The Operator's Guide to **Electrical Safety Compliance Testing**

ASSOCIATED RESEARCH, INC.®

Preface

Most people who design, build or sell electrically powered products, sub-assemblies or components are unfamiliar with testing the electrical safety of their products.

Manufacturers of testing instruments and the agents responsible for establishing test procedures are sometimes at a loss to explain the how and why of a test and the true meaning of the test results. Some people, when faced with the challenge of performing a test, become uneasy at the thought of working with a high-voltage system.

Associated Research, Inc. developed this booklet to address these concerns and to clarify the necessity of electrical safety tests, identify what information can be gained from them, and learn how to apply the results properly so that all electrical systems operate safely and efficiently.

Safeguards to protect test operators and bystanders also will be discussed. We hope to clarify a complex subject and alleviate concerns about safety, operation and analysis.

If you have any questions or concerns, or if you are interested in having Associated Research provide educational materials for your company's test personnel, please give us a call at 1-800-858-TEST (8378). You can also download technical white papers, articles and other material for use in training and education directly from our website at www.asresearch.com.

Sincerely,

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Introduction: Safety & Reasons to Test Insulation

As a woman reached for a dry towel after her bath, she made contact with her electric clothes dryer and was electrocuted. The woman acted as a ground path for the ungrounded dryer supplied with a two-prong plug, and the dryer's faulty insulation system caused the woman's electrocution. (1)

Many injuries and electrocutions are caused by electrical products with faulty insulation or when a product's safety grounding system is defeated. Like the woman who acted as a ground path for her ungrounded clothes dryer, a person who uses an ungrounded power drill while standing on a damp garage floor or another person who touches an ungrounded space heater when his or her clothes are wet both run the risk of accidental electrocution if products are not properly insulated.

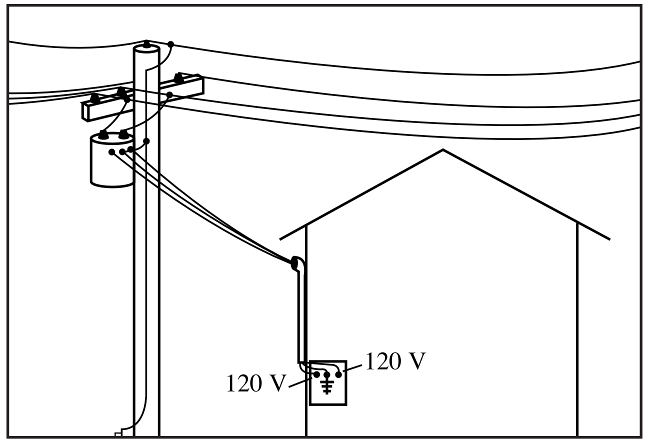
As manufacturers of products designed for consumer or industrial use, ***we cannot prevent product users from defeating grounding systems, we can only warn them of the risks.*** However, we must prevent products with faulty insulation from leaving our factories.

The insulation in a product which concerns us most is that which separates the power line circuit from everything else—secondary, low-voltage circuits, isolated power supplies either inside or outside the product, the shell or case of the product, whether groundable or not, etc.

This insulation prevents current from an ordinary household outlet, an almost unlimited power source, from becoming hazardous by finding a ground path with something that is not meant to be a ground path.

Current flows into any available ground path because most power distribution systems are ground-referenced. 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 a ground connection at a single point (See Figure 1). 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 120/240V systems also provide power across independent ungrounded hot lines. But each of those 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) Wire 120/240V AC, Single phase secondary distribution systems

To protect consumers, manufacturers need to perform several types of electrical safety tests to ensure that products, household electric coffee makers and brewing devices, for example—meet industry standards for product construction, performance, ratings, markings and instruction manuals.

But only one test, the Dielectric Voltage-Withstand test, is required for every appliance shipped. (2)

Manufacturers have additional reasons for insulation testing. Not only do they want to prevent faulty components from being installed in their products, but they must also catch workmanship defects in assemblies before they are installed. The earlier a defect is detected, the less a manufacturer will have to spend reworking the product. Many manufacturers are performing tests to ensure product quality for ISO compliance. Other manufacturers may test to protect themselves from product liability suits. However, as a rule, user safety always is the greatest concern.

(1) Mazer, William M., Electrical Accident Investigation Handbook, Electrodata, Inc., Glen Echo, Md., 11/83 sec. 9.2.70.9

(2) UL Standard 1082 for Household Electric Coffee Makers and Brewing-Type Devices, Underwriters Laboratories, Inc., Northbrook, Ill. 2/81

Safety of the Test Operators & Bystanders

Suggestions for the Test Station

Choose an area away from the mainstream of activity, where employees' normal routines will not be interrupted. The area must be clearly marked, minimum clearances of 3 to 8 feet must be maintained around any exposed live parts to protect unqualified persons. 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 which might be accidentally contacted.

Mark the testing area with clearly posted signs that read: **DANGER—HIGH VOLTAGE TEST IN PROGRESS. UNAUTHORIZED PERSONNEL KEEP AWAY.**

Set up the test station so that the power, except 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 an event of an emergency, the power must be shut off before anyone enters the test area to offer assistance.

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. 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.

IF IMPROPERLY USED, A DIELECTRIC WITHSTAND TESTER CAN SHOCK, BURN OR CAUSE FATAL INJURIES!

If the instrument can be operated by remote switches, consider two switches (palm buttons) that must simultaneously be actuated. Space the switches far apart. You may have to use a separate (anti-tie down) relay or control. 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.

Dielectric Voltage-Withstand instruments must be connected to a good ground. 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 such problems as incorrect wiring, reversed polarity or insufficient grounding. If you see anything other than an 'OK' signal, turn off and unplug the instrument immediately. Do not use it until the wiring is repaired.

Keep the testing area clean and uncluttered. Make sure the test operator (and any observers) knows exactly which product is being tested, which is waiting to be tested and which has already been 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.

Suggestions for Training the Test Operator

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 potential hazards and how their actions can create potential hazards. Is is important to make sure that the test operator understands the following;

1. A test operator should have a basic understanding of electricity, voltage, current, resistance, and how they relate to each other. They should also understand conductors, insulators and grounding systems.

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 as well as the circuits that are being energized.

3. A test operator should understand the approach distances and corresponding voltages to which they may be exposed.

4. A test operator should be trained to understand the specific hazards associated with electrical energy. They should be trained in safety-related work practices and procedural requirements as necessary to provide protection from the electrical hazards associated with their respective job or task assignments. Employees should be trained to identify and understand the relationship between electrical hazards and possible injury.

5. A test operator should understand that the three primary factors that determine the severity of electric shock are:
A. The amount of current flowing through the body
B. The path of the electrical current through the body
C. The duration or length of time the person is exposed

6. A test operator should know that the human body responds to current in the following manner:
A. 0.5 to 1 mA is the perception level
B. 5 mA a slight shock is felt, a startle reaction is produced
C. 6 -25 mA for women and 9 -30 mA for men can produce the inability to let go
D. 30 - 150 milliamps results in extreme pain, respiratory arrest, ventricular fibrillation and possible death
E. 10 Amps Cardiac Arrest and severe burns can occur

7. A test operator working on or near exposed energized electrical conductors or circuit parts should be trained in methods of release of victims from contact with exposed energized conductors or circuit parts.

8. A test operator should understand that the test instrument is a variable voltage power source and the current will flow to any available ground path. They should be aware that contacting the device under test (DUT) during the test can result in a dangerous shock hazard under certain conditions.

9. A test operator should understand that if the return circuit is open during the test then the enclosure of the DUT can become energized. This can occur if the return lead is open or the operator lifts the return lead from the DUT while a test is in process.

10. A test operator should be made aware of the importance of discharging a DUT. Lifting the high voltage lead from the DUT before the test is complete can leave the DUT charged. When you are performing a Hipot test you are testing the insulation between two conductors which is essentially a capacitor. This capacitor can act as a storage device and hold a charge even when performing an AC test. If the circuit is opened at the peak of the applied voltage then the DUT could, even under an AC test, hold a charge. When the test is allowed to finish and the voltage is reduced to zero the charge is dissipated through the impedance of the high voltage transformer of the Hipot tester. Most DC Hipot testers today employ an output shorting device to discharge the DUT, but the Hipot must remain connected to the DUT throughout the test cycle.

You should emphasize to the operator the range of output voltage as well as the correct voltage to be used for the products being tested. Explain how much current the instrument can supply, and that current, not voltage, injures or kills.

In addition, operators should be warned 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, including removal from a testing job. Lastly, warn operators not to wear jewelry, especially hanging bracelets or necklaces, which could become energized.

Modern test instruments with microprocessor control offer password-protected modes of operation, allowing the operator to access only certain functions. These features should be used whenever applicable. If operators are not restricted, they should be trained not to adjust controls during a test and not to change test setups without proper authorization.

Suggestions for Test Procedures

Verify that the high-voltage output is off before making connections.

Connect the low return side of the instrument first. Securely connect the clip lead to the exposed metal parts being tested.

If you use a clip lead to connect the high-voltage side of the instrument, handle the clip only by its insulator—never touch the clip directly.

If using an instrument with a panel mounted receptacle, first connect the return clip lead, then plug the product's cordset into the instrument. It should be absolutely clear to which product the cordset belongs.

When using a test fixture, be certain that it is properly closed and that all guards are in place. The test fixture should be interlocked with switches so that the test cannot begin if it is not in place.

Double-check the connections before testing. Provide enough clear space around the product being tested.

Follow the high-voltage lead from the instrument to the product and keep the lead on the bench running as close to the product as possible. Avoid crossing test leads. Neatly coil any excess lead halfway between the instrument and the product.

Develop a standard test procedure and follow that procedure throughout the test.

Check all instrument settings before beginning the test.

Test leads should also be checked periodically for excessive wear of the insulation or openings in the conductor.

Never touch any of the cables, connections or product during the test.

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 at one end, which is connected to a grounded wire.) 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.

After the test, turn off the high-voltage. Discharge DC-tested products for the proper length of time. Products tested with AC do not need to be discharged. This is further explained on pages 11 and 12.

In summary, for safe high-voltage testing, 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.**

Shock Hazard

The severity of shock received by a person who contacts an electrical circuit is affected by three primary factors:

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

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 an irregular heart beat which is known as fibrillation, which can cause the heart to stop the pumping action.

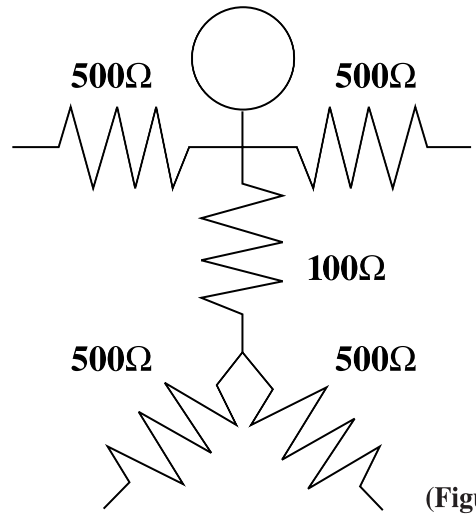
Startled Reaction

UL and ANSI conducted experiments in the 1960's to determine how the human body responded to different current levels. Tests were run using a 120 volt 60 Hz source. They determined that on average 0.5 mA of current is the perception level that can produce a startled reaction. Higher levels of current in the range of 5 to 10 mA start to produce an inability to let go. The electrical current causes a paralysis where you cannot release a handgrip on the circuit. Currents in the range of 20 to 40 mA between the extremities makes the muscles contract painfully, making breathing difficult leading to asphyxiation. Current levels in the 40 to 70 mA range lasting for 1 second or longer causes Ventricular Fibrillation that is frequently fatal. Further increasing the currents greater than 70 mA causes electrical burns and cardiac arrest.

Human Body Resistance

The human body on an average has about 1000 to 1500 ohms of resistance to the flow of electrical current. The outer layer of the skin provides the largest percentage of the body's electrical resistance. The amount of resistance the skin provides varies widely. Dry thick skin provides a much higher resistance than moist soft skin or skin which may have a cut or an abrasion. The parts of the body that conduct the electricity the best are the blood vessels and nerves. Therefore when a person receives a severe electrical shock many times internal injuries may result. The skin, like any insulator has a breakdown voltage at which it ceases to act like a resistor and is simply "punctured" leaving only the lower resistance body tissue to impede the flow of current in the body. This voltage will vary with the individual, but is normally in the area of 600 volts (See Figure 2).

- **Hand to hand 1000Ω**
- **120 volt**
- **Formula I = E/R**
- **120/1000 = 0.120 amps or 120 mA**



(Figure 2)

European Directives

CE MARK

WHAT IS THE CE MARK?

It is an indication of compliance to the European Union directives, which are currently in force.

WHAT ARE THE DIRECTIVES?

Directives are legal requirements that the manufacturers must fulfill to get products into the European free market. The aim of the directives is to remove the technical barriers to trade and to permit free access to the total European market.

Harmonized standards (not the directives) set out the technical provisions required for compliance to European safety requirements.

HOW DOES THE CE MARK AFFECT US?

Many products must now be produced and tested to standards that did not previously apply. More customers are now required to test products to strict safety standards in order to be able to sell their products into the European community.

Under the new European product liability directive the consumer does not have to prove that a product has caused damage. The manufacturer is liable for damage caused by a defect in its product. The manufacturer has to prove that its product has not been the cause of the damage.

Compliance to the European directives ensures that the product complies with the minimum safety requirements and that damage claims can be limited.

Machinery Directive

The Machinery Directive 89/392/EEC
Inception Date 1/1/90
Enforcement Date 1/1/95

The directive applies to machinery which is described as (1) linked parts or components, at least one of which moves with the appropriate actuators, control and power circuits, joined together for a specific application, in particular for processing, treatment, moving or packaging of a material and (2) an assembly of machines which in order to achieve the same end, are arranged and controlled so that they function as an integral whole, and (3) interchangeable equipment modifying the function of a machine which is supplied for the purpose of being assembled with a machine (or series of machines or with a tractor) by the operator himself in so far as this equipment IS NOT A SPARE PART OR A TOOL.

Machinery Directive Product Safety Standards

EN (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, EN 201, injection molding machines or plastics.

TESTS SPECIFIED UNDER EN 60204-1

• Continuity of the protective bonding circuit
Minimum of 10 amps at 50 Hz for 10 seconds. The maximum resistance is based upon the conductor size of the protective bonding circuit ranging from 0.100 to 0.330 ohms.

• Insulation Resistance test
500 volts DC between the power circuit conductors and the protective bonding circuit. The insulation resistance shall not be less than 1 megohm.

• Voltage test or Dielectric Withstand test
A period of at least 1 second between the conductors of all circuits and the protective bonding circuit. The test voltage shall have a value of twice the rated supply voltage of the equipment or 1000 volts, whichever is the greater value at a frequency of 50 Hz and be supplied from a transformer with a minimum rating of 500 VA.

Low Voltage Directive

The Low Voltage Directive (LVD) 73/23/EEC
Inception Date Feb. 1973
Enforcement Date 1/1/97

The low voltage directive states; "the member states shall take all appropriate measures to ensure that the electrical equipment may be placed on the market only if, having been constructed with good engineering practices in safety matters in force in the community, it does not endanger the safety of persons, domestic animals or property when properly installed and maintained and used in applications for which it was made."

Products with a voltage rating of between 50 and 1000 volts for AC and between 75 and 1500 volts for DC must comply with these unified standards if the products are to be marketed in the EU after January 1, 1997.

Harmonized product safety standards are to be drawn up by common agreement between the bodies notified by the member states and shall be kept up to date in the light of technological progress and the development of good engineering practice in safety matters.

Some examples of harmonized safety standards are:

• EN 60950 INFORMATION TECHNOLOGY EQUIPMENT

• EN 50091 UN-INTERRUPTIBLE POWER SUPPLIES

• EN 60065 DOMESTIC ELECTRONIC EQUIPMENT (TV, HI-FI, ECT.)

