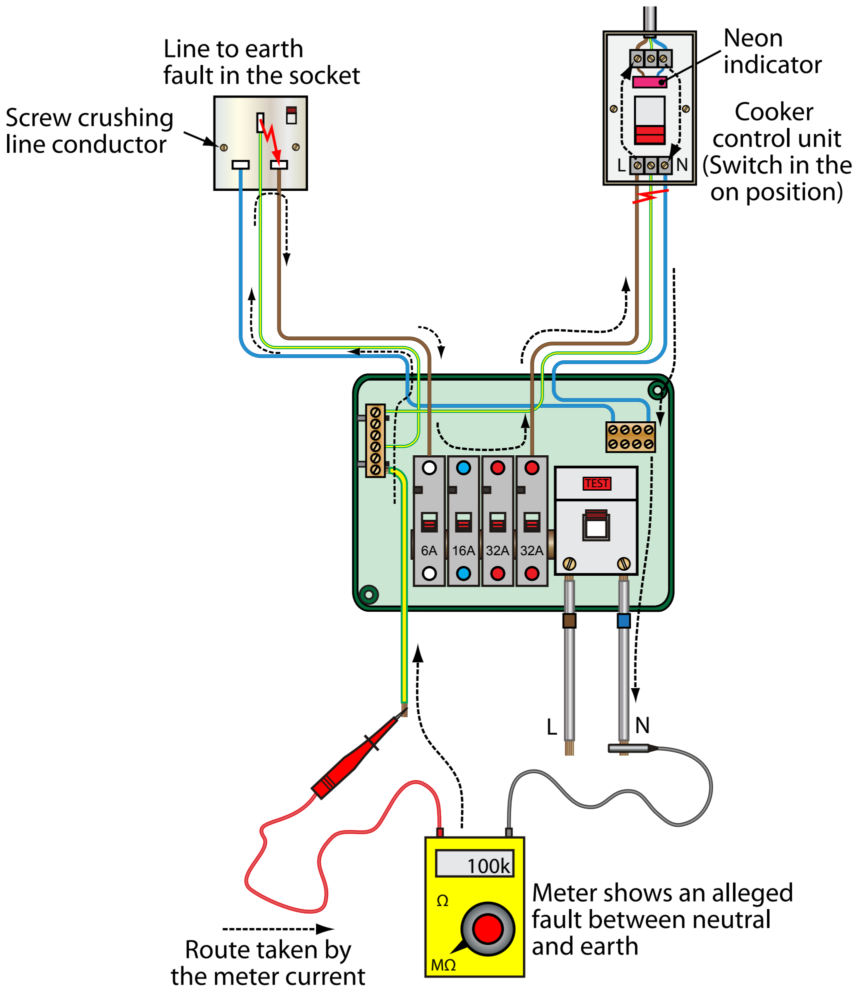
Level 3 Diploma
in
Installing Electrotechnical Systems & Equipment

C&G 2357

Unit 308 - Understand the principles, practicies and legislation for diagnosing and correcting electrical faults.



B&B Training Associates Ltd

Learning Materials for the Electrical Industry

Produced by

B&B Training Associates Ltd

For further information contact:

Mrs A Bratley

23 St Pauls Drive,

Tickton, Nr Beverley,

East Yorkshire

HU17 9RN

Tel:-01964 – 543137

Fax:-01964 – 544109

Email:- sales@bbta.co.uk

timbenstead@bbta.co.uk

terry@bbta.co.uk

Aims and objectives

There are **five** learning outcomes to this unit. The learner will be able to:

1. Understand the principles, regulatory requirements and procedures for completing the safe isolation of electrical circuits and complete electrical installations
    - Specify and undertake the correct procedure for completing the safe isolation of an electrical circuit.
    - State the implications of carrying out safe isolations.
    - State the implications of not carrying out safe isolations.
    - Identify all Health and Safety requirements which apply when diagnosing and correcting electrical faults in electrotechnical systems and equipment.

2. Understand how to complete the reporting and recording of electrical fault diagnosis and correction work
    - State the procedures for reporting and recording information on electrical fault diagnosis and correction work.
    - State the procedures for informing relevant persons about information on electrical fault diagnosis and correction work and the completion of relevant documentation.
    - Explain why it is important to provide relevant persons with information on fault diagnosis and correction work clearly, courteously and accurately.

3. Understand how to complete the preparatory work prior to fault diagnosis and correction work
    - Specify safe working procedures that should be adopted for completion of fault diagnosis and correction work.
    - Interpret and apply the logical stages of fault diagnosis and correction work that should be followed.
    - Identify and describe common symptoms of electrical faults.
    - State the causes of a variety of faults.
    - Specify the types of faults and their likely locations in wiring systems, terminations and connections, equipment/accessories and the like, and instrumentation and metering.

4. Understand the procedures and techniques for diagnosing electrical faults
    - State the dangers of electricity in relation to the nature of fault diagnosis work.
    - Describe how to identify supply voltages.
    - Select the correct test instruments for fault diagnosis work.
    - Describe how to confirm test instruments are fit for use, function correctly and correctly maintained.
    - State the appropriate documentation that is required for fault diagnosis work and explain how and when it should be completed.
    - Explain why carrying out fault diagnosis work can have implications for customers and clients
    - Specify and undertake the procedures for carrying out a range of tests in relation to fault diagnosis.
    - Identify whether test results are acceptable and state actions to take where unsatisfactory results are obtained.

5. Understand the procedures and techniques for correcting electrical faults.
    - Identify and explain factors which can affect fault correct, repair and replacement.
    - Specify the procedures for functional testing and identify tests that can verify fault correction.
    - State the appropriate documentation that is required for fault correction work and explain how and when it should be completed.
    - Explain how and why relevant people need to be kept informed during completion of fault correction work.
    - Specify the methods for restoring the condition of building fabric.
    - State the methods to ensure the safe disposal of any waste and that the work area is left in a safe and clean condition.

1: Safe isolation

In this session the student will:

- Have the opportunity to refresh their understanding of safe isolation

At this stage of your training to become an electrician you should be familiar with the safe isolation procedures, but as this unit it concerned with fault finding and the dangers that might bring, we will briefly revisit the main points.

Safe working practices

The Electricity at Work Regulations 1989 is the principal legislation relating to electrical testing activities.

Regulation 4(3) requires that 'work on or near to an electrical system shall be carried out in such a manner as not to give rise, so far as is reasonably practicable, to danger'.

Regulation 14 places a strict prohibition on working on or near live conductors unless:

(a) It is unreasonable for the equipment to be dead;
(b) It is reasonable for the work to take place on or near the live conductor; and
(c) Suitable precautions have been taken to prevent injury.

Safe working systems would involve carrying out a full risk assessment, included in that;

- taking precautions to prevent people who are not doing the testing coming into contact with exposed live parts
- taking precautions to prevent the testers coming into accidental contact with exposed live parts
- protecting and insulating both the equipment being worked on and the testing equipment
- using test equipment that is suitable for the job;
- making sure that people doing the work are suitably trained and experienced so that they understand safe working practices and the equipment on which they will be working.

Before any testing is carried out ensure that:
The equipment which is to be worked on is safe for the intended tests; and the working environment does not present additional dangers. These dangers include:

- inadequate space to work safely;
- insecure footing;
- insufficient light;
- potentially flammable gases or vapours;
- explosive or conductive dusts.

Identification of circuits to be isolated

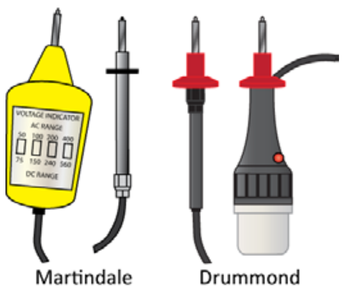
In many cases actual physical identification will be necessary and this may be aided by the use of appropriate drawings, diagrams and other written information. You should never assume that the labelling or drawings are correct without having proved that the circuit is dead

Selecting suitable points of isolation

The means of isolation can be an adjacent local isolation device such as a plug and socket, switch-disconnector, circuit breaker, fuse etc. as appropriate, which is under the direct control of the competent person carrying out the work.
These devices can be used without further precautions provided there is no foreseeable risk that the supply could be reinstated by others.
When there is no such local means of isolation or there is a risk of reinstatement of the supply as above, the circuit or equipment to be worked on should be securely isolated by other means. Isolation of equipment or circuits using the main switch or DB switch-disconnector is the preferred method.

Voltage detection instruments & isolation equipment

For the testing of a potentially live source, two pieces of test equipment are required, along with lock-off paraphernalia. These items are:



Approved voltage testers

Voltage proving unit


Isolation accessory

Label

Padlock

Instruments used solely for detecting voltage fall into two categories.

These are:

i) Detectors which rely on an illuminated bulb (test lamp) or a meter scale (test meter). Test lamps fitted with glass bulbs should not give rise to danger if the bulb is broken. It may be protected by a guard. An example is shown on the right.

These detectors require protection against excess current. This may be provided by a suitable high breaking capacity (hbc or hrc) fuse or fuses, with a low current rating (usually not exceeding 500 mA), or by means of a current-limiting resistor and a fuse. These protective devices are housed in the probes themselves. The test lead or leads are held captive and sealed into the body of the voltage detector.

ii) Detectors which use audible sound as well as lights to indicate the presence or lack of a voltage source. Such a detector is shown on the right and is popular with electricians as they can also be used as a continuity tester, which is useful for fault finding.

A tester is of no use if we cannot guarantee its effectiveness. This is where the proving unit comes into its own.

A proving unit is a d.c. voltage source that checks its own status and is then a known reference voltage against which the voltage tester can test itself. Without this, we cannot guarantee the voltage tester, at which point it is useless.

Guidance is provided by the HSE in the form of Guidance Note GS 38 ‘Electrical test equipment for use by electricians’. This gives the minimum requirements for the test probes.

Using correct testing methods

Actions common to both dead and live working

- Identify the circuit or equipment to be worked on or near and the work to be done
- Plan the work
- Specify correct system of work (preferably written)
- Specify level of supervision and whether a second person is necessary
- Select and instruct competent workers
- Ensure correct working methods
- Provide and ensure use of appropriate protective equipment

Dead working procedures

- Identify circuit or equipment to be worked on
- Cut off supply, isolate and secure isolation
- Retain keys.
- Post 'caution' and 'danger' notices
- Prove circuit or equipment dead
- Apply circuit main earth(s) where necessary
- Take precautions against adjacent live parts where necessary
- Issue permit-to-work where necessary
- Apply local earth(s) where necessary

Live working procedures

Work on or near live conductors should rarely be permitted (Regulation 14).

Many accidents to electricians, technicians and electrical engineers occur when they are working on equipment that could have been isolated. There are some circumstances where it is unreasonable to make equipment dead because of the difficulties it would cause (Regulation 14), such as fault-finding.

