Learning resource

Isolate and test low voltage electrical subcircuits
(level 2, credits 2)

Trainee Name: ______________________________

Acknowledgement

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Introduction

Working with electricity is dangerous. You will regularly use test gear on live circuits, work on wires that seconds ago would have killed you had you touched them. The stakes are high, and the payment could be your life. All so morbid! But true.

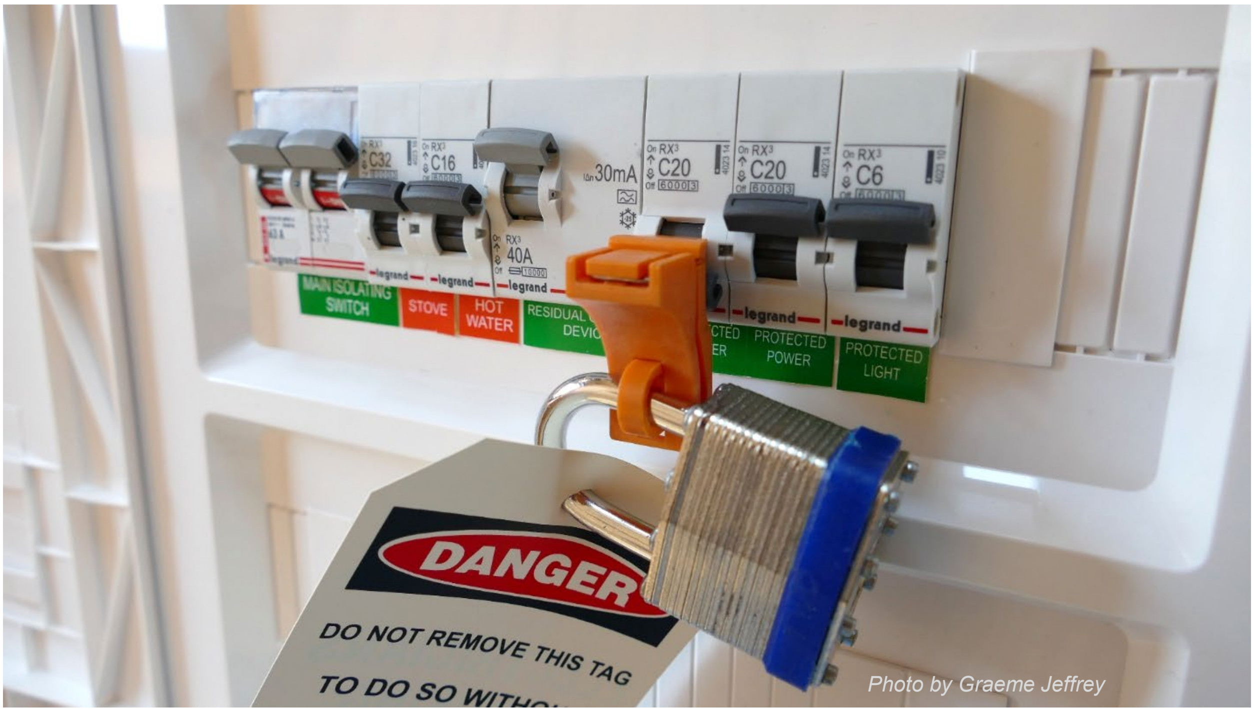
That is why you need to know what you are doing and how to make a circuit safe to work on.

Pay attention to this unit, and while it may seem daunting to a new apprentice, there are simple basic rules to follow that will help you be safe at work.

Learning Objectives

At the conclusion of this module the trainee will be able to demonstrate a basic introduction to knowledge of electrical testing for safety, which includes being able to:

- Isolate electrical circuits from the supply of electricity
- Test electrical circuits to ensure safety prior to reconnection



Isolating Electrical Circuits

Before working on a circuit, you must ensure that it is safe for you to do so. Part of making sure a circuit is safe is actually understanding what type of circuit you are working on and what sort of power supply the circuit has. It will make a difference to what you do.