• EN 61010 MEASUREMENT, CONTROL AND LABORATORY EQUIPMENT

• EN 60335 DOMESTIC APPLIANCES

Each standard provides a series of tests with specific test parameters and limits appropriate to the category of the equipment covered. Some examples are:

• INSULATION TEST
• DIELECTRIC WITHSTAND TEST
• RESIDUAL VOLTAGE TEST
• LINE LEAKAGE TEST
• EARTH GROUND BOND TEST

All the tests are designed to ensure safe operation of the equipment by the user, some of the tests also specify abnormal operational tests to predict the performance of the equipment should accidents or faults occur. Many of the specifications do not specify different tests for production vs. design. There are some proposed standards now being considered to establish production line tests such as EN 50116.

The technical construction file and the declaration of conformity requires the manufacturer to compile the conceptual design and manufacturing drawings as well as components and sub assemblies. Full design calculations and test reports are also required. In addition, the manufacturer must take all measures necessary to ensure the manufacturing process is in compliance and maintain technical documentation for 10 years after the last product has been manufactured. Based upon these requirements the manufacturers must perform checks on their products at random intervals and be able to document the test results.

Medical Directive

The Medical Devices Directive 93/42/EEC
Inception Date 1/1/95
Enforcement Date June, 1998

This directive is one of three medical directives. This directive covers any instrument, apparatus, appliance, material or other article, whether used alone or in combination, including software necessary for the proper application, intended by the manufacturer to be used on human beings for the purpose of: diagnosis, prevention, monitoring, treatment or alleviation of a disease, an injury or a handicap.

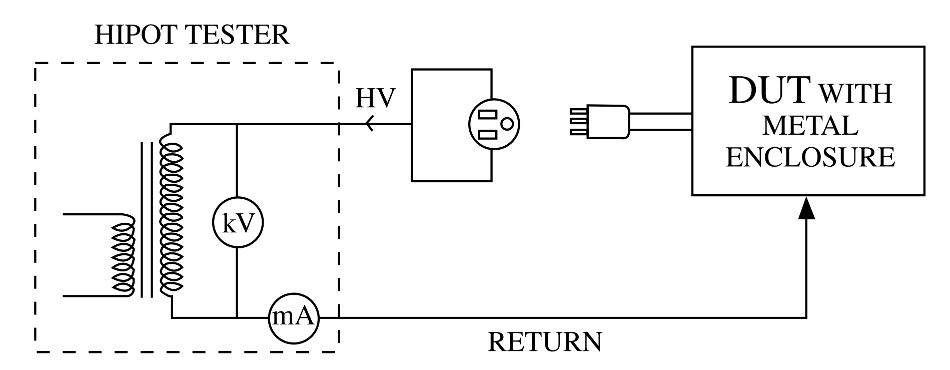
Investigation, replacement or modification of the anatomy or a physiological process. Control of conception and which does not achieve its principal intended action in or on the human body by pharmacological, immunological or metabolic means, but which may be assisted by such means. All devices being put on the market in the EU after June, 1998 must bear the CE mark. IEC 601-1 covers the general requirements for safety for medical electrical equipment.

Five Types of Electrical Insulation Tests

Dielectric Voltage-Withstand Tests (Hipot)

The Dielectric Voltage-Withstand test, or Hipot (High Potential) test, is designed to stress insulation far beyond what it will encounter during normal use.

The assumption is that if the insulation can withstand the much higher voltage for a given period of time, it will be able to function adequately at its normal voltage level—thus the term "voltage withstand test."



(Figure 3)

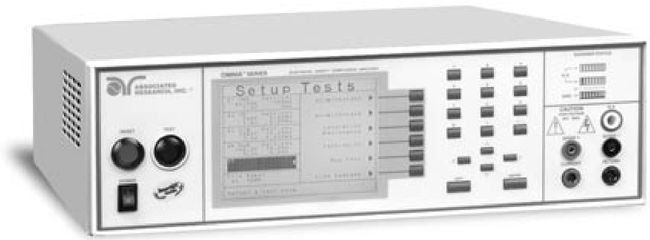
In addition to over stressing the insulation, the test also detects material and workmanship defects which result in conductor spacings that are too close.

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 (See Figure 3).

Agency Requirements

Independent and government test agencies—such as **Underwriter's Laboratories, Inc. (UL), Canadian Standards Association (CSA), International Electrotechnical Commission (IEC), British Standards Institution (BSI), Association of German Electrical Engineers (VDE), Technische Überwachungs Verein (TÜV)** and the **Japanese Standards Association (JIS)**—require Dielectric Voltage-Withstand testing to verify that a product's design meets their standards (design tests). They also



(Figure 4) OMNIA® Model 8104, 4-in-1 Electrical Safety Compliance Analyzer.

require a routine production line test for every product manufactured.

Another requirement driving product safety testing is the need for manufacturers selling products to Europe to comply with CE regulations.

These regulations call out requirements for performing a variety of emissions and electrical safety tests. Associated Research instruments have been tested to meet the CE regulations allowing our instruments to be used worldwide. AR instruments also meet the product safety requirements of EN 61010-1 and are TÜV/GS and C-UL-US listed (See Figure 4).

Design tests are performed on a product sample and usually are more stringent than the production line tests for the same products. AC voltage is specified more often than DC for these tests. For further details on this, see the DC testing section on page 13.

Test voltages are seldom less than 1000V, and for some products intended to operate at voltages between 100V and 240V, the test voltage can exceed 4000 volts.

A rule of thumb that most safety agencies use to determine the appropriate test voltage is to multiply the DUT's normal operating voltage by two and add 1000V.

Agency requirements also take the product's intended usage and environment into consideration. For example, medical equipment with applied parts that have direct contact with the patient are tested at 4000 V.

Most **double-insulated 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 UL standards. The most commonly used times are one second and one minute.

UL requires that Hipot test instruments meet certain output voltage regulation specifications to ensure that the DUT is stressed at the correct voltage.

For one-second tests, the Hipot's output voltage must be no less than 100 percent and no more than 120 percent of the specified test voltage.

When test voltage is applied for one minute, the Hipot's 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.

However, during a one-second test, the Hipot's voltmeter usually cannot respond quickly enough to show the operator the test voltage that actually was reached.

Depending on the safety standard, UL wants to ensure that a Hipot can maintain between 100 and 120 percent of the required test voltage while connected to an Adjustable Resistance Bank. The resistance bank has a maximum resistance of at least two megohms and is adjustable so that resistance is reduced stepwise in increments that do not exceed 25 percent of the preceding value.

Every manufacturer testing to UL specifications is required to have this resistor bank available for the UL inspector.

AC Voltage-Withstand Testing Advantages

- Waiting time is not required after applying the test voltage, nor is it necessary to apply the voltage gradually unless the DUT is sensitive to a sudden application.

- It is unnecessary to discharge the DUT after AC testing.

- AC stresses the insulation alternately in both polarities.

AC Voltage-Withstand Testing Disadvantages

The reactive component of the current (caused by the product's capacitance) is often much greater than the real component (caused by leakage).

Unless these two components are separated, the leakage current can increase by a factor of two or more without being detected.

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 kohm 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 120,000 ohms. (The threshold actually is slightly lower than this value because the current drawn by a 120 kohm resistor must always cause a failure indication.) Although UL specifies that the total current is important for safety reasons, the test cannot effectively detect an abnormally high insulation leakage if it is masked by normally high **reactive current** (due to capacitance).

Many engineers believe that AC voltage at elevated levels can damage even good insulation. However, the sheer variety of insulation types and combinations used make such blanket statements impossible to justify.

AC testing, particularly when it is applied for extended time periods, can degrade certain organic compounds. Air insulation typically is unaffected, as it is constantly being replaced by natural convection except in small sealed spaces.

Insulation damage can be minimized by selecting the lowest possible failure threshold, keeping the test voltage at, but not below, the required minimum, timing the test accurately and avoiding unnecessary re-testing.

Techniques of AC Voltage-Withstand Testing

Most Hipots have a high-voltage shutoff mechanism to protect the output transformer. This mechanism also turns on a failure indication which remains active and conspicuous until manually reset (See Figure 5). If an instrument's current capability is sufficient to test highly capacitive products, then it also presents a higher safety risk to the operator. The test connections and DUT must be handled with extreme care by competent operators, and unauthorized persons should not be allowed in the testing area.

(Figure 5) Hypot®III Model 3665 with manual reset and audible and visual failure indicators.

Some instruments incorporate several common safety tests into a single instrument. Instruments with either 3-in-1 capability (See Figure 6) (AC Hipot, DC Hipot & Insulation Resistance), 4-in-1 capability (See Figure 4) (AC Hipot, DC Hipot, Insulation Resistance & Ground Bond), 5-in-1 capability (AC Hipot, DC Hipot,

(Figure 6) HypotULTRA®III Model 7650 with graphic LCD readout.

Insulation Resistance, Ground Bond/Ground Continuity and Functional Run) and 6-in-1 capability, (AC Hipot, DC Hipot, Insulation Resistance, Ground Bond/Ground Continuity, Functional Run & Line Leakage) can dramatically simplify test connections and test setups and provide a fully automated testing sequence.

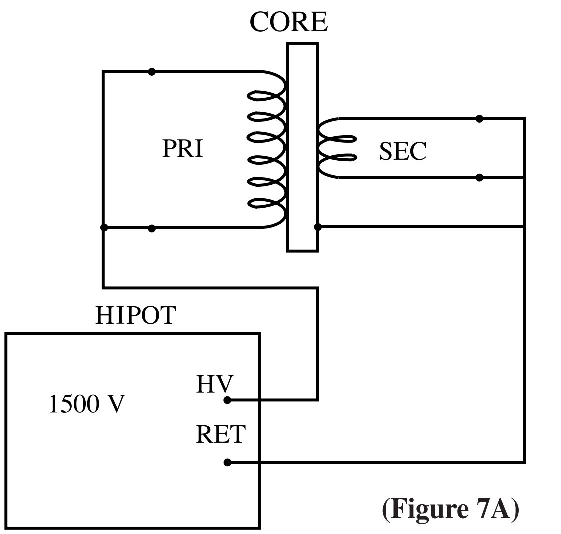
Component Testing

Once the proper instrument for the job is chosen a testing plan needs to be developed. Components are tested by determining which insulation is to be tested and arranging the test so that only that insulation is stressed. A common practice is to tie together connections of circuits which should not be stressed.

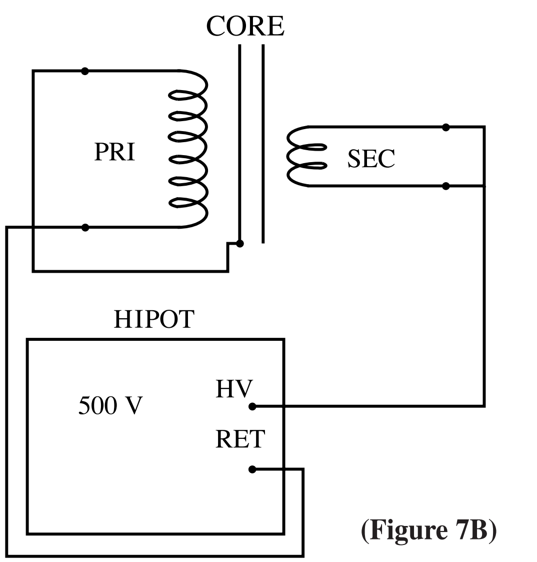
For example, suppose the user wants to test a potentiometer. Its dielectric withstand rating is 900V AC for one minute, either between the resistive element and the metal shell or between the wiper and the metal shell. Tie all three terminals (each end of the element and the wiper) together. The low (ground) side of the instrument should be connected to the metal shell, and the hot side to the three terminals. Then perform the test at 900V for one minute. By tying together the resistive elements you will apply potential across the insulation rather than the potentiometer.

Transformer Testing

Consider a second example in which a transformer is tested. While reading the specifications carefully, it is discovered that the transformer is rated at 1500V AC primary to secondary, 1500V AC primary to core and 500V AC secondary to core. Tie both leads of the secondary to the core and to the low side of the instrument, and tie both leads of the primary together and to the hot side. Test the transformer at 1500V. This tests



(Figure 7A)



(Figure 7B)

the first two specifications (See Figure 7A). Then tie both leads of the primary to the core and to the low side, and both leads of the secondary together and to the hot side, and test at 500V. This tests the third specification (See Figure 7B).

Do not leave windings open at one or both ends during a test. It is a good idea to connect the core to the low side of the instrument. If primary to secondary insulation is being tested, determine which is rated higher to the core and connect the hot side of the instrument to that winding. Connect the winding which is rated lower to the core together with the low side of the instrument and the core.

One should take special precautions when testing transformers with more than two windings. Always try to connect every winding and the core to one side of the instrument or the other.

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.

Before testing is 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 that particular combination of hookups.

Do this with each proposed connection combination and verify that all the desired tests will be made. Simplify the plan as much as possible, verify again that no ratings will be exceeded, and then proceed carefully with testing.

Some fully-automated instruments offer accessories such as high-voltage switching systems or high-voltage matrix scanners, which can be programmed to apply voltage to specific points in any combination. This makes it easier to test products that may require multi-point testing such as transformers, motors and components (See Figure 8).

(Figure 8) HypotULTRA® III Model 7620 can be provided with an optional built-in scanner with front panel status lights. A separate interconnectable scanner is also available as an option.

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 the line and neutral connections tied together. Some appliances have both 120V and 240V circuits, but return them to ground instead of using isolation transformers. In this case, a break in the connection between the returns of the 120V circuits and ground is needed before proceeding with the test.

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

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.

Connect the line and neutral terminals to one another and to the hot side of the instrument. Again, 240V products with some 120V circuits returned to ground will require breaking that return-to-ground connection before testing. Dielectric Withstand testers with built-in receptacles or external receptacle boxes greatly simplify 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.

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.

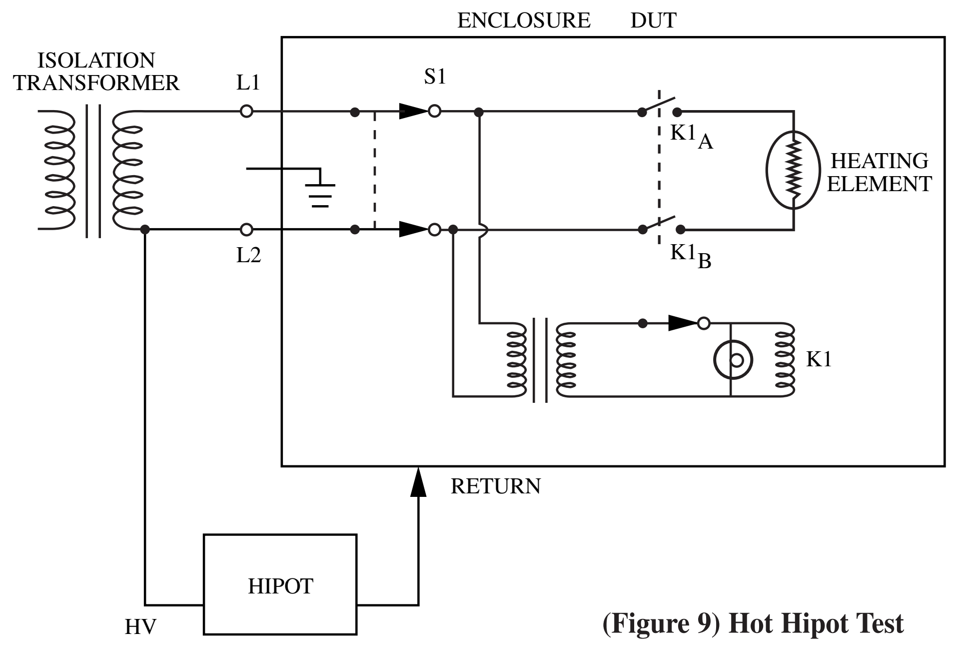
Although the pin usually is grounded during Dielectric Withstand tests, it does not substitute for the clip lead ground connection to the exposed metal of the product, which should be made before plugging the product into the instrument. Cord-connected products also should have all power switches turned on during a test.

If a product usually breaks down at a voltage just above the required test voltage, the product was probably designed with a small margin for safety.

If this cannot be improved, it is advisable to gradually raise the test voltage to eliminate any overshoot which might occur with a sudden application of voltage. Do not start timing any sooner than the point when the voltage reaches the full specified test voltage.

