

Arc Detection: Increased Quality Control, Safety-Hazard Detection, or Just a Nuisance?

Abstract: During a dielectric withstand test, there are two failure modes that can occur in the material being tested: (a) low insulation resistance which results in excess current flow, and (b) dielectric breakdown. This document will explain the difference between these two failure modes, and provide rationale for the need to detect both types of failures.

In general, the purpose of a dielectric withstand test is to place a high electrical stress on insulation materials for a short period of time. In this way, the integrity of the insulation materials can be quickly verified. The passing of a dielectric test indicates that the insulation will likely provide adequate protection for the life of the material at the relatively low electrical stress levels seen during normal use.

There are three types of insulation: air (or other gas or vacuum), over-surface (such as between traces on a circuit board), and distance-through-insulation. No insulation material is ideal - the material will always have physical limitations that limit its ability to provide electrical insulation.

One way to identify inadequate insulation is to monitor the current that flows through the insulation material during the dielectric test. This current is commonly referred to as "leakage current". This current has the same frequency and waveshape as the dielectric test voltage. If a DC dielectric test is conducted, the leakage current will also be DC. In general, the leakage current will obey Ohms law - the higher the test voltage, the more leakage current will flow.

Another term that is related to "leakage current" is "insulation resistance". Insulation resistance is a term that is generally associated only with DC dielectric testing, because AC dielectric testing causes additional current to flow through the insulation. This additional current that flows during AC testing is due to the capacitive effect of having an AC voltage between two points that are separated by an insulation material. This topic is discussed in detail in a separate paper.

During a DC dielectric test, the current flow can be determined by Ohms law: $V = I * R$, where V is the test voltage, I is the current that flows during the test, and R is the insulation resistance. For example, if the test voltage is 1000V, and the insulation resistance is 2 MegOhms (2,000,000 Ohms), the current will be 0.5 milliamps.

A separate way to verify the suitability of insulation material is to monitor for dielectric breakdown. Dielectric breakdown is different from excess leakage current (low insulation resistance) in many ways. A breakdown event is an abrupt discharge, or arc, that occurs as a result of a failure of the insulation. Generally, there will be little or no current flow at voltages below the breakdown voltage. As the voltage is increased, the current will increase suddenly as the arc jumps across (or punches through) the insulation. The breakdown event is nearly instantaneous, and is independent of the waveshape of the test voltage (AC vs. DC).

The current that flows during a dielectric breakdown is still governed by Ohms law. An electric arc is generally a low resistance, so that the current flowing during the breakdown is relatively high. In some

cases, there is additional resistance in series with the breakdown arc. This can occur when there is more than one layer of insulation, and only one of the layers fails. If this happens, the current that flows in the breakdown arc will be limited by the resistance of the remaining insulation. Note that the two (or more) layers of insulation do not have to be the same type of material; one layer could be an air gap, and another layer could be tape (distance-through-insulation).

Many dielectric withstand testers do not have separate breakdown-arc detection circuitry. Only the leakage current is monitored, and an acceptable Pass/Fail threshold for insulation resistance/excess leakage is established. An assumption is made that if a breakdown occurs, it will not have significant current-limiting (due to insulation resistance in series with the arc), and therefore the arc will be detected as “excess leakage”. A dielectric tester with separate arc detection will be able to “sense” the arc, even if the current level is below the “excess current” limit.

An impedance-limited arc is not necessarily a safety issue. However, it does usually indicate a quality-control issue, and can also help identify potential safety hazards that may manifest themselves only after months or years of normal use. Consider the following example:

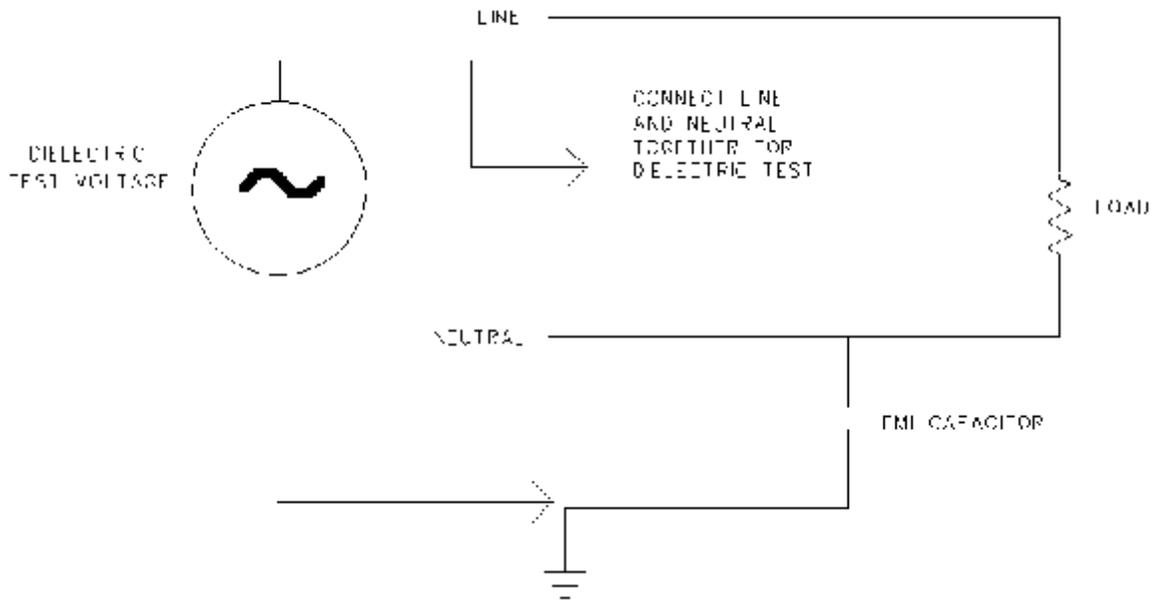


Fig. 1

During a normal (Passing) dielectric test, current will flow through the capacitor according to Ohms law. If a DC test voltage is used, only a very small amount of current will flow through the capacitor due to the very high insulation resistance of the dielectric insulation material inside the capacitor.

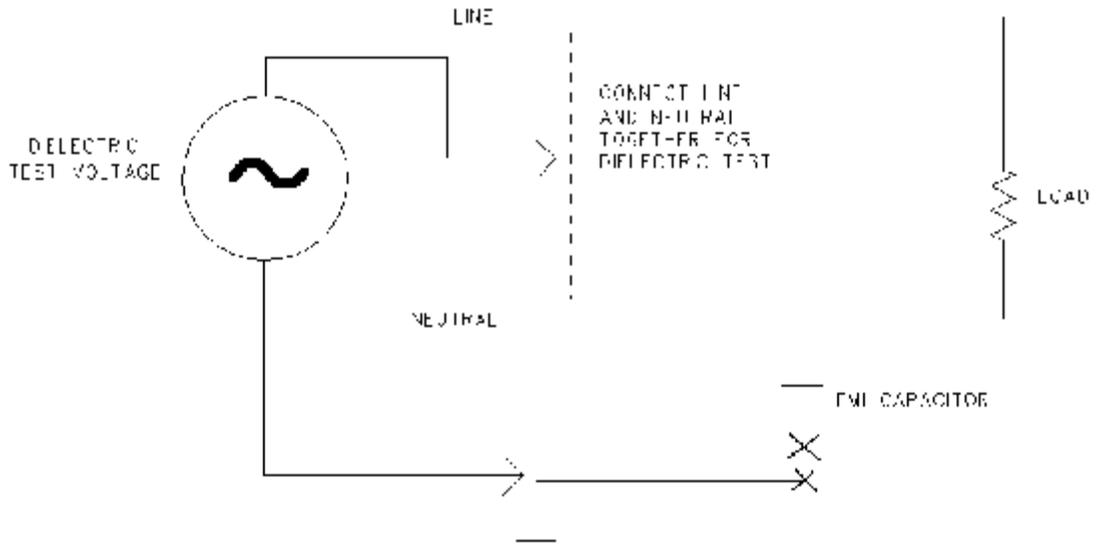
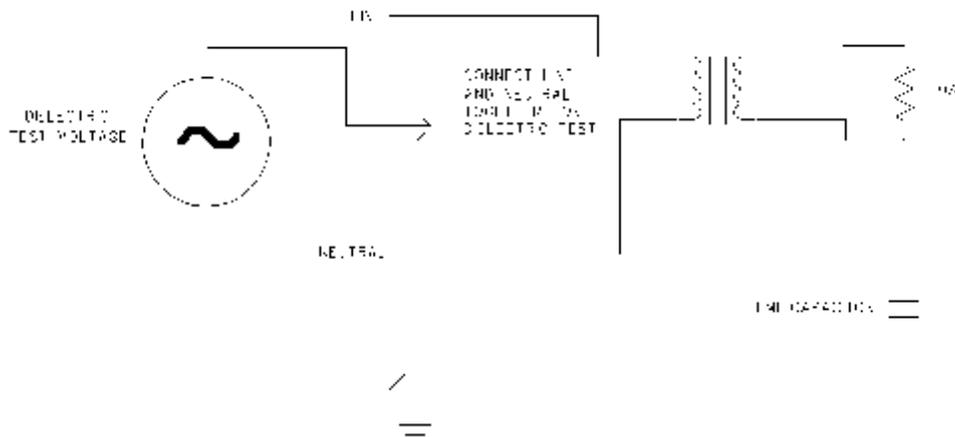


Fig. 2

In this case, the connection of the EMI capacitor to ground has been broken (due to a cold solder joint, poor contact of a circuit board mounting hole to the chassis, paint on the chassis, etc.). During the dielectric test, an arc will occur across the broken connection, but the total current that flows will be limited by the impedance of the capacitor. This example is not a safety issue, because the EMI capacitor is *supposed* to be connected to ground. This is definitely a Quality Control issue, as the assembly process is not being adequately controlled. In addition, this product will suffer from EMI/EMC problems because the EMI capacitor is not connected as intended.