- Identify the circuit or equipment to be worked on or near and the work to be done
- Ensure suitable precautions are taken and that suitable protective equipment is used
- Ensure adequate working space, access, and lighting. Restrict access to area of live work
- Ensure accompaniment is provided if necessary. Accompaniment to be trained to give assistance

Locking devices

The point of isolation should be locked off using a unique key or combination retained by the person carrying out the work.

If a plug has been withdrawn, make sure that it cannot be reconnected to the electrical supply while work is taking place on the circuits or apparatus. If a fuse is removed, make sure that it or a similar one cannot be reinserted by taking it away or by locking the box or enclosure until work is completed.

In the case of multiple isolations on a DB, a multi-lock hasp can be used to prevent access to a main isolator until such time that all persons working on a system have completed their work and removed their padlocks from the hasp.

Used with a single padlock

Used for multiple padlocks

Warning notices

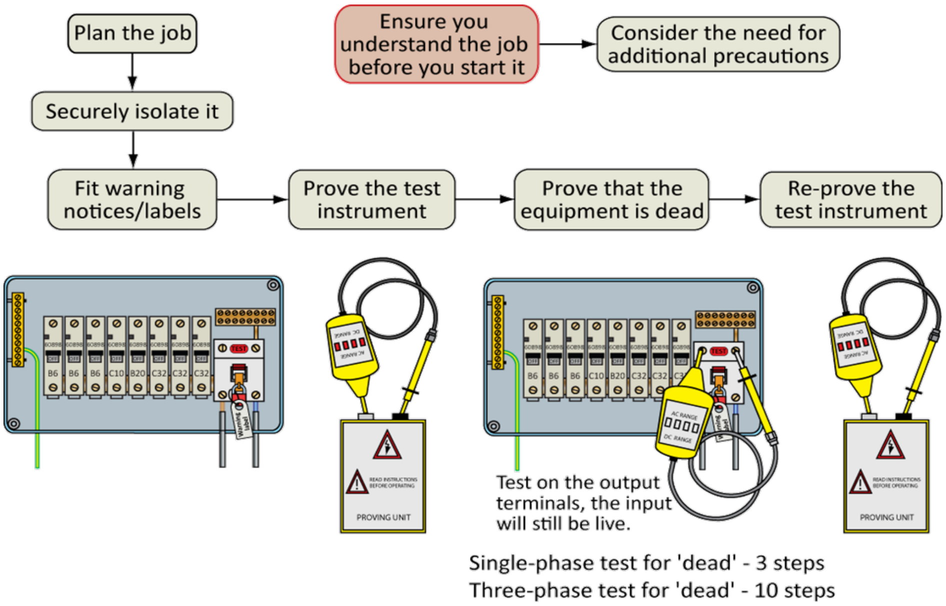
Put a notice or label at the place of disconnection so everyone else knows that work is being done. A good system is to use a 'caution' notice to indicate that someone is working on the apparatus and may be injured if it is re-energised.
This should be supplemented by 'danger' notices adjacent to the place of work indicating nearby apparatus that is still energised. Notices or labels should be easily understandable to anyone in the area.

It is also important to remove labels or notices when they no longer apply so that persons using the system are not left wondering if any danger still exists. It is often useful for the 'caution' and 'danger' notices to have a space for the name of the person working or in charge and for the date. All keys should be retained in a secure place.

Correct sequence for isolating circuits

Before isolating and circuit or piece of equipment it is necessary to inform those around you in advance that you are going to do so. This is important so that data may be saved, machinery switched off, jobs that need power and lighting re-scheduled etc.

Protect yourself and others by erecting safety barriers if necessary.



Exercise 1

1. What are the three requirements of Regulation 14 that allow live working?

2. Before starting testing, what environmental dangers should you look out for?

3. Name four suitable points of isolation.

4. List some requirements of GS 38.

5. State the procedure for carrying out a safe isolation.

2: Reporting and recording of fault diagnosis

In this session the student will:

- State the procedures for reporting and recording information on electrical fault diagnosis
- State the procedure for informing relevant persons about information on electrical fault diagnosis and correction work
- Explain why the information must be given, clearly, courteously and accurately
- specify safe working procedures that should be adopted for completion of fault diagnosis and correction work
- interpret and apply the logical stages of fault diagnosis and correction work that should be followed

Reporting and recording information on fault diagnosis.

The procedure for reporting and recording information on electrical faults will vary depending on whether it is a client or colleague. Whoever is reporting the fault needs to give as much information as possible to help the fault finder. The information about the fault should be written down so that records can be kept of the conversation. This should ideally be written on a job card or similar. Getting the information from a non technical person might require patience, but remember that being polite is important.

Listening to the client and informing them of what you intend to do is part of your job as an electrician. It maybe that what you have heard might lead you to suspect that the fault is dangerous and the circuit equipment must not be used until further investigation is carried out. This will mean you will have to use all your technical knowledge.

Any verbal information given to the client should be backed with a written copy.
Once the fault has been found there will need to be a discussion as to how to put the fault right. This could be quite straight forward, in which a quote for the task can be given, if required.
If the fault finds something serious there will be research to be done on whether it is worth repairing equipment, rewiring, or replacing faulty parts. This will be a longer process.

Any information must be given politely and accurately.
Giving inaccurate information could be dangerous and if this lead to injury, fire or even death. You would be liable!
When you have completed the fault finding and rectified the faults, it is good practice to take time to explain to the customer what you have done and why, then any relevant documents and test result sheets handed over.
A customer who feels that they have been treated in a professional manner and kept informed of the work in progress is much more likely to ask you to do work for them again.

Safe working procedures:
The EWR (Electricity at Work Regulations 1989) requires that you are competent. This means you must be able to apply both technical knowledge and experience.

- Competence means you are fully trained and know what you are doing
- Remember Ignorance is no excuse as far as the law is concerned, if you are in any doubt don't do it
- The task must be planned in such a way that no live working takes place
- The risk to injury must be limited

Effective communication with others in the work area

Considering others
There are people to consider such as your fellow workers, your customers/client, the public and the effect on the building and its users if power is cut off.
You should ensure that when isolating the circuit that others who are working around you are warned that the supply will be turned off and you should allow ample time for them to finish what they are doing. You are not going to be very popular if you cut of the power to drills, leave everyone in the dark etc.

Customer / Clients
Every effort should be made to notify the client well in advance of any loss of supply and for commercial installations, effort should be made to try to arrange any shut down during hours when the impact will be minimised. There are certain types of machinery and plant which could be damaged if suddenly switched off, the impact of going from full power to none could rip bolts from fixings, send potentially dangerous goods and equipment flying. Machinery using magnetic clamps would lose grip of the objects.
In domestic situations, there may be vulnerable people such as the elderly and very young children who need light and heat.

Public

Any area that the general public may occupy and the effect an interruption in the electrical supply will have on them needs to be considered. Lighting in areas such as shopping centres, underpasses, car parks and other public access points need to be maintained so that the public are able to move around in or exit the buildings safely. The working area must be maintained in a safe condition with no danger to the public. Before removing power to lifts, escalators or any public area, the area must be checked and warning notices positioned first.

In a local night club, the lighting was turned back on after a period of black-out and before informing those who might still be in the building. As it turned out; several members of the public were still inside enjoying themselves as young couples do whilst the building was in darkness. The problem was that a faulty lighting contactor had been by-passed.

Yourself the inspector

Before you begin the process of isolating systems or equipment, you must be competent, that means; trained in the procedure, understand what you are going to do, have the correct equipment and PPE etc.

Use of barriers

When member of the public or other colleagues are likely to be in the area when the testing is taking place, barriers should be erected, to protect both yourself and others.

Positioning of notices

Notices should be positioned to warn of the dangers of the electrical testing. These should be in place to keep people out and to warn that a circuit has been isolated and should not be used.

Safe isolation

A quick reminder

- Notify others that isolation is to be carried out.
- Identify circuit to be isolated and isolate, lock off the circuit and fix notices.
- Prove voltage tester is working by using a known live supply or by using a proving unit.
- Check the circuit is dead.
- Recheck voltage tester is still working.

The circuit is locked off at the isolation stage, you have taken control of the circuit and need to make sure it cannot be made live while you are testing for it being 'dead'.

Logical approach to fault finding

Some faults are relatively easy to find and rectify, others might have no information available other than that there is a fault. These occasions will need all your training and experience. The recognised system for fault finding is as follows

i) Identification of symptoms.

Ask the clients or person working on the system what happens, were there any flashes bangs or smells.

ii) Collection and analysis of data

Talk to the people who use the system/equipment, as they might know what is wrong.
Use of sources/types of information such as the IEE Wiring Regulations, Installation Certificates, Installation Specifications, drawings/diagrams, manufacturer's information and operating instructions, previous test results
Carry out a visual inspection of the location of the fault, and decide what action needs to be carried out. Discuss with the person reporting the fault the best way to repair it.

iii) Maintenance records

Check any maintenance records to ensure that it has been properly maintained and if there have been any records of previous faults. This only works for large commercial/industrial sites. In domestic settings there will be no records.

iv) Experience (personal and of others)

When gathering information, ask other personnel who might have more experience than yourself of this type of fault, it could save you some time. Remember; don't be embarrassed by asking a colleague, you cannot be expected to know every type of fault on every type of system. There is no shame in admitting you don't know something.

v) Checking and testing (e.g. supply, protective devices)

Before getting the test equipment out try checking the obvious thing first, using an approved voltage meter check the supply is on at the origin and locally. Has a fuse operated or an RCD tripped, if they have this would help confirm the location and type of the fault on a circuit or equipment. Look for the obvious first, before confirming isolation and carrying out a whole sequence of tests.

Interpreting results/information

Once you have all the information and test results are gathered it is time to interpret the results. Having hopefully discovered the fault it is time to rectify it.

Fault correction

Hopefully this will be a straightforward process, but think about the whole system you are working on. Why did the fault occur? It is a good idea to think about the system, you don't want to be back tomorrow and repair the fault again if the fault you are working on was caused by another fault somewhere else. This is time consuming, expensive and embarrassing.

Functional testing

Before you turn the supply back on there are certain tests to be done.
Check all the covers are back on. Switch off loads, because the sudden 'inrush' of current can cause protective devices to blow. In addition the sudden starting of live machinery can be dangerous to the machine and people. Reset any devices to their original settings.
Test the equipment to make sure it is electrically sound as well as functioning as it should, by operating switches etc.

Restoration

The site should be restored to its original condition. The extent of the restoration should have been discussed with the client before the repair of the fault. With any electrical work, the site must be left in a clean and safe condition and the waste disposed of according to the hazard it represents.

