the safety of persons who are required to work with electrical equipment/systems. Where appropriate, records of action taken should be produced and maintained.

3.1 **Electrical Supplies and Equipment**

The Estates Unit is responsible for the provision of safe electrical supplies within University buildings up to and including the electrical outlet sockets. Estates is also responsible for arranging the routine inspection/testing of all portable electrical appliances held by Schools/Units.

Where Schools/Units wish to extend the fixed wiring system within a building, the work must be carried out through Estates. Schools/Units are responsible for any further distribution of the supply beyond the electrical outlet, and for its own electrical equipment.

Staff with a concern regarding electrical safety should immediately bring the matter to the attention of an appropriate member of staff e.g. the chief technician or School/Unit Safety Co-ordinator. If any doubt exists about the safety of a piece of electrical equipment, it must be taken out of service immediately, labelled "DO NOT USE", and sent for repair by a competent person.

3.2 **Competent Persons**

Persons carrying out the testing and/or repair of electrical equipment, or carrying out experimental work on electrical equipment or its associated connections must have appropriate knowledge, training and experience to enable them to work safely. Persons who are not thus qualified may

work on electrical equipment provided suitable and sufficient supervision is provided by an appropriately qualified person.

*General guidelines for competence are as follows:*

* experience in working with electricity;

* an adequate knowledge of the associated hazards;

* knowledge of all relevant current safety standards;

* a clear understanding of the precautions required to avoid danger;

* sufficient experience in the type of electrical work involved;

* the ability to recognise whether it is safe for work to continue, particularly in respect of unfamiliar equipment and unfamiliar locations.

It is for the Head of School/Unit to decide whether a particular individual is competent to carry out work with electrical equipment, on the basis of assessment of the task, the competence of the individual and the particular job.

**4. Hazards to Persons**

Thedangers involved with the use of electricity are well known, these being shock, burns or other injuries potentially with fatal results.

4.1 **Effects of Electric Shock**

Excessive electric current flowing through the body causes muscles to go into spasm, inhibits the respiratory centre in the brain, causes fibrillation of the heart and destroys body tissue. Electric shock can cause cardiac arrest or cessation of breathing, either of which can be fatal. This effect is related directly to the magnitude and duration of the current passed through the body and to the physical path taken by the current. Particularly dangerous paths are from hand to hand, or hand to foot, as they transverse the pacemaker system controlling the heart. This can lead to fibrillation, that is a state of rapid, irregular contractions of the heart muscle, which reduces the effective pumping action of the heart and impairs blood supply to vital organs, particularly the brain.

4.1.1 ***Procedure for the safe treatment of an individual who has or is suspected of having suffered an electric shock.***

* Check your own safety and the safety of others before approaching casualty.

* Assess if casualty is still in contact with the supply.

If so, switch off the appliance at the mains or withdraw the plug from the outlet socket. Only if this is not possible should an attempt be made to pull the casualty away using insulating material e.g. piece of dry wood or scarf.

* Look for signs of life, for example, breathing, movement, cough or change in colour.

* If none of the above are evident phone for an ambulance dial 9999 and ask for the ambulance service. Advise the controller that ' a casualty has suffered an electric shock and that he/she has had a cardiac arrest' - do not hang up, answer any questions ambulance control asks and take advice.

If you have been trained in CPR commence 30 chest compressions followed by 2 breaths of mouth to mouth resuscitation - continue until Emergency Service staff arrive.

**Note:** Training in such techniques can be arranged through the Environmental, Health and Safety Services. In addition, as a supplement to training, a wall chart displaying these techniques should be posted in a prominent position in relevant areas.

### 4.2 **Burns**

Burns can occur externally or internally. External burns can be caused by the passage of an electric current through the skin or as a result of an electric arc or a short circuit. Burns resulting from short circuits are often made worse by pieces of molten metal, from vapourised conductors, embedding in the skin. Internal burns are caused by the passage of electric current through blood vessels and internal organs. In addition, some forms of electro-magnetic radiations such as radio-frequency and microwave radiation can produce burns at a distance. The actual depth of the burn caused by the passage of an electric current is likely to be greater than it appears, with damage to underlying tissue, although its area may be relatively small.

First-Aid

If possible, cool the burn by immersion in clean cold water for at least 10 minutes then cover with a clean polythene bag or cling film. All cases of electrical burns require immediate medical attention.

### 4.3 **Other Injuries**

Other injuries can occur for example when a person falls from a ladder after receiving an electric shock. Quite often the injuries from the fall can be more serious than the initial shock.

## 5. Hazards to Buildings and Equipment

### 5.1 **Fire**

Fires are frequently started by electrical apparatus and can be caused by sparks, arcs, short-circuits, overloading and old wiring.

Sparks

A spark is the sudden discharge or passage of electricity through air between two conductors or from a conductor to earth or nearby metal.

Since the current produced is usually small, sparks rarely cause serious fires except in cases where there is an explosive gas nearby or where highly flammable material is in contact with the conductor. An explosion can be caused by the ignition of flammable gases by a spark from an electric contact. In all cases where a flammable or ignitable atmosphere or vapour is present, special care is necessary in the design and selection of the electrical equipment.

Arcs

An arc is a much larger and brighter discharge in which the current flow may be very large. It usually arises when a circuit is broken, e.g. when switch contacts separate, or when a conductor melts or fractures leaving a gap across which electricity continues to flow. When an arc is established, the air in the vicinity becomes ionized and forms a conductor which may allow current to continue to flow to a nearby metal framework. A large arc can cause serious burns both to an operator nearby and to any adjoining material. It can also produce molten metal splashes which can cause additional injury.