The Hot Hipot Test

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 as voltage is applied to both conductors. Some products especially those that are powered from a 220 volt source use relays that open both sides of the line.



(Figure 9) Hot Hipot Test

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 to perform the test. However, when testing a completed product these two options are not always available. 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 jumper out the circuits to be tested. The operator must also remember to remove all the jumpers when the test is complete. Therefore manufacturers are looking at more efficient testing solutions.

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. 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 (see figure 9). This is required as most power systems are ground referenced, and the 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. The return circuits of the Hipot testers are designed to handle a very small current usually in the order of milliamps of current, while the power source would be capable of supplying hundreds of amps of current. Not using an isolation transformer could also result in false failures during the Hipot because the neutral side of the line is referenced to earth.

Indications of Electrical Breakdown

Dielectric breakdown may be defined as the failure of insulation to effectively prevent the flow of current, sometimes evidenced by arcing. If voltage is raised gradually, breakdown will begin at a certain voltage level (where current flow is not directly proportional to voltage). When breakdown current flows, especially for a period of time, the next gradual application of voltage often will show a breakdown beginning at a lower voltage than initially measured.

The following conditions can sometimes indicate breakdown of the device under test.

1. Arcing
2. Erratic kilovoltmeter
3. Breakdown or arc lamp may flicker

However, newer instruments which have line and load regulation are designed to maintain a constant output voltage, therefore voltage variations as a result of the arcing condition may not exist. Digital metering may not have a fast enough sampling rate to display voltage variations and the response time of some analog meters may be too slow. The sensitivity settings of Hipot testers vary, some may not detect high impedance arcing conditions, some may only respond to maximum current levels.

Many standards do not specify a maximum allowable leakage current. UL introduced what is referred to as the 120 kohm requirement in 1983 on some standards to try to establish a sensitivity setting for Hipot testers. The standard states the following: "When the test equipment is adjusted to produce the test voltage and a resistance of 120,000 ohms is connected across the output, the test equipment is to indicate an unacceptable performance within 0.5 seconds. A resistance of more than 120,000 ohms may be used to produce an indication of unacceptable performance, if the manufacturer elects to use a tester having higher sensitivity."

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

Indications of Excessive Leakage Current

Most instruments have adjustable thresholds for leakage, below which they will not indicate a leakage failure. In an instrument with a high-reactance type of transformer, excessive leakage often is indicated by a separate leakage light, and the voltmeter reading can drop to near zero.

In the type of instrument which has failure and high-voltage shutoff circuitry, excessive leakage will trigger the failure system.

Models with current meters will indicate excessive leakage current. Excessive leakage current may be defined as AC or DC current flow through insulation and over its surfaces and AC current flow through a capacitance (where current flow is directly proportional to voltage). If breakdown does not occur, the insulation and capacitance are considered a constant impedance. Most instruments have adjustable thresholds for leakage below which they will not indicate a leakage failure.

Additionally, some models have a display that will provide details on the type of failure as well as a meter memory system that will hold the last voltage and current readings displayed before failure of the DUT.

(Figure 10) Hypot®II Model 4500D 500 VA AC Dielectric Withstand Tester.

500 VA AC 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 and 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 states. 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 tests that manufacturers are required to perform under the CE directives for safety testing are largely based on the IEC (International Electrotechnical Commission) and EN (European Norms) standards. Some of these reference specifications mandate the use of a Hipot tester with as much as 500 volt amperes (VA) of output power (See Figure 10).

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
VxI = 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. For many manufacturers, this means having to test products with a Hipot of a much higher output rating than they have previously used to comply with U.S. safety-agency requirements. While other specifications from UL and CSA (Canadian Standards Association) also specify a 500 VA rating, unlike the IEC and EN specs, they permit certain exceptions.

WARNING
Remember to discharge the product after DC Hipot testing!

A Hipot with 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 Hipot 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 trigger the need for a 500 VA Hipot.

500 VA Safety Risks

Unfortunately, the 500 VA output capacity poses a considerable safety risk for the Hipot operator: the higher the current output of the Hipot, the more potentially lethal the test. Hipot 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 this reason we recommend that manufacturers not use a 500 VA tester unless the specifications they are testing to require it or they are certain that the device they are testing is so highly capacitive that a typical lower VA rated Hipot will not be able to test the product.

DC Voltage-Withstand Testing Advantages

DC Withstand testing is sometimes chosen as an alternative to the AC Withstand test because of some of the advantages it offers. If the DUT is highly capacitive it would require an AC Hipot which has a very high output current capacity due to the capacitive reactance of the product. This higher current capacity can expose the operator to considerable safety risk. A DC tester can be used which has a much lower current capacity to perform the same test with much less risk to the operator.

During DC Hipot testing the item under test is charged. The same test item 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 product under test. 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 less than what would be required in an AC tester to test the same product.

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.

In addition, DC Hipot testing is the only option for testing some types of components, such as the voltage ratings of capacitors and the inverse voltage ratings of diodes.

DC Voltage Withstand Testing Disadvantages

Unless items being tested have virtually no capacitance, the test operator must gradually raise the voltage from zero to the full test voltage. The more capacitive the DUT, the slower the voltage must be raised.

This is very important when instruments with failure and high-voltage shut-off circuitry are used, as they almost instantaneously indicate failure if the total current (including charging current) reaches the leakage threshold. This requirement adds an undetermined amount of time to the test and often calls for either automatic instruments or more skilled operators.

The DUT must be discharged after the test. A good rule of thumb is to apply a ground for the same length of time as the high voltage was applied. Some instruments have built-in discharge circuitry. When using such models, leave the DUT connected for a sufficient time after the test. DC only stresses the insulation in one polarity.

Regulatory agencies do not always accept DC testing as a substitute for a required AC test. Even when they do, the conversion factor by which the AC voltage must be multiplied is not consistent—it can vary from 1.414 to 1.5 or 1.7.

Although an AC Hipot test sometimes can be used in place of a Line Voltage Leakage test, a DC Hipot test can never substitute for a Line Voltage Leakage test. This is because most products being tested will actually operate on AC voltage.

Techniques of DC Voltage-Withstand Testing

Several varieties of DC voltage-withstand instruments are available:

• Some are instruments with simple **high-reactance transformers** with rectifiers and filters added to them.

• Some instruments use conventional transformers and have failure and high-voltage shut-off circuits.

• Some models are AC/DC switchable, while others are available with current displays. Current metering is somewhat more popular in DC testing than in AC because of the ability to monitor the decay of the charging current.

The connections for the DC tests generally are the same as for AC tests because the same insulation is being stressed. The most important difference is that the voltage must be applied gradually so that the charging current will not exceed the leakage threshold.

When testing items with little capacitance, the DC test can be similar to the AC test in that the gradual application of voltage is not as important.

Indications of Electrical Breakdown

Breakdown indications are the same in DC testing as in AC testing (See Page 24), the DC withstand voltage of the DUT will typically be higher than the AC withstand voltage due to the peak value of the AC voltage is 1.414 times higher. The equivalent DC level would therefore have to be at a minimum of 1.414 times the AC voltage. Caution must still be taken when performing a DC test, if the item under test does breakdown this does not mean that the item was fully discharged, care must be taken to discharge the DUT before handling.

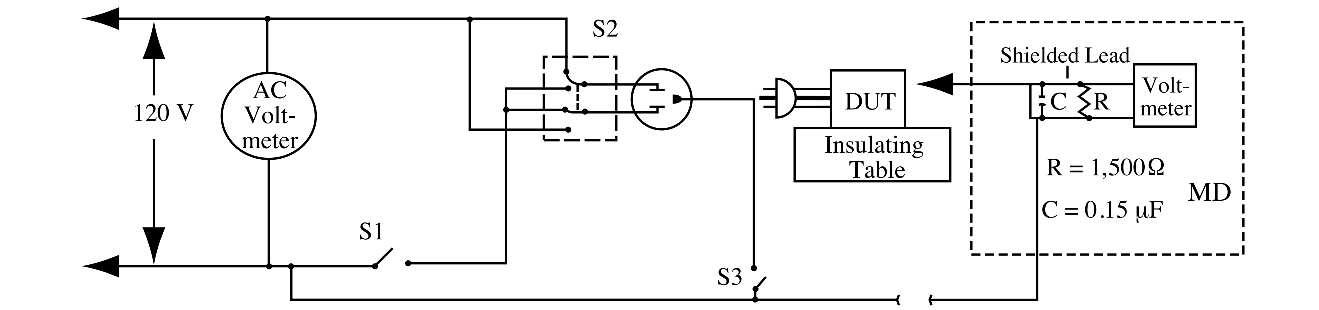
Indications of Excessive Leakage Current

The total current drawn by the DUT is shown on the current display or sensed by the failure circuit. It consists of the leakage current, which is dependent on the present voltage level, and the charging current, which is dependent on the rate and amount of the last voltage increase and the time that has elapsed since it occurred. The current always increases during a voltage increase.

When using instruments with a failure detector, it is necessary to limit the rate at which the voltage is applied to the DUT. If applied too fast, the failure detector may shut down the Hipot indicating a failure, which is actually a result of operator error.

The test should be repeated, applying the voltage at a slower rate of rise to be certain that the failures are from excessive leakage or breakdown, and not due to charging current. When using models with separate breakdown and leakage indicators and no failure circuitry, expect the leakage light to stay on for some time after a voltage increase.

If the light stays on indefinitely or longer than



(Figure 11) Circuit for line leakage testing

expected, suspect excessive leakage.

On models with current metering, set the current range switch to the highest range, and observe the current meter after the full test voltage has been reached. Each time the reading falls below the full scale value for each lower range, change the range to the next step down. Eventually, the reading should stabilize and can be compared to the normal reading for the type of product being tested. Of course, if the test operator wants to monitor how the current increases with the voltage, the test operator will have to record a meter reading after each incremental voltage increase.

On instruments with manually set current ranges, remember to select the highest current range each time the voltage is about to be raised. This is because each time you raise the voltage level you will also get an initial inrush of additional current which could overextend your metered range and possibly damage your meter.

More recent automatic instruments come complete with a single display that monitors both voltage and current as well as other information (See Figure 6).

Line Leakage Tests

Various studies show that the human body's threshold for **perceiving** electric current is approximately 1 mA (1). Because body weights differ, some people feel current at different levels. Once current exceeds a person's threshold it can cause a **"startle reaction,"** which is an uncontrolled muscular spasm induced by a sudden, unexpected electrical shock.

Because of the potential hazards these low-level currents present to the human body, **UL, CSA, VDE, IEC** and other private and governmental testing agencies have set standards for the maximum amount of current that may leak from a non-defective product operating at its normal line voltage. If the product is energized and an ammeter is connected between any exposed metal part and the neutral conductor, the ammeter must show less than a specific current level.

To simulate the effects of current on a human body, the ammeter should have an input impedance of 1500 ohms of resistance shunted by 0.15 µF of capacitance. This electrical network is referred to as a measuring device.

The Measuring Device (MD) is a model of the human body's impedance. The recommended circuit to simulate this impedance as specified by UL 544 for medical and dental equipment is shown in figure 11. The measuring device circuit differs depending upon the specification.

In many products the required maximum current is 0.5 mA (2). Although there are products where **current leakage** may exceed 0.5 mA—but not 0.75 mA—these products must be equipped with a three-prong grounding plug and appropriate user warnings. In most cases, products intended for fixed mounting where they are grounded in their installation are also allowed to exceed 0.5 mA. Leakage tests are first conducted with normal line and neutral connections to the DUT, then with the connections reversed. UL provides a schematic of a recommended circuit for making this measurement (See Figure 11).

Although numerous product safety tests are normally specified for electrical products, one of the most confusing aspects of such electrical safety compliance testing is leakage measurement. The two most important and common instruments used to detect abnormal leakage currents are the Line Leakage test and the Hipot or Dielectric Withstand test. Line Leakage test is a general term that actually describes three different types of tests. Two of these tests are the **Earth Leakage** test and the **Enclosure Leakage** test. The third test is the **Applied Part Leakage** test which is required only for medical equipment. All of these tests are used to determine if products can be safely operated or handled without posing a shock hazard to the user.

(1) Mazer, William M., Electrical Accident Investigation Handbook, Electrodata, Inc., Glen Echo, Md., 8/82 sec. 7.1.0.0

(2) Standard for Electric Air Heaters, UL 1025, Underwriters Laboratories, Inc., Northbrook, Ill., 4/84 sec. 29

Performing a Line Leakage Test

Many product safety specifications call for a Line Leakage test to be performed either as a design (type) test or as a production line test. Testing during the design stage gives the engineer crucial information on the integrity of the design, therefore an awareness of the applicable safety standards with which a product must comply is essential. Associated Research Line Leakage testers are designed to meet the safety agency compliance specifications as outlined by UL 544, UL 2601, UL 1563, UL 3101, IEC 1010, IEC 601-1 and the European Norm (EN) specifications.

The test is performed while the device under test (DUT) is operating either at its nominal line voltage or a 110 percent of its nominal specified input voltage, under both normal and single fault conditions. During the Earth Leakage test, measurements are made from the ground lead of the DUT to determine how much current flows back to the system neutral. During the Enclosure Leakage test, current can be measured between various points of the DUT chassis and system neutral (See Figure 11). The measurements, which are taken with a measuring device specified by the safety agency to simulate the impedance of the human body, indicate how much leakage current an end user could be exposed to under both normal and single fault conditions when the DUT is operating.

(Figure 12) LINECHEK® Model 510L Automated Line Leakage Tester.

The Line Leakage tester (See Figure 12) is designed to automate line leakage testing in a production line or laboratory environment.

Line Leakage Test Requirements

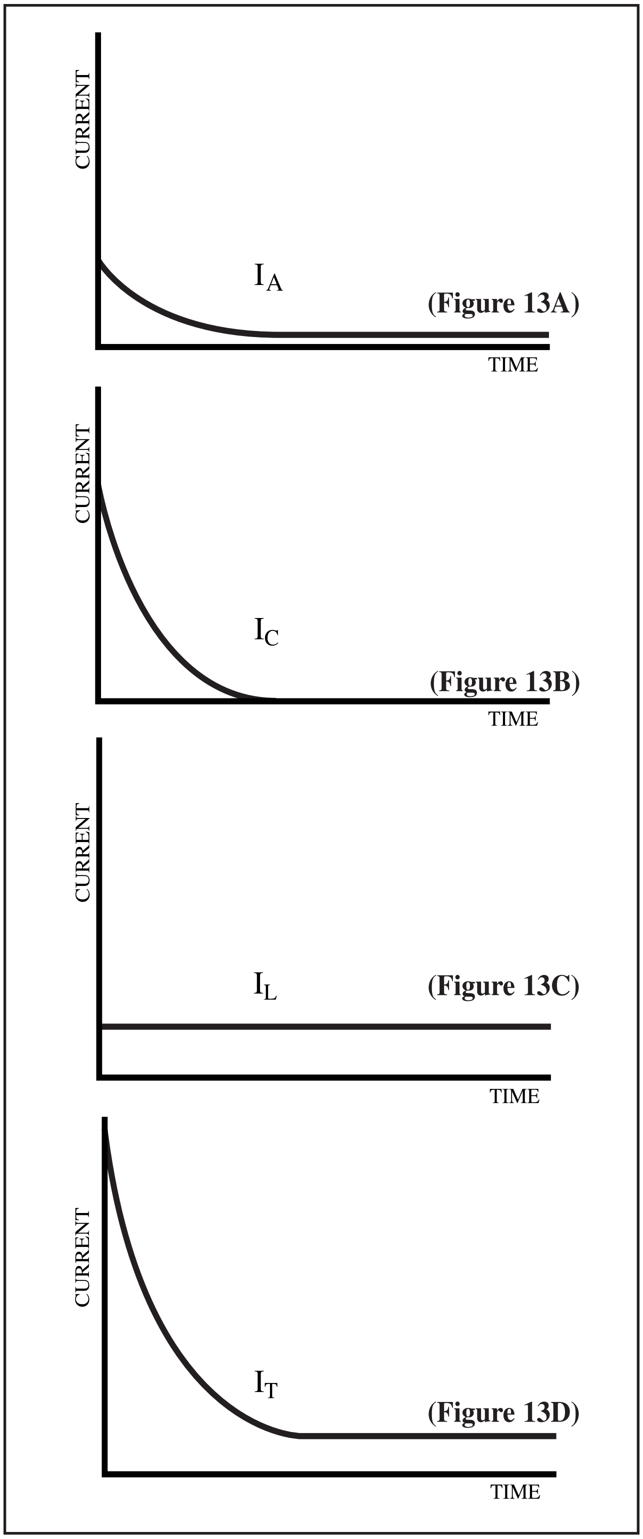
The leakage current measurement device in the Line Leakage tester provides specific load requirements which simulate both contact resistance and the resistance of the human body. There are specific limits as to the maximum allowable leakage currents that are acceptable during a Line Leakage test. These limits vary depending on the type of product being tested. Medical products have a much lower limit especially for patient-applied parts, because patients who are ill, unconscious, or anaesthetized may not be able to detect potential hazards, or their ability to react to them may be limited. For instance, their skin may be penetrated or treated to obtain a low skin resistance, which could pose a greater danger to them.

