Safety Handbook for Undergraduate Electrical Teaching Laboratories

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Contents

Introduction to the Handbook

1 This Handbook is written for undergraduate students who are performing set experiments in electrical teaching laboratories. These typically contain a variety of electrical and electronic equipment, including rotating machines, transformers, oscilloscopes, amplifiers, inverters, electrical supplies of all kinds, instrumentation, etc. It is mainly addressed to you, the student; however, the staff who plan and supervise the experiments will also find much that is relevant to their responsibilities.

2 The Handbook contains information and advice on a range of safety matters, some of which covers practices for which there is statutory legal obligation. This may be explained in the text, or the word 'must' may be used to indicate a statutory requirement. All other recommendations are advisory, which means they are examples of good practice. There may well be other ways of achieving the same effect, but people who adopt them need to be satisfied that their alternatives can be shown to be as safe or safer than that recommended.

3 The responsibility for complying with statutory requirements rests upon the staff who organise and supervise laboratory courses. However, students also have a duty of care in common law, and this effectively requires them to comply with all stipulated rules and guidelines for safe practice. It is important that you read this handbook, and follow its advice at all times. You should not enter any laboratory until you know the particular safety rules that apply to it and can undertake to abide by them.

4 In project work, particularly in the later years of study, a wider range of equipment is encountered, the ways in which it is used are more varied, and some equipment is of a non-standard, developmental nature. Such work is not fully covered by the advice given here, although there is much that is relevant to it.

5 There is a large body of safety literature, covering legislation and guidelines for good practice (see, in particular, the references at the end). But in fact safety is seldom complicated and for the most part is common sense, unfailingly applied. So far as personal behaviour is concerned, it comes down to three vital principles:

- know the dangers and what to do in an emergency
- *think* before you act and always act in a deliberate and responsible way
- be aware of the safety of others around you, for whom you exercise care as much as for yourself.

6 Statistics show that university engineering laboratories have a good safety record. But that should not lead to complacency, which is a first step to negligence. You may be exposed to dangerous situations without realising the risk, repeatedly, and come to no harm; you were lucky, but may be less so next time! Accidents tend to happen when you least expect them and strike fast, almost always as a result of exposure to danger that could have been avoided. And ignorance of what to do, when they happen, may multiply the consequences.

7 As a future professional engineer, you will almost certainly need to be familiar with a good deal of safety legislation and the implications it has for your work, whether it is in design, research, project engineering, management or consultancy. In any of these occupations, and more, you will have statutory responsibility under the criminal law for the safety of others, just as the staff who organise and supervise your work have responsibility for you. This is a most serious matter and there are heavy penalties for those who breach the law, by commission or neglect. Your first steps towards a professional knowledge of safety start with this Handbook.

There is an important general principle, concerning professional responsibility for safety. It is that the legal requirement to specify safe working practices for any particular operation, and to ensure those practices are observed, is ultimately the responsibility of all the competent staff (this responsibility on all staff cannot be shrugged off and placed on others' shoulders) whose designated tasks include specifying the operation (in whole or in part) and overseeing the way it is conducted. These staff must assess the nature and degree of the dangers inherent in the operation and must specify appropriate practices to prevent danger, so far as is practicable, taking account of all legal requirements and guidelines. They must also ensure that the safe working practices are complied with. As part of the process of assessing the dangers, there may be a requirement for a written protocol for each activity, which classifies the risks, both in nature and degree, and specifies appropriate practices and supervision. University staff are recommended to employ written protocols in their procedures for ensuring safety in laboratories.

8 Most of the text is concerned with safety at the undergraduate level, but some goes beyond. Many recommended practices are doubly important in later professional life, particularly because the power levels to which you are exposed can be much higher. But adopting good practices from the outset is vital, and it is helpful to see them related to real engineering situations. Also, it is hard to appreciate just how important safety is, if you have never experienced a serious accident - and most people have not. The material given in boxes, separate from the main teXt, covers a few practical matters and gives some examples that help to show how advice in the Handbook relates to safety in a professional context.

Safety Education and Supervision

Education for Safe Practice

9 It is recommended that at an early stage during the first year of your course, you should receive formal training about the following:

- safe use of hand tools
- correct use of fire extinguishers, especially those suitable for electrical fires
- basic first-aid and treatment for electric shock, including artificial resuscitation.

The following training at some point may also be considered helpful, at the discretion of staff:

- precautions to be observed for high voltages
- safe working with lasers
- safe handling of liquid nitrogen
- safe handling of compressed gases.

10 As part of your safety education it is recommended that in your first year you receive a copy of this Handbook (or equivalent) and that the principal safety issues it raises are discussed, in one or more lecture/seminar sessions.

11 It is recommended that you should sign an undertaking that you have read and understood the contents of the Handbook (or equivalent) and will endeavour to act in accordance with its advice at all times.

Students who have some degree of colour blindness should recognise that this is a potential source of danger, because colour coding of cables, terminals, warning lights, etc, is widely practised in electrical engineering. You are advised to act with particular care where circumstances call for it, particularly over the checking of circuit connections, confirmation that circuits are isolated, etc. Whenever you are in doubt, seek the advice of a colleague whose colour vision is normal. There are some categories of occupation in electrical engineering for which colour blindness might disqualify a person from employment, because of the associated safety hazard.

Supervision

12 As an undergraduate student in the early part of your course, you must not work in an electrical laboratory without the presence at all times of a responsible supervisor. However, an exception may be made for laboratories in which the equipment is of a highly safe nature (generally double-insulated) and in which you are not called upon to make electrical connections or work with mechanically moving equipment; computing laboratories are a good example. In later years of your course the requirement for a supervisor to be present in laboratories that contain significant dangers may be relaxed, with the explicit permission of responsible staff. However, there should always be someone else within sight and sound of your working position, and that person should know what action to take in the event of an accident.

The general rule is always that in dangerous situations you must take appropriate precautions. For an experienced engineer or technician, who is employed in particular categories of work, working alone may be permissible safe practice. But in other cases, safe working may clearly require a second person to be present.

13 The use of a small soldering iron when you are alone is permissible, but you should exercise particular care with it and where possible use a low-voltage iron.

14 A designated supervisor should be a member of the academic or technical staff, member of the research staff, or a postgraduate student who in the judgement of the professional staff is competent to undertake this duty. He or she should be familiar with the facilities of the laboratory, in particular the means for disconnecting supplies and calling assistance, and should also be familiar with the nature of the experiments that are being conducted. It is recommended that a designated supervisor should have received training in basic first-aid and treatment for electric shock, including artificial resuscitation.

Working Hours

15 In the early years, your permissible working hours in laboratories are simply those in which a designated supervisor is present. In later years, working hours are in accordance with the specific instructions of responsible staff (but see Paragraph 12). The laboratory should be locked shut at all times when it is not in use for approved purposes.

Unattended Equipment

16 If you have to leave .the laboratory, for even a short time, and if there is no other colleague present working with you on the same experiment, you should switch off electrical supplies to the test equipment. However, normal measuring instruments may be left on. (In later years, you may have an experimental project that needs to run continuously, unattended; in that case, it should be surrounded by a barrier, with a notice that gives warning and explains how to isolate the equipment and contact the person in charge.) Before obeying a fire alarm (or bomb alert), ensure that all supplies are isolated.

Dangers in an Electrical Laboratory

General

17 There are two main ways in which danger can arise. Firstly, equipment that you are using may be defective in some respect.

Good design and systematic maintenance minimise risks, but cannot create a perfect world. It is always possible that equipment you are about to use is broken, has deteriorated in some undetected way, or been misused so as to make it dangerous. Exceptionally, there may even be an unrecognised flaw in its design or construction.

