SCI
A DIVISION OF IKONIX USA

Ultimate Guide to Electrical Safety Testing

PREFACE

Electrical safety testing has historically been one of the most misunderstood, misapplied and misinterpreted inspection functions administered by manufacturing companies. Some manufacturers have looked upon safety testing as an extraneous set of procedures that must be performed to satisfy some safety agency standard. Although testing for product safety is a primary concern, electrical safety testing can yield valuable information about product design and integrity. To help manufacturers better understand the value of safety testing, the first edition of Basic Facts About High Voltage Testing was written and published by Elmer Slaughter on January 18, 1957. Over the next 33 years Mr. Slaughter continuously edited and updated the material with information relevant to performing high voltage tests.

Slaughter Company is pleased to present this 10th edition to our valued customers. The booklet has been updated to reflect current instrumentation and technology as well as offer general explanations of the most common high voltage tests and how they are performed. We have also added sections pertaining to general safety precautions as well as useful testing tips and procedures.

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INTRODUCTION

Due to differences in testing standards across the globe it is becoming increasingly important for manufacturers to ensure that their products are safe for consumer and industrial use. What was once a general and loosely regulated industry is now being flooded with stringent national and international safety standards. The recent harmonization of safety standards in the European Union has led to an increased concern by manufacturers to make sure that their products comply with EU specifications. Meanwhile, regulatory bodies like UL have led to stricter rules on electrical products sold domestically. Although manufacturers of electrical products are becoming more familiar with electrical safety testing and compliance, many are still unfamiliar with this crucial part of the production process.

WHY DO I NEED TO TEST?

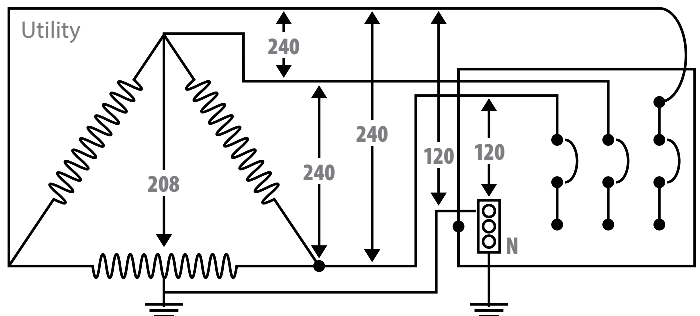
Safety agencies have implemented and enforced electrical safety testing for one reason: to protect consumers from potentially fatal electric shock. Many injuries and electrocutions are caused by either electrical products with faulty insulation or a product with a defeated safety grounding system.

The insulation in question is used to separate the power line circuit from everything else: low voltage circuits, isolated power supplies, chassis or case of the product, etc. This insulation prevents current from an ordinary household outlet, an almost unlimited power source, from becoming hazardous by finding a ground/earth path with something that is not meant to be a ground path.

HOUSEHOLD POWER AND ELECTRICAL SAFETY TESTING

Current flows into any available ground/earthing path because most power distribution systems are groundreferenced. When power is generated, one side of the generator output is connected to a ground at the point of output. Every time power is transformed from one voltage to another, one side of the secondary is grounded. In household power distribution all neutral wires in a house are connected to ground at a single point. Some power is distributed ungrounded so that the system will tolerate one fault to ground without shutting down. This typically is high voltage intermediate ground distribution, not directly accessible to the end user. Three-phase and 120/240VAC systems also provide power across independent ungrounded hot lines, but each of these lines is usually ground-referenced independently and each provides a predictable voltage to ground. Therefore, any line that contacts a ground path will allow current to flow. **Figure 1 and 2** each show a different example of how voltage is derived from a 3-phase transformer.

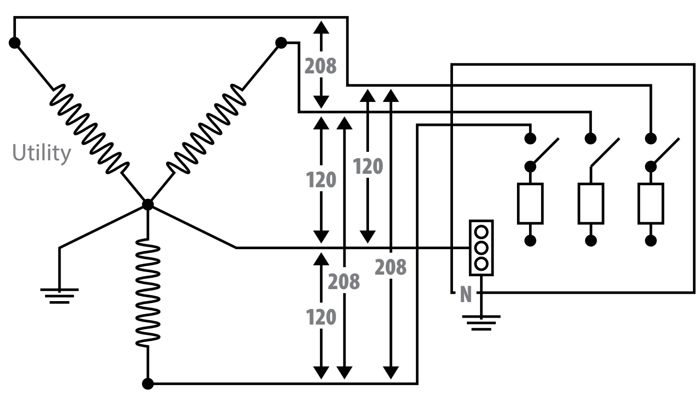
FIGURE 1 — 3-PHASE DELTA TRANSFORMER



120/240V 3Ø 4-Wire Delta System

The responsibility of performing electrical safety tests on consumer products ultimately rests on the manufacturer. These tests are performed to ensure that products including anything from household electric coffee makers to hairdryers and computers, meet industry standards for construction, performance, ratings, markings and instruction manuals.

FIGURE 2 — 3-PHASE Y TRANSFORMER



208Y/120V 3Ø 4-Wire Wye System

Aside from consumer safety, manufacturers have additional reasons for safety testing. Not only do manufacturers want to prevent faulty components from being installed in their products, but they also want to catch workmanship defects in assemblies before they are installed. Following a proper safety testing procedure can help to identify production problems before a product is shipped, preventing costly recalls and embarrassing public announcements. Many manufacturers also perform tests to ensure product quality for ISO compliance. Still other manufacturers test to protect themselves from product liability suits. Whatever the reason may be, electrical safety testing makes good sense for any consumer product manufacturer.

PRODUCT CLASSIFICATIONS

Electrical products have been broken down into two specific categories for electrical safety testing, Class I and Class II. A Class I product is terminated in a 3-pronged line cord, specifically consisting of a hot and a neutral input, and an earth ground connection to chassis. Class II products, also known as double insulated products, have no earth ground connection to chassis since the chassis itself is usually made of some insulating material such as plastic.

WHAT IS ELECTRICAL SAFETY COMPLIANCE?

Many manufacturers have heard terms such as UL listing, or CE mark, but aren't sure what they mean or how they apply to their products. Both of these terms and more are used within the electrical safety compliance industry. Electrical safety compliance is a general term used to describe the testing procedures a manufacturer's product must pass in order to be deemed safe to sell to consumers within specific countries. Many countries around the world, including the U.S.A., have their own test procedures to which electrical products must comply.

More often than not, regulatory agencies establish these compliance test procedures. They in turn provide their seal of approval, known as an agency listing, to a product that meets their standards (see **Figure 3**). In the United States, one of the most popular agencies is Underwriter's Laboratories (UL), in Germany, TÜV Rheinland, in China, China Compulsory Certification (CCC). It is important to note that in the United States, as in many other countries, the Federal government isn't involved in regulating these electrical safety compliance agencies — they are self-sustaining and self regulating. As a corollary to this point, there is no law in the U.S.A. that states a manufacturer must have a listing in order to sell an electrical product. However, in order to compete in today's market and to avoid potential customer injuries and lawsuits, obtaining a safety agency listing is a must.

FIGURE 3 — AGENCY LISTING

Underwriter's Laboratories

TÜV Rheinland

China Compulsory Certification

In addition to verifying the safety of their own product designs, it is also important for manufacturers to purchase safe equipment for use in their own production processes. The Occupational Safety and Health Administration (OSHA) helps to create standards for regulating safety in the workplace. This division of the U.S. Department of Labor designates Nationally Recognized Testing Laboratories (NRTL's) to provide listings to products that are safe for use in the workplace. NRTL's such as UL and the Canadian Standards Association (CSA) are recognized by OSHA as having adequate testing standards to verify that a product may be used in the workplace without endangering technicians and equipment operators. For more information about NRTL's contact your local OSHA office. OSHA's website, www.osha.gov will have the appropriate contact information. Although many safety agencies are specifically founded and/or affiliated with certain countries, most are accepted by a variety of nations. For example, even though UL is the most popular electrical safety agency responsible for consumer products sold in the United States, many other countries have deemed UL listed products acceptable to sell within their own borders. Likewise, the United States accepts many products that are TÜV listed to be sold within our borders. In any case, it is always beneficial to submit an electrical product for an agency listing no matter where the product is going to be sold.

**For a complete listing of national and international safety agencies please refer to the appendices.*

EXAMPLES OF COMMON SAFETY AGENCY STANDARDS

Safety agencies create a series of acceptable test procedures, known as standards, that a manufacturer must adhere to in order to receive the agency's listing. An example of a UL Standard that requires a Hipot test to be performed on appliances with motors is as follows:

UL STANDARD 73 - MOTOR OPERATED APPLIANCE

An appliance shall withstand for 1 minute without breakdown the application of a 60-hertz essentially sinusoidal potential between live parts and dead metal parts with the appliance at the maximum operative temperature reached in normal use. The test potential for the primary circuit shall be:

A One-thousand volts for an appliance employing a motor rate 1/2 horsepower (373 W output) or less or 250 volts or less."