Is the circuit a:

- Subcircuit
  - A circuit originating at a switchboard and to which only consuming devices or outlet points will be connected.
- Submain circuit
  - A circuit originating at a switchboard to supply another switchboard.
- Mains circuit
  - The first circuit originating at the incoming supply source and delivering the supply to the first switchboard in the installation

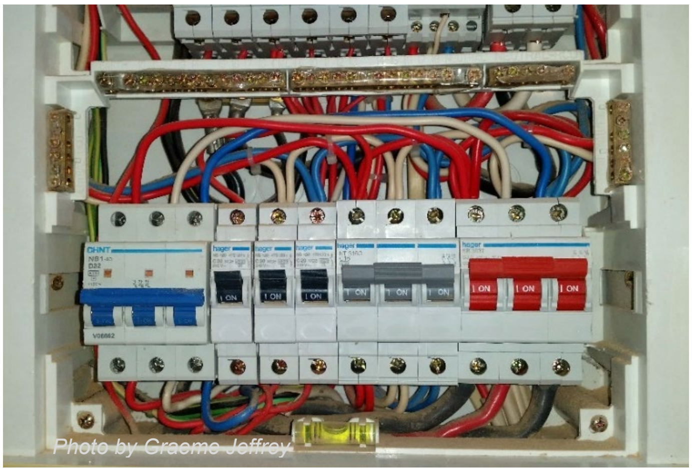


Photo by Graeme Jeffrey

Is the power supply:

- Single-phase
  - One phase conductor and a neutral conductor. 230V.
- Two-phase
  - Two phases, with or without a neutral conductor. 400V between phases, 230V between phase and neutral/earth.
- Three-phase.
  - Three phase conductors, with or without a neutral. 400V between phases, 230V between phase and neutral/earth.

Are there any special control systems or other factors that may liven the circuit without warning? Such as:

- Ripple controls
- Thermostats
- Daylight sensors
- Timers

Is there a possibility of a second supply on the same equipment or in the same place? A common example of this is the occasional light switch which has switches in different circuits, supplied by different protection devices.

Removing the load


Photo by Toi Ohomai

To extend the life of circuit breakers and to prevent arcing in fuse holders that may burn you, turn the load off before turning off circuit breakers or pulling fuses. This is often as easy as just switching off a socket outlet supplying an appliance.

High inductance loads are particularly bad for causing arcing, things like motors and fluorescent lights.

Turning off the load is also important so that electrical equipment doesn't jump into life when you re-liven a circuit. This could frighten someone or worse, hurt someone.

Isolating circuits

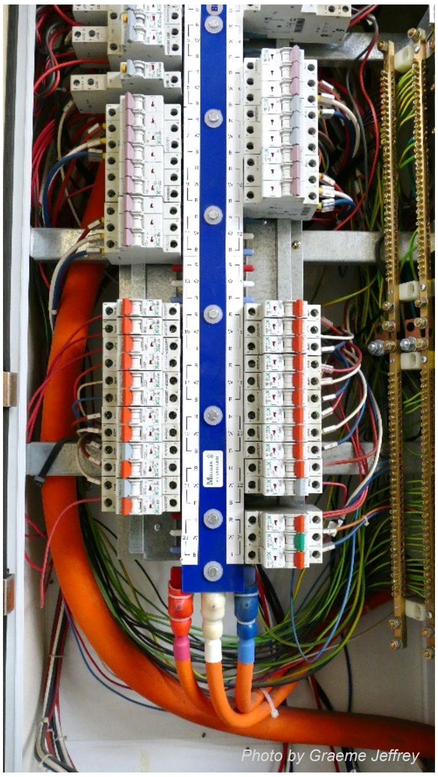


Photo by Graeme Jeffrey

Before isolating a circuit, it must be positively identified as either a single, two or three phase circuit. Since there is seldom an isolating switch for a circuit or subcircuit, the circuit will have to be traced back to the switchboard and its protection devices.

A quick look at the main switch for an installation will reveal if more than one phase is available to supply circuits. All power supplies should go through the main switch.