Short-Circuits

A short-circuit is formed when the current finds a path from the live conductor wire to the return wire other than the intended route through the apparatus. Since the resistance of the leads to the by-passed apparatus is low, the current flow may be large; and because the contact is probably poor, an arc may be established. Components can become white hot and cause the adjoining insulation to burn. The burning may then spread rapidly to any adjacent flammable material. Accumulators wired in series can give rise to extremely damaging high currents should a short-circuit occur; protection with circuit breakers or fuses is necessary.

Overloading and Old Wiring

Wiring is overloaded when it continuously carries an electrical current greater than it is designed to carry, as a consequence it becomes overheated and the insulation is damaged. If the overload is heavy, the insulation will break down and a short-circuit may be produced; if the overheating is smaller but persistent, the continual overheating will lead to carbonizing of the insulation and a possible short-circuit.

The insulation of wiring which has been in use for a number of years can become brittle, therefore alterations or additions must not be made to any old wiring without providing for its inspection. If wiring enclosed in a plastic insulation is overloaded sufficiently to raise its temperature appreciably, the insulation will become soft and lose its insulating properties. Proper consideration must be given to the load that any conductor is to carry before apparatus is connected to the supply.

## 6. Electrical Fire Fighting

First of all switch off the power to the equipment; then, if necessary, use a carbon dioxide extinguisher. Do not use water because of its electrical conductivity. Even if the appliance e.g. TV set, refrigerator, is switched off, an electrical capacitor can still administer a dangerous shock.

Although the primary task is to extinguish the fire, the planning of fire precautions should always take into account salvage of the damaged items. A residue-free, non-corrosive extinguishing agent is always to be preferred, particularly where delicate apparatus or materials may be present. Powder extinguishers should only be used as a last resort; it is almost impossible to remove the finest powder from complicated equipment e.g. switches and relays during salvage operations.

## 7. General Safety Measures

### 7.1 **Fixed WiringInstallations**

Staff should familiarise themselves with the positions of the main isolating switches for their area. In the event of an electrocution accident, fire or flood, it may be necessary to disconnect the supply. In the case of fire or flood never restore the supply yourself, contact Estates.

### 7.2 **Plugs**

Replacement or new plugs should have sleeved live and neutral conductor pins.Plugs which are not wired correctly, or in which the connections have been broken or damaged can be lethal.

1. Wires must be fitted to the plug as follows:

a. The **earth** wire is **striped green and yellow** and is connected to the terminal marked **E**.

b. The **live** wire is **brown** and is connected to the terminal marked **L**.

c. The **neutral** wire is **blue** and is connected to the terminal marked **N**.

2. The fuse must be of the correct rating, i.e. the lowest rating which will carry the appliance current continuously.

3. The plug must not be used to supply more than one piece of equipment.

4. The earth wire should be the longest of the three so that it is the last to become disconnected if the cable is excessively strained.

5. Uninsulated wires should not be visible in the plug-top.

6. Retaining screws should make good contact with the metal core of each wire and be screwed down tightly.

7. The clamp should be over the outer insulating cover and hold the cable securely in place.

8. Damaged plugs or those showing signs of overheating must be replaced.

### 7.3 **Multi-way Distribution Boards**

Multi-way distribution boards with 13 amp shuttered outlets may be used from a socket provided the total load does not exceed 13 amps. Wherever practicable, such distribution boards should be kept above floor level. This requirement is most important in situations where there is a possibility of water coming into contact with a live outlet. In no case should more than one adaptor be used in a socket.

**Note:** Multi-way cube adaptors are not permitted as they present a fire risk.

### 7.4 **Cables**

Cables must be of sufficient cross sectional area to carry the current that can flow through them in both normal and abnormal conditions, be adequately insulated and protected against mechanical damage under the prevailing service conditions e.g. armoured or double insulated cables for workshop or wet areas.

**Note:** Cables partly wound on drums must be de-rated to avoid overheating.

Most connections to apparatus are made by flexible cables. The minimum size of flexible cables for different purposes are as follows.

From 1970 the correct colour code for flexible cables is:

**Earth -** Yellow and green stripe

**Neutral -** Blue

**Live -** Brown

The colours for pre-1970 flexible cables are green, black, and red respectively. As these colours can be confused by colour-blind people, equipment with non-standard leads should be rewired, as soon as practicable, by a competent person to the current UK standard.

The International Standards for wire colouring is given in Appendix 2.

The supply lead should be a continuous length of cable with its sheath mechanically secured at both ends. The coloured cores must not be visible at any point. Supply leads should not be excessively long, trail along the floor or pass under carpets.

Leads carrying power from one piece of equipment to another must be fitted so that connecting plugs or sockets cannot leave bare live pins on disconnection (the pins must always be on the equipment which is being supplied).

7.5 **Fuses and Circuit Breakers**

These devices afford protection against excess current flow e.g. due to short circuit, before the overload has persisted long enough to cause damage. If a newly fitted fuse or a circuit breaker again blows upon reconnection the associated equipment must be taken out of service and the fault reported.

Single fuses (and also single pole switches) must be located in the live conductor.

A fuse must be of the correct rating for the equipment. Cartridge fuses normally rupture at about 60% overload so a 5 amp fuse fails at about 8 amps. This overload current must be within the current carrying capacity of the circuit or serious damage can occur.

Replacement fuses must be readily available to avoid any temptation to replace spent fuses with anything other than a fuse of the correct rating.

The primary purpose of a fuse is to protect equipment against overload and consequent damage by fire. Additional measures, such as earthing and/or earth-leakage circuit breakers are necessary to provide protection from shock.

7.6 **Earthing**

The external metal casing of electrical apparatus must be earthed as a legal requirement. The casings or screens of all electrical equipment must be fastened so that it is impossible to touch electrically live parts and if the equipment is disconnected from earth, a notice must be attached which makes this quite evident to any unsuspecting person. Only persons with appropriate experience should work with unearthed equipment.

