Dielectric testing: AC vs. DC part 2

PROLOGUE

Some questions and concerns have been raised recently regarding the difference between AC and DC dielectric testing. The purpose of this paper is to explain the fundamentals of each test and the theory behind dielectric testing, and to compare behavior of dielectric breakdowns in AC and DC tests.

DIELECTRIC TESTING REASONS

Dielectric testing is intended to check the integrity of the insulation for two basic reasons:

1. The insulation is tested at a voltage much higher than the voltage that the insulation is normally subjected to, in order to make sure that the insulation is not marginal. This also offers an insurance that the insulation is less likely to fail during normal operating conditions due to aging, deposits of dust, condensation, etc.

2. The insulation is tested at a voltage that represents the type of transient voltage spikes that occur on voltage systems. Transient voltage spikes on power lines are generally the result of nearby lightning strikes, but can also occur for other reasons. In general, these transient spikes are a very short duration - the spike lasts for less than 20 microseconds.

AC vs. DC VOLTAGE

Dielectric testing is conducted at a standard reference voltage. For example, the value of 1000 Vac is used. Note that the value of “1000 Vac” implies that this is an RMS voltage. RMS stands for “Root Mean Square”, which is a way of averaging. The RMS value of a voltage represents the average value of the voltage over time, and this value is important because standard AC meters display RMS voltages.

The standard value of 120VAC used in the power grids in the United States is an RMS voltage, and the appropriate way to describe this voltage is 120Vac, or 120V RMS. Peak voltages of the 120 Vac power appearing on the wall plugs in United States homes have a peak value of approximately 170 volts, as seen in Figure 1.

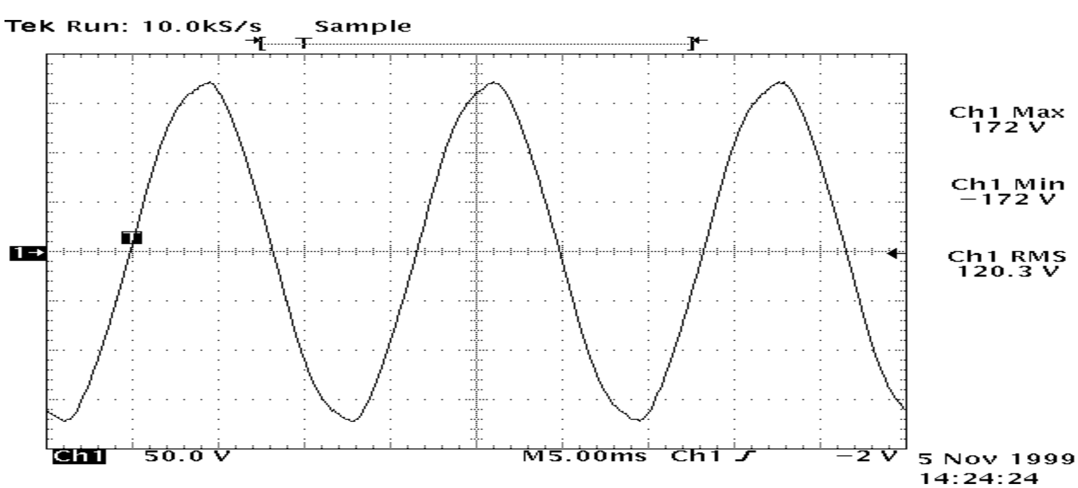

Figure 1: **120Vac waveform - Wall receptacle power in the U.S.**

AC vs. DC DIELECTRIC TEST WAVEFORMS

Figure 2 shows an AC waveform with an RMS voltage of approximately 1000 V. Note that the positive and negative peaks of the voltage are over +1400 Vpeak and -1400Vpeak.

The positive and negative peaks of a purely sinusoidal waveform are 1.414 times the RMS value of the waveform, as proven in calculus and engineering texts.