The Earth Leakage test must be carried out in both normal line conditions and single fault conditions, such as open neutral, reversed line and grounded functional earth. If applicable, an Applied Part Leakage test must also be performed. There are a minimum of eight possible combinations for each type of test, and additional tests are specified for applied parts. Leakage current limits can range from 0.01 milliamps to 10 milliamps depending on the type of DUT and the test that is being performed. The primary difference between the various Line Leakage tests is where the measuring device is placed. The Enclosure Leakage test measures the leakage current from the enclosure to other parts of the enclosure that, in normal use excluding applied parts, might be accessible to an operator or patient. The Applied Part Leakage test measures the leakage current from the patient lead connections back to the neutral conductor and between patient leads, depending upon the type of equipment.

As new editions of many safety standards are becoming harmonized with the "EN" specifications, the leakage measurements tests are now following the guidelines of the IEC 60950 standard. This standard titled "Methods of Measurement of Touch Current and Protective Conductor Current" utilizes different measuring devices and may specify the measurements to be done measuring either true RMS or Peak currents as a peak measurement is more accurate for non-sinusoidal waveforms.

Correlations Between Hipot Leakage & Line Leakage

The current measured during the Line Leakage test can be used to calculate the approximate current trip setting that should be used for a Hipot test. This would be an approximate setting, since a DUT's component tolerances could cause slightly different leakage readings among different DUT's. In calculating correlating



(Figure 13A) **(Figure 13B)** **(Figure 13C)** **(Figure 13D)**

leakage settings, it is important to consider the fundamental differences between the way the Hipot and Line Leakage tests are performed. Even though most Line Leakage testers offer switching to test both sides of the (hot and neutral) input line, they only measure leakage from one current-carrying component at a time to the DUT chassis.

The Hipot test measures leakage from both current-carrying components simultaneously, therefore it displays a higher leakage reading. A good rule of thumb is to set the Hipot trip current about 20 to 25 percent higher than the value determined by the following calculation: (Hipot test voltage ÷ Line Leakage test voltage) x Line Leakage test current = approximate Hipot current. For example, take a Line Leakage test voltage of 240 volts, a Hipot test voltage of 1480 volts, and an actual Line Leakage measurement of 2.0 milliamps. This calculation would look as follows: (1480 volts ÷ 240 volts) x 2.0 milliamps = 12.33 milliamps. Based on this calculation, and adding approximately 25 percent for tolerance, the Hipot leakage setting could be set to about 15 milliamps.

Insulation Resistance Measurements

Using an **Insulation Resistance** (IR) tester, connect two points that are separated by insulation and take a measurement. The measured value represents the equivalent resistance of all the insulation that exists between the two points and any component resistance that might also be connected between the two points.

The Insulation Resistance testers' power supply voltages vary from as low as 50 volts to as high as 10,000 volts, but the most common test voltages are 500 and 1,000 volts. All IR testers are supplied with DC output voltage.

When an Insulation Resistance test is made, there are three components of current flow:

- **Dielectric Absorption Current**—The insulation between two connection points may be thought of as a dielectric and capable of forming a capacitance. A phenomenon known as Dielectric Absorption occurs, in which the dielectric "soaks up" current and releases it when the potential is removed. This absorption occurs at the same time that the current is charging and discharging the capacitance, though it happens much more slowly. It is affected by the type of dielectric and is referred to as Dielectric Absorption Current, or I_A (See Figure 13A). Dielectric Absorption is particularly important in capacitors and motors.

To demonstrate this phenomenon, take a large capacitor and charge it to its rated voltage, then allow it to remain at that voltage for some length of time.

Next, quickly and completely discharge the capacitor by shorting the terminals until a voltmeter placed across it reads zero.

Remove the voltmeter, and again allow the capacitor to sit for some length of time with an open circuit across its leads.

If you place the voltmeter across the capacitor again, any voltage you find will be the result of Dielectric Absorption. Some capacitors exhibit this phenomenon more than others, with larger capacitors showing a more pronounced effect.

• **Charging Current**—The current required to charge a given capacitance is known as the Charging Current, or I_C (See Figure 13B). Like the Dielectric Absorption Current, the Charging Current decays exponentially to zero, but at a faster rate.

In most cases, the Charging Current determines how long it will take to make an accurate Insulation Resistance measurement. Once the reading appears to stabilize, the Charging Current will have decayed to a point where it is negligible with respect to the Leakage Current.

• **Leakage Current**—The current which flows through the insulation is the Leakage Current, or I_L (See Figure 13C). The voltage across the insulation divided by the Leakage Current passing through it equals the Insulation Resistance. To accurately measure insulation resistance, wait until the Dielectric Absorption Current and the Charging Current have decayed to the point where they truly are negligible with respect to the Leakage Current.

Some instruments with microprocessor control allow the user to program a consistent delay time into the instrument. This provides consistent results since the exact amount of delay time is allowed for each test.

The Total Current which flows is the sum of all three components explained above, and is designated as I_T (See Figure 13D). Total Current (I_T) decays exponentially from an initial maximum and approaches a constant value. This constant represents the Leakage Current. The Insulation Resistance reading is dependent on the voltage across the insulation and the total current. It increases exponentially from an initial minimum and approaches a constant value—the actual insulation resistance. Note that the reading will be smaller (and can never be greater) than the actual resistance, due to the effects of residual Dielectric Absorption Current and Charging Current.

Why Measure Insulation Resistance?

The Insulation Resistance test is very similar to the Hipot test. The IR test gives you an insulation value usually in Megohms. Typically the higher the insulation value, the better the condition of the insulation. IR tests are sometimes specified as an additional test to make sure the insulation was not damaged during the Hipot test.

Motor Testing

Those who manufacture, install, use 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.

Information of real value is obtained when a measurement is made when a motor is new, and again at least every year while it is in service.

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 one-minute Insulation Resistance reading.

For large motors, the Polarization Index should be at least 2.

(Figure 14) The Hypot®III Model 3670 with built-in IR Test capability.

Component Testing

Another application for Insulation Resistance tests is testing components before they are installed in a product. Wire and cable, connectors, switches, transformers, resistors, capacitors, printed circuit boards and other components are specified to have a certain minimum insulation resistance, and it is sometimes necessary to verify that these components meet their specifications.

Any component might have a limitation on the voltage that might be applied to it, or the insulation resistance might be specified to a particular voltage.

Pay attention to these restrictions to avoid damaging the component or making improper comparisons.

Use caution when selecting the proper test voltage. Do not exceed the voltage rating of a component or of a motor across the points where the measurement is to be made. Many users prefer to use the highest voltage that is available without exceeding the product's rating. In other cases, the customary test voltage is 500V whether or not the product being tested has a higher rating. Because an IR test can be a useful tool for diagnostics and component checking, an IR test mode is often included in some combination instruments (See Figure 14).

Although the IR test can be a predictor of insulation condition it does not replace the need to perform a Dielectric Withstand test. The following are some types of failures which are only detectable with a Hipot test: Weak Insulating Materials, Pinholes in Insulation, Inadequate Spacing of Components and Pinched Insulation.

Polarization & Ground Continuity Tests

Polarization tests and **Ground-Continuity tests** often are required to be performed with the Line Voltage Leakage tests or the Dielectric Voltage-Withstand test. Unlike other tests discussed thus far, these are not insulation tests. Instead, their purpose is to ensure that safety connections have been made properly.

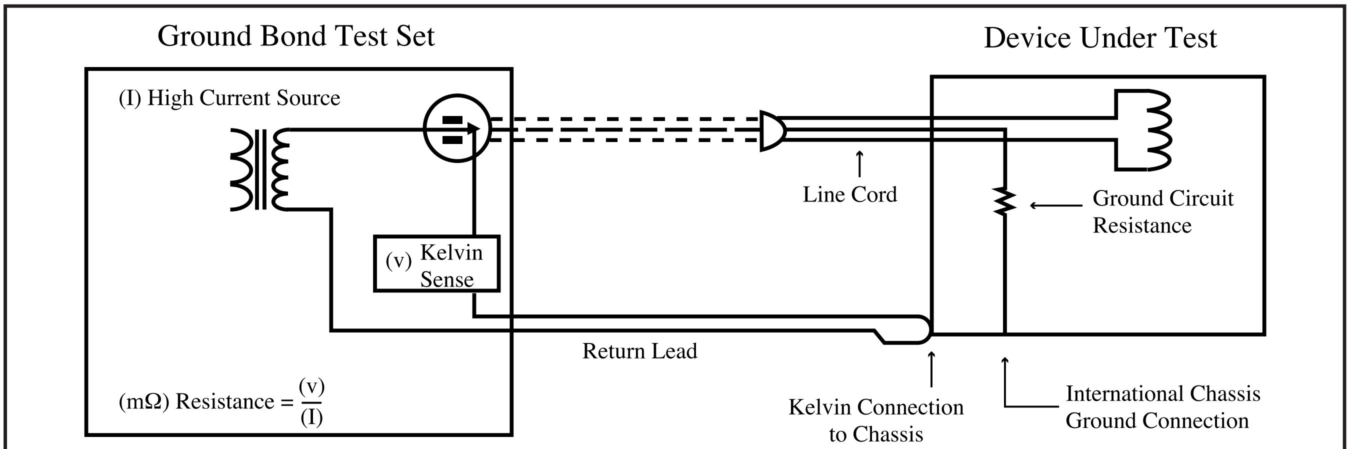
Cordset manufacturers and makers of products which use polarized line or mains cords are required to conduct Polarization tests. In some cases, this involves a continuity test, while in others visually inspecting the wiring is sufficient for compliance. The Polarization test is designed to verify that the line and neutral conductors are not interchanged and is often required as a **production line test.**

The grounding of electrical circuits and electrical equipment is required to protect against electrical shock, safeguard against fire, and to protect against damage to electrical equipment. The grounding of the metal enclosures or exposed dead metal on the equipment also establishes a common ground or earthing reference or zero potential difference between multiple pieces of equipment which may be in the same proximity.

A ground continuity test is normally required as a production line test on electrical equipment to verify that there is continuity in the ground circuit of the device. The main function of this ground is to protect the operator of the equipment against electrical shock. 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 flow through the ground conductor of the equipment allowing the excess current to flow, 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 three-to-two prong adapter. Because these practices are so common, products with three-wire line cords are still required to pass the same Dielectric Voltage-Withstand tests as ungrounded products.

Class I products utilize only basic insulation, the integrity of the ground circuit is what protects the



(Figure 15) Circuit for Ground Bond Test

operator if a fault should occur in the insulation.

Ground Bond Tests

The Ground Bond test or Ground Impedance test determines whether the safety ground circuit of the DUT can adequately handle the fault current in case the product's insulation should ever become defective. Should a product fail, a low impedance ground system is essential to ensure that a circuit breaker or fuse on the input line will act quickly enough to protect the user from receiving a dangerous electrical shock.

Some international compliance safety agencies such as CSA, IEC, VDE, BABT and TÜV require a Ground Bond test on all DUT's as they leave the production line.

This test should not be confused with simple low-current continuity tests. A low-current test indicates that there is a safety ground connection, but it does not completely test the integrity of that connection—for example, it may not detect a ground connection that is maintained by only a few strands of wire.

To test for a good bond of the DUT's ground system 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 measure the induced voltage across the safety ground circuit to determine the impedance of the ground connection (See Figure 15).

Because the measured values are usually so low, the user should be careful not to read the resistance of the test leads that are used to connect the test instrument to the DUT. If this is inadvertently done, it might be erroneously concluded that the DUT has a safety ground failure, simply because the combined resistance of the DUT and the test leads will have exceeded the maximum resistance level.

Make sure to use a test instrument that can eliminate the test leads' resistance from the test results.

There are several techniques to account for test lead resistance:

• The first would be to simply perform a test with the leads directly connected to each other without the DUT connected.

Note the reading during this test and subtract this value from your total reading once you test the actual DUT.

When utilizing an instrument that has an adjustable trip point, the resistance of the test leads should be added to the maximum resistance level allowed. For example, if the maximum allowed ground bond resistance is 100 milliohms and the test lead resistance is 37 milliohms, the trip should be set for 137 milliohms.

• To use the electronic offset capability available on some instruments, first connect the test connections together at the contact point of the DUT. Then, set up the instrument to perform a test and calibrate itself to automatically subtract this resistance level from future measurements.

• The "Kelvin Method" 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, separate set of leads measures the voltage drop across the DUT directly at the contact. The Ground Bond test usually is performed before the Dielectric Voltage-Withstand test.

(Figure 16) HYAMP®III Model 3140 shown with a Hypot®III Model 3670.

Because a Hipot test is a stress test between the DUT's current-carrying and non-current carrying components, you should first test the non-current carrying component with a Ground Bond test to verify the non-current carrying connection will hold its integrity if the current carrying connection fails.

For Ground Bond tests, choose compatible safety instruments (See Figure 16) or a single instrument with both Hipot and Ground Bond capability. That way, a single connection to the DUT can be used to perform

Functional Run Tests

While product-safety tests help ensure that a product is safe, they do not provide any indication that the product will operate correctly. A good example of this is a product with a short circuit across the hot and neutral conductors. This equipment will pass a Hipot test because the hot and neutral normally are connected together for that test. However, when the DUT is connected to line power, the short circuit condition will cause input circuit breakers or fuses to trip. To detect failure conditions before a product is shipped, most manufacturers run functional tests after final safety testing to verify the functionality of the products (See Figure 17). These tests verify that the product performs its intended functions. The tests also may monitor the input voltage and current of the DUT to detect any problems. These parameters are not measured as part of the safety testing, and the limits are product specific.

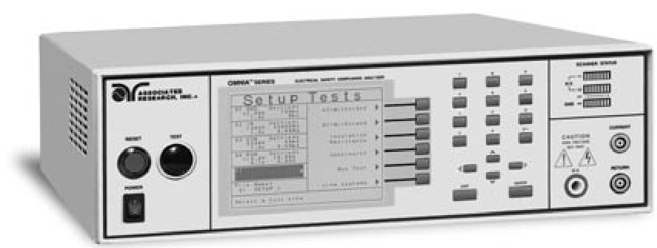
(Figure 17) RUNCHEK® Model 905D Fully-Automated Run Test System.

Tests While the DUT Is Operating

Current draw is the most common test performed while running the DUT. This measures the current into the DUT to determine that it is operating within its fuse rating. Leakage Current, another common test, is a simple measurement of leakage from the case of the DUT to ground. This should not be confused with Line Leakage. This simple leakage resistance must not exceed 0.1 W plus the resistance of the supply cord. An adequate ground must have an impedance level low enough to limit the voltage to ground and facilitate the operation of the circuit protection device should a fault occur. Ground Continuity normally is specified as a routine production-line test and can be done with a simple device such as a test-light/battery-buzzer combination or ohmmeter, although a more sophisticated test with some type of consistent measurement parameter is recommended. This test verifies that continuity of the ground conductor is present. Ground Bond is the preferred method of testing safety ground circuits on products sold in Europe and in any other application where a good ground system is critical. This test stresses the ground connection with high current and causes a failure on a weak connection. Ground Continuity only verifies that the safety ground connection exists. Since it is a low current test, it does not use a specific measuring device, nor does it switch input power configurations to the DUT into fault conditions. The test simply determines leakage to the case if the safety ground circuit is broken. In addition to these tests, manufacturers may record power and power factor measurements while the DUT is operating.

