Guidance

Electrical Safety

University of Strathclyde Glasgow

Issue Date: March 2014

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1. Summary of the Electricity at Work Regulations 1989

The purpose of the Electricity at Work Regulations 1989 is to require precautions to be taken against the risk of death or personal injury from the use of electricity in work activities. Staff undertaking electrical work should familiarise themselves with these regulations and the accompanying technical Memorandum of Guidance on the Electricity at Work Regulations 1989.

Regulations 4 to 16 relate to all electrical work in the University and cover the following areas:

Regulation 4
Is a general Regulation and acts as a catch-all. It imposes 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.

Regulation 5
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.

Regulation 6
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.

Regulation 7
Is concerned with the insulation, protection and placing of conductors. It sets out the basic principles to prevent danger from conductors.

Regulation 8
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.

Regulation 9
Seeks to preserve the integrity of 'referenced' conductors, i.e. conductors connected to earth or any other reference point.

Regulation 10
Requires that all joints and connections in a system are mechanically and electrically suitable for use and applies equally to both temporary and permanent connections.

Regulation 11
Is concerned with the provision of excess current protection.

Regulation 12
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 so that inadvertent reconnection is prevented.

Regulation 13
Covers the preferred method of working on electrical systems, namely that it is de-energised before work commences.

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 were appropriate;
4. providing dead at point of work;
5. demarcation of safe zone of work;
6. where necessary, safeguarding from adjacent live conductors; and
7. release for work by the issue of a safety document e.g. a Permit to Work.

Regulation 14
Sets out the limited circumstances where live working is permitted and prescribes the precautions then required.

Regulation 15
Deals with a number of miscellaneous matters relevant to the safe operation of electrical equipment, namely working spaces, access and lighting.

Regulation 16
This Regulation is of particular relevance to University departments. It requires individuals to have "technical" knowledge and experience to prevent danger and avoid injury and states that “where individuals do not have sufficient expertise, the degree of supervision must be appropriate for the hazard involved with that particular type of work”. Technical knowledge and experience may include:

1. adequate knowledge of electricity;
2. adequate experience of electrical work;
3. adequate understanding of the system to be worked on and practical experience of that class of system;
4. understanding of the hazards which may arise due to the work and the precautions which need to be taken; and
5. ability to recognise at all times whether it is safe for work to continue.

2. Maintenance

2.1 General

Failure to maintain equipment is a major cause of accidents involving portable equipment. The likelihood of accidents occurring and their severity will vary depending on the type of equipment, the way in which it is used and the environment in which it is used. For example, a high risk activity is the use of a pressure washer powered by a 230V electrical supply, with the cable trailing on the ground where it can be damaged by vehicles and other equipment, and where water is present. Damage to the cable or other parts is likely to expose the operator or others to electric shock. Similar risks result when equipment such as drills or portable grinders are used in harsh and sometimes wet environments where there is a higher probability of mechanical damage. Lower risks result from equipment such as floor cleaners, kettles or electrical chargers (mobile phone, tablet, laptops etc.) that are used in benign environments such as offices. Such equipment can still be subject to intense use and wear, which can eventually lead to faults that can also result in a shock, burn or more rarely, a fire.

Departments must ensure that all electrical installations and equipment (fixed, portable and transportable) are maintained in a safe condition. Portable or transportable electrical equipment (hereafter referred to as portable equipment) means equipment that is not part of a fixed installation, but is intended to be connected to a fixed installation or generator, by means of a flexible cable and either a plug and socket, or spur box or similar means.

This includes equipment that is either hand held or hand operated while connected to the supply, intended to be moved while connected to the supply, or likely to be moved whilst connected to the supply. The electrical supply to the equipment is assumed to be at a voltage that can give a fatal electric shock to a person, i.e. more than 50 V ac or 120V dc.

There is a wide variety of electrical apparatus which can be described as portable. At one end of the spectrum there is equipment such as portable power hand drills, vacuum cleaners, waterbaths etc. which are open to abuse and mistreatment and which, if not carefully maintained, can fail to danger.

At the other end of the spectrum there is equipment such as fridges, PC's etc., which, although they can be described as "portable", are not open to mistreatment and abuse on the same scale and, consequently, should not need the same frequency of inspection and testing.

Any maintenance systems should be designed to be proactive, i.e. planned to prevent incidents arising, rather than reactive where action is taken following an incident, and based on an assessment of the risks from similar categories of equipment, or in some cases individual items of equipment; procedures must be carried out more frequently where the risk is high. Factors to consider when making the assessment include:

- type of equipment and whether it is handheld or not;
- manufacturers recommendations;
- initial integrity and soundness of equipment;
- age of equipment;
- working environment in which the equipment is used (e.g. wet or dusty) or likelihood of mechanical damage;
- frequency of use and duty cycle of the equipment;
- foreseeable abuse of equipment;
- effects of any modifications or repairs to the equipment; and
- analysis of previous records of maintenance, including both formal inspection and combined inspection and testing.

Appendix 1 gives suggested initial time intervals between 'user checks', 'formal visual inspections' and 'combined inspections and tests'. Heads of Departments may use the suggested intervals as a starting point, but every situation has to be considered in relation to the type of equipment, its use and its environment.

It should be remembered that, in some cases, the environment in which the equipment is used is as important a consideration as the equipment itself and there are various pieces of electrical equipment used in cold rooms which must also be given a high priority. Other examples are electrical equipment of all kinds when used in a wet or humid place. Also, equipment used in areas where there is a high chance of damage by corrosive chemicals, oils, solvents or sunlight. These agents are especially liable to damage the insulation of such equipment. Any electrical equipment used outdoors, in field work etc., must also be given special priority. All equipment used in such environments should be tested every 6 months and must be tested not less than once every 12 months.

2.2 Inspection of Portable Equipment

Although a good initial level of safety can be achieved by correct selection and use of equipment and its connectors and cables, lasting safety can only be attained by on-going and effective maintenance. The maintenance programme should include visual inspection, testing, repair and replacement and should determine whether equipment is fully serviceable or remedial action is necessary. Cost effective maintenance of portable electrical equipment can be achieved by a combination of:

- checks by the user;
- formal visual inspection by a member of staff trained and appointed to carry them out; and
- combined inspection and tests by an electrically competent member of staff or by an approved contractor.