All earthing wire must be capable of carrying the maximum possible fault current. Whenever practicable, apparatus should be provided with a protective device which will break the circuit should a dangerous fault to earth occur.

Great care must be exercised when using electrical equipment in high earth leakage areas such as cold rooms, washing-up rooms, and in medical/biological laboratories where "wet" experiments are in progress.

The continuity of earth connections, particularly on portable equipment, must be checked periodically.

7.7 **Residual Current Devices (RCD's)**

The application of a residual current device to a conventionally earthed system should be considered where it is vital to provide an additional backup protection against failure of the primary earthing system. A RCD will prevent a person from being subjected to a lethal shock from a

fault current to earth, by limiting the duration of the shock, usually to 30 milliseconds.

**Note:** <u>a fuse is also required as RCD's do not protect against short-circuits between live and neutral.</u>

A standard residual current device is designed to operate on a.c. current only. Many modern appliances such as power-tools, VDU's and teleprinters contain solid state devices which may create a pulsating d.c. current affecting the operation of a standard RCD and this may lead to loss of protection. Pulsating d.c. fault current sensitive RCD's are now available and should be employed wherever necessary.

RCD units are packaged either as fixed installations fitted to the incoming supply or in the form of a power breaker 13 amp fused plug. Every RCD unit is fitted with a test button which should be operated regularly to prove breaker operation.

### 7.8 **Safety Extra Low Voltage System**

Asafety extra low voltage system is one in which the voltage does not exceed 50V AC between conductors in a circuit which is isolated from the supply mains and from earth by means such as a safety isolating transformer. Lower voltages may be necessary when working in close contact with earthed metalwork. The DC value corresponding to 50V AC is recognised as 120V DC ripple-free. Safety extra low voltage is recommended for hand lamps and soldering irons. It should also be used for other small hand-held tools where there is a risk of electric shock.

### 7.9 **Reduced Voltage System**

This system requires the star point or mid-point of the reduced voltage (i.e. 110V or less) transformer to be earthed. In this system the voltage to earth is about half the supply voltage.

For electrically driven hand-held portable tools the 110V centre-tapped (CTE) system is recommended. As most shocks occur between a live part and earth the use of this system will reduce the shock risk.

### 7.10 **Insulation of Portable Apparatus**

Portable apparatus used at normal mains voltage is required to have basic insulation. In addition, the metalwork must be earthed so that it cannot become live in the event of an insulation failure. All-insulated and double-insulated apparatus do not require earthing.

It is particularly important to insure that all apparatus and tools not required to be earthed are rigorously and frequently tested as such tools can become a source of danger if they become damp. Thus, they should always be kept in a dry place and used with an eye to the possible presence of water. Double-insulated apparatus should never be used if the case is cracked or if there is a risk of exterior metal parts touching other live circuits.

All-insulated

All-insulated is the term for apparatus or tools having two layers (or equivalent) of insulation, one of which covers or comprises the outer casing so that metalwork cannot be touched.

Double-insulated

Double-insulated is the term for apparatus or tools where all exposed metalwork is separated from the conductors by two layers of insulation so that the metalwork cannot become live.

## 8. Isolation from the Mains Supply

It is necessary to provide means of disconnecting cables or apparatus from the source of supply.

For portable apparatus, with a non-inductive load of < 3kW at 240V AC, pulling the plug out is the best method, but for fixed equipment it is necessary to have manual isolating switches.

More than one circuit or motor should not be disconnected by the same isolating switch, unless it is clear that under no circumstances will it be necessary to use one while work is being carried out on the other.

Isolators should be designed so that they can be locked in the open position to ensure that no one can switch on while another person is working on the apparatus; isolators should always be 'suitably located' as near to the controller or starter as possible. Isolators must never be locked in the 'ON' position; the occasion may arise when speedy isolation is imperative.

If the isolating switch is under the immediate and sole control of the operator, no special requirements exist. If the isolating switch is remote, care must be exercised to ensure that the supply is not reconnected; it will usually be sufficient to remove the fuse and leave a note in its place. If the supply is not drawn through fuses, the supply should be locked in the 'off' position and the key kept by the operator, a note being left for the other users.

In every laboratory there must be a master isolator which will disconnect the whole of the laboratory from the supplies. This will be marked "SWITCH OFF IN EMERGENCY"and all persons using the laboratory must know of its function. When the laboratory is empty and no apparatus is in use, this switch will be put in the 'off' position. Clearly, no apparatus with exposed terminals must be left on unattended.

Before carrying out work on isolated apparatus it is necessary to ensure that it is dead. It is not sufficient to obtain a 'no voltage' signal from a test instrument; the test instrument should itself be tested to ensure that it is operational.

## 8.1 **Transformers**

Double Wound Transformers

Double wound transformers provide a means of isolating equipment from the mains supply and are a valuable aid to safety when employed to supply mains to hazardous areas and test benches. Transformer supplies can be dangerous if contact is made between both conductors.

Auto-transformers and Variacs

Auto-transformers and variacs *do not isolate.* If these are wrongly connected the whole apparatus may be raised to live voltage with respect to earth. It is important to make sure that one side of the supply is taken from the same end of the winding as the neutral of the supply, *not* the live lead. It is important to take great care not to damage the winding of the variac.

## 8.2 **Batteries and Accumulators**

Either single or banks of batteries can be used to provide power supplies isolated from the mains. Such supplies are as dangerous as a main supply of equivalent voltage and must be treated with appropriate precautions. Since high currents can flow if banks of batteries are short-circuited, care should be taken to ensure that short circuits cannot occur. Where possible current limiting resistors should be fitted.