18 Secondly, danger can arise through the actions of yourself and others around you. About 70% of all electrical accidents occur through unsafe working practices. Always remember that every action you take can affect not only your own safety, but also that of friends and colleagues. Your dangerous action may amount to no more than the lack of a moment's forethought, or it may be more persistent negligence or even plain folly. The most experienced people sometimes commit the most foolhardy acts, as a consequence of being so familiar with equipment and the work they do with it that they lose their sense of caution.

An experienced chartered electrical engineer, holding a senior position in a large factory, was assisting electricians attempting to repair a 415 V air circuit breaker. Despite the fact that the breaker was live, he tried to unjam its trip mechanism by the improvised use of a screwdriver, with the enclosure open. The electricians warned him that this was very dangerous and he should stop immediately, but he continued. The screwdriver slipped, causing an earth fault, and he received severe flash burns to his face and arms.

19 The dangers from electricity itself are obviously important in an electrical laboratory. These fall into three main categories: shock, physical injury due to involuntary movement induced by shock, and burns. But dangers can also arise from mechanical equipment in the laboratory, both large and small.

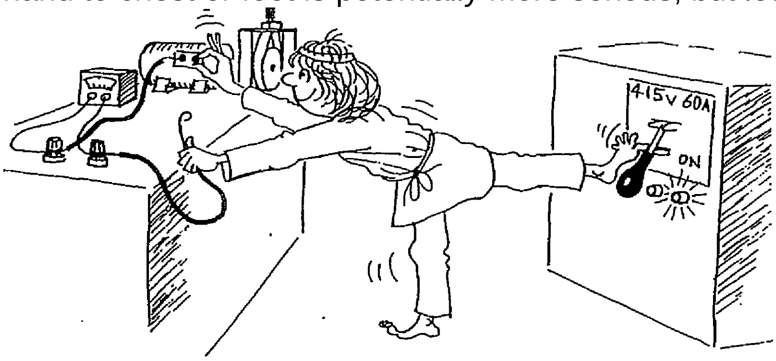
A high proportion of people have received a shock from the 240 V mains at some time; some even boast of it. It is easy to suppose that the danger is slight, but about 50 people a year die from such shocks in England, Scotland and Wales, of which about 40 are in the home and 10 in the work-place. Accidents of all kinds in the work-place caused by electricity (including electrostatic discharge), notified yearly, average over 900 reportable injuries and dangerous occurrences, with some 300 major injuries and 20 fatalities.

Electric Shock

20 Electric shock is a `pathophysiological effect', which means that it interferes with the normal bodily processes so as to threaten life. The effect may be no more than an unpleasant tingling sensation in the part of the body that contacts the electrical source. Alternatively it may produce temporary muscular paralysis, fibrillation (quivering) of the heart muscle, or cardiac arrest (complete cessation of the heart-beat). Also, a shock may produce violent, uncontrollable recoil of the body and limbs, due to involuntary muscle spasm. Death due to electric shock is most commonly caused by the consequences of fibrillation, but may also be due to asphyxia (suffocation due to paralysis of the breathing muscles), immediate cardiac arrest, or physical injury caused for example by falling and striking the head as a result of the spasm.

A technician in a technical college modified a TV set to take headphones. Unfortunately he did not understand that the set was a live-chassis type, so that the headphones and jack-plug were live at 350 V dc when the set was in use. A student using this equipment received a severe shock and burns, and was rendered unconscious. Additionally, however, as he collapsed the TV set was pulled down on top of him and his shoulder blade was broken.

21 The severity of electric shock depends on the magnitude and duration of the current that flows and the path it takes through the body. These factors in turn depend on the voltage of the source of electricity, its internal impedance (negligible in most cases), and frequency. They also depend on the points of contact that the body makes with the source, so as to complete a path for the current, and the resistance that the body presents: To receive a shock, you require two points of contact with a voltage difference between them, such as 'live' to 'earth' or to 'neutral'. A current that flows from hand to hand, across the chest region, presents great danger to heart function, though it is not in fact the worst; left hand to chest or foot is potentially more serious, but less likely to occur in a laboratory.



22 Voltages greater than 50 V rms ac at 50 - 60 Hz, and 120 V ripple-free dc, in normal dry working conditions, can cause dangerous levels of current to pass through the body. (The standard domestic mains ac voltage in the UK is about 240 V rms.) In damp or wet situations lower voltages can be dangerous, particularly if the contacting parts of the body are moist because this reduces the contact resistance, which is a main component of the body's resistance. (The effect is similar if the skin is broken at the point of contact.) Frequencies of 50 Hz (European standard) and 60 Hz (American standard) are about the worst for affecting the heart, both higher and lower being less injurious. If the hand forms one of the contacts and is closed around the source of the shock, it tends to grip convulsively and be unable to let go; contrary to common belief, the effect is greater with ac than dc.

A welder was working in a confined space on board ship in Central America, using a 450 Hz electrical Welding generator. The electrode holder came into contact with his bare chest. The voltage Was 70 V (not far above the safe limit for dry conditions) and the frequency less dangerous than 50 Hz, but conditions were hot and humid and he was killed.

23 The hand-to-hand or hand-to-foot resistance of a dry body with typical electrical contacts averages about 1300 SI at 240 V ac or dc. This is a characteristic with negative slope, resistance increasing when the voltage is lower and vice versa. A person is not in danger from an electric shock in which the current does not exceed 5 mA ac or 20 mA dc, or alternatively (for a pulse or discharge) in which the total energy received does not exceed 5 J.

Burns

24 As the energy level of a shock increases, there is increasing danger of serious burning, particularly near to the points of entry and exit of the current, where current density and localised heating is greatest. Such burns are usually deep and slow to heal. Severity of entry and exit burning depends upon current magnitude and duration, and contact area; these in turn are influenced by voltage level, contact pressure, and state of moistness of the skin, so it is hard to generalise. As one indication, if firm dry contact is made with a bare wire of about 1 mm diameter at 240 V for a period of considerably less than a second, localised burning of the flesh may result to a depth of a few mm.

A service, engineer working on a wall-mounted control cubicle had switched the unit off only at its internal miniature circuit breaker.

He then attempted to remove it from the wall, but in so doing allowed his fingers to touch bare conductors on the incoming side of the breaker. He received a 240 V shock and was unable to release his grip due to muscular spasm (see Paragraph 22) for about 30 seconds. As a result, his fingers were badly burned and one subsequently had to be amputated. More extensive burning of body tissue by passage of current, such as may threaten life, is typically associated - though it does not necessarily occur - with higher voltage levels, around 6.4 kV (11 kV 3-phase line-to-line) and more.

Flash Burns

25 Serious 'flash burns' can occur when heat is generated by an electric current, without the current passing through the body. A very nasty accident may arise from a metal watch strap or bracelet, for example, if it forms a short-circuit between two adjacent parts of a circuit with a voltage between them. The terminals of lead-acid batteries, as found in road vehicles and often in laboratories, are a notable danger in this way. The operating voltage may be no more than 6 or 12 V and seem safe, but these are potentially high-energy sources capable of passing current of 1000 A and more. This can heat and melt the metal almost instantly, burning and severely injuring skin, tendons and other tissue in the wrist, almost certainly causing scarring and disablement. If you wear a watch with a metal strap, or a metal bracelet, you should remove it when working with electricity. Rings on fingers, and metal tools such as spanners that do not have insulated surfaces, also pose a danger of accidental short-circuits and flash burns.

If you allow an uninsulated spanner to bridge the terminals of a car battery, there will be a violent arc and part of the spanner will probably be melted. If the battery is in poor condition, rapid evolution of gases and internal arcing may cause it to explode, spraying sulphuric acid.