While we say should, to become an old electrician and not a statistic, you can never assume, you must always be careful, suspicious and you must be sure.

There are times where you might be working on an installation that previous owners or someone thinking they are handy have done some work and it is dodgy!

You are going to hear the following over and over because, it is so important to your personal safety.

The two "Golden Rules"

1. Test before Touch – always test electrical wires are not live before you touch them.

2. Prove-Test-Prove

(a) Prove the meter works on a known supply.
(b) Test for Isolation.
(c) Prove the meter still works on a known supply so you know your meter hasn't failed during the test.

Isolation at the Switchboard

Photo by Graeme Jeffrey

All being correct, for a single-phase circuit, there is one fuse or circuit breaker, for a two-phase circuit, two, and for a three-phase circuit, three.

For multiphase circuits, combined circuit breakers with one linked handle are commonplace.

At the switchboard, there will be a number of fuses or circuit breakers, you will have to find the correct ones.

Fuses will need to be removed and circuit breakers turned off to identify the ones that are feeding the circuit that you are isolating.

If there is not much information available about the circuit, or the labelling is not very helpful, you are going to have to use your investigative skills to find the correct protective devices.

Because you may need to work your way through a few circuits before you get to the right one, it is important to first check with the owner or supervisor of the area before starting.

It could be inconvenient or even disastrous if you shut down a computer and corrupt a file someone has been working on for days, stop a manufacturing process or turn someone's home based life support equipment off.


Photo by Graeme Jeffrey

You could affect:

- Medical equipment
- Life support equipment
- Office equipment
- Manufacturing processes
- Appliances mid cycle
- Computers
- Baking in the oven (especially if it is a cake for your smoko!)

Take care that you have a process to correctly identify the right protection devices for the circuit.

Failure to identify the correct fuses or circuit breakers may result in one or more of the following happenings:

(a) Withdrawing incorrect fuses may cause another appliance, piece of equipment or circuit to fail or stop during an essential operation (think of that cake!). Seriously though you could cause real problems if you are not careful.

(b) Withdrawing fuses supplying an appliance or circuit in operation could “draw an arc” and cause damage to equipment or personal injury.

(c) The appliance or circuit to be disconnected will be left energized, thereby creating a possible hazard.

Procedure for correct isolation

Do your best to narrow down the correct protection device. Use clues like:

- Labelling
- Type and size of cable
- Number of phases
- Current rating of the protective device
- Technology (circuit breaker finder as shown)

Next, use some form of live circuit indicator to help find the correct circuit. There are a variety of ways this can be done, depending on the circumstances. It is always easier with a helper, but it can be done by yourself. Use a:

- A voltmeter
- An indicator light
- A buzzer

While monitoring the indicator, turn off the protective device and see if the voltage disappears. If it does, well done, it looks like you have got the right one.

But are you sure? What else may have happened at the exact same time? The power went off? A timer just turned the circuit off? Someone else turned a switch? Coincidences happen.

To live to be an old electrician, always take away any doubt by using the “thrice” (three times) rule.

Note: The thrice rule

Once a fluke, twice more likely, thrice is nice.

Turn the device on and off two more times to make a total of three offs, and as any gambler knows, the odds of that being a coincidence are just too high. You can have confidence that you have the right one.

Secure the isolation

Well done, you have found the correct circuit protection device or isolator. Now you have to make sure that the circuit stays safe while you work on it.

Danger is still possible. An isolation is not complete or safe unless the isolation has been secured.

A person could mistakenly replace a fuse or close an isolating switch not knowing that work is in progress.

Photo by Graeme Jeffrey

With a fuse, a simple precaution is to remove the fuse and put it in your pocket or to replace it with a blank or dummy fuse.

If you are still not certain it is safe, you can remove the circuit conductor from the fuse behind the panel and tape it up or put a connector on it to prevent re-livening.

Most isolators and circuit breakers have a locking facility which can be used to prevent accidental re-closure.

Use a padlock and keep the key in a safe place.