The Case for Automatic Testing

Depending upon the complexity of the DUT, the same operator who performs product safety tests may perform the run test at the end of the assembly operation. After a product has passed safety tests, it is connected to line power and the functional run tests are performed. Usually, the operator has a limited amount of time to perform both the safety and the run tests and do a visual inspection. With a high-speed production line and many opportunities for distractions, it is possible to miss a problem in the product. Also, manually recording too much information often results in lost productivity. All this makes the consistency of tests that are performed manually very questionable in most manufacturing environments. Many European Norm (EN) product safety standards now require that manufacturers of consumer products document all test results. Documentation also is required of ISO compliant manufacturers.



(Figure 18) OMNIA® Series 5 Electrical Safety and Functional Run Testing in a single enclosure.

Same Station Safety and Functional Run Testing

Today it is possible to offer one test station that performs both safety and run tests with one connection to the DUT. This can save a tremendous amount of time. An automated system can monitor minimum and maximum readings for Voltage, Current, Watts, Power Factor, and Leakage Current (See Figure 18). The duration of the tests also may be programmed into the system, providing for more consistent tests. If any parameter falls outside its limits, the system will signal a failure automatically. Tests can be linked together to allow the operator to test products that have multiple settings. All test data can be stored to a file; all possible pass/fail statistics can be recorded with the operator ID, date, and time. This information can be viewed in detailed, summary, graphic or stored in an ASCII format. It can be exported to a spreadsheet, word-processing, or database program. Automation also makes a change-over on the line much faster because test programs for each type of product can be loaded from a database. For manufacturers using bar codes to identify products, test programs can be loaded from a computer file linked to the bar code.

Summary

By automating the functional run test and the product safety tests into the same test area and linking them together, you can improve the reliability and efficiency of production testing. The operator is less likely to skip a test while trying to keep up with the production line and does not have to read several meters during the testing process since automatic instruments monitor violations of preset limits. Each model and serial number can be recorded along with the test results. As a result, the tests are consistent from one product to the next, and data can provide your engineering and quality departments with valuable information.

Scanning Matrix Systems

Products such as transformers, motors, cables or any DUT's that require high voltage tests at various points are ideal applications for use of scanning matrix systems. Major concerns with manual multi-point testing have been the high risk of incorrect connections

(Figure 19) Modular Scanner Model SC6540 for multi-point or multiple product testing.

due to operator error as well as the safety risk of having the operator exposed to high voltage while making connections. A way to address this is by using scanning matrix systems that are basically switching networks that can automatically make connections by switching the safety tester test outputs to various test point connections of the DUT.

Scanners can be built-in to some safety testers and can have 4 to 8 output ports. For DUT's requiring additional test points stand-alone external scanners can be selected with up to 16 outputs. Scanners can also be linked together allowing for even more connection points.

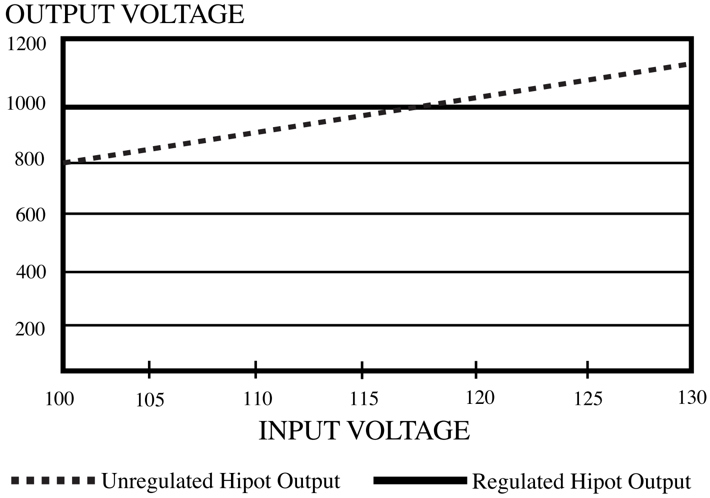
The latest scanners can control Hipot, Ground Bond and Continuity test outputs. The switching sequence is controlled either through the host safety testing instrument or in some cases the scanner might be controlled directly by PC control. Modular scanners offer the benefit of flexibility in that they can be configured to match the needs of various applications allowing customization to specific test environments (See Figure 19).

In addition to multi-point testing scanners can also be used in test environments where it is desirable to connect multiple products at one time and cycle through testing in a batch mode. In either application scanners have proven to save time and enhance operator safety.

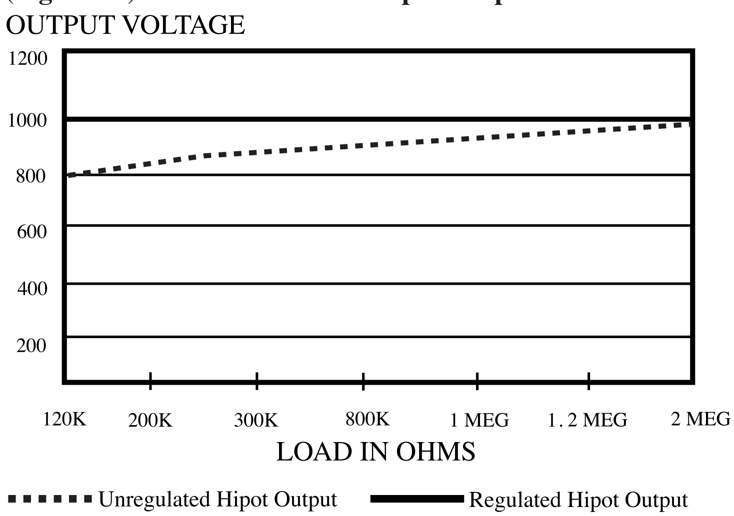
Figure 19 - Model SC6540 modular scanner can be configured with up to 16 test points for testing either high voltage, high current or basic continuity tests.

Recent Technology Developments

(Figure 20) Load Variation vs. Hipot Output



(Figure 21) Load Variation vs. Hipot Output



As reviewed in the section "Agency Requirements" on page (7), the actual agency requirements for Dielectric Withstand testing are quite basic. Most Hipots offered today can meet these fundamental requirements. For the most part, it has not been new agency specifications that have driven new technology developments in safety testing instruments. The demand has occurred because of concern about operator safety as well as ensuring that manufacturers adequately test the safety of their products. Developments in technology, particularly within the last decade, have made features available that were previously impossible. Associated Research has made a commitment to incorporate any new technology into our products that can enhance user safety and simplify testing procedures. Often this new technology is actually less costly than the old systems it replaces. Please take time to read through the following new developments and consider the benefits these features could offer in your specific application.

Line and Load Regulation

Line connected instruments can be affected by a few uncontrollable external factors. A Hipot instrument transforms the input voltage of 115 or 230V AC to an output value of several thousand volts. This means that the output voltages stability is directly linked to the input voltage level.

Line voltage fluctuations are common in manufacturing settings where several pieces of machinery may be powered by a single input line circuit or where power is unreliable. Fluctuations in input voltage can cause drastic changes in the output voltage.

For example, if the line voltage drops below a certain level, the output voltage can actually fall below agency requirements. On the other hand, if line voltage increases, the output voltage can exceed recommended voltage levels and damage the DUT.

Consider a product that has an operating voltage of 120 volts. Based on the rule of thumb calculations mentioned earlier (double the operating voltage and add 1000 volts), a compliance agency requires test voltage to be 1240 volts. This means that after adjustment, the Hipot would produce approximately 10.33 volts of output for each volt of input to achieve the 1240 volt requirement. Now, assume that the line voltage drops to 105V. The Hipot is still set to produce 10.33V for each volt of input, so the output voltage now drops to about 1085V.

Therefore, any device being tested while the input voltage is low, actually is being tested at 155V below the required test voltage.

Figure 20 shows the effect that line voltage variation can have on the output test voltage of a Hipot.

This is why Hipot testers are now available with regulation circuitry that maintains the desired output voltage setting. Such regulation circuitry monitors the input voltage and electronically adjusts to assure that the preset voltage level is maintained.

Loading conditions also can greatly affect the output voltage applied to the DUT. Many manufacturers have a standard procedure for setting the Hipot voltage while the DUT is connected. This ensures that the proper test voltage will be reached when the Hipot tester is operating under a loaded condition.

Unfortunately, the set-up procedure becomes a little more complicated in manufacturing environments where different products come down the assembly line and into the testing area. These different products could represent differing loads while the test instrument was originally set to a single specific load.

Figure 21 shows how output voltage changes if the load is changed from 120 kohm to 2 megohms. This compliance issue underscores the importance of providing Hipot instrumentation that can maintain constant output voltage even when the load varies. In the past, the only way to solve this problem was to use Hipot instruments that could provide extremely high current levels without collapsing under load. In some cases, these instruments could have output current capabilities in excess of 100 milliamps.

This approach might have solved one problem, but it created another one. Instruments that produced these high output currents posed an unnecessary safety risk to the test operator.

A load-regulated instrument can electronically monitor the loading effect on the Hipot and compensate for these load variations to maintain the preset output voltage. This approach does not require the Hipot to have excess output current capability, so it ensures compliance with agency requirements while not risking operator safety. All Associated Research Hipot testers include line and load regulation.

No Load Setup of Trip Current & Voltage Output

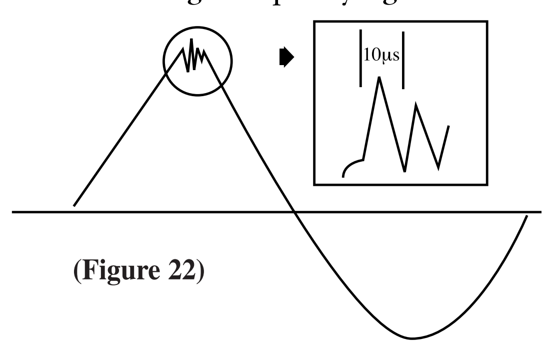
Setting up the test parameters with an older style Hipot tester is where the operator is at maximum risk of injury. The reason for this is that with older analog instruments it is necessary to run high voltage in order to set the voltage and current trip parameters. During this setup period the user must make adjustments with high-voltage activated. A major benefit of microprocessor control is the no load setup feature. With this capability all test parameters are adjusted digitally through a menu driven program without high-voltage activated. This technique is much safer and more accurate than older methods. For this reason all Associated Research instruments now include no load setup capability.

Breakdown vs. Arcing

Breakdown can be defined as a condition where voltage discharges across or through the 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 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. 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 (See Figure 22). These short duration pulses or spikes may not immediately result in a

High Frequency Signal



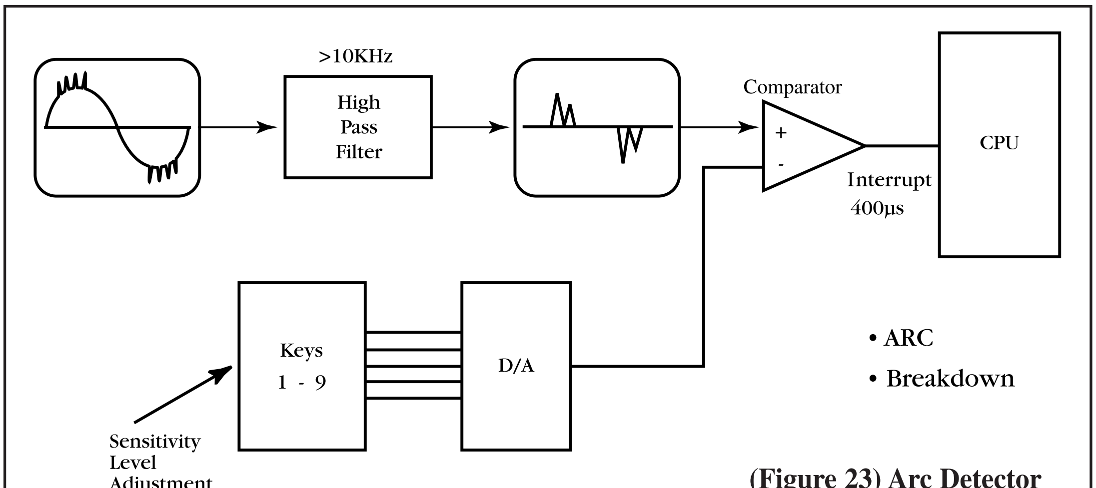
(Figure 22)

High frequency signal which appears on sine wave when arcing condition appears.

disruptive discharge causing the current to increase or the output voltage 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 that the discharges do not provoke a drop in the test voltage." Please keep in mind that although an agency might allow a DUT with corona to pass the Hipot test, this corona may be an indication of a potential problem in the insulation system.

Arc Detection

The geometry of an arc is not a constant. For example, breakdown voltages may vary greatly between two rounded surfaces or two sharp points which have the same gap spacing. The impedance and distributed capacitance of the circuits between the point where the arc is generated and the detector may also effect the **di/dt** (rate of change of current versus time) of the current waveform being monitored by the arc detector. The amount of voltage, rate of rise, polarity, and the waveform all effect the speed in which corona and arcing conditions occur. Temperature, humidity, and atmospheric pressure all influence the voltage at which corona begins as well as breakdown voltage levels.



(Figure 23) Arc Detector

An Arc Detection system incorporates a high pass filter circuit that only responds to high frequencies that are greater than 10 kHz. These high frequency signals are fed into a comparator and checked against the sensitivity level adjustment that the user selected during setup. If this level is exceeded an interrupt signal is fed into the CPU, which shuts down the Hipot in 400 microseconds (See Figure 23). While the leakage and overload detection circuits are always active, some instruments allow the user to shut off the arc detection circuit. We have found that many manufacturers may use arc detection for diagnostic or research and development purposes but on the production line it may actually be best to not use arc detection.

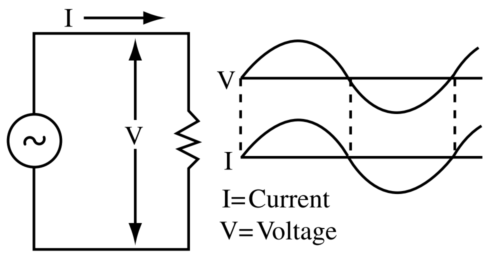
Many appliances such as power tools and vacuum cleaners have low level arcing conditions present as part of their normal operation. In many cases safety agencies acknowledge that low level arcing does exist and allows it in manufacturing tests. Therefore arc detection circuits used in this type of production environment could show a failure condition when indeed the product is good. On other types of products such as medical electronics, especially patient connected devices, low level arcing conditions need to be detected for safety reasons. In these applications arc detection can have real benefits.

Because of test condition variables and the lack of safety agency standards in defining maximum limits for arcing and leakage currents, AR has taken a flexible approach in its instrument designs. On instruments that contain the functions to set both the high trip limits for leakage current and trip limits for arcing conditions, we feel the customer must have the ability to set variable limits that can be adjusted to meet specific test requirements. We also provide the customer with the option to enable or disable the arc detector circuit. This may be done independently of the high current trip circuit that Hipot testers must have for compliance testing. Arc detection when used properly and under the correct conditions can provide valuable information on product design and safety. However, the manufacturer must first determine that arc detection is applicable to their products to avoid failing products that are actually electrically safe.

Real Current

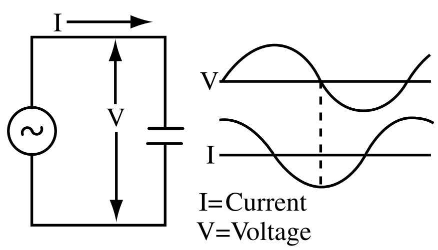
When performing Hipot tests, voltage is applied between current carrying conductors and accessible conductive surfaces to test the insulation of the product.

(Figure 24) Resistive Current



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

(Figure 25) Capacitive Current



Leakage Current which is due to the capacitive element is 90° out of phase with the output voltage waveform.