Exercise 2

1. You have been asked to go to a supermarket where the manager complains that one of his freezer cabinets is not working.
    a) What paperwork do you need before you go?
    b) What are you going to do upon arrival at the supermarket?
    c) What are you going to do at the completion of the job?

2. A three-phase motor is fed from a distribution board some 24 m away. The circuit is protected by HBC fuses and there is a star/delta starter and local isolator situated within 5m of the motor. Explain the safety precautions you would consider and describe how you would safely isolate the circuit to allow work on the motor.

3: Symptoms of electrical faults

In this session the student will:

- Identify and describe common symptoms of electrical faults.
- State the causes of a variety of faults.
- Specify the types of faults and their likely locations in wiring systems, terminations and connections, equipment/accessories and the like, and instrumentation and metering.

Electrical faults

No two situations are ever the same so it would be impossible to write a book of all faults you will ever come across.

Regulation 314.1 of BS 7671 states;
Every installation shall be divided into circuits as necessary to:

- Avoid hazards and minimise inconvenience in the event of a fault
- Facilitate safe inspection, testing and maintenance
- Take into account of hazards that might arise from the failure of a single circuit such as a lighting circuit.
- Reduce the possibility of unwanted tripping of RDCs due to excessive protective conductor (PE) currents not due to a fault
- Mitigate the effects of electromagnetic interference (EMI)
- Prevent the indirect energising of a circuit intended to be isolated

Compliance with these regulations will help locate faults more easily, by process of elimination (checking fuses) or looking to see which one has operated.
Most electrical faults would become apparent by:

- Loss of supply
- Low voltage
- Operation of overload or fault current devices
- Component/equipment malfunction/failure
- Arcing

Loss of supply

At the origin of the installation

Loss of supply at the incoming meter would be the supply company's problem and would be caused by a problem at a substation or workmen/thieves cutting cables. Lightning strikes and other natural causes such as high winds, thunderstorms etc. can also cause damage to overhead lines or equipment.

Check that the client has paid their bills!

Occasionally it can be caused by the supply company's protective devices operating, this is usually down to misuse of equipment, poor design, or overloading of the supply company's equipment.

Localised loss of supply

If circuits have been installed according to BS7671 Section 314 then if a fault occurs on any one circuit it should not affect any other final circuit or cable leading up to the consumer unit. Only the circuit protective device feeding that circuit should have operated.

Operation of overload and fault current devices

Overloads

Protective devices are designed to operate when excess current, greater than that of the design current passes through it. The excess heat causes the fuse to rupture or the device to trip. Overloads are not necessary faults in themselves, but investigation needs to be made as to why it happened and clients advised of fire hazards.

Causes of overloads

- Extra loads places on an existing circuit or installation
- Motor starting current not accounted for on motor circuit.
- Socket outlets overloaded beyond the rated load of the circuit.

Earth faults or short circuits

Most earth faults are caused by the cable sheath rubbing on sharp metal edges, or trapping a conductor when screwing a metal plate onto the metal box.

Causes of short circuit faults

- Termination connected wrongly and not tested before energising
- Wrong type of connector
- Insulation breakdown
- Breaking of live circuit by nail or similar

Operation of fuses/cb's due to short circuit. This mainly occurs when a cable is damaged or cut through by mistake.

With modern fuses and circuit breakers it is difficult to tell the difference between an overload and short circuit when they operate. Semi-enclosed fuses tended to break in the middle of the element on overload and vaporise on short circuit.

Recognise faulty /damaged faulty components

Sometimes it is obvious when a component is faulty. A fluorescent tube with both ends blackened gives a clue as to what the problem is.
A fire element with the element obviously broken shouldn't cause too many problems.
Although it is important to use your experience when fault finding, it is equally important not to assume anything. Always collect information in a logical manner and analyse what you are told, what you can see and what the tests tell you.

Modern electronic components are much more difficult to interpret and more damage can be caused by testing. Use of a flow chart to diagnose faults may be essential.

Appreciate the reasons for and the effects of arcing

An arc is caused by the electric current continuing to flow through an ionised column between the contacts. In low voltage systems the arc is normally broken by moving the contacts far enough apart to interrupt the arc. Direct current systems are more of a problem as the current does not naturally stop at a zero point in the cycle as it does in alternating current circuits. For this reason you will often see a switch rated at say 0.5 A d.c but 10 A a.c.

A.C. circuits with a poor power factor also cause much more arcing than a circuit closer to unity power factor. The energy stored in the coil keeps the arc flowing.

Arcing at contacts causes pitting of the contact faces which reduces the actual area that comes into contact so causing a high resistance at the contact and a tendency to overheat. The contacts will eventually burn out.

What are the causes of electrical faults?

There are very few types of faults; these can be listed as follows. They are not in any particular order of importance or severity.

1. High resistance
2. Transient voltages
3. Insulation resistance
4. Excess current
5. Short-circuit
6. Open-circuit

Before we investigate this list in more detail, it is worth mentioning that you must know the basics of how electrical systems and equipment function if you are to make correct judgements about what is wrong. Consider an example.

A heater is being tested using an ohmmeter. You gain a reading of 50 Ω between the line and neutral conductors. Is this piece of equipment functioning properly?

To begin with, you have to start thinking about what it is that you should be expecting. A heater is going to be mainly a resistor although there will be an element of inductance because it will probably be coiled. A heater will need to have a resistance that allows a reasonable amount of current to flow so that it actually heats up. So let's look at a little bit of Ohm's law.

We will assume that the supply is 230 V, 50 Hz a.c. So:

$I = \frac{U}{R} = \frac{230}{50} = 4.6A$ Is this a lot of current flow? Let us think what power it will generate.

$$P = I^2 R = 4.6^2 \times 50 = 1058W \simeq 1.06KW$$

You can see that even with a rough measure we can get a sensible level of power. A 1 kW heater is not unreasonable.

The point to all of this is that you needed to have the technical knowledge to make a reasonable judgement.

Capacitance, inductance, circuit theory, maths, a.c. theory, three-phase theory, all have their part to play at relevant moments. Don't get into the habit of compartmentalising your knowledge. Apply your technical knowledge at the right moment and your faultfinding will have a sound base.

Let us now look in turn at the typical causes of the faults listed above. The causes are not exhaustive and you may have experienced some different ones yourself.

1. **High resistance**

- Long cable runs, this can lead to excessive volt-drop causing something not to work correctly.
- Cross-sectional area of cable too small, again this can lead to excessive volt-drop. Remember; $R \propto \frac{l}{a}$, this will help you determine what is reasonable.
- Poor or loose connections
- Corrosion causing by joining dissimilar metals which leads to electrolytic action taking place.
- Crushed cable caused by the laying of floorboards for example.
- Cores cut off conductors so that they fit into the terminal. This reduces the effective csa leading to an increase in resistance and temperature.

There are two equations which need to be at the back of your mind at all times;

i. $I = \frac{U}{R}$, what current is likely to flow from the resistance reading obtained

ii. $P = I^2R$, what power will be developed, will the joint etc get hot.

2. **Transient voltages**

These are caused by switching. When equipment that contains inductors and capacitors are regularly switched then a short-term voltage spike (transient voltage) is injected onto the system. This voltage can be very high and is more than capable of causing damage. There is no fault, but there is a problem. Transient voltages are a natural function of the switching of capacitive and inductive devices. The biggest culprits are lightning, large motors and electric arc welding sets.

This can cause damage to computer systems, injecting a signal onto data cables and it can also cause arcing at switch contacts with consequent overheating.

3. **Insulation failure**

There are a number of reasons why the insulation may fail:

- Wear and tear may cause cables to just outlive themselves. This is where looking at past schedule of test results is useful; you can observe a trend in the insulation resistance values.
- Environmental factors. Quite simply the wrong type of cables has been installed in a particular set of conditions. The cable may need additional protection for temperature or chemicals etc. As an example, pvc cables rot when they are in contact with oil-based products such as polystyrene.
- Drawing in new cables over existing ones in conduit. If they are pulled in too fast they can cause cable burns on the existing cables.

4. **Excess current**

This is usually down to poor design or dangerous DIY activities.

- Overload from a motor not running freely or being too small for its duty.
- Too many lights on a circuit. This is easily done when a new householder changes a pendant drop for a multi lamp fitting throughout his property.
- Shower too large for the circuit cable. This is very common nowadays as the rating of showers seem to be getting larger.
- Ring final circuit overloaded. This is very common in offices during a cold spell of weather.
- Fitting change for one of a higher rating. This is a typical DIY occurrence when say a 100 W outside light is replaced for a 500 W halogen sun-flood. With the advent of LED lamp technology, this problem will soon be a thing of the past.

5. **Short-circuit**

This is usually down to poor DIY activities, no self respecting electrician would ever make the following errors.

- Incorrect polarity at socket outlets
- When changing a lighting fitting, connecting all browns together and all blues together at a lighting point that has used the three-plate method. This is mainly the doing of DIY novices.
- Trapping cables when fixing; floorboards, trunking lid, conduit boxes, accessories to metal back boxes etc.
- Water getting into fittings that have an inappropriate IP rating for their location.
- Mice chewing through cables
- Lack of grommets used where cables could rub on metal due to vibration etc.

6. **Open-circuit**

This is usually because something has broken such as:

- Fuseable link in an electrical heater such as a night-storage heater. It is quite common for householder to cover the vents with clothes to dry them. This causes overheating.
- An overload has operated and not reset or has become damaged by its operation. Think about thermistors placed in motor windings for this very reason.
- Cables not connected properly.
- Poor maintenance.
- Start button in motor starters are very flimsy these days. They are prone to failing open circuit.
- Micro switches in zones valves sticking in the open position.

Exercise 3

1. You lose the supply to a section of the site. State three items that you might want to consider.

2. A cooker appears not to have a supply. How might you approach this problem?

3. Investigate the nature of a transient voltage – what is it and how is it created. What type of equipment can generate it?

4. A cable is run through the fabric of a small domestic installation. What types of fault could occur and what reasons might explain the fault.

5. A 10 mm^2 copper protective bonding conductor is 25 m in length. When carrying out a continuity test a reading of 2.5 ohms was measured. Is this acceptable, and if not, what will your actions be? What reading should you have been expecting?

4: Types of faults and their location

In this session the student will:

- Specify the types of faults and their likely locations in wiring systems, terminations and connections, equipment/accessories and the like, and instrumentation and metering.
- Be able to state what if any, special precautions should be taken in the pursuit of fault finding.

The types of faults possible in wiring systems is fairly broad and it would be impossible to list every type of fault, however, we can discuss the more common ones.

