Slaughter
Instruments for Electrical Test & Measurement

DIELECTRIC WITHSTAND TESTING OF MODULAR AND MANUFACTURED HOMES

The controversy of AC vs. DC Dielectric Withstand testing of modular and manufactured homes has been an issue for years in part due to a misunderstanding of the test itself. Some of the common questions that manufacturers ask are:

- Do I test with AC or DC voltage?
- What is the proper test voltage and what part of the circuit do I need to test?
- How do I interpret my test results?
- How is it possible to be able to test the entire manufactured home with all the appliances still connected without damaging the appliances?

This article addresses these questions and other aspects of AC vs. DC testing.

The U.S. Department of Housing and Urban Development, Manufactured Housing and Standards Division issued a memorandum in June of 2000 to All Primary Inspection Agencies and All State Administrative Agencies regarding dielectric strength testing of modular and manufactured homes as specified in standard # 24 CRF 3280.810(a).
The memorandum states the requirements of the Dielectric Withstand test, which is as follows; "*The wiring of each manufactured home is to be subjected to a dielectric strength test between live parts and the manufactured home ground and between neutral and the manufactured home ground. The test is either to be performed between 900 to 1079 volts for one minute or between 1080 to 1250 volts for one second. The test is conducted on each manufactured home to stress the insulation to determine if it is capable of resisting transient power line surges to which the wiring may become subjected, identify any low resistance areas of the insulating material and any dielectric breakdown paths of failures that may exist.*" Please note that the test is **not** to be conducted from phase to phase, or between the hot and neutral conductors as this could result in damaging appliances that may be connected. The standard does not specify whether AC or DC should be used to perform the test but the voltage ranges indicated in the standards have historically been accepted as AC values.

AC voltages are normally specified as root-mean-square (RMS) values. The RMS voltage is the effective value of a varying or alternating voltage; this value will produce the same power loss as a continuous voltage when applied to a pure resistive load. The peak value of a sine wave is actually 1.414 times greater than the RMS voltage (figure 1). To perform an equivalent DC test, the test potential would be 1.414 times the RMS value to achieve the equivalent peak voltage. Using the RMS values specified in 24 CRF 3280.810(a) the DC equivalents would be 1273 to 1526 volts for a one minute test or 1527 to 1768 volts for a one second test.

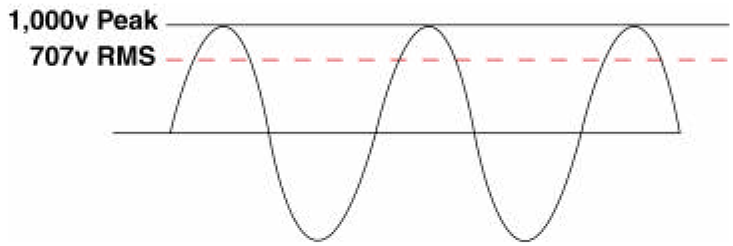

Figure 1 RMS Voltages vs. Peak Voltages

During a hipot test, voltage is applied across the insulating material between current carrying conductors and ground. This in fact is very similar to the characteristics of a capacitor, which is simply two conductors separated by an insulating or dielectric material. The circuitry that needs to be tested within a manufactured home can be very capacitive in nature because of the size and surface area of the circuits. For this reason the majority of the leakage current seen during an AC hipot test can be a direct result of the capacitive reactance of the circuit and not the insulation resistance. This capacitive reactance is low and can range from less than 50k up to 200k ohms in comparison to the insulation resistance of the home, which is typically greater than 1 megohm. A capacitor will allow AC current to flow through it while it blocks the flow of DC current once it charges up to the applied potential. Current flows through a capacitor when there is a change in the applied potential or charge. When performing an AC test the charge is changing at a rate of 60 cycles per second. This is the reason that AC cannot charge the capacitive component of the device under test (DUT). This results in much higher leakage currents when performing an AC hipot test than is observed when performing a DC hipot test.

