25 Safety

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25.1 Commonsense safety

Safety is, to a large extent, common sense, and therefore the action carried out by any person is only as dangerous as that person allows it to become. However, no matter how careful we are, accidents, incidents and near misses still happen. Therefore, it is necessary for us to be able to carry out two separate functions with respect to safety. These are:

1. Recognise a dangerous situation and take steps to avoid it by employing risk management techniques.
2. If an accident does occur, know the procedure to assist the injured or rectify the problem. This is termed *first aid.*

25.2 Electric shock

The human body will allow current to pass through it, providing the EMF applied to the body is sufficiently high. This produces the physiological effect on the body. The effect on the human body, termed an *electric shock,* will vary depending on the resistance of the body and the EMF applied.

The shock to the body can be very mild, in which case the muscles will twitch, or extreme, where the heart will stop and the victim may die unless urgent action is taken.

In addition to the shock, the current that is passed through the body can cause burns and tissue damage, both to external areas and internal organs. These burns can be so severe as to cause death.

The resistance of the body will vary from person to person. Some people have damp or continually moist bodies, particularly hands. These people are more likely to feel electric shock than those with dry skin. The reason electric current can pass through the human body is because the body comprises about 70% liquids which contain minerals and will make the body conduct.

The severity of an electric shock is dependent on a number of factors:

1. The point of entry and exit of the electric current, i.e. if the current is passed through any vital organs, such as the heart, the effect is much more severe.
2. The resistance of the body at the time of the shock, i.e. if the body is moist or wet, its resistance will be lower, therefore more current will be passed through it.
3. The available current and EMF; high current will cause burns, high voltage will cause muscle spasms.

What to do for electric shock

Make sure that you do not become the second victim, but act quickly. Remove power from the victim by:

1. switching it off;
2. pulling or pushing the victim away from the power source, using an insulator,
3. call emergency services

Examine the victim and carry out resuscitation procedure as required. A copy of modern resuscitation procedures is included in most first-aid manuals. A knowledge of this procedure is necessary for the amateur regulatory examination.

The victim of an electric shock may grasp the conducting wires and the current will make the victim hang on. Do not touch the electrified person unless you are insulated from them, otherwise you may receive a shock.

Other points to remember when working in an area on live equipment where an electric shock may be received are:

1. Try never to work alone — a friend may save your life.
2. Keep the contact with the circuit to a minimum, e.g. keep one hand in your pocket.
3. Remove headphones or any other electronic equipment which may be indirectly connected to the circuit under test.

4. Use insulated tools for tuning or adjustments.
5. Work on an insulated surface. This includes the floor and bench you work on. If the floor cannot be insulated, work in rubber soled shoes.
6. Make sure your working surface is dry.
7. Look out for other earthed objects in your working area.
8. Keep your work area tidy and free from unnecessary objects.
9. Capacitors can retain a high voltage charge for a long period of time. These charges can cause lethal electric shocks. High voltage capacitors should be stored with a short circuit across their terminals

It is recommended that those at work on electronic equipment complete an approved course of study in first aid, such as those provided by the Red Cross, St Johns Ambulance and many other first aid training providers, to learn resuscitation techniques and other first aid principles and practices.

25.3 High-voltage safety

Those involved in radio and electronics will often work with high-voltage power supplies. These supplies will contain DC or AC high voltage. High voltages will be present in the power supplies and circuits within radio equipment. When the covers are removed from the equipment, a hazardous situation is present. Switching off the equipment and disconnecting from the main supply will remove this hazard. However, in many instances the equipment must have power connected to it to make adjustments and carry out fault-finding procedures. In some instances interlocks are fitted to disconnect the power when equipment covers are removed. Interlocks should never be defeated unless qualified persons are managing the situation and other safety procedures are in place.

All high-voltage wiring should be insulated with proper insulating material such as polyvinyl chloride (PVC). Exposed high-voltage leads are not tolerated.

All high-voltage power supplies should be fitted with bleeder resistors to discharge the power supply capacitors. This will ensure that no electric shock can occur after the supply is switched off. The supply should be tested with a multimeter to ensure that no voltage is present at the output of the supply prior to commencing work. In some instances bleeder resistors have gone open circuit. The shock that can be obtained from a charged capacitor can be lethal. High-voltage capacitors should always be stored with a short circuit fixed across their terminals to ensure that they are known to be discharged when they are handled. Power supplies and other equipment which contain mains auto transformers including variacs should always be operated with care or avoided. These transformers do not provide isolation from the mains which is provided by a separated primary and secondary winding.

A variac is a type of adjustable auto transformer usually consisting of a toroidal winding and a mechanism to switch the number of turns used in the circuit.