Wiring systems

General purpose PVC

- Insulation failure is common when insufficient precautions are not taken when installing this type of cable in hazardous environments.
- Cables being pinched or hit by nails when fastening down floorboards.
- Overheating when terminating in enclosed fittings.
- Potential short-circuits at lighting points when 3-plate method is used.
- Insulation failure from the effects of solar radiation.
- Fittings used externally do not have the correct IP rating

Conduit & trunking (metal)

- High resistance from joints not being tight.
- Short-circuit when cables are trapped or insufficient care has been taken when drawing them in.

MI, FP200, SWA etc.

There are a number of reasons why faults occur with these cables. It depends on the type of cable, but it usually comes down to people not installing things correctly:

- MI cable, if the gland is not sealed properly, water can get in and over time a fault is created. In addition the pot can rotate if it is not fitted properly and this can cause a twist to occur with consequent faults
- With swa cables, glands are sometimes made off with some of the strands not fixed properly, or worse, with some of them cut out! Any reduction in the armouring is a reduction in the overall size of the cpc and as such is dangerous.

Terminations and connections

Cable connections

Faults occur here for a number of reasons:

- Loose connections. These lead to an increase in heat and hence resistance. This in turn leads to more heat being generated until either a protective device operates, a cable open circuits or a fire starts
- Different metal connections. Aluminium and copper do not like each other chemically. When they are in direct contact they react with each other and there is a resistance increase at the point of connection.

Switches etc.

We are now dealing with accessories, and again the list can be endless:

- Switches are incorrectly chosen for the rating of the load leading to heat build up, shortened life and welding of contacts.
- Sockets are still connected incorrectly with links left out from the front plate to the rear of the box. Connections that are loose will lead to a build up of heat and a classic sign is a slight discolouration near the pins.
- Switchgear has similar problems to both sockets and switches, with loose and incorrect connections. Other problems include incorrect ratings for the connected load and short circuit ratings.
- Contactors can have the wrong coil fitted; poor overload settings, incorrect ratings, loose connections, low oil in dampers, wear on contacts etc.
- Electronic devices are usually very reliable, but when they are operated beyond their design parameters than problems occur. The two specific areas are with dimmer switches and certain RCD's, where testing using a 500 V d.c. insulation resistance tester may damage the internal components. Loose connections will also cause overheating and possible damage.

Luminaires

Problems that occur with light fittings include:

- Loose connections causing overheating
- Incorrect size of lamp causing overheating, which causes the wires to harden and become brittle
- Shades that are too heavy causing strain to be put on connections.
- Loose connections causing overheating
- wrong rating of flex for a specific set of conditions, i.e. heat resistant flex not used for connection to immersion heater
- Incorrect use of cord grips leaving the connection taking all the strain.

Instrumentation and metering

The choice of instruments and their associated control gear is very important. Instruments are used in installations to measure current, voltage, power factor and power. It is common for current and voltage transformers to be used for this. They have the benefit of allowing large currents and voltages to be measured whilst using small test instruments and limiting their effect on the circuit being measured:

- Calibration needs to be maintained as errors in readings can cause problems when certain processes automatically occur when certain values are reached;
- Correct procedures for maintenance, particularly when dealing with current transformers. If a current transformer is open-circuited then a very large voltage will appear on the secondary, with every possibility that this will lead to the destruction of the winding;
- Wrong instrument chosen for a task will lead to the possible destruction of the instrument, damage to the circuit being measured and danger to the person using the instrument.

Protective devices

Protective devices include fuses, circuit breakers, moulded case circuit breakers, overloads and RCDs:

- Fuses can be installed incorrectly, wrong fuse wire used, poor discrimination, poor breaking capacity and incorrect use. Low breaking capacity may lead to the fuse not merely blowing a thin piece of wire, but actually blowing apart and creating shrapnel when a fault occurs.
- Circuit-breakers can have the incorrect rating, the wrong type and a low breaking capacity. The low breaking capacity can lead to the circuit-breaker welding the contacts closed which will mean that it will not open under real fault conditions, although it will retain the appearance of being fine. The wrong type will lead either to unwanted tripping when inductive loads are turned (use of Type B instead of C or D) on or no operation under fault conditions if the fault current cannot be maintained high enough (use of Type C or D instead of Type B).
- Overloads can be incorrectly set, have the wrong breaking capacity or be of the wrong type for a specific installation location.
- RCDs do not operate on overload or short circuit conditions and as such are an earth leakage or imbalance device. They can have a low breaking capacity, poor discrimination and can operate when not wanted.

Special precautions

Previously we have considered types of faults and where we might find them. In this final part of the session of this outcome we are going to consider some of the particular situations where special precautions need to be taken. We are going to consider eight specific areas where additional precautions need to be considered.

1. Lone working
2. Hazardous areas
3. Fibre optic cabling
4. Electro-static discharge
5. Electronic equipment
6. IT equipment
7. High frequency or capacitive circuits
8. Storage batteries.

1. Lone working

For safety reasons working alone is not recommended, but for practical reasons in many cases it has to be done. If you are working alone you must inform someone of where you are going to be, what you are going to be doing and how long you expect to be there. If possible arrange for someone to contact you from time to time. As with all work areas a thorough risk assessment and appropriate safe systems of work must be carried out. This will serve several purposes, one to make sure you have everything you need before you start, and to make sure you have all PPE and safety devices you need but most importantly any potential risks to your safety have been considered before you start.

When you have finished don't forget to inform others, so you don't cause alarm if you are not where you said you would be!

2. Hazardous areas

Regulation 6 deals with the siting and selection of electrical equipment. Faults could occur because of incorrect wiring or equipment being used. When investigating a fault, in an area which would be considered hazardous, extreme care must be taken.

The faults that might occur are;

- Mechanical damage due to insufficient protection
- Breakdown due to high or low surrounding temperature
- Effects of the weather - cold causing brittle cables - sunlight breaking down the insulation

- Equipment with the wrong IP index being installed resulting in water getting into places it shouldn't be
- Dust and dirt clogging up equipment
- Corrosion causing faults on connections etc
- Vibration causing loose connections
- Vapour and gases penetrating equipment
- Damage due to animals eating the cables or the acid from their bodily fluids.

Don't forget that even dust can cause explosions; be careful when using test instruments!

3. Fibre-optic cabling

Fibre optics is the carrying of information over long distances in thin fibres of very pure glass. The first optical fibre telephone link was working in Britain in 1977. Optical fibre cables are lighter, smaller and easier to handle than normal copper cables.
The problems associated with fibre optic cables are:

- End radius. When the fibre optic cable is bent too tightly the light does not get reflected internally and loss of signal occurs.
- Joints. There needs to be a perfect end connection to link lengths of fibre optic cable together. This requires special equipment and training.
- Looking down the end of a fibre optic cable when the light is on is not wise as far as eyes are concerned.

There are some new applications of fibre optic cables for lighting purposes. These have a different light source and are not used for carrying signals. The light coming from a ***light box*** some distance away.

4. Electro-static discharge

Static is caused for a variety of reasons. When you walk across a nylon carpet and then touch something metal you may well find that you receive an electric shock. This electric shock has been caused by the charge that you have built up, suddenly discharging through you when you touch something that conducts. This shock can have quite a high voltage, and can be dangerous to certain electronic circuits, particularly circuits containing chips.

Before you work on any circuitry which you feel may be susceptible to damage by the effects of static, you should always discharge yourself to some earthed metalwork or wear a discharge band on your wrist to make sure that you are at a low potential relative to the circuitry.

Capacitance however appears in many areas, without a capacitor being present. As long as there are two conductors separated by an insulator, then there will be a capacitive effect. The effects of this are minor though.

MICC cables after they have been tested often retain sufficient charge to give a shock. Cables that run parallel for long distances, such as transmission lines, gain a certain level of capacitance. There is even a capacitive effect between the windings of coils, although it is very small and is swamped by the size of the inductor, it is still there.
If you are asked to work in areas such as petrol stations, chemical works, or flour mills where the risk of explosions caused by sparks from static electricity is great you will need special training and possibly specialist equipment.

5. Electronic equipment

Damage to electronic components can occur either because of incorrect use of test instruments or static electricity.

As stated previously, static electricity is eliminated by strapping the body to the chassis of the equipment and tying that to earth.

The use of an insulation resistance tester on certain components is guaranteed to cause problems. Most electronic components have been designed to operate at extra low voltage, whilst an insulation resistance tester commonly injects 500 V into a circuit.

Correct preparation for hands-on work to ensure that there is no static and no use of insulation resistance testers is vital.

6. IT equipment

The shutdown of IT equipment can lead to many people turning prematurely bald! This usually occurs when vast amounts of data have just been wiped because it hasn't been saved. It is never acceptable to just switch off a supply and start working on the supplies to a computer system when no back-up has occurred. Many businesses only operate because there are computers and as such it is important to liaise with the client to ensure that shutdown only occurs at acceptable times. This will usually be just after a major back up of all their systems.

7. High frequency or capacitive circuits

Variations in frequency can cause major problems to items of equipment, and the use of systems that create high frequencies can lead to damage. High frequency supplies can also cause burns.

In addition, certain items of office equipment, such as power supplies, can have very large capacitors present. These capacitors can contain enough energy to cause real risk to those working on it. It is necessary to discharge any capacitors before work is carried out on a power supply.

In most areas of an installation where you might reasonably expect to see capacitors, such as with power factor correction capacitors, you will find that they have a resistor connected across them to ensure that they discharge over a short period of time.

Do not take risks!

8. Storage batteries

Rooms containing storage batteries are becoming less than in previous years but in case you do come across one, we will mention some safety precautions.

- Room must be well ventilated.
- No naked lights or smoking.
- Make sure of the correct terminal connections.
- Observe the warning signs/notices that will be displayed.
- Correct polarity must be observed if you have needed to disconnect any batteries.
- Terminals and connections must be lubricated using petroleum jelly (Vaseline).
- Use insulated tools and be very careful not to drop any on top of the battery terminals.

When batteries are being charged then hydrogen is given off. If you make a mistake then an explosion can occur. You will find those rooms that are used for the charging of lead-acid batteries have a reasonable ventilation system.

Exercise 4

1. A socket-outlet is showing signs of discolouration: state two possible reasons why this is happening.

2. A 16 A Type B BS EN 60898 circuit-breaker trips when a bank of discharge lights are switched on. State the probable reason for this.

3. A 5 A switch is used to control a 5 A load of fluorescent fittings. Is there any problem with this? Why?

4. When a short-circuit occurs two protective devices operate. Why is this?

5. State three faults that could cause a 12 V SELV spotlight to fail

5: Safe working procedures prior to fault diagnosis

By the end of this session the student will:

- Describe how a system is to be prepared for safe working.
- Be able to state how to identify test voltages.
- Be able to list what test instruments are used

The basic principle that we must consider is that you should have a clear understanding of what you are doing. The EWR (Electricity at Work Regulations 1989) requires that we are *competent*. Competence requires that we can apply both technical knowledge and experience. Competence also implies that you are aware of what you don't know!

