Electrical Safety Testing of Electrical Installations and the verification of Electricians Test Tools

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What is Electrical Safety Testing?

As safety regulations globally become more enforced, testing appliances and electrical installations for electrical safety has become more common

At its most basic, electrical safety testing consists of measuring electrical circuits and appliances to ensure that they comply with national safety standards

Facts and Statistics

- In the US, over 400 electrocutions occur each year, approximately 180 related to consumer products
- 25% of U.S. consumers don't understand the purpose of their GFCIs
- Nearly one-half of U.S. families never test their GFCI's
- Electricity is the cause of over 140,000 fires each year, resulting in 400 deaths and $1.6 billion in damages

Source : http://ccd.fnal.gov/fire/Electrial_Safety.pdf

Electricians Test Tools

In this presentation I will be covering 3 typical test tools that an electrician will be using

- Insulation Tester
- RCD Tester
- Loop Tester

Electricians Test Tools

We will be covering :

- What the tool is used for
- Traditional method of verification of test tools

Insulation Testers

Insulation Testing

Insulation testers measure the resistance of the casing/insulation of equipment such as Televisions, Toasters and Hair Dryers. Any appliance that can have mains voltage applied should be tested to ensure that the mains is isolated from the case of the appliance

Insulation Testing

Insulation testing is an important element of ensuring that electrical appliances are safe for the end user in the case of a fault occurring.

An example fault could be a stray strand from the live conductor has moved to make contact with the outer casing of the appliance

Insulation Testing

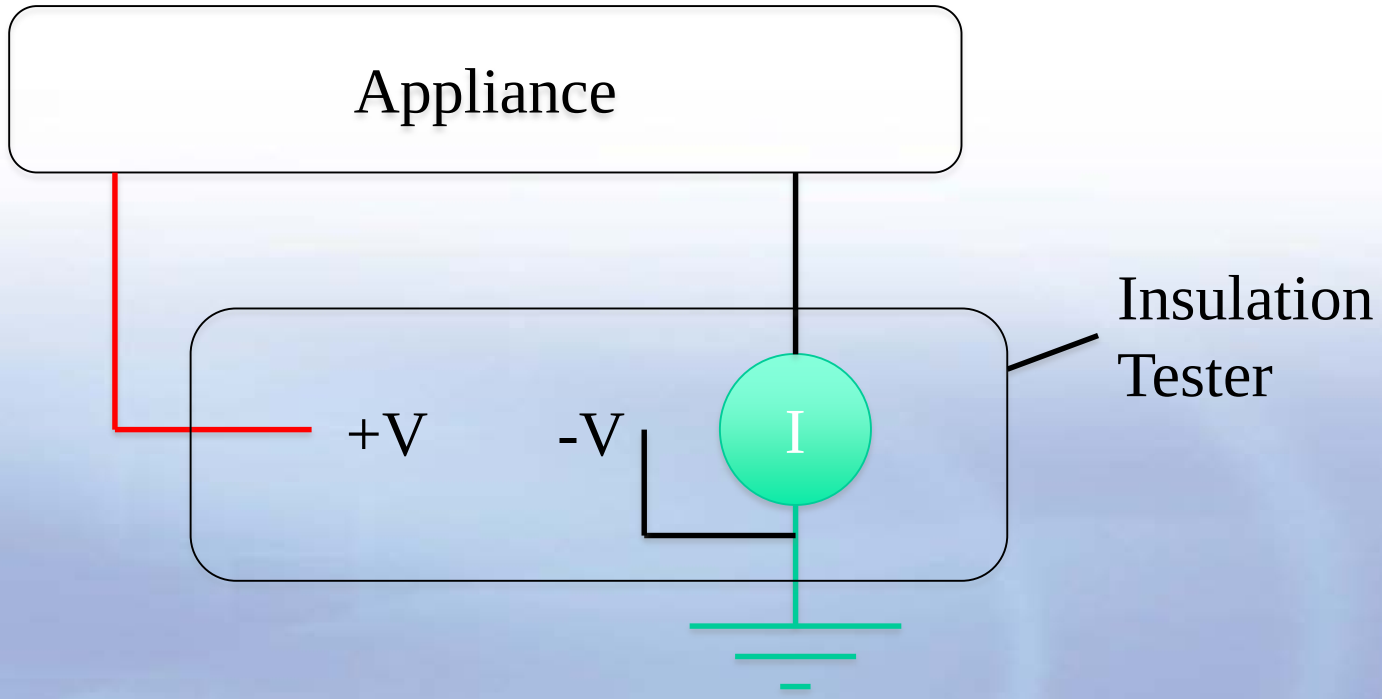
In this case, it would be hoped that the casing of the appliance would prevent current from ‘leaking’ to ground through an alternative path

This is especially important for consumer goods such as televisions and white goods. Especially those that may be subjected to moisture such as a kettle.