B One-thousand volts plus twice the rated voltage for (1) an appliance employing a motor rated more than 1/2 horsepower or more than 250 volts, or (2) an appliance applied directly to persons - see item C."

C Twenty-five hundred volts for an appliance that is applied in a wet or moist condition directly to persons."

Another example of an agency standard is provided by the U.S. Department of Housing and Urban Development. They recently mandated Dielectric Withstand testing to be performed on all modular and manufactured homes in the following standard:

H.U.D. #24 CRF 3280.810(A)

The wiring of each manufactured home is to be subjected to a dielectric strength test between live parts and the manufactured home ground and between neutral and the manufactured home ground. The test is either to be performed between 900 to 1079 volts for one minute or between 1080 to 1250 volts for one second. The test is conducted on each manufactured home to stress the insulation to determine if it is capable of resisting transient power line surges to which the wiring may be subjected, identify any low resistance areas of the insulating material and any dielectric breakdown paths of failures that may exist."

THE EUROPEAN UNION AND THE CE MARK

Many manufacturers also are curious about the CE Mark and what it means (see **Figure 4**). Quite simply, the CE Mark is an indication of compliance to the European Union directives which are currently in force. These directives (laws) are legal requirements that manufacturers must fulfill in order to sell products into the European free market. The aim of these directives is to remove the technical barriers to trade and to permit free access to the European market. Harmonized standards (not the directives) set out the technical provisions required for compliance to European safety requirements. EN's (European Norm standards) are based on IEC (International Electro-Technical Commission) standards which are broken down into:

TYPE A or basic standards such as EN 292, 292-1, 292-2, EN 1050; safety of machinery/terminology. These are basic standards that give the basic concepts and principles for the design and the general aspects that apply to all machinery.

TYPE B or generic standards (group safety standards) dealing with one safety aspect or one type of safety related device that can be used across a wide range of machinery.

TYPE C or product specific standards giving detailed safety requirements and risk categories applied for a particular machine or group of machines, such as EN 201, injection molding machines or plastics.

FIGURE 4 **CE MARK**

Under the new European product liability directive, manufacturers are liable for damage caused by a defect in their product and it is their responsibility to prove that the product was not the cause of any damage. Compliance to the European directives ensures that the product meets the minimum safety requirements and that damage claims can be limited.

It is important to note that the CE Mark is a self-certification mark, and therefore not regulated by any safety agency. The harmonized standards are available for manufacturers to setup and perform the tests themselves as opposed to submitting a product in order to get a safety agency listing.

COMMON ELECTRICAL SAFETY TESTS

Electrical safety tests are loosely broken down into 2 separate groups, **design or type tests**, and **routine production line** tests. Design tests are usually performed to detect product flaws during the design stage of an electrical product. The information retrieved from a design test is useful for finding potential problems with product design and development. Production line tests are usually required to be performed on 100% of the products leaving a facility for sale to consumers. A production line test helps to ensure a particular product is safe for consumer use.

DIELECTRIC VOLTAGE-WITHSTAND TEST

This test, commonly referred to as a Hipot test, is used to stress the insulation of a product far beyond what it would it encounter during normal operation. High voltage is applied from the mainsinput lines to the chassis of the product in order to look for insulation breakdown. The hipot test is a 100% production line test and can be performed using either an AC or a DC voltage.

GROUND CONTINUITY TEST

This test is usually used to determine if the ground wire of a product is intact. A low voltage is applied from the chassis of the product to the ground pin in order to determine if the appropriate amount of current flows.

GROUND BOND TEST

This test is used to verify that the ground conductor of a product has a low enough impedance to handle any fault current to ground. High current flows from the ground pin of the product's line cord and through the chassis in order to determine if the cabling is capable of handling excessive current flow should a fault occur.

INSULATION RESISTANCE TEST

This test is used to verify the resistance of a product's insulation by applying a DC voltage and measuring the resulting leakage current.

DIELECTRIC VOLTAGE WITHSTAND TEST (HIPOT)

The Dielectric Voltage Withstand test or Hipot (High Potential) test is by far the most common type of safety test performed by electronic product manufacturers. This test is designed to stress a product's insulation far beyond what it would encounter during normal use. The assumption is that if the insulation can withstand a much higher voltage for a given period of time, it will be able to function adequately at its normal voltage level for the life of the product, hence the term "voltage withstand test." **Figure 5** shows the circuitry of a Hipot tester.

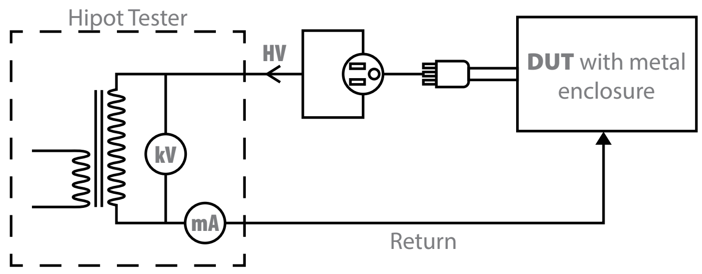
In addition to over-stressing the insulation, the test can also be performed to detect material and workmanship defects, most importantly small gap spacings between current carrying conductors and earth ground. When a product is operated under normal conditions, environmental factors such as humidity, dirt, vibration, shock and contaminants can close these small gaps and allow current to flow. This can create a shock hazard if the defects are not corrected at the factory. No other test can uncover this type of defect as well as the Dielectric Voltage Withstand test.

Most independent and government safety agencies require a Dielectric Voltage Withstand test to verify that a product's design meets their standards (known as a design test). They also require a 100% routine production line test for every product manufactured.

LEAKAGE CURRENT AND DIELECTRIC BREAKDOWN

The purpose of a Hipot test is to check for excessive leakage current flow through a product's insulation. Under normal conditions, any electrical device will produce a minimal amount of leakage current due to the voltages and internal capacitance present within the product. Yet due to design flaws or other factors, the insulation in a product can breakdown, resulting in excessive leakage current flow. This failure condition can cause shock or death to anyone that comes into contact with the faulty product.

FIGURE 5 **HIPOT CIRCUITRY**



Dielectric breakdown may be defined as the failure of insulation to effectively prevent the flow of current, sometimes evidenced by arcing. If the voltage is raised gradually, breakdown will begin at a voltage level where current flow is not directly proportional to voltage. When breakdown occurs, especially for a long period of time, the next gradual application of voltage often causes a breakdown to occur at a lower voltage than initially measured. The best indication of dielectric breakdown is a leakage current measurement significantly higher than the nominal current measurement.

The maximum leakage current is dependent upon the test voltage; therefore, the leakage current trip setting will vary depending upon the product being tested and the capacitance of that product.

GENERAL HIPOT TEST CONSIDERATIONS

Test voltages are seldom less than 1000 volts. When testing products that are intended to operate at voltages between 100 volts and 240 volts the test voltage can exceed 4000 volts. A good rule of thumb that most safety agencies use to determine the appropriate test voltage for an electrical product is to multiply the device under test's (DUT) normal operating voltage by 2 and add 1000 volts.

TEST VOLTAGE = NOMINAL INPUT VOLTAGE * 2 + 1000

Agency requirements also take the product's intended usage and environmental conditions into consideration. For example, medical equipment with applied parts that have direct contact with a patient is tested at 4000 volts.

Most double-insulated (Class II) products are subjected to design tests at voltage levels much higher than the rule described above.

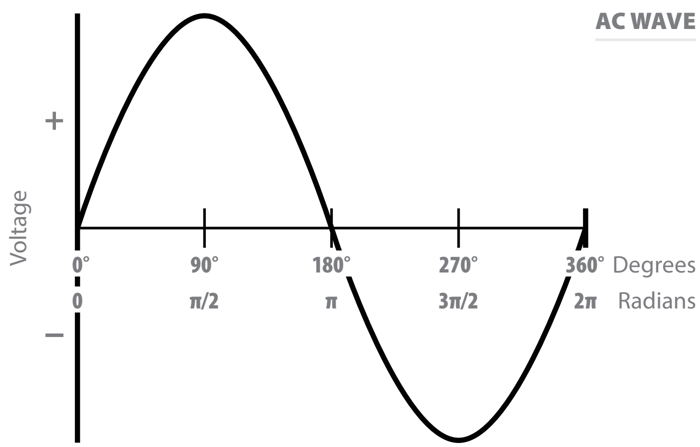
The amount of time high voltage must be applied during testing is also specified in many safety agency standards. The most common test durations are 1 second for production tests and 1 minute for design tests. Further, agencies like UL require that Hipot testers meet certain output voltage regulation specifications to ensure that the DUT is stressed at the correct voltage. Output regulation capability is very important when Hipot testing for 1 second since the test operator doesn't have enough time to correct the output voltage if it rises or sags. For 1 second tests, the Hipot's output voltage must be no less than 100% and no more than 120% of the specified test voltage. When the test voltage is applied for 1 minute, the Hipot's kilovolt meter can easily be monitored to see if the output voltage has varied. The operator also has enough time to adjust the output voltage to the correct level if necessary.