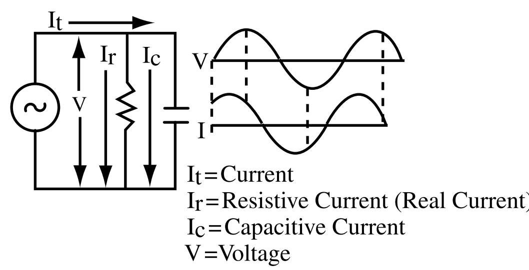
The leakage current which is due to the insulation resistance of the product is resistive, which is in phase with the applied voltage (See Figure 24). One problem which arises is the circuit which we are testing is also a circuit for a capacitor, (defined as two conductors separated by a dielectric material). The application of AC test voltage to a capacitive item causes a Reactive Current that is 90 degrees out of phase with the applied voltage (See Figure 25). 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. The Real Current is due to the insulation resistance of the product and the applied voltage (See Figure 26). This is why in some applications it is important to use a commercially available AC Hipot tester with the capability to read Real Current.

The alternative to using an AC Hipot tester with Real Current is to use a DC Hipot. The advantage of using DC is once the capacitance of the item under test is charged to the test potential the only leakage current remaining is due to the insulation resistance of the product. Unfortunately, DC Hipot tests are not always accepted by safety agencies.

The physical design of a product is primarily the 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. It is therefore important to be able to separate these two leakage currents. Any increase in the Real Current leakage is an indication that the quality of the insulation has deteriorated due to age or workmanship issues during the manufacturing cycle.

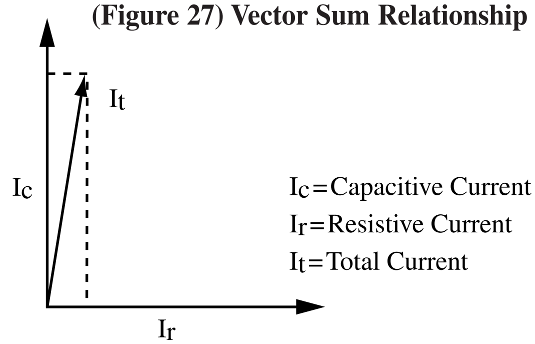
A graphic example of the Real Current issue can be seen while looking at Figure 27. A combination of resistive and capacitive currents are produced on the

(Figure 26) Resistive & Capacitive Current



Combination of Resistive and Capacitive leakage current causes some level phase shift between the voltage and current sine waves.

(Figure 27) Vector Sum Relationship



Vector sum relationship of capacitive current and resistive current.

device under test (DUT) which will produce some level of phase shift between the voltage and current sine waves. The Total Current sine wave is no longer either in phase or 90 degrees out of phase with the voltage waveform. To determine the Real Current we need to sample the signal of the instantaneous Voltage and Current and calculate the Real or Average Power (Watts), this includes information regarding the Real Current phase angle. This information is fed into the CPU which then divides the average power by the average voltage and the result is the Real Current. The formula is as follows, V I cos(I) / V= I cos(I) = Real Current.

In cases where distributed capacitance in a product is a problem and AC Dielectric Withstand tests are mandated by safety agency specifications you should be using an instrument that has a Real Current feature. This way you are assured that the Real Current will be known and thus the real quality of the insulation within your product will also be known. An instrument without a Real Current circuit may produce erroneous information about the quality of the insulation system. Without Real Current you would have to either perform a DC Hipot test which may not be allowed by the safety agency or you may need to perform an Insulation Resistance test to determine the true quality of the insulation system. Real Current saves you both time and money by not having to purchase additional equipment or perform additional tests.

Electronic Ramping (Up and Down)

Because Hipot testing instantly applies high-voltage to a DUT, it may cause electrical damage to components.

Several new testing techniques have been developed to eliminate this problem. One such technique that was developed as a solution is the ramp up and down feature. This feature ensures that the DUT's are not compromised from the application of high voltage by providing a timed and gradual method to increase and or decrease output test voltage. The ramp up and down technology effectively reduces the amount of damage occurring on DUT's sensitive to rapid changes in voltage.

Ramping is also very important when performing a DC Hipot test. A common problem with DC testing is that if high-voltage is applied instantly or raised too quickly, a false failure could be indicated by the Hipot because of the in-rush charging current the DUT will initially draw. If voltage is gradually brought up, false trips can be avoided since the current drops as the DUT charges. Because of this, electronic ramping is much more popular in DC testing.

Patented Ramp-HI

A disadvantage of DC testing is that sometimes the time required to allow charging current to stabilize is considered excessive in some high volume manufacturing environments. Associated Research offers a patented Ramp-HI feature that solves this problem. This allows customers to use a DC Hipot and still satisfy high volume production needs. The Ramp-HI system can be programmed to allow for a higher trip setting during the ramp cycle allowing the DUT to be charged as rapidly as possible without causing false failures. Once the Hipot reaches the full test voltage the processor will then revert back to monitoring the actual trip setting which could be a much lower value. If the leakage current does not drop below the high trip setting by the time the Hipot switches to the dwell mode, a high limit failure is indicated.

High and Low Current Sense

The Hipot test usually is not monitored in an automated testing environment. This means that it is not always possible to visually confirm that the DUT has been connected properly. An improperly connected Hipot or an open conductor in a test lead will not show excess current flow or electrical breakdown—two conditions that indicate a failed test. In this type of situation, the instrument may in fact give a green light to products that have not even been tested.

To solve this problem, it was necessary to not only develop a system that monitors and indicates a failure when excessive current is present, but also to develop circuitry that monitors minimum current conditions. This enables the user to set the Hipot in such a way that it can determine whether current levels fall within parameters the user has already defined. During the test, if the current level falls between the minimum and maximum allowable levels, the DUT is considered to have passed. If the Hipot detects current falling below the minimum during the test, it gives a failure signal. This signal tells the operator that a failure condition was caused by the current dropping below the required minimum level. This usually means that there is an open circuit condition or a test lead has fallen off the DUT.

This system works very effectively in AC Hipot testing where a minimum leakage level current is almost always measurable. Unfortunately, during DC testing the minimum level of current is often below the range a conventional low current measurement circuit can detect. The reason for this is that when first applying the DC high-voltage, a capacitive DUT will cause in-rush current to flow. But after the DUT is fully charged and during the dwell cycle, the actual leakage can be very low or zero. With conventional High/Low current systems this would cause a false low trip as soon as the current drawn by the DUT dropped below the minimum limit setting.

Patented Charge-LO

Fortunately technology has been developed that addresses this problem and offers the benefits of High/Low detection to DC Hipot users. The Charge-LO system is a high speed detection circuit that detects the presence of the charging current pulse when voltage is initially applied to the DUT. It can be assumed that if any charging current is flowing at any time, the Hipot must be connected to the DUT. If the circuit does not detect even momentary charging current the DUT fails the patented Charge-LO test. This new system allows DC Hipot users to have the security of knowing that the DUT is properly connected and that a Hipot test is being performed.

Software Calibration

Most safety agencies such as UL require annual calibration of all electrical safety testing instruments. Although Associated Research recommends that instruments be returned to the factory annually for calibration and updates, we realize this is not possible in all cases. Some customers prefer to use their own in-house metrology department to maintain the calibration accuracy of all instruments. This has posed a safety problem for the technicians responsible for performing this calibration. Since Hipots output high-voltage, removing covers can be extremely hazardous. To further complicate this, older instruments utilize internal potentiometers which require the technician to adjust pots, with a screwdriver, that are often times located very near components that are at high-voltage potential.

In order to provide our customers with as safe an instrument as possible, we have adopted software calibration on all instruments. This eliminates the requirement for the technician to remove any covers and reduces the possibility of accidental contact with high-voltage. This new calibration method also eliminates the need for potentiometers which are difficult to adjust and can often times drift, causing inaccurate test results. With software controlled calibration the technician merely connects a standard meter and presses a single button to begin the calibration program. When prompted, the technician then enters the meter reading from the standard meter right from the front panel keypad of the instrument. Once the power to the instrument is shut off, the new calibration values are automatically written to the non-volatile memory of the test instrument. This provides a very simple, and more importantly, a safer way of doing calibration on all Associated Research instruments.

Patented CAL-ALERT®

Many of AR's new instruments include clock chips therefore AR has been able to add a new built-in calibration alert feature. This feature automatically alerts the user when the instrument is due for annual calibration. The calibration alert will allow the instrument to give an advanced alert that the calibration due date is approaching. The alert date is like an alarm clock that will warn you in advance of the actual calibration due date. After a calibration is performed the alert date is automatically set 11 months after the calibration date. The CAL-ALERT system effectively eliminates the need for manual tracking of calibration dates and unnecessary paperwork. Both of these advantages work to increase the likelihood of maintaining the instrument within the required specifications and lessens the responsibility of the operator.

Patented SmartGFI®

Another new safety feature that will be added to new Associated Research products is a protection circuit called SmartGFI. You may be familiar with the term GFI (Ground Fault Interrupter) circuits or GFCI (Ground Fault Circuit Interrupters). These types of safety circuits are mandated today by the National Electrical Code (NEC) and other organizations to be used in "wet" environments and are most commonly found in bathrooms, kitchens and basements. Many line cord manufacturers are also adding a GFI circuit to their line cords that are connected to products that are being used in potentially hazardous environments such as power tools, pressure sprayers and hair dryers to name just a few.

AR in its continuous effort to provide the safest high voltage testing instruments has designed a new circuit to help prevent electrical shock in cases where an operator may come into contact with the high voltage circuit. The SmartGFI basically has a sensing circuit that will open thus disabling high voltage when excessive leakage flows from chassis to earth ground. The circuit is smart because it doesn't matter if the DUT is in a "floating" or in a "grounded" (earthed) configuration. It automatically senses the DUT's configuration and will turn itself on or off. Other GFI circuits some manufacturers use today in their safety testers must be turned on and off manually by the operator depending upon if they are testing a DUT that is floating or grounded. In the case of manually set GFI circuits it is far too easy to forget to properly set or reset this feature. In the case of the SmartGFI it is truly a safety feature because we have eliminated the operator from the equation, SmartGFI is always present working transparently in the background. It is important to note that any GFI circuit just like the SmartGFI circuit will function correctly only in the case where a DUT is floating and the safety tester is using a floating return configuration.

Enhanced Graphic Liquid Crystal Display

An Enhanced Graphic LCD provides the user with flexibility in viewing test results, test set up, data and even various menu prompts that are not available in other types of displays. The enhanced graphic LCD increases the area for display of information. This effectively provides the user with greater visibility and presents the information in an easier more readable format. The operator is now able to view test set up and results without having to interpret and decipher abbreviations. The graphic LCD also allows the user to view detailed prompts from the screen allowing prompt functions to guide the user through the correct test process. The enhanced graphic LCD makes electrical safety testing easier, clearer, and more efficient.

Prompt Screens

Many applications require certain steps and procedures to be taken during the test cycle. Applications will call for the DUT switches to be activated or test leads and probes to be applied in a different manner or removed all together. The prompt feature was designed to help avoid operator error that may occur with the complication of adding various steps to the test cycle. The instrument can be programmed to display prompt messages as a part of a test cycle serving as a reminder to the operator. When a prompt is used as part of a test set up, the test will pause and a prompt will appear on the screen before the next step is initiated and remain on the screen until the test button is pressed. During the pause the operator-configured message is displayed instructing the test operator on the action they need to perform before continuing the test.

Patented VERI-CHEK®

Verification of failure detect circuitry of the electrical safety tester is required by safety agencies such as CSA, UL, TÜV and others to validate that the instrument is performing and functioning correctly. A common request by inspectors during on-site follow up visits is to have the manufacturer prove the functionality of the instrument. The VERI-CHEK allows a user to easily and quickly validate the operation of the instrument. The VERI-CHEK can be enacted each time the instrument is powered up. The instrument then begins to display a series of user-friendly prompts, which prompt the user through the steps required for verification. When the verification process is completed detailed results are displayed indicating whether the instrument passed the verification. Functions that can be verified include AC Hipot, DC Hipot, Ground Continuity, Ground Bond and Insulation Resistance.

These latest technological developments help manufacturers quickly perform electrical safety tests while ensuring that the tests comply with agency specifications. Incorporating microprocessor technology, many new and enhanced functions have been added to address the traditional limitations of AC and DC testing found in analog Hipot designs. Software control provides the operator with a user friendly interface and eliminates many of the possibilities for errors.

In review, the five primary electrical safety tests are:

- **Dielectric Voltage-Withstand Tests**
- **Line Voltage Leakage Tests**
- **Insulation Resistance Tests**
- **Polarization and Ground Continuity Tests**
- **Ground Bond Tests**

A safety test instrument may incorporate any or all of these test modes in a single instrument.

Automated Testing

Every manufacturer is familiar with the inherent conflict between the need to produce products quickly and efficiently and the need to provide adequate testing.

This conflict of interest can tempt manufacturers to take shortcuts that compromise the operator and product safety. Fortunately, modern test instruments have finally reached a level of sophistication that eliminates the need to make this type of trade-off. Integrated and automated test systems can perform all required tests on the DUT quickly, accurately and through a single connection. As a result, test operators no longer need to make multiple connections, the tests themselves are more reliable, and operators can perform tests far more quickly and at a lower safety risk. Test operators and manufacturers also need to store and retrieve test information. Automation fulfills that need.

Associated Research offers our Autoware® software to control our complete line of automated test instruments. This stand-alone software captures, stores and analyzes test results (See Figure 28).

Many manufacturers collect and analyze the data they gather from successive testing and use it as information to make their products safer and more reliable, as well as to comply with ISO, TQM, SPC and some IEC requirements.

For example, a manufacturer might analyze current leakage readings during a Hipot test. Data kept on file over several years might indicate that typical leakage readings during a 1500V test, on a certain DUT, were consistently 2 milliamps. If this manufacturer produced the same product and later noticed readings as high as 5 milliamps, he might want to know why the new test results varied from the old readings.

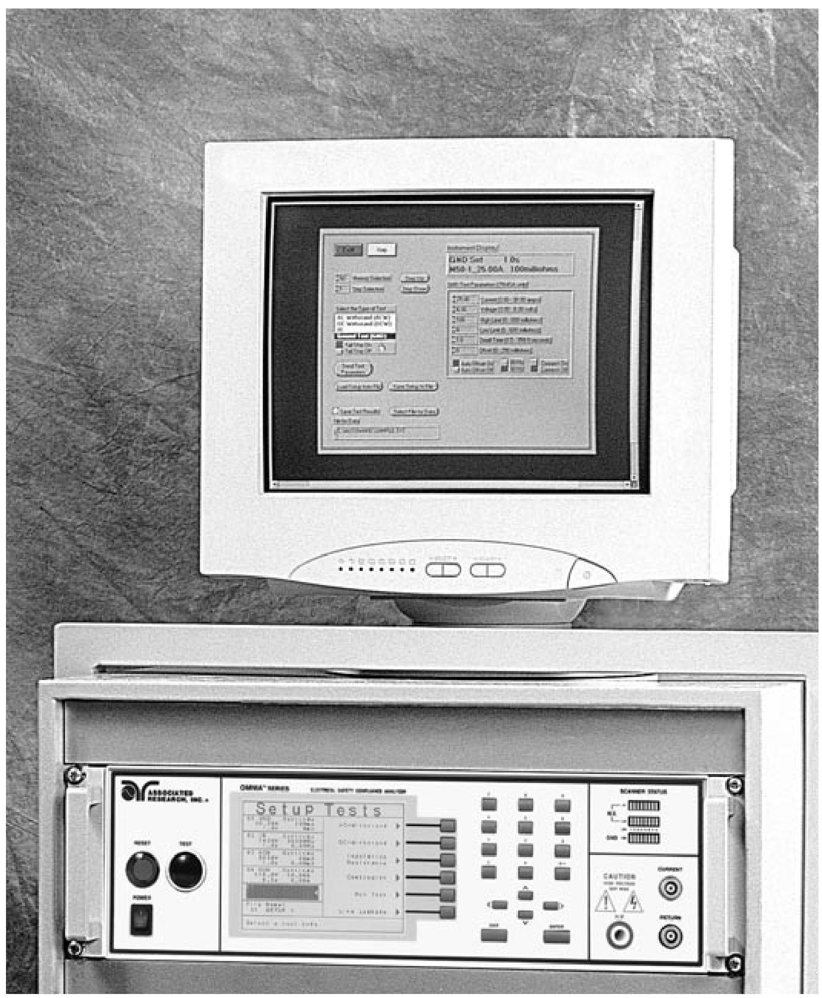
Neither of these conditions would cause a failure if the leakage trip point on the Hipot were set to 10 milliamps, but the increase in leakage current suggests that something in the manufacturer's process may have changed and should be reviewed.