26 Short-circuits occasionally happen due to mechanical failure of equipment, not involving an operator's actions. Switchgear, for example, can suffer an internal short-circuit giving rise for a fraction of a second to an intense electric arc, which consists of ionised gas at very high temperature.

It is important to understand that the more energy is poured into an electric arc before it is extinguished by the action of protection circuits and circuit breakers, the More dangerous it is. As the local power rating of the system increases, so this arc energy inevitably increases. (If for any reason the lowest level breaker fails to act, there will be extra delay before a higher level breaker acts - see Paragraph 75 - and the danger is multiplied.) In distribution sub-stations of power systems, which have a high power rating because they serve large areas of activity, the arc energy due to a short-circuit occurring in faulty switchgear can be so high that steel enclosures are vaporised and the liberated heat is sufficient to maim or kill personnel within a radius of a metre or so. Such arcs may be accompanied by the ejection of molten metal or burning oil, causing further injury. The sub-station for a large university building would have a high enough power rating to be dangerous in this way; that for an individual laboratory much less so.

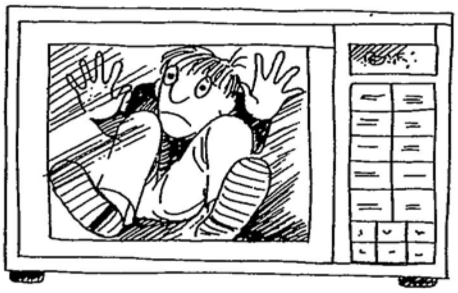
Other Burn Injuries

27 Some parts of equipment which carry current may get hot, due to normal operation (though such hot parts are generally required to be guarded), but especially if a fault current is flowing. These can cause direct contact burns to the body. Electric soldering irons are an everyday danger in the laboratory, and should be handled with great care.

28 Damage to the eye may be caused by viewing the high power arc that can occur during a fault, or especially the arc produced in electric welding (if dark goggles or a visor are not worn). This causes intense inflammation and irritation, known as 'arc eye'.

A test engineer attempted to push a loose fuse holder into a 415 V distribution board with a screwdriver. This slipped, causing a line-to-line short-circuit. The engineer suffered arc eye and flash burns to his hand.

29 The effects of electric shock (discussed in Paragraphs 20-23) reduce as frequency increases, because high frequency currents tend to flow in parts of the body other than the nervous and muscular system. At radio frequencies (above 500 kHz), the main effect on the body is burning. The radiated energy of microwaves (1 GHz and above) penetrates into the body before it is absorbed, producing burns deep inside - together possibly with other effects - if the radiated power level is high. (The microwave oven works on just this principle.)



Fires

30 Serious fires may be started by electricity. This can be simply due to ignition of flammable material (wooden panels, for example) touching or close to surfaces which get hot, either through normal working or fault conditions. A common danger is breakage of the live or neutral lead in a flexible cable, so that sparking at the break generates heat and ignites either the cable insulation or neighbouring material. Insulation fires (PVC etc) generate fumes that are highly toxic to personnel and very corrosive to other equipment (often a major cause of capital loss in industrial fires). Ignition of flammable vapours, dust, or oily rags, can occur due to sparking from electrical equipment, discharge of electrostatic voltage, or by contact with hot surfaces. Intense radiation, from radio-frequency or microwave sources, can also cause ignition. It is important that electrical fires are tackled using the correct type of extinguisher, which is suitable for use with possibly live conductors within the area of the fire. (See Paragraph 80.)

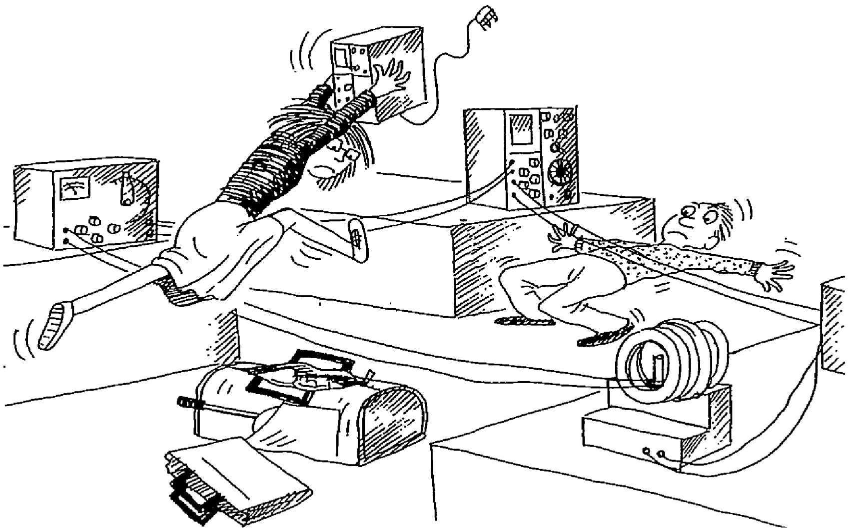
An employee was pouring flux thinners into a wave soldering machine, when the flammable vapours were ignited by a spark, due to build-up of electrostatic charge. The fire did much damage, but no-one was hurt.

Mechanical Dangers

31 There are many potential mechanical dangers in electrical laboratories, all of which are prevented by good practice. The most common are:

- rotating shafts, brake drums, belt drives, and other moving parts, whose protective guards have been removed

- stroboscopic effects caused by fluorescent lighting, which can make rapidly rotating components appear stationary
- electrical leads connected between benches and/or across gangways, causing people to trip and fall, possibly onto live equipment or pulling it down on top of them
- electrical leads that are close to machines, shafts, couplings, belts, or other moving components
- equipment projecting into gangways, inviting collision by an inattentive person who assumes the way is clear
- bags, brief-cases, items of portable equipment, etc, left on the floor in any area where people walk (particularly dangerous because they are below eye level)
- objects close to the edge of a bench or table, where they can be easily knocked off
- spillage of water or other conducting liquid, which must be mopped dry immediately and equipment switched off until this is done
- large objects which are heavy enough to cause you injury if you attempt to lift them - always consult a supervisor before lifting heavy objects.

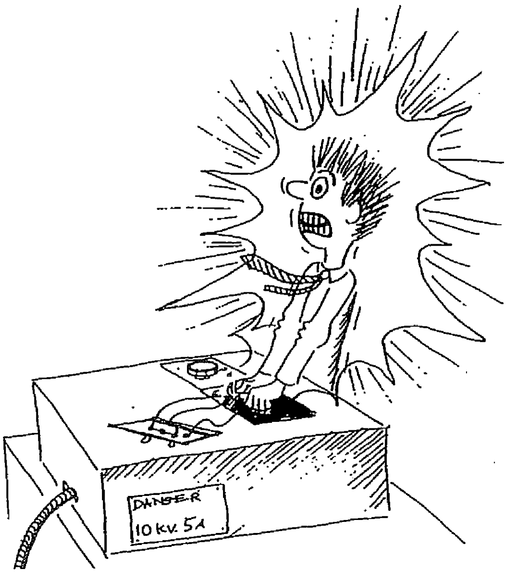


Safe Use of Equipment

General

32 Equipment should always be used within the manufacturer's technical specification, or as clearly instructed by staff. This applies particularly to maximum levels of voltage, current and power.

Many items of electrical equipment carry external rating plates which indicate permissible limits of important parameters and possibly other information. Get in the habit of consulting the rating plates, and other available sources of information such as operating manuals, wherever possible, and checking that you are using the equipment within its designed specification. If in doubt, seek advice from the laboratory staff.