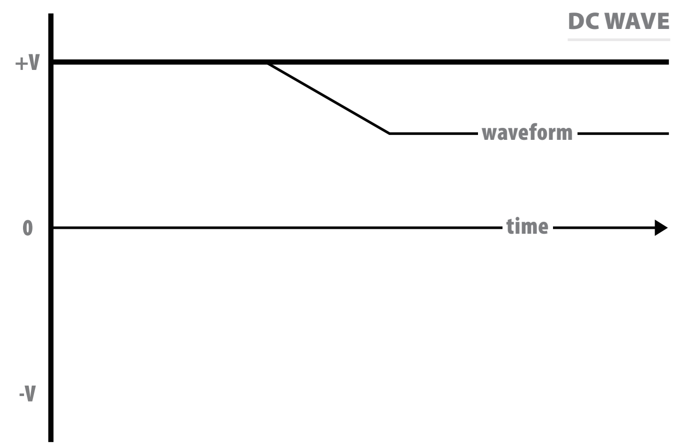
Most Hipots today have a programmable leakage current limit threshold. The test operator can adjust the limit to the value specified by safety agency standards. If the DUT has faulty insulation and a breakdown occurs, the leakage current will exceed the threshold and the Hipot will indicate that a "hi-limit failure" or an "overload failure" has occurred. Many manufacturers are often confused about how they are to determine the appropriate leakage current limit threshold for specific products if it isn't specified in an agency standard. A good rule of thumb is to perform a Hipot test on a handful of known good products while recording the nominal leakage current measured by the test instrument. Once an average nominal leakage current value has been determined, the leakage current limit threshold can be set to a value much higher than the average.

AC VS. DC HIPOT TESTS

Manufacturers may or may not be required to perform a specific type of Hipot test depending upon the DUT and the standard to which it is being tested. Most Hipot manufacturers offer testers with AC or DC output capability and both tests have inherent advantages and disadvantages that become evident depending on the characteristics of the product being tested. (see **Figure 6**)

FIGURE 6 **AC VS. DC TESTING**





AC HIPOT ADVANTAGES

- Slow ramping of the test voltage is unnecessary due to the changing polarity of the applied waveform.
- It's unnecessary to discharge the DUT after AC testing.
- AC testing stresses the insulation alternately in both polarities.

DC HIPOT ADVANTAGES

- The test can be performed at a much lower current level, which saves power and posses less risk to the operator.
- Leakage current measurement is a more accurate representation of the real current.
- DC testing is the only option for some circuit components: diodes, capacitors, etc.

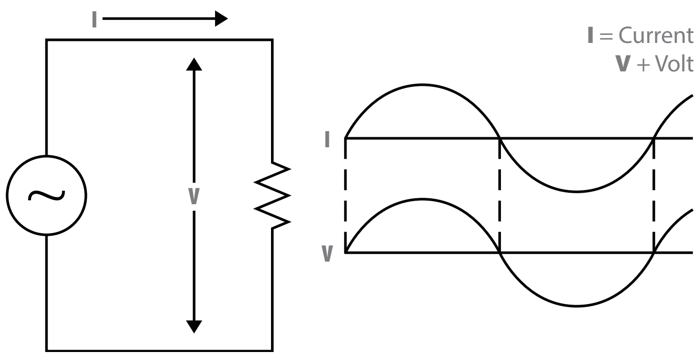
Many of the differences associated with AC and DC Hipot tests stem from the capacitive nature of a product's insulation. While the leakage current due to the insulation resistance of the product is resistive and is in phase with the applied voltage, the circuit which is being tested also has some internal capacitance (two conductors separated by a dielectric material). The application of an AC test voltage to a capacitive item causes a reactive current that is 90 degrees out of phase with the applied voltage. The leakage current that is read by most AC Hipot testers is the vector sum or total of the reactive current and the resistive leakage current or real current.

Figures 7, 8, and 9 demonstrate resistive current, reactive current and the vector sum relationship between the two. The real current is due to the insulation resistance of the product and the applied voltage. The physical design of a product is the primary controlling factor that determines the capacitive reactance of a product. Today many products have higher capacitive leakage currents because filter capacitors have been added to the input circuits to enable them to comply with EMC regulations. The resistive leakage current within a product is primarily dependent on the type of insulating material that was chosen for that product and the applied voltage. The exact value of the resistive leakage or real current is usually the determining factor that dictates the quality of the insulation at a particular voltage. Unfortunately, the reactive current is often much greater than the real current. Unless the two components are separated, a doubling or more of the real current leakage can go undetected.

This point is ignored by some UL standards that specify the minimum sensitivity of voltage withstand instruments in the following way: if the instrument is set up as usual and adjusted for a test and a 120 kΩ resistor is tested instead of the product, then the test must fail. This means that the maximum permissible total current (reactive and real) is equal to the test voltage divided by 120 kΩ. The threshold actually is slightly lower than this value because the current drawn by a 120 kΩ resistor must always cause a failure indication. Although UL specifies that the total current is important for safety reasons, the test can not effectively detect an abnormally high insulation leakage if it is masked by normally high reactive current (due to capacitance).

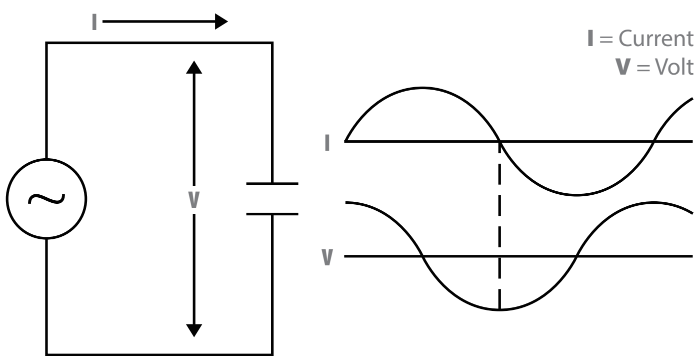
DC Hipot testing is sometimes chosen to avoid the problems associated with AC Hipot testing. During DC Hipot testing the DUT is charged. The same capacitance that causes reactive current in AC testing results in initial charging current which exponentially drops to zero during DC testing. Once the item under test is fully charged the only current which is flowing is the true leakage current. This allows a DC Hipot tester to clearly display only the true leakage of the DUT. The other advantage to DC testing is that since the charging current only needs to be applied momentarily the output power requirements of the DC Hipot tester can typically be much lower than what would be required in an AC tester.

FIGURE 7 — RESISTIVE CURRENT



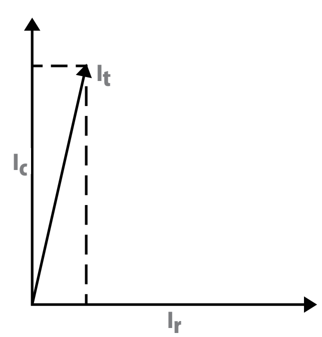
Leakage Current which is due to a resistive element is in phase with the output voltage waveform.

FIGURE 8 — CAPACITIVE CURRENT



Application of an AC test voltage to a capacitive element causes a reactive current that is 90° out of phase with the applied voltage.

FIGURE 9 — VECTOR SUM RELATIONSHIP



I_c = Capacitive Current
I_r = Resistive Current
I_t = Total Current

Vector sum relationship of capacitive current and resistive current.

By gradually applying the voltage and allowing the charging current to diminish after each small increase, highly capacitive products may be tested with far less power than would be required by AC instruments. While this reduces the inherent danger to the operator, it significantly increases the required testing time.

PROCEDURAL DIFFERENCES

The differences between AC and DC waveforms necessitate a variation in Hipot test procedures. Although the test is basically the same, the test operator needs to take into account the relationship between a DC waveform and its equivalent AC waveform. AC waveforms are often listed as RMS (root mean squared). This RMS value, known as the effective value, provides a load with the same amount of energy as a DC waveform of the same voltage: a 25 volt DC source provides the same amount of effective energy as a 25 volt RMS AC source.

The actual quantitative value of the RMS AC waveform is much higher at the peaks of the sine wave. In fact, the difference between a peak AC waveform measurement and the RMS measured value is 1.414. The calculation looks as follows:

RMS VOLTAGE * 1.414 = PEAK VOLTAGE

Since a Hipot test is stressing the insulation of a DUT with high voltage, the applied test voltage must be the same value whether it is AC or DC. It is unnecessary to worry about the effective RMS value since the energy delivered to the DUT is of no importance. As we discussed in a previous section, a good rule of thumb for determining the test voltage during an AC Hipot test is to multiply the nominal input voltage (usually from a wall outlet given as an RMS voltage) by 2 and add 1000 volts. For a DC test use the following procedure to assure that the DC voltage is the same value as the peak of the AC waveform: multiply the calculated AC voltage by 1.414.

DC HIPOT TEST VOLTAGE =
AC HIPOT TEST VOLTAGE * 1.414

By performing this operation, the DC voltage is applied at the same level as the peak of the AC voltage waveform.