AC hipot testing is often performed in multiple steps. This typically includes separating circuits and disconnecting appliances because some hipot testers do not have the output capacity to test the entire home. This lack of capacity is usually exhibited by the inability of the tester to reach the specified test voltage without going into failure mode. The operator must then determine if the failure condition is the result of excessive leakage current trip setting or if a breakdown of the insulation caused the failure. Many older testers lack current meters in their design. This makes it difficult for the operator to determine the nature of the failure condition. Circuit breakers must be shut off to isolate circuits and then each circuit must be retested separately.

When performing a DC hipot test, once the applied voltage charges up the capacitance of the DUT, the true leakage current observed during a DC test is usually very small. The main advantage of DC testing over AC is that manufacturers can use smaller, lighter, more portable instruments and are able to test the complete home with the appliances, GFCI's, smoke detectors and fluorescent fixtures connected. This allows the manufacturer to test the entire modular home with a single connection as a single test. For these reasons DC Hipot testing of manufactured and modular homes is quickly becoming the preferred method of testing. The only drawback is that you typically must ramp up the voltage to keep from having a false failure shutting down the hipot. This is due to the high initial total current, which includes charging current that flows until the circuit capacitance is fully charged, dielectric absorption current and the steady state leakage current. (Figure 2.)

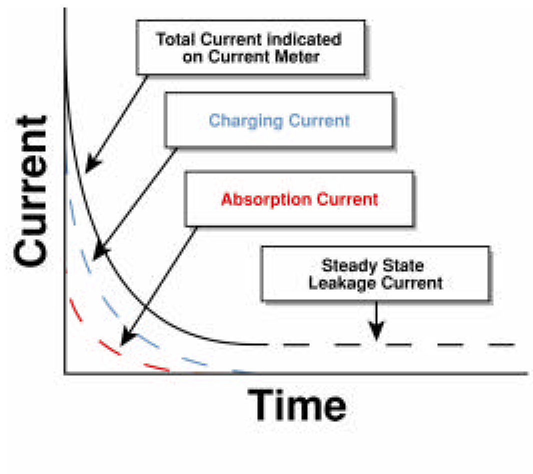

Figure 2 Direct Current vs. Time

The dielectric absorption current is the current that flows into a capacitor following its initial charge due to a gradual penetration of electrical stress into the dielectric. It is also the current that flows out of a capacitor following its initial discharge. This current represents a reversible stored energy that can be released after the applied voltage is removed. Setting the ramp time for a two to three second ramp should solve the problem of false failures by allowing enough time for the DUT to charge slowly and therefore keep the total current below the trip threshold. The trip level of the DC tester can be set to a lower level as compared to the trip level when performing an AC test. The leakage current observed when doing DC testing is a true indication of how good the insulation is because reactive current does not mask true steady state leakage current. The trip level of the hipot is typically adjusted around 1 milliamp when performing the test with DC, as compared to trip levels greater than 20 milliamps when performing the test using an AC tester.

This brings up the issue of safety. Underwriters Laboratories (UL) and the American National Standards Institute (ANSI) ran tests in the 1960's to determine the human body's responses to different levels of electrical current. The tests were conducted using a 120 volt 60 hertz source. They determined that on average, 0.5mA of current is the perception level and can produce a startle reaction. Higher current levels in the range of 5 to 10 mA will cause paralysis of the extremities, effectively producing the inability to let go. Currents in the range of 20 to 40 mA between the extremities cause the muscles to contract painfully, making breathing difficult, and leading to asphyxiation. Current levels in the 40 to 70 mA range lasting for one second or longer cause ventricular fibrillation. Currents greater than 70 mA cause severe electrical burns and can cause cardiac arrest.