Departmental management should monitor the effectiveness of the system and take action where faults are found, particularly when faults are frequent.

2.2.1 User Checks (Visual)

The member of staff using the equipment should be encouraged to look at it critically and check for signs that it may not be in a sound condition. **Appendix 2** gives examples of typical user checks that should be applied to portable equipment, extension leads and associated plugs and sockets. The user should make visual checks prior to and during use. Any faults should be reported to departmental management and the equipment taken out of use immediately. Departmental management must take effective action to ensure that the equipment is not used again until it is repaired.

In each department there must be a full reporting system whereby if an individual is aware that a piece of electrical equipment is faulty or suspected of being so, there is a well-defined written system for reporting such instances to the Departmental Safety Convenor. The suspect or faulty equipment must be taken out of service, labelled 'FAULTY - DO NOT USE' and kept secure or have its associated plug removed, until examined by a competent person.

2.2.2 Formal Visual Inspections

The most important component of an inspection regime is usually the formal visual inspection. Such inspections can pick up most potentially dangerous faults and the maintenance regime should always include this component.

All portable equipment should be inspected at regular intervals based on an assessment of the risk. 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 of the equipment.

The formal visual checks can be carried out by a suitably trained and competent member of staff who has sufficient information and knowledge of what to look for, and what is acceptable and who has been given the task of carrying out the inspection. Typical formal visual checks are also detailed in Appendix 2. To avoid danger, trained staff should know when the limit of their knowledge and experience has been reached.

Departments should use simple written guidance to summarise what to look for and which procedures to follow when faults are found or when unauthorised equipment is found in use.

The pattern of faults can help department management decide what action to take depending on what the faults show:

- the wrong equipment is being selected for the job;
- further protection may be necessary in a harsh environment; and
- the equipment is being misused.

2.2.3 Combined Inspection and Tests

The checks and inspections outlined above, will if carried out properly, reveal most (but not all) potentially dangerous faults. However, some deterioration of the cable, its terminals and the equipment itself can be expected after significant use. Additionally, the equipment may be misused or abused to the extent that it can give rise to danger. Some of these faults, such as a 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. Heads of Department are responsible for ensuring that all portable/transportable electrical appliances within their areas of responsibility are inspected and tested at the required intervals.

Testing is required:

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

New electrical equipment should not require testing within its first year of service.

When setting the frequency of combined inspection and testing, account should be taken of any recommendations which the manufacturer may make along with the use and service conditions.

A suitable combined inspection and testing of portable apparatus will include an examination of the casing, cable and plug for signs of damage or deterioration as mentioned above. In addition, the relevant British Standard for the apparatus should be consulted and any recommended tests, e.g. insulation and earth continuity tests, should be carried out at the appropriate time intervals. There are two main tests which are required by the Regulations - the earth resistance test and the insulation test. There are a variety of portable appliance testers on the market which will carry out such tests.

Class I equipment has a conductive, usually metal, outer casing and the earth lead of its cable is connected to this casing; the earth test checks that the resistance of this connection to earth is sufficiently low.

Class II equipment has no need of an earth conductor. It has two sets of insulation to prevent the outer casing becoming live in the event of an electrical fault.

Both types require an insulation test. Only Class I can be tested for earth resistance.

2.2.4 Competency Requirements

Combined inspection and testing requires a greater degree of competence than required for inspection alone, because the results of the tests may require interpretation and appropriate electrical knowledge will be needed. People carrying out testing of portable electrical equipment must be appropriately trained for this work. It is the Head of Department's responsibility to ensure that staff are competent for the work they carryout. Basically, there are two levels of competency:

- the first level is where a member of staff not skilled in electrical work routinely uses a simple pass/fail type of portable appliance tester (PAT), where no interpretation of readings is necessary. The member of staff would need to know how to use the PAT correctly. Providing the appropriate test procedures are rigorously followed and acceptance criteria are clearly defined, this routine can be straightforward; and

- the second level is where a member of staff with appropriate electrical skills uses a more sophisticated instrument that gives actual readings requiring interpretation. Such a member of staff would need to be competent through technical knowledge or experience related to the type of work.

Departments with suitably qualified competent persons can undertake the testing and management of the testing programme themselves, or alternatively they can opt to use the University's approved electrical testing organisation. Departments opting to use the testing organisation can arrange this through Estates Services.

Most types of portable electrical equipment can be subjected to the earth resistance test and/or the insulation test without risk of damaging them. However, some types of electronic equipment may be susceptible to damage, e.g. some computer equipment. In such cases it would be wise to seek advice from the manufacturer or from an electronically qualified person before carrying out such tests.

Appendix 3 summarises the typical checks performed under a formal inspection and test.

2.3 Maintenance and Test Records

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. equipment brought to work by staff. 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.

Departments that carry out their own testing will find it useful to label equipment to indicate that the equipment has been tested satisfactorily, i.e. has been passed safe and when the date for the next test is due. This will reduce the chance of items being missed on consecutive test occasions.

An inspection procedure for portable electric appliances is given in Appendix 2. All such inspections should be recorded. A typical record may include the following information:

- means of identifying the unit, e.g. serial number;
- frequency of inspections;
- electrical tests (including statement of pass/fail criteria);
- the results of tests (pass or fail);
- name of the person who carried out the inspection; and
- date of inspection.

2.4 Repair and Replacement

The repair of most portable electrical equipment requires specialist knowledge and expertise if the faulty or damaged equipment is to be restored to the necessary safe condition. It is often more cost effective to replace cheaper items than to repair them. Similarly, it is better to replace than to repair faulty or damaged plugs, connectors and flexible cables.

Where flexible cables have been in use for a long time, it is better to replace rather than repair them because conductor wires, insulation and sheathing materials deteriorate. Replacement of relatively short lengths of unsatisfactory cable is usually cheaper than carrying out repairs.