Rechargeable batteries can release hydrogen and additionally contain corrosive chemicals. Such batteries must be adequately ventilated and care taken to ensure that sparks do not occur in the vicinity of the battery. Precautions should be taken to avoid spillage of the contents.

When a single battery in a bank needs replacing, (particularly mercury batteries), replace the entire bank. Sealed batteries must never be heated or thrown on to a fire; they can explode.

## 9. Work on 'Live' Electrical Equipment

This section covers the risks and protective measures associated with work on live conductors with voltages at or below 415V phase to phase or 240V phase to earth. There are many reasons why it may be of use to work on a piece of equipment whilst there are accessible live parts. There are four main areas.

1. Testing during assembly or production.

2. Fault finding during repair.

3. Research or development work using oscilloscopes and similar instrumentation.

4. Work at fuse boards and electrical distribution boards.

In some of these cases it may be convenient, but not absolutely necessary, to work on equipment while it is still live. Personnel doing this type of work are reminded that under the Electricity at Work Regulations 1989, they may only do such work if there is no reasonably practicable alternative.

All persons who work on or close to live conductors must follow the safe working practices recommended by the Health and Safety Executive in the publications entitled, 'Memorandum of guidance on the Electricity at Work Regulations 1989 and 'Electricity at work - safe working practices' (HSG85). All such work carried out by Estates staff and electrical contractors employed by Estates must also comply with relevant health and safety rules produced by the University and Estates.

## 10. Periodic Inspection of Electrical Installations and Apparatus

Fixed electrical installations should be tested by a competent person at the frequency set by the IEE Regulations for Electrical Installations. A test certificate should be prepared showing the date and results of the investigation and test.

Apparatus which has been designed to the standards of the IEE Regulations should receive the periodic inspection and maintenance which the design requires.

### 10.1 **Inspection of Portable Electrical Apparatus**

All portable equipment, including extension leads, should be inspected at regular intervals. When setting the frequency of an inspection account should be taken of any recommendations which the manufacturer may make along with the use and service conditions

A suitable inspection for portable apparatus will include an examination of the casing, cable and plug for signs of damage or deterioration. In addition, the relevant British Standard for the apparatus should be consulted and any recommended tests, e.g. insulation and earth continuity tests, included in the inspection procedure. An inspection procedure for portable electrical appliances is given in Appendix 3.

All such inspections should be recorded. A suitable record will include the following information:

(a) means of identifying the unit, e.g. serial number;

(b) frequency of inspections;

(c) electrical tests (including statement of pass/fail criteria);

(d) result of test (pass or fail);

(e) name of the person who carried out the inspection;

(f) date of the inspection.

Whenever practicable a unit should be labelled to show when its inspection and maintenance are due. Guidance on the frequency of inspection/testing of portable electrical equipment is given in the University publication, 'Guidance Notes on Inspection and Testing of Portable Electrical Equipment'.

## 11. Safety Measures

### 11.1 General

The risk of sustaining an electric shock can be minimised by adopting good working practices:

* A suitable Permit-to-Work system should always be in place and operated, to ensure the effective isolation of hard-wired equipment and electrical systems before repair or maintenance work commences;

* Due care must always be exercised when switching off main power supplies to ensure that only the intended circuits are isolated. Lock-off systems must be used, where necessary;

* Switch off and withdraw the plug prior to carrying out any repair work or modification to portable electrical equipment;

* If equipment is suspected of having become live, switch off, and have it tested by a competent person;

* Do not handle any electrical equipment with wet hands and do not work in close proximity to water supplies or other earthed metalwork;

### 11.2 Offices, Libraries and Lecture Theatres

The majority of people working in offices, libraries and lecture theatres rarely think of electrical safety. Nevertheless, an increasing amount of electrical appliances, usually of commercial origin are located within these areas. The following points should be noted for the safe use of electrical appliances:-

1. New equipment should be inspected by a competent person before being taken into service.

2. Plugs must be fitted by a competent person using the correct colour coding for cables.

3. Fuses must be of the appropriate rating for the appliances. A 13 amp fuse is rarely correct.

4. Wires should be a suitable length and not trail across the floor.

5. Multi-outlet cube adaptors should not be used; install additional sockets or use multi-way distribution boards with 13 amp shuttered outlets.

6. Do not use lighting sockets to supply power to equipment.

7. The user of the equipment should regularly inspect for damage to casings, cables and plugs etc., and for loose screws.

8. Do not use equipment if you think it is defective. Report the fault and warn other users.

9. Do not attempt to repair equipment yourself.

10. Always follow the manufacturers instructions. Do not use or attempt to adjust equipment unless you know how. If in doubt, get a competent person to help you.

11. In the event of a fire or a fault, disconnect the apparatus. Do not use a water based fire extinguishers on live electrical equipment.

12. Certain office equipment e.g. photocopiers may emit ozone which is toxic. Such equipment should only be used where there is good ventilation.

11.3 **Laboratories**

The modern laboratory is full of electrical apparatus, much of it is fragile and frequently associated with other hazards such as water, corrosive or flammable materials. The hazards associated with the use of such apparatus are very real. The following points on general safety precautions should be noted:-

1. Know where the main isolators for your laboratory are situated.

2. New equipment should be inspected by a competent person before being put into service. This is of particular importance in the case of home-made apparatus.

3. Plugs must be fitted by a competent person.

4. The correct colour coding for wires and cable must be used.

5. Wires should be of the correct length and follow a safe route.

6. Where there are insufficient fixed sockets, multi-way distribution boards with 13 amp shuttered outlets may be used.

7. Electrical equipment must be inspected at regular intervals.

8. Do not use equipment which you suspect as being faulty.

9. Equipment should be repaired by a competent person where possible in a properly equipped workshop.

10. Inspection covers must not be removed from equipment except by a competent person as even when disconnected equipment may be dangerous.

