Electrical Safe Working Practice

MA NUE 044

6077S

Electrical Safe Working Practice

Overview

Safe working practices are an essential part of working in any industry. In the era before the 1980's governments used legislation in an attempt to control or prevent workplace injury, illness and death. These acts of Parliament tended to be very *prescriptive*. This means each act tried to specify, in detail how to prevent injuries in each workplace. These Acts often needed amendments as the nature of each workplace changed or as new hazards were perceived. The result was a very technical set of rules that were difficult to interpret and maintain. There were differences between states that led to inconsistencies even in similar workplaces.
From about 1980, a series of Inquiries recommended a more performance-based approach to occupational health and safety. The New South Wales Occupational Health and Safety Act 2000 contains provisions that place much of the responsibility for health and safety in the workplace in the hands of employers. Provisions of the Act require employers to consult with their employees on health and safety matters.
If you are going to be involved in the day to day, safe operation of your workplace you will need to develop skills that will allow you to identify hazards and conduct risk assessments.
This module will explain risk management principles for some electrical and non-electrical hazards. You will be given the opportunity to practice applying control measures for various non-electrical and electrical hazards including hazards associated with low voltage, extra-low voltage and high current installations. While this module basically stands alone, you will need some prior knowledge of the Occupational Health and Safety Act. For this reason you should have completed Occupational Health and Safety – 7793T before attempting this module.

Contents

Gather your resources

You will need the following resources at some stage during this module
Hazards at work – Second edition Petrusia Butrej and Grahame Douglas – OTEN
Code of practice for risk assessment – Workcover New South Wales.
www.workcover.nsw.gov.au/Publications
Summary of the OHS Act 2000 – Workcover New South Wales.
www.workcover.nsw.gov.au/Publications
Risk management at work. Guide 2001 – Workcover New South Wales.
www.workcover.nsw.gov.au/Publications

Assessment

This module contains two assessment events.

Assessment 1	Risk Assessment Project	40%
Assessment 2	Theory / practical test	60%

Risk assessment project

Assessment criteria

Conduct a risk assessment on a given work environment documenting and assessing the risks.

The workplace risk assessment should cover typical electrical and non-electrical hazards associated with industrial or building site.

Describe control methods for dealing with hazards in the workplace

Theory /practical test

The theory practical test could include multiple choice, short answer and essay type questions. The learning outcomes covered include:

Learning outcome 1: Demonstrate an understanding of the principles of risk management and assessment of risk.

Assessment Criteria		Content outline	Learning Strategies	Assessment Strategies	Resource or comment
1.1	Describe the principles of risk management and state the purpose of each.	Introduction to hazard identification and risk management	Assignment, research	Combined project with unit 2, Theory test	_Workcover publicatons
1.2	Conduct a risk assessment on a given work environment documenting and assessing the risks identified	Risk management procedures	Assignment, research	Combined project with unit 2, Theory test	Workcover publicatons

Learning outcome 2: Demonstrate knowledge and skills in dealing with non-electrical hazards encountered in electrical work.

Assessment Criteria		Content outline	Learning Strategies	Assessment Strategies	Resource or comment
2.1	Identify typical non-electrical hazards in the workplace.	Non electrical hazards traffic, asbestos etc ladders power tools	Assignment, research	Theory test, project	Workcover publications

2.2	Describe control measures for dealing with hazards identified in 2.1	Hazard information, MSDS, Use and care of safety equipment	Assignment, research	Theory test, project	Workcover publications

Learning outcome 3: Demonstrate knowledge and skills for dealing with hazards associated with low voltage, extra-low voltage and high currents.

Assessment Criteria		Content outline	Learning Strategies	Assessment Strategies	Resource or comment
3.1	Identify the parts of an electrical system and equipment that operate at low voltage and extra-low voltage	Circuit diagrams batteries etc construction sites	Circuit diagrams, identification of equipment types and characteristics	Theory test, project,	Sparks fly, Workcover code of practice Hazards at work (OTEN)
3.2	Identify the parts of an electrical system and equipment where high currents are available	Estimation of fault levels, effects of high fault current	Identification of circuit components	Identification of control equipment. Theory test, Project	Workcover code of practice Hazards at work (OTEN)
3.3	Describe control measures	Methods of fault current control, Safety procedures when working on electrical equipment	Hazard control methods,	Theory test, Project	Workcover code of practice Hazards at work (OTEN), Australian Electrical Wiring Practice

Learning outcome 4: Demonstrate an understanding of the risks and control measures associated with high-voltage.

Assessment Criteria		Content outline	Learning Strategies	Assessment Strategies	Resource or comment
4.1	Identify the parts of an electrical system and equipment that operate at high-voltage	Identification of HV equipement, Differences between LV and HV equipment	HV safety procedures	Theory test, project Practical exercise	AS3000 Industry code of practice HV Safe Working Procedures
4.2	Explain the terms 'touch voltage', 'step voltage', 'induced voltage', and 'creepage' as they relate to the hazards of high	Outline stray voltages in a HV installation that may be hazardous	Basic calculations, Circuit diagrams	Theory test, project	AS3000 Industry code of practice HV Safe Working Procedures

	voltage.				
4.3	Describe the control measures used for dealing with the hazards of high voltage.	Describe earthing and bonding in HV installatons	Interpretation of circuit diagrams	Theory test, project	AS3000 Industry code of practice HV Safe Working Procedures

Learning outcome 3: Demonstrate knowledge and skills in relation to safety, selection, use, maintenance and care of test equipment.

Assessment Criteria		Content outline	Learning Strategies	Assessment Strategies	Resource or comment
5.1	Describe the safety characteristics of electrical testing devices.	Categories of test meters	Selection of test equipment for given situations	Practical exercise Theory test	AS3000 Industry code of practice HV Safe Working Procedures
5.2	Demonstrate the safe use of electrical testing devices	Selection and safe use of test equipment and instruments	Demonstrate correct use of equipment	Practical exercise Theory test	AS3000 Industry code of practice HV Safe Working Procedures
5.3	Describe the safety checks and storage methods for maintaining the safety of testing devices.	Safety inspections of test equipment and leads	Inspect faulty equipment, report on suspect equipment	Practical exercise Theory test	AS3000 Industry code of practice HV Safe Working Procedures

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Section 1 Risk Management

Introduction

The Occupational Health and Safety Act 2000 places a "duty of care" on employers. This means that employers must ensure the health, safety and welfare of their employees when at work. This duty does not replace any obligation on the part of employees to maintain safety in the workplace. Employees must take reasonable care of the health and safety of themselves and others. It is a requirement of the OH&S Act that employees must co-operate with employers in their efforts to comply with occupational health and safety requirements.
This section will outline basic procedures you might use to assist your employer fulfill his duties under the OH&S Act. It will also improve your chances of identifying hazards in your workplace.

What you'll learn

When you have completed this section you should be able to:

- Describe the principles of risk management and state the purpose of each
- Conduct a risk assessment on a given work environment documenting and assessing the identified risks.

The references you need for this section are:

- Risk management at work – Guide 2001
  Workcover publications.

- Low Voltage Electrical Work – Code of Practice 2001
  Workcover publications

- Hazards at Work – Second Edition. Section 3

What is risk management

The Occupational Health and Safety Act of NSW and the OH&S regulation now require risk management as an integral part of managing the health and safety of employees in the workplace. Risk management is a way that all stake holders in a workplace can minimize the possibility of an accident that causes injury or work practices that can lead to illness perhaps over a long period of time. Employers should **identify any foreseeable hazards** that may arise in the workplace and **assess the risk** of harm arising from the identified hazards. It is then up to the employer to eliminate the hazard or at least **control the risk**.

Types of hazards

Consider the following example.

You are required to install a galvanized metallic troughing system at floor level in a small office. The office construction is mainly brick. This task will involve:

- Preparing and clearing the work area. This could include moving furniture such as desks or filing cabinets
- Preparing the metallic troughing system by cutting to length and drilling holes for cable access
- Drilling the wall for fixings

Exercise 1

Categorise the hazards involved with this task using the outline below.

Categories of hazards

You could group the hazards into about five major categories.

- Physical
- Chemical
- Ergonomic
- Biological
- Psychological

Seeing these categories may help you to identify hazards. It helps if you have some kind of checklist to categorise dangers in the workplace.
The *Workcover publication* ***Risk Management at Work – Guide 2001*** outlines five steps for hazard identification.

- Take a look at past accidents
- Talk to the workers doing the jobs
- Walk around the work area to see what is happening
- Review information you may have on a particular aspect of the work area
- Think about the future and ask "What if"

Physical hazards

What are the physical hazards associated with installing this troughing?

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Chemical hazards

Chemical hazards might include:

- Skin reactions to dusts (Dermatitis)
- Eye irritation by dusts or other agents

Chemical hazards are due to the presence of gases, dusts, fumes, vapours and liquids.
List chemical hazards you might encounter doing this job.

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Ergonomic hazards

Ergonomic is a term that applies to the design of the workplace. In this case the workplace is the office area where you may be cutting, drilling and fitting the troughing. An ergonomic hazard may be due to:

- Work bench too low and you have to bend over to complete the job
- Poorly designed or poorly maintained tools leading to fatigue
- Workspace too restricted. Not enough room to complete the task without causing another hazard
- Poor ventilation and light

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Biological hazards

Infections caused by bacteria and exposure to viruses, such as hepatitis are examples of biological hazards. The problem could be compounded if the office happens to be part of a hospital. Biological hazards may be spread by air conditioning for example.

Psychological hazards

These hazards are not all in your head. There is a definite link between factors that cause stress such as shiftwork, harassment, dealing with the public and constant low levels of noise that contribute to loss of well being. These factors are often cumulative causing a problem after some considerable exposure. These factors may lead to poor workplace performance and excessive absenteeism.

Risk Assessment

The exercise that you have just completed is the first step in any risk management scheme. You have to identify hazards before you can take the next step. Once you have identified the hazard you now have to determine how serious the problem might be. In other words you have to **assess** the risk. The Workcover publication *Code of Practice for Risk Assessment* suggests the following steps to assess the risk:

- Identify factors that contribute to the risk
- Review health and safety information that is relevant to the particular hazard
- Evaluate the likelihood of an injury occurring and the likely severity of an injury or illness that may occur
- Identify the actions necessary to eliminate or control the risk
- Identify records that are necessary to keep so you can eliminate or control the risk

It helps if you try to visualize how an accident could happen and what factors may contribute to the accident. Past accident reports are one of the best aids you can use to identify risk factors and hazards. Stories from the work place are also a rich source of information you could use to identify hazards and control methods. Try to imagine the consequences if one part of a process or piece of equipment fails. Many accidents are the result of equipment malfunction.

You now need to rate each hazard to decide how much effort should go into elimination or control.

Hazard Rating

Each hazard should be rated according to the following:

- Likelihood of an accident caused by the hazard. Consider such factors as length of time and frequency of exposure to the hazard.
- Likely severity of any injury or illness that may occur as a result of exposure to the hazard

You could use a table to rate each hazard. Any hazard that you give a high rating should be attended to first. The following table was adapted from the Workcover Authority booklet *Six Steps to Occupational Health and Safety.* In this example, 1 is the highest risk and 6 the lowest.

Rating	1	2	3	4	5	6
Likelihood of accident						
Severity						

Let's use the example of to rate the risk associated with installing the troughing. One of the hazards we identified may have been:

- Dropping a hammer on your toe
- Strains when moving furniture
- Trips and falls

Now we rate the hazard.

Hazard	Likelihood of accident						Severity					
	1	2	3	4	5	6	1	2	3	4	5	6
Dropping the hammer on your toe			x									x
Strains moving furniture		x							x			
Trips and falls		x						x				

You can only do this reliably if you have first hand access to the worksite.

Elimination or control of risk

You have now identified some of the hazards that confrontyou. You have categorized the risk that each hazard poses. The next step is to eliminate or at least control each risk. Elimination is the best option but not always possible. One of the hazards that we categorized as a high risk was trips and falls. The result of a fall on a hard floor is difficult to quantify. There are many variables that could compound the severity of the fall. If you happened to be carrying a heavy object at the time of the accident the results could be very severe. How, then can we eliminate the risk?

We could make sure that the area we need to walk through is clear of obstacles. We could insist that whenever anything is dropped on the floor, it is immediately cleared up. All our hazard control methods should be tabulated in a clear and logical way so that anyone who has to do this job can be familiarized with the dangers and safety control methods.

Risk Control Summary

The following table is an example of how you could summarise hazards, risks and control methods.

Task	Hazard	Risk	Control method
Installing troughing system	Moving heavy objects	Strains, hernia	
	Sharp objects	Cuts and abrasions	
	Carrying long sections of metal	Strains, hernia	
		Slips and falls	

You may find that the risks you identify are easily grouped and the control methods are easily identified. Your highest priority is to eliminate the hazard. If you can't eliminate the hazard then control is the next option.

Analysis of your assessment may indicate that:

- further training that applies to a range of hazards is needed for your workers.
- you may be able to eliminate hazards by changing the way you purchase your materials, for example, use smaller packages to help manual handling.
- you may be able to redesign the work area to reduce hazards.
- you may be able to divide physically demanding jobs between a group of workers thereby reducing fatigue. Perhaps some jobs may need more than one worker to be performed safely.

The risk management process

From the previous examples you can see the steps you could use to manage your risks. We can summarise this procedure:

- Identify the problem (Hazard identification)
- Categorise the seriousness of the risk (Risk assessment)
- Decide on elimination or control methods.

The risk management process is not complete however unless you monitor your control measures and review these measures to make sure they actually work. Remember this is only one part of a more complete OH&S plan for the work place.

Review questions

1 What is the name of the NSW Act that places a duty of care on employers?

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2 What is the name of the organization that administers this Act in NSW?

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3 What are the three general steps for risk management?

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4 List five general categories of hazards in the workplace.

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5 List five steps for hazard identification.

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6 What are examples of physical hazards.

7 What effect could a chemical hazard have on you?

8 What is an example of a biological hazard?

9 Identify two possible causes of stress associated with the workplace.

10 List five steps for risk assessment.

11 What are two categories you could use to rate a hazard?

Project 1

Conduct a risk assessment for an operator who uses a petrol powered lawn mower to mow grass on the public nature strip of typical suburban domestic premises. Use a table to categorise the task, hazard, risk and control methods.

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Section 2 Workplace Hazards

Introduction

The first section of this module was an introduction to the risk assessment process. Unfortunately, many of the hazards you face in industry are difficult to identify without some further knowledge. For example, some substances appear safe enough but may pose a severe health hazard if used or handled incorrectly. Asbestos is one example. In this section we will outline some of the non-electrical workplace hazards and safety procedures you could use to identify some not so obvious hazards.

What you will learn

When you have completed this section you should be able to:

- Identify typical workplace hazards
- Outline control methods for dealing with hazards

References for this section:

- Safety Meter Positive performance measurement tool
    - Workcover publications
- Low voltage electrical work – Code of Practice
    - Workcover Publications
- Hazards at Work – Butrej and Douglas
    - OTEN and Workcover
- Material Safety Data Sheets from materials suppliers

Hazards in the workplace

Young workers below the age of 25 are most likely to have an accident in the workplace. According to statistics from Workcover - NSW, about 60% of all workplace injuries are sprains and strains. Back injuries account for about 30% of workplace injuries. For young, inexperienced workers, the most common injuries are:

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Manual handling is the major cause of injury to young workers while the next most common causes of injury is slips, trips and falls and being hit by moving objects. From workers compensation statistics, 98-99, the occupations with the highest risk of injury are:

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The industry divisions with the highest incidence of injury are:

- Mining
- Agriculture, forestry and fishing
- Construction
- Manufacturing
- Transport and storage

If you are an apprentice in the electrical industry you are in an injury high risk category. It is important that you develop skills that allow you to identify hazards before you become another figure in the statistics.

Identifying Workplace Hazards

Studies of safety in the workplace have found that one of the most successful methods you can use to identify hazards is to divide the workplace into sections or areas. You can then look for contributing factors for a hazard in each section. The categories of hazards should represent the key risk areas for your particular work place. To be effective, Workcover – NSW recommends the maximum number of categories in your assessment should not exceed eight.

What are typical categories

The categories could vary according to the type of work you undertake. However some categories apply to nearly all workplaces. Typical categories could be:

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If you work in a ware house then you might include a special category for fork lifts and hoists.

Contributing factors to hazards

What are some of these factors?
Some of the factors that follow were covered in **Occupational Health and Safety – 7793T.** We will review some of these factors in the following activity.
Write the title that would best fit with the following descriptions.

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Work practices are procedures or methods you might use to protect yourself from injury in the work place, wearing eye protection or ear protection, for example.

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Keeping your work area organized and tidy is an excellent first step for avoiding accidents. Keeping access ways clear and removing rubbish before it builds up is part of this process. Housekeeping refers to this practice.

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Areas that are poorly lit may be a hazard. Generally the lighting level must be suitable for the type of work undertaken in that area. For example, the lighting level in a stairwell or hallway is a lot lower than the lighting level you need in a workshop where small parts and close tolerance work is involved.
Electrical refers to maintenance of equipment especially electrical leads that may contribute to an accident.

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There are many opportunities for accidents of this type in a workplace. Besides the obvious contributing factors such as wet, slippery surfaces you need to be aware of factors that may complicate an accident. Sharp materials that extend into the workplace may cause a severe wound from only a small fall.

It is generally your responsibility to make sure the equipment you use is safe. This includes such things as checking guards and controls for compliance with safety regulations.