Where longer lengths of cable are involved, if the damaged part is close to one end, cut it off. If the damage is not near one end, after removing the damaged section, the cable can be joined using a proprietary cable coupler. If a coupler is used, the socket part should be on the section fed from the electricity supply side and the plug should be on the cable connected to the equipment.

2.5 Periodic Testing of Fixed Electrical Installations and Apparatus

Fixed electrical installations should be tested by a competent person at least every 5 years (3 years in the case of agricultural/horticultural installations). Guidance on inspection and testing may be found in the Institution of Electrical Engineers (IEE) Regulations for Electrical Installations. A test certificate should be prepared showing the date and results of the investigation and test.

The University Electrical Engineer is responsible for co-ordinating this on a University wide basis and Heads of Department should liaise with Estates Services to ensure testing of their fixed electrical installations is up to date.

3. General Safety Measures

3.1. Isolating Switches

Staff should familiarise themselves with the position of the isolating switches for their area. If departments are not sure of the appropriate isolating switch for an item of electrical equipment they should contact Estates Services for advice. 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 Services**.

3.2. Plugs

Plugs which are not wired correctly, or in which the connections have been broken or damaged, can be lethal.

- wires must be fitted to the plug as follows:
    - the **earth** wire is **striped green and yellow** and is connected to the terminal marked **E**;
    - the **live** wire is **brown** and is connected to the terminal marked **L**; and
    - the **neutral** wire is **blue** and is connected to the terminal marked **N**.

- the fuse must be of the correct rating, i.e. the lowest rating which will carry the appliance current continuously;
- the plug must not be used to supply more than one piece of equipment;
- 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;
- uninsulated wires should not be visible in the plug-top;
- retaining screws should make good contact with the metal core of each wire and be screwed down tightly;
- the clamp must be over the outer insulating cover and hold the cable securely in place;
- damaged plugs or those showing signs of overheating must be replaced; and
- damaged sockets or those showing signs of overheating must be notified to Estates Services and the said socket must not be used until repairs have been effected.

3.3. Adapters

Adapters should not be used unless absolutely necessary. In no case should more than one adapter be used in a socket.

Multi-way distribution boards with 13 amp shuttered outlets may be used from a socket provided the total load does not exceed 13 amps and they are designed to BS 1363.

3.4. Cables

Cables must be of sufficient cross sectional area to carry the current that can flow through them in both normal and abnormal conditions, and 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. Check information on cable drum for maximum loading when wound or else completely unwind the cable off the drum.*

Reference must be made to the appropriate sections in the current edition of the IEE Wiring Regulations for appropriate cable selection.

From 1970 the correct colour code in Britain for flexible cable 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 re-wired, as soon as practicable, by a competent person to the current UK standard.

If equipment is being imported from outside the UK, staff should ensure it is provided with a correct UK power cable.

The supply lead should be a continuous length of cable with its sheath mechanically secured at both ends. The colour cores must not be visible at any point.

Cables 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).

Two core cables may be used with equipment having double or reinforced insulation and corresponding to BS 4743: 1979 safety class II.

3.5. Fuses and Circuit Breakers

The primary purpose of a fuse is to protect equipment against excess current flow, e.g. due to short circuit, before the overload has persisted long enough to cause damage by fire.

A fuse must be of the correct rating and specification for the equipment. Cartridge fuses are designed to rupture at a specified percentage above normal Full Load Current (FLC) at a pre-determined time. The circuit equipment must be capable of carrying the overload current until such time as the protection (the fuse) operates.

If a newly fitted fuse or 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.

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

Additional measures, such as a Residual Current Device (RCD), are necessary to provide protection from electric shock. Selection of suitable RCDs can be determined from the appropriate section of the IEE Regulations.

3.6. Earthing

The external metal casing of electrical apparatus must be earthed as a safety 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. Apparatus must 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 laboratories where “wet” experiments are in progress.

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

3.7. Earth Leakage Circuit Breakers

The application of an earth leakage circuit breaker (more correctly known as a Residual Current Device (RCD)) to a conventionally earthed system should be considered where this is vital to provide an additional backup protection against failure of the designed earthing system. An 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: A fuse is also required as RCDs do not protect against short-circuits between live and neutral.*

Many circuit breakers on normal mains (240 V) operate at 30 milliamps which, is still capable of producing a severe shock.

A standard residual current operated circuit breaker is designed to operate with an AC current only.

Many modern appliances such as power-tools, VDUs etc., contain solid state devices which may create a pulsating DC current affecting the operation of a standard RCD and this may lead to loss of protection. Pulsating DC fault current sensitive RCDs are 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. A record must be kept of RCD tests.

3.8. Reduced Voltage System

Preferably the use of battery operated power tools should be considered wherever possible in preference to power tools and in particular for use in hazardous situations. Where this is not possible, reduced voltage power tools must be used. This system requires the star point or mid-point of the reduced voltage (i.e. 110 V or less) transformer to be earthed. In this system the voltage to earth is about half the supply voltage.

Guidance on both the maximum voltage which should be used and the preferred portable apparatus for specific situations is given in **Appendix 4**.

The conditions outlined in Section 4 of Appendix 4 ~~1~~ cover most situations in University departments. It follows, therefore, that where battery tools cannot be used, University departments should use only portable power tools which work on the 110 V Centre Tapped Earth (CTE) system. All new portable mains power tools must be 110 V CTE. It should be remembered that most shocks occur between live and earth. Therefore, the use of this system will reduce the risk of a lethal electric shock.

All contractors on University premises should be informed that only 110 V CTE power tools can be used on University premises.

3.9. Insulation of Portable Apparatus

Portable apparatus used at normal mains voltage is required to have basic insulation. In addition, the metal work must be earthed so that it cannot become live in the event of an insulation failure. Apparatus and tools are now obtainable which are **all-insulated** and **double-insulated** and do not require earthing.

It is particularly important to ensure 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 care and awareness 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.

3.9.1 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.

3.9.2 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.

3.9.3 Portable Electric Hand Tools

Portable motor-operated tools, all-insulated or double-insulated, must comply with BS EN 60745-1 and must bear the certified trade mark of the British Standards Institution. Double-insulated apparatus must comply with BS 2754 and must bear the certified mark of the British Electrical Approval Board.

