To Pot or Not

Two common types of electrical testing are easily confused; insulation testing and “high-potting”. Both are similar in their method, but critically differ in degree and aim. An understanding of the basis for the two tests is paramount to their respective applications.

Insulation testers are also known by the generic name megohmmeters. High-pots derive their name from “high potential”, a reference to their test voltages, and are also dielectric breakdown testers. Both types have two terminals by which a high voltage is applied across the test sample. Some current will flow through the insulation of the test item, and is measured by the tester’s circuitry. Usually, the current flow is small...nano-Amps...but increases as insulating material ages and becomes worn or is damaged by catastrophic events like voltage spikes or a sudden influx of contaminants, as in flooding. As current flow is the inverse of insulation quality, the tester uses this information to make its determination. In insulation testing, the test voltage is a means by which a measurement is taken and displayed. In high-potting, voltage is more of an end, just to see if the insulation can take it. The two methods overlap quite a bit in their use, technique, and design of instrumentation, so it is a good idea to be familiar with both.

The prime goal of insulation testing is to provide a measurement. Megohmmeters are always DC testers. The high-voltage output is direct current. The tester measures the parameters of voltage and current, and via Ohm’s Law, calculates the resistance of the insulation on the test item. Because the purpose of insulation is to seriously retard current flow, there isn’t much of it before the test item has broken down. Consequently, the megohmmeter must be capable of measuring very small currents, but conversely, can be severely limited in its maximum output. Accordingly, insulation testers are typically limited to only a few milli-amps of test current. This limitation serves four purposes. First, it makes the testers comparatively safe. Even though they commonly output up to 15 kV and sometimes higher, insulation testers are not dangerous to the extent that their voltages may imply. While they are sometimes unfortunately used for practical jokes, at least they will never be a means of capital punishment.

That does not mean that safety can be treated with a cavalier attitude, however. The item being tested can certainly become lethal. Capacitive items can store large static charges that remain after conclusion of the test and pose a serious hazard. While insulation tests are always performed off line, the test item can become energized either through human error or an “event”, and accidents can occur. Fortunately, quality megohmmeters have redundant safety features that protect the operator as much as is reasonably possible.

Secondly, current limitation facilitates the implementation of convenient on-board power sources, most notably batteries. Common AA batteries can output a thousand volts in a handheld instrument through current limitation, and sealed lead-acids can provide higher voltages without having to go to line power. Thirdly, current limitation protects the test item in the event of breakdown. Many failed test items can be restored to service by simple maintenance like cleaning and drying. But this
would not be so simple if breakdown current had pinholed or in some other way physically damaged the insulation. With limited current, when resistance becomes too low, something has to yield, and that is the test voltage. Accordingly, when no more current flow can be accommodated, the voltage collapses. A good quality instrument should exhibit sharp rise of test voltage up to a resistance value commensurate with “good” insulation; i.e., around 1 megohm for 1 kV tests, 5 megohms for 5 kV, and so on. Below these values, insulation isn’t truly insulation any more, but above these values, full selected test voltage should be maintained so that the item is being tested to proper specifications. Some testers of poor quality exhibit slow rise that doesn’t reach selected voltage until well into the megohm range. Such models are not providing a true 1 kV test, or whatever the specified voltage is, and should be avoided.

Finally, current limitation serves one of the most valuable purposes of insulation testing: predictive/preventive maintenance. It would be counter-productive to have the recommended testing procedure stressing insulation to the point of reducing its life. Therefore, the limited power behind an insulation test allows it to be performed again and again over the life of a given piece of equipment while extending the life, not abbreviating it.

So it is that the immediate aim of an insulation test is to provide a measurement. It is then incumbent upon the operator to make proper use of this information. Consequently, insulation testers should be operated by adequately trained personnel. Among other things, the operator must be familiar with the circuit that is being tested, know what lead hookup is testing what element of the item under test, and know how to interpret results. This is no easy task, considering that “good” insulation might be anything from a few megohms to several tera-ohms. The operator also must know how to interpret pointer travel and dancing digits, and be familiar with various industry-standard test procedures that serve the purposes of testing the same insulation in different ways, saving test time, or providing built-in “good/bad” interpretation. In short, an insulation tester demands considerable operator involvement.

High-pots differ on all of these points. Yes, they apply high voltage across insulation and measure leakage current, but the similarity ends there. If that wasn’t enough, high-pots come in two completely different types. These are industrial high-pots and cable high-pots. Industrials are used (generally as a requirement) by manufacturers of electrical products to assure the safety of the product before it ships and falls into the hands of the user. Cable high-pots are employed by the utilities as a pre-conditioner in the fault-locating process, and in installation and maintenance checks of other high-voltage equipment.