There are other examples where a “breakdown through resistance” can be a potential safety issue:

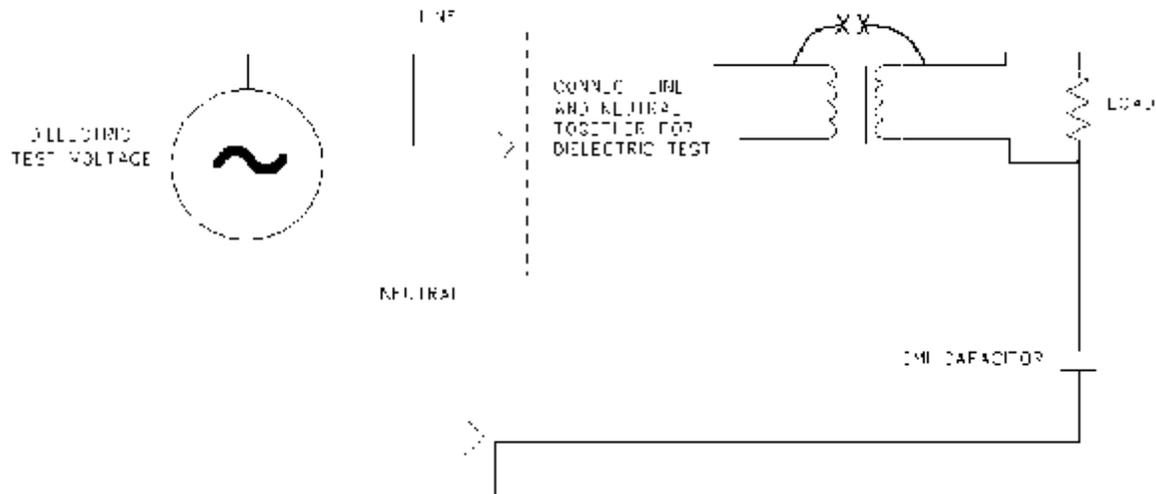


Fig. 3

In Fig. 3, the intent of the dielectric test is to create electrical stress on the transformer insulation, to ensure that the construction and insulation inside the transformer are adequate.

Fig. 4

In Fig. 4, the insulation inside the transformer is damaged. During the dielectric test, arcing will occur across/through the transformer. However, the arcing current will be limited by the impedance of the EMI capacitor. A dielectric tester without separate arc detection will generally not see this as a failure, even though the insulation in the transformer is inadequate (results will vary depending on the impedance of the EMI capacitor).

An easy way to determine if a dielectric tester has separate arc detection circuitry (or to quantify the sensitivity of the arc detection circuitry) is as follows:

1. Select a “safety agency approved” Y capacitor. Typical values are 3300 pF or 4700 pF.
2. Connect the test leads of the dielectric tester across the capacitor.
3. Select an appropriate test voltage and perform a dielectric test. A good value to start with is 1000 V.

4. The dielectric tester should not indicate a failure. At the end of the test, disconnect one of the capacitor leads.
5. Using great care (high voltages are involved!) start another dielectric test, while bringing the unconnected test lead close to the unconnected capacitor lead. A small spark will be created when the two points are brought together. If the dielectric tester does not have separate arc detection, this spark will not be identified as a failure. A dielectric tester with separate arc detection will “see” the arc and indicate a dielectric breakdown failure.
6. Experiment with different test voltages and different capacitor values to determine the arc-sensitivity level of the dielectric tester. As a separate experiment, use a suitable resistor (about 500K Ohms, physically large enough that arcing does not occur across the body of the resistor, or use multiple resistors in series) and repeat the tests.

Conclusion:

Arc detection is an important part of dielectric testing. There are some situations where an impedance-limited arc will not be detected by dielectric testers that only have “excess leakage” type failure detection. Whether this type of arc is a safety hazard or not is case-dependant, but it is almost always (at minimum) a Quality-Control issue. A prudent manufacturer will take steps to determine the arc-sensitivity level of their dielectric test equipment in order to maximize the benefit of performing dielectric tests.