3.10 Arc Faults

Arcing refers to a “luminous discharge of electricity across an insulating medium, usually accompanied by the partial burning of the electrodes”. The insulating medium can be an air gap, insulation worn thin by aging, abuse or a number of other factors. The conditions for arcing may form over a wide range of time intervals, from milliseconds to decades, before an arcing fault develops. Both current level and duration are factors that allow arcs to generate the heat needed to cause a fire. Arcing faults can readily produce temperatures in excess of 1000^{o} C with as little as an ampere of current flowing. Arcing also gradually breaks down organic insulating materials. As these materials carbonize, they release hydrocarbon vapours that allow the conduction of electricity more easily than the air/metal interface. This further supports the process of arcing. There are three basic types of arcing:

3.10.1 Line-to-neutral arc faults

A damaged power supply cord can be an example of a line-to-neutral arc fault. Power supply cords can experience repetitive flexing that, over time, may damage the insulation and/or conductors inside. This flexing may be caused by repetitive use – plugging and unplugging a machine day after day or wrapping a cord around the equipment for storage, for example, - or from a door or other weighty obstruction that continually pinches the cord. This process may cause the cord to be worn to the point that the insulation between the line and neutral conductors is no longer sufficient to prevent an arc from forming. The insulation material will carbonize quickly, causing an arc fault and further degradation of the insulation. To minimise these faults care should be taken to avoid repeated flexing of cables at the same place or pinching of the cable itself.

3.10.2 Line-to-ground arc faults

A line to ground arc fault can occur from an event as simple as hanging a picture. Very few people know what is behind the plasterboard when they drive in a nail. The nail driven to hang a picture can easily penetrate the insulation of wiring which typically includes a bare ground wire positioned between individually insulated live and neutral conductors. If the live wire insulation is damaged by a nail, a line –to-ground arc can easily occur. The danger may not be realised quickly. Sufficient air may separate the nail from the ground wire to prevent immediate arcing. However, surges along the wire such as those generated by vacuum cleaners or lightning, can cause a carbon path to form between the energized nail and the ground wire, starting a process of a line-to-ground arc fault. To minimise these faults the position of electrical cable runs should be established before fixings are placed into plasterboard walling.

3.10.3 Series arc faults

A series arc fault can occur anywhere in the live or neutral wire of a circuit. By definition, the current flowing in a series arc fault is limited by the load on the circuit. The connection of wires at terminal blocks or receptacles e.g. inside equipment or at wall sockets is an example of a place where a series arc fault may occur, particularly at screw connectors. The screw connector may become loose through inadequate tightening, vibration of equipment or through counter clockwise movement of the conductor in the connection due to a torque force being applied to the conductor itself e.g. bending of overlong conductor wires. This loose connection may carry the current without arcing after installation. However, intermittent current flow is part of the design of every electrical system and appliance. With very few exceptions, electrical circuits do not run continuously. Loads cycle on and off, either manually or automatically. This intermittent current flow creates heating and cooling cycles at the screw terminal connection. This cycling can cause a thin oxidation layer to form on connection surfaces. This oxidation layer acts an insulator. However when the line voltage is enough to exceed the insulating value of the oxidisation layer, electrons jump the insulating gap, allowing current to flow in the form of an arc fault. The increased heat from arc formation further accelerates the formation of a carbonised path. To minimise these faults care should be taken to ensure screw terminal connectors are adequately torqued to secure the conductor and prevent movement. Inspection and maintenance schedules for electrical equipment and installations should include a check on the condition of electrical connections for signs of overheating and security of the conductor in the connector.

4. 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 240 V AC, switching the appliance off and then pulling the plug out is the best method, but for fixed equipment it is necessary to have manual isolating switches. (Users should ensure they retain control of the disconnected plug to prevent accidental reconnection by others.)

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 must be designed so that they can be locked in the open position to ensure that no one can switch on whilst users are working on the apparatus; isolators should always be ‘suitably located’ as near to the controller or starter as possible.

Isolators must never be left locked in the ‘on’ position; the occasion may arise when speedy isolation is imperative.

In every laboratory where apparatus with live terminals is in use there must be a master isolator which will disconnect the whole of the laboratory/work area from the supplies. This must be marked “SWITCH OFF IN EMERGENCY” and all persons using the area must know of its function. When the laboratory/work area 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 (the circuit is isolated from the electrical supply and discharged to zero voltage). 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.

4.1. Transformers

4.1.1 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 on supply mains to hazardous areas and test benches. Transformer supplies can be dangerous if contact is made between both conductors.

4.1.2 Auto-Transformers and Variacs

Auto-transformers and variacs (variable autotransformer) **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.

4.2. 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, in addition, 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. It should be noted that in such cases an appropriate COSHH (Control of Substances Hazardous to Health Regulations) risk assessment should be carried out and suitable control measures put in place and protective clothing worn.

Sealed batteries must never be heated or thrown on to a fire; they can explode. They should be disposed of through the University hazardous waste service, run by Estates Services.

5. Work on Live Electrical Equipment

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

- testing during assembly or production;
- fault finding during repair;
- research or development work using oscilloscopes and similar instrumentation; and
- work at fuse boards and electrical distribution boards.

Work on or near live conductors should rarely be permitted. In most cases adequate planning and work programming will allow work to be carried out as the regulations require, i.e. with the equipment dead. There can be a temptation to justify working on live equipment if it is 'convenient' rather than necessary. This is **not permissible**. Personnel doing this type of work are reminded that, under the Electricity at Work Regulations 1989, they may only work on live equipment if there is no reasonably practicable alternative. Regulation 14 requires that three conditions are met for live working to be permitted where danger may arise. It is stressed that if just one of those conditions cannot be met, live working cannot be permitted and dead working is necessary. The conditions are:

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

Under the Electricity at Work Regulations 1989, work on live equipment should only be carried out if there is no reasonably practicable alternative. Personnel wishing to work on live equipment *must* present a written case to the Head of Department, justifying the need to work live, detailing the safe system of work to be used and their competence to carry out the work, in terms of experience and technical knowledge. If the Head of Department is satisfied with the case and the risk control measures detailed, then written permission for live working may be given at their discretion. Estates Services has its own control arrangements for live working.

