

Understanding the Leakage Current Test

The “Understanding the Product Safety Tests” Series

One of the deadliest hazards to human life has a very simple name: “Leakage Current”. Leakage Current is the current that flows through a person when they touch an electrical product. The *Leakage Current Test* is a test that is performed on all cord connected products but a test that few people understand. Let’s review the elements of this test:

Purpose of the Test is to measure the amount of current that passes through a person when that person touches an electrical product. For example, when you touch a vending machine, electrical current is passing through your body from the vending machine.

- 1) A few related facts about the human body:
 - a) The human body’s perception to shock decreases as the electrical frequency increases. Mains power frequency of 50 or 60 Hz is particularly bad for electric shock.
 - b) The human body can be represented electrically as a resistor/capacitor network that shunts off higher frequencies.
 - c) The human body’s primary resistance to shock is in the skin. Skin resistance is reduced with moisture – so there are additional leakage current concerns for products used in contact with moist skin (especially hand-held products). Similarly, opening of the skin can also substantially reduce the body’s ability to resist shock. Therefore, medical products are also required to have much lower leakage current levels and the medical leakage current tester has a lower impedance human body circuit.
 - d) Young children and the elderly are also highly susceptible to shock – it takes very low levels of leakage current to cause serious heart rhythm disturbances in the young and the old. So much so that we wonder how many heart attacks in the elderly have been induced by low levels of leakage current. Similarly, death from “complications during surgery” can also be the result of unidentified leakage current.
- 2) Electrical current follows the path of least resistance. And you know from above that the human body is represented by an R/C network (resistor/capacitor) = a resistance that is much greater than a grounding wire. As such, all leakage current will bypass the user and go to ground (earth) for a reliably grounded product.
 - a) This is why we do not measure leakage current for Field Wired products (conduit connected). Field Wired products are considered permanently installed with a reliable ground since they are to be connected by a licensed electrician (who will verify the ground). Therefore, for field wired products, all leakage current is assumed to go to ground and not through a person touching the product.
 - b) For cord connected products, we assume that something could reasonably go wrong to prevent the product from being grounded. In which case the person touching the product is the only path to ground for the leakage current = all leakage current will go through the person. This is why we always measure leakage current on cord connected products and, during the test we disconnect the ground.



Test Method involves fully energizing and operating the product being tested as it is intended.

- 1) While the product is energized, a “leakage current meter” is applied between the product and ground.
- 2) The leakage current meter provides the “body circuit” representing the human body impedance (human body simulator) and the current measurement thru the body circuit. Consider that the two leads for the leakage current meter act as the hands or hand and foot of a person. In this manner, the leakage current tester can be connected such that it simulates a person touching the product while also touching ground.
- 3) The amount of leakage current is dependent upon several factors including the insulating materials in the product, the mains voltage, and whether the product has an EMI filter. Because leakage current is mains voltage dependent, we always perform the test using the upper tolerance of the input voltage rating (110% of rated – for example, 240VAC rated product will be tested at 264VAC).

Mains Test Power Configurations are a part of the leakage current test that most test personnel conduct without understanding or considering the reason.

- A) Neutral Reference: Many standards require connecting the leakage current meter between the product enclosure and neutral (instead of ground). Note that by definition, the neutral is “grounded” (this is how a neutral is created). As such, we accomplish the same results with more repeatable, reliable test results (reduces errors caused by different distances to the common earth grounding point).
- B) Open Ground: During the test, if the product is grounded through its power cord, the ground is disconnected. This insures that all “leakage current” goes thru the simulated person (leakage current tester). This also represents the real world worst case scenario where a grounded cord connected product does not have a ground connection (i.e. ungrounded receptacle or, missing ground pin in an extension cord or, in an old house without grounded receptacles). For all cord connected products except electrical medical products, the earth ground connection is considered unreliable. Therefore, the “open ground” condition is considered “normal operation”.
- C) Polarity Reversal: Many standards also require that the product is also tested with the polarity reversed on the mains power. Polarity reversal can easily occur when products are used with an ungrounded extension cord. Polarity reversal is also common for mains power that does not have a neutral. It can also happen when a homeowner replaces a power outlet and inadvertently reverses the mains wiring. Therefore, polarity reversal is considered “normal operation”.
- D) Open Neutral: Mains power with an open neutral is a single fault condition that is required during leakage current testing. This is where we understand the importance of the “open ground” and “polarity reversal” conditions being considered “normal operation”. The safety standards requires testing involving single fault conditions, but never double fault conditions. The highest leakage in a product occurs during simultaneous open ground and open neutral conditions. For medical products, where the ground is considered reliable, opening the ground is a single fault condition – and therefore, open neutral is not conducted with the open ground as that would be a double fault condition. For all other products, it is considered a single fault condition.



Test Objectives: The objective of the Leakage Current test is to verify that the electrical insulation used to protect the user from a Risk of Shock is suitable for the application. Leakage Current testing is used to verify that the product does not leak excessive current when contacted by the user.

- 1) Excessive leakage current can cause the heart to go into ventricular fibrillation resulting in cardiac arrest which can lead to death.
- 2) Leakage current measurement levels depend on the amount of capacitance in the products' solid insulating materials. Different types and number of layers of an electrical insulation results in varying amounts of inherent capacitance through the insulation. This capacitance causes low amounts of current to "leak" through the insulation.
- 3) Leakage current levels can be significantly elevated in products that are subject to EMI requirements (FCC, CE-EMC). These products must incorporate EMI filters on their incoming mains power to provide clean power to sensitive electronics while also protecting from radiating emissions back onto the power line. These filters incorporate capacitors to ground, these capacitors can cause high leakage current when operating normally. If the product is for professional use only, the standard may permit high leakage current with warning markings for the user to insure the product is reliably grounded (so the user isn't subjected to the high leakage current). Otherwise, an isolation transformer must be added to power the product thereby isolating the product from ground – which will almost eliminate leakage current to ground.

As you can see, we don't simply perform the tests because they are in the standard. Each test in the standard has a set of objectives that relate to the 6 Hazards of Product Safety. The Leakage Current Test is performed as part of the Risk of Shock compliance review. High leakage currents cause cardiac arrest leading to death. It is therefore a very important test – another test that directly saves lives.

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