Earthing Instruments

33 A common mal-practice is to disconnect the earth lead in the three- pin plug of an oscilloscope or other instrument, so that its signal earth and the potential of its casing 'float' in a manner that the manufacturer did not intend. That is exceedingly dangerous and must never be permitted. Not only are the conducting outer parts of the equipment no longer solidly earthed, but they may be connected into a circuit so that they are at a dangerous potential (or a potential that may become dangerous if there is a fault elsewhere). Moreover, the instrument is likely through oversight to remain in this state and be used unsuspectingly by others; it can then be live at 240 V due to a simple mis-connection or other cause, and becomes a lethal device waiting to claim a victim. The recommended solutions are to use:

- an all-insulated instrument designed to be floated
- one with built-in differential inputs that filter a common-mode component from the wanted signal
- external isolators between signal source and instrument
- an isolating transformer to supply the instrument; this enables the signal earth lead to be isolated from the supply earth and connected to another point of earth potential (to eliminate earth loops only).

A university student was playing electric guitar in a band rehearsal. It was his own equipment but another student had badly fitted a plug to the microphone amplifier; connections were only finger-tight and the earth was loose, making the equipment unearthed. Worse still, the loose earth wire touched the live conductor in the plug, so the metal casing of the microphone was at 240 V. The guitarist held the microphone, touched the earthed metal strings of his instrument with the other hand, and was killed.

Multi-Meters and Hand-Held Probes

34 Multi-meters are potentially dangerous because it is so easy to set them incorrectly either for current or for low voltage, when actually measuring high voltage. That can destroy the instrument and in a system with high power ratings lead to a short-circuit with serious flash burning. Before using, check the range! Their use should be minimised. Fused multi-meters (and fused hand-held probes - see next paragraph) are greatly to be preferred, but beware that the instrument's current shunt may still be unfused, which is dangerous. The incorporation of 13 A high rupturing capacity fuses into all meter and probe circuits, is convenient, simple, and an extremely effective aid to safety. Their use is strongly encouraged.

An-electrician was checking a 415 V supply with an unfused multi-meter. It was wrongly set to a low voltage range, and caused a short-circuit which burned his hands. In another case, again with 415 V, the multi-meter was set to the 2 V range. This meter was fused, but unfortunately the electrician had also mis-connected one lead, into the instrument's 'current'. socket. The internal current shunt was unfused, so that a 3-phase short-circuit developed, and the electrician received severe flash burns.

35 Use of hand-held probes should be minimised and they should be designed with a shroud down to the tip, preferably of the retractable spring-loaded type. Never use improvised probes or designs with long exposed metal ends.

Two electricians used a multi-meter to check fuses in a 415 V switch-fuse unit. To save removing the fuses - the Oro* procedure - they defeated the interlock on the unit's cover, to measure internal voltages. Improvised leads were used as probes, which did not attach securely to the meter; one pulled loose. One man held both ends of this lead, thinking he had the free ends of the two leads, and applied them across the 415 V, causing a line-to-line short-circuit. Both technicians suffered severe flash burns.

Hand Tools

36 It is a common mistake to suppose that small hand tools, particularly of the kind which are found in electronics laboratories, are not dangerous. Many unpleasant accidents occur through carelessness and mis-use, with soldering irons, de-soldering tools, screw-drivers, stripping tools, etc. Treat all tools with the care they deserve.

Eye Protection

37 Certain types of electronic circuit device, such as electrolytic capacitors, lithium batteries, and some power transistors, etc, are capable of exploding when they fail through mis-use, or other cause. You should minimise the hazard this represents to eyesight, by not allowing your face to be close to such devices when they are exposed and operating. If you possess a pair of safety glasses, it would be sensible to wear them when working with circuits that contain such devices. Take similar precautions when using a soldering iron, to protect against small particles of very hot flux or solder that may be projected from the iron or workpiece.

Energy Storage Devices

38 Devices that store energy need to be treated with special care, and this includes:

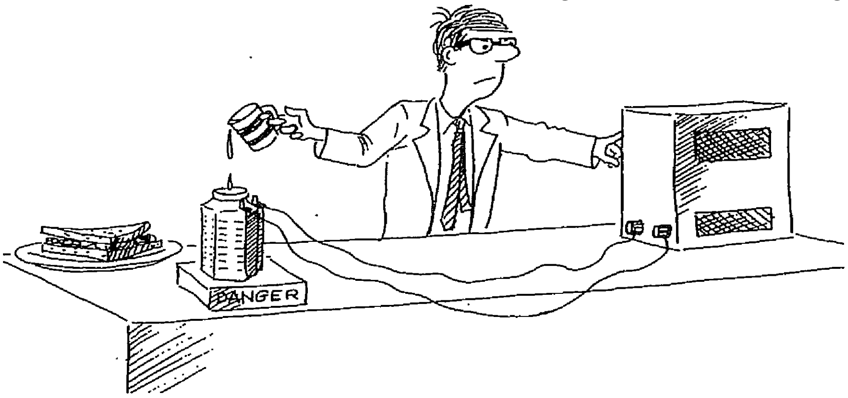
- batteries
- capacitors
- inductors
- rotating shafts and flywheels
- containers of flammable or explosive chemicals
- cylinders containing gas *under pressure
- dewars containing cryogenic liquids such as liquid nitrogen which

may be used, for instance, in experiments on superconductivity.

-An internal connection came loose in a simple hand lamp, causing a short-circuit across its nickel-cadmium rechargeable batteries.
The lamp's plastic case over-heated and gave off gases which ignited explosively, blowing a hole in the side of the lamp. Fortunately, no-one was injured.

Lead-acid batteries pose a particular danger when being charged; electrolysis commences when charging is complete, liberating an explosive mixture of hydrogen and oxygen. This is easily ignited, particularly through a spark caused by removing the charging leads without first switching off the charger. Many serious accidents have happened this way. It is important to switch off first and to keep the charging area well ventilated. (See also Paragraph 25.)

39 You should always include an isolator and a fuse of appropriate rating in a lead-acid (or other high-energy) battery circuit. Capacitors are capable of holding charge for periods of minutes after equipment has been switched off, and large electrolytic capacitors (of the kind used in the smoothing circuits of power supplier and other electronic apparatus) may hold charge to an energy level that greatly exceeds the safe maximum (see Paragraph 23). Clearly therefore, it is not safe to remove the -casing from electronic equipment simply because it is disconnected from the supply. Make sure that capacitors have been discharged before handling by being shorted across their terminals. This should be done through a suitable resistor, which controls the rate of discharge to avoid damaging the capacitor or over-beating the shorting conductor. With large electrolytic capacitors, leave the short in place; if it is removed, the capacitor can `recover' substantial charge due to internal electrochemical effects and so again become a danger.



40 Current-carrying inductors are also a source of danger. However, inductors in the laboratory are unlikely to store significant energy, by sustaining a free-wheeling current, for more than a second or so after switch-off. But never open a simple isolating switch, for example, in the field winding of a dc machine when it is excited; if you do, a very large transient voltage is produced, causing a self-sustaining arc that can injure people and destroy the switch. (The use of a special switch, with a by-pass element to dissipate the inductive energy, safely overcomes this problem.)

Positioning Equipment

41 Measuring instruments, and bench equipment of all kinds, should be standing securely on work surfaces that are intended for that purpose. Never position instruments on improvised surfaces, such as tops of stools and chairs, window sills, the floor, etc.

42 Always ensure that instruments are positioned where they can be read easily, accurately, and safely, without leaning over circuits and equipment. The same point applies to isolators; never arrange your equipment so that you must lean over it in order to switch on or off.

Faulty Equipment

43 If you come across equipment that is faulty in any respect, you have a duty of care to yourself and others to report it to a responsible person. That person has a duty in law to ensure that the equipment is immediately withdrawn from use until the fault is put right, or it is inspected and declared safe. Never try to repair faulty equipment yourself, and do not use it until its safety is verified.