A computer-controlled safety test system can easily be configured to store test data so that it can be retrieved and evaluated to meet these information and decision needs.

Another important reason for the growing need to automate is to be ISO compliant. One of ISO's main objectives is to ensure that manufacturers can prove that their products have been adequately tested and documented. If a manufacturer has automated records of the test results required by a safety agency, he has the necessary documentation to prove all products have passed the tests.

Furthermore, keeping the results from various safety tests on file can shield the manufacturer from potential litigation related to product safety.

Many U.S. manufacturers are successfully selling their products in Europe, and many products shipped to



(Figure 28) Fully-Automated Test Station with OMNIA® Series 6 set-up for PC control through Autoware® software.

Europe must display the CE mark to indicate compliance with European Community standards.

One requirement to obtain the CE mark stipulates that manufacturers must conduct proper testing and keep adequate records of test results. Using an automated system controlled by a computer can quickly transform data filing and storage into a relatively simple task.

Three methods are commonly used to interface a compliance safety instrument into an automatic test system.

Programmable Logic Control (PLC)—Some electrical safety testing instruments come with proprietary interfaces that provide the test operator with a convenient way to connect the instrument to a variety of test instruments. These interfaces range from a simple foot switch for hands-free test initiation, to a computer-based automatic test system for statistical process control and ISO compliance.

The benefit of this type of automation is that it does not necessarily require computer programming to set up a basic test system. Through simple switches and analog inputs and outputs, the instrument can control most functions remotely.

Using this type of proprietary interface to control test functions and retrieve test data through a computer, you may need a special controller card and interface cable. You can also use instrument control software packages to control many functions of safety test instruments through a user interface on a computer. Another choice is to consider a safety test instrument that comes complete with industry standard interfaces that can easily be incorporated into an already complete automated test system.

RS-232 Interface—Another method of connecting the instruments to computers is to use an RS-232 interface. An advantage of this type of system is that most computers come with an RS-232 port, no special controller card is required, and there are fewer constraints on the length of interface cable needed to connect the test instruments to the computer. However, there are two limitations: the RS-232 interface primarily is used to connect a computer to a single test instrument; and RS-232 is a serial communication method which is much slower than other methods of interfacing, such as GPIB.

IEEE (GPIB) Interface—The GPIB interface, sometimes called the General Purpose Interface Bus, is a general purpose digital interface system that can be used to transfer data between two or more devices.

Particularly well suited for interconnecting computers and instruments, this interface requires the installation of a GPIB interface card into a computer and is the most popular choice in controlling instrumentation. The GPIB interface can be a very economical choice since it gives the test operator the ability to control up to 15 instruments on a single bus.

Another advantage to GPIB is its high data transfer rate of up to several Megabytes per second. Although bus extender devices are available, the GPIB interface's basic limitation is that the bus length cannot exceed 20 meters (65 feet) and the distance between devices cannot exceed two meters (6.5 feet) (See Figure 28).

A computer interface allows the operator to access all set-up modes of the safety instruments through a computer. It allows the test operator to automatically and quickly cycle through all the tests he or she is required to perform and to store and evaluate all the test results.

Many manufacturers are concerned with the operator skill level required to set up and use an automated system. This concern has been addressed by some manufacturers of computer-controlled safety test instruments. Automatic systems can be purchased with a software package that guides the test operator through the set up with a Windows-style program.

While the best method for automating electrical safety tests depends upon the preference and requirements of the specific manufacturer, technology and instrumentation is available to assist you in thoroughly testing each product. You can then ensure the electrical safety of your operators and the safety of those who use your products.

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(APPENDIX A) Glossary of Terms

ALTERNATING CURRENT (AC)—Current that reverses direction on a regular basis (usually 60 times per second in the United States).

ARC DETECTION—The ability of a circuit to detect the short duration current spikes normally in the range of 10 microseconds which have peak amplitudes in the milliamp range. These high frequency spikes normally appear on the peaks of the output wave prior to catastrophic or destructive arc breakdown which result in complete failure of the insulation.

BREAKDOWN—The failure of insulation to effectively prevent the flow of current, sometimes evidenced by arcing. If voltage is gradually raised, breakdown will begin at a certain voltage level (whereby current flow is not directly proportional to voltage). Once breakdown current flows, especially for a period of time, the next gradual application of voltage will often show breakdown beginning at a lower voltage than initially measured.

CAL-ALERT®—The patented CAL-ALERT feature automatically alerts the user when the instrument is due for re-calibration. This eliminates the need for manual tracking of calibration dates.

CE MARK—The CE Mark is the manufacturer's or importer's mark of conformity declaring compliance with all applicable directives (Safety, EMC, Machinery, Medical and others). The use of the CE Marking and the Declaration of Conformity will be mandatory for most products sold in the European Community.

CHARGE-LO—The Charge-LO Circuit sets a minimum charging current which is based on the DC test voltage, the rate of rise, and the capacitance of the DUT. This circuit confirms that the DUT is connected when performing a test.

CLASS I PRODUCTS—Products grounded through a third pin of the input cord.

CLASS II PRODUCTS—Products not grounded through the input cord. These products must have double insulation.

CONDUCTIVE—Having a volume resistivity of no more than 10^3 ohm-cm or a surface resistivity of no more than 10^5 ohms per square cm.

CONDUCTOR—A solid or liquid material that current can pass through, and has a volume resistivity of no more than 10^3 ohm-cm.

DIELECTRIC—An insulating material positioned between two conductive materials in such a way that a charge or voltage can appear across the two conductive materials.

DIRECT CURRENT (DC)—Current that only flows in one direction. Direct current comes from a polarized source, meaning one terminal is always at a higher potential than the other.

DOUBLE INSULATED PRODUCTS—This is a product where the insulation is comprised of both Basic and Supplementary Insulation. The basic insulation is the insulation which is applied to live parts to provide basic protection against electrical shock. Supplementary insulation is independent insulation applied in addition to basic insulation in order to provide protection against electrical shock in the event of a failure of basic insulation.

DUT—Device Under Test.

FREQUENCY—The number of complete cycles in one second of alternating current, voltage, electromagnetic or sound pressure. In the case of alternating current and other forms of wave motion it is expressed in hertz.

GPIB— General Purpose Interface Bus.

Glossary Continued

HIPOT TEST, SECURITY or FLASH TEST, DIELECTRIC VOLTAGE WITHSTAND TEST and HIGH POTENTIAL TEST—Common terms for the deliberate application of over-voltage to a DUT to test dielectric strength.

IEEE-488—A GPIB standard for instrument control.

INSULATING—Having a volume resistivity of at least 10^{12} ohm-cm or a surface resistivity of at least 1014 ohms per square cm.

INSULATION—Gas, liquid, or solid material that has a volume resistivity of at least 10^{12} ohm-cm and is used to reduce or prevent current flow between conductors.

ISO—International Standards Organization .

LEAKAGE—AC or DC current flow through insulation and over its surfaces, and AC current flow through a capacitance (whereby current flow is directly proportional to voltage). If breakdown does not occur, the insulation and/or capacitance is considered a constant impedance.

MEGOHMMETER—A meter capable of measuring resistances greater than 200 megohms. Usually requires a higher voltage power supply than ohmmeters that measure less than 200 megohms.

PLC—Programmable Logic Control, an automation method using relay technology.

RAMP-HI—The Ramp-HI feature allows you to set a high limit charging current during the Ramp function which is higher than the high limit setting which would be chosen for the dwell cycle. This allows you to charge the DUT as rapidly as possible without causing false failures.

RS-232—A standard form of serial communication through a personal computer.

SENSITIVITY—The minimum current flow required to cause an indication of unacceptable performance during a Dielectric Voltage-Withstand test.

SmartGFI®—The patented SmartGFI is a high speed shut down circuit that provides maximum operator protection. If the circuit detects excessive leakage to ground, it shuts down the high voltage in less than 1 millisecond. SmartGFI is automatically activated if the DUT is not grounded. The operator does not need to make the decision whether to activate the SmartGFI.

SPC—Statistical Process Control. A system by which one samples and inspects the output of a process to determine if one should adjust the process to bring the items or goods into an acceptable quality standard.

VERI-CHEK®—The patented VERI-CHEK feature is a menu driven process by which the instrument's failure detectors are proven to be functioning properly, "verifying" the functionality of the electrical safety tester and connected accessories.

(APPENDIX B) Associated Research Patents

PATENTS

U.S. Patent No.	Description
6,744,259	This patent covers the VERI-CHEK® feature, an internal verification system, found in Associated Research high-voltage safety testers to verify the functionality of the tester.
6,549,385	This patent covers the SmartGFI® circuit used in Associated Research high voltage safety testers to protect operators from exposure to high voltage.
6,538,420	This patent covers the interconnection of a run test system to an electrical safety tester including the built-in high voltage switching circuit.
6,515,484	This patent covers an advanced user interface including features such as Pause/Prompt, CAL-ALERT®, Security Access Functions and a flexible menu structure allowing tests to be added through plug in modules.
6,054,865	This patent covers multi-function safety compliance analyzers that are capable of performing AC and DC Dielectric tests as well as Insulation Resistance and either Ground Continuity or Ground Bond with a single instrument.
6,011,398	This patent covers the multiple circuits used in our line leakage testers to simulate the impedance of the human body.
5,828,222	This patent covers the exclusive RAMP-HI® circuit as used in DC Hipot testing to allow a higher level of current draw during the ramping to allow for more rapid charging of the device under test.
5,936,419	This patent covers the exclusive CHARGE-LO® circuit as used in DC Hipot testing to detect charging current as an indication that the device under test is properly connected.
5,548,501	This patent covers the H.V. auto discharge circuit that is used in all AR DC dielectric withstand testers.

PATENTS PENDING

SC6540	Modular Scanning Matrix
OMNIA 8100 Series	Multi-Function Electrical Safety Compliance Analyzers

(APPENDIX C) Safety Agency Listings

cb scheme

The CB scheme is based on the IEC standard and means that a recognized National Certification Body (NCB) has tested our products and they are recognized in more then 30 countries.

The most recognized International Safety mark. This safety listing signifies that the product was safety tested to IEC 61010.

CE is the abbreviation of the European Communities and this mark tells customs officials in the European Union that the product complies with one or more of the EC Directives.

This mark indicates compliance with both Canadian and U.S. requirements. It signifies that the products have been tested to UL 61010-1 and listed.

Associated Research in early 1998 began a program to safety list all of its products. We received the first coveted TÜV-GS certification on March 3, 1998. Since then the following instruments have been tested and certified by the safety agency shown below. In addition, all these products have passed EN61010 for CE compliance. AR is the only company in its industry to carry the TÜV-GS International Safety listing as well as the UL safety listing on some models.

No.	Model	Description	CB Scheme Certificate No.	TÜV-GS Certificate No.	UL Listing No.
1	510L	Stand-alone Line Leakage Tester	DE2-003312	S9955654	
2	3130	30A Ground Bond Tester	DE2-004909	S-50010562	E204261
3	3140	40A Ground Bond Tester	DE 02007384	S1-50042888	E204261
4	3160	60A Ground Bond Tester	DE 02005714	S50023517	E204261
5	3605	AC Withstand Voltage Tester	DE2-004324	S3-50005125	E204261
6	3665	AC/DC Withstand Voltage Tester	DE2-004324	S3-50005125	E204261
7	3670	AC/DC/IR Withstand Voltage Tester	DE2-004324	S3-50005125	E204261
8	5030DT	Ground Bond Tester	DE2-001328	S9853570	
9	5500DT	AC Withstand Voltage Tester	DE2-001329	S9853569	
10	5560DT	AC/DC Withstand Voltage Tester	DE2-001329	S9853569	
11	7500DT	500 VA Safety Compliance Analyzer	DE2-002988	S9954651	
12	7504SA	500 VA Safety Compliance Analyzer	DE2-002988	S9954651	
13	7550DT	AC/DC/IR Safety Analyzer	DE2-001938	S9853225	
14	7620	AC Safety Compliance Analyzer	DE2-006113	S50029821	E204261
15	7650	AC/DC/IR Safety Compliance Analyzer	DE2-006113	S50029821	E204261
16	8104	OMNIA Electrical Safety Compliance Analyzer	approval pending	approval pending	approval pending
17	8105	OMNIA Electrical Safety Compliance Analyzer	approval pending	approval pending	approval pending
218	8106	OMNIA Electrical Safety Compliance Analyzer	approval pending	approval pending	approval pending

(APPENDIX D) Sample Safety Agency Specifications

INFORMATION TECHNOLOGY EQUIPMENT	STANDARD/HARMONIZED STANDARD NUMBER: EN 60950 (IEC) 60950 (EN 50116)											
	DIELECTRIC WITHSTAND			GROUND BOND/CONTINUITY				EARTH LEAKAGE		INSULATION RESISTANCE		
	Test Voltage*	Max. I	Test Time	Test Current	V Limit	Max. R	Test Time	Test Voltage	Max. I	Test Time	V Limit	Max. R
PERFORMANCE	1.0-3.0 KVAC or 1414-4242 DC see spec.	No Breakdown	60s	25 A AC or DC	≤ 12 V	≤ 0.1Ω	60s	< 300	3.5 mA	60s	500	≥ 2MΩ
PRODUCTION			1-6s	25 A AC or DC	≤ 12 V	≤ 0.1Ω	5s	Not Required		Not Required		

INFORMATION TECHNOLOGY EQUIPMENT	STANDARD/HARMONIZED STANDARD NUMBER: CAN/CSA 22.2 No. 60950-1-3 UL 60950-1											
	DIELECTRIC WITHSTAND			GROUND BOND/CONTINUITY				EARTH LEAKAGE		INSULATION RESISTANCE		
	Test Voltage*	Max. I	Test Time	Test Current*	V Limit	Max. R	Test Time	Test Voltage	Max. I	Test Time	V Limit	Max. R
PERFORMANCE	1.0-3.0 KVAC or 1414-4242 DC See Spec.	No Breakdown	60s	40 A for 20 A CKT	≤ 12 V	≤ 0.1Ω	60s	< 300	3.5 mA	60s	500	≥ 2MΩ
PRODUCTION			1-6s	Continuity test				Not Required		Not Required		

*If the DUT is fused, the Ground Bond test is 2x Fuse Rating of DUT. Max R should be < 2.5 V and test time should be 120s.

INFORMATION TECHNOLOGY EQUIPMENT	STANDARD/HARMONIZED STANDARD NUMBER: CSA 22.2N950 (CSA 22.2 No. 0.4)											
	DIELECTRIC WITHSTAND			GROUND BOND/CONTINUITY				EARTH LEAKAGE		INSULATION RESISTANCE		
	Test Voltage*	Max. I	Test Time	Test Current	V Limit	Max. R	Test Time	Test Voltage	Max. I	Test Time	V Limit	Max. R
PERFORMANCE	1.0-3.0 KVAC or 1414-4242 2121 VDC	No Breakdown	60s	30 A 60 Hz	≤ 12 V	< 4 V 133 mΩ	2 min	< 300	3.5 mA	60s	500	≥ 2MΩ
PRODUCTION (3)			1s	30 A 60 Hz	≤ 12 V	< 4 V 133 mΩ	5s	Not Required		Not Required		

MEDICAL EQUIPMENT	STANDARD/HARMONIZED STANDARD NUMBER: EN 60601-1 (IEC) 601 UL 2601-1											
	DIELECTRIC WITHSTAND			GROUND BOND/CONTINUITY				EARTH LEAKAGE		INSULATION RESISTANCE		
	Test Voltage*	Max. I	Test Time	Test Current	V Limit	Max. R	Test Time	Test Voltage	Max. I	Test Time	V Limit	Max. R
PERFORMANCE	1.0/1.5 KVAC 115/230 V or 2121 VDC	No Breakdown	60s, 10s ramp up/down	10-25 A	≤ 6 V	≤ 0.1Ω	5s	See Spec.		Not Required		
PRODUCTION (3)			1s	10-25 A	≤ 6 V	≤ 0.1Ω	5s	See Spec.		Not Required		

Sample Safety Agency Specifications Cont...