SAQ 1
Define the term 'competent' as described in BS 7671

Remember the following two points before isolating:

- The person who is working must be ***competent*** to do the task. ***Ignorance is no excuse*** as far as the law is concerned. If you are in any doubt then don't do it
- The task must have been planned in such a way that no live working takes place. The risks to injury must be limited. This is where method statements are useful. If you can think about how you are going to tackle a job before you start, then you will not only have considered what tools and access equipment you will need, but also what PPE may be required.

Fault finding is unique in as much as you are intending to prove a supply exists to a piece of plant, accessory etc. This means that working live is necessary and the risk of electric shock is present. It is for this reason that tools used are fit for purpose. This includes not only test equipment conforming to GS 38 but also screwdrivers and such are suitably insulated for the voltages present. Consider also the use of an insulated mat to stand on, fibreglass stepladders ect.

It must be borne in mind that the risk of electric shock is not limited to you the electrician, but also anyone else in the vicinity. This could be the householder, colleagues at work, ordinary persons at their workplace or even the general public. The risk is that machinery or power circuits could suddenly start or stop without due warning being given.

When checking for the presence of a supply voltages consider the instrument you are using.

- **Voltmeter** Check that the leads are in good condition and are suitably insulated for the voltages present.
  Not all instruments have an auto range facility so start on a high range and work downwards.
  Make sure the instrument is set for the type of supply, i.e. a.c. or d.c.
  If the voltmeter is analogue, make sure you understand how to read the scale.
- **Proprietary test lamps** The leads on these instruments are generally more robust than for multi-meters, but check condition anyway.
  The advantage of these is that they are always ready for the size and type of voltage you are likely to come across. Don't forget to use the proving unit.

Test instrument for fault diagnosis work

There are a wide range of test instruments available today and each one has a particular function when used for fault diagnosis.

Test instruments

1. Voltage indicator.
2. Low resistance ohm meter.
3. Insulation resistance testers.
4. EFLI and PFC tester.
5. RCD tester.
6. Tong tester/clamp on ammeter.
7. Phase sequence tester.

1. Voltage indicator — Used for establishing and checking for a supply.
   Some voltage indicators also have a buzzer which allows them to be used for:
   - identifying cores in a multi-cored cable
   - continuity testing where the ohmic value of the cable cores is not important.
   - Checking the action of switches (intermediate) etc.

Do not use a multi-meter as a voltage indicator, they do not conform to GS 38.

2. Low resistance ohm meter.
3. Insulation resistance tester.

This instrument is used where knowing what the ohmic value of a cable is important. This might include;

- checking that the value of bonding conductors has a low resistance.
- verifying that the closed loop resistance in a ring final circuit is low.
- checking the resistance of a coils, solenoids etc.
- checking the insulation of cables such MI.

Remember, these instruments also have a kΩ scale. It is a good policy to start off with the lowest scale and work upwards. The majority of faults can be found using the Ω scale. This prevents the potential for damage to sensitive electronic equipment when fault finding.

4. EFLI and PFC tester

This instrument is selected when there might be a problem with disconnection times and the earth fault loop needs checking.
If the potential fault currents needed checking at a particular location to verify that the installed equipment was suitable then this would be the instrument to use.

5. RCD tester.

If there is problem with nuisance tripping of RCDs and RCBOs, then this instrument will be able to verify the correct operation of the devices.
The best setting to use would be the ramp function as this would show at what point the protective device operates.
Check for the presence of further RDCs upstream of the one being fitted. Unless they are of the time delay type, it will always be a race to see which one will trip first.

6. Tong tester/clamp on ammeter.

There are times during fault finding where you need to know the value of current flowing, but for operational reasons cannot shut the plant down. This instrument is ideal for those times. The one shown to the right is for heavy duty which is reflected in the level of construction.
Bear in mind that using this instrument involves live working, therefore, extreme caution must be taken.

Whilst working at Rothmans in Darlington for Haden Young, the foreman was concerned that the bus-bar chamber feeding the compressor house was a bit too hot to touch, and therefore reasoned that something must be wrong. His instruction was to remove the bus-bar cover and measure the current on each line and the neutral. This was scary as the cover was big and heavy and made of metal! After safely removing the cover, the line currents were measured using a tong tester and a value of about 100 A was found on each line. This tallied with the specification for the humongous compressors. There was no problem; a conductor operating temperature of 70°C is warm and must not be confused with thinking there is a fault!

7. Phase sequence tester.

These testers come in many styles, shapes and sizes. But they all do one job, they show the order of the phases in a three-phase system
This is particularly useful for making sure that three-phase connected loads will function or rotate or designed.
Before using test instruments such as the one on the lower right, check that the leads comply with GS38.

Before using any of the above test instruments it is imperative that they are in good condition and fit for purpose. A visual check will ensure they are ready for use but what about being fit for purpose? A cost effective solution would be to use a check box such as the one on the right. It is easy to create log sheets for the instruments you use to monitor or trend their accuracy.

Exercise 5

1. What instrument would you use to identify the conductors in a 7 core MI cable?

2. You have been informed that a water heater circuit is faulty. What tests would you perform to determine what the fault is?

3. A single-phase motor fails to rotate and hums when it is turned on. Give two possible causes of the problem.

4. A 3 kW water heater is fed from a 230 V supply. What resistance would you expect when testing the element?

5. A 32 A, 30 mA RCBO protects a ring circuit in an office. The RCBO is in the habit of operating when not wanted. Give one possible cause of this problem.

6. A large transformer is protected by a 50 A Type C circuit-breaker: occasionally the circuit-breaker operates when not wanted. Can you suggest any possible cause?

Challenging question

7. You have been asked to check the earth-fault loop impedance of a circuit which is protected by a 30 A BS 3036 protective device. The reading shown on the ELI test instrument is 6 Ω. Upon further investigation you discover an earth connection has a resistance of 4 Ω.

   Assume the earthing system is TN-S and the supply voltage is 230 V, 50 Hz.

   a) What is the maximum permitted earth-fault loop impedance value to comply with BS 7671?
   b) What is the value of fault current that would flow under fault conditions?
   c) What hazards would exist if you did not rectify this situation?

6: Fault diagnosis procedures and associated paperwork

By the end of this session the student will:

- State what documentation is used when fault finding.
- State the implications fault finding has on clients/customers.
- State the procedures for carrying out fault diagnosis.

Documentation

The documentation that is useful when fault finding could be any or all of the following:

- manuals or manufacturers data sheets
- wiring diagrams
- previous test sheets
- installation specification along with any relevant as-fitted drawings

I have always maintained that if you know how something should work then you can fault find. It is not difficult to draw yourself a simple circuit diagram of say a lighting circuit that contains a mixture of two-way and intermediate switches, or an S-plan heating system. If you can verify the continuity of each cable or lack thereof when testing, then the fault will usually present itself if there is one. The key is to look carefully at any drawings or data sheets and apply some logical thinking.

If the fault is serious and requires a new part or an addition/alteration to an existing circuit, then you will need to complete a Minor Electrical Installation Works Certificate and give this to the client upon completion of the work. It may also be that the circuit/system may need to be left safely isolated until repairs can be completed.

Implications of fault diagnosis work

An electrical fault is an unplanned event. This can affect a business premises or domestic installations in different ways.

Businesses

1. A business, particularly the larger ones may employ their own maintenance electricians. This is an advantage as the electrician will be familiar with the plant and the fault may be repaired quickly.
2. With plant not running, a fault can turn into a costly event.
3. Lost business sales with production out of commission.
4. Lost business opportunities where services are not being provided as in smaller outlets such as shops, hairdressing salons, garages etc.
5. Valuable data could have been lost because of abrupt power failure.
6. Increase downtime whilst waiting for items to effects repairs.
7. If electricians need to be out-sourced, then on-site training and familiarisation needs to be undertaken.
8. If the fault is in a large supermarket, the safety of the general public must be considered.
9. If the fault is in a hospital, temporary supplies may need to be organised.

Domestic

1. Will definitely need to call in an expert (unless the owner has done the 2357 course!). This can take a period of time and then there is the uncertainty of the capability of the electrician.
2. If a business is run from home, there could be a prolonged period of down time with a potential of lack of earnings.
3. If the fault is on a stair lift, there is a distinct problem for those with mobility difficulties. It would be wise for the householder to belong to a scheme offering support in times of electrical failure.

There could be instances where the fault is on the district network operator’s cables and if this is the case, you have no control over the time taken for repairs to be carried out. If your clients premises has circuits that must be kept live, then you need to discuss with them some form of alternative supply options.

Procedures for carrying out fault diagnosis tests

Continuity

This is test is described by BS 7671 as being a dead test. Therefore, the supply must be switched off before connecting the test instrument to any conductor which would be expected to be live under normal operating conditions. Due notice should be given to those who would be affected by the isolation of the circuit. Careful planning would guarantee that disruption is kept to a minimum.

This instrument is used for checking all continuity problems include earthing and bonding related issues. Do not remove any earthing or bonding conductors for testing, unless the whole installation is switched off.

SAQ 2

What is the function of an earthing conductor?

SAQ 3

What is the function of a bonding conductor?

Insulation Resistance

This is also classified as being a 'dead test', therefore the same safety measure apply here as well as for the continuity test.

Going into an unfamiliar building to fault find using an insulation resistance tester, means that the electrician will have to be extra vigilant on looking out for sensitive electronic equipment that might be connected into a potential faulty circuit. The first step should be to discuss with the owner what it is you intend to do and what the dangers are in using a 500 V d.c. tester.

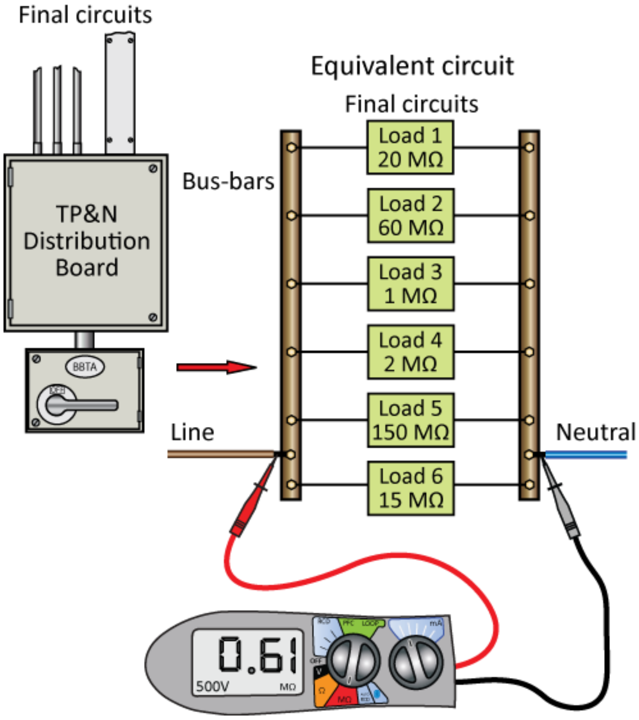
On a new installation, this test would reveal any departures from the Regulations and rectification would have been carried out before the installation was put into service and handed over to the client. For existing installations that have been in service for a number of years, periodic testing using an IR test instrument could reveal dangerous conditions that have built up over time. Such conditions could be contact with a live conductor with a metal support bracket or the metal frame of a partition that was erected post testing of the installation.