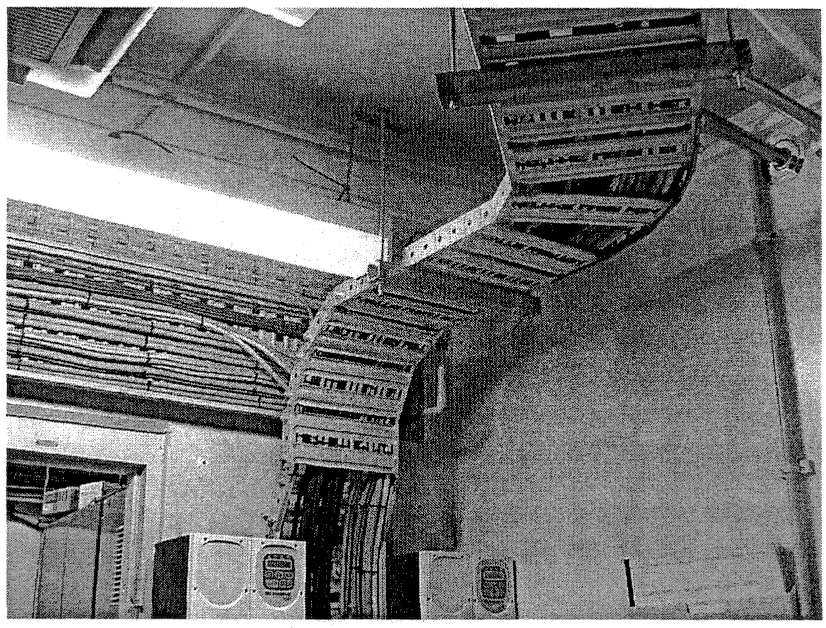
Activity 2 - Examples of hazards

You have to install a short section, about six metres, of cable tray in an underground car park. You have to drill holes in a slab above your head to fit masonry anchors and cut the tray to suit a change in direction.

What precautions will you use to minimize the effect of any hazards you meet?
As a starting point, list the steps in the job and then apply each of the categories from above and any others you feel necessary.

Steps for completing the work

- Mark out route
- Drill holes for supports
- Cut tray and assemble section
- Fit tray



We are only considering the installation of the tray and not other factors such as getting the tray to the site.
As an example, we will consider some of the contributing factors to a hazard and procedures you could use to minimize the risk. Firstly, marking out.

Work practices

What work practices should you employ when marking out?

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Housekeeping

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Electrical and lighting

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Protection against slips, falls and falling objects

Plant and equipment

Ladders or scaffolds

SCAFFOLD FALL INJURES TWO MEN

Two men were injured when a two-metre scaffold fell over. The men were repairing a townhouse when the incident occurred. One man suffered multiple fractures including both arms and legs and the other man multiple fractures and severe head injuries.

These are a few points for an example. As an exercise complete the following sections for the remaining tasks.

Drilling Holes for masonry anchors

Add at least two more items in each category

Work practices (Add at least two more)	• Erect barriers to stop traffic or use another qualified person to control traffic flow. • Use reflective vests in poor lighting in car park. • Your turn • •

Housekeeping	• Keep area clear of materials and tools • •
Electrical and lighting	• Use portable lamps to increase light • Check all appliance leads for damage • •
Protection against slips, falls and falling objects	• Tools and equipment secured to prevent falling onto people below • •
Plant and equipment	• Check masonry drill for correct operation • •
Ladders and scaffolds	• Check ladder for defects • •

Cut and assemble tray

The categories in this section need to reflect the methods you use to cut and assemble the tray. You could use a hacksaw to cut the tray or, more likely, an angle grinder with a metal cutting disk. Assembly involves spanners or sockets and other hand tools.

Fatal Fall

A 53-year-old electrician died from head injuries when he fell from an aluminium extension ladder onto the concrete floor below. The deceased man had been checking a hot water heater during the installation of electrical equipment in a new kitchen when the accident occurred.
Workcover news.

Work practices (Add at least two more)	• Erect barriers to stop traffic or use another qualified person to control traffic flow. • Use reflective vests in poor lighting in car park. • Your turn • •
Housekeeping	• Keep area clear of materials and tools • •
Electrical and lighting	• Use portable lamps to increase light • Check all appliance leads for damage • •

Protection against slips, falls and falling objects	• Tools and equipment secured to prevent falling onto people below • •
Plant and equipment	• Check angle grinder for correct cut off disk • •
Ladders and scaffolds	• Check ladder for defects • •

Another point about ladders

Do not use aluminium ladders if there is a risk of contact with electricity. Fibreglass ladders are now the ladder of choice for electricians. Other trades may be at risk as well. The following is an extract from the Queensland publication *Guidelines for Electrical Workers.*

An electrical worker was hospitalised after he received a shock while working on an aluminium ladder installing cables on a cable tray. The foot of the ladder had cut through a flexible cord supplying temporary lighting.

Fit masonry anchors and tray.

The tray should hang below the ceiling attached to long threaded rods. There should be nuts and washers above the tray and below the tray

Work practices (Add at least two more)	• Erect barriers to stop traffic or use another qualified person to control traffic flow. • Use reflective vests in poor lighting in car park. • Your turn • •
Housekeeping	• Keep area clear of materials and tools • •
Electrical and lighting	• Use portable lamps to increase light • Check all appliance leads for damage • •
Protection against slips, falls and falling objects	• Tools and equipment secured to prevent falling onto people below • •
Plant and equipment	• Check spanners and sockets for correct fit • •

Ladders and scaffolds	• Check ladder for defects • •

Review and summary of hazards

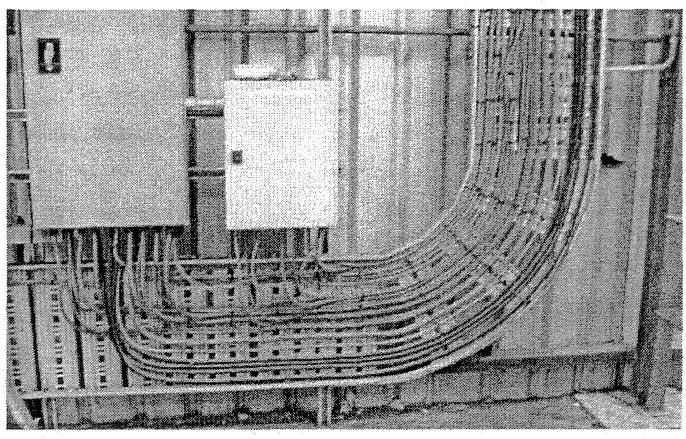
Identifying these hazards without actually seeing the job is difficult, however, you will need to be able to foresee some of the problems so that you can have the solutions in place before you start work. You can check some of your suggestions against the information at the end of this section.

You may have thought of other safety precautions as well. Most of the items in this table are of a physical nature. There will be other jobs where you come into contact with hazards that are not as obvious. The dust generated whilst drilling is an example of a hazard that you might overlook. Dust of this nature can cause diseases like lung cancer or silicosis. The occurrence of silicosis is declining in Australia and is now a rare condition. One of the problems associated with diseases of this type is the time the disease takes to develop. Lead times of ten years or more are typical. So the precautions you take now, or don't take, may not affect you for some time.

The principles outlined in the tables above are also the basic principles you should use for a safety inspection of a workplace or site.

Exercise 3

You need to build a small switchboard panel for a factory control panel. You will have to mark out hole centres, drill or cut access holes and holes for mounting screws using appropriate machine tools and coolant. After the drilling process the next step is to mount the equipment and pre-wire the panel. Some soldering will be necessary. After all wiring is complete you will repaint any scratches on any metalwork and repaint sections damaged when you drilled or cut access holes. You will complete the work in an electrical workshop.



Complete the following table for this procedure. You may find that quite a large proportion of the preceding exercise will apply here as well.

Work practices	
Housekeeping	
Electrical and lighting	
Protection against slips and falls	
Plant and equipment	
Other categories	

Other hazards

This job you have just completed introduces some more hazards that we may not have mentioned. Let us remind you about some.

Hazard 1-

The risk of causing permanent hearing damage is related to both loudness of the noise and the length of exposure. For example two minutes working in noise levels of 114 decibels dB(A) may cause the same amount of damage as eight hours working in 85 dB(A). Noise related injuries are slow to develop and may not have a large effect on your lifestyle for a number of years. The damage is cumulative and irreversible. Cutting steel switchboard surrounds with a hole saw or jig saw could generate noise that is in excess of 85 dB(A). The best approach is to reduce noise at the source. In this case it would be better to use a *punch* to create the holes for panel access rather than a hole saw or jig saw. If you must use a saw then you must use ear protection.

Hazard 2-

Switchboards and panels manufactured prior to 1988 often contained asbestos. The most common form of asbestos is *chrysotile (White Asbestos)*. This material produces tiny fibres that may lodge in your lungs. These fibres form the nucleus of tumors and cancers that are extremely aggressive. The incubation time for these tumors is fairly long and even though asbestos has been banned for some time the number of asbestos related compensation cases continues to rise.
It is unlikely you will be exposed to asbestos in a new switchboard. You may, however be exposed to asbestos in older installations.
You should assume that asbestos is present in:

- Any boards marked on the rear face with "Zelemite, Lebah, Ausbestos, etc." or with any signage indicating the presence of asbestos
- Any older black mounting boards with a smell of bitumen or coal tar. Asbestos has no odour but the composite binder smells of coal tar).
- millboard (soft, cardboard-like material) and asbestos cement (AC) sheet. Any cement sheet (colloquially known as 'Fibro').

Do not disturb these materials or the dust that accumulates in the switchboard.

NSW Electrical Industry Asbestos Awareness Committee in conjunction with *Workcover – NSW* publishes information about asbestos. They recommend the following procedures if you have to work with these panels.

- Use dust control and **low speed** drills for drilling operations
  A drill attached to a vacuum cleaner fitted with a High Efficiency Particulate Air (HEPA) filter via an appropriate dust extraction unit has been demonstrated as a safe method.
- Use a respirator that has an appropriate rating if you cannot use any other engineering solution to remove the hazard
- The electrical panel, meter box and any electrical equipment installed on or removed from the panel must be cleaned of dust and swarf as part of the work procedure. A vacuum cleaner suitable for asbestos work is an adequate method of cleaning up as it removes all residual dust and swarf from the box, the panel, around cables and electrical equipment.
- For electrical panels identified as containing asbestos, assume the dust and swarf inside the cupboard/ box housing the metering equipment is contaminated with asbestos fibres. Use Plastic (non-conductive) vacuum cleaner hoses and attachments to remove this dust.
- Remove and dispose of asbestos waste in accordance with the requirements of the Environmental Protection Agency -NSW. The EPA has strict guidelines for handling asbestos. Generally, removal of materials like asbestos is undertaken by specialised companies registered for that purpose.

Synthetic mineral fibres

Name two types of synthetic mineral fibres.

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It is more likely in this day and age you will come into contact with synthetic mineral fibres or SMF. These materials do not represent the same hazard to health as asbestos.

Vapours and fumes

Now, a similar problem to dust is the effects of vapours and fumes. Certain vapours or fumes may also be hazardous to health. To minimize the risk associated with vapours you should:

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Carbon monoxide poisoning

Five construction workers were treated in Blacktown Hospital after inhaling carbon monoxide while stripping down a building at Blacktown TAFE. The noxious fumes resulted from operating an internal combustion engine in a sealed room in which asbestos was being removed. All five men were released from hospital and have not suffered any permanent injuries.
Workcover news.

What types of materials cause vapours and fumes?
Obviously internal combustion engines give off toxic fumes but so do many other materials. Some of the more common sources are:

- Solvents found in cleaning agents and paints
- Burning materials or materials being heated during welding and soldering operations
- Rotting materials or the results of oxidization of metals. (Sometimes oxidization of metals robs the atmosphere of oxygen. This often happens in large metal containers such as the holds of ships).

Exercise 4

List three possible sources of fumes or vapours associated with our switchboard job.

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Finding information

How can you find out about the materials you use in the workplace?
Read the label for a start. If the material is recognized as being of a hazardous nature, the handling precautions should be included as part of the packaging.
In the Occupational Health and Safety module you would have been introduced to the Material Safety Data Sheet (MSDS). There is a MSDS available for any chemicals you use in the workplace.
What is a material safety data sheet (MSDS) and what does a material safety data sheet tell you?
The information on the MSDS includes:

- the ingredients of the product
- the health effects of the product and first aid instructions
- precautions to follow when you use the product
- safe handling and storage information.

Just because an MSDS has been provided this does not automatically mean that the product is now safe to use. You should read the MSDS carefully and do a risk assessment.

Exercise 5:

Outline safety procedures you should undertake if you have to paint your switchboard surround with an anti corrosive primer.
List items of personal protection, engineering controls and outline spill and leak procedure for paints.
You should use an MSDS for this information.

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Exercise 6:

Use the information available on a MSDS for cement and answer the following questions. This information is readily available on the internet or on the back of the packaging.

- What is the short term effect of cement if it is swallowed?

____

____

- What are the long term effects of cement if it is inhaled?

____

____

- List the first aid directions if you get cement in your eyes or on your skin.

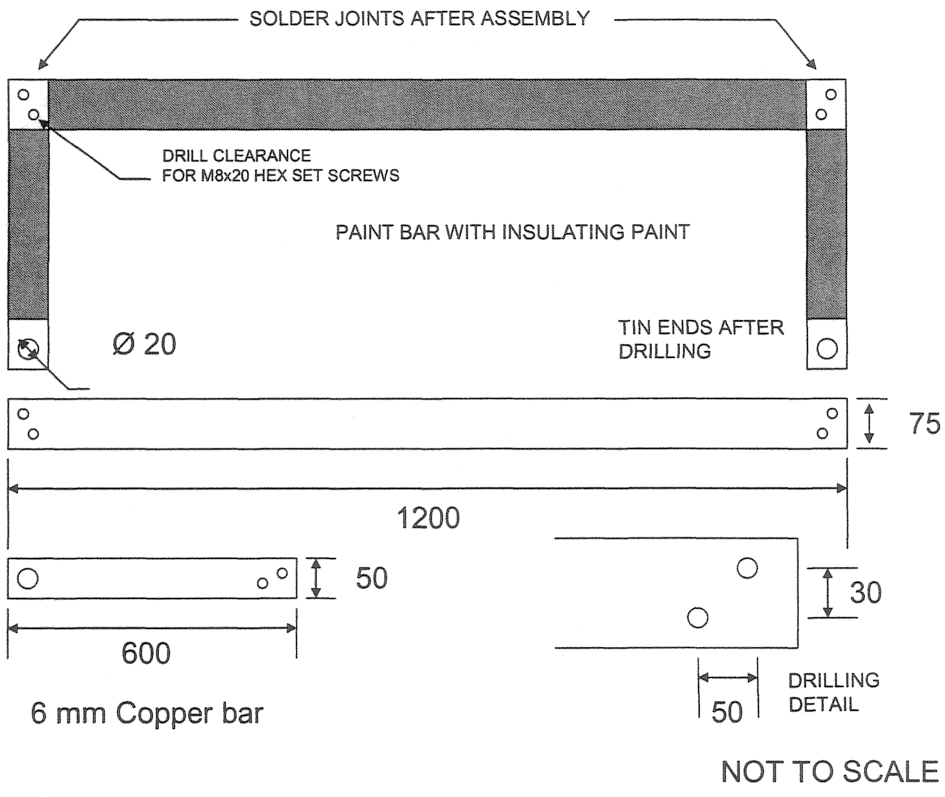
____

If you have worked through the exercises in the first two sections of this module you should be able to identify basic workplace hazards and conduct a basic risk assessment for yourself. You should be able to find information about materials you use and safe work practices. Submit the following exercise to your teacher.

Activity

You have to make a section of copper bus bar for a large switchboard. (Drawing supplied). This work will be carried out in an electrical workshop equipped with the usual tools and equipment such as pedestal drills and grinders. The copper bar is supplied in 6m lengths and stored on a metals rack at the workshop along with other materials. You will have to cut the sections of bar to length, dress ends square if not square and drill holes as shown on the diagram. You will have to clean all sections of the bar that have to be either tinned or painted. This usually means making sure the bar is free from oil or grease.
Identify any hazards that may be involved for this job and conduct a risk assessment. Present your assessment in table format outlining the

- Parts of the task and
- Hazards that you may encounter
- Controls for minimizing risk.


SOLDER JOINTS AFTER ASSEMBLY
DRILL CLEARANCE
FOR M8x20 HEX SET SCREWS
PAINT BAR WITH INSULATING PAINT
Ø 20
TIN ENDS AFTER
DRILLING
75
1200
50
600
30
50
DRILLING
DETAIL
6 mm Copper bar
NOT TO SCALE

Check your progress

1. What is the age group most likely to have an accident in the workplace?

2. List four of the most common injuries in the workplace

3. What are the three industry divisions with the highest incidence of injury?

4. What is the maximum sound level before you should use noise protection?

5. Name one type of dust that is associated with lung disease.

6. List three methods you could use to minimize the production or effects of dust if you had to install new equipment on an old switchboard.

7. Name one source of carbon monoxide.

8. How can you find out about materials that you might use in the workplace?

Electrical Safe Working Practice

Section 3 Electrical Hazards

Introduction

The earlier sections of this module are an introduction to workplace hazards and risk management. If you have completed the exercises in those sections you should now be able to apply the basic procedures of *risk management*. In this section we will take this procedure a step further and apply those principles to the parts of an electrical installation. You cannot see electricity and the effects of an electrical accident can be extremely severe. A simple accident may result in loss of life and loss of property. The risks of injury and damage associated with accidents in electrical installations vary depending on the system voltage and available fault current. Some installations may operate at voltages above 10 000V but energy levels are so low that little damage will be done under fault conditions. On the other hand, if you place a short circuit across the terminals of a 12 volt car battery, you could do considerable damage, especially if the battery explodes. So in this section we will identify the sections of the electrical installation that operate at low and extra-low voltages and try to outline the risks associated with each section.

What you will learn

When you have completed this section you should be able to:

- Identify the parts of an electrical system and equipment that operate at low and extra-low voltage
- Identify the parts of an electrical system where high currents are available
- Identify equipment that may be connected to high current systems
- Describe Hazard control methods

Resources for this section

Code of practice – Low Voltage Electrical Work
Workcover NSW
Hazards at work – Butrej and Douglas
Second edition - Section 8
Electrical Wiring Practice – Petherbridge and Neeson

Electrical Hazards

Two general categories of electrical hazards are:

If you are part of the electrical circuit, the flow of current though your body will:

- Cause burns along the current path
- Create some other physiological effect that will be as equally life threatening.