Insulation Testing : Principle of Operation

Insulation testers test the resistance at high voltages to ensure that if the case of an appliance is exposed to mains voltage (for instance, the wiring inside the appliance becomes loose and contacts the case) that the casing will not ‘break down’ and allow current to ‘leak’ through the casing to earth

Insulation Testing : Principle of Operation



Basic Block Diagram of Insulation Tester

Insulation Testing: Principle of Operation

An Insulation Tester works by applying a known voltage, and measuring the current flowing across the resistive material

Using ohms law, the insulation tester then returns the results as a resistance, typically in the order of Megohms

Insulation Testing

Insulation testing is typically performed at voltages greater than the peak voltage of the mains supply, to ensure that under a typical in use fault condition (when used on a conventional mains supply in day to day use) that the insulation will not fail

110V Mains Supply – 250V

230V Mains Supply – 500V

Insulation Testing

This is seen as the maximum voltage that a typical household appliance will ever have applied in a fault condition and still allowing for additional confidence that the appliance will not ‘break down’

For industrial applications the test voltage can be much higher to allow for additional confidence

Insulation Testing : Verification

Performing verification of an insulation tester consists of :

1) Voltage Output Verification
2) Resistance Measurement
3) Current supplied by the tester

Insulation Testing : Verification

1: Voltage Output Verification

Measuring the voltage output of the insulation tester is a simple verification

Using a DC Voltage meter with ranges of up to 1000V, with accuracies suitable for the insulation tester, the voltage output can be verified

Insulation Testing : Verification

2: Resistance Measurement

Verifying the resistance measurement on an insulation tester should be performed across the full range of the insulation tester, testing at all available voltages.

Insulation Testing : Verification

2: Resistance Measurement

Verifying the resistance ranges requires a high voltage resistance decade box, with values from 100k Ohms, upwards to 1G Ohms

Some testers have ranges of up to 10G Ohms

Insulation Testing : Verification

2: Resistance Measurement

Ideally, the insulation tester should be tested on each of its voltage output ranges. This will require a decade box that can withstand up to 1000V

Insulation Testing: Verification

3: Current supplied by tester

Insulation testers have specifications for the current supplied by the tester for each voltage range.

Typically modern testers will provide 0.5mA at each voltage, however older testers may provide up to 1mA at 1000V

Insulation Testing : Verification

3: Current supplied by tester

Depending upon the voltage range being tested, this will require a different resistor for each voltage range that must be tested.

During this test, the voltage must also be measured to ensure that the tester is still delivering the full test voltage while under load

Insulation Testing : Verification

3: Current supplied by tester

The current can be measured using a DC current meter measuring the current in the circuit, and then using a DC voltage meter across the insulation tester to ensure that the voltage that is being provided by the tester is within specification while under load

RCD's / GFI's

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Examples of RCD/GFI devices

RCD / GFI

RCD’s (Residual Current Devices) or GFI’s (Ground Fault Interrupters) are devices that go between your mains appliance and the socket / mains supply

The purpose of an RCD / GFI is to prevent current finding alternative paths to ground in the event of a faulty appliance

RCD / GFI : Principle of Operation

An RCD / GFI works by measuring the current in the Live (Hot) conductor and comparing against the current in the neutral connector

If there is an imbalance between the two conductors it indicates that the current has found an alternative path (typically to Earth). At this point the RCD/GFI breaks the circuit

RCD / GFI : Principle of Operation

RCD's typically operate at currents of less than 30mA at times of less than 30 milliseconds

This is intended to be fast enough to prevent current from flowing across a human and causing great harm

RCD/GFI or Circuit Breaker

There can be some confusion between a Circuit Breaker and an RCD / GFI

A Circuit Breaker operates in a similar manner to a RCD/GFI Device. When a current that is above the specification, the Circuit breaker breaks the circuit