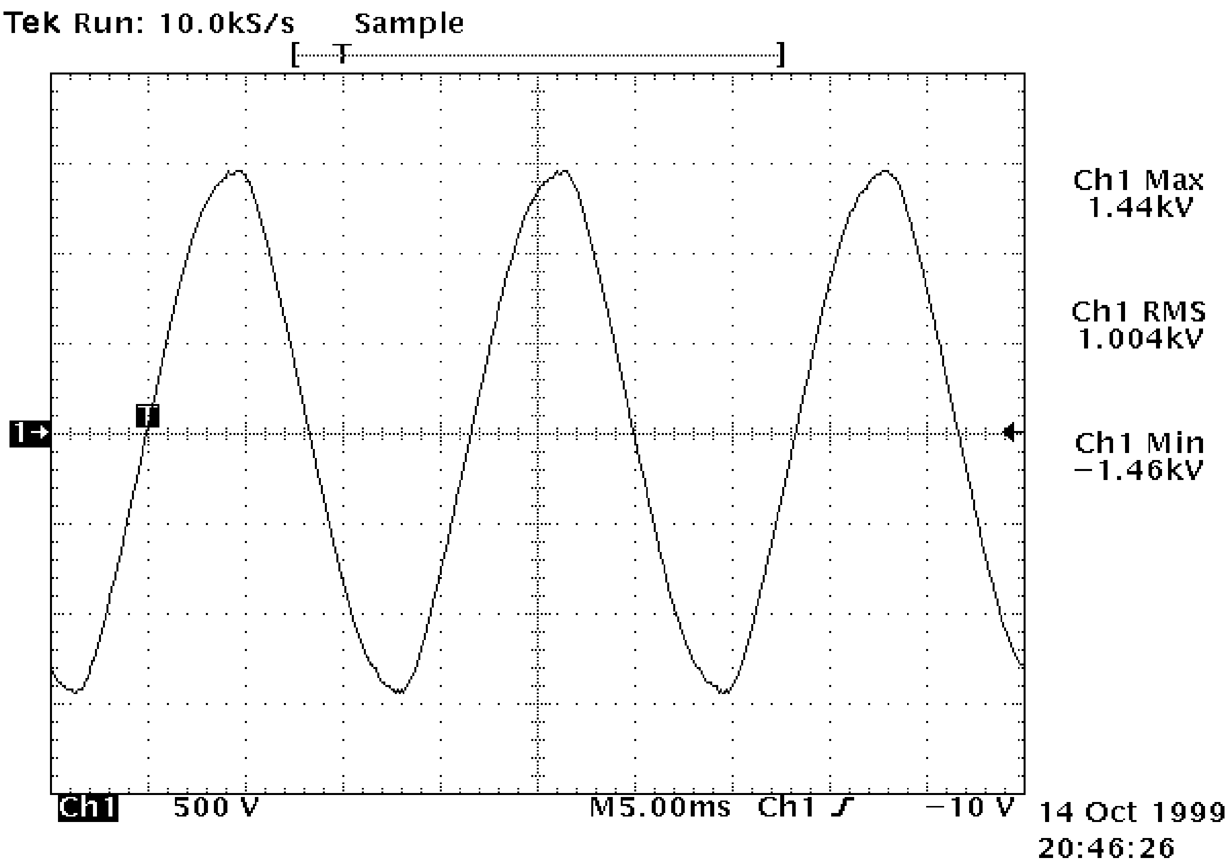

Figure 2 - 1000Vac Waveform

During dielectric strength testing, the maximum stress on the insulation being tested occurs at the peak of the AC test voltage. Therefore, if a DC test is conducted, it is appropriate to conduct the test at a level of 1.414 times the AC test voltage value, *so the value of the DC voltage is equal to the AC voltage peaks*. For a test voltage of 1000 Vac, this would require a DC test voltage of 1414 Vdc to represent the same peak voltage, and the same level of stress on the insulation. The DC test voltage of approximately 1414 Vdc that represents the equivalent test voltage to 1000 Vrms AC is shown in Figure 3. Note that the peak of the test voltage in both Figure 2 and Figure 3 is the same.