11. In the event of a fire use a $CO_2$ on live equipment. Try to disconnect the equipment if you are sure that this can be done without personal risk.

12. Always follow the manufacturers instructions and observe any relevant University and/or School/Unit local rules.

13. Equipment for use in especially hazardous areas such as wet areas or in the presence of flammable or corrosive materials, must be specially designed for such a purpose.

14. Special attention should be paid to earth connections. Consider if the use of residual current devices (RCD's) or isolating transformers would be an advantage.

15. Electrical equipment must not have exposed live terminals.

16. Beware of capacitors. High grade capacitors must always be shorted before being handled.

17. Electrical apparatus removed from refrigerators and cold rooms must not be used until it has had time to warm up and dry out.

18. Do not store flammable solvents in a non-modified domestic refrigerator (modification involves the removal of all electrical sources of ignition normally located within the cabinet).

### 11.4 **Special Risks in the Experimental use of Electrical Equipment in Laboratories**

#### 11.4.1 ***Electrical Equipment and its Experimental Use***

Many experiments carried out by undergraduates or postgraduates call for the use of electrical equipment which is continually being altered and improved. It is then usual to work with exposed live terminals, switches, rheostats and circuits. Under these conditions, lone work is not permissible and appropriate levels of supervision must be provided.

The level of supervision should be determined by the competence of those who are carrying out laboratory work. A high degree of supervision, and a stringent regard for safety and limitation of danger is appropriate in the case of undergraduate work. Undergraduate experiments in particular should be designed to ensure that any risk to students is minimal. It is also important to install a safety-conscious attitude in undergraduates, and those who prepare experiments and who demonstrate should point out the measures taken to ensure safety.

#### 11.4.2 ***Light Current Laboratories***

Where only small currents are in use a difference in attitude is permissible although the same dangers of shock and arc exist, albeit to a lesser extent.

It is not usually necessary to leave circuits live whilst inserting or removing components, and wherever possible they should be switched off. If a circuit is to be altered whilst live, using a soldering iron, consideration should be given to the currents which may flow into the earthed case of a soldering iron, the arc that might result and the overloading of the circuit.

Work done with exposed circuits should be done in rooms with insulated floors, and care should be taken not to touch earthed equipment and the circuit at the same time.

It is desirable that undergraduate laboratories should have isolated supplies with residual current devices (RCD's).

Greater care than is normally taken is required when dealing with voltages of more than 650V and of short circuit capability greater than 10 mA. They should normally be shrouded or screened in such a way that they are fully protected. Power supplies of this nature are usually contained in television sets, oscilloscopes and many other types of electronic apparatus. The outer cases of such instruments should only be removed when the possible danger has been considered.

#### 11.4.3 ***High Current Supplies (Low Source Impedance)***

The use of power supplies of high current rating poses the additional danger of an accidental short-circuit causing a large arc in which molten metal may be splashed on the operator, especially into his eyes. It is therefore extremely important that all connections are securely made and that accidental short-circuits are not allowed to occur. These conditions may also arise if a direct current circuit of large inductance and low resistance is switched off. In this instance an appropriate discharge resistor should be used.

The measurement of voltage with floating wires or prods should be performed with care. Voltages believed to be greater than 650V must not be measured in this way, but with permanently connected instruments. Fuses or circuit breakers of appropriate rating must be used whenever possible to limit the fault currents. High current supplies at voltages greater than 650V should never be exposed, but should be insulated and protected.

### 11.4.4 *High Voltage Supplies of Low Source Impedance - Use in Restricted Areas*

High voltage supplies are defined in the Factories Act legislation as those having a potential to earth greater than 650V. Low source impedance is defined as an equivalent series source impedance of 500 ohms or less.

No person shall work alone with high voltage apparatus**.** All high voltage apparatus must be adequately guarded by screens or ropes placed at an adequate distance from any exposed live parts. In addition, warning notices stating 'DANGER - HIGH VOLTAGE' must be attached in conspicuous positions during the period that the apparatus may be energised.

The minimum clearance from the nearest live part to the nearest point to which a spectator may approach shall be:

| **Peak Voltage to Earth** | **Clearance (Feet)** | **Clearance (Metres)** |
|---|---|---|
| Not Exceeding 10 kV | 8' 8" | 2.60 m |
| Exceeding 10kV but not exceeding 20kV | 8' 9" | 2.66 m |
| Exceeding 20kV but not exceeding 30kV | 9' 0" | 2.74 m |
| Exceeding 30kV but not exceeding 50kV | 9' 6" | 2.90 m |
| Exceeding 50kV but not exceeding 100kV | 11' 0" | 3.35 m |
| Exceeding 100kV but not exceeding 150kV | 12' 6" | 3.80 m |
| Exceeding 150kV but not exceeding 250kV | 16' 0" | 4.90 m |

Temporary conductors must be of adequate size, easily visible and securely supported. They should only be used during the development period.

The academic member of staff in charge of research must insure that adequate means are provided whereby in an emergency the apparatus can be rapidly isolated and stored energy discharged to earth.

In the case of prolonged tests, clear instructions must be displayed indicating the simplest method of isolating the test apparatus.

The following rules apply for all work with high-voltage apparatus:

1. Before a person enters a high-voltage enclosure all supplies must be isolated and checks performed to ensure that the apparatus is dead.

2. No apparatus shall be touched until it is known to be properly earthed.

Fixed Installations (Enclosures)

This covers all installations where the high voltage apparatus is surrounded by an earthed box or cage which cannot normally be moved without dismantling.

(i) Warning notices should be displayed at the entrance to the enclosure and a warning light should indicate when the apparatus within the enclosure is live.