Departments wishing personnel to work on live equipment *must* complete a risk assessment of the work and draw up a Safe System of Work justifying the need to work live and detailing the control measures which will be put in place to ensure the safety of personnel under all appropriate circumstances. Obviously these controls measures will vary depending on the particular job but they may include such provisions as earth free zones, double wound transformers and circuit breakers (remembering the operating characteristics of these), Perspex guarding with test point access etc., and the competency of the person who is working 'live'. Detailed guidance on the risk assessment and suitable controls can be found in HSE Guidance HSG 85 "Electricity at Work, Safe Working Practices" which is free to download from the HSE website.

Departments must ensure that the experience and technical knowledge of those who are asked to work live is compatible with the particular job.

The competency of those carrying out such work, therefore, must be assessed and, if necessary, appropriate supervision must be given.

As a general rule, members of staff, especially research students, should not work 'live' on their own and should be accompanied by another person who has suitable and appropriate technical knowledge of the work being carried out.

6. Safety Measures for Specific Areas

6.1. Offices, Libraries and Lecture Theatres

The majority of people working in offices, libraries and lecture theatres are possibly unaware 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.

- new equipment must be inspected by a competent person before being taken into service. In most cases this will need no more than a visual inspection to confirm that the appliance is properly connected to a suitable plug, appropriately fused and has no obvious faults in the connecting cable. A record of this must be kept;
- plugs must be fitted by a competent person using the correct colour coding for cables;
- fuses must be of the appropriate rating for the appliance;
- wires should be of a suitable length and should not trail across the floor;
- multi-outlet adaptors should not be used. A multi-way fuse distribution board (to British Standard Specification 1363) with 13 amp shutter outlets should be used if additional sockets are required;
- the user of the equipment should regularly inspect for damage to casings, cables and plugs etc. and for loose screws;
- do not use equipment if you think it is defective - report the fault to the responsible person in the department;
- do not attempt to repair equipment yourself;
- n the event of a fire, use CO_2 (preferably) or dry powder extinguisher on live equipment. NEVER USE WATER EXTINGUISHERS. Try to disconnect the equipment if you are sure that this can be done without personal risk;
- certain office equipment e.g. electronic stencil cutters, may emit ozone which is toxic. Thought should be given to appropriate ventilation before bringing in such equipment. (COSHH Risk assessment may be required); and
- all electrical equipment must be inspected and tested at regular intervals. An appropriate record must be kept. (See Section 2.1.3)

6.2. Laboratories

6.2.1 General Safety Measures

The modern laboratory is full of electrical apparatus, much of which 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:

- know where the main isolators for your laboratory are situated;
- new equipment should be inspected by a competent person before being put into service. This is of particular importance in the case of in-house assembled apparatus. (See section 6.3.1);
- plugs must be fitted by a competent person;
- the correct colour coding for wires and cables must be used;
- wires should be of the correct length and follow a safe route;
- where there are insufficient fixed sockets, multi-way fused distribution boards (to British Standard Specification 1363) with 13 amp shuttered outlets may be used;
- electrical equipment must be inspected and tested at appropriate intervals. (Please see section 2.1.3) ;
- do not use equipment which you suspect may be faulty - report it to the Departmental Safety Convenor;
- equipment should be repaired by a competent person, where possible in a properly equipped workshop;
- inspection covers must not be removed from equipment except by a competent person, as equipment may be dangerous even when disconnected;
- in the event of a fire, use a CO_2 (preferably) or a dry powder extinguisher on live equipment. NEVER USE WATER EXTINGUISHERS. Try to disconnect the equipment if you are sure that this can be done without personal risk;
- always follow the manufacturer's instructions and observe any relevant University Local Rules or Guidance and/or Departmental Safety Regulations;
- 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, e.g. ATEX rated; (EU Directive; *Appareils destinés à être utilisés en **AT**mosphères **Ex**plosibles)*
- special attention should be paid to earth connections. Consider if the use of residual current circuit breakers or isolating transformers would be an advantage;
- electrical equipment with exposed live terminals should only be used if there is no practicable alternative. It should be noted that where such conditions exist the regulations require that specific precautions be imposed;
- beware of capacitors. High grade capacitors must always be shorted before being handled;
- electrical apparatus removed from refrigerators and cold rooms must not be used until it has had time to warm up properly. If wet it must be checked by a competent person before use; and
- 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).

6.2.2 Electrical Equipment under Development

Many experiments carried out by undergraduates or postgraduates call for the use of electrical equipment which is continually being altered and improved. It may be that such work involves 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 in charge of 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, or to be taken to ensure safety.

It is for each department to risk assess the hazards of electrical work to all staff, research and 4th year project students. **This Risk Assessment and Safe System of Work must be in writing and must identify the particular hazards of the project and detail how they will be controlled. Electrical Safety - as with all other forms of safety, is the responsibility of the Head of Department. However, each student's supervisor must ensure that an appropriate Risk Assessment/System of Work which is suitable and sufficient is formulated before any work is carried out.** This must be signed by both the supervisor and the student. The supervisor should hold the original with a copy issued to the student and the Head of Department (who may decide these will be held by the Departmental Safety Convener). The assessment must be kept under review and updated as necessary. Training on the process of Risk Assessment can be arranged through Safety Services if required.

All fixed high voltage equipment used in research should be enclosed by an earth box or cage which cannot normally be moved without dismantling. (Obviously this cannot be considered reasonably practicable in every case.) If such a cage is to be used, then warning notices should be displayed at the entrance to the enclosure and a warning light should be activated when the apparatus within the enclosure is powered up. Such enclosures must be appropriately electrically interlocked. All such interlocks must be of a design such that they fail to safety. No person shall work alone with high voltage apparatus.