Accidents of this type are generally called *electrocutions or electrical shocks.*

An electrical explosion is caused when the energy that flows into a fault in the circuit causes the temperature of the circuit components to get so high that some parts melt or vapourise. Accident victims of an electrical explosion may not have been in direct contact with the electrical circuit but they may be severely injured just the same.

Contributing factors for electrical accidents

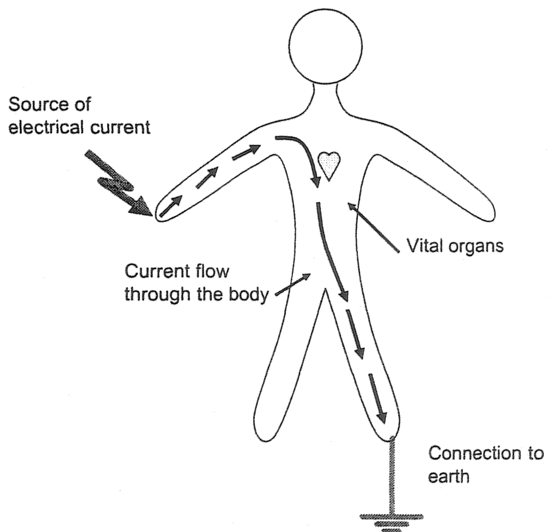
You should be able to identify factors that contribute to the severity of an accident. In the following sections we will outline some of the factors that increase the likelihood of a fatality

One Killed And Two Injured By Electrocution

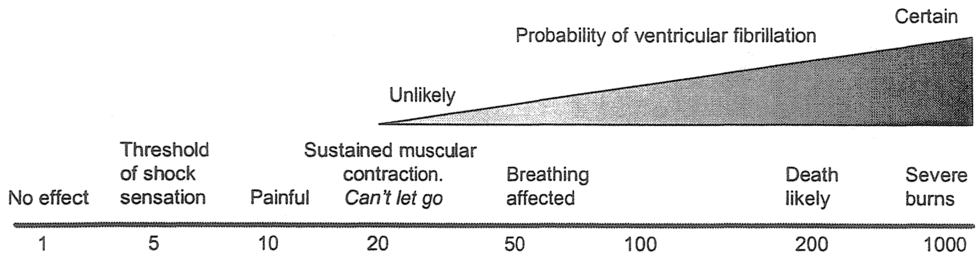
A 20-year-old apprentice painter was killed while working at Cessnock TAFE. The deceased man and two colleagues were pushing a mobile aluminium platform to a new location when it came into contact with 11 KV overhead powerlines. The two men were critically injured from the electric shocks and treated in hospital. Workcover NSW.

Electrocution

We generally apply the term *electrocution* to fatalities that involve electricity. A person is *electrocuted* if the flow of electricity through the body causes damage or prevents vital organs from functioning. Not all electric shocks are life threatening. The effect of electric current on the human body is covered at length in various text books. You could refer to Electrical Wiring Practice – 6th edition, chapter 14 and Hazards at work – second edition, section 8 for further information. In summary, the passage of electric current through the body has the following effects.



The voltage that causes electric shock cannot be specified exactly as the resistance of the victims body is not fixed. The resistance between the ears is generally lower than the resistance measured hand to foot. Skin resistance is much higher dry than wet. Generally circuits that operate below low voltage (up to 50V AC, 120V DC) are considered reasonably safe under most conditions. Even these voltages may be lethal where the body is immersed in water or in operating theatres.



Milliamperes (One second contact, 50 Hz supply)

Use one of the references listed above to answer the following questions.

1 What is the likely physiological effect if you have a 50 Hz current of 50 mA pass through your body for half an hour?

2 At what current would you find it difficult to let go of a conductor?

Avoiding contact with electricity

The regulations contained in the SAA Wiring Rules are primarily designed to reduce the hazards to users of electricity. It is essential you maintain these standards and do not introduce a situation that reduces the effectiveness of these safety regulations. Contact with live electrical parts is prevented by:

As an electrician, you will be expected to work on electrical installations but you should not reduce the effectiveness of any safety factors such as earthing, guards and barriers. This applies to all installations including temporary services and builders supplies. One way you might introduce a hazard where there was not one before is by placing a metallic scaffold beneath electrical aerial cables. Electrical supply authorities publish information you can use to assess the risks if you are working near power lines. Only under very unusual circumstances should you work on low voltage circuits that are *live*. You should only undertake this work if you have been trained and have the appropriate safety equipment. As stated in the WorkCover Code of Practice for Low Voltage Electrical Work, personal protective equipment is the least preferred way of dealing with risks.

The only time you should work with the circuit energised is when you are fault finding or testing.

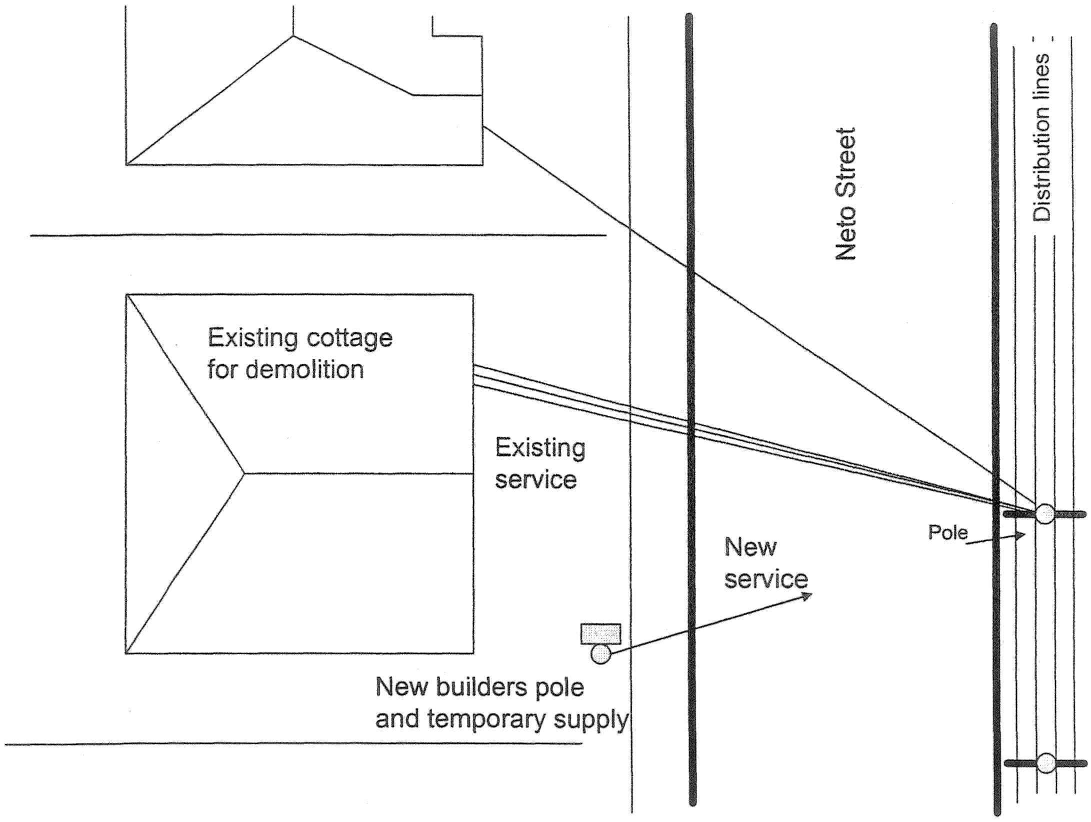
Electrical Hazards

Every electrical installation and task must be assessed for hazards. The list that follows is a summary of hazards from a WorkCover code of practice – Low Voltage Electrical Work, section four. This list includes:

- Voltages that appear between
  - terminals of equipment and accessories
  - terminals and earthed metal
  - terminals and exposed live conductors and conductive parts of the surrounding environment such as damp brickwork
  - earthed metal and disconnected conductors such as neutrals
- Reduced safety due to
  - hazardous locations and explosive atmospheres
  - damp or wet areas
  - cramped situations such as roof spaces and under floors
- Multiple supply sources for a single switchboard or circuit including *off peak*, emergency supplies and uninterruptible power supplies
- Induced voltages on long circuits or stored charge in capacitors
- Incorrectly labeled circuits and incorrect circuit identification procedures
- Hidden or undetected live electrical cables in work area

You have to organize the removal of power on a demolition site and install a 150mm x 6m metal builder's pole on the position shown on the site map. You also have to determine if there are any other electrical hazards that may affect workers during the demolition of the house.
The building marked for demolition is a fifty year old house that has a three phase service attached to the front of the building. The service line originates on a supply authority pole on the opposite side of the street.

- Identify hazards associated with the completion of this job
- Conduct a risk assessment
- Outline hazard control methods you intend to use



Answer the question by completing the following table.

Hazard Identification	Risk	Control measures
Thoroughly inspect the site and adjacent area to identify the existence of all power lines.		Contact local electricity supplier for information. Dial before you dig
Demolition begins before power isolated.		
Identify switchboard material for the presence of asbestos.		Refer to WorkCover for information and correct disposal procedures.

Power still connected to supply after scheduled cut off date.		Thoroughly test installation after disconnection for the presence of unidentified supply. Use volt stick as last line of defence to detect live lines.
Metal builders pole installation.		Power lines within 4 metres should be de-energised, insulated or other wise made safe before starting work. High voltages need higher separation distances. See local electricity supplier.
Metal builders pole installation.	Injury caused by manual handling	
Switchboard equipment and protection (Builders supply).	Electrical shocks and electrocution.	
Operating distances between plant such as cranes and power lines.		No power lines within 4 m of the site. Spotters not used to observe operation of plant where electrical contact is possible.
Inappropriate electrical switchboard.	Contact with electricity and water damage to panel.	
Unauthorised access to live power on site.		Electrical switchboard lockable outside work hours. RCD protection fitted to all outgoing circuits. Site fenced.

Electrical burns

The fact that electrical current produces heat is commonly demonstrated in appliances like electric jugs and room heaters. The heat produced and element temperature is controlled by careful circuit design. If you increase the voltage applied to a wire wound, heating element, the temperature will rise until you exceed the melting point of the wire. When the wire melts, the circuit is no longer continuous and the current flow stops.

Circuit protection

A fuse is one application of the controlled heating effect of an electrical current. If the current in the circuit increases above an acceptable level, the heat energy used by the fuse element causes the temperature of the fuse element to rise until it melts.
Circuit breakers use the heating effect of the current as well as magnetic fields to trip the switch and open the circuit.
The operation of the circuit breaker and the fuse takes time. Sometimes, you may find the speed with which the circuit protection operates is not fast enough to prevent damage to the equipment connected to the circuit. You will contribute to the problem further if you use fuses or circuit breakers with ratings that exceed the normal current carrying capacity of the circuit.

Energy in the fault

The energy at the fault is determined by the time the fault current flows and the magnitude of the fault current. The damage to property and risk to life caused by a short circuit fault varies depending on these two factors.

Limiting circuit fault current

Where is the fault current lowest?

The fault current is limited primarily by the impedance (resistance) of the energy source, supply cables and the cause of the fault. The term impedance, which is the opposition to electrical current, includes factors such as resistance and reactance that are a normal part of the circuit.

Current limited

Many extra low voltage systems are current limited. Extra-low voltage is any voltage below 50V AC and 120V DC. Systems of this type don't need a fuse or circuit breaker protection on the output side of the power supply. Analogue telephone systems (48V) and 12 volt lighting systems are two examples of current limited supply systems. Many 240/12 volt transformers used for down lights have a maximum short circuit current of about 20A. They will not sustain that current for long before they are damaged. They are unlikely to explode, however. Some electronic types are short circuit protected.

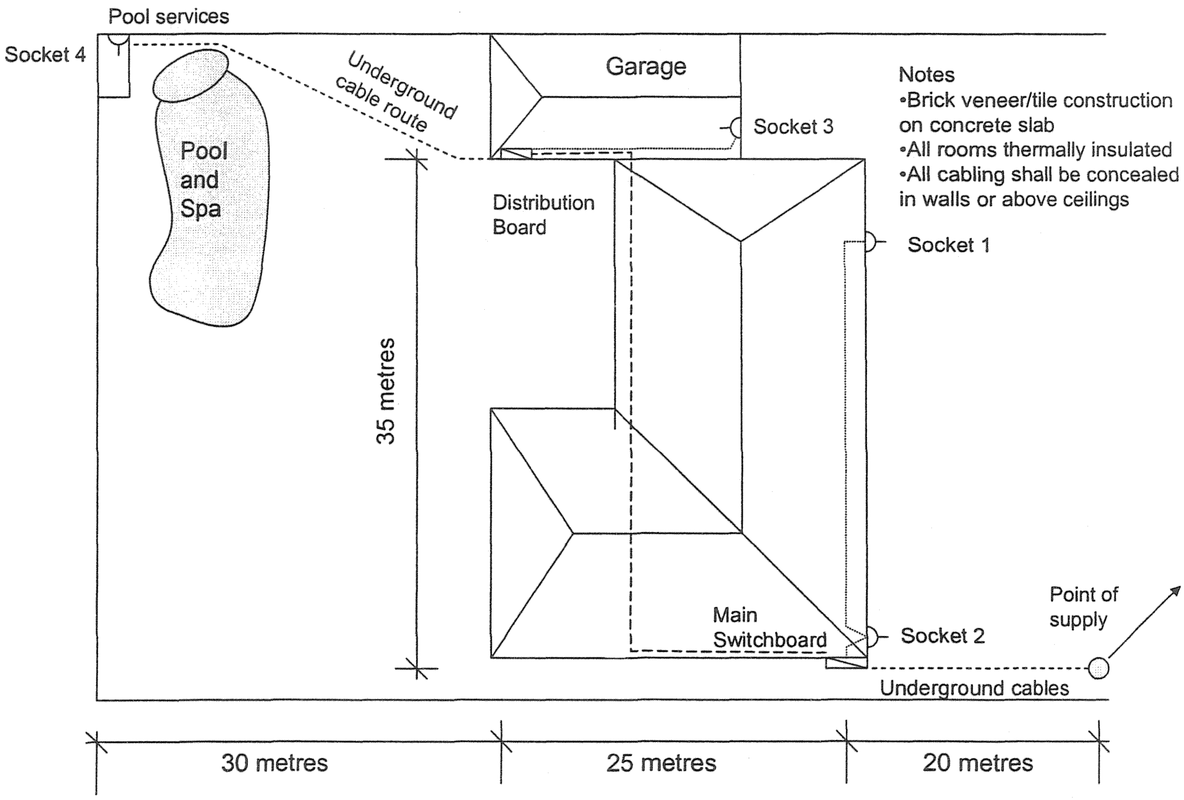
High circuit impedance

Ordinary low voltage circuits must be protected against short circuit and overload faults by suitable circuit breakers or fuses at the origin of the circuit.
Low voltage is defined in AS3000 as:

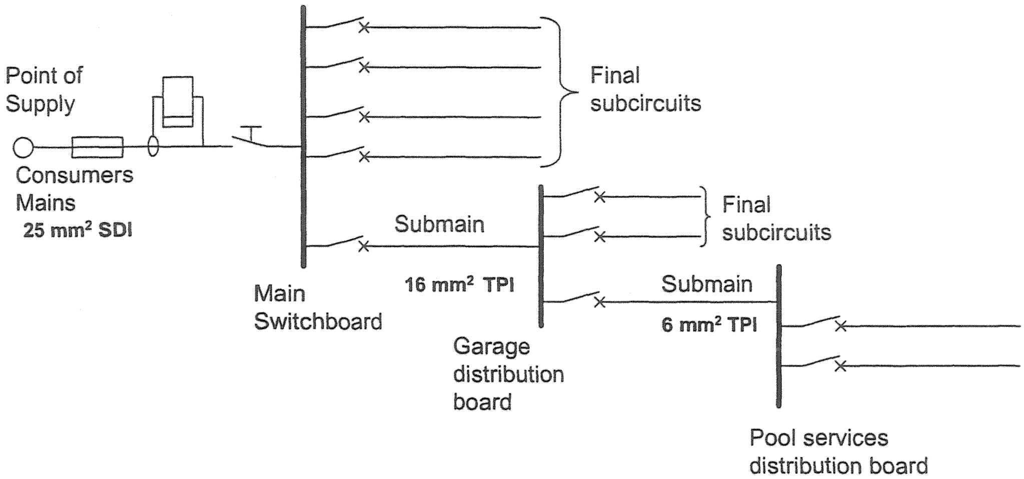
The maximum fault current that will flow, however, is mainly determined by the impedance of the fault path. As a rough guide, the longer the circuit and the smaller the diameter of the cable, the lower will be the fault current.

Typical fault levels

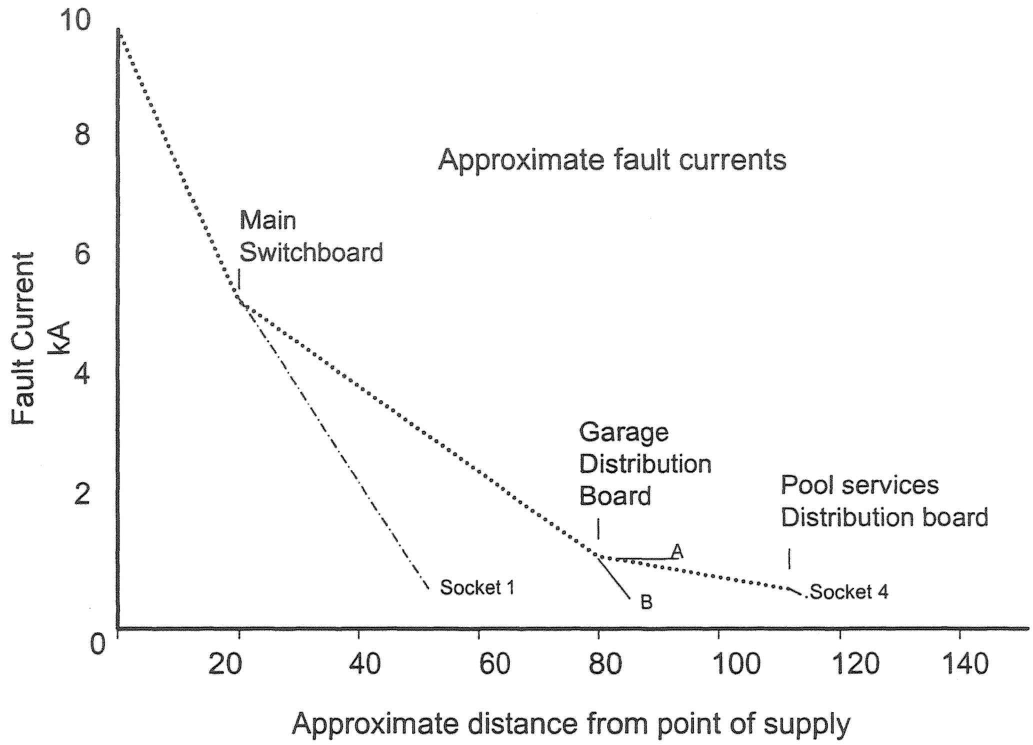
The diagram below is a site plan of a domestic installation. The fault current level at the point of supply in an urban situation is about 10 000 amperes. (NSW Service and Installation Rules). As you move along the circuit away from the point of supply, the short circuit current will decrease. The graph following shows this reduction.