Earth connections

Earth connections reduce the risk of a person getting a lethal electric shock. Earth connections should not be removed other than by a qualified person. The earth connection to an amateur radio station should be as follows:

1. An RF earth, direct to an earth stake as close as possible to the radio equipment, provides a return for RF signals generated at the transmitter.
2. A separate AC earth installed by a qualified electrician provides a safety aspect of a known earth as well as a very short earth run for the equipment via the power outlets in your shack. A short earth run of low resistance is necessary to provide a very low impedance path if an AC-to earth fault occurs. This fault condition should blow a fuse or trip a circuit breaker.
3. The mast for your antennas should also have a separate earth to provide a low resistance path for any static discharge which may occur in the area of your station. Allowing such discharges to find their way back to the equipment via an AC or RF earth, can cause a hazardous situation, as well as possible damage to your equipment.

25.4 Australian mains wiring

240 volt AC mains

Warning. Alterations or modifications to mains wiring is illegal for any person other than a qualified licensed electrician. This may include leads designed to plug into power outlets. Check with your supply authority or call a suitably qualified electrician.

The 240 volt AC mains has three connections:

1. active
2. neutral
3. earth.

The active supplies the power to the circuit. The active wire in our equipment should always be switched and fused or have a circuit breaker. This will open the circuit if a fault condition occurs. The earth provides a low impedance path for fault current.

The neutral is the return circuit for the active. This in conjunction with the active can also be switched, i.e. double-pole switching. This provides additional safety as, if the incoming lead is reversed, the active is still removed when the equipment is turned off.

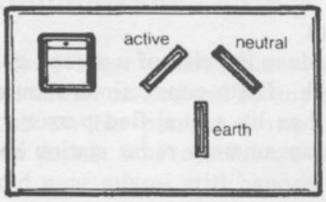

Figure 25.1 GPO configuration

Power wiring in Australia should be carried out to Australian standard AS/NZS 3000:2000. All wiring back from the general power outlet must be carried out and inspected by a suitably qualified licensed electrician. A detailed knowledge of this wiring is not necessary. However, we as amateurs will construct power supplies, make extension leads, etc., which we shall connect to the mains. Therefore, it is necessary for us to know the regulations and requirements for the safe connection of this equipment.

General power outlet (GPO) configuration Figure 25.1 shows the configuration of the active, neutral and earth connection for a standard 10 or 15 amp GPO. The active is connected to the top left, the neutral to the top right, the earth to the bottom centre.

Extension or connecting leads

Extension leads are often responsible for electric shock due to their being in poor condition or having incorrectly terminated wires. Reversal of the wires in an extension lead can cause the equipment to which it is connected to become live and an electric shock can result from touching the equipment. To overcome this problem, the wires in the mains lead are colour coded and AS/NZS 3000:2000 states the following recommended connection:

active — brown wire;
neutral — blue wire;
earth — yellow/green wire.

Frayed or damaged leads are potential sources of electric shock and should be replaced. If repaired the repairs should be completed by an appropriately qualified person. Figure 25.2 shows the correctly terminated plug and socket for a 3 core flexible 240 volt mains lead.

25.5 Circuit breakers and fuses

A fuse is included in the circuit to protect the wiring. Fuse rating should always be observed and heavier fuses should never be placed in the circuit under any circumstances. Incorrectly rated fuses can cause fire as well as damage to equipment. The neutral is often at earth potential; however, this is not always the case.

The earth is connected to a local earth stake to provide a low impedance path to cause the equipment to blow a fuse if a short or low resistance path occurs between the active and the earth. The earth connection is vital to the equipment and must always be short and of very low resistance.

Circuit breakers are available in two general types: thermal and magnetic. The *thermal circuit breaker* is used for current overload. A temperature sensitive circuit within the breaker causes it to open the circuit if the overload causes the temperature to rise significantly. The temperature must return to normal before the circuit breaker is reset.

The *magnetic circuit breaker* has a small coil included, the magnetic field of which will trip the breaker when excess current is passed through it. This principle is not unlike a solenoid. This breaker cannot be reset until the excessive load causing the current is removed.

The advantage of the circuit breaker over the fuse is that the fuse, if it blows, must be replaced by a new fuse or fuse wire, whereas the circuit breaker is reset to restore it to its normal operating condition.

