QuadTech

Application Note

A Practical Guide to Dielectric Testing

Almost all manufacturers of electrical or electronic equipment are required to make dielectric tests on the products they produce. Dielectric tests consist of both insulation resistance measurements and hipot or dielectric strength tests. These tests are performed in order to:

- detect manufacturing faults on electrical equipment.
- verify the quality of insulating material used in electrical equipment.
- verify that electrical installation was done correctly.

Lets look at insulation resistance testing, AC & DC hipot testing and some of the regulations that govern electrical safety testing (EST).

Figure 1: QuadTech Guardian 2500 Series AC/DC/IR Hipot Testers

What's That Mean?

Leakage Distance: The smallest required distance, measured on the surface of the insulating material, between two conductive parts, to avoid breakdown.

Leakage Current: The steady state current flowing through an insulating material that is subject to high voltage.

Breakdown: The failure of electrical insulation to provide a dielectric barrier to current flow. Every breakdown creates more or less damage to the insulating material therefore the test can be destructive.

Insulation Resistance: Characteristic of an insulating material that being subject to voltage, indicates a resistance such that the value of the leakage current which flows through it stays within acceptable limits.

Dielectric Strength: The ratio between the voltage at which breakdown of the insulating material occurs and the distance between the two points subject to that voltage.

What is an Insulation Resistance (IR) Test?

Measuring insulation resistance is a fairly straightforward procedure. Find two points between which there is insulation, make connection with an insulation tester (sometimes called megohmmeter) and make a measurement. The measured value represents the resistance of all the insulation between the two selected points.

An insulation test is made by applying a stable DC voltage across the connection points, usually something less than 1000V, this will cause a small amount of current to flow through the insulating material. The current that flows through the device is called leakage current. The voltage across the insulation, divided by the leakage current (Ohm's law, R = V/I) equals the insulation resistance. The insulation between two points can generally be thought of as a capacitive component, when the voltage is applied the device "soaks" up current or charges, and when the voltage is released it discharges. When the device is fully charged the steady state current that flows is the leakage current used to calculate the insulation resistance discussed above.

There are several reasons for measuring insulation resistance. A single insulation resistance measurement, along with experience and guidelines on what to expect indicates if a device is fit for use. An insulation resistance measurement is most often used to verify that components meet their resistance specifications before they are installed in a new product. For example, things like cables, connectors, switches, transformers, resistors, capacitors, printed circuit boards and other components that must have a minimum insulation resistance to be used for the purpose they were intended. Such a device may have a limitation or be specified for test at a particular voltage to avoid damage.

When performing insulation resistance measurements there are some important precautions to be observed in order to avoid leakage currents being created by the measurement procedure itself. Measurement leads should have good shielding (often connected to guard potential), and be as short as possible. The operator placing a hand close to the device under test can alter or make unstable the measurement result. Some insulating material or even operator clothing is sometimes capable of generating static electricity or electrical fields that can alter the measurement results.

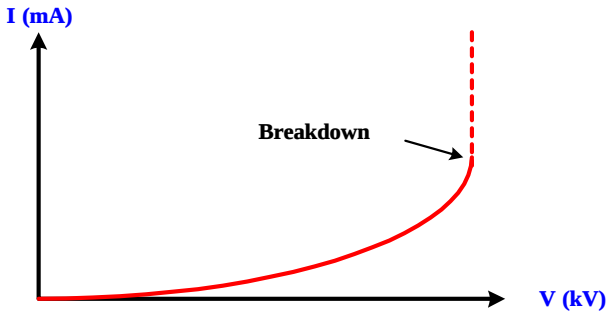

Figure 2: Insulation Breakdown (Leakage Current vs. Applied Voltage)

What is a Hipot Test?

The Hipot test (sometimes called a dielectric withstanding test or a breakdown test) is designed to stress insulation well beyond what it would encounter in normal use. If insulation can withstand a voltage above its normal rating for a given period of time, it is assumed that it will function adequately at its normal voltage levels. The testing process also has the ability to uncover defects in the insulating material that can leave insufficient insulating material or physical space between current carrying conductors. Over time, dirt, contaminants, humidity and even vibration close these gaps between conductors, allowing current to flow and thus creating a shock hazard.

The hipot test is probably the best known, the most often performed and most important production line safety test. Almost without exception, this test must be performed on every consumer and industrial appliance type product. The insulation that concerns us most in an electrical product is that which separates the power line circuit from everything else. The reason why current will flow from a product power line into any available ground path is because our AC power distribution system is ground referenced. In each house, a ground connection is made and all neutral wires in the house are connected to ground at some point.

Think about what would happen if the insulation should break down between the high voltage power line of an improperly grounded household appliance and the case. Any power line that contacts a path to ground will cause current to flow. If you happen to have the appliance in your hand while standing on the damp basement floor or touching the kitchen sink, you have completed the ground path for current to flow and the result is shocking! Many people have been injured as they used electrical products with faulty insulation and/or defective grounding systems.

Perform a hipot test by connecting the low side of the tester to one side of the device and the high voltage side (or probe) to the other side. When testing a completed appliance product the low side is usually connected to the ground and/or exposed case of the product and the high side to the line and neutral tied together. To prevent damaging a device the test voltage should be increased gradually over a period of time, this is called ramping. Current monitoring looks for changes that exceed the limit, either steady state, short duration pulses (arcs) or both. The voltage level is maintained for a programmed duration after which the voltage is shut off and the device discharged.

If at any time while the voltage is applied, the current limit is exceeded the high voltage is turned off immediately and a breakdown indicated. The actual voltage and current at breakdown is often indicated. If no breakdown occurs over the specified test time the tester would indicate a PASS, signifying that the device is good. Only after the tester high voltage is turned off and the device allowed to discharge should it be disconnected.