Not to scale



Line diagram showing typical cable sizes.



Graph showing the change in possible fault currents as the circuit length increases.

1 Write the approximate fault current levels at the following locations. Use the graph as a guide.

- Point of supply ____________________
- Main switchboard ____________________
- Garage distribution board ____________________
- Pool services distribution board ____________________

2 On the graph, locate the position that represents the fault current for socket 2.
What is the approximate fault current at socket 2?

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3 Which of the lines marked A or B on the graph would represent the change in fault current along the cable that supplies socket 3?

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4 Which socket outlet would feed the largest amount of energy into a short circuited, faulty appliance?

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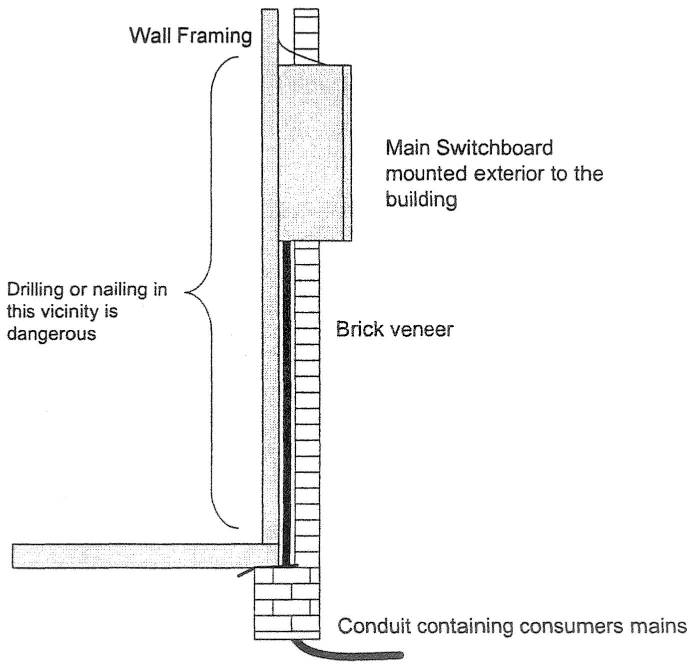
5 A fault at which switchboard will give the biggest bang?

Electrical Hazards

In many installations it is common practice to bury cables in a mortar filled groove cut in a masonry wall. This groove is commonly called a *chase*. Most of the time, these *chases* house the cables for switches or 10A socket outlets. Even if these cables are enclosed in rigid PVC conduit, there is a possibility that an unsuspecting worker or handy man could drive a nail into the cables creating a short circuit. The SAA Wiring Rules provide specific guidelines that an electrician should follow when using this installation method. The SAA Wiring Rules state that unprotected cables installed in a chase in a masonry wall must be installed vertically above or below the accessory. You may also bury cables in a masonry wall provided you are within 150mm of the join of the walls or ceiling. This information is useful for trained electrical people but other trades or workers are not always so well informed.



Out of Site, Out of Mind

Some time ago a worker was badly injured when he drove a nail into a set of consumer mains causing a short circuit and subsequent explosion (Workcover Safety Alert 4010). Consumer's mains are not protected by fuses in all situations. The fault currents under these conditions would be close to the maximum specified in the NSW Service and Installation Rules.

Exercise

Refer to the site plan to complete this exercise.
The owner of the premises has contracted you to install the switchboard in the garage. This job includes cabling between the main switchboard and the garage through the roof area of the house. Conduct a risk assessment of the work you need to do to complete this task. Refer to the diagram and your experience in the workplace to determine some of the installation conditions you are likely to encounter.
You could use the Workcover Code of Practice for Low Voltage Electrical Work as a guide.

Task	Risk	Control measures

Chapter 5 of the Code of Practice for Low Voltage Electrical Work outlines many risk factors that may be present if you have to modify, fault find or repair electrical work. Factors such as incorrectly labeled circuits, lack of information about isolation points and poor work practices will contribute to a major accident.

Exercise

1 Outline suitable control methods for the identified risk factors in the following table.

Risk factors	Control methods
Attempts to start machinery under repair by uninformed workers	
Supply may become live during the work	

Automatic, unexpected starting of machinery after supply is restored	
More than one source of supply at a switchboard	
Working alone in close proximity of live conductors and terminals	
Test equipment and test probes inappropriate for the procedures and tests	
Lack of knowledge about circuits and equipment	
Incorrect or poorly maintained test equipment	
Working on equipment in hazardous areas without specialist advice	

Job planning and correct and appropriate testing procedures will go a long way toward maintaining electrical safety. The best method for reducing risk is to eliminate the hazard. The first option for eliminating the possibility of electrical accidents is to isolate the circuit and then test to prove it is isolated. Complete testing procedures before touching any terminals or conductors.
Other options for reducing risk include:

- Substitution
- Isolation
- Use of personal protective equipment.

Substitution: Using substitution means you could use *extra low voltage* for your circuit supply instead of a more hazardous Low voltage. This may be useful for circuits for garden lighting and underwater luminaries but is not always an option for heavier electrical loads.

Isolation: You can isolate yourself from the hazard by installing barriers, insulate live terminals and conductors using approved insulation techniques or do the work some other time when the power can be removed.

Personal Protective Equipment You should have basic personal protective equipment available for yourself and your employees. Basic PPE includes items such as safety boots.

In the space provided list six items of personal protective equipment you should carry if you are an electrical contractor engaged in commercial and domestic installation work.

2 Personal Protective Equipment

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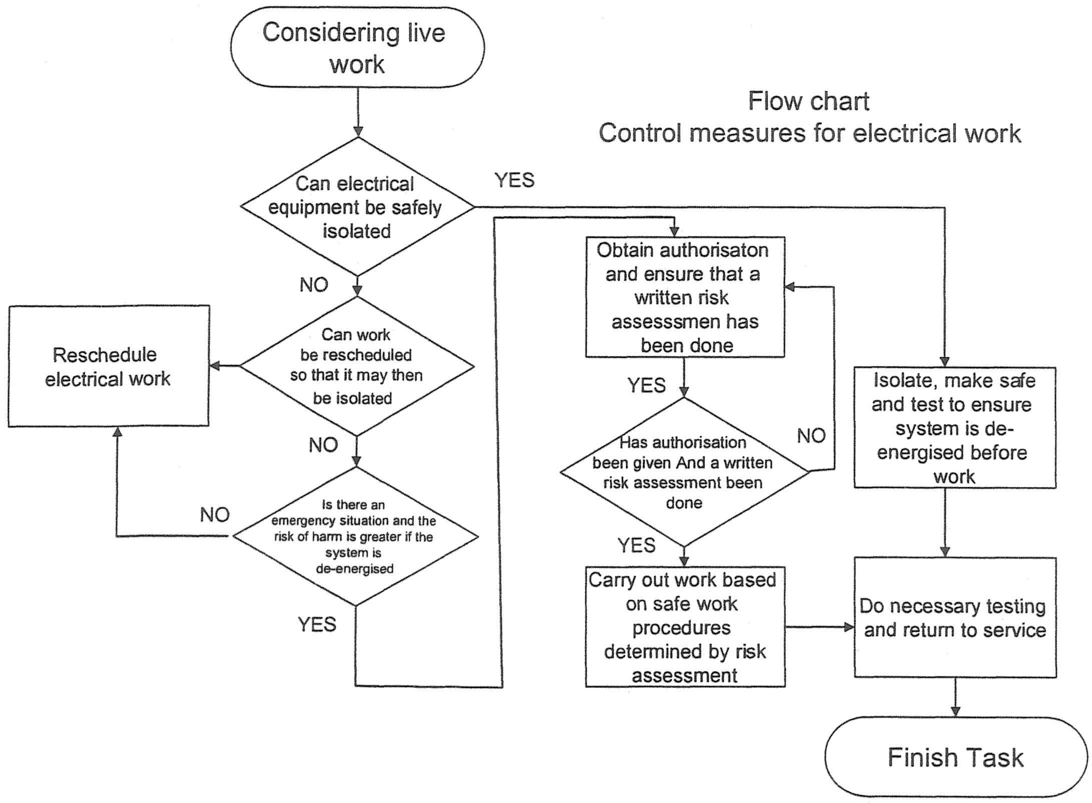
Considering working on live equipment?

Occasionally, electricians feel obliged to cut corners and try to minimize inconvenience to a customer by not isolating the circuit being modified or repaired. It is a very foolish worker who thinks he is saving time by not isolating a circuit on which he is about to work. A simple mistake like cutting the wrong conductors could cost you a pair of side-cutters at the least and cost you your life at worst.
Sometimes, however, it is necessary for you to work on live terminals, cables and equipment. The following flow chart from the Code of Practice for Low Voltage Electrical Work summarises procedures in this situation.



Summary of control methods taken before and during work on live equipment

Work on live circuits, other than testing, should only be undertaken in emergencies and only:

____

____

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Qualifications

People involved in the work must be:

- Competent, qualified and confident of applying the safe working procedures for the job
- Authorised by employer and person in control of premises
- Provided with appropriate PPE for the task
- Observed by a safety observer who is competent in electrical rescue and cardio-pulmonary resuscitation

Preparation

The work area should be clear of obstacles so workers can leave and enter quickly and safely and the following equipment should be available:

- Appropriate test equipment
- Well maintained, insulated tools and accessories. Testing tools must be up to date and have been inspected to make sure they are serviceable
- First aid equipment and facilities. Emergency Services contact numbers should be made available on site
- Evacuation lighting
- Fire fighting equipment suitable for fighting electrical fires

Precautions

The isolation point for the electrical supply must be established and labeled and unauthorised persons must be kept out of the work area by barriers or signs. Electrical workers working on live equipment need to ensure that all precautions are carried out and adhere to the following precautions:

- Work carefully and in an un-hurried manner
- Follow employers safe working procedures
- Assume all exposed conductors and terminals are live
- Maintain an awareness of the voltage between exposed terminals and earth
- Keep accessible electrical fire fighting equipment
- Have a competent safety observer competent in electrical rescue and CPR

Not finished?

Make sure that unfinished work is not a hazard to others in the workplace. Even during the work procedures you should be certain that what you do does no affect the safety of others. It is good work practice to:

- Physically secure cables and terminate all exposed conductors
- Tape and tag terminals, cables and equipment that may contribute to a hazard
- Inform appropriate people that work is not complete and still in progress
- Take all necessary precautions to make sure that un-insulated or exposed sections cannot become live
- Label all sections and circuit that are affected

Exercise

1 You are adding a series of outside lights to a house. To complete this job you choose to extend the existing lighting circuit to include the extra lights. If you cannot complete the job in one day you should

(A) Turn off all lights in the house and instruct the owner not to turn them on until he hears from you

(B) Isolate the lighting circuit at the main switch board by turning off the circuit breaker and telling your apprentice to turn it on before he goes home

(C) Isolate the circuit by removing the cable for the final subcircuit from the fuse or circuit breaker terminal and leave it off until you have finished the work

(D) Start wiring the outside lights leaving the incomplete section isolated from the supply until you have completed and tested the new section

2 If connecting the outside lights means you need to connect to the light circuit in several places you should:

(A) try to keep the supply connected to minimize inconvenience to the owner

(B) use the light switch to isolate each light that you have to loop out of when you are making connections

(C) check the circuit with a multimeter before you cut cables or add connections

(D) isolate the circuit at the switchboard using suitable procedures and accessories to make sure the circuit cannot be re-energised

3 Outline the sequence of steps you would take to ensure safety if you were installing the circuit between the garage distribution board and the pool area by numbering the steps in the list below.
Write one hazard associated with each of the steps in the list.

Number	Step	Hazard
	Install conduit	
	Dig trench	
	Survey area for hazards and other services	
	Install cables	
	Terminate cables in garage distribution board	
	Terminate cables at pool distribution board	
	Test submain and connected circuits	
	Test operation of all accessories and motors	

What else can go wrong?

There are many hazards associated with electrical and for that matter any physical activity. Your risk assessment should have included not only hazards associated with electricity but some of the hazards mentioned previously. These hazards include

- possibility of asbestos or other dangerous dust and fibres
- using ladders, both step and straight

- dangers of power tools

to name a few.
You might also consider hazards associated with working in confined and hot spaces such as the roof space in summer. This hazard is compounded if there are live electrical circuits in the roof space and you are using power tools there as well. Personal jewelry such as metal chains and rings may cause a flashover if they come into contact with live terminals. Metal jewelry will heat up very quickly if you are confronted by an electrical arc and cause a burn at that point. You should not wear rings and chains at work.

More hazards

Because you did such as good, safe job on the garage distribution board, what if the owner asks you to install the circuit for the pool as well? What type of new hazards could this exercise introduce?
You should approach any installation that requires excavation of some type with caution. Often there is no way of knowing what you find when you start to dig.

What types of services are normally underground?

List three utilities that may have services underground.

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Dial before you dig

Telstra advertise this service. The number is 1100. This service will advise you if there are cables or services in the area you are about to excavate.

Even less obvious hazards

Dermatitis

In some parts of NSW and even urban areas, the soil has been poisoned by toxic waste or other uses. If your excavation is on a landfill site, you should proceed with caution. Some previously rural sites have been used for cattle dips. It was common practice to gouge a hole in the ground and fill it with a chemical to kill parasites on cattle. Unfortunately the active life of these chemicals is extremely long and it remains active in the soil long after the hole is filled. The expansion of towns has reclaimed rural land for housing so some people have found that some of these sites are now their back yard.
Contact with this type of material may lead to headaches, skin problems and breathing difficulties. Often your nose is the best set of test gear for this situation. If you find areas that are contaminated with unidentified toxic waste you should notify the owner and the Environmental Protection Agency.

Melanoma

Any task that exposes you to outdoor conditions carries the risk of sun burn and associated skin damage. The most extreme condition is skin cancer or melanoma. You can reduce your risk from melanoma by using protective clothing and sun screens.

Fitness

Digging a hole carries all the risks associated with extreme physical activity. You should make sure you do not work beyond your capacity to work safely any time. Use correct procedures for lifting and manual handling. Make sure your equipment is safe to use. This includes shovel handles, pick and mattocks. Safety footwear is also essential.

Controlling risks

The activities in this section are a small part of the type of risk assessment you undertake on every job. Breaking the whole job into smaller activities is a more manageable way of identifying hazards and assessing the risks. It also lets you delegate authority for certain aspects of the risk assessment.
An employer must identify all the health and safety hazards which could harm workers or other persons in their workplace. You may be part of this process by your contributions to occupational health and safety committees for example. The WorkCover Code of Practice – Low Voltage Electrical Work lists the following ways of identifying hazards and the seriousness of each.

Identifying hazards

- Visual check by walking through the workplace using aids such as plans or maps
- Looking at the way work is conducted
- Consulting with workers
- Reviewing workplace records for previous incidents, accidents and injuries
- Using information from manufacturers and suppliers about the proper use of plant and equipment
- Taking advice from an outside expert of independent adviser

Assessing the seriousness of the risk

The factors that could increase the risk to you or others include:

- Sources of low voltage exposure
- Number of people involved
- Nature of work
- Work practices
- Type of equipment
- Layout and condition of workplace or premises
- Capability, experience, skill and age of workers
- Abnormal conditions that may arise

The employer or his representative should identify any Individual needs of the people who have to carry out the work. Several factors could affect a workers ability to perform certain tasks. For example:

- Physical fitness
- Visual deficiencies such as colour blindness
- Medical conditions such as heart disease, claustrophobia or epilepsy
- Prescribed drugs for temporary ailments
- Proper training
- Fatigue

WorkCover News June-August 2002.
A 41 year old electrician died while working on light fittings in a ceiling cavity.

Even experienced workers may overlook simple precautions and procedures that could have kept them safe. Make sure you assess every task before you place yourself in danger. The combination of severity of injury and the likelihood of injury determines the risk so you should deal with the highest priority first. Remember, though, all risks need to be controlled.

Review questions

1 List four methods outlined in AS/NZS 3000:2000 that may be used to prevent contact with live parts.

2 List four precautions you should take before starting demolition work.

3 What is the main factor that determines the fault level at any point in the installation?

4 What is the highest fault level that is likely to occur in a domestic installation and at what point is it likely to occur?

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5 What is an acceptable method you could use to control each of the following risk factors?
Supply being reconnected before you are clear of the live cables.

More than one source of supply at a switchboard

Working on equipment in close proximity to live conductors

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6 What is the first step you need to take if you are contemplating working on live equipment?

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7 What is the significance of the phone number 1100?

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8 What is Dermatitis?

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9 List five steps you could use to identify hazards in a workplace.