(ii) The enclosure should be fully interlocked and be constructed so as to prevent accidental contact with live parts by ancillary apparatus or metal rods, etc., inadvertently pushed through the open mesh of a cage. If, for any reason, it is necessary for an interlock to be by-passed the academic member of staff in charge of the research must draw up a Permit-to-Work system which should be ratified by the School/Unit Safety Co-ordinator. Such interlock by-passes should be clearly indicated at the interlock and should be used for the minimum time possible.

High voltage enclosures may be:

(a) 'Permanent'

(b) 'Temporary' (expected period of service < 3 months)

(c) 'Very short term' (expected period of service < 1 week)

(a) Permanent enclosures which can be entered must be soundly constructed of fire-proof materials and, if unroofed, be at least 2 metres high, but the walls need not be solid from top to bottom. Use may be made of close mesh perforated metal, safety glass or plastic windows.

(b) The type of temporary enclosure will depend on the scale of the experiment, but must be of rigid construction and suitably locked or interlocked.

(c) Very short term experiments must be enclosed, and have danger notices posted. If it is necessary to rely on rope or tape barrier and notices, the apparatus must not be left unattended whilst live.

### 11.4.5 *High Voltage Supplies of Low Source Impedance - Use in Laboratories*

Portable or semi-portable power supplies which are in general use in laboratories present a major risk to health. High voltage sources of up to about 10kV are commonly used in laboratories without being confined to a restricted area. They are particularly dangerous when they have low source impedance, and great care should be taken to see that they are fully insulated. These power supplies must be equipped with interlocks on all doors and panels which can be removed without tools. While new equipment is fitted with such interlocks, many old power supplies are not. Old apparatus should be inspected and, if necessary, brought up to standard or taken out of service.

If the power supply contains large high voltage capacitor banks, an earthing rod should be fitted or some other method of discharging the capacitors such as a gravity operated dump switch.

The high voltage output should be taken from a shrouded socket which is labelled with the maximum voltage and current. At the research apparatus end, all exposed metalwork should be securely bonded to earth. The high voltage lead should preferably be terminated with a shrouded plug and socket, but if this is impracticable the lead should be securely clamped and the connections fully shielded from the operator.

Electrophoresis Equipment

The potential for injury arises because not only are large quantities of electrical energy involved but also because the supporting medium is commonly immersed in either saline or buffer.

A safe system of work for electrophoresis requires that power supplies to tanks are always switched off before the lid of the tank is opened. In addition, supplementary protection by interlocking the power supply is necessary to ensure that anyone who forgets to switch off is not at risk. Effective interlocking may be provided by well shrouded sockets on the tank lid which are permanently connected to the DC supply connector and which separate from the corresponding contact pins on the tank body which are connected to the electrodes. Thus opening the tank lid automatically removes the power.

Current Limited Portable Power Supplies

Wherever possible the maximum current should be limited to 10 mA or less by inserting a suitable resistor of ample current-carrying capacity on the unearthed side of the supply. Such current limited supplies are often thought of as being inherently safe, but there is no clear dividing line of current capacity above which the apparatus can be said to be potentially lethal, and below which it is inherently safe. Below 1mA supplies are not likely to be dangerous.

### 11.5 **Electronic and Electrical Workshops**

It is the duty of the workshop supervisor to identify and assess all hazardous operations in the workshop.

1. It is foreseeable that there will be circumstances where work is carried out on or near live conductors. Prior to the commencement of any such work staff must consult the relevant sections of the HSE publications entitled, **Memorandumof guidance on the Electricity at Work Regulations 1989** and **Electricity at Work safe working practices, HSG85.**

The following basic conditions also apply:

a. The entrance to these workshops should display a notice warning visitors that the workshop is a hazardous area;

b. The floors of the workshop should be covered with an insulating material;

c. Benches including working surface must be of non-conducting material and where people are working back-to-back between benches the space should not be less than 1.5 metres;

d. All socket outlets must be supplied via earth leakage circuit breakers and the whole workshop must be provided with an easily identifiable mains isolator switch.

2. As far as is practicable equipment should fail to safety. Access to live conductors should not be possible without removing a screwed down cover.

3. Mains leads should be of the correct current carrying capacity, be mechanically secured with a clamping grommet and be either double insulated or of three-cored type and the conventional colour identification scheme.

Where double insulated mains lead is used, the insulation should have adequate mechanical strength and should consist of a functional and a protective insulation.

Where three-cored mains lead is used, the earth lead should be either soldered or crimped to an earth tag and firmly screwed to an earth terminal on the chassis. The *earth terminal* should not be used for securing other components.

4. All accessible metal parts should be constructed so that they are provided with a permanent and reliable earth continuity path to the main earth terminal.

Internal wiring and other live conductors should be secured, or the inner surfaces of exposed metal parts insulated, to prevent any possibility of live conductors coming into contact with exposed metal parts in the event of an accidental disconnection. Leads used to carry power to portable apparatus or from one chassis to another must be arranged so that connecting plugs or sockets do not leave bare live pins when disconnected.

5. Great care should be taken in selecting the correct value of fuse for protection against insulation failure or overload. When connecting mains plugs to commercial equipment, always refer to the manufacturer's hand book and fit the recommended value and type of fuse.

6. Where an instrument or piece of apparatus has been supplied with a mains lead with non-standard colour code, the lead should be removed and replaced with one conforming to the current British Standard colour code.

7. Portable tools and hand inspection lamps should be operated from isolating transformers. A double-wound transformer with the centre tapped to earth, 50 volts for lighting and 110 volts for portable tools may be used.

### 11.5.1 ***Design and Construction of Electrical Equipment***

The Health and Safety at Work etc Act, 1974, places a duty on any person who designs, manufactures, imports or supplies any article for use at work to ensure, so far as is reasonably practical, that the article is so designed and constructed as to be safe and without risks to health when properly used. All apparatus constructed by School/Unit staff should be inspected and approved by an authorised person before being placed into service and thereafter inspected at regular intervals to ensure that the installation remains in a satisfactory condition.