Since a hipot test can be destructive it is often prudent to perform an insulation resistance measurement on a device before and after a hipot test. This can be done most efficiently with the Guardian series tester that employs sequence test capability.

Requirements and Regulations

Government and independent testing agencies require hipot testing to verify that a product meets their design standards. Such tests must be performed on each product coming off a production test line. Specifications can call for both AC and DC testing depending on the specific type of product. AC is often specified more than DC and can be more stressful to the product, accelerating any possible breakdown. A common rule is to test a device with a test voltage of the same type that will be applied during its final use.

The most often used specification requires a product be able to withstand voltages equal to approximately twice the normal operating line voltage plus 1000 volts. For certain products the specified voltage can be well in excess of this minimum. Hipot test equipment must also be sensitive enough to detect brief increases, or arcs, in current flow as well as the steady state current.

The amount of time a voltage must be applied is also specified in many standards. The tester must have the capability to adjust the amount of time the high voltage is applied, one second and one minute are common duration's specified.

Besides meeting agency regulations there are additional motivations to make sure hipot testing is performed on 100% of electrical products manufactured. One is product liability, where it is the responsibility to eliminate any life threatening injury that a product might cause. Anyone who sells a product in a defective condition that is dangerous to the user, is subject to liability for physical harm caused to the user. This is why you will often hear of product recalls where the government or even the manufacturer has deemed the product unsafe to use. Another motivation to hipot test is occupational safety. It is the responsibility of employers to provide non-hazardous tools for its employees to use and to train them in their use. Under The Occupational Safety and Health Act (OSHA) any company can use a product only if approved by OSHA regulations, including UL approval.

Table 1: Partial Listing of Common Regulatory Agencies

Agency	Acronym	Country of Origin
Occupational Safety and Health Association	OSHA	United States
Underwriters Laboratories	UL	United States
Canadian Standards Association	CSA	Canada
International Electrotechnical Commission	IEC	Switzerland
Association of German Electrical Engineers	VDE	Germany
British Standards Institute	BSI	United Kingdom
Japanese Standards Association	JIS	Japan
International Standards Association	ISO	Switzerland

AC or DC? That is the Question

Test specifications can call for AC or DC testing or both (an often confusing issue), depending on the specific product type. AC is often specified more than DC and can be more stressful. For example, power line consumer products are much more likely to experience AC voltage transients than DC transients. The bottom line is, that a product should be tested for the voltage it is most likely to experience, but there are pros and cons of each.

Advantages of AC Testing - AC stresses the insulation equally in both polarities versus single polarity DC. No waiting time is required after applying a test voltage and it is not necessary to discharge the product after testing. AC tends to accelerate breakdown in flawed material faster and in many cases is considered a more realistic condition for product testing. Some agencies do not consider DC testing an acceptable alternative to AC testing.

Disadvantages of AC Testing - AC hipot tests on capacitive devices require more current (reactive current) than DC hipot tests using the same voltage as the AC peak voltage. Many people feel that excessive current at high voltage through a capacitive device can damage the product. Damage can range from total destruction at breakdown to a subtle weakening of the insulation with failure occurring at some later time when the product is in use. If a device is characterized before the dielectric test by measuring its insulation resistance and is again measured after test, a comparison of the two values will detect these subtle failures. In many cases the apparent resistance of the dielectric will be greater after the test (due to dielectric absorption of the material). The test sequence capability possible with the Guardian testers becomes that much more important in this particular situation.

Advantages of DC Testing - DC testing is often used for non-destructive testing of devices by more or less predicting an impending breakdown and discontinuing the test before the breakdown occurs. This is accomplished by raising the test voltage in small increments and waiting for the charging current to diminish after each step. Should the current take a sudden rise a breakdown may be imminent. Stopping a test at this point will prevent destruction of the material but does not tell where the breakdown would have occurred. Note that this technique of testing increases the required test time.

DC testing is the only choice for testing some parts such as the voltage rating of capacitors or the inverse voltage rating of diodes.

Disadvantages of DC Testing - For highly capacitive devices DC testing is less practical since it is necessary to raise the voltage slowly, otherwise the total current can reach the leakage threshold almost instantaneously and give false indication of failure. The gradual voltage rise not only adds time to the test but requires that the test be very carefully controlled. It is then necessary to discharge the device for a considerable time afterwards.

Again, DC testing is not considered as an equivalent to AC testing by most agencies. In many cases an AC test can be used in place of a line voltage leakage test, a DC test cannot substitute for a line voltage leakage test. DC stresses the insulation in one polarity only versus AC, which stresses the insulation in both polarities.

Conclusion

The purpose of a dielectric analyzer is to verify the quality and electrical safety characteristics of a product. The testing of dielectric materials in a production environment can be complicated and destructive to some percentage of the product. Should it be an AC or DC test? We have found the answer depends on how the product will be used. Does it really have to be destructive? Non-destructive testing has become more popular when limitation of maximum current is combined with rapid removal of the voltage source. A more acceptable technique is to perform the non-destructive insulation resistance test before and after the hipot test. The ability to compare the minute changes in before and after values provides a much greater sense of security of product performance over the long run.

Figure 3: Guardian 6000 Series Electrical Safety Analyzer

Figure 4: Guardian 1000 Series Hipot Tester

For complete product specifications on the Guardian Series of Hipot Testers and Electrical Safety Analyzers or any of QuadTech's products, visit us at http://www.quadtech.com/products. Call us at 1-800-253-1230 or email your questions to info@quadtech.com.

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