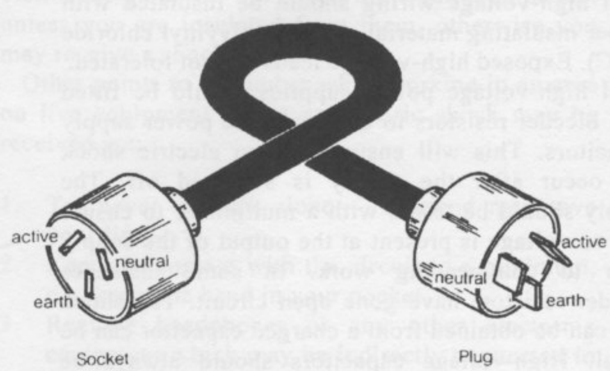

Figure 25.2 Flexible lead

Earth leakage or core balance breakers

These circuit breakers, often termed safety switches, are very popular and are often found in the home and workplace as well as used in conjunction with portable power supplies (generators). These circuit breakers detect and trip if excessive current flows to earth or if the voltage of the earth system is excessive. As portable equipment can be connected to a suspect earth or even to a supply where the active and neutral or earth are reversed, these circuit breakers reduce the chance of the operator receiving fatal shocks. Consideration should be given to having this type of circuit breaker installed by a qualified licensed electrician in areas where radio equipment will be operated.

25.6 Lightning

Lightning is the result of a static build-up within the clouds. It is not exactly known how this static build-up is produced, but scientists have put forward a number of theories. These theories are beyond the scope of amateur examinations; it is sufficient for us to know that under some circumstances the clouds become positively charged at their top and negatively charged at their bottom.

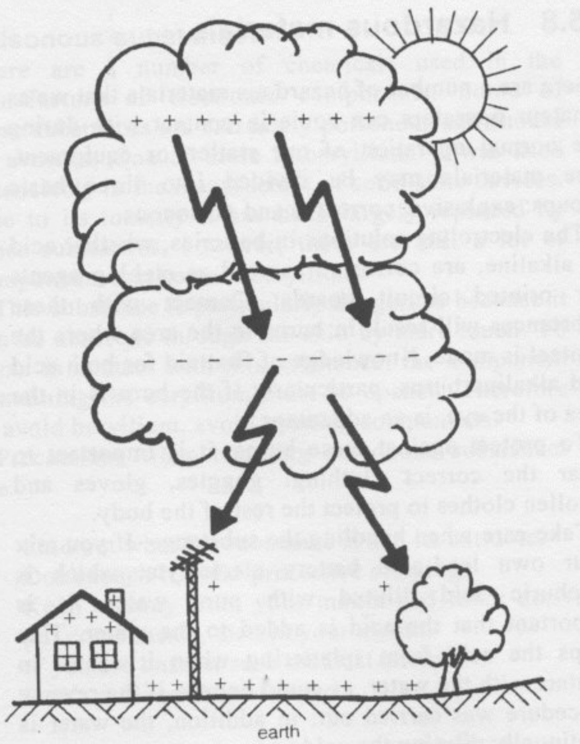

Figure 25.3 Static charges within storm clouds

The charge is approximately +24 coulombs and −20 coulombs. The distribution of the charges is as shown in Figure 25.3.

When the charge within the cloud reaches a particular potential, the air which is acting like a dielectric is broken down and a flash of lightning results. The ground assumes a charge which is positive with respect to the base of the cloud to allow this strike to take place.

The voltage gradient required to break down the air is approximately 100000 volts per metre over a distance of 50 metres in raindrop-filled air.

Most lightning bolts occur within the cloud. This tends to even the charges and it therefore takes some time to rebuild the charge prior to another strike. However, about one bolt in four actually strikes the ground. The power in one lightning strike is enormous.

1. One bolt can have a difference in potential between the charges of several hundred million volts.
2. The average current in a strike is 20,000 to 100,000amperes.
3. The air around the strike is superheated to as high as 30,000°C. This causes the air to expand explosively to produce thunder.

As lightning contains all this power and, in general, will tend to strike the highest conducting medium, i.e. a radio tower or mast, we must take precautions to stop this energy from entering premises. Lightning can enter a building via:

1. the radio mast or antenna system;
2. the 240 volt main distribution;
3. the telephone line.

The lightning entering the premises can be divided into two types:

1. a *direct strike,* i.e. the lightning hits the tower mast or antenna system;
2. a *nearby strike* which induces a high voltage which finds its way into the premises by the resultant current seeking the lowest resistance path to flow.

A direct strike to the antenna system when the equipment is connected will result in severe damage no matter what precautions are taken. It is therefore good practice to disconnect all antennas from their equipment and earth them to a good earth if a storm is approaching.

Disconnect equipment well in advance of an approaching storm. Attempting to disconnect equipment during a storm can result in an electric shock. In addition, the mast must be earthed to provide a low resistance path in case of a strike. A lightning rod fitted to the mast may reduce the resistance to earth for the lightning's current and therefore reduce the damage to the mast if lightning should strike.