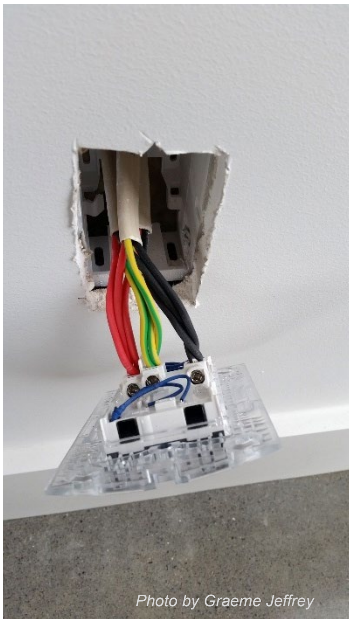
A personal danger tag should accompany each lock used on an isolation.

The tag identifies the person who put the tag and lock in place.

Test for Isolation

Remember the first golden rule?

Test before Touch – always test electrical wires are safe before you touch them.



Having isolated the circuit, you need to test the circuit before touching it.

This is to make sure that every conductor is safe before you start working on it.

The voltage indicator you used before was just to help you find the right circuit.

Now you need to get serious, and properly test that all the equipment and conductors on the circuit are dead (and not you).

Things can go wrong, and it is often when problems combine that people get caught out. When there is a disaster, it is often when two or more factors come into play which turn an everyday situation into a death trap.

There are a number of instances where parts of the circuit may still be energised, for example:

- The circuit is wired incorrectly.
- The isolation switch is not in the phase conductor.
- The wrong circuit has been isolated.
- The wrong switch, fuse or circuit breaker has been operated.
- As the equipment is pulled away from the wall, a cable contact fault is created.
- Damaged insulation or bad termination causing intermittent contact between two conductors, one from another live circuit.
- The appliance or equipment is supplied from two sources, or there are live conductors present from controls such as:
  - Thermostat switches
  - Control sensors
  - 3 plate ceiling roses
  - Limit switches
  - And many more possibilities

Testing for isolation must be done with a suitable test instrument with a correct rating and category.

Warning!

- Serious question - if you pick up your voltmeter and turn it on right now, what voltage reading does it give you?

Is your answer 0V?

- Oh, okay then, the circuit is isolated safe to work on! Your meter says 0V!

I hear you say you've lost it mate! What are you on about?

- The point is, a voltmeter not connected to a circuit, or a broken voltmeter, or a voltmeter with a broken lead all give a 0V reading, and that is exactly what we want to see to confirm a safe circuit isolation, no volts.

Can you see the problem?

- So, if you:
- don't get the meter connected properly to a live circuit, or
- if you use a meter that is broken, or
- have a broken lead, or
- have blown fuse in the lead, or
- the mulitmeter is set on the wrong setting (DC instead of AC)

- *- on a **live circuit** you will get a safe reading of* 0V *and that says that the circuit is isolated and safe to work on! .... And it is not!*

Danger! Danger! Danger!

- The absolutely and critically most important reading you will ever take for you safety can be achieved with a broken voltmeter sitting in the back of the van!

- You must always be absolutely sure that your meter is working properly before you trust a result of 0V.

I hope that point has got through because, that is exactly why there is a second golden rule.

Remember the second golden rule?

Prove-Test-Prove

- *(a) Prove the meter works on a known supply.*
- *(b) Test for Isolation (and get 0V).*
- *(c) Prove the meter still works on a known supply so you know your meter hasn't failed during the test.*

Proving is done by using the test instrument on a live circuit to check that it is working properly and observing the correct measured voltage is displayed.

The reason for this is to prove that the meter is working at the beginning and still working at the end of your testing. You can then be confident that your test result is reliable.

Procedure for tests

As a sparkie, you could be called to work on something that is faulty, a socket outlet for example.

So, you are dealing with a fault situation. The cause might be that there is a short in the cable and the earth has become live. Or a home owner has connected the wiring up and got it all wrong.

Assume is not a tool sparkies are to have in their toolbox. Assume makes statistics, not old sparkies.