6.3. Electronic and Electrical Workshops

6.3.1 General Safety Measures

- where work on 'live' equipment is carried out the following recommendations are made:
  - the entrance to these workshops should display a WORKSHOP AREA notice clearly warning visitors of the particular specified safety regulations that apply;
  - the floor of the workshop should be covered with an insulating material. Bench surfaces should 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; and
  - all socket outlets should be supplied via earth leakage circuit breakers and the whole workshop must be provided with an easily identifiable mains isolator switch;
- as far as is practicable equipment should fail to safety. Access to live parts should not be possible without removing a screwed down cover. Mains leads should be of the correct current carrying capacity, be mechanically secured and be either double insulated or of the three-cored type and of 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 equipment chassis. The earth terminal should not be used for securing other components;
- 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;
- great care must be taken in selecting the correct fuse specification 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;
- 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 British Standard colour code;
- soldering irons should not be used without an earth connection and must be of the low voltage type; and
- Portable tools and hand inspection lamps must 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. HSE publication INDG 354 "Safety in Electrical Testing at Work" gives good advice on the subject.

6.3.2 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 practicable, that the article is so designed and constructed as to be safe and without risk to health when properly used.

All apparatus constructed by departmental staff should be inspected and approved by an authorised person(s) before being placed into service and thereafter inspected at appropriate intervals to ensure that the installation remains in a satisfactory condition.

The standard of safety in electrical and electronic apparatus generally applied in the UK is that laid down in BS EN 61010-1 2001 Safety Requirements for Electrical Equipment for Measurement, Control and Laboratory Use - General Requirements. This standard should be applied to electronic apparatus constructed in departments.

Additionally, electrical apparatus for medical use or which may be used to take measurements from persons should conform to BS EN 60601-1 1990 Medical Electrical Equipment - General Requirement for Safety.

If departments are designing/building electrical equipment which may be connected to individuals (i.e. either as volunteers or patients), then it is even more important that each Head of Department satisfy themselves that there is a system within the department which ensures the competence/supervision of those designing and building the equipment. If need be, a competent person should check the integrity of the equipment. A rigorous inspection and testing procedure must be implemented.

There are obviously ethical questions involved for such equipment; however, such considerations are outwith the scope of this guidance.

6.4. Difficult Environments

All electrical equipment, including socket outlets and other fittings such as lights should be chosen bearing in mind the environmental conditions of use. A portable tool which is safe in one situation can become lethal under different circumstances. Precautions for certain difficult environments are given in Appendix 4.

Coded Classifications

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 I P 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 BS EN 60529.

Hazardous Environments

Broadly there are two types of hazardous environments:

- Wet Areas - where water or aqueous chemicals can enter electrical equipment; and
- 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.

6.4.1 Wet Areas

The electrical hazards associated with wet areas are those of damp, wet or corrosive conditions with non-insulated structures and flooring. The dangers are those of shock and short-circuit.

6.4.2 Field Work, Greenhouses and Biological Procedures Unit.

Equipment used in these areas must 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 appropriate intervals. (See section 2.1.3.) Equipment should be protected by earth-leakage circuit breakers and/or isolating transformers (double wound). Where reasonably practicable, 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.

6.4.3 Wash-Up Areas

Not all equipment used in these areas will be waterproof. Extra care, therefore, should be exercised in order to avoid any liquid entering electrical equipment and/or fittings. Equipment which is wet must not be used until it has been tested by a competent person.

6.4.4 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). Wet, non-waterproof equipment should be checked by a competent person before being used. Where reasonably practicable, equipment should be low voltage.

6.4.5 Areas with Flammable or Explosive Atmospheres

These areas require electrical equipment which is intrinsically safe. 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:

All work areas where flammable or explosive substances (gases, liquids, powders) are stored or used must be risk assessed in accordance with The Dangerous Substances & Explosive Atmospheres Regulations (DSEAR) and the areas appropriately classified and zoned. This will indicate the standard of intrinsically safe electrical equipment required.

The University Electrical Engineer should be consulted in advance about any electrical installation which is intended for use in a flammable atmosphere.

A flammable atmosphere must not be introduced into any room, enclosure or working area in which the electrical installation is not in accordance with BS EN 60079-14.
Precautions must be taken to prevent ignition of flammable atmospheres by the discharge of static electricity.

The risk of ignition of a flammable vapour 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 material is an oxygen carrier such as rust, frictional sparking can occur. In such circumstances, non-sparking handtools may be a suitable alternative. Portable apparatus with light metal enclosures should not be used in hazardous areas.

If "petroleum" or "petroleum products" as defined by the 1928 Petroleum Consolidation Act are stored, a licence is required and the Fire Safety Adviser should be consulted.

Refer to Safety Services' Guidance document on Dangerous Substances and Explosive Atmospheres for further advice.

6.4.6 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, Safety Services and the University Electrical Engineer should be consulted for advice.

Appendix 1 - Suggested Initial Frequency of User Checks, Formal Visual Inspections and Combined Inspection and Test

Type Of Equipment	User Checks	Formal Visual Inspection	Combined Inspection & Test
Equipment used in construction environments	110V – Weekly 230V mains – Daily/Every Shift	110V – Monthly 230V mains - Weekly	110V – Before first use on site then 3-monthly. 230V mains – Before first use on site then monthly.
Light Industrial	Yes	Before initial use then 6-monthly	6 – 12 months
Heavy industrial or high risk of equipment damage	Daily	Weekly	6 – 12 months
Office information technology, e.g. desktop computers, photocopiers, fax machines	No	1 – 2 years	None if double insulated, otherwise up to 5 years.
Double insulated equipment not hand held. e.g. fans, table lamps	No	2 – 3 years	No
Hand-held, double insulated (class II) equipment, e.g. some floor cleaners, irons, kitchen equipment	Yes	6 months – 1 year	No
Earthed (class 1) equipment, e.g. kettles, some floor cleaners	Yes	6 months – 1 year	1 – 2 years
Equipment used by public	Yes, by member of staff	3 months	1 year
Cables and plugs, extension leads	Yes	1 year	2 years

Where one figure is given, this is a guide for anticipated average use conditions; more demanding conditions of use will require more frequent formal inspections, and/or combined tests. Where a range is shown, the small interval is for more demanding conditions of use, the longer interval is for less demanding ones. Where electrical equipment is used by the public, and the department does not have direct control over the way in which it is used, formal inspection will need to be done more frequently. After the first few formal inspections, the information obtained can be used to review the maintenance programme and adjustments to the intervals. A low failure rate would indicate that the interval can be increased and a high failure rate that the interval must be shortened.