Project

Conduct a risk assessment for your apprentice who you have asked to install the circuit for the pool – spa area. Your apprentice will have to dig a trench for the conduit, install the conduit in the trench and pull in the cables from the pool distribution board to the garage.
List the sequence for the job and the risks about which he should be aware and a control plan for each risk.
Use a table to organise your assessment

Task	Risk	Control measures

Electrical Safe Working Practice

Section 4 High Voltage Installations

Introduction

By now you should be able to outline a basic risk assessment and risk control plan for yourself and others. We have outlined physical hazards by which you are confronted in a typical workplace. We have also introduced some hazards that are not always obvious unless you have some prior knowledge. Electrical hazards are hazards of this type. Unless you know what to look for and the nature of the hazard then there is every chance of an accident.
Installations or circuits that operate at high voltages present all the hazards of low voltage circuits plus hazards of their own. In this section we will outline features of high voltage systems and introduce control methods for hazards.

What you will learn

When you have completed this section you should be able to:

- Identify the parts of an electrical system and equipment that operate at high voltage
- Explain terminology that identifies high voltage hazards
- Describe control methods for dealing with the hazards of high voltage

References

Electrical Wiring Practice – Petherbridge and Neeson
AS/NZS 3000:2000 Wiring Rules
http://www.era.co.uk/product/Grod/tutorial.htm
Network Standard 0156 Energy Australia http://www.energy.com.au
http://www.usbr.gov/power/data/

Definition of High voltage

Use AS3000-2000 to define high voltage.

High voltage distribution

Generally the electrical supply and distribution system uses the following voltages:
Low voltage distribution - 400V
High voltage distribution - 11 000V

- 33 000V
- 66 000V
- 132 000V

330 000V and 500 000V are two other voltages used for high voltage transmission of electrical energy between the power stations and regional substations.

Work on high voltage distribution systems is a highly specialized area of the electrical industry and you would not be permitted to work on this equipment without special training. You could, however, come into contact with the high voltage distribution system accidentally.

High voltage safety

Take the following cases reported by WorkCover as examples:

A WorkCover Inspector, in March 1997 found a transportable home being moved on a low loader by a company manufacturing transportable homes in Batemans Bay.
The inspector saw an employee riding on the roof ridge of the home using his shirt to lift a phone cable suspended just below the high-tension wires. The employee, who was almost 5 metres above the roadway, was walking in a crouched position along the ridge, holding the cable up, as the truck pulled the home beneath the wires.

In this case, even though no-one was hurt, the potential for a disaster was apparent. The company was fined by WorkCover.

Not so lucky

Seven people were injured by electric shock, two seriously, at Cordeaux Dam when a crane came into contact with 310,000 volt, overhead power lines.

A 20-year-old apprentice painter was killed while working at Cessnock TAFE. The deceased man and two colleagues were pushing a mobile aluminium platform to a new location when it came into contact with 11 KV overhead powerlines. The two men were critically injured from the electric shocks and treated in hospital.

The problem here is that even though the high voltage system was installed according to accepted industry standards, the safety factors were reduced by unsafe work practices. A risk assessment of the area should have highlighted the dangers of the power lines and possible contact with workers. The same procedures we outlined in the previous section apply to this type of situation. The lines should be made safe or work practices arranged so contact with the lines was not possible.

Other factors that could lead to unintended contact with power lines include:

- Scaffolding being erected nearby
- Maneuvering long lengths of guttering and down-pipes near power lines. There have fatalities caused when boat owners have assembled the metallic mast of a sailing boat beneath power lines and accidentally

contacted the lines. Farmers have been electrocuted in a similar way when irrigation pipes or grain augers have hit high voltage power lines.

- working in *cherry pickers* beneath power lines
- Tip trucks operating in the tip position beneath lines. The raised tray of the truck hitting the power lines
- Building temporary structures near to power lines allowing easy access
- Reduced clearance under power lines caused by fallen trees or other storm damage

WorkCover publish a Building Site Risk Assessment for Overhead Electrical Hazards. Complete the following table by writing the minimum clearances specified in the Hazard Profile contained in that document.

Voltage	Distance
Up to 132 000 V	
Above 132 000 V and up to 330 000 V	
Above 330 000 V	

You can reduce the risk if you have another worker act as a spotter while ever work continues in the vicinity of the power lines. The spotter can warn you if you accidentally reduce the clearances outlined above.
AS/NZS 3000:2000 recommends that high voltage substations and equipment should not be accessible to unauthorised persons. In general all substations must provide an environment that allows safe operation of the high voltage electrical equipment and protect both authorised personnel and the public.

Signs

Clauses in AS/NZS 3000:2000 specify the requirements for safety signs.

Exercise 1

What is the requirement for signs which are designed to draw attention to the dangers of unauthorised access to high voltage electrical equipment?

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Recognising high voltage aerial systems

There are certain characteristics of aerial supply systems that give you an indication of the operating voltage. In general, the higher the operating voltage of the cable, the greater the clearance between the cable and ground. This means that if two cabling systems, operating at different voltages, share the same pole, the system with the higher voltage is on top.
Another indication of the operating voltage is the number of discs in a disc insulator string.
Refer to supply authority information in your area for accurate information and complete the following table.

Line Voltage kV	Number of disks	
	Termination	Suspension
	1 or 2	1 or 2
	4	3
	6	5
	8	

You will find other types of insulators used besides disk types. 11kV lines sometimes use insulators similar to low voltage *pin* insulators and 66kV and 132kV systems use *Line post insulators.*

High voltage supports

The following diagrams illustrate a range of high voltage support structures and insulators. Complete the table that identifies the typical operating voltages of the towers

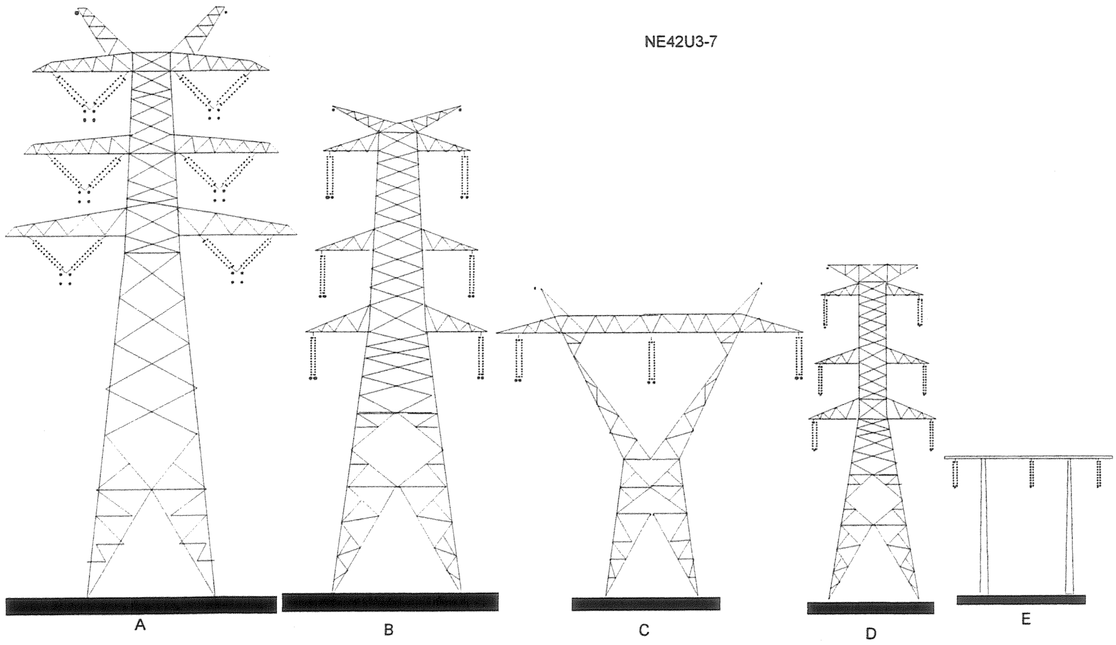


Figure 1

	500 kV Steel tower Dual circuit
	330 kV Steel tower Dual circuit
	330 kV Steel tower Single circuit
	132 kV Steel tower Dual circuit
	132 kV Wood pole

Write the name of the insulators illustrated next to each diagram

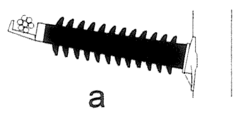
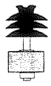

a

Figure 2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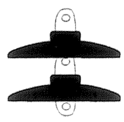
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______________________ ______________________ ______________________

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Exercise 2

Assess the voltage present on the equipment in the following diagrams.

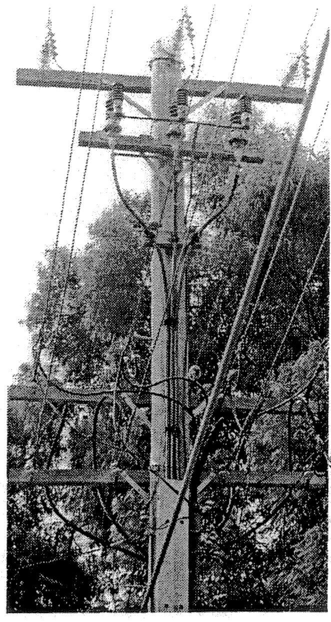
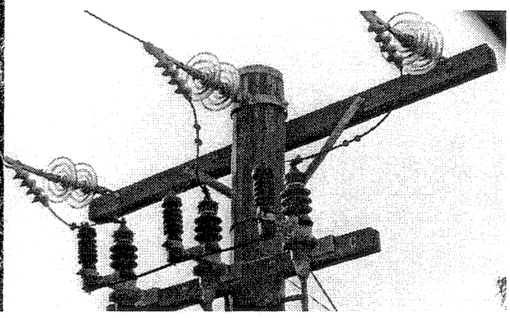
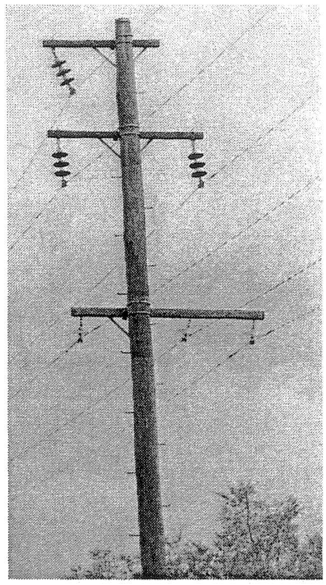

Figure 3

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High voltage underground systems

Overhead power lines are one major hazard but underground systems may be equally as dangerous and harder to see.

Activity 3

What is the phone number you should use before you commence excavation?

____

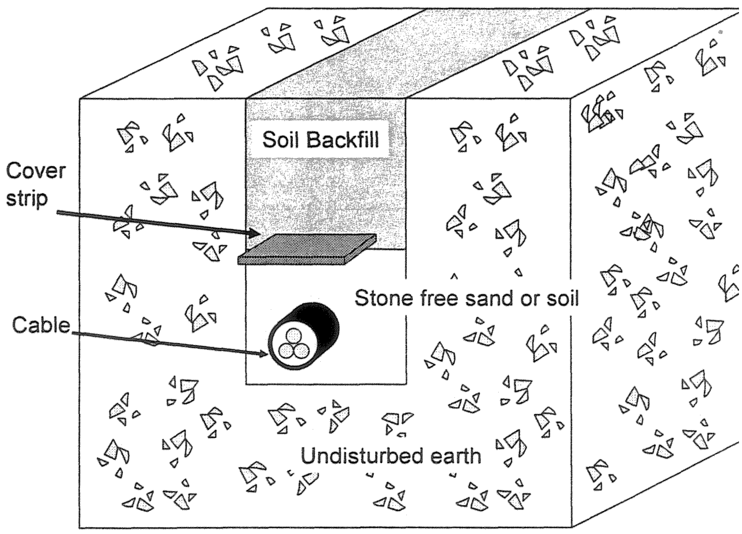
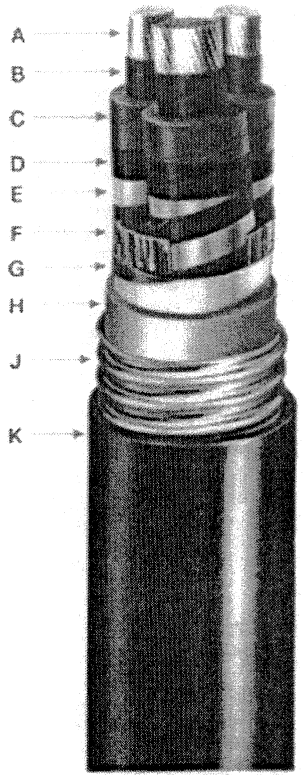


Figure 4 Underground cable and cover strip

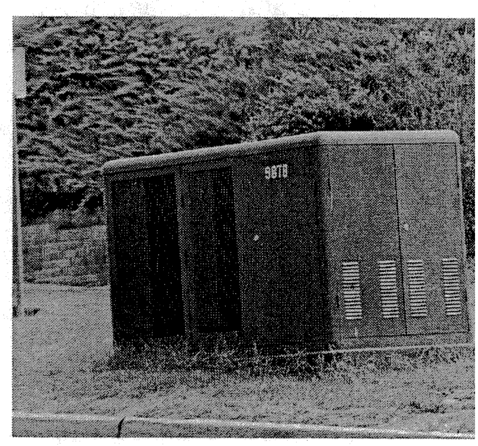
High voltage underground cables are substantially different from low voltage cables. In addition to the insulation, most underground HV cables have screens around each conductor and a screen that surrounds the whole cable. The cable assembly is then wrapped in steel wire armour which is then served with another layer of PVC or Polyethylene. It is not uncommon for high voltage cables to be gas or oil filled so that there is no air trapped between conductors and conductors and sheath. Filling the gaps in the cable with oil or an inert gas increases the voltage rating of the cable.



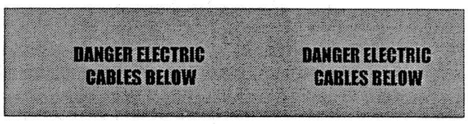
See Electrical Wiring Practice, volume 1 chapter 4 for an illustration of a high voltage cable.

Recognising underground cable installations

To avoid contact with a high voltage underground service, you often need to identify the above ground features associated with these types of installations. Sometimes it's possible to identify areas that have been disturbed and so could be the route of an underground cable. Underground high voltage cables should be installed at least 750 mm underground measured between the top of the cable and the surface. Earthworks may have disturbed the upper layers and the cable may only have a top cover of 600mm so they are easily disturbed by a large digging machine. Generally, the backfill used in the cable trench is imported material and so you can see the difference when you start to excavate. Further, most cables have a plastic warning tape or other type of material buried slightly above. Complete the following list of materials typical of these warning and protective layers:



Kiosk substation connected by underground cables



Polymeric cover strip

a) ______________________________

b) ______________________________

c) ______________________________

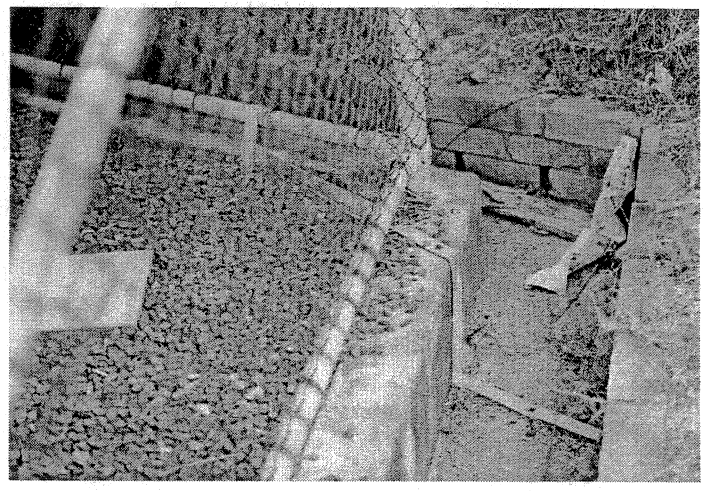
d) ______________________________

You cannot rely on the presence of these materials however, so you should examine the site carefully for indications that cables are buried in the area. If the position of cables is indicated on plans and drawings you should excavate by hand until the cable covers are unearthed. You should then mark the location of the cables above ground by flags or painting on the ground above the cable.

High voltage earthing systems

Treat any cable that is part of a high voltage installation with caution, even earth conductors. Sometimes there are bare earthing conductors buried in the close proximity of older pole substations and switchyards and other structures associated with a high voltage installation.

The position of these conductors is not always recorded on supply authority plans and you should exercise great care if you are working in the vicinity of these installations. If you do uncover cables that are not recorded on any plans, you are obliged to notify the relevant supply authority immediately. There are two recognized earthing systems in AS/NZS 3000:2000 for earthing of substations.



Earthing at the boundary of a HV switchyard

Activity 4

1 Name the two earthing systems described in AS/NZS 3000:2000.

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2 What is the recommended layout for the earth electrodes in relation to an earth grid network?

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3 What is the recommended resistance to earth of the combined earthing system used in HV installations?

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4 What is the difference between a combined HV earthing system and a separate earthing system?

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5 List the acceptable resistances to earth of the high voltage earth in a separate earthing system.

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6 What are the resistances to earth of the earthing system of the low voltage system in the HV substation?

