Engineer's Notebook

Basic Insulation Testing Methods & Instruments

Basic Insulation

Testing Methods & Instruments

Whether you are in the smallest or the largest plant in the world, electric wire can be found everywhere. Motors, transformers, generators, cables, etc. all have wiring covered with some type of insulating material. Insulation is designed to contain the current used to power the equipment in your facility and maintain its path along the conductor it encloses.

No insulation has infinite resistance (is perfect), so small amounts of electricity do flow along and through insulation to ground, which is the basis for the operation of insulation testing equipment (current clamp-on probes also take advantage of this fact). Typically, this current flow is so small it does not cause problems, but a variety of problems can occur if insulation is allowed to deteriorate.

The most common causes of deterioration in your insulation are caused by environmental and/or physical damage. Moisture (including sustained high humidity) and extremes in temperature; vibration, abrasions, cuts or other mechanical damage; dust, dirt, grease or oil; plus normal electrical stress all contribute. As cracks and holes develop and are filled with contaminates, breakdown accelerates as does the potential for outright failure.

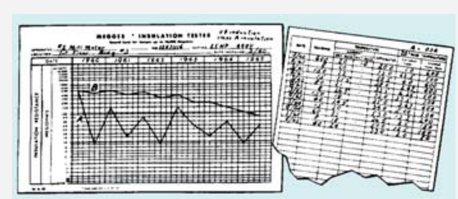
The drop in insulation resistance can be sudden when equipment is flooded or a wire is cut. Usually, however, there is a gradual drop which gives ample warning, if checked routinely.

The best way to evaluate insulation quality is to take measurements at regularly scheduled intervals so that trends can be monitored. Planned reconditioning of motors and equipment can then be accomplished without risk of serious injury or catastrophic failures in your manufacturing process.

The standard tool for insulation testing is the megohmmeter. They are essentially a voltage/current generator with a built-in high range resistance meter allowing megohms to be read directly. The generator produces high DC voltage which causes a small current flow through and over the insulation surface. The resistance values are then read on the display of the meter. What really matters are trends in these readings over a period of time, and the location and importance of the equipment being tested. Run all of your tests under consistent environmental conditions, and keep good records, comparing results carefully.

Lessening resistance values are your warning that problems are developing and that maintenance should be scheduled. There are two basic rules to keep in mind. First, persistent downward trends in insulation resistance should be considered a warning even though readings are higher than the suggested minimum safe values. Second, if your trend readings are consistent, your insulation may be good, even though your readings may be lower than recommended minimums.

For many years, maintenance professionals have used the one-megohm rule to define the allowable lower limit for insulation resistance. The rule states that insulation resistance should be approximately one megohm for each 1000 volts of operating voltage, with a one megohm minimum. (By following this rule, a motor rated at 2400 volts should have a minimum insulation resistance of 2.4 megohms). Each plant, however, should establish their own standards.



Typical record of insulation resistance giving a definite downward trend toward an unsafe condition.

Total current in insulation testing has three components:

1. **Capacitance Charging Current which starts out at a high level and drops after the insulation has been charged to full voltage.**
2. **Absorption Current which is based on the absorption effect of good insulation compared to that of moist or contaminated insulation.**
3. **Leakage (Conduction) Current which is a small steady current through and over insulation.**

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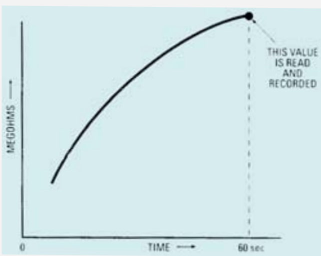
There are three basic insulation test methods that are employed to help diagnose problems. (1) Short-time or spot-reading tests; (2) Time-resistance (absorption) tests; and (3) step or multi-voltage tests.

When conducting a Short-Time/Spot Reading Test, the megohmmeter is connected to the insulation to be tested and is operated for a short time (60 seconds is usually recommended). Keep in mind that as the capacitance "charges" the resistance reading will increase and you are taking one reading at a point on a curve of increasing resistance values. For example, the value at 30 seconds is typically less than the 60 second reading of a test operation. Remember that temperature, humidity and insulation condition will also affect readings when performing spot tests. If the apparatus you are testing has a small capacitance such as short wiring runs, this test is ideal. However, most equipment you will be testing is capacitive so doing spot readings, without prior testing, can only be used as a rough guide to insulation condition.