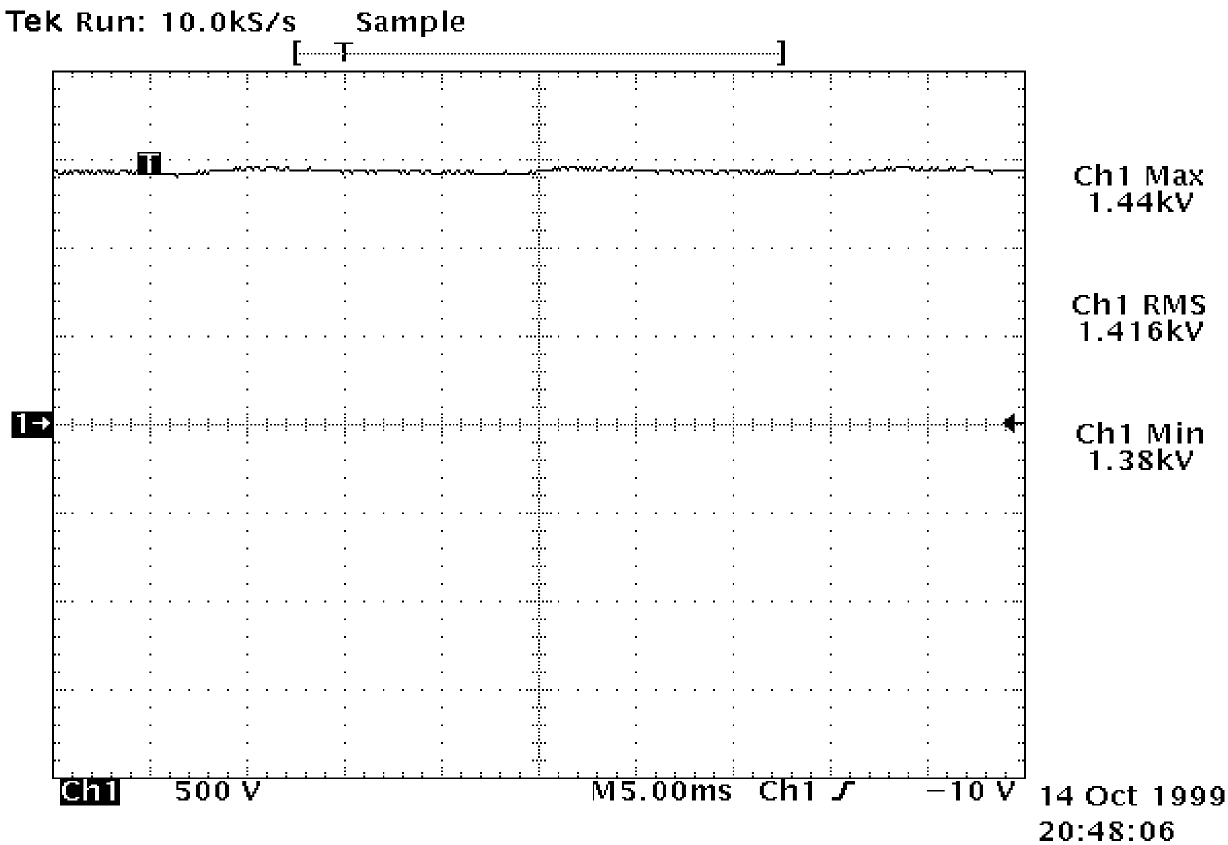

Figure 3 - 1414 Vdc waveform

AC vs. DC DIELECTRIC BREAKDOWN EVALUATION

Because the electrical stress on the insulation is highest at the peak of the AC waveform, dielectric breakdown will occur at the peak of an AC test voltage. Refer to Figure 4, an actual