Based on the information above, performing a hipot test using a DC tester that has a trip level set for 1 mA would limit the shock hazard the operator could be exposed to as opposed to conducting a test with AC where the trip level could be set in excess of 20 mA. It is important to note that the DC hipot will shut down at a much lower current level limiting the exposure from the hipot. However, this doesn't mean that the operator will only receive a 1 mA shock. The device under test, after being fully charged, can act like a capacitor and discharge its stored energy into a load such as a person who accidentally may come into contact with the circuit. This stored energy or charge on the DUT can be much greater than the energy available from the hipot. Stored energy is calculated by using the formula $V^2C/2$. For example, the capacitance value for a filter capacitor in a DC hipot tester might be 0.01 microfarads. This means that at 1530 volts the capacitor would deliver a charge of 11.7 milijoules of energy. A DUT could have a distributed capacitance of 0.05 microfarads, which at 1530 volts will deliver 56.2 millijoules of energy, five times the energy available from the hipot.

Another area of concern for manufacturers is potential damage to appliances within the manufactured home during a hipot test. Keep in mind that appliances within the manufactured home have already been hipot tested to comply with their product safety listing. If performed correctly, the test stresses the insulation between what are normally current carrying conductors and the dead metal or ground on the appliance. This is ensured by placing the power switch on the appliance in the on position, connecting the return of the hipot to the dead metal on the appliance and applying high voltage to the hot and neutral conductors. Performed in this way the test applies an equal potential to both sides of the components within the circuit. This same method should be followed when testing the complete manufactured home. High voltage should be applied to both phases and to the neutral (the neutral must be isolated from ground) and the return should be connected to ground. All switches and circuit breakers should be in the on position. (Figure 3.) Connecting the hipot to the manufactured home in this manor will allow testing of the complete home with the appliances connected.

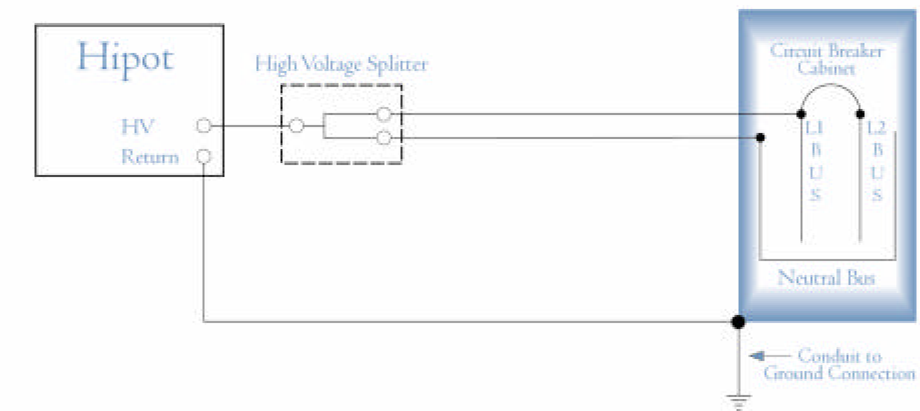

Figure 3 Hipot Tests of Manufactured and Modular Homes

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Summary

There has been a trend towards DC Dielectric Withstand testing of modular and manufactured homes. There are advantages and disadvantages to both AC and DC testing which are listed in the chart below. DC testing seems to offer more significant advantages. Instruments are more portable and allow the complete home to be tested in one step. The hipot testers themselves are safer since the current trip setting can be set to a much lower level, thus reducing the shock hazard. More importantly the test results obtained from DC leakage current readings give a true indication of the quality of the insulation system since the leakage current observed is due to the insulation resistance and not the distributed capacitance of the manufactured home as in AC testing. While AC testing has been the norm, advanced technologies such as microprocessor control and electronic ramp and dwell timers have made DC testing a more viable and effective means of testing entire modular and manufactured homes.

DC TESTING	
Advantages	Disadvantages
- Smaller lightweight instrument	- Must ramp up voltage
- Test entire home	- Risk with not discharging DUT
- Safer due to less current	- Must convert RMS to DC equivalent
- Reads true leakage current	
AC TESTING	
Advantages	Disadvantages
- Test at specified RMS voltage	- Larger tester required
- No ramp required	- Usually cannot test entire home
- No need to discharge DUT	- Safety risk due to higher current