Induced strikes can be protected against to some degree. A large number of lightning arrestors are available to provide some protection against lightning strikes. These devices are based on the principle that the current from a strike is seeking the path of least resistance to earth. Therefore a dielectric between earth and the equipment to be protected is provided. The theory is that this dielectric (usually air) will be broken down by the high voltage, providing the path of least resistance.

If a storm approaches:

1. switch off all electrical equipment and remove the plugs;
2. disconnect all antennas and earth them. Care must be taken while doing this as the impending storm may be inducing high voltages in your antenna system. A coaxial switch will assist with this disconnection and earthing procedure.
3. remove all equipment connected to the telephone line, such as audio couplers, modems, etc.

25.7 Safety and RF energy

RF energy has the ability to cause severe and superficial burns as well as damage to internal organs. RF burns always take a long time to heal and although not generally painful at first become very painful after some time. The heating effect of RF is familiar to us in the form of a microwave oven. Care must be taken when working around RF circuits that are powered up, as physical contact with the RF conductor is not always necessary to receive a burn. In addition, at the higher frequencies the body cavities such as eye sockets become resonant, therefore tending to absorb the RF energy. Understanding electromagnetic radiation (EMR) is a licence condition

The simplest protection against RF energy is: ensure a distance between you and the source —

1. keep away from antennas when transmission is in progress;
2. keep covers on the equipment when operating as they act as a shield;
3. always earth your transmitting equipment;
4. never remove shielding, including covers, and operate equipment as this may result in high levels of localised RF energy.

It is important to realise that the operator is more likely to have problems with RF burns at higher frequencies, i.e. VHF, UHF and SHF, than at HF frequencies. In some instances a simple detector (even your wave absorption meter) can be used to detect RF energy. This test will give you relative indication of leakage of RF energy.

If you receive an RF burn that becomes painful, seek medical attention. These RF burns may not be immediately apparent as it takes some time for the internal tissue to become damaged and burnt.

There is growing concern that exposure to RF fields may be hazardous to health if exposed over a long period of time. Research in this field is continuing largely as a result of the massive use of mobile phones which expose persons to RF fields at UHF and SHF frequencies. Generally keep maximum distance between the RF field and you, use shielding where possible to keep exposure to a minimum and operate equipment according to manufacturer's specifications. This will minimise the risk. Remember that the higher the frequency and the higher the power the higher the risk of EMR exposure

25.8 Hazardous materials

There are a number of hazardous materials that we as amateur operators can come in contact with during the normal operation of our station or equipment. The materials may be divided into three basic groups: explosive, corrosive and poisonous.

The electrolyte solutions in batteries, whether acid or alkaline, are corrosive as well as etching agents for printed circuit boards. Contact with these substances will result in burns in the area where the contact is made. Knowledge of first aid for both acid and alkaline burns, particularly if the burn is in the area of the eye, is an advantage.

To protect against these burns, it is important to wear the correct clothing: goggles, gloves and woollen clothes to protect the rest of the body.

Take care when handling the substance. If you mix your own lead-acid battery electrolyte, which is sulphuric acid diluted with pure water, it is important that the acid is added to the water. This stops the acid from splattering when it comes in contact with the water, as could happen if the reverse procedure was carried out; in addition, the water is continually diluting the acid.

Charging and discharging batteries

When a battery is charged or discharged, hydrogen gas may be given off. This gas, mixed with air in the correct proportion and ignited, will explode. Battery explosions can cause major damage, not only by force of the explosion, but by the spreading of the electrolyte during the explosion. The following rules should apply when operating batteries:

1. Always check the charge/discharge rate of a battery. This is generally set by the manufacturer. However, the normal charge/discharge rate for a battery is no greater than one-tenth the ampere/ hour capacity of the battery.
2. When charging or discharging a battery ensure that there is adequate ventilation.
3. Keep all naked flames and sparks away from the battery at all times. The electronic equipment that we operate will often produce sparks, e.g. when relay contacts open and close. Always switch off the charger prior to disconnecting the battery charger leads, otherwise as the leads are disconnected a spark will result and could cause the battery to explode.
4. Always treat the battery as if hydrogen is present, even if it is not being charged or discharged.

Poisonous substances

There are a number of chemicals used in the manufacture of electronic components. Some of these substances are extremely poisonous and should be avoided. One of these is beryllium. It was used extensively in the manufacture of solid-state devices. Due to its toxicity it has been largely replaced by other substances, however, there are still a lot of components that contain beryllium.