Electrical/electronic equipment produced for sale must comply with the requirements of all relevant EC and UK legislation.

The standard of safety in electrical and electronic apparatus generally applied in this country is that laid down in the current relevant British Standard.

## 11.6 **Field Work, Greenhouses, Animal Houses, Cold Rooms, Solvent Stores and other Difficult Environments**

Apparatus should be protected against environmental conditions of use. A portable tool which is safe in one situation can be come lethal under different circumstances.

Degrees of Protection Provided by Enclosures

Enclosed ventilated apparatus is only suitable for use in clean conditions. A coded classification is adopted internationally to indicate the degree of protection afforded by an enclosure against solid or liquid materials entering. The classification is indicated by the letters IP followed by two digits; the first of these indicates the degree of protection against entry of solid materials from 0 (no protection) to 6 (complete protection against ingress of dust). The second digit indicates protection against entry of liquid (up to 8, which is protection against indefinite immersion in water under pressure). Full details of this system are given in the relevant British Standard.

Hazardous Environments

Broadly there are two types of hazardous environments:-

a. Wet Areas - where water or aqueous chemicals can enter electrical equipment:

b. Flammable or Explosive Atmospheres - where there is a risk that flammable vapours or dust can be ignited by electrical equipment.

In both cases maintenance should only be carried out after removal of the equipment to a properly equipped workshop.

### 11.6.1 ***Wet Areas***

Field Work, Greenhouses and Animal Houses

The electrical hazards associated with these areas are those of damp, wet or corrosive conditions with non-insulated structures and flooring. The dangers are those of shock and short-circuit. All equipment must therefore be designed for the purpose it must be waterproof or protected to ensure it does not get wet or damp. Wiring should be mechanically protected, toughened and double insulated. Where extension cables are used, these should be as short as possible and mechanically robust. Protection is particularly important where animals may cause damage by chewing. Connections must be waterproof and secure, earth connections being particularly important. Equipment must be inspected and tested at intervals of not more than 6 months. Equipment should be protected by earth-leakage circuit breakers and/or isolating transformers. Where possible low voltage equipment should be used. Earth continuity detectors are also of value in many situations. Never use equipment which is wet unless it is of a waterproof construction. Home made equipment must be inspected by a competent person before being put into service.

Cold Rooms

Cold rooms present a special problem. While the atmosphere is frequently very dry, condensation can occur, particularly when equipment is removed from the room. Permanent wiring should be waterproof and power sockets safeguarded by earth-leakage protection.

If a cold room is to be used as a laboratory it will not always be possible to ensure that only waterproof equipment is used. However, great care should be taken not to use equipment removed from the cold room until it has time to warm up and dry out (normally several hours). Where possible, equipment should be low voltage. As a result of use under such conditions equipment should be regularly inspected.

### 11.6.2 ***Areas with Flammable or Explosive Atmospheres***

These areas require electrical equipment which is spark-proofed and which does not get hot. Adequate earth connection is vital. Normal electrical apparatus must never be used under such operating conditions. All work within these areas must be carried out in accordance with the following recommendations:

1. Electrical installations which are designed for use in areas which have or may have a flammable atmosphere should comply with the relevant British Standard.

2. A flammable atmosphere must not be introduced into any room, enclosure or working area in which the electrical installation is not intrinsically safe.

3. Precautions must be taken to prevent the ignition of flammable atmospheres by the discharge of static electricity.

4. The risk of ignition of a flammable vapours due to frictional sparking from the use of light metals and their alloys should be considered. Where light metals are brought into contact with other materials, particularly when the other materials is an oxygen carrier such as rust, frictional sparking can occur. In such circumstances, non-sparking hand tools may be a suitable alternative. Portable apparatus with light metal enclosures should not be used in hazardous areas unless special precautions are taken to avoid frictional contact.

Oxygen Enriched Atmospheres

It should also be noted that most electrical equipment is not suitable for use in oxygen enriched atmospheres. If this condition is likely to be encountered, the Director Environmental Health and Safety Services should be consulted for advice.

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**Appendix 1**

**Electrical Safety**

**Poor Electrical Connections Can Cause Fire or Kill People by Electric Shock !**

Therefore,

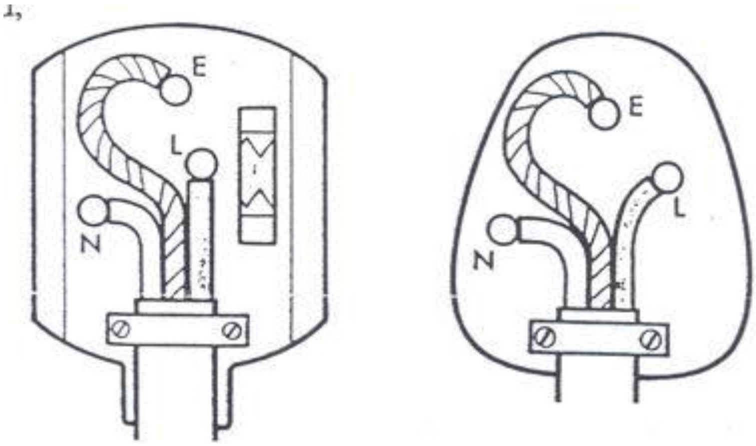
Do not leave cables trailing where they may be damaged.

Do not overload sockets.

You are responsible for the condition of plugs and cables connected to your own equipment. You should therefore make sure that plugs are wired correctly and that you replace damaged plugs or cables. In all cases you should ensure that your equipment is fitted with a plug which bears the stamp of the Association of Short circuit Testing Authtorities (ASTA).