RCD/GFI or Circuit Breaker

The difference is that a Circuit breaker measures the total current in the circuit, and trips when the total current flowing is greater than the trip limit (similar to a fuse)

An RCD / GFI can have the characteristics of a Circuit Breaker (that it will trip when a set current flows through the circuit), but also measures for an imbalance between the Live and Neutral conductors

RCD / GFI's : Testing

Many RCD / GFI devices have built in 'self test' functions. However this function only tests that the RCD / GFI will trip and disconnect the Live / Hot connection. It does not test at what current the RCD / GFI will trip, or how long it takes for the current to be terminated

To fully test a RCD / GFI a dedicated RCD tester must be used

RCD / GFI : Testers

Typical RCD Testers

RCD / GFI Testers : Verification

When verifying correct operation of an RCD Tester, there are several separate stages of verification

1. Trip Time Verification
2. Trip Current Verification
3. AC Voltage Measurement (Not on All Testers)

RCD / GFI Testers : Trip Time Verification

RCD's / GFI's have different trip times and trip current depending upon the application.

RCD / GFI testers only have settings for Current, so to test the timing measurement a method is required that can time the actual trip time of the RCD / GFI device and compare this against the reading from the Tester

RCD / GFI Testers : Trip Time Verification

It is important to note that a RCD/GFI tester does not SOURCE current, it will DRAW current from the Live conductor and return to earth, creating an imbalance between the Live and Neutral conductors.

RCD / GFI Testers : Trip Time Verification

To Measure trip time (the time that a tester is drawing current from the RCD until the circuit is broken) the traditional method is to use a scope (with storage facilities) and measure the time from when the trip current starts to the time that the trip current is terminated by the RCD / GFI

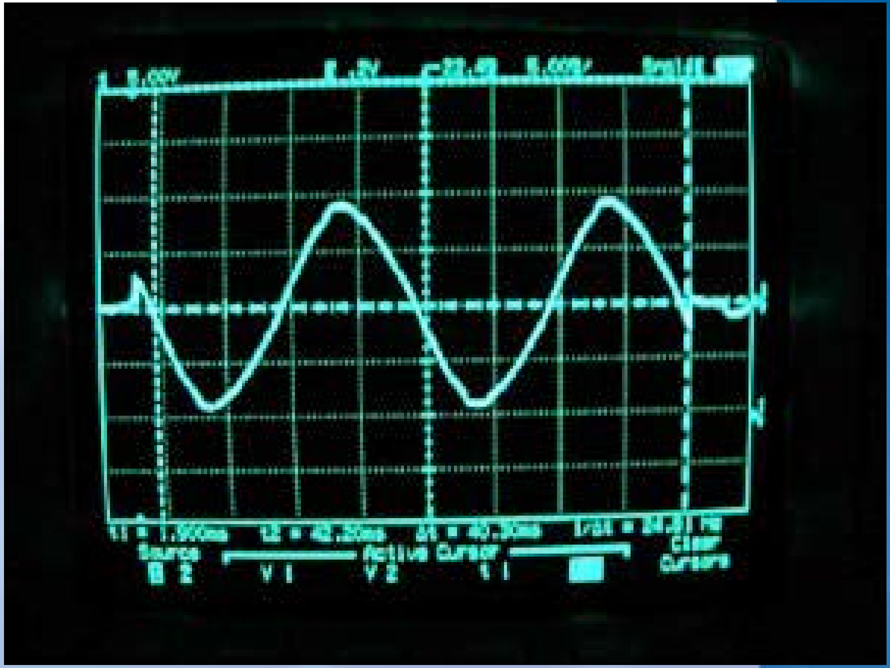
RCD / GFI Testers : Trip Time Verification

To Measure trip time (the time that a tester is drawing current from the RCD until the circuit is broken) a mains voltage source must be used that will trip after a set time (i.e. using a 30ms RCD / GFI)

The time that the current is present is measured by placing a resistor in the earth line and using an oscilloscope to accurately count the trip time

RCD / GFI Testers : Trip Time Verification

Using a 5ms/Division setting on an oscilloscope, we can measure this 40ms RCD device very accurately. From this we can verify the measurement on the RCD tester



RCD / GFI Testers : Trip Time Verification

This traditional method will require RCD's of varying current and timing specifications, as well as an oscilloscope to view the time that the fault current is present before the circuit is broken.