BREAKDOWN VS. ARCHING

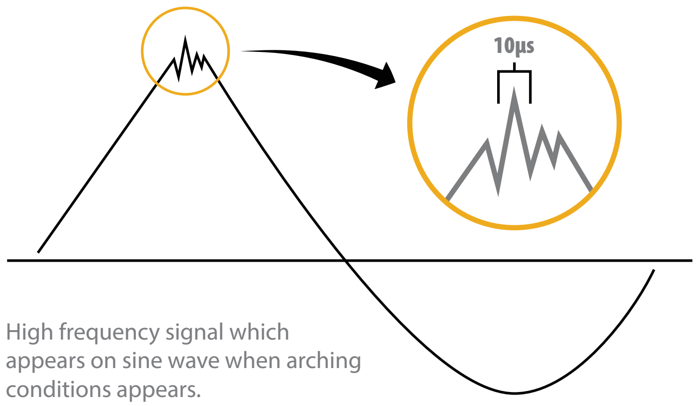
Breakdown can be defined as a condition where voltage discharges across or through a product's insulation and causes excessive current flow. Traditionally, a Hipot tester is designed to monitor and measure the current flow generated by this type of catastrophic insulation failure. A Hipot with its current trip point exceeded will indicate a failure and high voltage will immediately be shut down.

Preceding a dielectric breakdown, corona or high impedance arcing may form around a conductor. In some environments corona can be defined as a luminous discharge caused by the ionization of the air. Corona is a partial breakdown caused by a concentration of electrical stresses at the edge of an electrode in an electrical field.

High impedance arcs and corona generate high frequency pulses which ride on the low frequency wave (see **Figure 10**). These pulses may have a frequency ranging from less than 30 kHz to more than 1 MHz, and may be very short in duration. Many times these pulses are much less than 10 microseconds. These short duration pulses or spikes may not immediately result in a disruptive dis- charge causing the current to increase or the output volt- age to drop. IEC 60601-1 for medical electronic equipment states the following:

"During the test, no flashover or breakdown shall occur. Slight corona discharges are ignored, provided that they cease when the test voltage is temporarily dropped to a lower value, which must be higher however, than the reference voltage and provided

FIGURE 10 HIGH FREQUENCY SIGNAL



High frequency signal which appears on sine wave when arching conditions appears.

that the discharges do not provoke a drop in the test voltage."

Please keep in mind that agencies only offer vague regulations on arcing conditions involved in Hipot testing. At the time of this writing there is no requirement forbidding a DUT from producing an arc when undergoing a Hipot test. Further, arcing can sometimes cause false failures during production line testing. In order to determine how arcing applies to a particular type of product, start with an investigation of the required testing standards.

GROUND CONTINUITY TEST

A Ground Continuity test is often required to be performed with the Dielectric Voltage Withstand test. Unlike the Dielectric Voltage Withstand test, the Ground Continuity test is not an insulation test. Instead, its purpose is to ensure that the DUT's safety ground connections have been made properly.

Grounding electrical equipment provides a second line of defense against electric shock over and above the basic insulation of a product. This grounding of the metal enclosures or exposed dead metal on the equipment also establishes a common ground or earth reference between multiple pieces of equipment which may be in close proximity to each other.

A Ground Continuity test is normally required as a 100% production line test on electrical equipment to verify that there is continuity in the ground circuit of the device. When an insulation fault develops between the line circuit and the exposed metal parts, the ground conductor provides a path for the dangerous fault currents to return to the system ground at the supply source of the current. If the ground circuit is of a low enough impedance, the current will circulate through the ground conductor of the equipment, enabling circuit breakers or fuses to open. By grounding the exposed metal parts, all normal leakage current is safely routed to ground and does not flow through people who touch the product.

Of course, this system only works if the user does not defeat the safety ground. Users often defeat safety grounds by removing the ground prong from a plug or by using an ungrounded 3-to-2 prong adapter. Because these practices are so common, products with 3-pronged line cords are still required to pass a Dielectric Voltage Withstand test just as ungrounded (Class II) products. The integrity of the ground circuit is what protects the operator if a fault should occur in the insulation of a Class I product.

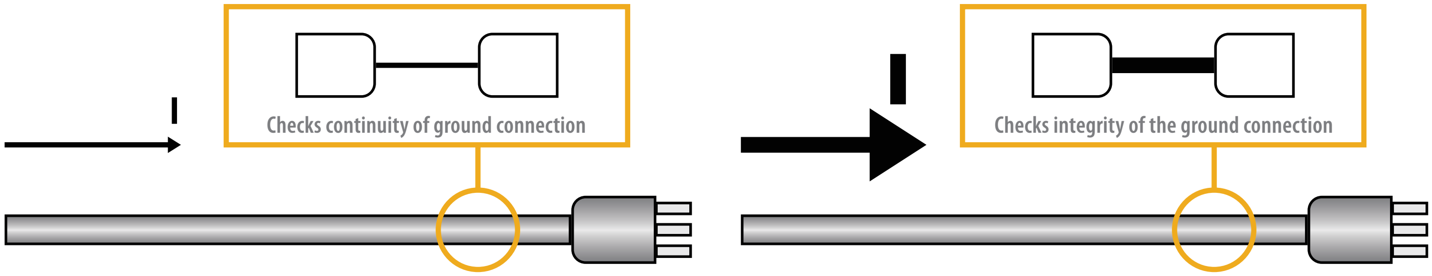
GROUND CONTINUITY TEST CONSIDERATIONS

The Ground Continuity test does have its shortcomings. The ground connection to a product should be rated to handle its nominal input current in case a fault occurs and the line voltage becomes present on the product's metal enclosure. Some testers equipped with the Ground Continuity function only give an indication if continuity is present. Therefore, the test operator has no way of knowing the impedance, or strength of the ground connection. A Ground Continuity test could very well pass a product that has only 1 strand of wire connecting its chassis to ground. If a fault were to occur, this connection wouldn't be capable of handling the input current to the product and could create an open ground condition and a shock hazard. For this reason, many electrical product manufacturers have been turning to the Ground Bond test as a more thorough alternative to the Ground Continuity test.

GROUND BOND TEST

The Ground Bond test or Ground Impedance test can be used to determine whether the safety ground connection of a DUT can adequately handle the fault current resulting from a dielectric breakdown. By simulating a failure condition and circulating excessive current through the DUT's ground connection, the Ground Bond test helps to verify the integrity of the connection to earth ground. Should a product's insulation fail, this low impedance ground connection is essential to ensure that the lethal fault current will flow to ground and not to a person that comes into contact with the DUT's metal enclosure.

Many safety standards require a Ground Bond test to be performed by manufacturers as a 100% production line test in addition to a type test. **A Ground Bond test has distinct advantages over a Ground Continuity test**. While a Ground Continuity test can be performed to verify the connection between a DUT's enclosure and earth ground, only a Ground Bond test can verify the integrity of that connection. This distinction is of great importance when considering the potentially lethal fault currents that



CONTINUITY TEST ADVANTAGES

- Verifies the **existence** of a ground connection.
- The test is quick to set up and easy to perform.
- Usually used as an extra feature during Hipot test.

GROUND BOND TEST ADVANTAGES

- Verifies the **integrity** of a ground connection.
- Provides more valuable safety information about DUT.
- Can be combined with a Hipot test for a more complete safety testing system.

can exist as a result of dielectric breakdown (See **Figure 11**). Without a ground connection capable of sustaining the fault current associated with dielectric breakdown, a DUT can become a dangerous fire hazard as well as pose a potentially fatal shock risk.

General type test requirements specify a Ground Bond test to be performed at 2 times the current rating of the DUT. The test voltage shouldn't exceed 12 volts, and the duration of the test is usually 120 seconds. The calculated impedance of the ground conductor should not exceed a value of 0.1Ω.

GROUND BOND TEST CONSIDERATIONS

In order to test for good integrity of a product's ground connection in a production environment, an instrument must be able to provide the required low voltage output current through the DUT's safety ground. At the same time, the instrument must be capable of measuring the induced voltage across the safety ground connection in order to determine the circuit's impedance. Because the measured values are usually so low, the test operator needs to be careful to negate the test lead resistance of the connections being used. If this is not done correctly, it might be erroneously concluded that the DUT has a safety ground failure, simply because the combined resistance of the test leads and the DUT ground connection exceeds the maximum resistance level.