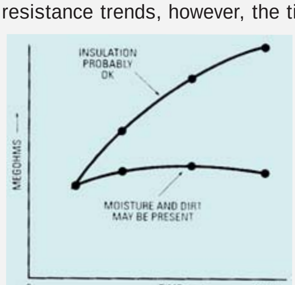
A Time-Resistance Test is typically independent of the effects of temperature and can often give you conclusive information without the availability of past test results. It is based on the absorption effect of good insulation compared to that of moist or contaminated insulation. Successive readings are taken at specific times (a 30 vs. 60 second test will work, although a 1, 2, 5, and 10 minute test gives the best evaluation) and the ratio between readings is noted. It will take longer to charge the capacitance of good insulation, and values will continually increase due to absorption current.



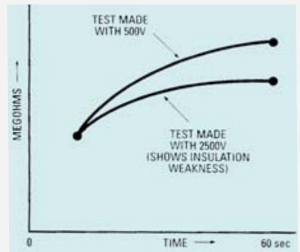
Typical curve of insulation resistance (in megohms) with time for the "short time" or "spot reading" test method.

If the insulation contains moisture or contaminates, the absorption effect is masked by high leakage current and the resulting values, over time, will remain fairly constant. Another benefit of this test is that the values obtained are independent of the size of the equipment. The increase in resistance for clean dry insulation occurs in the same manner whether a motor is large or small (very small equipment without much insulation volume may reach maximum very quickly, flattening the absorption ratio, but not actually meaning there is a problem). If you plan to use time resistance tests in your maintenance program, be sure to select a megohmmeter with a locking (rather than momentary) test button. Line powered models may also be desirable depending on your testing loads.

Step-Voltage Tests require the use of multi-voltage megohm-meters allowing you to apply two or more voltages in steps, like 250, 500 and 1000 volts. It is only necessary to keep the test voltage constant between steps for about 60 seconds. The short period between steps will not affect resistance trends, however, the time period between steps should be the same for a given piece of equipment. You then look for reductions of insulation resistance as each voltage increase is made. If the readings become lower it is a sign of an insulation weakness. Although other test step ratios can be used, applied voltages should preferably be in the ratio of 1 to 5 or greater (500 then 2500, for example). It has been determined that a change of 25% in the insulation resistance value, at a 1:5 voltage ratio, is usually due to the presence of excessive moisture or other contaminates.



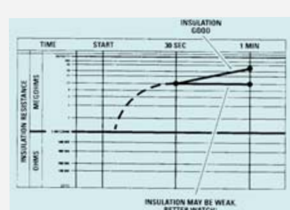
Typical curves showing dielectric absorption effect in a "time-resistance" test.



Typical curves with the "step-voltage" test.

The benefit of this test is that effects of aging or mechanical damage in clean, dry insulation may not be revealed at lower stress. Applying voltage in increased steps produces electrical stresses that simulate or exceed those found in actual service. Local weak spots then begin to influence overall resistance, and resistance values begin to drop as electrical stress increases. Even though your megohmmeter's highest voltage does not stress the insulation beyond its rating, multi-voltage tests will often reveal problems.

The most standardized and widely-used form of Time-Resistance Test is known as the Polarization Index. This also frequently appears in the literature as a "PI Test". By definition, it is a 1-minute reading divided into a 10-minute reading. It can be performed at any voltage, but higher voltages tend to give better results because they typically have greater measuring ranges. This enables the instrument to continue taking readings for the full 10 minutes, as opposed to "over-ranging" before the conclusion of the test. PI tests are useful and popular because they reduce the procedure to a simple division of two values, while yielding highly informative results. Typically, a "flat" PI of less than 2 indicates a need for immediate maintenance or repair. A result of 2 - 4 indicates that the equipment is "good", but should be scheduled for maintenance at some convenient time. A value above 4 indicates no need for attention in the foreseeable future. Thus, the PI test provides a means of making a reliable on-the-spot determination without resorting to test records or interpreting megohm values. It is particularly good for large capital equipment that might otherwise require extensive charging times, extremely high test voltages, and the interpretation of enormous megohm readings. While the performance of a PI does not require a specialized model, modern testers may offer an automatic PI capability.



Typical card plot of a time-resistance or double-reading test.

Source information for this article was assembled from the Megger reference source "A Stitch in Time…"
The Complete Guide to Electrical Insulation Testing.