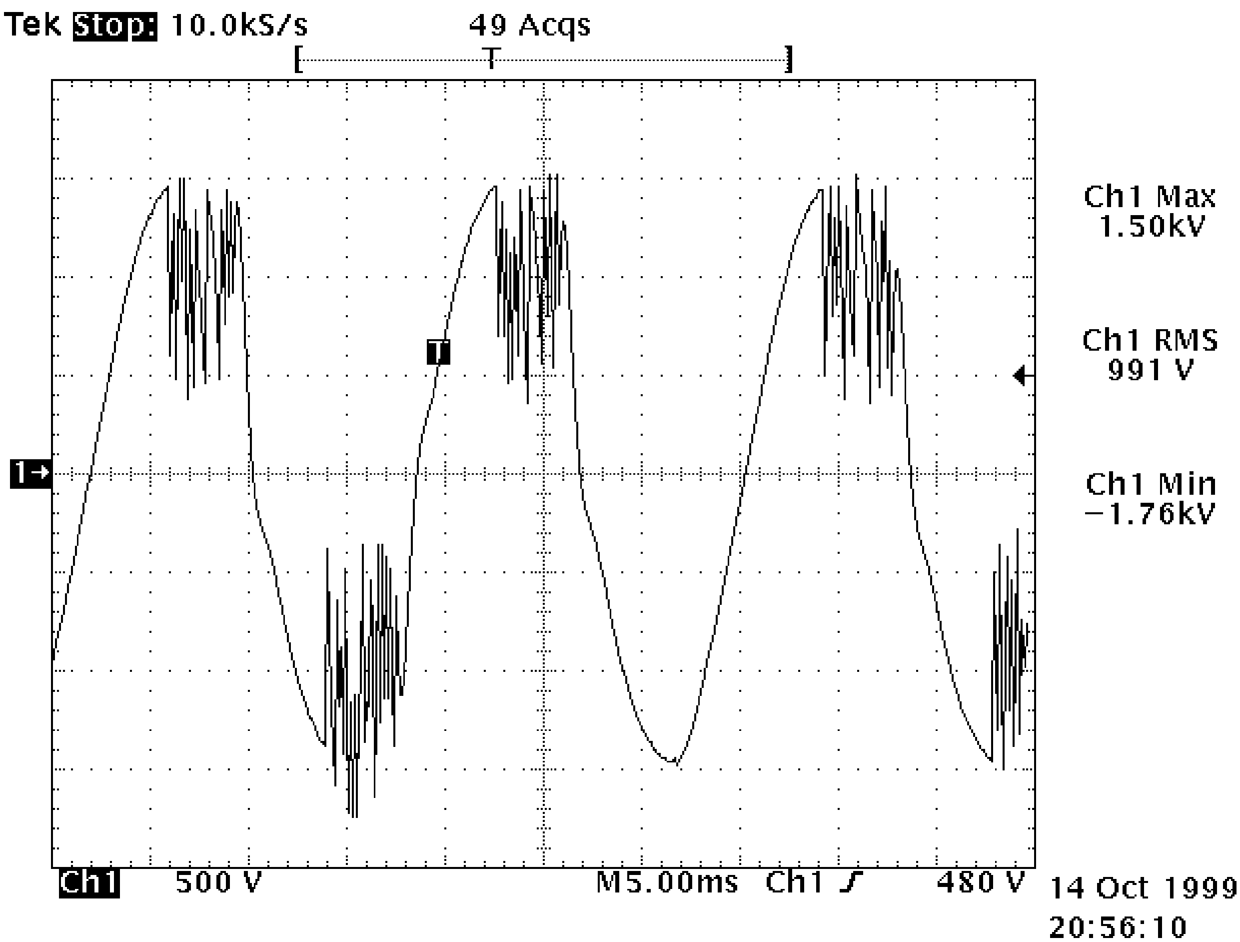

Figure 4: AC Voltage Dielectric Breakdown

oscilloscope-created picture of an AC voltage dielectric breakdown. Note that the voltage is smooth as the voltage increases to the peaks, then abruptly breaks down at the peak voltage.