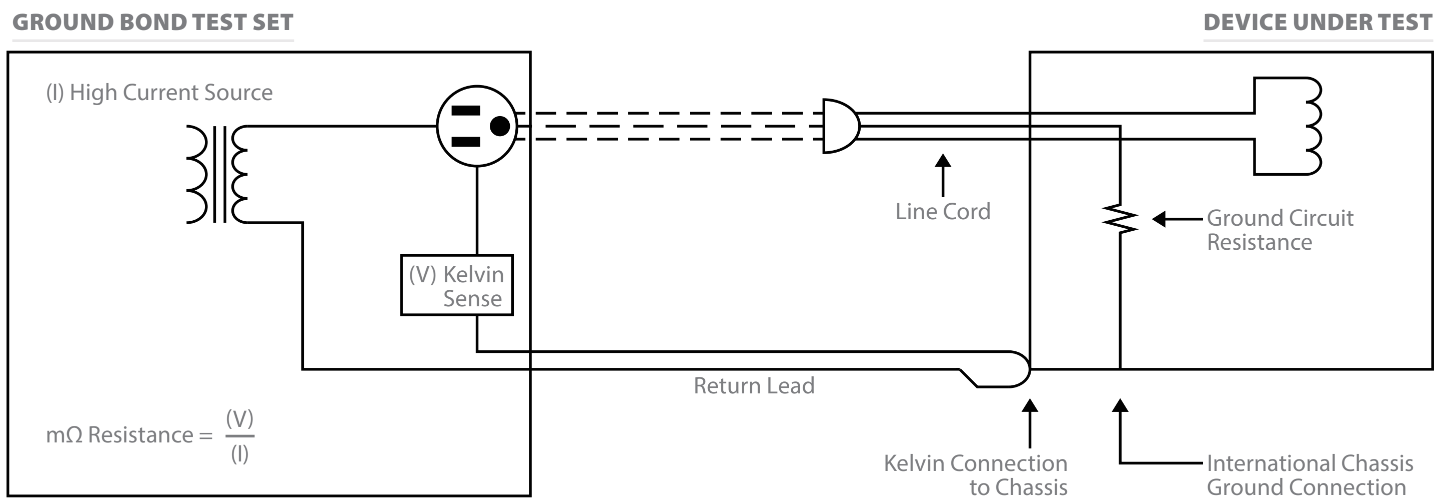
METHODS TO DETECT THE TEST LEAD RESISTANCE:

1. Perform a test with the leads clipped together and subtract the corresponding impedance measurement from total measured impedance of the DUT.

2. Some units come equipped with an automated offset feature that automatically subtracts the test lead impedance from the total measured impedance of the DUT. This operation is quick and easy, usually the result of pushing a single button.

3. The "Kelvin Method" (see **Figure 12** on next page) could also be used to monitor the induced voltage through a very low resistance connection. This proven connection technique uses a four-probe system to eliminate the resistance of any test lead wire from the results. One set of leads applies the required current for the test while a second set of leads measures the voltage drop across the DUT directly at the contact point.

FIGURE 12 **KELVIN METHOD**



THE GROUND BOND TEST AND THE HIPOT TEST

The Ground Bond test and the Hipot test are interrelated, and when used in combination can be an excellent way of ensuring electrical safety compliance of any manufactured product. As stated above, the Ground Bond test is used to verify that the integrity of a DUT's ground connection is capable of handling the fault current resulting from a dielectric breakdown. A Hipot test is used to verify that a DUT's insulation is working properly to prevent dangerous voltages from being present on the product's enclosure. The correlation comes into play if the insulation of a product fails to prevent dielectric breakdown from occurring. If this becomes the case, the fault current will circulate in the ground connection of the DUT. Due to this interrelation between the two tests, it is always a good idea to perform a Ground Bond test on a DUT **BEFORE or DURING** a Hipot test. Performing the tests in this sequence helps to ensure that the ground connection of a DUT can handle the fault current that can occur if the product suffers from a dielectric breakdown.

INSULATION RESISTANCE TEST

The Insulation Resistance test is used to provide manufacturers with a quantifiable value for the resistance of their product's insulation. An Insulation Resistance tester applies a DC voltage across the insulation of a product and measures the corresponding leakage current which is used to calculate the resistance of the insulation. Although most IR testers have a variable output voltage, the test is usually specified at 500 or 1000 volts.

Although related to a Hipot test, the IR test provides more information about the DUT, which can be useful in certain applications. Further, the IR test is sometimes called out by safety agencies to be performed after the Hipot test in order to make sure that the DUT's insulation was not damaged as a result of the high voltage applied to it.

IR tests are always performed using a DC voltage. This is due to the real and reactive current components produced as a result of the DUT's dielectric (in this case, the product's insulation). Applying a DC voltage to the DUT negates the reactive (sometimes called imaginary) current component caused by the product's capacitance and allows the IR test to perform a true real current measurement. If this were not the case, the IR tester would produce erroneous resistance measurements with consistently lower values.

Sometimes the IR test is used to find the Polarization Index (PI) of a DUT. This is often the case with motor manufacturers. This is done by performing two separate IR tests, one test at a duration of 10 minutes, and another test at a duration of 1 minute. The 10 minute test result is then divided by the 1 minute test result and the final number is called the Polarization Index of the DUT. Performing multiple PI tests over the life of the DUT can give accurate information about the quality of a DUT's insulation.

The following shows the calculations for finding Voltage, Resistance, and Current of your Insulation Resistance and Hipot Tests:

$$V = I \times R \qquad \text{OR} \qquad I = \frac{V}{R} \qquad R = \frac{V}{I}$$

INSULATION RESISTANCE TEST CONSIDERATIONS

As with a DC Hipot test, the IR test applies DC voltage across the dielectric of a product. Since most products are in some way capacitive in nature, the test operator should be aware of a few considerations. It is important to allow the test to run for a period of time before recording any measurements. This is due to the charging currents necessary to charge the capacitance of the product. If this current isn't allowed to settle over time, the test could produce erroneous results. Generally, the test measurement is specified to be taken after at least 60 seconds in order to record an accurate measurement.

Accuracy always plays a big part when performing an IR test. For this reason it is very important to keep the test conditions as stable as possible each time a test is performed. Temperature, humidity, and cleanliness of the DUT are all factors that can alter an IR measurement and produce erroneous results. If the temperature during the test cannot be controlled, the IR measurement must be corrected for a temperature of around 40°C. A general rule of thumb states that for every 10°C increase in temperature, divide the IR reading by 2. Likewise, for every 10°C decrease in temperature, multiple the IR reading by 2.

While performing electrical safety tests, technicians will be exposed to potentially lethal voltages. In order to avoid injuries and fatalities, every manufacturer that incorporates safety testing into the production process should make sure that the test operators are fully aware of the risks inherent to the job. Providing operators with proper education about the basics of electricity and safety testing will help avoid injuries, costly lawsuits, and even deaths.

OPERATOR SAFETY

SHOCK HAZARD

It is important for any test operator required to perform electrical safety tests to understand electric shock and the effects electricity has on the human body. The severity of an electric shock received by a person who contacts an electrical circuit is influenced by 3 primary factors:

1. The amount of current flowing through the body.
2. The path of the current through the body.
3. The length of time the person is exposed to the current.

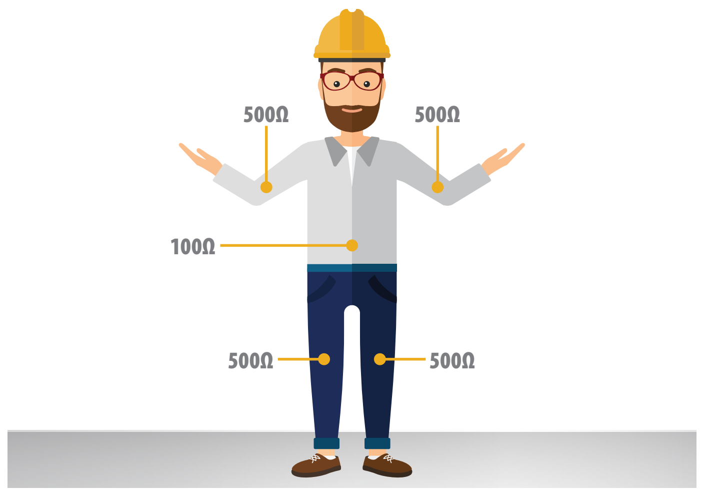
Burns are the most common form of shock-related injury. Any person who is exposed to voltages in excess of 50 volts is at risk of being injured from an electrical shock. Currents as low as 50 mA can cause irregularities in an individual's heartbeat, which can lead to heart failure and cardiac arrest.

STARTLE REACTION

In the 1960's UL and ANSI (American National Standards Institute) conducted experiments to determine how the human body responded to different current levels. Tests were run using a 120-volt 60 Hz source. The studies determined that on average 0.5 mA of current is the perception level that can produce a startle reaction. Higher levels of current in the range of 5-10 mA inhibit a person from letting go of the electric circuit producing the shock. Currents in the range of 20-40 mA flowing through the body's extremities can cause the muscles to contract painfully, make breathing difficult and sometimes lead to asphyxiation. Current levels in the 40-70 mA range lasting longer than 1 second can cause ventricular fibrillation and sometimes cardiac arrest. Increasing the current to levels above 70 mA causes extreme electrical burns and death.

HUMAN BODY RESISTANCE

FIGURE 14 HUMAN BODY RESISTANCE



On average, the human body has a resistance of 1000-1500Ω from one hand to the other (see **Figure 14**). The outer layer of the skin provides the largest percentage of the body's resistance. Yet due to genetic and environmental conditions, the skin's resistive properties can vary greatly. Dry thick skin has a much higher resistance than moist soft skin or skin that has a cut or abrasion. The skin, like any insulator, has a breakdown voltage. This breakdown voltage will vary with the individual, but is normally in the area of 600 volts. When this point is exceeded the insulating properties created by the skin break down and the only remaining impedance to the flow of electric current is the body's tissue. Unfortunately, the parts of the body that conduct electricity the best are the blood vessels and nerves. Thus, an extreme electric shock that breaks down the skin's insulating property can cause internal injuries to the tissues and organs of the body.