Remember: ASSUME spells –

makes an ASS (donkey) out of U and ME


Photo by Graeme Jeffrey

You must never assume that the neutral or earth conductors are not live, they may be for some odd reason.

You must always test all conductors to ensure that they are all safe to touch.

So how do you do that? Read on.

You are going to use the prove test prove method and do the isolation tests. You must check every conductor is not live, it doesn't take long.

Single phase isolation test procedure:

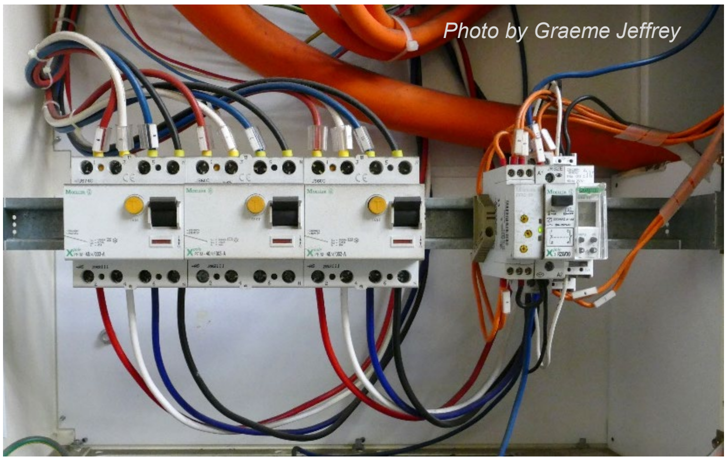
(a) Prove the meter is working.
(b) Test phase to neutral.
(c) Test phase to earth.
(d) Test neutral to earth.
(e) Prove the meter is still working.

Three phase isolation test procedure:

(a) Prove the meter is working.
(b) Test phase 1 to phase 2
(c) Test phase 1 to phase 3
(d) Test phase 2 to phase 3

(e) Test phase 1 to neutral
(f) Test phase 1 to earth
(g) Test phase 2 to neutral
(h) Test phase 2 to earth
(i) Test phase 3 to neutral
(j) Test phase 3 to earth

(k) Test neutral to earth.
(l) Prove the meter is still working.



If the isolation test shows parts, or all of the circuit to still be alive, then check for one of the following errors:

- The wrong isolating switch has been operated.
- The wrong fuses or circuit breakers have been operated.
- The wiring is damaged, faulty or wrongly installed.
- The circuit is being fed from two different sources.
- The isolating switch is not in the phase conductor.

The problem may be a combination of two or more of the above.

Tests for safety before re-livening

Before re-livening a circuit, you must test that it is safe for re-livening.

AS/NZS 3000 section 8 sets out the requirements for testing fixed wired circuits. It contains a lot more specific information than is able to be included in this resource.

It is important that you read and understand section 8 of AS/NZS as this is the standard that governs most of your work in the electrical industry.

AS/NZS 3017 also sets out some test methods for testing low voltage electrical installations.

The Visual (AS/NZS 3000 8.2)

While not a test as such, a visual check is included as part of the testing of a fixed wired installation.

It is important as test instruments cannot always show physical defects or unsafe conditions in electrical installations.

A careful visual check should be made for the following:

- The general mechanical condition of the installation.
- Earth continuity conductors are connected to the earth bar and neutral conductors are connected to the neutral bar.
- Earth bonding has been done for all extraneous metal parts. AS/NZS 3000 specifies earthing and bonding requirements.
- Broken components and conductor supports.
- Loose terminations of conductors.
- Stray conductor strands protruding from terminations.
- Burnt or damaged conductor insulation.
- Effectiveness of flexible cord or cable anchorage.
- Switches and protective devices are labelled as to the type of circuit they control or protect.
- Condition and rating of fuses, overload devices, overheating devices, switches and indicator lamps.

See AS/NZS 3000 8.2 for a more comprehensive list.