Appendix 2 - Portable Electrical Equipment User Checks and Formal Inspection Check List

It is recommended that the following checks be made by the user ***EVERY TIME BEFORE HANDHELD PORTABLE ELECTRICAL EQUIPMENT IS USED***.

- check the cable sheath is undamaged (apart from a light scuffing)
- check the plug casing is undamaged? (no cracks, no bent or damaged pins)
- check the outside of the plug, cable and casing are free of signs of overheating? (no burns or scorch marks)
- check there are no inadequate joints in the cable, including taped joints.
- check the outer sheath of the cable is effectively secured where it enters the plug or equipment. Obvious evidence for failure would be if the coloured insulation of the cable conductors were showing.
- check the cable is free from kinking and other mechanical damage.
- check the casing of double insulated equipment is free of obvious damage.
- check there is a visually obvious earth connection to the casing where this is made of metal and not protected by double insulation.
- check there is a label to say that the tool has been tested within the past six months.

Formal Visual Inspection checks should include the user checks mentioned above, and the following additional checks:

- removing the plug cover and ensuring a fuse is being used (not a piece of wire or a nail etc.);
- checking that the cord grip is effective;
- checking that the cable terminations are secure and correct, including an earth where appropriate; and
- there is no sign of internal damage, overheating or ingress of liquid or foreign matter.

A formal visual inspection should not include taking the equipment apart.

Appendix 3 - Inspection & Test Procedure for Portable Electrical Appliances in Offices and Other Low Risk Environments

Listed below are typical routine electrical checks for portable apparatus to be carried out by a suitably competent person. This check list is intended as a guide. Certain apparatus may need different or additional inspections and tests.

	Item	Test	Pass Condition
1	Mains lead	(a) Visual inspection	Two layers of insulation and BS colours. No damage (apart from light scuffing). No inadequate joints in cable, including taped joints. No evidence of overheating.
		(b) Mains plug	Correctly connected. Cable clamp gripped to sheath (Conductor insulation not showing). Correct fuse fitted. Pins undamaged. No evidence of overheating.
2	*Either:* Mains lead instrument	(a) Visual inspection of panel male connector	BS type or equivalent.
		(b) Attempt to open socket without tool	Unopenable
		(c) Attempt to pull cable from female connector	No movement
	or: Grommet/clamp	*or*	
		(a) Inspection of grommet	Cable insulation protected
		(b) Sharp pull on cable	No appreciable movement
		(c) Rotation of cable	No rotation
3	Mains on/off switch	(a) Visual inspection	Correct operation. No damage
	Either 4 or 5:		
4	Conducting case	(a) Visual inspection (if marked ⧈ treat as item 5). Each tester which will check resistance and pass a current of a least twice the fuse rating.	Undamaged case. No loose parts/screws. No evidence of overheating or contamination. Earth resistance 0.1 Ω or earth resistance 0.5 Ω for loads fused at 3A or less.
		(b) High voltage insulation 500 V AC minimum test.	No fault indicated after 5 seconds.
5	Insulating case	Visual inspection.	Maker's double insulation mark ⧈ visible. Case undamaged. No loose parts/screws. No evidence of overheating or contamination.
6	Accessible fuse holders	Visual inspection.	No damage. Removal of carrier does not permit live* part to be touched.
7	Exposed output connections	(a) Visual inspection (b) For outputs greater than 50 V test short-circuit current	No voltage greater than 50 V. Short-circuit current less than 5 mA.

* i.e. - live at more than 50 volts when in use.

Appendix 4 - Typical Precautions for Difficult Environments

	Situation	Precautions
1	Persons working in water in contact with metalwork and in damp or humid conditions (e.g. in a tank).	Avoid using portable electrical apparatus: pneumatic power tools are preferable. Electric lighting, if essential, should be 25 V DC or CTE* maximum and fixed out of reach.
2	Apparatus used where jets of water may be present (yards, car washing bays etc.).	Use voltages of 50 V AC, 120 V DC or less. If higher voltages are necessary because of power requirements, the equipment should be of special construction, e.g. waterproof. The supply to earthed equipment should incorporate backup protection, preferably earth monitoring (see HSE Guidance Note PM29, Electrical Risks From Steam/Water Pressure Cleaners).
3	Work in close contact with metal work but cool, dry conditions (e.g. fabrication). Dusty or damp locations where there is no close contact with earthed metalwork.	Use voltages of 50 V AC or 120 V DC or less. (110 V AC CTE* may be used in conjunction with all-insulated or double-insulated (i.e. Class II) tools). Frequent cleaning of ventilation louvers etc. is necessary.
4	Building and construction sites. Quarries, ad hoc maintenance work in factories etc. Outdoor use in good weather.	Reduced voltage supplies are preferred (e.g. 110 V AC CTE*).
5	Clean 'kind' situations.	All-insulated or double-insulated portable apparatus is preferred. Earthed equipment may be used. Sensitive RCDs recommended.
6	Corrosive atmospheres.	Anticorrosive finish and/or apparatus may be pressurised to exclude the harmful atmosphere. Discuss application with manufacturer/supplier.
7	Flammable atmospheres.	Certified explosion protected apparatus required. ATEX category depends on DSEAR classification of hazardous zone.

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

Appendix 5 - Rules for the Introduction and Use of Domestic Electrical Equipment in University Residential Accommodation

Items of domestic electrical equipment may be brought into and used within residences with the proviso that strict adherence is given to the following:

1. Equipment and connecting leads must be serviceable and in a safe condition;
2. Plugs must be wired in the correct manner and incorporate fuses of the correct rating for the equipment;
3. A plug must supply only one piece of equipment;
4. If extra sockets are required, multi-way distribution boards with 13 amp shuttered outlets must be used; and
5. Distribution boards must comply with the British Standard. BS1363

In self-catering residences additional cooking equipment may be brought in for use in kitchen areas only. The following electrical equipment is not permitted for use in study bedrooms:

- Electrical under/over-blankets;
- Additional heaters;
- Sandwich makers/toasters;
- Microwaves/small ovens;
- Electric Kettles;
- Fridge freezers;
- Chip pans; and
- Sunbeds;

Mini cup boilers are not permitted for use anywhere in residences. In the event of University personnel finding electrical equipment which does not conform to the standard above, the University reserves the right to take whatever action it deems necessary. If in doubt, contact the Residences Manager within Estates Services, who will advise or seek advice from an appropriate qualified person.