44 If a fuse blows in equipment, you should isolate the whole circuit, check its connections and look for any obvious causes of a fault. Check instruments and their ranges. Only then replace the fuse and reconnect the supply, with the supervisor's approval.

Avoid Accidents by Correct Behaviour

45 Unauthorised people must not enter any laboratory. ('Authorised' people are those to whom permission has been granted by the professional staff responsible for the laboratory.) You must not enter laboratories where you are not authorised to go, and you must not invite friends into a laboratory who are not authorised to enter. You are only authorised to perform approved experiments at approved times; you may not connect personal mains-operated equipment to the laboratory supplies without permission.

46 You should not take food or drink into an electrical laboratory, or any other. Not only does eating and drinking distract your attention from the main task, but if liquids or moist solids get into electrical equipment they can create conducting paths which are highly dangerous (as well as being likely to cause expensive damage). Any spillage of water or other conducting liquid must be immediately attended to (see Paragraph 31).

A woman was using a hired carpet cleaner, when its hose burst, causing water to enter the electrics of the machine as well as spilling onto the carpet. She was working in bare feet and received an electric shock.

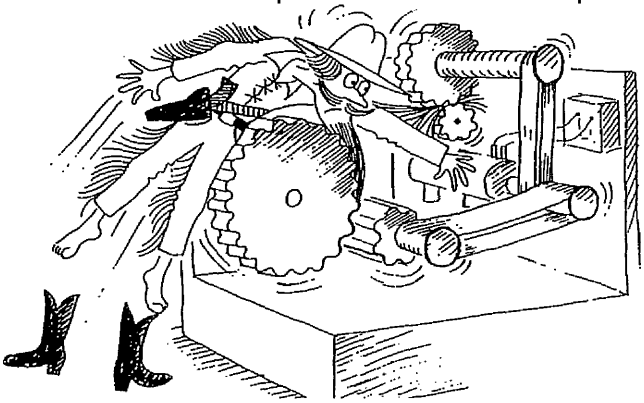
Clothing and personal effects

47 Your clothing should be suitable for the job you are going to do:

- do not wear an overcoat, because its bulk will hinder your arm and hand movements and the cuffs may catch on projections from equipment
- do not wear clothes which are loose or trailing, or excessively tight, or have any features that may impede your movements or catch in equipment (whether electrical or mechanical), particularly not large loose cuffs, trailing fringes or tassels
- do not wear a scarf, and make sure that your tie is firmly secured so it cannot trail in equipment
- secure long hair so that it is under control and cannot trail
- if you have a metal bracelet or a watch with a metal strap, take it off and put it in

your pocket, similarly with other metal items such as large rings

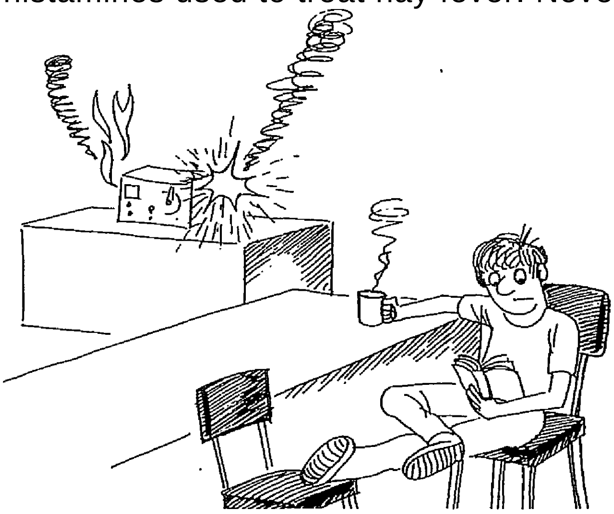
- do not wear wet clothing or work with wet hands
- do not wear personal stereo headphone equipment in the laboratory.



48 Any personal effects that you have brought into the laboratory, such as brief cases, bags, removed clothing, etc, should be stowed tidily, either in a place set aside for the purpose or under the bench, where no- one may be caused to trip: Such items should never be on the bench, alongside floor-standing equipment, or anywhere on the open floor. The only personal equipment on the bench should be your log book for recording results, writing and drawing instruments, perhaps a calculator, and the instruction sheet for the experiment. Place these in an area away from the equipment and its associated wiring.

Be Alert and Careful

49 You should aim to be alert and attentive at all times. This can require conscious effort, particularly if part of the experiment is repetitive or slow to perform. Try to plan ahead so that you are not excessively tired for laboratory sessions, and do not attempt to work in a laboratory if you are ill to the point that concentration and reflexes are seriously impaired. Guard against medications that make you drowsy or affect judgement, particularly those which do not obviously have this effect, such as anti-histamines used to treat hay fever. Never drink alcohol before working in a laboratory.



50 Do not run in a laboratory, walk. Do not shout, or make sudden noises that might distract your colleagues. Think before you act, never do anything absent-mindedly, and move and work in a deliberate manner.

Tidiness

51 Aim to be neat, tidy and systematic, in everything you do. A cluttered environment leads to mental confusion and incorrect procedures, both contributory causes of accidents. Tidiness is also an aid to good experimental work.

Connecting Up and Conducting Experiments Safely

General

52 Check that you know the whereabouts of the items of laboratory safety equipment discussed in Paragraph 80, including the isolators for your supplies and the emergency trip button. The local isolators for your supplies should be under your control alone - check that is so; if it is not, then confirm the special arrangements to guarantee safe working (see Paragraph 54).

Isolating Equipment

53 Never assume that a circuit is dead because you have switched off! It may remain live because an isolator has failed, or it may be fed from more than one supply. It is good practice to isolate a circuit by switching off, then withdrawing the supply plug from its socket (or removing supply leads from terminals) on the load side of the isolator, before working on the circuit.

Professional practice when isolating equipment is to switch off, then test all parts of the isolated circuit to verify there are no voltages present, and additionally, to check both before and after these tests that the instrument used for verification is operating correctly. An electrician opened a 3-phase 415 V isolator supplying a distribution board, to carry out work on the board. He failed to check-test that the isolator had opened correctly. In fact one phase remained closed, probably due to improperly tightened screws during manufacture. He caused a short-circuit while working and received flash burns to his face.

54 Many laboratories have a central distribution facility (plug-in board or console) for feeding special supplies such as 120 V dc to individual work areas. This will have been set up before you enter the laboratory. It is good practice to check these arrangements - but do not make adjustments yourself! There should be an isolator for each distributed supply adjacent to your work area and under your control. Check that is so; if not, very special arrangements for switching need to be agreed with the supervisor, because there must be effective means for disconnecting the supply and securing the isolation of your equipment.

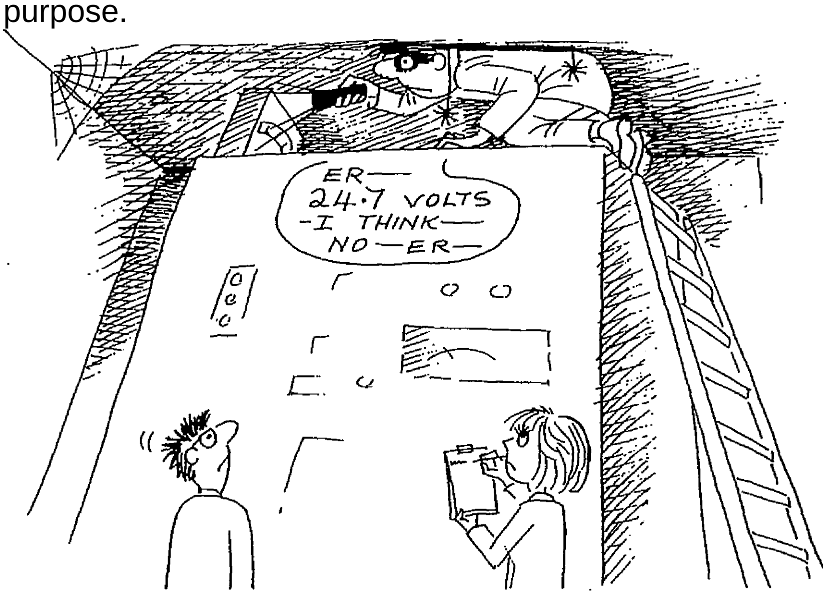
Instruction Sheets, Circuit and Connection Diagrams

55 You are strongly advised to study the instruction sheet for the experiment before coming to the laboratory, if it has been made available. Otherwise, set a period aside to read it carefully *and* ensure that you understand it fully before making any connections.