Earth Continuity (AS/NZS 3000 8.3.5)

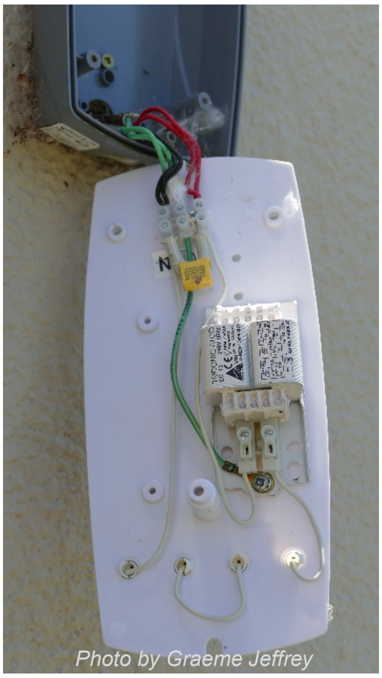


Photo by Graeme Jeffrey

Earth continuity tests are carried out between exposed metal parts of the electrical installation and the earth bar.

This test is carried out with an ohmmeter set to the low ohm scale, to register the expected low resistance values.

The purpose is to prove an unbroken, low resistance path from the earth bar to any exposed metal or earth termination. This being correct, will cause circuit protection devices to operate if there is a fault.

The resistance value of a fixed wired earth continuity conductor should be low enough to trip the protective device and be consistent with the cross-sectional area and length of the earth conductor.

The maximum resistance values for earthing conductors are given in AS/NZS 3000 Table 8.2.

Insulation Resistance (AS/NZS 3000 8.3.6)

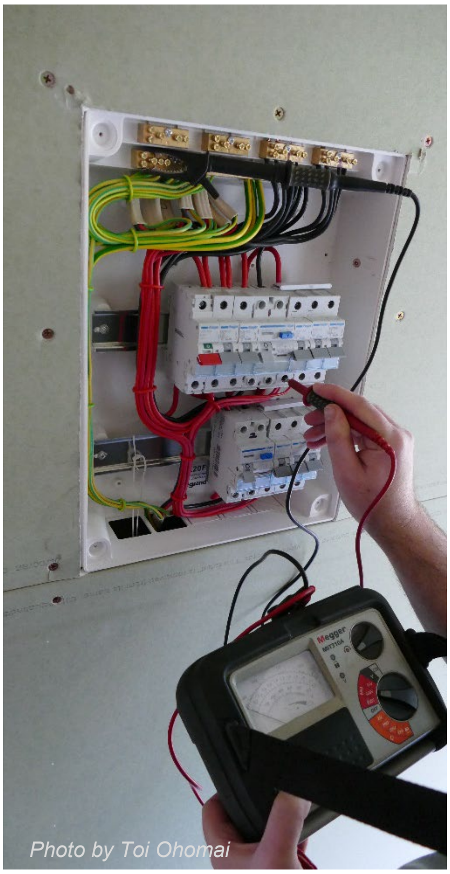


Photo by Toi Ohomai

Insulation resistance tests are very important and test how good the insulation of a circuit is.

This test is done with an insulation tester that puts out 500V DC to give the insulation a workout at a higher voltage than it will get in service. See AS/NZS 3000 8.3.6.1.

For the earth continuity we want the conductor to have as little resistance as possible so that the most current will flow. With insulation resistance, it is the opposite. We want the resistance of the insulation to be as high as possible - to stop current flow.

How high? One million ohms is the least AS/NZS 3000 8.3.6.2 will accept, and if your test is that low, 1 megohm (one million ohms), then you would be worried about what is wrong. A billion ohms is achievable and would be much better.

There are some exceptions where the insulation resistance can be lower, see AS/NZS 3000 8.6.3.2.

It may be necessary to remove the subcircuit earth from the earth bar to complete insulation resistance testing. If this is done, you must remember to reconnect it and do an earth continuity test after you have.

CAUTION: Circuits in which semi-conductor components are used, for example in RCDs, require special consideration while insulation testing.

Many semi-conductor components will not withstand the higher voltage of an insulation resistance tester and may break down. When testing such electrical circuits, observe the following precautions:

(a) Disconnect semi-conductor components before making an insulation resistance test between phase and neutral; or, if impractical,

(b) Join together both the phase and neutral and then test between this pair and earth.