MEDICAL EQUIPMENT	STANDARD/HARMONIZED STANDARD NUMBER: CSA 22.2 No. 601.1 (CSA 22.2 No. 0.4)											
	DIELECTRIC WITHSTAND			GROUND BOND/CONTINUITY				EARTH LEAKAGE		INSULATION RESISTANCE		
	Test Voltage*	Max. I	Test Time	Test Current	V Limit	Max. R	Test Time	Test Voltage	Max. I	Test Time	V Limit	Max. R
PERFORMANCE	1.0/1.5 KVAC or 115/230 V or 2121 VDC	No Breakdown	60s	30 A 60 Hz	≤ 12 V	< 4 V 133 mΩ	2 min	< 300	3.5 mA	60s	500	≥ 2MΩ
PRODUCTION (3)			1s	30 A 60 Hz	≤ 12 V	< 4 V 133 mΩ	5s	Not Required		Not Required		

MEDICAL EQUIPMENT	STANDARD/HARMONIZED STANDARD NUMBER: UL 544											
	DIELECTRIC WITHSTAND			GROUND BOND/CONTINUITY				EARTH LEAKAGE		INSULATION RESISTANCE		
	Test Voltage*	Max. I	Test Time	Test Current	V Limit	Max. R	Test Time	Test Voltage	Max. I	Test Time	V Limit	Max. R
PERFORMANCE	1.0 KVAC or 1.0 + 2X rated V	No Breakdown	60s	25 A	≤ 6 VAC	≤ 0.1Ω or ≤ 0.2Ω See Spec.	5s	< 300	0.5 mA	Not Required		
PRODUCTION	1.0-3.0 KVAC See Spec.		1s	Basic continuity any device				Not Required		Not Required		

LABORATORY, CONTROL, TEST & MEASUREMENT EQUIPMENT	STANDARD/HARMONIZED STANDARD NUMBER: EN 61010-1 IEC (1010) UL 61010-1											
	DIELECTRIC WITHSTAND			GROUND BOND/CONTINUITY				EARTH LEAKAGE		INSULATION RESISTANCE		
	Test Voltage*	Max. I	Test Time	Test Current	V Limit	Max. R	Test Time	Test Voltage	Max. I	Test Time	V Limit	Max. R
PERFORMANCE (TYPE)	820-1350 VAC or 1159-1900 VDC	No Breakdown	60s	25 A	≤ 10 V	≤ 0.1Ω	60s	< 300	3.5 mA	Not Required		
PRODUCTION (ROUTINE)			2s ramp 2s dwell	Basic continuity any device				Not Required		Not Required		

LABORATORY, CONTROL, TEST & MEASUREMENT EQUIPMENT	STANDARD/HARMONIZED STANDARD NUMBER: CSA C22.2 No. 1010.1 (CSA 22.2 No. 0.4)											
	DIELECTRIC WITHSTAND			GROUND BOND/CONTINUITY				EARTH LEAKAGE		INSULATION RESISTANCE		
	Test Voltage*	Max. I	Test Time	Test Current	V Limit	Max. R	Test Time	Test Voltage	Max. I	Test Time	V Limit	Max. R
PERFORMANCE	820-1350 VAC or 1159-1900 VDC	No Breakdown	60s	30 A 60 Hz	≤ 12 V	< 4 V 133 mΩ	2 min	< 300	3.5 mA	Not Required		
PRODUCTION			1s	Basic continuity any device				Not Required		Not Required		

Sample Safety Agency Specifications Cont...

PORTABLE ELECTRIC TOOLS	STANDARD/HARMONIZED STANDARD NUMBER: UL 45											
	DIELECTRIC WITHSTAND			GROUND BOND/CONTINUITY				EARTH LEAKAGE		INSULATION RESISTANCE		
	Test Voltage*	Max. I	Test Time	Test Current	V Limit	Max. R	Test Time	Test Voltage	Max. I	Test Time	V Limit	Max. R
PERFORMANCE	1.0-3.5 KVAC See Spec.	No Breakdown	60s 5s ramp	Basic continuity any device				< 300	0.5-3.5 mA See Spec.	60s Double Insulated Requires 10s	500 500	≥ 50 KΩ ≥ 1 MΩ
PRODUCTION			1s	Basic continuity any device				Not Required		Not Required		

MOTOR OPERATED APPLIANCES	STANDARD/HARMONIZED STANDARD NUMBER: UL 73											
	DIELECTRIC WITHSTAND			GROUND BOND/CONTINUITY				EARTH LEAKAGE		INSULATION RESISTANCE		
	Test Voltage*	Max. I	Test Time	Test Current	V Limit	Max. R	Test Time	Test Voltage	Max. I	Test Time	V Limit	Max. R
PERFORMANCE	1.0-3.0 KVAC See Spec.	No Breakdown	60s	Not Required				< 300	≤ 0.5-0.75 mA See Spec.	Not Required		
PRODUCTION			1s	Basic continuity any device				Not Required		Not Required		

PORTABLE ELECTRIC LAMPS	STANDARD/HARMONIZED STANDARD NUMBER: UL 153											
	DIELECTRIC WITHSTAND			GROUND BOND/CONTINUITY				EARTH LEAKAGE		INSULATION RESISTANCE		
	Test Voltage*	Max. I	Test Time	Test Current	V Limit	Max. R	Test Time	Test Voltage	Max. I	Test Time	V Limit	Max. R
PERFORMANCE	1.0-3.0 KVAC See Spec.	No Breakdown	60s	Not Required				Not Required		Not Required		
PRODUCTION			1s	Basic continuity any device				Not Required		Not Required		

COMMERCIAL ELECTRIC COOKING APPLIANCES	STANDARD/HARMONIZED STANDARD NUMBER: UL 197											
	DIELECTRIC WITHSTAND			GROUND BOND/CONTINUITY				EARTH LEAKAGE		INSULATION RESISTANCE		
	Test Voltage*	Max. I	Test Time	Test Current	V Limit	Max. R	Test Time	Test Voltage	Max. I	Test Time	V Limit	Max. R
PERFORMANCE	1.0 KVAC or 1.0 + 2X rated V	No Breakdown	60s	Not Required				< 300	≤0.5-0.75 mA See Spec.	60s	500	≥ 50 KΩ
PRODUCTION	1.2 or 1.0 + 2X rated V		1s	Basic continuity any device				Not Required		Not Required		

Sample Safety Agency Specifications Cont...

HOUSE HOLD REFRIGERATORS AND FREEZERS	STANDARD/HARMONIZED STANDARD NUMBER: UL 250											
	DIELECTRIC WITHSTAND			GROUND BOND/CONTINUITY				EARTH LEAKAGE		INSULATION RESISTANCE		
	Test Voltage*	Max. I	Test Time	Test Current	V Limit	Max. R	Test Time	Test Voltage	Max. I	Test Time	V Limit	Max. R
PERFORMANCE	500 V or 1.0 KVAC + 2X rated V	No Breakdown	60s	Not Required				< 300	≤ 0.75	60s	500	≥ 50 KΩ
PRODUCTION	600 V-1200 V See AC Spec.		1s	Basic continuity any device				Not Required		Not Required		

ELECTRIC FANS	STANDARD/HARMONIZED STANDARD NUMBER: UL 507 (2)											
	DIELECTRIC WITHSTAND			GROUND BOND/CONTINUITY				EARTH LEAKAGE		INSULATION RESISTANCE		
	Test Voltage*	Max. I	Test Time	Test Current	V Limit	Max. R	Test Time	Test Voltage	Max. I	Test Time	V Limit	Max. R
PERFORMANCE	1.0 KVAC or 1.0 + 2X rated V	No Breakdown	60s	Basic continuity any device ≤ 0.1 Ω				< 300	0.5-2.5 mA See Spec.	60s	500	≥ 50 KΩ
PRODUCTION			1s	Basic continuity any device				Not Required		Not Required		

VACUUM CLEANING MACHINES AND BLOWER CLEANERS	STANDARD/HARMONIZED STANDARD NUMBER: UL 1017 CSA C22.2 No. 343											
	DIELECTRIC WITHSTAND			GROUND BOND/CONTINUITY				EARTH LEAKAGE		INSULATION RESISTANCE		
	Test Voltage*	Max. I	Test Time	Test Current	V Limit	Max. R	Test Time	Test Voltage	Max. I	Test Time	V Limit	Max. R
PERFORMANCE	1.0-2.5 KVAC See Spec.	No Breakdown	60s	Not Required				< 300	0.5-5 mA See Spec.	Not Required		
PRODUCTION	1.2-3.0 KVAC See Spec.		1s	Basic continuity any device				Not Required		Not Required		

ELECTRIC HOUSEHOLD COOKING AND FOOD SERVING APPLIANCES	STANDARD/HARMONIZED STANDARD NUMBER: UL 1026											
	DIELECTRIC WITHSTAND			GROUND BOND/CONTINUITY				EARTH LEAKAGE		INSULATION RESISTANCE		
	Test Voltage*	Max. I	Test Time	Test Current	V Limit	Max. R	Test Time	Test Voltage	Max. I	Test Time	V Limit	Max. R
PERFORMANCE	1.0 KVAC	No Breakdown	60s	Not Required				< 300	0.5-2.5 mA See Spec.	60s	500	≥ 50 KΩ
PRODUCTION	1.2 KVAC 1.0 KVAC		1s 60s	Basic continuity any device				Not Required		Not Required		

Sample Safety Agency Specifications Cont...

HOUSEHOLD ELECTRIC COFFEE MAKERS	STANDARD/HARMONIZED STANDARD NUMBER: UL 1082											
	DIELECTRIC WITHSTAND			GROUND BOND/CONTINUITY				EARTH LEAKAGE		INSULATION RESISTANCE		
	Test Voltage*	Max. I	Test Time	Test Current	V Limit	Max. R	Test Time	Test Voltage	Max. I	Test Time	V Limit	Max. R
PERFORMANCE	1.0 KVAC	No Breakdown	5s ramp 60s	Not Required				< 300	0.5-2.5 mA See Spec.	Not Required		
PRODUCTION	1.2 KVAC 1.0 KVAC		1s 60s	Basic continuity any device				Not Required		Not Required		

ELECTRIC COMMERCIAL CLOTHES DRYING EQUIPMENT	STANDARD/HARMONIZED STANDARD NUMBER: UL 1240											
	DIELECTRIC WITHSTAND			GROUND BOND/CONTINUITY				EARTH LEAKAGE		INSULATION RESISTANCE		
	Test Voltage*	Max. I	Test Time	Test Current	V Limit	Max. R	Test Time	Test Voltage	Max. I	Test Time	V Limit	Max. R
PERFORMANCE	1.0 KVAC < 1/2 hp 1.0 KVAC + 2X rating > 1/2 hp	No Breakdown	60s	Not Required				Not Required		60s	250	≥ 50 KΩ
PRODUCTION	1.2 KVAC or 1.2 KVAC + 2.4		1s	Basic continuity any device				Not Required		Not Required		

ELECTRIC HOT TUBS AND SPAS (1)	STANDARD/HARMONIZED STANDARD NUMBER: UL 1563											
	DIELECTRIC WITHSTAND			GROUND BOND/CONTINUITY				EARTH LEAKAGE		INSULATION RESISTANCE		
	Test Voltage*	Max. I	Test Time	Test Current	V Limit	Max. R	Test Time	Test Voltage	Max. I	Test Time	V Limit	Max. R
PERFORMANCE	1.0-2.5 KVAC	No Breakdown	60s	Not Required				< 300	0.5-3.5 mA See Spec.	60s	500	≥ 250 KΩ
PRODUCTION	1.2-2.5 KVAC		1s	Basic continuity any device				Not Required		Not Required		

* Test Voltage is listed for products rated up to 250 VAC Primary to Earth and Primary to Case.

(1) Requires a 500 VA output Hipot tester for Performance and Production line tests.
(2) Excludes Recreational Vehicle Fans (see standard).
(3) There is no clear indication of either a Ground Bond test or Ground Continuity test being required. However, AR recommends that a Ground Bond test be performed on a routine production line basis.

Exceptions and deviations exist in all specifications, even those that are “harmonized”. The examples shown above are representative samples of some of the most commonly used safety standards. These are examples only and it is AR’s opinion that you should check your particular standard or check with your local compliance safety agency before setting up your testing compliance programs. Significant differences may exist between “performance” or “type” tests and “production” or “routine” tests.

(APPENDIX E) Sources of Additional Information

Associated Research, Inc. Web Site www.asresearch.com

This site includes full information on all our instruments, links to other safety related sites and technical articles to help answer the most common safety testing application questions. If you do not have access to the Internet you can use the enclosed reply card to request a hard copies of all AR's literature

American National Standards Institute
11 West 42nd Street, 13th Floor, New York, NY 10036
UNITED STATES
www.ansi.org
U.S. source for IEC standards and other domestic and international standards.

Asociación de Normalización y Certificación, A.C. (ANCE)
Av. Lázaro Cárdenas No. 869 Fracc. 3, esq. con Júpiter
Col. Nueva Industrial Vallejo C.P. 07700, México, D.F.
MEXICO
Phone: +52 (55) 5747-4550 Fax: +52 (55) 5747-4560
www.ance.org.mx
E-mail: ance@ance.org.mx

ASTM
100 Barr Harbor Drive, West Conshohocken, PA 19428-2959
UNITED STATES
Phone: 610-832-9585 Fax: 610-832-9555
www.astm.org
E-mail: infoctr@astm.org

BEAB
1 Station View, Guildford, Surrey, GU1 4JY
UNITED KINGDOM
www.beab.co.uk

British Approvals Board for Telecommunications
Claremont House
34 Molesey Road, Hersham, Walton-on-Thames,
Surrey KT12 4RQ
UNITED KINGDOM
www.babt.co.uk

British Standards Institution
389 Chiswick High Road, London W4 4AL
UNITED KINGDOM
www.bsi.org.uk

Canadian Standards Association
178 Rexdale Boulevard, Rexdale, Ontario, M9W 1R3
CANADA
www.csa-international.org

Comité Européen de Normalisation Electrotechnique
Rue de Stassart, 35, B-1050 Brussels M9W 1R3
BELGIUM
www.cenelec.be

IEC Central Office
3, rue de Verenbé, P.O. Box 131, 1211 Geneva 20
SWITZERLAND
www.iec.ch/home-e.htm

ISO International Standards Organization
1, rue de Verenbé Case postale 56 CH-1211 Geneva 20
SWITZERLAND
www.iec.ch/home-e.htm

Institute of Electrical and Electronic Engineers, Inc.
345 East 47th Street, New York, NY 10017
UNITED STATES
Phone: 800-678-IEEE (Customer Service)
www.ieee.org
E-mail: customer.service@ieee.org

International Product Safety News
www.safetylink.com
E-mail: ipsn@connix.com

Japanese Standards Association
1-24, Akasaka 4, Minato-ku, Tokyo 107
JAPAN
Publisher of English translations of Japanese Industrial Standards.

National Institute of Standards and Technology
Gaithersburg, MD 20899-0001
UNITED STATES
www.nist.gov

National Electric Manufacturers Association
Standards Publication Office
2101 L. Street, N.W., Suite 300, Washington, D.C. 20037
UNITED STATES
Phone: 202-457-8400 Fax: 202-457-8473
www.nema.org
Issues standards for electrical products.
A free catalog is published annually.

OSHA Region V Office
230 South Dearborn Street, Room 3244, Chicago, IL 60604
UNITED STATES
Phone: 312-353-2220
www.osha.gov

The Standards Council of Canada
45 O'Conner Street, Suite 1200, Ottawa, K1P 6N7
CANADA
Phone: 613-238-3222 or 1-800-267-8220 (Sales only)
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