**Wiring Plugs**

Wiring plugs is not only a matter of connecting the wires to the right places, although you must do that - as illustrated:




The **earth** wire is **green and yellow stripes** and must be connected to the **terminal marked E.**

The **live** wire is **Brown** and is connected to the **terminal marked L**.

The **Neutral** wire is **Blue** and is connected to the **terminal marked N.**

Other details of a correctly wired plug are:-

The Earth wire should be longest of the three so that it is the last to be disconnected if the cable is pulled from the plug.

No bare wires should be visible in the plug - the bare wires should be hidden by the retaining screws. the retaining screws should be screwed down firmly.

The cable should be securely held in place by the cable-clamp as illustrated - the clamp should hold the outer cable and the inner wires should not be visible outside the plug.

**Fuses**

It is important to use a fuse of the correct rating. For example, a 13 amp fuse will not give proper protection for a 100W light bulb which draws less than 3 amps.

| Equipment Power Rating | Fuse Rating |
|---|---|
| Up to 500 Watts | 3 amp fuse |
| 500 - 1000 Watts | 5 amp fuse |
| 1000 - 2000 Watts | 10 amp fuse |
| 2000 - 3000 Watts | 13 amp fuse |

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**Appendix 2**

**International Standards for Electrical Wire Colours**

| Country | LIVE (2 Wire cable) | NEUTRAL (2 Wire Cable) | LIVE (3-Wire Cable) | NEUTRAL (3-wire Cable) | EARTH (3-Wire cable) |
|---|---|---|---|---|---|
| Great Britain | Brown | Light Blue | Brown | Light Blue | Green and yellow |
| Canada | Black* | White or Grey | Black | White or Grey | Green and Green/Yellow |
| Denmark | Black* | Blue | Brown or Black | Light Blue or Blue | Green and yellow |
| Finland | Black or Brown | Light Blue | Brown | Light Blue | Green and Yellow |
| Greece | Any colour **Except:** Grey, Yellow or Blue | Grey | Any colour **Except:** Grey, Yellow or Blue | Grey | Yellow |
| Japan | Black | White | Black | White | Red |
| Poland | Black* | Light Blue | Black | Blue | Green and Yellow |
| Switzerland | Any colour **Except:** Yellow and Light Blue | Any colour **Except:** Yellow and Red | Brown | Light Blue | Green and Yellow |
| USA | Black* | White or Grey | Black | White or Grey | Green or Green/Yellow |

*** = Black for Live in 2 core cords is now being replaced by Brown**

## Appendix 3

## Inspection Procedure for Portable Electrical Appliances

The following inspection procedure is for single phase appliances (up to 13 amps) which plug into normal 240 V AC supply.

1. **Inspect Appliance to ensure that:-**

- The equipment is not physically damaged;
- Allcovers etc are in place.

2. **Inspect Applicance Lead to Ensure that :-**

- The insulation is intact and without cracks or fraying;
- There are no joins;
- It is not badly 'kinked';
- The length of lead is appropriate for the positioning of the appliance;
- The wiring terminations on the appliance, if readily visible, are correctly made.

3. **Inspect Plug Top to Ensure that :-**

- The plug top is in good condition, wothout any parts missing. Where a new 13 amp plug is required, it must be a safety plug which incorporates partially shielded phase (live-neutral) pins and bears the ASTA stamp.
- The wiring connections are firmly and correctly made

  Live - Brown wire

  Neutral - Light Blue Wire

  Earth - Green and Yellow striped wire

- There are no strands of wire shorting terminals within the plug top or making an electrical path to the outside of the plug;
- The cable clamp grips firmly the outer isnulation of the cable;
- The fuse is the correct rating for the appliance and bears the ASTA certificate mark.

If the fuse rating is not marked on the appliance, check the data label of the appliance for electrical loading in Watts: this may be marked with a 'W'.

4. **Appliance Safety Test**

The procedures for portable appliances safety testing require that electrical tests are carried out upon the appliances to confirm the integrity of the earthing and insulation.

4.1 ***'Class 1' Appliances***

<u>Earth Bond Test</u>

A 'Megger' or equivalent may be used to test the insulation and Earth impedence. The advised test procedure is as follows:

Measure the continuity resistance between exposed metal parts of the appliance and the earth pin of the appliance plug.

To pass the test, it should be be less than 0.1 ohm (for 5, 10, 15 A conductors of not greater than 10, 15, 30 metres).

<u>Insulation Test</u>

Measure the insulation resistance by shorting together (for the test only) the live and neutral pins of the appliance and measuring the resistance between them and the Earth pin.

To pass the test, the insulation resistance measured at a test voltage of about 500 V DC between the live pin and the earth pinwith all switches on the equipment in the ON position must be greater than 2 M ohms.

### 4.2 ***'Class 2' Appliances***

<u>Insulation Test</u>

A test voltage of about 500 V DC is applied between the live and neutral shorted together (for the test only) and a clip or probe held against the appliance body while the test is in progress.

To pass the test the resistance must be greater than 2 M ohms.

## 5 **Portable Appliance Testers**

Portable Appliance Testers (PAT) are available for performing automatically the measurements described above. Some instruments will supply readings while others operate on a Pass/Fail basis as indicated by coloured lights.

**NOTE:** The following type of equipment should not be tested with a standard PAT as the insulation of the appliances internal wiring can be damaged: electronic test/measuring instruments, radios, record players, Hi-Fi Units etc, desk top calculators, audio-visual appliances, electronic typewriters, dictation equipment etc.

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| **Version number** | **Purpose / changes** | **Document status** | **Author of changes, role and school / unit** | **Date** |
|---|---|---|---|---|
| V1.0 | Revision | Draft | Paul Szawlowski | 26/06/2019 |
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| | | | | |
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