Polarity (AS/NZS 3000 8.3.7)

Polarity testing is necessary to ensure that no shock hazard arises from the incorrect connection of conductors.

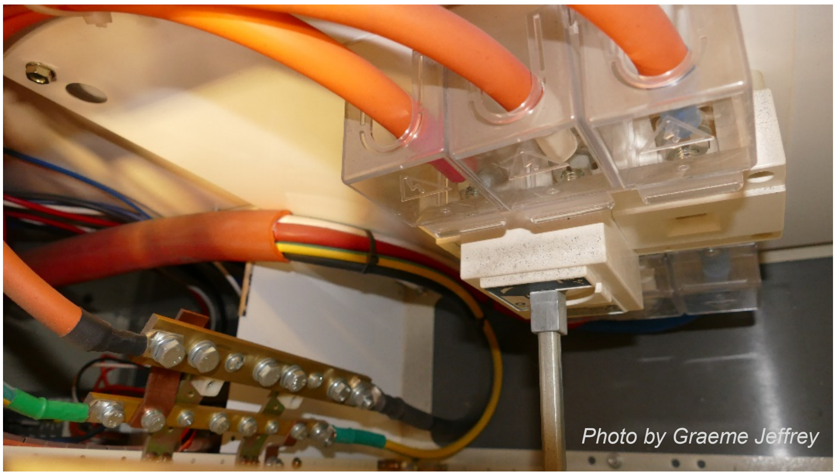


Photo by Graeme Jeffrey

The tests must check for, and prevent:

- Combinations of incorrect phase, neutral and earthing conductors.
- Connections resulting in the exposed conductive parts of the electrical installation becoming livened.
- Switches or protective devices incorrectly connected in neutral (or earth) conductors, resulting in parts of appliances, such as heating elements and lampholders, remaining energized when the switches are in the OFF position.
- Multi-phase equipment, such as multi-phase motors, and semiconductor-controlled equipment operating in an unpredictable manner.

See AS/NZS 3000 8.3.7.2 for more details.

Correct circuit connections (AS/NZS 3000 8.3.8)

When doing correct circuit connection checks, you are checking that:

- The earth conductor does not normally carry current.
- There are no short circuits.

You have to prove that all the conductors are correctly connected, that there is no transposition of conductors and no interconnection between different circuits.

Verification of impedance (AS/NZS 3000 8.3.9)

Also known as an earth fault loop impedance test (EFLI), this test is only required for socket outlets that are not RCD protected.

The idea of the test is to check the impedance (the grown-up AC version of resistance) of the “loop” in which the fault current has to flow, (including the earth conductor) when an earth fault occurs.

When an earth fault happens, it is important that the fault “pulls” heaps of current through the protective device - to cause it to trip. The EFLI needs to be low enough to cause heaps of current to flow.

This is all about protecting people by stopping the voltage on bare metal getting high enough to cause injury to someone touching it at the time of an earth fault.