To increase the chances of finding such faults/hazards, Regulation 612.3.1 states that for IR testing between live conductors and protective conductors, the protective conductors **must** be connected to the earthing arrangement of the installation. In other words, do not remove the protective conductors from the MET.

For new installations the results are compared with Table 61 of BS 7671. For tests on existing installations, the results should be compared with any available records to identify if there has been any deterioration.

If a grouped test of circuits is carried out at a distribution board, the readings may be lower than expected. Remember, the IR test of circuits is the same as adding resistors in parallel.

Consider the diagram below.



When IR testing as a group or sometimes called a global test, the overall IR reading can be lower than the minimum value stated in Table 61.

$$\frac{1}{R_T}=\frac{1}{R_1}+\frac{1}{R_2}+\frac{1}{R_3}+\frac{1}{R_4}+\frac{1}{R_5}+\frac{1}{R_6}$$

$$\frac{1}{R_T}=\frac{1}{20}+\frac{1}{60}+\frac{1}{1}+\frac{1}{2}+\frac{1}{150}+\frac{1}{15}$$

$$\frac{1}{R_T}=1.64$$

$$R_T=\frac{1}{1.64}=0.61M\Omega$$

This result falls foul of Table 61. On closer inspection it is found that a couple circuits have low values of IR, but do meet the minimum vales.

SAQ 4

What would be the effect if load 3 was protected by an RCBO, and the IR test gave the same reading when tested between live conductors and its protective conductors?

Polarity

This is a 'dead test' and is carried out using a low resistance ohmmeter. Correct polarity can be confirmed during the continuity test of the circuit and protective conductors. Depending upon the cross-sectional area of the circuit conductors, the resistance readings will be very low, in the order of 0.01Ω to 0.5Ω (R1 +R2). Values in excess of this may indicate a high resistance connection and further investigation is recommended.

Earth fault loop impedance

This is a live test and safety measures must be put in place before you start. Notify everybody that might be affected by this test. Check to see what protective device is installed as this will be needed during the compliance stage. If an RCBO is used, make sure your test instrument has a no-trip setting.

The protective measure commonly used in the majority of installations to protect against electric shock is basic protection and automatic disconnection of supply.

Insulation resistance testing verifies the condition of basic protection. Performing earth fault loop impedance testing verifies the integrity of the measure; fault protection.

Overcurrent protective devices must, under earth-fault conditions disconnect fast enough to reduce the risk of electric shock. Using a loop-tester such as the Megger LT 320 will check the condition of the earthing system, the reading obtained is checked against the tabulated values given in BS 7671. The On-Site Guide would be the preferred source as the 80% rule has been applied.

This test is very important for the older installation, as it is likely that some deterioration of the earthing system will have taken place. If the measured value does not compare with the tabulated values then some remedial action is needed. The test is carried out at the farthest point of the circuit. If the reading does not comply with BS 7671 then it is unlikely the protective device will disconnect within the correct time.

RCD/RCBO Operation

One of the problems with these devices is nuisance tripping. It could be that one of the installed circuits has a low IR to earth reading such as 1 MΩ which would give a leakage current of 23 mA. This should normally not be enough to cause a typical 30 mA residual device to operate. However, it could be that a device having an incorrect residual current rating has been installed, and you as the electrician called in to fault find needs to verify this.

One method of determining the operational state of the installed RCD/RCBO, is to use an instrument such as the Megger RCDT320 and set for the ramp function. This will show the point at which the device operates.

Current and voltage measurement

This is a live test and safety precautions must be undertaken before commencing.

One of the most common types of faults is electrical equipment not working properly, because of excessive volt-drop which is the result of high resistance in the circuit cables.

Measuring the voltage at the point of utilization with a propriety voltage tester such as the Fluke T5-1000, would show if there was an issue with volt-drop. This tester can also measure current without breaking the circuit by use of its open jaw, it can act as a continuity tester due to its inbuilt beeper and can measure resistance up to 1 kΩ.

No wonder it's priced at £123.50 (Farnell)!

Any measurements of voltage can be compared against Table 4Ab in Appendix 4 of BS 7671.

> *Whilst working for an electrical contractor at Cattrick Garrison, I was asked to go to REME (Royal Electrical & Mechanical Engineers), to investigate why a 12 V fire alarm bell was not sounding as loud as it should be. The site was enormous and checking throughout the cables length, it eventually dawned on me it could be a problem with volt-drop. The test instruments in those days were not as sophisticated as they are today, and not all electricians had one in their tool box, I was no exception. After borrowing a voltmeter from REME I discovered that there was indeed a large volt-drop. If the supply is 230 V, you can afford to lose a few volts, however, on a 12 V system, every volt is precious.*

Phase sequence

One of the easiest faults to find is that of a three-phase motor turning in the wrong direction. The remedy is to interchange any two lines.

The phase sequence is always tested on a new installation, but for older installations where there may have been a change of energy meter or supply transformer, it is no guarantee that what was right before remains correct. The instruments available are similar to that shown which is a Fluke 9040 and costs about £160 (Amazon). Some multifunction testers have a phase sequence facility built in.

Where the tests discussed above results in readings that do not comply with BS 7671, the remedial action would likely involve installing a new circuit cable, a new fuseboard giving better overcurrent protection etc. In most case this will involve completing a certificate for the client, either the minor one or the full electrical installation certificate. The documentation for an installation must always be kept up-to-date and stored in a secure location.

Exercise 6

1. Name four sources of information that can be used when fault-finding.

A. Previous test reports.
Manufactures data
Wiring diagrams
"As fitted" Installation drawings.
Equipment specifications

For the following four situations state what evidence you would gather and how you would gather it. Once you have shown how you would gather the evidence, explain what you believe the problem to be and suggest a solution.

2. A single-phase capacitor start induction motor is running normally. It is turned off for a short period of time and when it is turned back on it fails to run, although it is humming.

3. You are carrying out an insulation resistance test on an installation from a mains distribution board. You find that there appears to be three faults. One fault seems to be a short-circuit (line to neutral); the second appears to be a short-circuit (line to Earth); the third appears to be a short-circuit (neutral to Earth).

4. A three-phase motor turns on, but seems to be 'sluggish' and does not make the right sound. After a period of time the overloads in the starter operate.

5. You have recently installed banks of high pressure sodium luminaires in a bus garage. They are controlled by a small number of contactors and protected by 16 A Type B circuit-breakers. The circuit-breakers keep tripping for no apparent reason.

7: Factors which affect repair or replacement

By the end of this session the student will:

- Understand the issues determining repair or replacement during fault diagnosis.
- Explain why relevant people need to be kept involved during fault correction work.

In the previous session we considered the symptoms of particular faults. With any faulty equipment a key question will be, 'should I replace or repair the equipment'? This is important and there are a number of thoughts that should pass through your mind. It is these that we will consider in this session.

SAQ 6

Just spend a couple of minutes and try and identify what factors will affect your decision to repair or replace an item of equipment.

Access

Before we consider whether equipment should be replaced or repaired, or even before we begin fault finding itself, we must be aware that the work we do for a customer and the wishes of the customer are key. For example, imagine that you are called to an office with lots of computers etc. You cannot simply start turning circuits off without recognising the customers' own business depends on the work being maintained. Data must be saved and people must be kept busy.

SAQ 7

What choices are open to you when wanting to access a busy office to find a fault or carry out some repairs?

An electrician was called to a generator fault in a large clothing retailer in Glasgow. He turned the supply off without informing anyone and the computer controlling the whole of the point of sale system was turned off. No sales could be made, records of all sales made that day was also lost.
If the system also formed part of the stock control records, the damage would be even greater.
The electrician was marched off the premises.

Repair or replace?

There comes a point when looking at a piece of equipment that you need to be absolutely convinced that it is worth repairing. In the same way when a fault appears on an installation the problems may be so complicated that the only recommendation is for a rewire.

There are a number of factors that we need to consider when coming to any judgement about these issues. These are:

- Cost of replacement – not only how much will it cost, but also how much will the cost of labour be. Assuming that the replacement might not be immediately essential, what will be the cost of doing nothing?
- Availability of replacement – how quickly can the item be found? Is it an off-the-shelf item or will a special order need to be made?
- Downtime during the fault and repair – how much production is lost? If the production cost is too great, how can the repair be time-managed?
- Availability of staff and resources – is the labour in place to safely and efficiently repair the fault?
- Legal responsibility – this includes warranties and the requirements of licensing authorities and H&S legislation.
- Is the replacement item compatible with existing equipment?
- Will the replacement fit in the available space?

Installation

When you are called to an installation it is usual to go for a repair. A number of the factors listed above do apply however.

The cost of replacing an installation varies depending on the size, but a full rewire can run into thousands of pounds.

The issue of downtime is important within a production or commercial environment. It may be that downtime leads to the destruction of products, and on farms this can include animal deaths where chickens require fans running to maintain cool enough temperatures.
In those circumstances it is often quicker and easier to simply replace damaged items rather than spending too much time on finding the actual fault directly.

Staff availability for the repair is also relevant. Not every electrician is comfortable in every situation when fault finding. In addition the employer has to manage his staff. People cannot be stood around just waiting for something to happen, unless of course someone is willing to pay for that time.

In many industrial and commercial environments access can only be gained at certain times. This may be due to health and safety reasons or just because of the processes and work patterns involved. When access times vary then the electrician has to fit around the client.

Access to parts of the installation will be affected by how much can be turned off and this depends on the nature of the organisation of the switchgear. It is normal to be able to isolate sections. However, you do need to be aware that simply disconnecting circuits may not be wise. Remember that disconnection of protective conductors when other circuits are still live can lead to dangerous potentials appearing across the protective conductor should a separate earth fault occur elsewhere on the installation.

Certain aspects of an installation may require that an emergency or standby supply comes into operation. This must be taken into account when isolating is taking place, and where it can reasonably be expected that this will lead to the standby supplies activating.

Consider also the possibility of multiple supplies being connected to the system, e.g. PV, wind turbines, hydro etc.