The errors in this method mainly consist of errors in Scope triggering, and determining the start of the timing period

RCD / GFI Testers : Trip Current Verification

When using an RCD tester to verify an RCD, you must ensure that the RCD tester is drawing the correct current from the RCD

This current typically varies from 10mA to 1A, however typically the most important range is 30mA for domestic installations

RCD / GFI Testers : Trip Time Verification

To perform this, the traditional method is measuring the current draw by the tester from a supply when the RCD test is initiated by measuring AC Current in the earth line using a true RMS multimeter with a peak hold function as the trip current will only be present for approximately 1 second (if there is no RCD in the circuit that the tester is being used on)

RCD / GFI Testers : Trip Time Verification

Alternatively an oscilloscope with storage functionality could be used, however this method requires different value resistors to be placed in the earth line to provide a voltage across the resistor that the oscilloscope can display

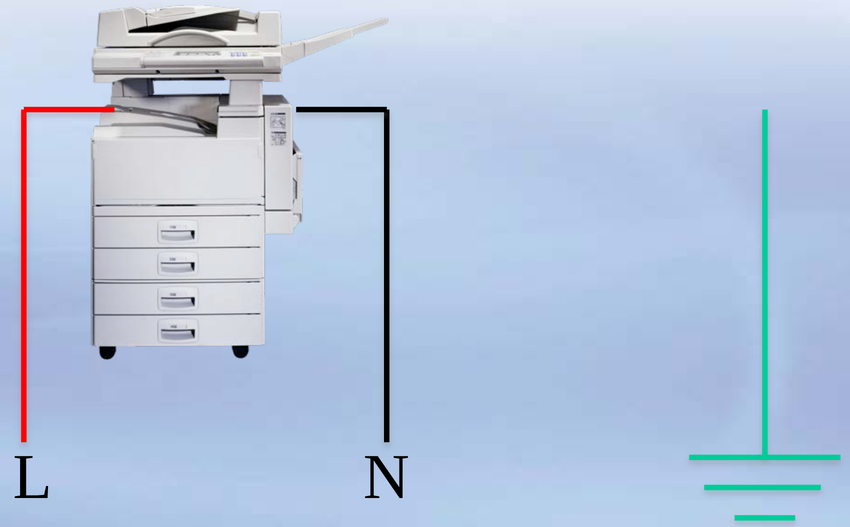
RCD / GFI Testers : Trip Time Verification

When measuring the trip current, it is not necessary to place an RCD / GFI in the circuit, as the fault current will terminate after approximately 2s (this will vary from tester to tester)

Loop Resistance / Impedance

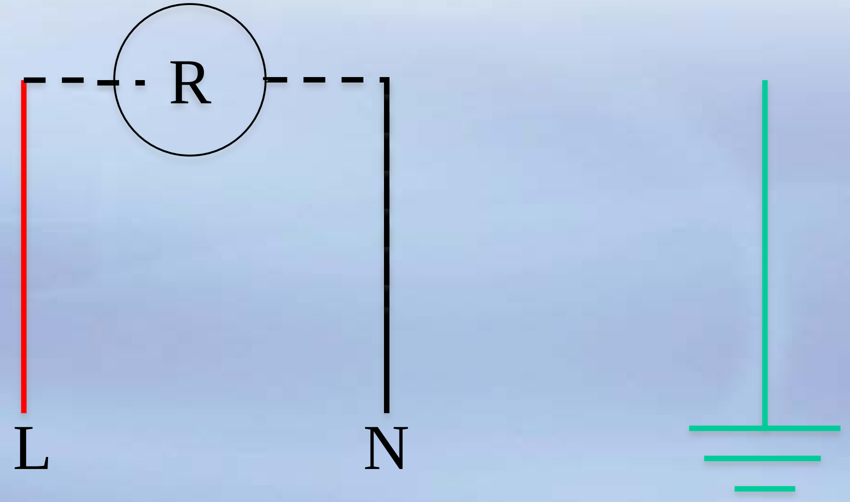
Loop Resistance / Impedance

When an Appliance is connected to a socket, the appliance completes a ‘Loop’ in which current flows, from the power station to the appliance and back