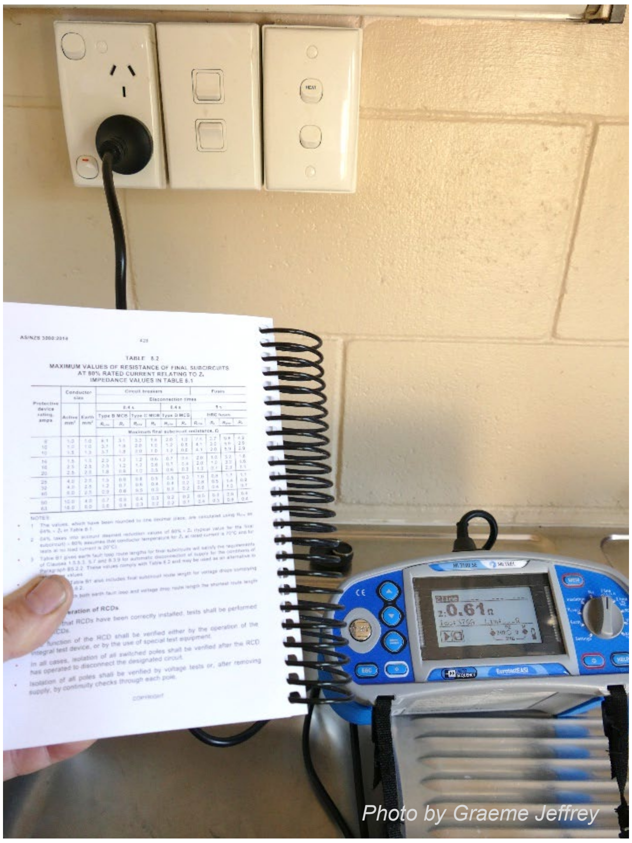


Photo by Graeme Jeffrey

When an earth fault loop impedance test is done, the result can be compared to AS/NZS 3000 table 8.1 to check if the result is okay. If the result complies, then during an earth fault, the protection device will have enough current flowing through it to trip within the times set out in AS/NZS 3000 5.7.

See AS/NZS 3000 8.3.9 for more details.

The reason why RCD protected circuits do not need this test is because, if there is an earth fault, an RCD will trip more than fast enough to comply with AS/NZS 5.7 - no problem. The earth loop impedance is much less significant in this scenario. See AS/NZS 3000 5.7.5, (note).

RCDs are a far superior system, a big improvement only needing a tiny fraction of the fault current required to trip MCBs or fuses via the earth fault loop.

Operation of RCDs (AS/NZS 3000 8.3.10)

Photo by Graeme Jeffrey

AS/NZS 3000 8.3.10 sets out the requirements for testing RCDs installed on fixed wiring.

Note: the tests required in AS/NZS 3000 are not actually about testing the operating parameters of the RCD, rather that it is wired correctly and actually does the job of disconnecting the circuit as it should. It is about the correct installation of the RCD.

The required tests in AS/NZS 3000 8.3.10.2 are:

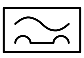
- Verify the RCD disconnects the supply to the correct circuit by:
  - Pushing the test button of a Type A RCD; or
  - Using test equipment to test the RCD.
- See further explanation notes in AS/NZS 3000 8.3.10.2

The result of the test is that the RCD has disconnected the supply. As a single-phase RCD is required to disconnect both the phase and neutral, your tests must include proof that both the phase contact and the neutral contact have opened.

1. You can achieve this by using an ohmmeter across each of the contacts, after the RCD has tripped and after the supply has been removed, to prove there is no connection (warning: take care not to connect an ohmmeter across a live circuit); or

2. By doing a voltage check on the contacts of the tripped RCD as follows:
   a. Tests (as per the RCD in the photo), assuming the incoming supply side is at the top.
      i. Prove your meter - this can be done by doing test (ii)
      ii. Test that the RCD is effectively connected in the circuit and has a supply on it by testing for voltage on the supply side between 1 and the top N.
      iii. Test for voltage between 1 and bottom N with RCD off.
         1. (0V shows the neutral contact is open).
      iv. Test for voltage between top N and 2 with RCD off.
         1. (0V shows the phase contact is open).
      v. Prove your meter (this can easily be done by doing test (ii) again).

Photo by Graeme Jeffrey

The symbol for type A RCDs is 

Removal of locks and tags

Once all tests have been completed, and the circuit is known to be safe, the next step is to remove your lock and tag and re-liven the circuit.

If you are working with someone, or in a place where other people are and there is a chance that livening the circuit could take them by surprise, or put them in a dangerous position, then inform them that you intend re-livening the circuit and make sure it is safe to turn the power back on. You never know what someone has thought of quickly doing while the power is off.

Certification

The final point to remember is that the paperwork needs to be done and the circuit must be certified.

Depending on what work has been done, a Record Of Inspection, a Certificate Of Compliance and or an Electrical Safety Certificate need to be issued as necessary.

The Skills Organisation
0508 SKILLS (0508 754 557)
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