The final aspect that must always be considered is the legal responsibilities. The Electricity at Work Regulations place responsibilities on a number of people, including the electrician. When a fault occurs and nothing is done about it by the client, then he is responsible in law for himself, his workers and anyone who might visit the site or place of operation.

If a client calls an electrician out to a fault and then refuses access to those areas necessary to the finding and repairing of the fault, then the client is responsible in law for the fault and any problems that arise from it.

If a client calls out an electrician and lets him get on with the job of finding and repairing the fault then all the responsibility falls on the electrician. The electrician automatically becomes the '***responsible person***' (***duty holder***). This means he is responsible for those parts of the installation that are under his control, and not only for those areas of the installation that he is working on but also those parts that he affects by his working.

Very careful judgements need to be made when looking at any fault in an installation.

Equipment

The judgements to be made with a piece of equipment are similar but with some necessary complications.

The cost of replacement becomes a major factor when thinking about repairing an item of equipment. Manufacturing processes today mean that it is often more cost efficient to replace an item of equipment than repair it. You are charged out at a set rate by your employer, that rate can reasonably be in the region of £20-45/hour. The question of whether to repair a £20 piece of equipment with something new or repair it is quite an easy one to answer. In the same way many smaller motors are cheaper to replace than repair, even though they are quite expensive. The cost of rewinding motors makes the decision debatable.

The availability of replacement with a like for like item is also problematical when the equipment is a number of years old. You may end up having to repair because that equipment is absolutely necessary and so replacement is not an option. Alternatively a replacement for something more modern might be considered.

An item of equipment might be easy to repair whilst it is in situ, however, the loss of production may more than outweigh the cost of replacement, and so replacement becomes the only option. In fact in most maintenance departments they will have certain items of equipment duplicated just so they can replace with a minimum of downtime. The same legal responsibilities apply for items of equipment as for whole installations. For this reason PAT testing of portable appliances has become prevalent.

Relevant people involved in fault diagnosis

There are several people who will be involved in fault diagnosis.

- The person reporting the fault.
- The person who organises the fault to be investigated.
    - Anyone tasked with researching documentation such as maintenance records.
    - Anyone tasked with safety issues that might be present on site.
- The person who needs to organise the work schedules whilst the investigation takes place.
    - Backing up data
    - Stand-by supplies
    - Safe guarding other workers and the public
    - Changing work rotas
- The person assigned to fault find
- The people who will decide whether to repair or replace the faulty equipment or circuit
- The person/s who will carry out the redial work
- The person/s who deal with any paperwork or hand over procedures

This could be just two persons depending on or where the fault is; the client and the electrician.

Fault finding can be a relative lengthy process depending upon the complexity of the fault.
It may be that the information given of the fault is scant, and you might have to do some functional testing yourself to identify which tests you need to carry out to locate the fault.
In any event it is important that you discuss at each stage of the process with the client. If you are doing live testing, safety measures need to be implemented. It is necessary to keep your colleagues informed which circuits are going to be worked on and when you are going to make things live.

When I was an electrical instructor at Billingham Skillcentre, one of my electrical trainees was asked by the bricklaying instructor to investigate why his electric cement mixer was not working. He found the fuseboard withdrew the BS 3036 fuses and put them on top of the board. On the same day at roughly the same time, the plastering instructor, who also used the same cement mixer for his floor screed, asked a different electrical trainee why the mixer wasn't working. The second trainee saw the fuses lying on top of the board and pushed them back into their holders. The first trainee received an electric shock and was very lucky it wasn't fatal. If better communication had taken place amongst colleagues, especially me, this dangerous incident would not have happened. Remedial lessons on safe isolation followed!

The first person to meet and have a discussion with upon arriving at the premises is the workforce manager. That person will have the authority to grant you access or suggest when you can undertake your fault finding, and if the business wanted a repair or a replacement.

Exercise 7

1. A large commercial office contains approximately fifty (50) personal computers, five laser printers and two inkjet printers. The supplies for the computers are fed from eight circuits with the printers all fed from the same circuit. All circuit are protected by 32 A 30 mA RCBOs. The client has called you to complain that at certain times the RCBOs trip for no apparent reason.
   a) What factors will affect how you approach this problem?
   b) What is the likely problem?
   c) Suggest possible solutions to the client.
   d) How might your chosen solution be put into effect with the minimum of disruption?

2. The motor on a conveyor system is running hot.
   a) What are the possible causes of a motor overheating?
   b) How would the problem be investigated with the minimum disruption?
   c) How would you solve the problem?

8: Restoring the building after fault correction

By the end of this session the student will:

- Understand how to restore the building fabric
- Understand how waste materials should be disposed of.

This final session considers the after effects of fault diagnosis and correction.

When the quote has been made for diagnosing a fault, an agreement should have been made with the client as to who will carry out the repairs and the extent of any restoration of the property.

Typical reasons where repair becomes necessary:

- Nail or screw in a cable that is in a wall and not enclosed in earthed metal conduit.
- Cable running under the floorboards that has been burnt accidently by a plumber repairing copper pipes.
- Replacing a cable passing through walls.
- Damage to fire barriers

Building Regulations

Meeting the requirements of the Building Regulations is the responsibility of the person carrying out the building work and, if they are not the same person, the owner of the building

Any repairs to the building fabric must conform to the Building Regulations. Guidance on achieving this is provided by the 14 Approved Documents.

Consideration must be given to maintaining or improving the same building integrity that previously existed.

Listed below are some of the Approved Documents you need to bear in mind.

- Document A deals with structural safety
- Document B deals with fire safety (domestic)
- Document C deals with resistance to moisture and contaminates
- Document E deals with sound
- Document F deals with ventilation
- Document M deals with Access and use of buildings
- Document P deals with electrical safety
- Document 7 deals with workmanship and materials

It is not the aim of this unit to discuss all 14 Approved Documents, but to draw your attention to the fact that they do exist, and when carrying out repairs or restoration, the requirements must be met.

Making good

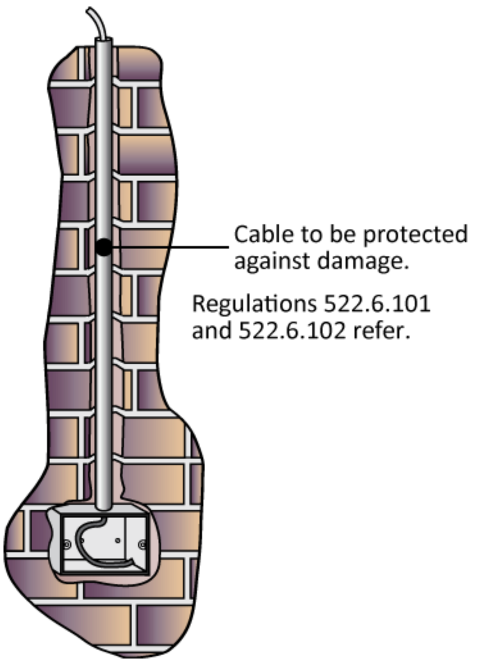
For a variety of walls, there will be a variety of skills required to make them good. It isn't your job to build the wall, but you should be aware of what you can do.

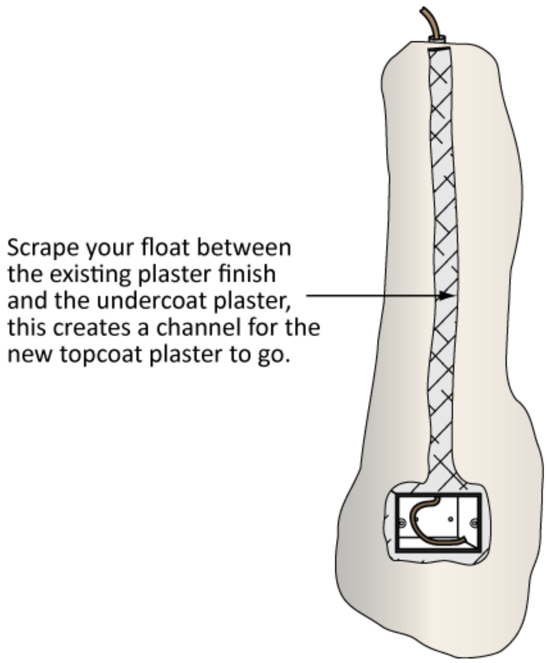
Chases

When a wall is chopped out to make room for a cable, there are a number of factors that you need to take into account.

- make sure that you have placed a dustsheet down where necessary
- always wear appropriate safety equipment such as goggles, facemask and good shoes
- only chop out what you need to cover the cable and whatever is protecting the cable, such as channel (casing), conduit, or oval tubing
- make the cuts clean. Don't wander all over the place.

When you come to make good, consider what the original wall is covered with. If the wall is cement rendered then you should mix something similar and vice-versa for plastered walls.





When plastering walls:

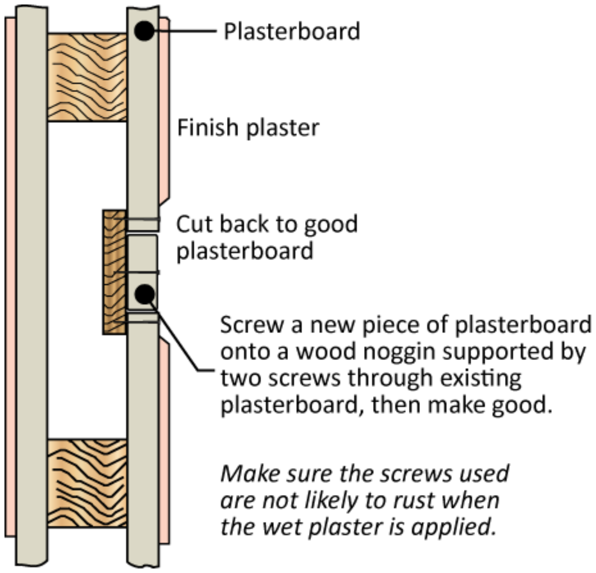
- wet the chase that you are going to plaster. This allows the new plaster to combine with the old
- mix some filling plaster. Most often this will be browning, although some walls require a type of plaster called bonding plaster, which holds things together better
- this mixture should be pushed into the entire chase and should be left 1 mm-2 mm lower than the surface. This makes room for the skimming plaster.
- mix the skimming plaster when the filler has 'gone off'. You shouldn't leave plaster standing around, as it will harden. Skim up to the old surface and try not to go proud, you may end up having to sand it down.

A common problem is where the chase in the wall is not deep enough. In such circumstances the cable and/or channelling sits proud of the surface. Don't think that you can cover over your mistake by forming a neat little hump. It will be noticed!
If you have disturbed any fire barriers between rooms or floors, this must be replaced to the current approved standards

Hollow walls

When a wall is made up of plasterboard, there may well be occasions when you have to repair the wall. Obviously, it is no good merely filling up the hole with plaster. You will have to think through what you are doing much more carefully.