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Risk assessment for excavation near underground high voltage cable

This table is an example of a risk assessment and management scheme

Risk	Management
Contact with HV underground service	Obtain information using "dial before you dig" service
	Have all plans on site at all times
	Mark cable routes on the ground and with flags that are visible to all machine operators
	Calibrate underground boring equipment
	Have all emergency phone numbers on site
	Have a representative of the supply authority present during excavation and cable location procedures
	All people on site are aware of the presence and location of all underground cables and conduits
	Erect safety barriers, fencing or para-webbing to protect staff and members of the public from contact with cables or open trenches.
	Erect safety barriers, fencing or para-webbing to protect underground cables from being disturbed or contact with excavation machinery
	Maintain first aid equipment on site and identify personnel suitably trained to provide first aid to accident victims

Contact with hazardous voltages

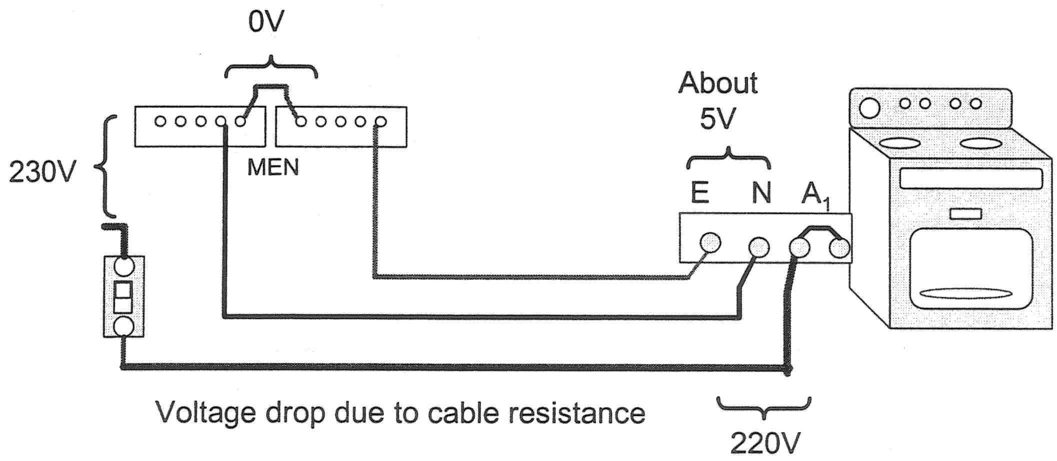
Obviously, direct contact with high voltage power lines or live terminals will have extremely serious consequences. The high currents associated with a high voltage fault have an explosive entry to and exit from the body. Any tissue along the current path will *burn* and be destroyed.
You can also receive an electric shock without coming into direct contact with the high voltage system. Sometimes even earthed metal parts of the high voltage system may have voltages that are dangerous.

> Electrical injuries are often more severe than they appear to be from the outside. Injury occurs not only at the contact site, but also along the path the electricity takes, and at the exit location. Frequently, there is also extensive muscle damage that will not be evident from a visual examination of the skin. These deep tissue injuries cause severe swelling that requires a deep incision extending from the hand to the shoulder to relieve the pressure. If this is not done, the mounting pressure from the swelling will shut off the blood supply by compressing the arteries, rapidly destroying any remaining healthy tissue. Extensive dead skin removal is often necessary to prevent massive infection. Deep burns result in unsightly scars that will often continue to enlarge for 12-18 months after the burn occurs. These scars are not only a cosmetic problem, but may seriously interfere with joint function because motion increases the tension across the wound, which tends to produce even more scar tissue.
>
> Internet document.

Touch and step voltages

Why don't birds that perch on power lines get electrocuted?
Current must flow through your body before you will experience an electric shock. If all parts of your body are at the same voltage or potential, then no current will flow. Current will only flow if different voltages or potentials exist and they are connected by a conductor. All parts of the bird on the line are at the same potential so no current flow and no electric shock.
Earthing or bonding metallic parts of equipment and cabling systems is one way of making sure there are no potential differences between individual exposed conductive items such as metallic supports and housings. In theory at least any parts that are 'earthed' are at the same potential.

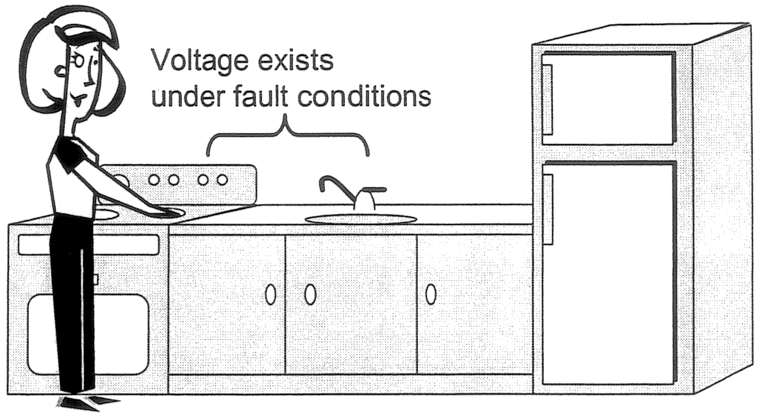
Voltage drop as a source of potential difference

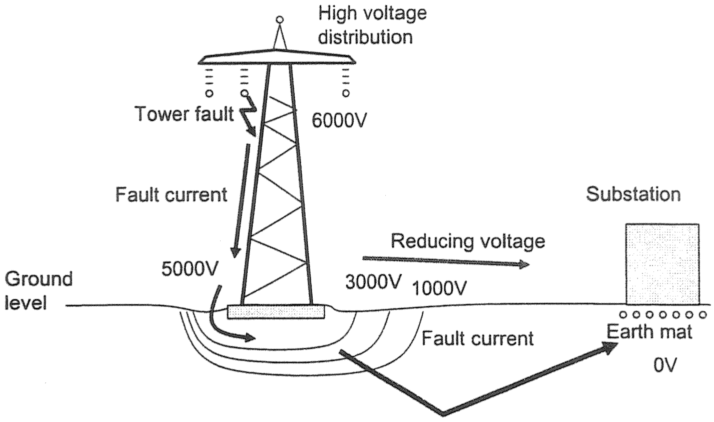


A potential difference exists between the

- supply actives,
- the actives and earth and
- actives and neutral (where one exists).

It is generally safe to assume that the voltage at the switchboard of an installation is the same as the voltage at the load end of the circuit. Under normal conditions, the load voltage won't be exactly the same as the supply voltage but should be within about 5% of the supply voltage. You can see in the diagram that the neutral and earth are at the same potential at the switchboard but when current flows through the circuit conductors, a small voltage difference between the neutral and earth now appears at the load end. This voltage difference is due to the voltage drop along the neutral conductor.

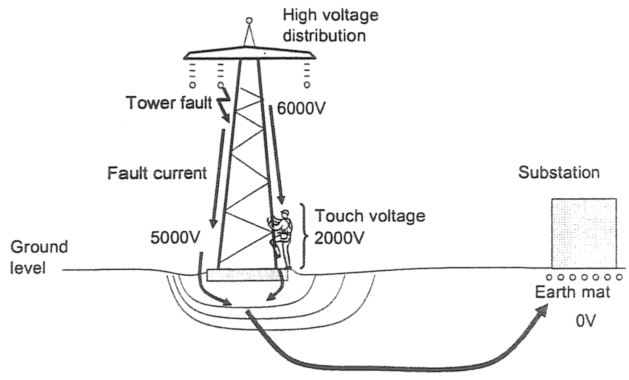


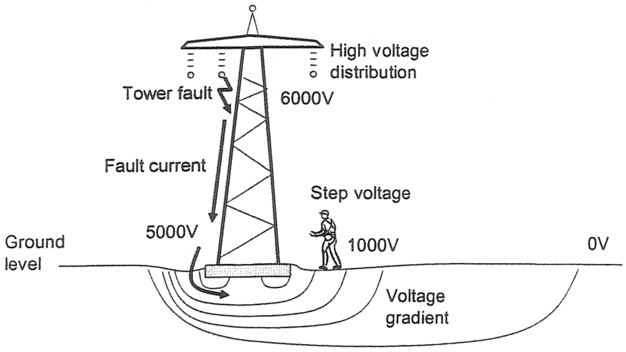


Fault conditions

If for some reason the active conductor comes in contact with the metalwork of the stove, the voltage of the stove metal work will rise above the normal earth voltage. This voltage only exists for as long as it takes for the circuit breaker to trip (fraction of a second). For this brief time the framework of the stove could be 100 to 200 V above normal earth potential. For this time a potential difference occurs between the stove and any other earthed metalwork in the vicinity, the kitchen sink, for example.

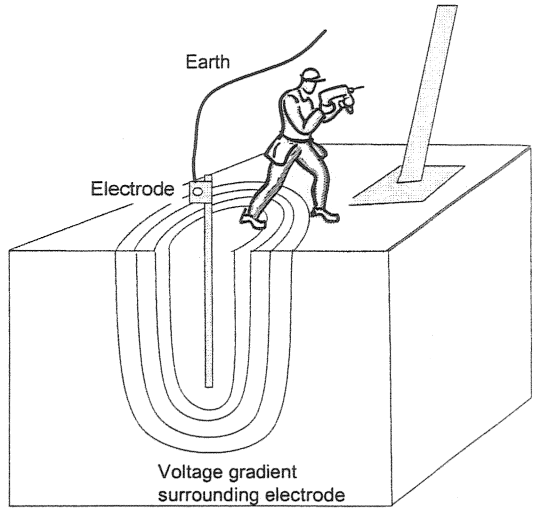
In a properly designed low voltage, electrical installation, this transient voltage is not likely to be dangerous. If the supply voltage was 11 000 volts, this touch voltage may be a thousand volts or more. You're not likely to find many 11 000 volt stoves but similar situations happen when a line from a high voltage distributor accidentally comes in contact with exposed metal such as the metal frame of a supporting tower.





The fault current flowing through the metal frames to earth cause voltage differences. Because of the magnitude of the current, even though the resistance values are only fractions of an Ohm, these voltages may be lethal.

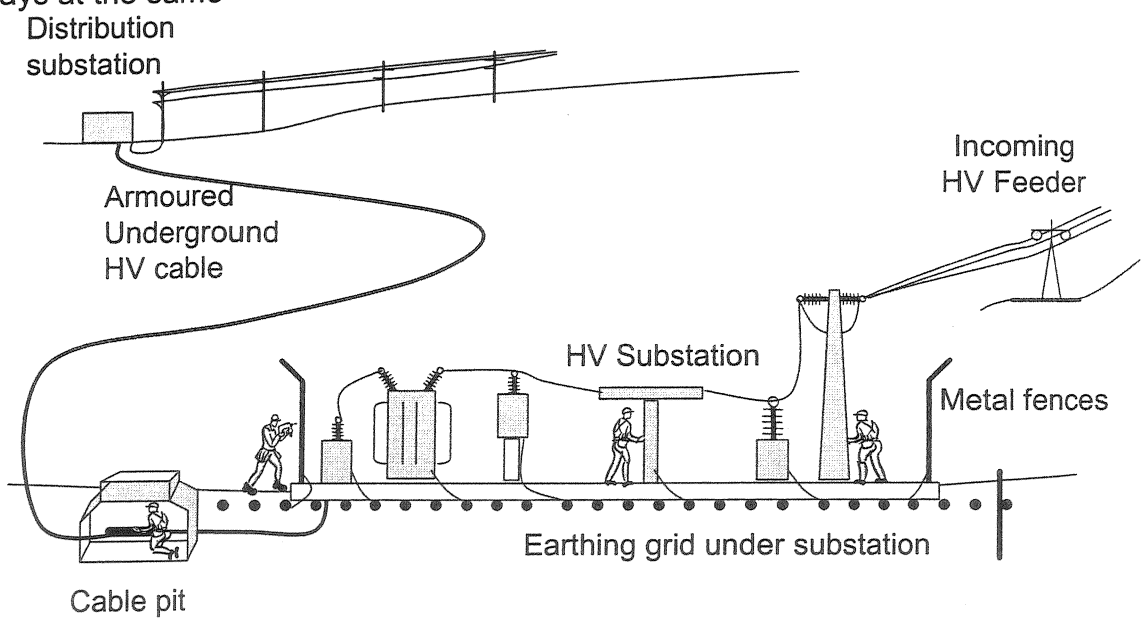
The design of the earthing system associated with high voltage installations must take into account the possibility of a worker standing and reaching over to exposed metallic parts as a fault occurs (touch voltage). The worker must also be protected from the effects of a fault current flowing though the ground, creating a voltage difference between their feet (step voltage). A step means a distance of about 1 metre.



Earth grid

No connection to the planet earth is a perfect connection. All connection methods leave some resistance for the current to overcome. Currents tend to flow deep in the earth rather than along the relatively high resistance of the top layers. As the upper layers of the earth have the highest resistance, it follows that these layers will develop the greatest voltage drops.

High voltage substations have a network of metallic bars and electrodes forming a grid underneath them. Fault currents flowing to earth cause a rise in the voltage between the grid and earth generally. Because all sections of the grid are connected by low resistance conductors, all metalwork connected to the grid stays at the same



potential. Anyone standing on the grid and touching any metal connected to the grid, such as the fence, are protected from a lethal shock. Even if the voltage on the earthed metal rises a thousand volts, all metal is at the same potential so no current flow between metallic parts, just like the bird on the power line.

Exercise 7

1 Using AS/NZS 3000:2000, list the sections of a HV substation that must be connected to the combined HV earthing system.

2 How often should the earthing resistance be measured so that it complies with AS/NZS 3000:2000?

Earth potential rise

One side effect of a fault on the incoming feeder in the diagram is that any metal connected to the HV substation earthing grid will be at the same voltage as the grid. The voltage of the earth some distance from the HV substation will be zero volts. Large potential differences could exist between the edges of the earth grid and surrounding earth. Metalwork such as the armour of the underground cable that services the distribution substation could be at a higher voltage than other metalwork in contact with the earth. This problem could be serious in a cable jointing pit where any screens or armour surrounding the cable would now be at a higher potential than the surrounding metalwork such as access ladders or cable supports. You must use suitable safety procedures to minimize the risk of electric shock caused by this earth potential rise. Two methods you could use to safeguard against electric shock are to:

- Insulate all exposed metal parts which may be earthed or
- Use a wire mesh to bond all exposed metallic parts so that no voltage differences can occur.

This also works in reverse. A fault in the substation could cause the earth grid voltage to rise substantially. A service such as a metallic water pipe could be at normal earth potential because it is buried in the ground outside of the substation area. A voltage could develop between the water pipe and the normally earthed metal in the substation. Bonding the water pipe to the substation earthing system prevents this voltage causing an accident.

Induced voltages

Other factors could lead to hazardous voltages on isolated equipment besides electrical faults. Voltages may develop on isolated high voltage equipment because of:

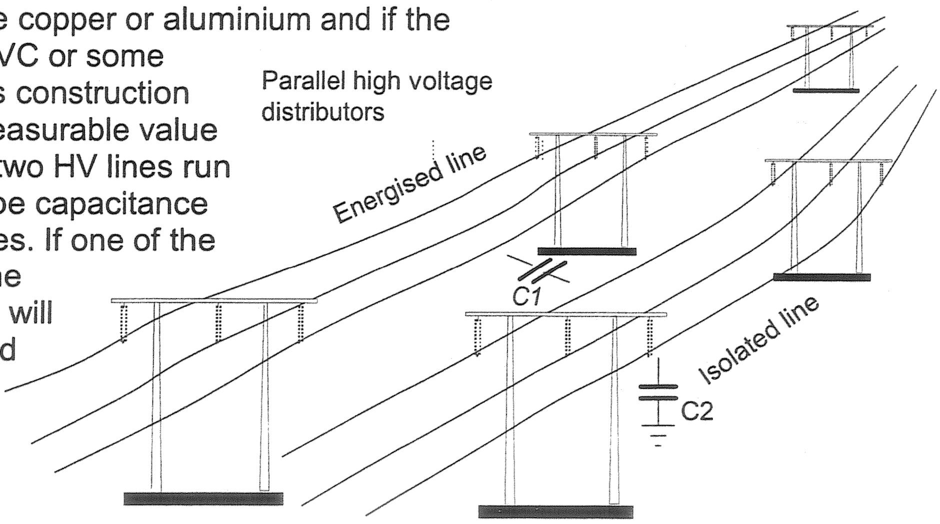
- Static charges
- Capacitive coupling
- Electro-magnetic induction

Static charges

A simple example is the voltage that builds up on a car due to static charges. You know this charge has developed when you step out of the vehicle and get a shock from the car door. Wind and friction generally produce these charges when conditions are dry and there is no circuit, such as conductive tyres, that allows the charges to dissipate. Even though the voltages are high, the energy level is not and so the shock is more of a nuisance rather than life threatening.
This type of hazard is generally not a problem on high voltage equipment but could be hazardous on long, insulated lines. Also, contact with a high voltage discharge may not in itself be fatal but the unexpected shock could startle you enough to make you fall from a ladder for example.

Capacitively coupled voltages

A power cable is basically two or more conductors separated by insulation material. This is the same basic construction as a capacitor. It doesn't matter if the conductors are copper or aluminium and if the insulation is air, PVC or some other material, this construction will have some measurable value of capacitance. If two HV lines run parallel there will be capacitance between these lines. If one of the lines is isolated, the capacitance effect will allow the energised line to charge the isolated line. The voltage



coupled onto the isolated line depends on:

- The operating voltage of the energised line and
- The distance separating the lines. (The closer the lines the higher the voltage)

Even though voltages on the isolated line could rise to several thousand volts, the charging currents are generally low. There is enough current however to provide a shock.

Static charges and capacitively coupled voltages are easily drained away when you connect an earth on the conductors. Earthing HV cables and conductors is standard practice before any work commences.

Electro-magnetically coupled voltages

When an isolated power line runs in parallel with another energised line carrying current, the magnetic field surrounding the energised line induces a voltage in the isolated line. The two lines act in a similar way to the windings on a transformer. The energised line is the primary and the isolated line, the secondary. Earthing one end of the line does not remove the problem. The voltage on the opposite end of the isolated line may be higher than any where else on the line and if you are working on this end you will still be at risk. The usual procedure for HV distributors is to isolate and attach earths at both ends. Earths are then added at the workplace. Long lines can have induced voltages around 1500V and the protective earthing conductors may have to carry induced currents of 30 amperes or more depending on the current carried by the parallel, energised line.

If the towers supporting the cables are in a dry, rocky or sandy area where earthing is difficult, high touch and step potentials exist around the tower legs, guy lines and earthing electrodes. In these areas, you could use a local earthing arrangement, bonding metalwork, earth electrodes and a conductive mat. The maximum step potential may exist at the edge of the conductive mat so you would need to provide safe access as well.