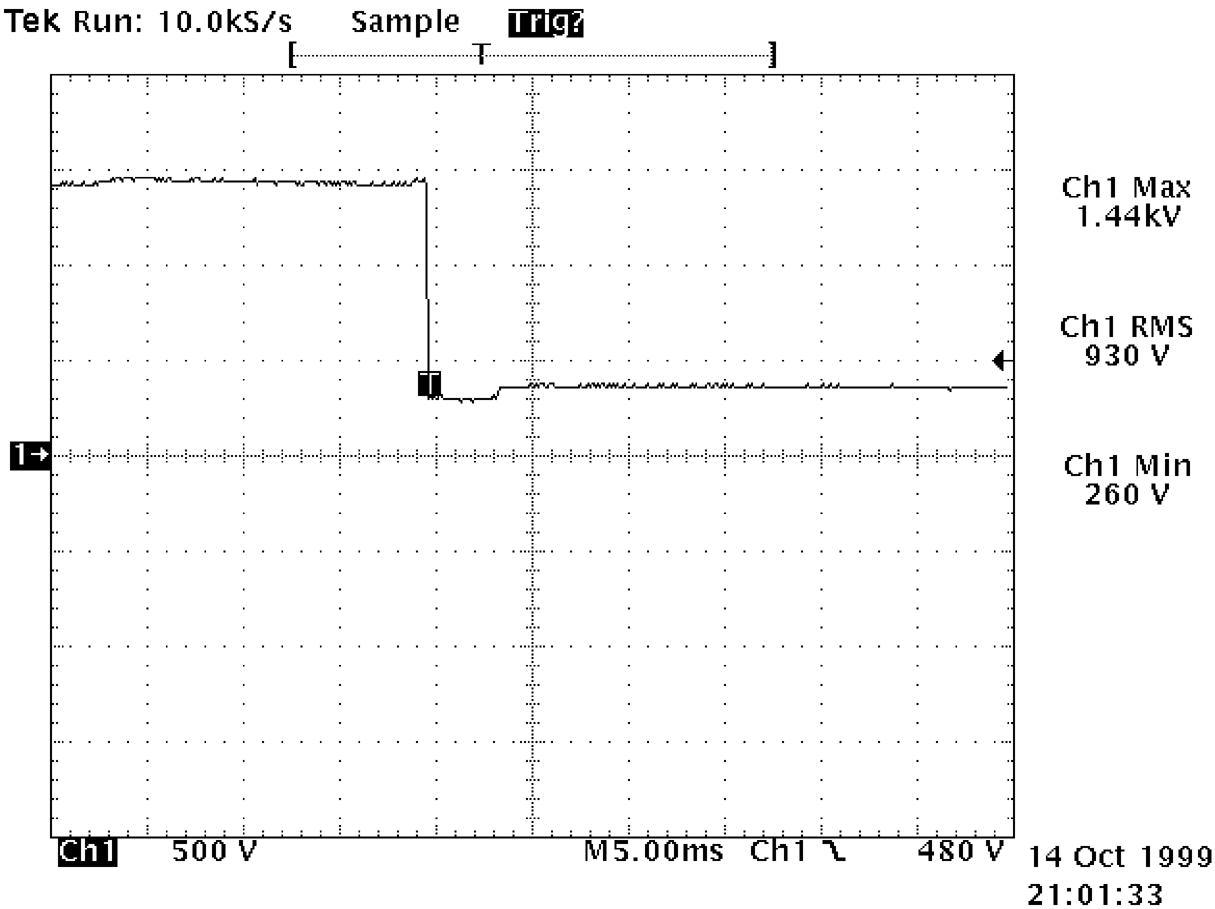

Figure 5 - DC Voltage Dielectric Breakdown: HT5000 Voltage Shutdown Enabled

Figure 5 shows the occurrence of a similar DC voltage breakdown.

As we saw in Fig. 4, the breakdown occurs at the peak of the AC voltage. From Fig. 2, we saw that the peak of the AC voltage is a value of 1.414 times the RMS value of the AC voltage. Therefore, for the AC and DC tests to similarly stress the insulation, it is necessary to conduct the equivalent DC dielectric withstand test at a value of the peak of the AC test voltage, not the RMS value of the AC test voltage.

It is also important to note how abruptly a dielectric breakdown occurs. This is shown in Figure 6. The same breakdown as shown in Figure 5 has been expanded 50,000 times - the time base on the scope has been changed from 5 mS (milliseconds) to 100 nS (nanoseconds) in order to "zoom in" on the breakdown event. Note that the time that it takes for the voltage to drop from the peak value to zero volts is 10 nS; approximately a million times faster than the period of the 60 Hz AC test voltage waveform. Because the breakdown occurs so quickly, and because it occurs at the peak voltage of the AC waveform, the AC and DC voltages 'appear' exactly the same to the breakdown; that is, a peak voltage of very long duration. In fact, to restate the above, the peak voltage of the AC waveform lasts a much longer than the breakdown itself.

In conclusion, we can say that a breakdown occurs so quickly that the difference between an AC test voltage and a DC test voltage is insignificant.