A simple calculation reveals the extremely lethal current capability of a household outlet:

HAND-TO-HAND RESISTANCE: 1000Ω
OUTLET VOLTAGE: 120 VOLTS FORMULA: I = V/R
120/1000 = 0.120 AMPS, OR 120 MA

TEST OPERATOR TRAINING SUGGESTIONS

For safety reasons, it is very important that test operators are equipped with the appropriate knowledge to safeguard themselves and others from accidental electrical shock.

When training an operator it is important to make them aware of the potential hazards inherent to safety testing, and how their actions can create further hazards. The following is a list of general topics a test operator should be familiar with:

1. A test operator should have a basic understanding of electricity, including voltage, current, and resistance. The operator should understand how these three topics relate to each other. The operator should also understand the differences between conductors and insulators, and how grounding systems work.

2. A test operator should have a working knowledge of the test equipment, the tests that are being performed, and the hazards associated with the tests.

3. A test operator should be trained in safety-related work practices and procedural requirements in order to provide protection from the electrical hazards associated with their particular duties.

4. A test operator should understand the 3 primary factors that determine the severity of electric shock (see the preceding section).

5. A test operator should know how the dangers of different current levels and how the body responds to each level (see the preceding section).

6. A test operator working on or near exposed energized electrical conductors should be trained in methods to release shock victims in contact with electrical circuits.

7. A test operator should be aware of the DUT's ground configuration and understand that contacting the DUT under certain conditions could cause a severe shock.

8. A test operator should understand that an open return lead during a test can result in the DUT chassis becoming energized.

9. A test operator should understand the importance of discharging a DUT after testing has been completed.

Manufacturers should also emphasize that defeating any safety systems or allowing unauthorized personnel into the testing area are serious breaches of testing procedure safety and will result in severe penalties. Advise technicians not to wear jewelry, especially hanging bracelets or necklaces, which could become energized.

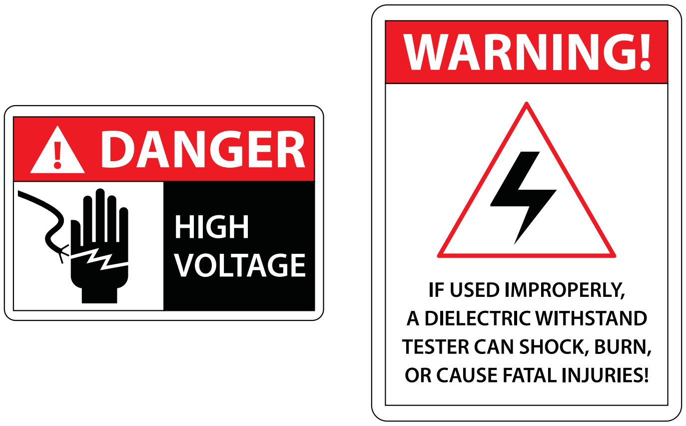
TEST STATION SAFETY

One of the best ways to prevent injury to test operators is to ensure that the test station is set up safely and securely. Choose an area away from the mainstream of activity where normal employee routines will not be interrupted. The area must be clearly marked and minimum clearances of 3 to 8 feet must be maintained around any exposed live parts. Shields, protective barriers, or protective insulating materials shall be used to protect each employee from shock, burns or other related injuries while the employee is working near exposed energized parts.

Mark the testing area with clearly posted signs that read: DANGER-HIGH VOLTAGE TEST IN PROGRESS. UNAUTHORIZED PERSONNEL KEEP AWAY (see **Figure 15**).

Set up the test station so that the main power, except warning and status lights, can be cut off by a single switch. Position the switch at the perimeter of the test area and label it clearly. Instruct employees that in the event of an emergency, the power must be shut off before anyone enters the test area to aid.

FIGURE 15 **TEST AREA SIGNAGE**



Use only a non-conducting table or workbench for tests. Remove any metal objects that are between the test operator and the products being tested. Ground all other metal objects that are not in contact with the DUT; do not leave them “floating.” If small products are being tested, use a non-conducting material, such as clear acrylic, to construct guards or an enclosure during the test (see **Figure 16** for an example). Fit the enclosure with an interlocking switch so that it will not operate unless the enclosure is in place. Use insulated safety floor mats in the test area to isolate the operator from ground.

FIGURE 16 TESTING ENCLOSURE

A NOTE ON ELECTRICAL SAFETY TESTING AND ESD PROTECTION:

More and more manufacturers performing electrical compliance tests are also involved in following ESD protection protocol. It is very important that ESD procedures and equipment not be used during electrical safety testing, including anti-static robes, benches, or floor mats. All of these items are used to intentionally ground the test operator, a condition that could potentially cause injury or death to a high voltage test operator. ESD workstations are not designed for voltages greater than 250V.

If the instrument can be operated by remote switches, consider two switches (palm buttons) that must be activated simultaneously. Space the switches far apart. This will ensure that the test operator doesn’t come into contact with any high voltage while the test is being executed. A separate relay or control may be used. Never make any connection to the instrument that could energize the high-voltage independently, i.e., without the control of the operator unless the test application is fully automated.

Be certain that the power wiring to the test bench is properly polarized and that the proper low-resistance bonding to earth ground is in place. Some instruments use monitor circuits that check the connections to the power line and ground. The warning lights on these “line monitors” are designed to show potential problems such as incorrect wiring, reversed polarity or insufficient grounding.

Keep the testing area clean and uncluttered. Make sure the test operator (and any observer) knows exactly which product is being tested. Provide considerable bench space around the product being tested. Place the instrument in a convenient location so that the operator does not have to reach over the product being tested to activate or adjust the instrument.

Keep a non-conductive hook in the area to be used in case an employee comes into contact with a current carrying conductor. Have fire extinguishers readily available in case a fire occurs.

GENERAL TEST PROCEDURE CONSIDERATIONS

1. Always verify that the high voltage output is off before making any connections.
2. Always connect the low return side to the instrument first in order to prevent the DUT from becoming energized. Securely connect the clip lead to the exposed metal parts being tested.
3. Always handle both return and high voltage clips by their insulating material, never by the conductive metal. Keep the leads on the bench as close to the DUT as possible and avoid crossing test leads. Neatly coil any excess lead halfway between the tester and the DUT.
4. Test leads should be checked periodically for excessive wear.
5. If using an instrument with a panel mounted receptacle, first connect the return clip lead and then plug the product’s cord set into the instrument.
6. When using a test fixture, be certain that it is properly closed and that all guards are in place.

7. Double check the connections before beginning a test.
8. Develop a standard test procedure and always follow it; don't take any shortcuts.
9. Double check all tester settings before the test.
10. Never touch any of the cables, connections or DUT's during a test.
11. Have a "hot stick" on hand when doing DC testing (a hot stick is a non-conducting rod about two feet long with a metal probe connected to ground at one end). If a connection comes loose during the test, use the "hot stick" to discharge any surface that contacted the instrument's hot lead — simply turning off the power is not sufficient.
12. After the test, turn off the high voltage.
13. Discharge DC-tested products for the proper length of time.
14. Perform a daily verification test on the equipment to assure everything is operating properly.

IN SUMMARY

For safe high voltage testing, always remember to:

→ Keep unqualified and unauthorized personnel away from the testing area.

→ Arrange the testing area out of the way of routine activity. Designate the area clearly.

→ Never touch the DUT or the connections between the DUT and the instrument during a test.

→ In the case of an emergency, or if problems arise, turn off the high voltage first.

→ Properly discharge any DC-tested product before touching or handling connections.

HIPOT TEST APPLICATIONS

TRANSFORMER TESTING

Transformer testing requires care in order to ensure that its various voltage ratings aren't exceeded. For example, a transformer is rated at 1500 volts AC primary to secondary, 1500 volts AC primary to core and 500 volts AC secondary to core. In order to test the first two specifications, a test operator should tie both leads of the secondary to the core and to the return of the instrument, and both leads of the primary together and to the high voltage. The Hipot test is then performed at 1500 volts AC (see **Figure 17**). In order to test the third specification, the test operator should tie both leads of the primary to the core and to the return of the instrument, and both leads of the secondary together and to the high voltage. The Hipot test is then performed at 500 volts AC (see **Figure 18**).

1. Special care should be taken to avoid damage to the transformer during a Hipot test.
2. Do not leave windings open at one or both ends during a test.
3. It is a good idea to connect the core to the return of the instrument.
4. If primary to secondary insulation is being tested, determine which is rated higher to the core and connect the high voltage of the instrument to that winding. Connect the winding which is rated lower to the core together with the return of the instrument and the core.
5. Carefully observe the ratings of every winding to every other winding and to the core. If no rating is given between a pair of windings, find out what the rating is, or connect the pair to the same side of the instrument.
6. Before testing has begun, and once a combination is decided upon, review the specifications to be sure that no ratings will be exceeded. Make notes as to which specifications will be tested with a particular combination of hookups. Do this with each proposed connection combination and verify that all the desired tests will be made.
7. Simplify the plan as much as possible, verify again that no ratings will be exceeded, and then proceed carefully with testing.