56 The instruction sheet may include a circuit diagram, in which case, study that particularly carefully. But it may be part of the exercise for you to draw your own; if so, draw it fully, reasonably neatly and logically arranged. You should also draw a labelled connection diagram showing exactly how the terminals of all items of equipment are to be interconnected. With simple circuits it may be satisfactory to show the information about connection as labelling on the circuit diagram; otherwise a separate diagram is needed. So far as possible, make the layout of equipment on your diagram correspond with its physical arrangement. Never start to connect up equipment without having a connection diagram.

Equipment, Familiarisation and Arrangement

57 Check that all your supplies are electrically isolated (see Paragraph 53) before touching any equipment or making connections. Then, do not simply start to connect up in an unthinking, mechanical fashion. That is not a safe procedure - nor do you learn the most from the experiment. Familiarise yourself with the equipment, making sure you understand the labelling of all terminals, sockets and knobs, and their functions. So far as you can, check the voltage, current and power ratings of equipment (see Paragraph 32), and satisfy yourself it is all to be used within specification. Similarly check that all instruments appear to have signal ranges appropriate for the job they have to do. Arrange your equipment in a neat and regular fashion, ensuring it is positioned so that it will be convenient and safe to use. Ensure that all instruments are securely placed on benches and tables intended for the purpose.

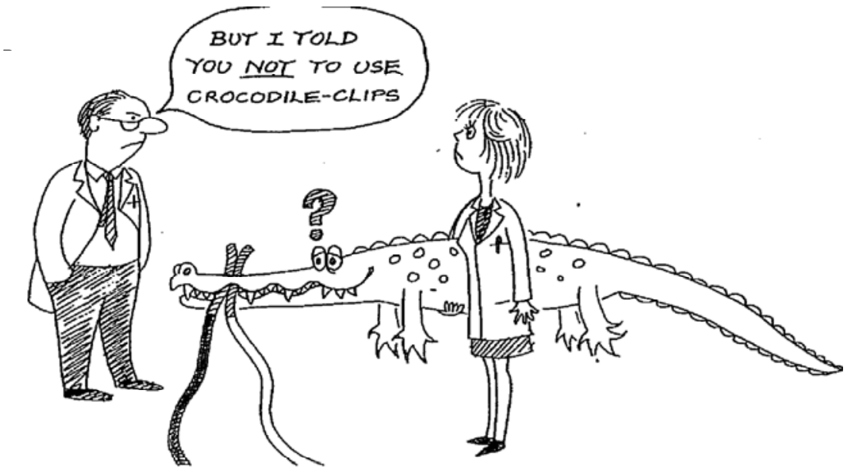


Connecting Up

58 Proceed to make connections logically, so as to ensure the job is correctly done and subsequent checking simplified. Connect the main current-carrying paths of the circuit first, including connections through ammeters, and check these. The cross-section of copper in these connecting leads must be suitable for the rms current that is to be carried, or over-heating will result. Next, add the potential pick-off leads that go to voltmeters, voltage coils of wattmeters, oscilloscopes, etc. Incorporate any RCDs that have been provided, making sure they are in the intended parts of the circuit (see Paragraph 76).

In professional practice, the potential pick-off leads would be much smaller in cross-section than the current carrying leads, but in a teaching laboratory leads of just one size may be stocked. Assuming PVC-covered cables, an insulating wall thickness of 0.6 mm is rated for a maximum voltage to ground of 300 V rms. For a copper cross-section of 1 mm^2 and above, a guide to maximum permissible current density for the cable in free-air conditions is 10 A/mm^2 rms, reducing to 6 A/mm^2 at 0.5 mm^2; because free-air conditions do not apply to a cable lying on a bench, somewhat lower values of current density might be appropriate.

69 Always use connecting leads of appropriate length, with the right connectors. They need to be neither so short that they are strung near-taut between terminals, nor so long that they are hanging over the edge of the bench or festooned on the bench top or floor. Ensure that leads with spade connectors are of the correct size for the terminals, so that bare metal cannot be touched when they are attached.



60 When wiring is complete, double-check connections for accuracy. This entails not only making sure that all the required connections are correctly made, but equally important, that no unwanted additional connections are accidentally included - which happens surprisingly easily! If more than one student is working on the experiment, it is good practice for one to be allocated the task of connecting up and another to perform the double-check. Make sure that every screw-down terminal is as tight as you can manage. It is a common fault to leave terminals so lightly fastened that they barely grip - the lead connectors, with the obvious dangers that a live lead may come loose during an experiment or a terminal may overheat due to poor contact.

It is sometimes recommended to use only one hand when making connections, perhaps keeping the other in a pocket, so as to avoid any risk of a shock between hands across the chest region. This can do no harm, though it reduces dexterity. The advice is superfluous if proper isolation procedures are observed.

Before Switching On

61 Have a supervisor check your circuit, unless you are specifically advised that you may proceed on the basis of your own checking for that experiment.

62 If you are working with a group of colleagues, make sure it is clearly understood by the whole group that nothing is switched on until everyone gives their assent.

63 Do not switch on until:

- all spare leads, spare equipment, hand tools, writing instruments, stationery, etc, etc, have been removed from the vicinity of the test equipment and tidied away
- the equipment is laid out in a manner that is convenient for taking readings and

making adjustments, so there is no need to lean over wiring and instruments and no risk of anything being knocked over a all casings for equipment, electrical shrouds and mechanical guards, are fixed in position

- the gangways are clear
- all controls have been set to sensible and safe positions for the start of the experiment
- you know what control adjustments are to be made after switching on, and can appreciate their implications

You have reviewed all the arrangements for the experiment and double-checked they are correct.

Be Prepared

64 Before switching on, mentally sort out the nature of the work to be done, so that you can concentrate on the equipment when it is live. Be clear what tasks are to be performed, and determine the order in which work is to be carried through. If you are working in a group with one or more colleagues, allocate tasks between you. So far as possible, construct in advance any tables in your log book required for the recording of results.

Performing the Experiment

65 Switch on mains supplies to instruments and other test equipment first, and check that all appears to be functioning normally (i.e. warning lights are on, outputs are registering zero, etc). Most instruments have variable sensitivities to suit signals of widely different magnitudes; where these are not of the auto-ranging type, make sure you have set the sensitivities to suit the expected signals.

66 Switch on the supplies to the main test equipment, and perform preliminary tests in order to:
m appreciate the general nature of the effects you are studying NI check that all behaviour appears normal •
establish ranges of variables for test purposes, etc.
Then proceed with recording the main experimental results, in an organised manner.

67 When any changes to the experimental equipment are required that necessitate changing electrical connections, or removing shrouds or guards, you must first switch off, isolating the equipment from its supplies (see Paragraph 53). Never be tempted to make what seems to be a simple modification to a circuit while it is still live.