The manufacturers of electrical goods are often required by various agencies to assure the public of the safety of their product by testing it to independent standards. Organizations like UL, CSA and VDE (Underwriters Laboratories, Canadian Standards Ass’n and Verband der Electrotechnik) require a final high-pot test for many types of product from consumer goods to commercial equipment. The testers are radically different: generally AC, do not provide a measurement, concerned only with pass/fail, and tolerate virtually no operator involvement.
AC high-pots are preferred because they simulate the voltage stress that will be experienced by most equipment when in operation. Because of the reversing polarity, AC tests tend to pick up end defects in windings better than DC, which concentrates stress more to the middle. However, many products possess considerable capacitance in their design (large windings, parallel runs of wiring and cable) so that charging currents “trip” the testers. With a DC insulation test, the trained operator knows to watch for the stabilization that comes with full charge. But with an AC test, that never happens, unless the test item can be completely charged on a half cycle (before current flows the other way). This requires considerable power, large transformers, and prohibitively bulky, expensive and unwieldy test equipment. Accordingly, standards agencies generally allow a DC test to be substituted, with test voltage adjusted from RMS to AC peak.

Also called a “dielectric strength test”, a high-pot test is just that. It is concerned with the strength of insulation, its ability to withstand voltage stress, rather than with its measurement. Some high-pots do indeed include meters that indicate current or resistance, but these are ancillary functions. The purpose of the tester is to break down marginal insulation...literally kill the weak. Products manufactured with electrical defects...faulty components, incorrect assembly, loose strands...can present a serious, sometimes lethal hazard. Manufacturers don’t want them to get off the end of the assembly line. The high-pot stresses the insulation at high voltage. The most prevalent standard is twice rated plus one thousand volts, so that 120V-rated items would be tested at 1240 volts. It is expected that the test will break down and short out any marginal items.

Industrial high-pots have two primary controls, one to set voltage and the other for trip current. Current levels are based on accepted values relevant to the reaction of the human body. Not all studies, and not all experts, always agree, but generally 0.5 mA is considered perception level, 5 mA provides a “shock”, and 12 mA is approaching “let-go” current, where the victim can no longer release the source. Therefore, high-pots are typically adjustable across a similar range. If leakage current exceeds the set level, the high-pot must both visibly and audibly “trip”. Test time is commonly one minute, but in the interest of practicality, a one-second test at appropriately higher voltage may also be allowed.

Finally, the specifying agencies want no risk of human error. Unlike an insulation tester, high-pots are often operated by minimally trained personnel off the factory floor. The instrument should do all the work. The operator just changes the test item and pushes buttons. Often the supervisor will set the controls at the start of the run. From the viewpoint of the agencies, the idea is to have uniform testing, with the tester either passing or failing the item. Human judgment, which is absolutely critical in insulation testing, is taboo in industrial high-potting.

Industrial high-pots can be used in troubleshooting applications where their voltage is sufficient, and some industries like aeronautical and electro-motive use them to break down marginal equipment so that it doesn’t go into service. This usage bridges the gap to high-voltage dielectric test sets that are used for commissioning, maintenance testing and troubleshooting of transmission cable and transformers, motors, bushings and other equipment that operates at elevated voltages. Typical test
voltages are values like 70 to 160 kV. The design of such models is a careful balance of breakdown power, measurement reliability, safety and practicality.

Test voltages are multiples of common transmission voltages in order to fully accommodate stress tests. They are used for both proof and maintenance tests. Proof testing is similar to factory high-potting. It looks for breakdown under stress, and is used as an acceptance test upon commissioning and when repaired equipment is returned to service, as in a cable splice. Maintenance testing looks for a value that makes a determination as to equipment’s condition and future service. Current is the preferred unit of measurement rather than conversion to the reciprocal resistance because it is directly observed and easier to work with. Testers commonly operate around 5 mA, although much greater currents are available in some models. Although 5 mA approximates the output of a megohmmeter, the much higher voltages produce a quantum leap in power.

In keeping the testers as safe as possible, 5 mA is about the lower limit that will still produce an effective high-pot. For added safety, the power supply is typically a separate module from the control unit, so that the control can be limited to line power only while the high voltage is kept a safe working distance away. At these voltages, arcing becomes a sinister threat, as personnel may not anticipate danger from an airborne arc. Industry-standard safe working distances must be maintained, and keeping the control module separate makes that possible. Portability is served by having air-insulated power supplies that keep the weight down, while a DC test aids practicality by providing the necessary power in smaller, lighter units than could be accommodated with AC.

High-voltage dielectric withstand testers therefore complete the trio by combining critical aspects of both the insulation tester and the industrial high-pot. Depending on the operator and the application, they can be used as measuring devices for maintenance regimes or as breakdown sources to remove equipment from the field.