FIGURE 17 TRANSFORMER TESTING 1500V

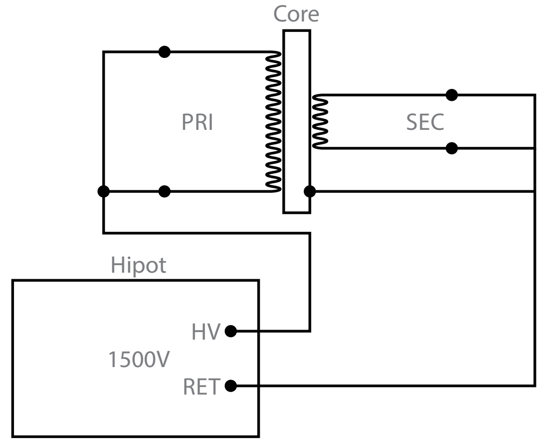
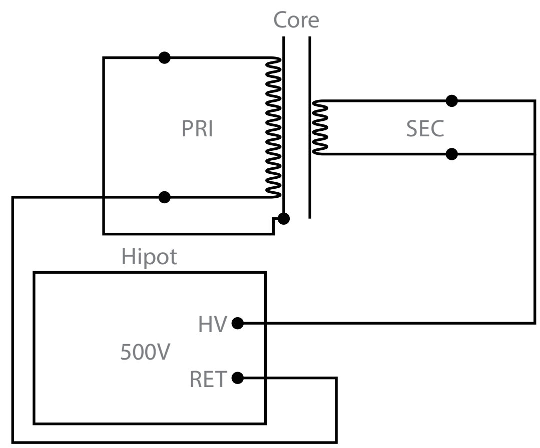


FIGURE 18 TRANSFORMER TESTING 500V



APPLIANCE TESTING

When testing hard-wired finished products such as built- in appliances, one normally will connect the low side of the instrument to the frame or exposed metal and the high side to both the line and neutral connections.

1. Turn on all power switches on the appliance for the test so that all internal circuits are tested.

2. Note that over-voltage should never be applied to the same points where normal line voltage is applied. Instead, the instrument is connected to the exposed metal parts of the product from all the line and neutral circuits tied together.

3. Cord-connected finished products are tested in much the same way. Connect the exposed metal parts of the product to the low side of the instrument. If a test is being performed on double-insulated products, the product may need to be wrapped in foil and the returns connected to the foil.

4. Connect the line and neutral terminals to one another and to the hot side of the instrument. Dielectric Withstand testers with built-in receptacles or external receptacle boxes greatly simplify the testing of cord-connected products. The receptacle box for the Hipot test is wired specially — the line and neutral sides of the receptacle are connected to one another and to the instrument's hot side.

5. Because a Ground Continuity test often is required in addition to the Dielectric Withstand test, the receptacles ground connection frequently is used to check ground continuity. Although the pin usually is grounded during Dielectric Withstand tests, it does not substitute for the clip lead ground connection to the exposed metal of the product, which should be made before plugging the product into the instrument.

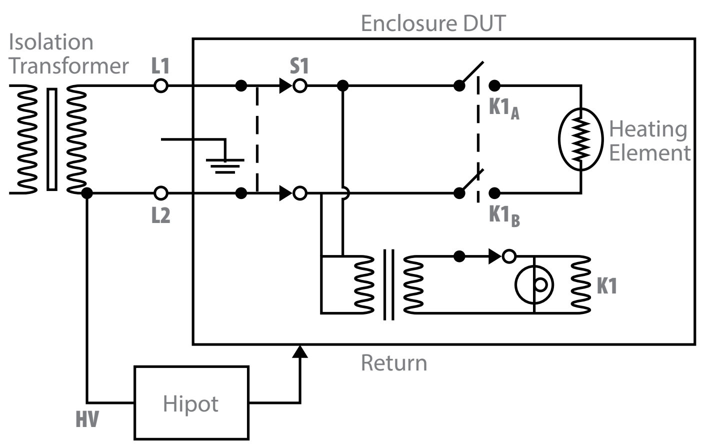
HOT HIPOT TESTING

Some circuit designs utilize relays to interrupt or apply power to other circuits. If only one side of the line is opened by the relay the complete circuit is still tested if voltage is applied to both conductors. Yet some products, especially those that are powered from a 220-volt source, use relays that open both sides of the line. When both sides of the line are opened the circuits controlled by the relays are not tested.

In order to test these circuits the relays must be closed manually. If the relays cannot be closed these circuits must be bypassed in order to perform a Hipot test correctly. However, depending on the individual relay, it may not be possible to manually close the contacts. In addition it may be very difficult and time consuming to short out the circuits to be tested.

A unique method of performing the Hipot test is to run the test while the DUT is powered up. This is known as a "hot" Hipot test (see **Figure 19**). The hot Hipot test allows the operator to close or energize circuits controlled by relays. This is accomplished by utilizing an isolation transformer to power up the DUT. The Hipot voltage is then applied between one leg of the energized circuit and the case of the DUT. An isolation transformer must be used to isolate the incoming power supply voltage from earth. This is required since most power systems are ground referenced, and the

FIGURE 19 — HOT HIPOT TEST



return circuits on most Hipot testers are also at ground or near ground potential. If the isolation transformer is not used, line current can flow back through the return circuits of the Hipot resulting in damage to the test instrument and creating a potential shock hazard. In addition, failure to use an isolation transformer could also result in false failures during the Hipot test because the neutral side of the line is referenced to earth.

500 VA HIPOT TESTING

Several years ago, the European Union began enforcing requirements for compliance safety testing of most electrical products sold into the European Community. These requirements were established to safeguard the health of both consumers and workers, as well as to protect the environment. The intention was to provide a set of harmonized standards for product safety and quality testing that would be accepted by all EU member countries. Once it has met the test requirements, a product must be affixed with a CE approval notification before it can enter the European market.

The Hipot test that manufacturers are required to perform under the CE directives for safety testing is largely based on the IEC (International Electrotechnical Commission) and EN (European Norms) standards. Some of these referenced specifications mandate the use of a Hipot tester with as much as 500 volt-amperes (VA) of output power.

A Hipot's VA rating is a measure of its output power, calculated by multiplying the maximum voltage of the Hipot by its maximum current output.

V = VOLTAGE
I = CURRENT
VA = VOLT AMPERES
V * I = VA

Two important specifications that call for a 500 VA of output power, without exception, are IEC 204 and EN 60204, part of the Machinery Directive, which became effective on January 1, 1995. Any electrical machine imported into Europe must pass these requirements before it is allowed to display the CE mark. This forces many manufacturers to test their products with a Hipot capable of a much higher output rating than they may have used to comply with U.S. safety-agency requirements. While certain specifications from UL and CSA also specify a 500 VA rating, unlike the IEC and EN specs they permit certain exceptions.

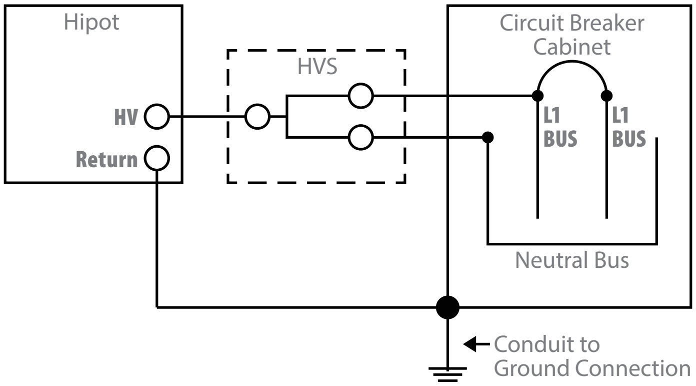
A Hipot capable of producing 500 VA should provide enough output power to test a device under a loaded condition without allowing the output voltage to fall below the specified setting. The applications most commonly requiring a Hipot with a 500 VA rating are those in which an AC voltage must be applied to a highly capacitive load. Applying an AC test voltage to a capacitive DUT causes a flow of capacitive leakage current, which can have a dramatic effect on the total leakage current that the Hipot measures; the capacitive leakage current is often much greater than the current that flows due to resistive leakage, and in itself could cause the need for a 500 VA Hipot.

Unfortunately, a 500 VA output capacity poses a considerable safety risk for the test operator: the higher the current output of the Hipot, the more potentially lethal the test. Test operators work in an environment that calls for extreme caution. The severity of an electrical shock is dependent on a number of factors, including voltage, current, frequency, duration of exposure, current path, and the physical condition of the person who receives the shock. For these reasons it is recommended that manufacturers do not use a 500 VA tester unless they are required to in order to comply with the specifications of the test. A 500 VA Hipot tester is also recommended when testing a product so highly capacitive that a typical lower VA rated Hipot will not be able to test the product.