This substance is particularly dangerous because it can be absorbed through the skin by mere touch. To come in contact with this substance, the component containing the beryllium must be opened. Therefore to avoid beryllium, avoid opening components.

Precautions when handling poisonous substances are:

1. Find out what the substance is and its antidote.
2. Don't touch it, wear protective clothing.
3. Keep it away from your mouth and food; don't put components, etc., in your mouth.
4. If you are unsure, seek medical advice.
5. Don't pull components apart.

All heavy metals should be considered dangerous, handled correctly, and disposed of properly. This includes solder which contains lead. Always wash your hands and avoid contact with food while soldering. Mercury in mercury batteries and other electronic/electrical equipment must also be disposed of correctly.

Polychlorinated biphenyls used in old style capacitors and transformers can be dangerous to your health, particularly when vapours produced when this chemical is warm, are inhaled. It is believed polychlorinated biphenyls are carcinogenic. Unless this chemical is disposed of correctly it will damage the environment.

25.9 Masts and antennas

When operating a radio station, large antennas will often be used, particularly at HF. These antennas, and the masts to which they are attached, should always be kept clear from overhead power lines. This includes the antennas used when mobile. A 10 metre quarter-wave antenna, mounted in the centre of a vehicle roof, is considered to be too large to safely avoid tram, train or overhead power lines. Look before erecting antennas or masts. Always check for any obstacle that could foul the antenna, particularly power lines.

Care must also be taken when climbing a mast. When this is necessary, as it will be from time to time, always work with a friend and use the correct safety equipment.

1. A safety helmet, glasses, boots and gloves should be worn by both the person up the mast and the person on the ground.
2. Use an approved safety belt or harness while carrying out the work aloft.
3. Use a safety line up the mast which can be used to effect a rescue and know the rescue technique.
4. Secure all tools, etc., so that they cannot be dropped to the ground.
5. Work out exactly what you want to do when up the mast before you start climbing.
6. Falls prevention techniques are mandatory and must be employed
7. Radio equipment or hardware must not be connected to power poles or other power carrying structures. Understand "*no go zone*" requirements.
8. Where electromagnetic radiation, high voltage or current is present in an area, equipment, should signposted and physical restraints such as guards, fences or cages may be required to limit access

25.10 Safety and mobile operation

There are a number of safe operating procedures you must comply with when operating portable or mobile. Some of these are laws laid down by the State as traffic laws or road rules. Two of the most common are:

1. The operator must not speak into the microphone or operate equipment when driving. In some States it is an offence to do so unless hands free.
2. The equipment installed in the vehicle must be secure, and must not obstruct the driver's vision or ability to control the vehicle.

A check of your State road rules will provide you with any other requirements that may be necessary to operate portable. Other points to keep in mind:

1. Never operate transmitting equipment while your vehicle is being filled with petrol. A spark could cause an explosion.
2. Never operate a transmitter in an area where blasting is taking place. Detonators may be set off due to the RF energy. Signs reading 'switch off radio transmitters' will be displayed in these areas.
3. Be aware of the interference that the radio transmitter might cause to electronic equipment in your car, such as electronic ignition, electronic panel meters and electronically controlled braking systems.
4. Avoid transmitting in any area where an explosive gas may be present, such as around LP gas bottles or natural gas installations.

25.11 Purchased or hired mains operated equipment

All mains operated equipment should be approved by the relevant state or territory authority or other relevant electrical authority and should have an approved equipment label. It should be noted that this will vary from State to State and between countries.

25.12 Slips, trips , falls and fires

Good housekeeping should apply all around a radio station. If equipment and the installation are neat and tidy and all equipment is labelled with no dangling leads etc the likelihood of injury due to slips trips and falls as well as electric shock is greatly reduced.

Good housekeeping also reduces the risk of fire both electrical or other fires. The radio station should be fitted with fire extinguishers for electrical or other fires. Using the incorrect extinguisher on an electrical fire can result in an electric shock

Knowing the correct fire extinguisher to use and access to the extinguisher is fundamental to your safety.

25.13 Hearing protection

Those working with radio and electronics in particular when operating radio equipment will often wear head phones. When headphones are used the volume should be turned down before putting the headphones on and after putting them on, increase the volume to a comfortable level. When using test tones or listening to other audible signals keep the volume low. Continuous high levels of tone or other audible signals including "pops, crackles or static" can result in hearing loss or damage.

25.14 Station Security

The holder of a radio station licence is responsible for station security both from an illegal operation perspective and from a safety perspective.

Unauthorised persons must not have access to your station equipment or operate your station without a licence or your permission. You must have a means in place to make your station safe and secure.