Appendix 6 – Electrical Standards and Approved Codes of Practice

Listed below are some commonly used electrical standards and approved codes of practice, which may be applicable to the design of electrical installations or work with electricity undertaken within departments. The list is not exhaustive and additional standards and codes of practice may be needed to satisfy a specific application – it is the responsibility of the PI or person supervising the installation/work to select and apply these.

Electrical Power

Standard	Description
BS EN 61439 many parts	Low-voltage switchgear and controlgear assemblies.
BS 5266 Parts 1 to 10 also BS EN 50172	Code of practice for emergency lighting.
BS 5424 Parts 2 and 3, also IEC 60158 part 3	Specification for low voltage control gear.
BS EN 60422	Monitoring and maintenance guide for mineral insulating oils in electrical equipment.
BS 5839 Parts 1-11, also PD6531:2010	Fire detection and alarm systems for buildings.
BS EN 60079-30-2	Electric surface heating.
BS 6423	Code of practice for maintenance of electrical switchgear and controlgear for voltages up to and including 1kV.
BS 6626	Code of practice for maintenance of electrical switchgear and control gear for voltages above 1kV and up to an including 36kV.
BS EN 62305, 4 parts	Code of practice for protection of structures against lightning.
BS 7430	Code of practice for earthing
BS 7671	Requirements for electrical installations. IEE Wiring Regulations 17th Edition.
BS 7909	Code of practice for temporary electrical systems for entertainment and related purposes.
BS EN 50110 Parts 1 and 2	Operation of electrical installations.
IEC 60479 Parts 1-4, also PD6519	Guide to effects of current on human beings and livestock.
BS EN 60529	Specification for degrees of protection provided by enclosures (IP code)
BS EN 60947 Parts 1-8	Specification for low voltage switch gear and control gear.

Electrical Appliances

Standard	Description
BS 1362	Specification for general purpose fuse links for domestic and similar purposes (primarily for use in plugs)
BS 1363 Parts 1 – 5	13A plugs, sockets and adaptors.
BS EN (IEC) 60309 Parts 1,2,4	Plugs, socket-outlets and couplers for industrial purposes.
BS EN 60320 Parts 1,2	Appliance couplers for household and similar general purposes.
BS EN 60335 many parts	Specification for safety of household and similar electrical appliances.

Electromagnetic Compatibility

Standard	Description
BS EN 61000-6-3,4	Electromagnetic compatibility. Generic emission standard.
BS EN 61000-6-1,2	Electromagnetic compatibility. Generic immunity standard.
BS EN (IEC) 60801, part 2`	Electromagnetic compatibility for industrial –process measurement and control equipment. Electrostatic discharge requirements.

Flammable Atmospheres

Standard	Description
EEMUA 181	Guide to risk based assessments of Ex e & Ex n machines
EEMUA 186	A Practitioners Handbook – electrical installation & maintenance in potentially explosive atmospheres.
PD CLC/TR 50404	Code of practice for avoidance of hazards due to static electricity.
BS EN 61241	Electrical apparatus with protection by enclosure for use in the presence of combustible dusts.
PD CLC/TR 50427	Assessment of inadvertent ignition of flammable atmospheres by radio-frequency radiation. Guide
BS EN ISO 10497	Testing of valves. Specification for fire type-testing requirements.
BS 7535	Guide to the use of electrical apparatus complying with BS 5501 or BS 6941 in the absence of combustible dusts.
BS EN 60079, many parts	Electrical Apparatus for potentially explosive atmospheres
BS EN 60079-6	Explosive atmospheres. Equipment protected by oil immersion “o”.
BS EN 60079-2	Explosive atmospheres. Equipment protected by pressurised enclosures “p”.
BS EN 60079-5	Explosive atmospheres. Equipment protected by powder filling “q”.
BS EN 60079-1	Explosive atmospheres. Equipment protected by flameproof enclosures “d”.
BS EN 60079-7	Explosive atmospheres. Equipment protected by increased safety “e”.
BS EN 60079-11	Explosive atmospheres. Equipment protected by intrinsic safety “i”.
BS EN 60079-22-2	Explosive atmospheres. Gas detection. Selection, installation, use and maintenance of detectors for flammable gases or oxygen.
Energy Institute Model Code Of Safe Practice, Part 1 (IP1)	Electrical Safety Code.
Energy Institute Model Code Of Safe Practice, Part 15 (IP15)	Area classification code for installations handling flammable fluids
Energy Institute Model Code Of Safe Practice, Part 21 (IP21)	Guidelines for the control of hazards arising from static electricity.

Machinery

Standard	Description
BS EN I953	Safety of machinery. Guards. General requirements for the design and construction of fixed and movable guards.
BS EN ISO 13850	Safety of machinery. Emergency stop. Principles for design
BS EN 13849	Safety of machinery. Safety related parts of control systems. General principles for design.
BS EN 982	Safety of machinery. Safety requirements for fluid power systems and their components. Hydraulics.
BS EN 983	Safety of machinery. Safety requirements for fluid power systems and their components. Pneumatics.
BS EN 1037	Safety of machinery. Prevention of unexpected start-up.
BS EN ISO 12100	Safety of machinery. General principles for design. Risk assessment and risk reduction.
BS EN 1088	Safety of machinery. Interlocking devices associated with guards. Principles for design and selection.
PD 5304	Safe use of machinery.
BS EN 60204 many parts	Safety of machinery. Electrical equipment of machines.
BS EN 61069, Parts 1-8	Industrial process measurement and control. Evaluation of system properties for the purpose of system assessment.
BS EN 61310, Parts 1,2,3	Safety of machinery. Indication, marking and actuation.
BS EN 61496, 3 parts	Safety of machinery. Electro sensitive protective equipment.