MANUFACTURED HOME TESTING

With recent regulations put in place by the U.S. Department of Housing and Urban Development (HUD), Hipot testing has become increasingly important to manufactured and modular home manufacturers. In a new standard HUD calls out for all manufactured modular homes to be subjected to a Hipot test to check the integrity of the home's insulation. (See **Figure 20** on next page for an example.) The standard specifies that the test be performed between 900 to 1079 volts (AC RMS) for one minute or between 1080 to 1250 volts (AC RMS) for one

FIGURE 20 MANUFACTURED HOME DIAGRAM



second. A DC test may be substituted for the AC test if appropriate voltage levels are used 1.414 times the AC test potential. The test is conducted between the live parts and the manufactured home's ground, as well as between the neutral and the manufactured home's ground. It is important to refrain from conducting the test from phase to phase or between hot and neutral in order to avoid damage to any appliances that might be connected.

INSULATION RESISTANCE TEST APPLICATIONS

FEDERAL AVIATION ADMINISTRATION AND AEROSPACE TESTING

Insulation Resistance testing is extremely important to the airline and aerospace industries. With strict safety regulations currently in force, IR testing is a good way to verify the integrity of cable harnesses, engines, and motors on aircraft of all kinds. The IR test is often specified to be performed both before and after a Hipot test in order to determine whether a DUT's insulation has been weakened by the application of high voltage.

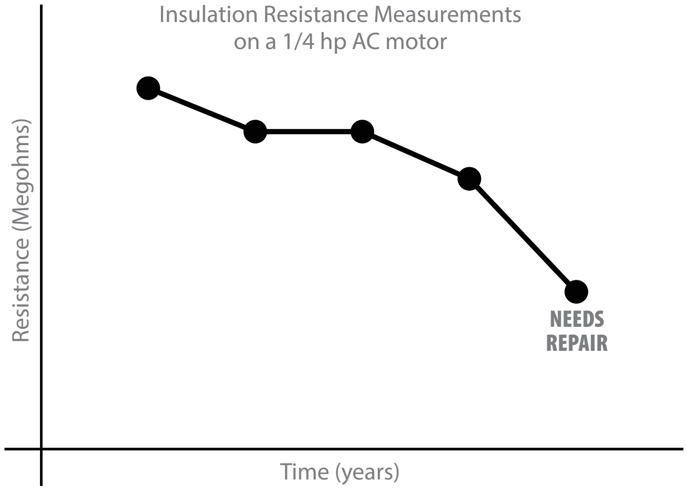
MOTOR TESTING

Those who manufacture, install, and repair motors find Insulation Resistance testing very useful in determining the quality of the insulation in a motor. To an experienced individual who knows how to interpret readings, a single insulation resistance measurement can indicate whether a motor is fit for use.

Important information can be obtained and recorded when a measurement is made on every new motor before it is used, and again at least every year while it is in service. This ongoing measurement process will allow the operator to keep track of the motor's insulation as time goes on and indicate if degradation is occurring (see **Figure 21**). The obvious knee in the curve will alert the manufacturer that the motor needs repair.

To test a motor with no history, a calculation called the Polarization Index is sometimes applied. This index is obtained by dividing a 10-minute Insulation Resistance reading by a 1-minute Insulation Resistance reading.

FIGURE 21 DEGRADATION TRACKING



SCI PRODUCT FEATURES

At SCI we strive to provide our loyal customers with simple and affordable test equipment with only the features they need. Our entire line of testers are simple-to-use, safe, and built tough. We have the right instrument to fit your needs no matter what your application requires. Some of our features include:

LINE AND LOAD REGULATION

The Hipot maintains a consistent pre-set output voltage even if the line power experiences fluctuations or the load changes suddenly.

ELECTRONIC RAMP AND DWELL

These features give the test operator more control over the duration and execution of the Hipot test. The Ramp feature enables the Hipot to ramp up the output voltage from zero to the test voltage over a user-specified period of time. The Dwell feature allows the Hipot to output a consistent test voltage for a user-specified period of time.

PLC REMOTE CONTROL

A 9-pin interface that provides out- puts for Pass, Fail, and Test in Process. The interface also provides inputs for Test, Reset, and Safety Interlock. This gives the user all the basic remotes required to configure these instruments through simple PLC relay control.

- Model 1305 contains only the Test input.
- Model 4320 includes all of the above plus memory location recall.

TAMPER-RESISTANT FRONT PANEL

Prevents operators from inadvertently or accidentally modifying test parameters, and ensures consistent and reliable test results, minimizing the need for costly and time consuming product retesting.

A

AC - Alternating Current - is the flow of electric current which reaches a maximum in one direction, decreases to zero, then reverses itself and reaches a maximum in the opposite direction. The cycle is repeated continuously, changing polarity and magnitude with time.

Agency Listing - Certification that a sample product has been tested by an independent third party agency (safety agency) and complied with national or international testing to standards applicable that particular product. Once certified, an agency label may be applied to the product to indicate compliance.

Arcing - A momentary flashover or partial discharge across a dielectric, sometimes visible as corona, due to the intense concentration of an electric field.

B

Breakdown - Catastrophic failure of a product's insulation resulting in excessive leakage current flow.

C

CE Mark - The CE Mark is a manufacturer or importer's self-declaration mark or label of conformity declaring compliance with all applicable directives and harmonized standards.

Class I Product - A product in which an additional safety precaution is provided in the form of a connection of the equipment to earth ground. The protective earth conductor in the fixed wiring of the line cord is attached to the chassis in such a way so that all accessible metal parts cannot become live in the event of a failure of the basic insulation.

Class II Product - A product that contains additional safety precautions such as double insulation or reinforced insulation. There are no provisions for protective earthing or reliance upon installation conditions, for these products.

D

DC - Direct Current - is the flow of continuous electric current in one direction that can change in magnitude but not polarity.

Design/Type Test - A safety test performed on a prototype model during the design phase of the product.

Dielectric - An insulator sandwiched between two conductors. In the case of a Hipot test, the DUT's insulation is considered to be a dielectric.

Directive - Laws drawn up to outline and regulate the responsibilities of electrical safety testing by any manufacturer that sells a product into or within a European Union country.

DUT - Device Under Test

Electrical Safety Compliance - When a manufacturer employs an electrical safety testing procedure that meets safety agency standards for a particular product.

E

EU - European Union.

G

Ground Bond Test - A high current test that checks the integrity of a Class I product's safety ground connection.

Ground Continuity Test - A low current test that verifies a Class I product's safety ground connection is continuous.

H

Hipot Test (Dielectric Withstand Test) - A high voltage test used to stress the insulation of a product and measure the resulting leakage current.

I

Insulation - A material that is a poor conductor of electricity. Used to isolate electrical circuits from ground and each other.

Insulation Resistance Test - A high voltage test used to record the resistance of a product's insulation.

K

Kelvin Method - 4-wire configuration employed in Ground Bond testing in order to ensure the accuracy of the measurement.

L

Leakage Current - Current that leaks through a product's insulation to ground.

P

Polarization Index - A practical measure of dielectric absorption expressed numerically as the ratio of the insulation resistance after 10 minutes to the insulation resistance after 1 minute of voltage application.

Production Test - A test performed on 100% of manufactured products after they are assembled, but before shipment.

R

Reactive Current - Current due to the capacitance of a product. Affects the total current measurement during an AC Hipot test but is neglected by a DC Hipot test.

Real Current - Current due to the resistance of a product's insulation.

RMS - Root Mean Squared value. A measurement used to classify an AC source that delivers the same amount of energy over time as a DC source of the same value.

S

Safety Agency - Independent or Federally-associated regulatory agencies that create and oversee electrical safety testing in specific countries.

Safety Ground - An extra low-impedance connection from the metallic chassis of a product to earth ground. Acts as a current path under fault conditions.

Standard - A nationally or internationally accepted universal testing procedure for ensuring product safety.

U

UL Listing - A marking that can be applied to an electrical product that certifies it has been tested to UL specifications and has been deemed safe for consumer and/or industrial use.

SAFETY AGENCY RESOURCES

American National Standards Institute
www.ansi.org

ASTM International
www.astm.org

British Standards Institution
www.bsigroup.com

Canadian Standards Association
www.csagroup.org

European Committee for Electrotechnical Standardization
www.cenelec.org

IEC Central Office
www.iec.ch

The Institute of Electrical and Electronic Engineers, Inc.
www.ieee.org

PSES - Product Safety Engineering Society - Chicago Chapter
www.ieeechicago.org

Intertek
www.intertek.com

Japanese Standards Association
www.jsa.or.jp/en/

National Institute of Standards and Technology
www.nist.gov

National Electric Manufacturers Association
www.nema.org

Occupational Safety & Health Administration
www.osha.gov

The Standards Council of Canada
www.scc.ca

TÜV Rheinland of North America, Inc.
www.tuv.com/usa/

Underwriters Laboratories, Inc.
www.ul.com

U.S. Consumer Product Safety Commission
www.cpsc.gov

VDE-Verband Deutscher Elektrotechniker
www.vde.com/en

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