Changing the connections on live equipment is always hazardous, not only for the obvious reason, but also because apparently minor circuit changes sometimes have unexpectedly drastic consequences. For 'example, opening the secondary winding of a current transformer while it is excited, in order to change instrument connections, can induce a very high secondary voltage that is extremely dangerous. There are circumstances in professional life where working on live equipment may be an approved procedure, but only with very special precautions.

68 At the end of the experiment, isolate all equipment, including instruments, and remove all connections that you have made to supplies.

Specification and Care of Equipment

General

69 All aspects of equipment call for safety awareness. This includes its design and manufacture, its selection for specified tasks and intended manner of day-to-day use, and the level of responsibility of operating personnel.

70 There must be sufficient clear bench space for the conduct of each experiment (including if necessary free-standing instrument tables of rigid construction and non-tipping design), so that experimental equipment and instrumentation can be properly laid out. There should be sufficient additional space on the benches so that students may place log books, calculators, etc, without invading the equipment area.

71 Gangways, to give access between experimental work areas and to the supply switches and emergency buttons, and to accommodate people working on experiments, must be evident. If necessary they should be indicated by floor markings, and where that is insufficient, by barriers. (Ropes or chains may be used, but are not as effective as collapsible or rigid barriers.) The recommended minimum width of gangways is 1 m between benches or floor-standing experimental equipment, and 1.5 m between benches at which people are working back to back. Gangways must be kept clear of obstructions at all times.

72 Clear and understandable labelling of all supplies, terminals, isolators, etc, is an inexpensive and effective aid to safety, and is highly recommended. Labels for such functions as 'stop', 'start', 'on', 'off', 'emergency', are particularly important.

Voltage Levels and Limited Energy Systems

73 In the first year of an undergraduate course, it is advisable that equipment to which students are required to make connections should operate at or below the safe voltage levels specified in Paragraph 22. This may be relaxed in subsequent years, at the discretion of the professional staff planning and supervising experiments. In the context of an undergraduate teaching laboratory, it may be advisable to regard equipment fed with supply voltage above about 415 V ac 3-phase line-to-line, or 400 V dc, as justifying extra precautions such as a surrounding barrier with a warning notice. It may sometimes be essential for undergraduates to work with exposed live conductors that are at a dangerous voltage and are not inherently safe (see Paragraph

23); in that case there should be a surrounding barrier with a warning notice and personnel should be required to be outside the barrier when equipment is live. Above 1000 V ac or 1500 V dc, if the equipment is not inherently safe, precautions should be taken to prevent access to exposed live conductors, for example by the use of a barrier with interlocks on the point of entry to exclude personnel from the test area when equipment is live.

74 Limited energy systems, designed to limit the energy that can be released in any situation that may put an operator at risk, also contribute to safety. In the undergraduate context, this may be interpreted as limiting power levels of experimental equipment and their protection levels so as to be not excessively high in relation to purpose. This is particularly desirable in the early years.

Protection Systems

75 Protection systems comprise circuit breakers and fuses, which together provide a system limiting the excess current and power that can be drawn. Power levels of breakers and fuses should be graded progressively, down from the very high level supplied to a building to the modest level supplied to an individual item of equipment. There should be discrimination, so that in the event of a fault the lowest appropriate level of breaker or fuse disconnects supply before any higher-level unit responds. Equipment supplied from a 13 A socket should be sub-fused at a level appropriate to its rating.

76 Additional protection is provided by 'residual current devices' (RCDs), which are suitable for single-phase and three-phase supplies up to a few kW. If you make contact with a live part of a circuit and also with earth, the RCD will detect the component of current that is not returning through neutral - because it is returning to earth as a shock through you! - and will quickly disconnect the supply before safe limits for shock are exceeded (see Paragraph 23). RCDs may be built into circuit breakers (RCCBs), and are also available to plug into 240 V sockets. They can be supplied for different current and power ratings and are designed to operate above a threshold level of residual current; 30 mA gives satisfactory protection of personnel without undue 'nuisance tripping'. They are valuable aids to safety, particularly with experiments that involve making connections with neighbouring earthed components. Remember they only act to prevent serious shock caused by contact between live and earth, not for example, liVe and neutral; they cannot therefore guarantee your safety.

A trainee technician was using a Variac with a vbitmeter connected on the output side. He removed the leads from the voltmeter, forgetting to isolate from the supply, touched the bare ends of the leads with both hands and received a shock which rendered him unconscious and burnt his hands. Supply to the Variac was through a RCD, but this did not prevent injury because it was a live-to-neutral shock. In another case, a bracket on a metal heated hospital food trolley cut through the insulation of a live lead. The earth lead was already loose, so the trolley was unearthed and became live at 240 V. An assistant touching the trolley received only a minor shock, because a ROD detected a live-to-neutral current imbalance and tripped the supply.

Electrical Shrouding

77 Electrical equipment in which insulation or casing do not prevent your contact with dangerous live parts must be safely shrouded, that is, provided with insulating covers so that no live parts can be touched by fingers. (See Paragraph 73 for exceptions.) Older instruments (such as ammeters with external current links, bench-standing resistors) and equipment designed for building into larger systems, may call for special shrouding. All casings and shrouds should be fixed in position before a circuit is made live.

78 The electrical supplies in a laboratory, and all connections to them, must be such that dangerous live parts cannot be touched. Connectors of the shrouded plug and socket type are preferable for safety, the same being true of voltmeter and ammeter connections (which may alternatively be included with the supplies as part of the fixed equipment). However, there is educational value in the direct experience of connecting up a circuit from basic components; professional judgement needs to be exercised by staff on these issues, having regard to the students' maturity and the level of competence required to work safely. Where uncovered screw-down terminals are employed, these must be of an insulated type such that bare metal parts (either on the terminal itself or on the lead-connectors that fit to it) cannot be touched with the fingers. It is therefore important to use the right size of lead-connector for each terminal size.

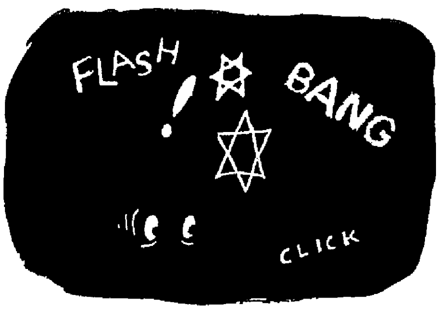
Mechanical Guards

79 All moving mechanical components, such as rotating shafts, couplings, brake drums, fly-wheels, etc, are a potential source of danger. It must be impossible for any part of the body, or loose clothing, to touch the moving components. A loose tie, for instance, touching a rotating shaft, can be 'grabbed' by it, resulting in a broken jaw - or a broken neck. Moving components may be 'safe by position', that is, fully enclosed within other equipment or so placed as to be out of reach. Alternatively (though not usually the case in an electrical laboratoi y) equipment may be provided with interlocks that require motion to be halted before access is possible. All other moving components must be provided with mechanical guards. All guards should be fixed in place, before mechanical equipment is put in motion.

Emergency Equipment

80 An electrical laboratory requires certain facilities and equipment• for emergency. These must include the following:

- emergency trip buttons, coloured red, sufficient in number that they are visible and quickly accessible to all persons in the laboratory, which when pressed disconnect all electrical supplies except the lighting



- first-aid supplies, preferably in the laboratory, or conveniently near
- an appropriate person (such as the supervisor) who is able to summon medical assistance
- a notice in the laboratory which indicates where the first-aid supplies are located and identifies the appropriate person to summon assistance.

