The Basics of Insulation Testing

What Is Insulation Testing?

In a perfect world, all the electrical current sent along a conductive wire would reach its intended destination. For various reasons, some of it is lost along the way. Wires are insulated with a resistant sheathing to contain the conductivity of the typically copper or aluminum core. But even with this insulation in place, some of the current still manages to escape.

Much like a leak in a water pipe, an imperfection in the insulation of a wire allows a steady flow of electricity to escape. This can be a detriment to electrical circuits and machinery. The purpose of testing is to determine whether the insulation is performing at an effective and safe level. Routine testing can identify problems before they result in injury or equipment failure.

As you’ll learn from this guide, insulation is subject to many elements that can cause it to perform at a less than acceptable level. Excessive heat or cold, moisture, vibration, dirt, oil, and corrosive vapors can all contribute to deterioration. For this reason, routine insulation testing is necessary.

The simple equation of Ohm’s law enables us to attach a numerical value to our resistance measurements. It states that resistance (ohms) equals voltage (volts) divided by current (amperes). Using Ohm’s law, insulation resistance is determined by pressurizing the conductor with a given voltage and dividing it by the current that escapes through the insulation and returns to the meter. This total current that flows through and along the insulation during a test is the result of three different components: capacitive current, absorption current and leakage current.

Capacitive Current

The initial surge of current that occurs when voltage is first applied to a conductor is called capacitive current. Like the first rush of water flowing through a hose, it typically starts out high and then drops quickly once the conductor is fully charged.

Absorption Current

Absorption current also starts out high and then drops, but at a much slower rate than capacitive current. As the voltage builds up, the absorption level in the insulation changes from high to low. This gradual change reflects the storage of potential energy in and along the insulation. Absorption current is an important part of the time resistance method of insulation testing.

Total Current in Insulation Testing

Testing the integrity of insulation requires measuring its resistance to current flow across it. A high level of resistance means that very little current is escaping through the insulation. Conversely, a low level of resistance indicates a significant amount of current may be leaking through and along the insulation.

The flow of electrical current through a conductive wire is similar to the flow of water through a pipe.
Proof Test (High Potential Test)

In order to protect against miswired and defective equipment, proof testing is an important step in the installation of new machinery. A proof test is often referred to as a go/no go test because it simply tests the system for errors or incorrect installation. The test is accomplished by applying dc voltage through the de-energized circuit using an insulation tester. A successful test is one in which no failure occurs during the duration of the measurement. Proof testing voltages are much higher than those used in routine maintenance test methods. The general guideline for deciding on a test voltage is based on the equipment’s nameplate rating. Follow the equation below to arrive at an acceptable test voltage.

\[
\text{Step 1.} \\
(2 \times \text{nameplate rating}) + 1,000V = \text{Factory AC Test}
\]

\[
\text{Step 2} \\
0.8 \times \text{Factory AC Test} \times 1.6 = \text{DC Proof Test Voltage}
\]

Types of Insulation Resistance Tests

Now that we have discussed the definition of insulation resistance and why it is important to measure, let’s turn our attention to when and how to test. The different types of insulation testing methods can be divided into two categories: installation (acceptance) tests and maintenance tests.

Installation Tests

When installing new electrical machinery or equipment, testing insulation resistance is important for two reasons. It ensures that the insulation is in adequate condition to begin operation and it provides a baseline reading to use as a reference for future testing.

Maintenance Tests

Due to fluctuating factors like moisture and temperature, insulation testing is mostly based on relative measurements. In other words, today’s reading of 1.5 megohms is more or less insignificant unless it can be compared to a previous set of measurements. Measurements taken during routine maintenance tests can give valuable information about the quality of insulation as conditions vary. In this article, we will discuss three such tests: the short time/spot reading test, the time resistance method and the step voltage (tip-up) test.

Short Time/Spot Reading Test

In a short time or spot reading test, the tester is connected across the insulation of the motor windings. A test voltage is then applied for a fixed period of time (usually 60 seconds). The most important aspect of this test is that it remains consistent in duration from test to test. Once the time period has elapsed, an insulation resistance measurement can be recorded.

As discussed earlier, a single maintenance test can act only as a rough guide for insulation quality. A more effective use of the short time testing method is to establish a series of test results over several months so that long-term trends may be examined. It is important to understand that a variety of factors such as temperature and moisture can cause fluctuations in test readings. Typically, insulation will deteriorate at a very gradual but consistent pace. A significant downward trend over the course of several measurements is usually a sign of insulation breakdown.
Testing insulation is an integral part of routine maintenance on motors.

When testing a high voltage distribution panel, it is important to use an insulation tester with high test voltages.

Time Resistance Method

Unlike the short time or spot reading test, the time resistance method can provide fairly conclusive results without the luxury of past test measurements. It is accomplished by taking successive readings at fixed time intervals and plotting them. This is an especially effective method when moisture and other contaminants might be present.

As mentioned earlier, absorption current starts out high and gradually decreases over time as voltage is applied. In a machine with healthy insulation, this trend will continue for several minutes and show an increasing level of resistance. On the other hand, if the insulation is poor, the level of resistance will flatten out after the initial capacitive charging current.