The cable spike

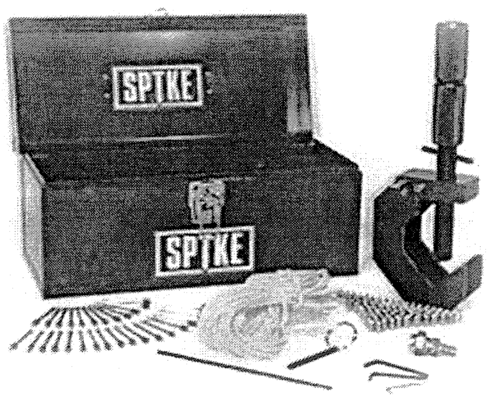


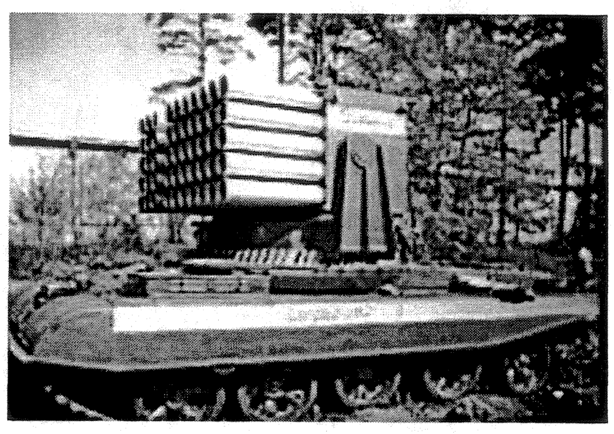
Figure 4 Explosive powered spike

Underground cable may be difficult to identify and test so before any work is begun, the isolated cable is pierced by a steel spike. This spike is controlled remotely so that if the cable is not isolated, the resulting explosion will not injure any workers. These devices may be explosive powered or hydraulic.

Fire extinguishers

Not all fire extinguishers are suitable for fires associated with electrical equipment or installations.
There are five main types of portable fire extinguishers.

- Water
- Foam
- Dry chemical
- Carbon dioxide
- BCF (not used anymore)



Serious Russian fire extinguisher

The most common types are water, dry chemical and carbon dioxide. Which of these is suitable for use on electrical fires?
To answer this question you need to know something about the nature of the supply voltage.

Up to low voltage

If you said "Carbon dioxide", 10 points. You could use Dry chemical also. Water is a poor choice for any fire where there is a chance the equipment is still connected to the electricity supply. Dry chemical extinguishers leave a residue that is difficult to clean up whereas carbon dioxide extinguishers leave no mess. For this reason, carbon dioxide extinguishers are the extinguisher of choice in low voltage substations and switchrooms.

High voltage

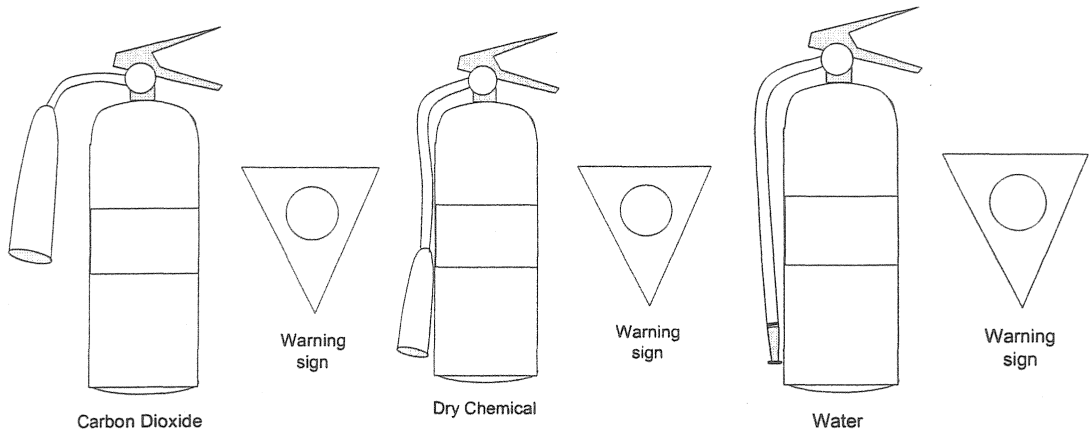
Even carbon dioxide fire extinguishers are not suitable for use on high voltage installations where supply is still connected. Fire fighters must prove the installation is disconnected and safe before starting to extinguish the fire.

Oil fires

Many components in a HV substation or switchyard such as transformers and circuit breakers are filled with insulating oil. An electrical fault could cause a leak and subsequent oil fire. Generally, you could use dry chemical, foam or carbon dioxide extinguishers to fight the fire provided all circuits were isolated. You should have specialist training on fire fighting equipment if you work on HV equipment.

Exercise 8

Colour the following outlines of fire extinguishers in their standard colours.



General safety requirements summary

Use the following points as a guide for working near high voltage cable installations.

All individuals involved in work near areas of high voltage cable installation must observe the following requirements:

- Secure a copy of the cable plan for the work site and note down the location where the cables are buried.
- Use an observer to watch for reduced clearances between equipment and HV aerial lines
- Be trained in first aid, and must carry a rescue kit in case of an emergency.
- Have personnel on site who are trained in pole top rescue procedures when working on aerial installations
- Be responsible for taking notice of all warning signs and any associated instructions.
- Note the location of the nearest telephone and check that it is working correctly.
- Have available on site a permit where required (e.g. road opening permit) for carrying out excavation work in the area.
- Wearing protective clothing, including reflective vests, safety footwear and safety helmet if required.
- Have available on site the appropriate contact numbers in case of an emergency.
- Set up the appropriate safety barriers, witches hats, and warning lights to reduce the risk of injury to the general public.

REMEMBER SAFETY IS EVERYONE'S RESPONSIBILITY

Review Questions

1 List four voltages that you would find in the HV distribution and sub transmission system.

2 Describe one way you can reduce the risk if you are working in the vicinity of HV aerial power lines.

3 What is the likely voltage rating of an aerial cable that is supported by a disk insulator that has three sections?

4 Where would you use a *polymeric cover strip*?

5 List three methods you could use to manage the risk of damage to a HV underground cable if you had to excavate nearby.

6 What is the difference between touch voltage and step voltage?

7 How are touch and step potentials reduced in a HV substation?

8 Describe two methods you could use to protect workers from a rise in potential that may occur in a cable pit at a remote location from a sub station

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____

____

9 How are capacitively coupled voltages controlled in an isolated feeder that runs parallel to a feeder that is still in service?

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10 What type of fire extinguisher is not suitable for fires in electrical equipment if the equipment is not isolated?

____

Electrical Safe Working Practice

Section 5 Electrical Safety Testing

Introduction

In the previous sections we have outlined procedures for assessing risks associated with various tasks in the workplace. In some cases risk could only be identified if you had specialized knowledge of the workplace and materials. Using test equipment is no different. Testing is an essential part of an electrician's duty. The electrician will test for safety as well as correct circuit operation. Working on live circuits is the last option to consider. You should, then, be confident that you can test an installation for dangerous voltages using a variety of test equipment. As well as using correct test procedures you must be able to detect test equipment that is not working correctly. One of the main purposes of this section is outline the safe use, characteristics and care of basic test equipment. Complete installation testing is outside the scope of this module. For a complete overview of testing and installation test procedures you should refer to NUE 408 Electrical installation testing and verification.

What you will learn

When you have completed this section you should be able to:

- Describe safety characteristics of electrical testing devices
- Demonstrate the safe use of electrical testing devices
- Describe the safety checks and storage methods for maintaining the safety of testing devices

References

Electrical Wiring Practice 6th edition – Petherbridge and Neeson
WorkCover Code Of Practice 2001 – Low Voltage Electrical Work
http://www.eso.qld.gov.au/publicat/safebook/
http://www.workcover.nsw.gov.au/Publications/index.asp

Electrical tests

The first test any electrician should master is the test procedure to find out if a circuit is "live" or "dead". A circuit is "live" if it is connected to a supply of electricity. You normally use test lamps or voltmeter for this test procedure and not your fingers. There are also non-contact voltage testers you might use especially in high voltage installations.
AS/NZS 3000:2000 Wiring rules outlines four mandatory tests for electrical installations. High voltage installations also require testing and certification.

Exercise 1

What are the four mandatory tests specified in AS/NZS 3000:2000? Quote the clause number in your answer.

In addition to these tests, high voltage installations using insulating oil require a test for the oil characteristics. Testing transformer oil is outside the scope of this module.

Risk Assessment

Before you undertake any tests, you should conduct your own risk assessment of the situation. If you have forgotten how to approach this assessment, review section 1 and section 3. The WorkCover code of practice – Low Voltage Electrical Work also has more information you should review.

Example

A customer complains that he has no hot water. The customer asks you to check the system to find the fault. What should you do?

Exercise 2

Complete the following risk assessment by suggesting items for the control plan.

Assessment

Hazard	Control Plan
Exposure to low voltage at water heater	• Identify the water heater control switches and isolators by testing

Exposure to low voltage at switchboard during testing procedures	• Identify all terminals and conductors that are live or could become live in the switchboard.
Exposure to possible injury caused by hot water or other causes	• Use safe system of work when exposed to hot water

What test equipment do we need?

The actual test equipment you could use is varied but fundamentally you will need a meter that will test circuit and insulation resistance and another that will test for voltage. Other test equipment such as an ammeter are essential for fault finding in some situations but are not called for in the basic mandatory tests in AS/NZS 3000:2000.
Three basic test instruments that should be in you tool kit:

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These functions could be in the same instrument. Other test instruments include:

- Ammeter (Usually a tongs or clip on type)
- Fault loop impedance tester
- Phase rotation meter

We will consider voltage testing first.

Testing for voltage

What instruments could we use to check for live terminals?
Suitable voltage sensing instruments include the following devices:

- Series test lamps for voltages up to 400 Volts
- Voltmeter (Usually part of a multi-meter)
- Neon test screwdriver
- Electronic voltage tester – Contact type
- Electronic voltage tester – Non-contact type

Each of these instruments has strengths and weaknesses and your own individual preferences will probably lead you to a choice.

Comparison of voltage sensing instruments

The operator of each of these testers requires considerable skill and knowledge to test electrical circuits and interpret the results. This summary is a guide only

Series test lamps	Multi-meter Volt range	Neon Tester	Electronic tester - Contact	Electronic tester - non-contact
Simple operation	More complex. Higher operator skills	Simple operation	Simple operation	Simple operation
Low cost	High cost	Low cost	Intermediate cost	Intermediate cost
Simple maintenance Changing lamps	Normally no user maintenance except for batteries	No maintenance	No user maintenance except for battery if fitted	No maintenance except for battery
On-off indications. Operator may be able to judge voltage after some experience	Accurate measurement of voltage to a fraction of a volt	On - off indication of voltage to earth. Not recommended for any other voltage measurement Unsuitable for voltages below about 90V	Staged voltage measurement to nearest 20 to 50 volts	Generally on – off measurement. Some testers will approximate the supply voltage to earth Not suitable for voltages below about 100V
May put operator at risk if not maintained or used incorrectly Recommend for use with fused leads	Generally safe Digital and electronic types not likely to contribute to hazards	Neon types use body of operator for test current.	Generally safe Not likely to contribute to hazards	Not suitable for armoured and screened cables Not as reliable as contact type testers
No internal power needed	Must have batteries	No batteries needed	Some types do not need batteries for voltage testing	Must have batteries
Relatively low internal impedance Will trip an RCD	High internal impedance Not likely to trip an RCD. Some instruments have a low impedance function.	High impedance Will not trip RCD	Most types will not trip RCD	High impedance Will not trip RCD

Exercise 3

Organise the testing instruments above according to the current they would draw when testing 230V.

Highest current	
Lowest current	

Exercise 4

Organise the testing instruments above according to the relative cost of the instrument. You may need to do some research to answer this question.

Test lamps	
Multimeter	Similar to Fluke 79
Electronic tester	Similar to Steinel Comb Check
Non Contact Electronic tester	Similar to Volt Stick
Neon screwdriver	

Highest cost	
Lowest cost	

Practical testing

With the exception of the neon tester and non-contact electronic testers the use of this equipment is fairly similar. In this section we will discuss some of the differences.

Series test lamps

The series test lamp is a basic voltage testing apparatus widely used by electricians. Its basic construction is probably its greatest advantage. Many electricians may have made their own set of test lamps rather than buy a set and some of these lamps may be sub standard.

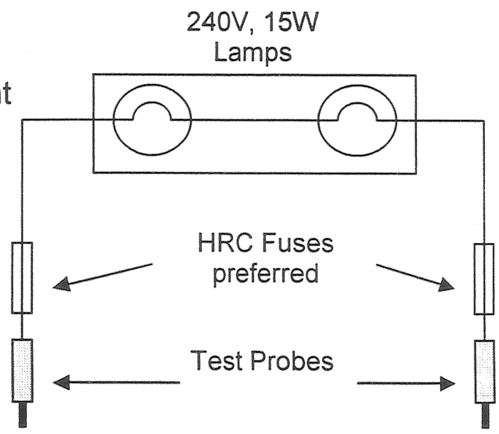
What to look for

Before you use test lamps you should inspect them and in particular look for:

- Two lamps connected in series giving a total voltage rating in excess of 400V
- Lamps are rated for the full circuit voltage

Other characteristics that could lead to an accident

- Leads that have damaged insulation
- Short circuits between leads internally that could cause an accident
- Lamps with a power rating in excess of 15W and are not protected from mechanical damage
- Excessive amounts of bare metal showing at the tips of the test probe. Generally about 3 or 4 mm is sufficient
- Fuse ratings in test probes not excessive. Fuse rating need not exceed about 500mA



A contractor received flash burns when a set of series lamps short-circuited. The leads of the lamps were damaged and not fused. - Extract from Guidelines for electrical workers Queensland

Multi-meter

A multi-meter is an essential piece of test equipment for an electrician or any tradesperson involved in installation and servicing. They may, however, be a waste of money if you do not know how to use them. Multimeters have several types of ranges as well as several settings within a range. Because we are about to test for voltage then the first thing we should do is check the range setting and select AC volts.

Each range or mode on the multimeter has their own peculiar characteristics. The voltage range is generally a high impedance range that draws very little current. Most digital multimeters have voltage ranges with an internal resistance between 5 and 10 megohms and an input capacitance below about 100pF.

The high internal resistance of a multimeter on the voltage range often causes spurious readings when you connect to cables that are open circuit. The meter may read 10 or 20 volts on a circuit that you know is isolated. You may find a similar reading even if you simply hold the leads in your hands. This voltage disappears if you connect the meter leads to a low impedance.

This voltage is an example of an induced voltage. Just as your radio receiver can tune into a signal that exists in free space, your meter picks up *hum.* Hum is low

frequency electromagnetic radiation (EMR) that is emitted from other circuits close to your isolated circuit.
Notice, you should have selected **AC Volts** not DC Volts. Selecting the DC range could be a fatal mistake. Most multimeters read the average voltage when the DC range is selected. The average voltage of a 230V RMS supply is *zero.* If you test this circuit you may think the circuit is isolated and put yourself and possibly others in real danger.
Correct isolation procedures is essential!

Surge voltage ratings

Another important specification that is often overlooked by the average electrician is the *maximum voltage rating.* This rating is expressed as the highest voltage between terminals and earth the meter can withstand continuously. Most instruments meant for use in the electrical trade will have a rating of about 600V. This rating is now expressed as a *Safety Class or Rating* and ranges from CAT I to CAT IV.

IEC 1010-1 Category	Typical use for multimeter with this rating
CAT I	Low energy and electronic equipment. Signal level
CAT II 600V	Outlets and long subcircuits, appliance servicing and portable equipment
CAT II 1000V	
CAT III 600V	Distribution level, distribution switchboards
CAT III 1000V	
CAT IV	Primary supply level, Supply authority distribution lines

Why do we need these ratings

When you are testing the voltage that appears at sections of the installation, you only expect to read the maximum voltage associated with your supply system. In NSW you would be very surprised if, when you are testing for voltage at the terminals of a water heater you measured a voltage in excess of about 240 V. 240V approximately, is the highest voltage, measured between live terminals and earth, that exists in the low voltage distribution system. If this is the case, a 600V rating is a safe bet. Before a meter can get a CATIII 600V rating it must withstand a peak impulse transient of 6000V from a low impedance source, typically 2Ω. This extra rating is your insurance that your meter will not self-destruct if a high voltage surge occurs.
If your meter begins arcing internally, its normally high internal resistance will now be almost zero Ohms. High currents will flow through the probes you are holding on the live terminals of your appliance. If you pull the probes away from the terminals, you will draw an arc from the tips of the probes. This arc could cause a *flashover* between terminals. The full available fault current of this part of the circuit will flow into this arc, melting the terminals and any other metal that is in the way. An explosion results that, not only damages your equipment and appliance, but may burn you as well. All this takes about half a second.

Creepage and Clearance

The higher surge voltage rating is due to increased spacing between terminals and components inside the instrument.
Creepage is the distance measured over insulating surfaces between live terminals.
Clearance is the distance between the live parts measured through the air
Larger distances allow the instrument to withstand higher over-voltage transients.

Incorrectly selected ranges

You can also cause an explosion if you select the wrong range or scale on the instrument. On older or low cost multimeters, you will damage the instrument if you connect it to the supply with the Ohms range or the Amps range selected. If the supply has a large fault current capacity, the meter may cause a short circuit and an explosion will result. Most multimeters now, are protected by a HRC fuse in the current ranges.

An electrical contractor suffered flash burns when testing for voltage with a multimeter at a switchboard. The meter was set to resistance scale and was not fitted with fused leads.
Extract from Guidelines for electrical workers - Queensland

Fused leads provide you, the electrician with some protection. The high currents caused by the incorrect connection of the meter would have blown the fuses in the meter leads preventing an arc at the tips of the probes.