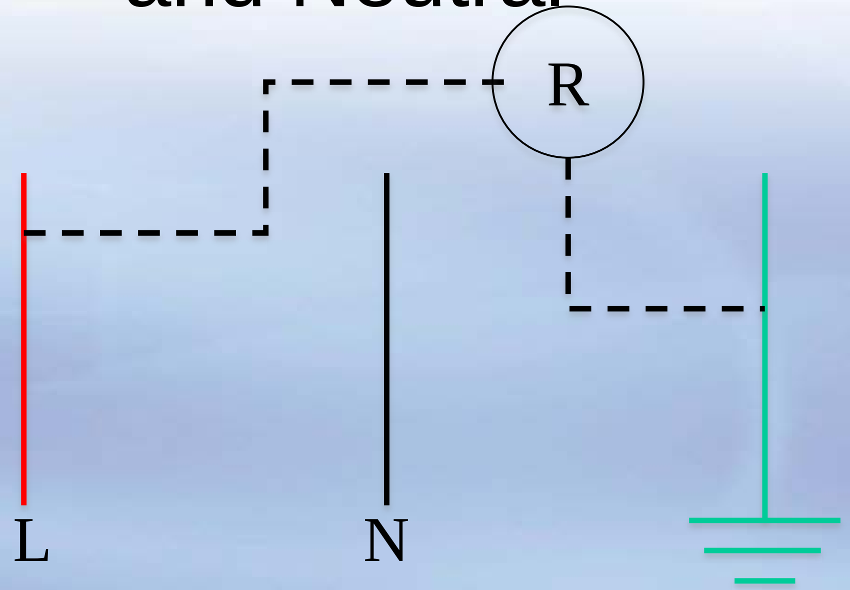
Loop Resistance / Impedance

Loop Resistance is the resistance in the wires between the power station / source and the socket. This includes wiring, sockets and circuit breakers / RCD's



Loop Resistance / Impedance

Typically Loop Testers measure the resistance from Live to Earth. Some Loop Testers however also test between Live and Neutral



PSCC (Potential Short Circuit Current)

Measuring the Loop Impedance is important when choosing the value of circuit breakers / fuses in a circuit.

If the Fuse / Circuit breaker in a circuit is too high a value for the circuit, it is possible that the fuse will not blow in the case that a fault does occur

This is called the Potential Short Circuit Current

Loop Tester : PSCC (Potential Short Circuit Current)

For Example :

A Circuit has been fitted with a 150A Circuit Breaker

The Loop Resistance is 0.8 Ohms

The Mains voltage is 110V

Loop Tester : PSCC (Potential Short Circuit Current)

One of the sockets in the circuit could have a faulty device connected where the Live (Hot) wire is directly connected to earth.

This will draw 137A (~15,000 Watts) through the wiring in the circuit and the Fuse would not blow

Eventually the self heating of the wire would be so great that a fire could break out

Loop Tester : PSCC (Potential Short Circuit Current)

There are many cases where this has occurred, where additional sockets have been added to a circuit (for instance, adding extra sockets in a laboratory) using low diameter cable, increasing the loop resistance.

This has then caused an electrical fire when a short has occurred and the circuit breaker has not tripped

Loop Tester : Principle of Operation

A Loop tester measures the loop resistance by drawing a high current (for domestic installations typically up to 26A) from the supply and measuring the drop in supply voltage

From this measurement the loop tester can determine the resistance

Loop Tester : Principle of Operation

To Measure the PSCC of a circuit, the Loop Tester measures the normal (unloaded) mains voltage, and then divides this by the loop resistance

Typically this figure is subject to variations and instability as loop resistance is typically measured as hundreds of milliohms and the calculation is approaching dividing by 0

Loop Tester : Verification

Traditionally testing a Loop tester consists of using high wattage, low value (typically in the order of 100mΩ) resistors and placing these resistors in the earth line of a Loop Tester to increase the Loop resistance.

This method however first requires a known Loop value.

Loop Tester : Verification

Verifying the current that the loop tester is drawing from the supply loop is essential in verifying that the loop is being tested under high current

To verify this, the current in the earth conductor would be measured through a high power resistor of a known value that can withstand 26A. This would then be measured as voltage with a multimeter

Loop Tester : Verification

As Technology improves, many Loop testers are also being fitted with the ability to measure Mains Voltage (To calculate PSCC)

To verify this an accurate RMS value of the mains voltage must be measured, and then compared against the reading on the Loop Tester

Conclusion

Electricians Test Equipment requires very different methods of calibration in comparison to typical test equipment

In almost all cases mains voltages are present, which make traditional methods of calibration not only difficult (with multiple lead changes and special adapters required), but also dangerous

Any Questions?