Dielectric Absorption Ratio

The best way to quantify the results of a time resistance test is through a dielectric absorption ratio. It is simply a ratio of two time resistance readings. A commonly used set of intervals is a 60-second reading divided by a 30-second reading. Another frequently used set is 10 minutes divided by 1 minute. This resulting value is referred to as the polarization index. The following chart provides general guidelines for how to interpret dielectric absorption ratios.
Condition Of Insulation Indicated By Dielectric Absorption Ratios

<table>
<thead>
<tr>
<th>Insulation Condition</th>
<th>60/30-Second Ratio</th>
<th>10/1-Minute Ratio (Polarization Index)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dangerous</td>
<td>–</td>
<td>Less than 1</td>
</tr>
<tr>
<td>Questionable</td>
<td>1.0 to 1.25</td>
<td>1.0 to 2</td>
</tr>
<tr>
<td>Good</td>
<td>1.4 to 1.6</td>
<td>2 to 4</td>
</tr>
<tr>
<td>Excellent</td>
<td>Above 1.6</td>
<td>Above 4</td>
</tr>
</tbody>
</table>

It is important to remember that these values are relative and can vary based on environmental conditions. Basic maintenance measures such as cleaning the motor windings will help produce more accurate results.

Step Voltage (Tip-up)Test

A step voltage test involves testing the insulation at two or more voltages and comparing the results. Good insulation will show a relatively consistent resistance reading regardless of the voltage applied. On the other hand, when the resistance level drops as the voltage level increases, it is usually an indication that the insulation is aging, contaminated or brittle. This occurs because small imperfections such as pinholes and cracks reveal themselves under increased electrical stress. When performing a step voltage test, it is important to start with the lowest test voltage and then proceed to the next voltage level. Test duration is typically 60 seconds. The graph below provides an example.

Results from this step voltage test indicate a weakness in insulation.

Testing Preparation

Preparing the equipment and your insulation tester correctly is crucial to your safety and the well-being of wiring and machinery. Outlined below is a process that you should make routine before every test.

1. Take equipment out of service

Shut down the apparatus, open switches, and de-energize. Disconnect the equipment under test from all other equipment and circuits including neutral and protective ground connections. Make sure proper lockout/ tagout procedures are followed during this step.

2. Check what will be included in the test

The more equipment included in a test, the lower the resistance reading will be. For this reason, it is very important to inspect the installation and understand exactly what is included. You do not want a reading to be affected by additional equipment not included in previous tests. However, if a complete installation with several pieces of equipment yields a high reading, it is safe to assume that each individual apparatus will yield an even higher reading. Consequently, sometimes separating components is unnecessary.

3. Discharge capacitance

Both before and after an insulation resistance test, it is important to discharge capacitance. Discharge time should be approximately four times as long as the test voltage was applied during the test.

Interpreting Results

What to do with the results of an insulation test can often be more complicated than the test itself. Every piece of equipment has a general insulation “personality.” In other words, if a machine is behaving in accordance with its normal tendencies, there is usually no cause for concern. However, a minimum value below which equipment should not be energized is
### Potential Conditions Discovered During Testing

<table>
<thead>
<tr>
<th>Condition</th>
<th>What To Do</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fair to high values, and well maintained</td>
<td>No cause for concern</td>
</tr>
<tr>
<td>Fair to high values, but showing a constant tendency toward lower levels</td>
<td>Locate and remedy the cause and check the downward trend</td>
</tr>
<tr>
<td>Low, but well maintained</td>
<td>Condition is probably all right, cause of low values should be checked</td>
</tr>
<tr>
<td>Very low values</td>
<td>Clean, dry out, or otherwise raise the values before placing equipment in service (test wet equipment while drying out)</td>
</tr>
<tr>
<td>Fair to high values, previously well maintained, but showing sudden drop</td>
<td>Make tests at frequent intervals until: 1. Cause of low values located and remedied 2. Values become steady at a lower level safe for operation 3. Values become so low that it is unsafe to keep the equipment in operation.</td>
</tr>
</tbody>
</table>

1 megohm per 1000 volts. Use the chart on the next page as a rough guideline for what to do with your readings.

It is extremely important to consult the operating handbook and the manufacturer for specific information and guidance as to whether a particular value as measured between two points should be considered acceptable or questionable. Test equipment is capable of providing accurate readings, but one must determine if a particular measured value indicates that a piece of equipment meets the manufacturer’s specification for insulation integrity.

### Connection Diagrams

The following four diagrams provide general guidelines to connect an insulation tester to most of the electrical equipment encountered. Remember that every piece of equipment is different. It is always wise to closely examine a specific apparatus to determine exactly what is included between the connected terminals.

**AC Motors and Starting Equipment**

When testing ac motors and starters, connect the insulation tester in parallel to the circuit. If a weakness exists, disconnect and test each component of the system separately.
DC Generators & Motors

With the brushes raised as indicated, the brush rigging and field coils can be tested separately from the armature. With the brushes lowered, the insulation resistance of the entire system will be tested.

Control, Signaling and Communication Cables

By connecting a communication cable, a single wire can be tested against all other wires and the cable jacket at the same time.

Wiring Installation

By testing at the main panel, the entire system can be tested to ground at one time, providing all switches in the distribution panel are closed. If weakness is detected, test each circuit separately.

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