It is also advisable that the fallowing be included:

- information on the notice indicating where medical assistance may be obtained at all times in normal working hours, with phone number(s)
- a further notice giving advice on treatment for electric shock including artificial resuscitation
- fire extinguishers of approved type for electrical fires
- a telephone.

The modern foam-spray extinguisher, approved for ordinary fires as well as for electrical fires up to 40 kV and meeting BS 5423 standards, is considered the most suitable, being much longer lasting in its effect than CO_2. One 9-litre extinguisher for every 200 m^2 is recommended.

Free-Standing Equipment

81 Equipment of the 'double-insulated' type is preferable wherever possible. This term applies to insulation systems meeting enhanced design specifications, such that any single fault does not pose a danger of electric shock to the user. Failing this, all conducting parts that may be touched on equipment that is live at a dangerous voltage must be connected to earth.

In some circumstances it may simply not be possible to provide an earth, to which all accessible conducting parts may be connected. This situation would not normally occur in a laboratory, however.

An example would be the electrical equipment on board a fire fighting vehicle. In that case, recognised practice is simply to bond electrically together all accessible conducting parts. They are therefore at a common potential (though that potential may not be earth), and so it is impossible to receive a shock by contacting any two surfaces, or more, simultaneously.

82 Generally speaking, environmental conditions in electrical laboratories pose no special dangers. It is worth mentioning that in other types of laboratory and particularly in field tests, there may be adverse environments. Humid conditions, as in some plant biology laboratories, or environmental test facilities for evaluating performance of apparatus in wet conditions, are examples. In such cases, it is important to select equipment specified as suitable by the manufacturer.

Explosive atmospheres are an important example of environmental hazards, occurring for example in mines and chemical process industries. Equipment for such locations is designed to be incapable of acting as a source of ignition for flammable vapours, and may be specially certified for this purpose.

Inspection and Maintenance

83 No equipment continues to function correctly and safely for ever. Periodic inspection and maintenance on a regular and systematic basis, as deemed to be necessary by a competent person, is therefore an essential part of safe procedures; there must be a management system to maintain all equipment so as to prevent danger. Inspection and maintenance should cover all aspects of basic fitness for purpose. One simple example is the periodic checking of all plugs and leads attached to equipment, to ensure that there are no breaks in continuity, of the live or neutral lines (which is a potential source of fire), or in the earth connection, and that cord grips are secure so that there is no mechanical strain on electrical terminals. Also, that insulation is everywhere intact, the equipment is basically functioning correctly and there are generally no developing weaknesses that call for corrective treatment. Loose leads that are made in laboratories for general experimental purposes must also be subject to periodic inspection and maintenance. Because equipment has been properly inspected and maintained, does not guarantee that it is safe when you come to use it - only that it was safe when last checked.

It will be clear (see the box following Paragraph 7) that it is the • responsible staff who are legally required to form a professional judgement about the appropriate frequency for routine inspections of equipment. This may vary widely, depending on circumstances of use. For example, the magnetic interlock switch on a food mixer guard failed within a year, and a man injured his hand. The equipment had been subjected to frequent pressure washing, so that short intervals between inspections were clearly needed.

Instruction Sheets

84 The instruction sheets for set experiments should be regarded as an integral part of the equipment and have a role to play in safety. They should be written to a good professional standard, explain clearly what work has to be carried out, and should either provide circuit and/or connection diagrams or require these to be drawn before connecting up. Any particular safety aspects should be explained, and a standard rubric emphasising the importance of safe working practices may be included. It is also helpful if the instruction sheet make S clear what stages of your work are to be checked by the supervisor before you switch on (see Paragraph 61).

85 Project work on a small scale is often introduced at an early stage in the undergraduate course, and it may be educationally desirable for the instruction sheets to be less prescriptive. Well established, safe working practices are then correspondingly more important. Staff who are responsible for such projects will have regard to the use of safe voltage levels where possible, the need for adequate supervision at all times, checking of circuits by competent staff at key stages in the work, and emphasis throughout on the adoption of correct, safe procedures.

Action in Emergency

86 The possibility of an emergency arising cannot be ruled out. When it does, you must be prepared and know:

- where the various facilities are that enable you to counter the danger
- what you have to do and how to do it.

You require training for emergency situations (see Paragraphs 9, 10) and this handbook is not a substitute for that. What follows is no more than a brief checklist of vital points.

87 Make it your business to know:

- where the emergency trip buttons are that cut off all power supplies
- where the fire extinguishers are and how to use them
- how to give first-aid, particularly artificial resuscitation, and how to summon further first-aid and medical assistance
- where the first-aid supplies are.

88 If a person is receiving an electric shock from equipment and is unable to let go, proceed as follows:

- isolate the power supply, either locally or using the emergency button, whichever is quicker
- do not touch the person in shock until the equipment is isolated
- if for any reason the supply cannot be switched off, use a length of wood (such as a broom handle) or dry cloth or a plastic or leather belt to push or pull the person clear, or if nothing is available then pull the person's loose clothing, but do not touch his/her flesh and do not put your hands under the armpits where clothing tends to be moist and therefore conducting
- Once the person is clear, apply treatment for electric shock as appropriate, including artificial resuscitation if necessary.

Further Reading and Information

The publications listed below provide more detailed information. References 1 - 3 (particularly 1) are relevant to the layout and equipping of laboratories, and the devising and organising of experiments; 4 - 7 especially concern the design and development of laboratory equipment; 8 - 13 cover various aspects of safety.

1 'Electrical Safety in Departments of Electrical Engineering', HSE Guidance Note GS 34, (under revision)*.

2 'Protection Against Electric Shock', HSE Guidance Note GS 27, ISBN 0 11 883583 1, 1984*.

3 'Safe Working Practices (Electricity at Work)',
HSE Guidance Booklet HS(G) 85, ISBN 0 11 882081 8, 1993*.

4 'Memorandum of Guidance on the Electricity at Work Regulations 1989', HSE Guidance Booklet HS(R) 25, ISBN 0 11 883963 2, 1989*.

5 'ME Regulations for Electrical Installations', 16th Edition, Institution of Electrical Engineers, ISBN 0 852965 109, also available as BS 7671, 1993*.

6 'Construction of Electrical Equipment for Protection Against Electric Shock', BS 2754, 1976=r'.

7 'Safety of Machinery', BS EN 292 , Parts I and 2, 1991*.

8 'The Effects of Current Passing Through the Human Body', BS PD 6519, Part 1, 1988*.

9 Hooper, E, `Bekingsale's The Safe Use of Electricity', ROSPA, ISBN 0 90635 55X, 1993.

10 Oldham-Smith, K, 'Electrical Safety and the Law
(A Guide to Compliance)', 2nd edition, Blackwell Scientific, ISBN 0 632 03274 X, 1993.

11 Fordham-Cooper, W, 'Electrical Safety Engineering', revised by D A Dolbey-Jones, 3rd edition,
Butterworth-Heinemann, ISBN 0 7506 1645 8, 1993.

12 'Health and Safety Responsibilities of Supervisors towards Postgraduate and Undergraduate Students', Committee of Vice Chancellors and Principals (CVCP), Annex 1 to N/93/111, 1993.

13 'Manual Handling - Guidance on Regulations', HSE Publication, ISBN 0 11 886 335 5, 1992*.

* HSE publications can be ordered by mail from HSE Books, PO Box 1999, Sudbury, Suffolk, C010 6FS.
A selected stock range of HSE publications is held by Dilions the Bookstore, Ryman the Stationer, and Ryman Computer Store. All British, European and International Standards can be ordered by mail from BSI Standards, Linford Wood, Milton Keynes, MK14 6LE.

For further enquiries about health and safety at work, contact the Health and Safety Executive at HSE Information Centre, Broad Lane, Sheffield, S3 7HQ.

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