Some try to stick in screwed up newspaper and then filling with plaster; certainly not the best of choices.



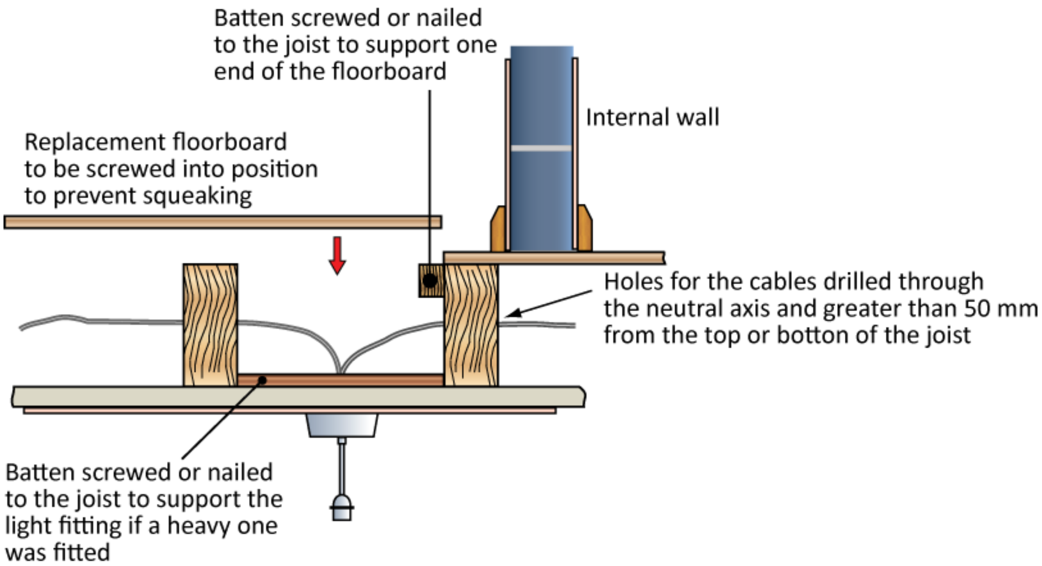
A better option may be to use some of the plasterboard that has been cut out, to fill the hole and then to plaster up to that. Other options could be to use blank plates to cover over where electrical equipment once was situated.

Floors

As with walls there is an almost infinite variety of flooring materials. The most common that an installation electrician will come across is the floorboard or chipboards and joist type.

You have to practice taking up floors; there is no substitute for doing it yourself, although again there are some things that you should consider.

- Before lifting a floorboard, remove the tongues by cutting along the edges. The same applies for chipboard.
- If you are using a circular saw (dangerous), make sure that you have set the blade just a little thinner than the floor, otherwise you may end up cutting into a cable or pipe.
- Never take up more than you need. Always think before doing any job and plan ahead.
- Remove any nails that are sticking out. Remember that you have a duty of care under the Health and Safety at Work Act.
- When you are replacing boards, clean up the edges. Don't force a board to fit. If it needs trimming do it carefully.
- Make sure that cables are not trapped and that there will be no chance of future accidents.
- Try to screw the boards down rather than nail them. This allows for later removal, and tells the person following you where cables lay.



If the new light fitting is recessed, make sure it has a hood if its location demands one.

Decorating

When beginning any work in an area where care has to be taken of the decorations you need to make the client aware of the probable and possible damage that may occur as a natural part of wiring an electrical installation. This will include:

- Damage to paintwork
- Damage to wallpaper
- Damage to plasterwork and coving
- Damage to wood and brickwork.

Not all damage can be avoided. The effect of a rewire can be minimised but it cannot have zero-impact. This requires the electrician to take reasonable care.
Where the wallpaper is to be kept then a cut through the paper and some water will help to ease the paper until it can be stuck down again later.

Where plaster has to be chopped out due to chases, straight edges should be used and restoration of the plasterwork should be done carefully. It is often better to get a plasterer in to do the work. Plaster coving should be avoided and special care should be taken where drops occur.

Fair-faced brickwork should be avoided as much as possible. However, if damage has occurred then simply filling up the hole with cement is not going to satisfy. If you can, it is worthwhile chopping out the whole of the brick and replacing it with a new one.

Damage to any woodwork should be repaired using new wood, rather than using filler, unless the damage is very superficial.

Try to leave things as they were. Whether you have been plastering, lifting boards or clearing up, try to do a good job. In the end the cutting of corners may well lead to a bad name, losing you work, or more importantly putting other people in danger.

Clearing up

A good worker always clears up after themselves. It leaves a good impression if you leave a site clean and tidy. This can make a difference if you want more work. peple remember these things.

There are wide varieties of waste materials. The normal run of the mill building material should ***not*** be swept under a floorboard, but be cleared up and taken off the site. If there is a skip available then that is ideal.

Most waste recycling sites now have facilities for recycling wood and construction materials such as rubble.

There are certain materials that should be treated with much more care however.

Fluorescent tubes contain a small amount of mercury. If these tubes are smashed where people can breathe in the fumes, then there is a real risk to health. Mercury is extremely poisonous and can send people, after a period of contact, mad!

Other types of fitting that are dangerous are the high- and low-pressure sodium fittings. These contain small amounts of sodium. Sodium reacts violently with the moisture in the air and can lead to burns and explosions. There are disposal points for these at most large recycling points.

Any asbestos found needs to be reported and placed in special bags then taken to special disposal points.

The introduction of the new waste disposal legislation (WEEE), makes the Environment Agency responsible for policing waste disposal. This has been adequately covered earlier in the course.

Last checks

The fault has been found and corrected and any repairs to the building fabric have been made. The circuit/s have been tested and you are about to re-energise the supply. However, there are just a couple of things you must do first.

Turning a supply on

1. **Check**.
   You must make sure that all covers are back on and screwed back. Many a fault has been put on by people screwing back front covers and catching a conductor sheath. If you turn something on, then you are responsible! So check.

2. **Switch off loads**.
   Loads can cause a protective device to trip or blow because the inrush current causes a very large level of current to flow for a short duration of time. This can be in the order of 5 to 10 times the normal full load current, and is more than capable of operating the devices. In addition, loads left in can cause switches to arc, causing people to 'jump'. This in turn leads to a reduction in the life of the switch.

3. **Never put a fuse in when a load is connected**.
   This can cause an arc to occur for the same reasons listed in (1 above) and the danger to the person putting it in.

4. **Try to avoid making a circuit breaker when a load is connected**.
   Although this is less of a problem than with fuses, it can still cause someone a surprise, particularly if a breaker trips at the same time as you are trying to turn it on.

Remember that turning a supply on is no substitute for a proper inspection and test of an installation. Merely waiting for a fuse or circuit breaker to operate to show up a fault is dangerous and criminally negligent.

Records

The work is finished, the circuits all work and you have restored the installation to almost pristine condition. The client is happy and you are happy as the bill has been paid. What's left?

Records must be kept of the work that you have done. This is necessary for a number of reasons, and the types of records kept are important.

- **Test results** – necessary to ensure that should a problem arise later some record shows what the test results were at that specific moment in time;
- **Client details** – to show what the work was and the payments that were made. This enables good relationships to be maintained and hopefully to gain future work.
- **Work details** – diagrams, charts, times etc. This enable future costs and times to be better estimated.
- **Documentation** – all the paperwork that passed between the client and the contractor. This is essential as it can act as proof should any disagreements take place at a later time.

It is the duty of the contractor to maintain the records. However, it is important to realise that records for the client are also important, and it is the responsibility of the contractor to leave a record of the installation at each distribution board or consumer unit. This is particularly important in the light of the new Part P Regulations.

Part P requires that sufficient information is provided so that anyone who follows on can carry out the work safely. This implies that every installation must have a diagram showing what is installed and how it has been wired.

Exercise 8

1. You have just completed the first fix of a rewire in a semi-detached dwelling. What restoration work should you now perform?

2. An old socket-outlet has been removed from a wall. The wall has a lath and plaster finish. How would you restore the wall to a reasonable condition?

3. Give three reasons why waste must be safely disposed of?

4. What is the process for turning a supply back on after successful fault diagnosis?

B&B Training Associates

Engineering Learning Materials

Attempt all questions.

All marks are shown in the right-hand margin.

You should aim to pass with a 85 % minimum mark.

Anything less than this mark should lead you to re-read the text.

1.	State two conditions where you could reasonably expect to work live.	2
2.	What is competence?	2
3.	State four requirements of an approved test lead.	4
4.	How might you isolate a circuit?	5
5.	What process would you follow when turning the supply back on in an installation?	4
6.	What is an inherent fault?	2
7.	Give four examples of inherent faults.	4
8.	State four common areas of fault.	4
9.	When diagnosing a fault what is required?	3
10.	A room is used to store batteries. What precautions would you take if you were called to investigate a fault in it?	4
11.	You are called to a fault on a motor. The client tells you that one moment it was working and the next it wasn't. After further questioning it becomes apparent that the motor has smelt 'funny' for a period of time and that it has not been working as well as normal. It is a three-phase induction motor. What will you do?	10
12.	An old school has had its lights originally wired in bare MI cable. You are called in to carry out a periodic inspection and test. After carrying out an insulation resistance test to earth you realise that the readings are lower than 0.8 MΩ. What is the one major problem and what will you do?	10
13.	A public school is having its dormitories renovated and turned into small study rooms for groups of four pupils. You have recently been running in long lengths of thermoplastic sheathed MI cable. The cable has not been stored too well and it appears to have a small lump at one point in it. After making off two ends of the MI you test it and note that there is a short circuit between the conductors. You check the ends and test again with no change in the results. What will you do?	8

14.	A motor is installed in a feed mill. It is very dusty and a DOL starter is used. You test and commission the installation and leave the site. After two months, you are called back to the feed mill with a complaint that the motor is hot and that it keeps tripping out. On investigation you can see that they have covered the starter with a wooden box to keep out the dust and the motor vents are covered with dust. State one inherent fault and two problems. What will you do?	8
15.	Name four sources of information that can be used when fault-finding.	4
16.	Name four types of instrument commonly used when fault finding.	4
17.	What use does a multi-meter have?	4
18.	Devise a system for maintaining records in an ordered fashion.	6
19.	A single-phase capacitor-start induction motor has ceased to work. There appears to be no supply to the motor. What type of test instrument(s) would you want to make use of? Give reasons for your choice(s)?	6
20.	A light in a bedroom on an upstairs lighting circuit fails to operate. The client has changed the ‘bulb’ and the fuse and has come to the end of their attempts. How would you approach this problem and what type(s) of instrument might you use?	6
	Total	**100**