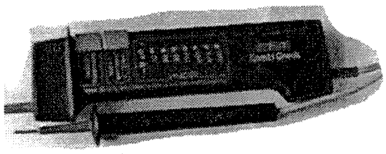
Neon Tester

This piece of test equipment is essentially a neon glow tube in series with a high value resistor, nominally about 50kΩ. The device generally takes the form of a small screwdriver, about 150 mm in length. Touching the blade of the screwdriver to any live terminals while you touch the top of the screwdriver causes the neon tube to glow. The current that causes the glow flows through the tester and you, to earth. Fortunately, the maximum current is somewhat less than 5 mA. This current is just high enough to be felt. The tester will not work on voltages below about 100V and you must be at earth potential before the tester will work as intended.
A power supply operating at a voltage below 100V may not electrocute somebody under normal conditions but you can get quite a bang if you happen to short circuit the supply terminals. Battery backup supplies will feed large currents into a short circuit for a short time. The danger here is not electrocution but fires caused by hot cables, melting insulation and an explosion caused by battery failure.
Neon testers are recommended as a last resort after you have used more effective test instruments. You should use a neon tester to test the exposed metal of a switchboard surround before you commence work. This test should detect the possibility of having a neutral and active reversed and the active connected to the MEN point. (You will deal with this test in another module).
A neon tester would cost about $4 and you generally get what you pay for.

Electronic Tester – Contact

Many electricians have retired their test lamps in favour of the Electronic tester. This instrument combines the ease of use associated with test lamps with some of the features of a multimeter.

The basic tester can discriminate a range of voltages from about 6V AC or DC up to 600V. Some of these instruments have an impedance that is low enough to cause an RCD to trip. Most have a high internal impedance that will not interfere with RCD operation.



Electronic tester – Non-contact

The non-contact electronic tester has taken the concept of the neon tester and removed one of the objectionable features. The non-contact tester does not rely on a current flow that uses your body as a conductor. Instead, it senses the electric field that surrounds energised cables or terminals. The cables do not have to be carrying current but simply connected to a voltage above about 150V. The instrument glows when it detects the voltage. This is a simple go-no go indication. The main use for this device is as a last test before you perform an operation such as cut through a cable in a group of cables that you have isolated or work on a distribution board with a local MEN connection. This instrument should give you an indication if you are about to touch live metal. You can also use these instruments to detect cables that are buried in plaster provided they are not buried too deep.

Using voltage testers

Before you declare any circuit isolated you need to follow these procedures.

- Inspect your test equipment. Do not use any equipment that has damage that will affect your safety.
- Prove the equipment will operate on the voltage you are about to test. There are battery powered products now available that generate a voltage you can use to test your equipment. Generally, you simply connect your meter or tester to a known live circuit.
- Test the circuit for voltage. You must test between all combinations of terminals and all terminals and earth. You must identify the circuit during this procedure. You may test the circuit and it appears dead but it may be controlled remotely or by some automatic process. Off peak water heaters are a common example. This is very important.
- Isolate the circuit. Once again, identification of the circuit is essential. Do not trust the labeling on the switchboard, prove it for yourself. Once the circuit is isolated, use acceptable locking or tagging procedures to make sure others cannot accidentally restore power.
- Re-test your equipment again. If your test equipment is now not operational, then get new equipment and start again.

An electrical mechanic received a severe electric shock while doing maintenance on a commercial dishwasher. It was found that C phase was not controlled by the isolating

switch for the dishwasher (neutral and C phase connections of the switch were transposed).
Extract from Guidelines for electrical workers - Queensland

There are combinations of circumstances where the frame of the water heater could be live and you would not detect this condition using the tests listed above. If you use a non-contact voltage tester or neon screwdriver to test the frame of the water heater you should not get caught out.

If you have measured the rated voltage across the terminals of the water heater element and the water is not heating then it is possible the element is open circuit. You could test this by measuring the resistance of the element.

Resistance testing

Resistance testing could be considered in two ways. We can measure the resistance or we can simply test for *continuity.* Which ever you use, it is essential that you do not connect any instrument to a live circuit unless you have selected the correct range.

Continuity testing

Continuity testing means we test to see if a circuit exists between two parts of an installation. Electricians often use this test when they are trying to identify a conductor that is installed with a group of other conductors and is not identified by colour or other markings. You may use this test to make sure the terminations on a socket outlet are correct.
Multimeters usually have a range that uses a constant current to check a circuit. When the circuit resistance is low enough, the meter *"beeps".* You don't have to look at the meter while you are doing this test. Electronic voltage testers usually have a feature like this also.

Precautions

The test voltage generated by your continuity tester seldom exceeds about 1.5V so under no conditions could you use this range to seriously test circuit insulation. Also, the meter *beep* means different things on different meters. Some instruments will beep when the circuit resistance is below some threshold resistance such as 100Ω. The continuity function on an electronic voltage tester may beep whenever the circuit resistance is below 1MΩ. If your tester thinks that anything up to 1MΩ is *continuous*, then this range is of little use. The insulation resistance of a water heater could be as low as 10 kΩ and still be acceptable. If an earth conductor has a resistance of 100Ω then an extremely hazardous condition exists.

Measuring resistance

It is probably better when fault finding and installation testing to use the resistance ranges of your instrument.
You need two specialist instruments to test resistance, the Ohmmeter and an Insulation Resistance (IR) tester. The difference between these two instruments

is outlined in the actual specification for the tests in AS/NZS 3000:2000 Clauses 6.3.3.2.2 and 6.3.3.3.
An insulation resistance tester must be able to maintain a test voltage of about 500V into a resistance of 1MΩ. Your Ohmmeter on the other hand must be able to measure accurately a resistance as low as 0.5Ω.
Manufacturers do market a single instrument that tests both of these characteristics but you need some skill and care to make these tests accurately.

Exercise 4

List the voltage variations that AS/NZS 3000:2000 allows for correct insulation resistance testing.

High value ______________________

Low value ______________________

Using the Ohmmeter safely

It is good practice to test every terminal with your voltmeter before you begin to use your Ohmmeter or IR tester.
If the water heater is isolated, you could now proceed to measure the resistance of the element. If you do not know what the resistance of the water heater element should be then there is little use of going any further. You should, by now, know how to calculate the element resistance.

Approximate resistance of typical water heater elements

Element rating (230-240V)	Resistance
4800 W	12Ω
3600 W	16Ω
2400 W	24Ω

Using the insulation resistance tester safely

The IR tester is an Ohmmeter that applies a much higher voltage to the circuit under test than a standard Ohmmeter. Most IR testers have at least two test voltages and many have three. The most common test voltages are:

- 500V DC The voltage specified by AS/NZS 3000:2000 Clause 6.3.3.3 for single and three phase circuits
- 1000V DC

In addition many IR testers have a 250V test range. This range is useful if you have to measure a resistance accurately that falls below 1MΩ.
Generally the insulation test is a pass – fail type test. The lowest insulation resistance for general wiring work is 1MΩ. However this value may be reduced for some appliances and sheathed heating elements.

Exercise 5

Between what parts of the installation is the Insulation Resistance test conducted?

The output of the IR tester is not likely to cause you an injury if you come into contact with the test probes. It will, however give you a shock.
Do not use this instrument to play practical jokes!

HV insulation resistance testing

Insulation resistance of HV installations is a specialized area. AS/NZS 3000:2000 Clause 7.8.13 outlines features of a HV test on a complete installation.

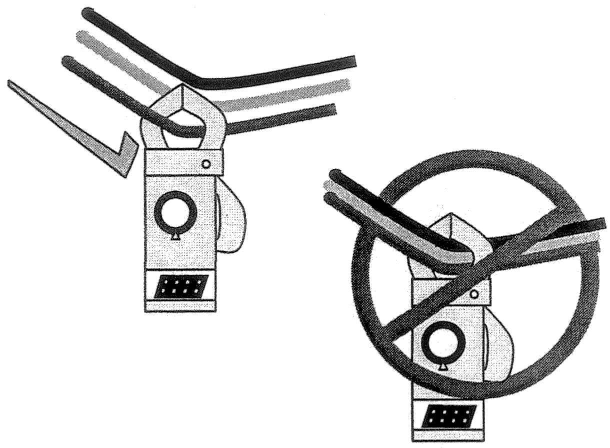
Precautions

- Make sure the supply is isolated. Always test for voltage before you test circuit or insulation resistance. Even a few volts on a circuit will upset the resistance reading.
- Make sure you do not have any parallel paths that might disguise a faulty element or give a low IR reading. It is probably better to remove at least one of the two conductors connected to the element. Correct IR testing of compete installations is covered in other modules
- Read the display carefully. Digital instrument often have an auto-ranging feature. This means the instrument selects the range that gives you the most accurate reading. It is easy to overlook the range reading and think you are reading Ohms when in fact the instrument is on the kΩ range. Most IR testers have a multiplication factor you apply to the meter reading, depending on the test voltage.
- Check zero setting. Most digital instruments do not require any zero calibration however some analogue instruments still need you to set the zero reading allowing for the resistance of leads and any changes in battery voltage.
- Test the battery voltage before you start to test. A low battery may add errors to your readings
- Warn other workers who may be exposed to conductors or terminals you are intending to do an IR test

You must be able to test circuits accurately and reliably so dangerous conditions do not go undetected.

So, with the water heater isolated, you have tested the resistance of the element and the contact resistance of the various pieces of control equipment such as the thermostat and the over-temperature cut out. The resistance of thermostats, over-temperature cut-outs and so on should be close to zero Ohms. If any of these pieces of equipment are faulty, you could now replace them. Under no circumstances should you reconnect an appliance with safety and control elements removed.

Before the water heater is placed back into service, you should test the resistance of the earthing circuit. The resistance of the earthing circuit should be in the order of 1Ω or less. The actual value depends on various factors outlined in AS/NZS 3000:2000 and is outside the scope of this module.



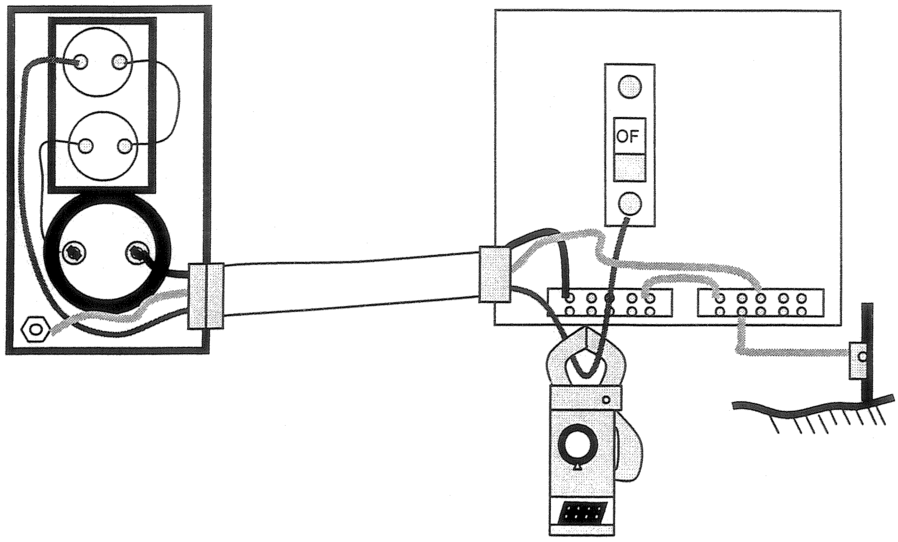
Testing circuit current

Before you declare the water heater repaired you should test the current drawn by the element. This is probably better than standing around for hours waiting for the large mass of water in the water heater to heat up.
Connecting an ammeter to a circuit is a tricky process. If you get the connection wrong you could cause a severe fault. Remember, the ammeter must always be connected in series. It is probably better if you use a clip on or tong type ammeter instead. Most electricians would use this instrument for current measurement. If you do not wish to have a separate tong tester, you could buy a unit that adds on to your voltmeter.

Using a tong type ammeter

The tong tester is a non-contact instrument that uses the strength of the magnetic field surrounding a conductor to determine the magnitude of the current flowing.

- The instrument may be a transformer type which is only suitable for AC currents or unfiltered rectified AC or
- A Hall Effect type which may be used on AC or DC. (much more expensive)
- Most tong ammeters are designed to work with mains frequency (50 Hz). The accuracy of the instrument decreases as the frequency rises. Most instruments will provide a reasonable degree of accuracy up to about 400 Hz.
- Most instruments have several ranges from as high as 1000A to about 6A. Some instruments have a mA range. This range is most useful when you are testing for leakage currents
- Most instruments have a voltage and Ohms function. You use these functions just like a normal multimeter. You need test leads for these ranges.
- The clamps must be closed securely before you take a reading. Having the clamps slightly open gives you an incorrect, lower reading.
- The instrument must enclose only one conductor other wise you will not get a true indication of the circuit current



Testing leakage current

The mA range on a tong ammeter is a useful addition. A leakage current of 15 mA may cause nuisance tripping of residual current devices. The low current range of the tong tester will let you locate sections of the installation with excessive leakage. With a few accessories, you can even test individual appliances that normally connect through socket outlets.
This is one of the times that you put all active and neutral conductors through the clamp of the tester at the same time.

Safety precautions

As circuits are energised when you are using a tong ammeter you should apply the same risk assessment as for any operations you perform on live circuits. You should refer to the WorkCover Code of Practice Low Voltage Electrical Work for a list of recommended control measures you should use when fault finding on or near live conductors.
In general, you should:

- Check the operation of your equipment before you use it
- Check the maximum voltage of the equipment on which you are about to work. You should not use a standard tong ammeter on any circuit that has a voltage in excess of 600V. Special instruments are needed for high voltage testing.
- Never measure current while test leads are still connected to the meter jacks
- Only use the tong ammeter around insulated conductors
- Avoid working alone when testing at a live switchboard. Use a safety observer
- Do not use any instrument that is damaged
- Manufactures recommend you wear personal protective equipment such as insulating gloves, eye protection and protective clothing if you are using a tong ammeter. This is not a bad idea anytime you are testing in an area where high fault currents are likely.

Activity 6

Describe one example of a part of an installation where there may be the likelihood of a high fault current (>1kA).

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Symbols

How do you know the instrument you paid good money for is fit and safe to use? Organisations such as the Institute of Electrical and Electronic Engineers (IEEE) or the International Electro-technical Commission (IEC) agree on certain standards of manufacture and design that would maintain an agreed level of safety and performance. These recommendations and others are agreed to by a panel of standards organizations from various countries. The recommendations are then written as a standard in that particular country. In Australia there is the Australian Standards Association who publish standards for use in many sections of the Australian community.

Testing laboratories use these standards to design tests for equipment or systems intended for use in the community. Manufacturers of equipment have their products tested by these laboratories who then issue a report certifying the equipment as complying with these standards. These products are listed on that laboratories data base. A listed product is commonly identified by the testing laboratory's listing mark (UL, TL, MET, FM, etc.) conspicuously attached to the product. This listing mark indicates that the device manufacturer has submitted a sample to the laboratory for product safety test and evaluation in accordance with the relevant product safety standard. Once the testing laboratory finds the product fully complies with the standard, it grants the manufacturer permission to affix the agency listing label to the products.

Agency marks are issued by testing laboratories that are recognized internationally. For example, almost all Multimeters will have the logo of the Underwriters Laboratory stamped on the case somewhere. UL is an independent testing organization from North America that is capable of making sure a wide range of equipment complies with internationally agreed standards. There are other organizations that perform this service also, each with their own distinctive logo. The inclusion of some of these logos on the case of the instrument is voluntary and others are mandatory. The CE mark (Europe) must appear on equipment intended for market in the European Community. In Australia electrical equipment must have a state approval number or bear the Australian Regulatory Compliance mark (RCM)

Most test and measurement equipment is tested by laboratories using equipment that is traceable to the National Association of Testing Authorities (NATA) Australia.

Samples of compliance marks

The table below contains some symbols you are likely to see attached to electrical equipment.

Exercise 7

Write the name of the organization that uses the symbol in the adjacent space.

CE	
TÜV Rheinland Product Safety GS	
NATA	
UL	
SP	

Exercise 8

The following anagrams belong to other organizations that are involved in standards. Write the meanings in the spaces following each.

NEDA ____

ANSI ____

Maintaining instruments

Most instruments that you use for testing installations and circuits require very little maintenance. A quality instrument will provide you with service for many years if you use a little common sense. The following list includes some precautions you should use to avoid damage and loss of calibration.

- Keep meters in their cases. Most meter cases provide protection from knocks. Some manufacturers provide cases that in combination with robust meter construction will survive a drop of two metres.
- Avoid wide ranges of temperatures. Some manufacturers state a minimum operating temperature of -10°C to a maximum of +50°C.
- Keep instruments away from moisture and corrosive chemicals.
- Turn you meter off when you have finished testing. Some meters will drop into a low power state when not used for a while but it is good practice to switch them off. Otherwise when you need the instrument next the battery will be discharged completely.
- Check your battery. Some instruments draw very little current. Battery life can be up to 1000 hours or continuous use. Most meters are used intermittently and so the batteries may last for a year. Check batteries regularly. Make sure the batteries do not leak and cause damage to the battery compartment.
- Inspect leads and probes. Faulty leads may cause incorrect readings especially when combined with poor test procedures. An open circuit lead

could be dangerous. Leads with bare sections or faulty insulation are equally as dangerous. Probes with long exposed sections can cause accidental short circuits and subsequent flashovers on busbars.

- Keep spare meter fuses with the meter. You will not be tempted to use sub-standard fuses if you accidentally blow a fuse.

Two electrical mechanics suffered severe flash burns while testing phase rotation at a large switchboard – a test probe shorted between phases. Extract from Guidelines for electrical workers - Queensland

Review questions

1. List four installation tests recommended by AS/NZS 3000:2000

2. What is the recommended power rating of lamps used in a set of series test lamps?

3. Name two types of voltage testers that do not require two test probes

4. How many different ranges are normally found on a multimeter?

5. What is meant by the safety class or rating of an electrical meter?

6. What is the difference between creepage and clearance distances?

7. Explain the difference between an Ohmmeter and a continuity tester.

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8. What is the test voltage recommended by AS/NZS 3000:2000 you should use to test the insulation resistance of a 230 / 400V three phase circuit?

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9. List four safety precautions you should take before you test the resistance of a heating element in a three phase kiln.

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10. What special precautions should you take before testing the insulation resistance of installation wiring?

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11. How does a tong ammeter detect the current flow in a conductor without making contact with the conductor?

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12. List four safety precautions you should take before testing current in a circuit if you are testing at a main switchboard

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13. What authority uses the following logo?

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