This can be proven by reference to Fig. 7, which is a picture of the same breakdown shown in Fig. 6, except the test was conducted using a DC voltage of 1.414 times the RMS value of the AC

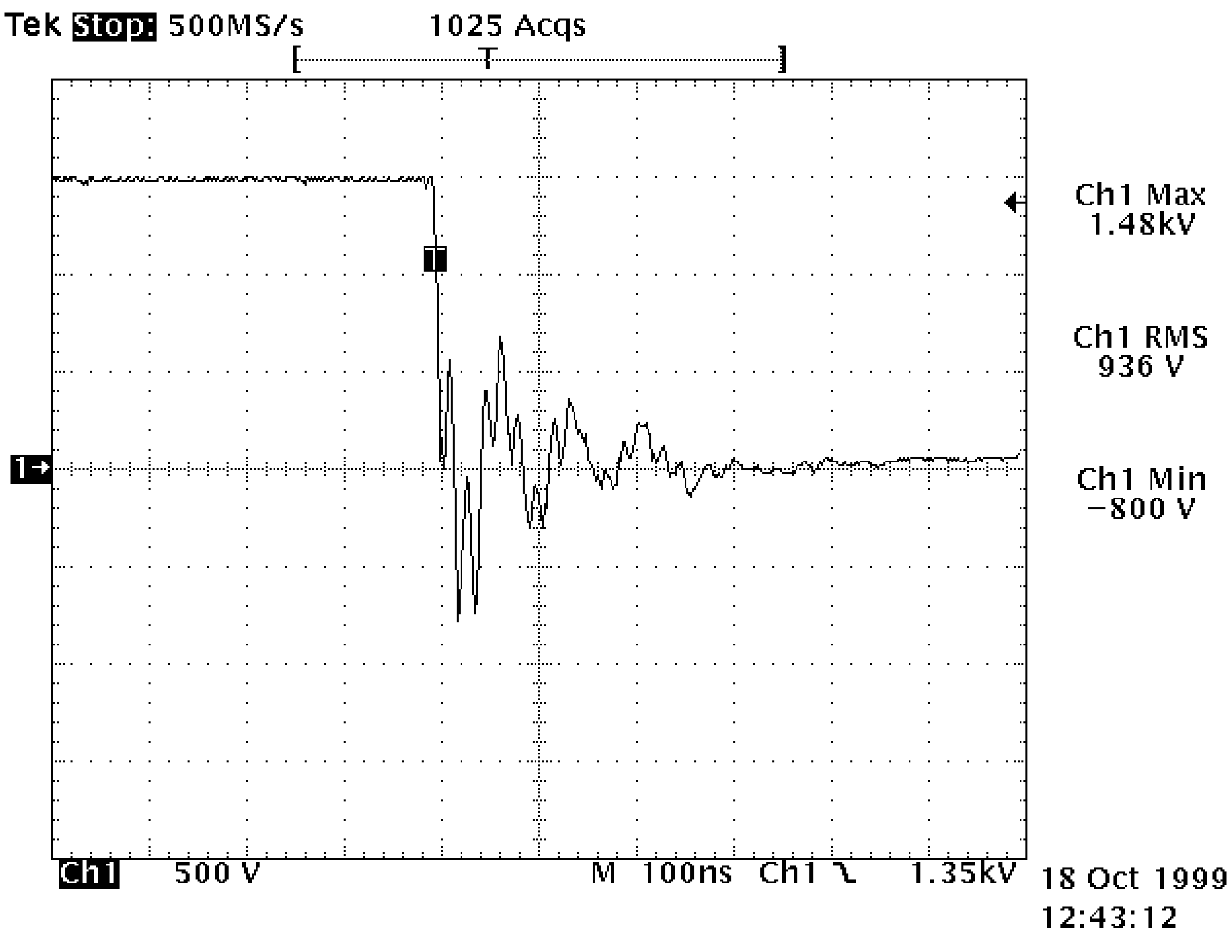

Figure 6 - AC Breakdown: First 600 ns

waveform. Comparison of Figures 6 and 7 show that the behavior of a breakdown between AC and DC conditions is identical.

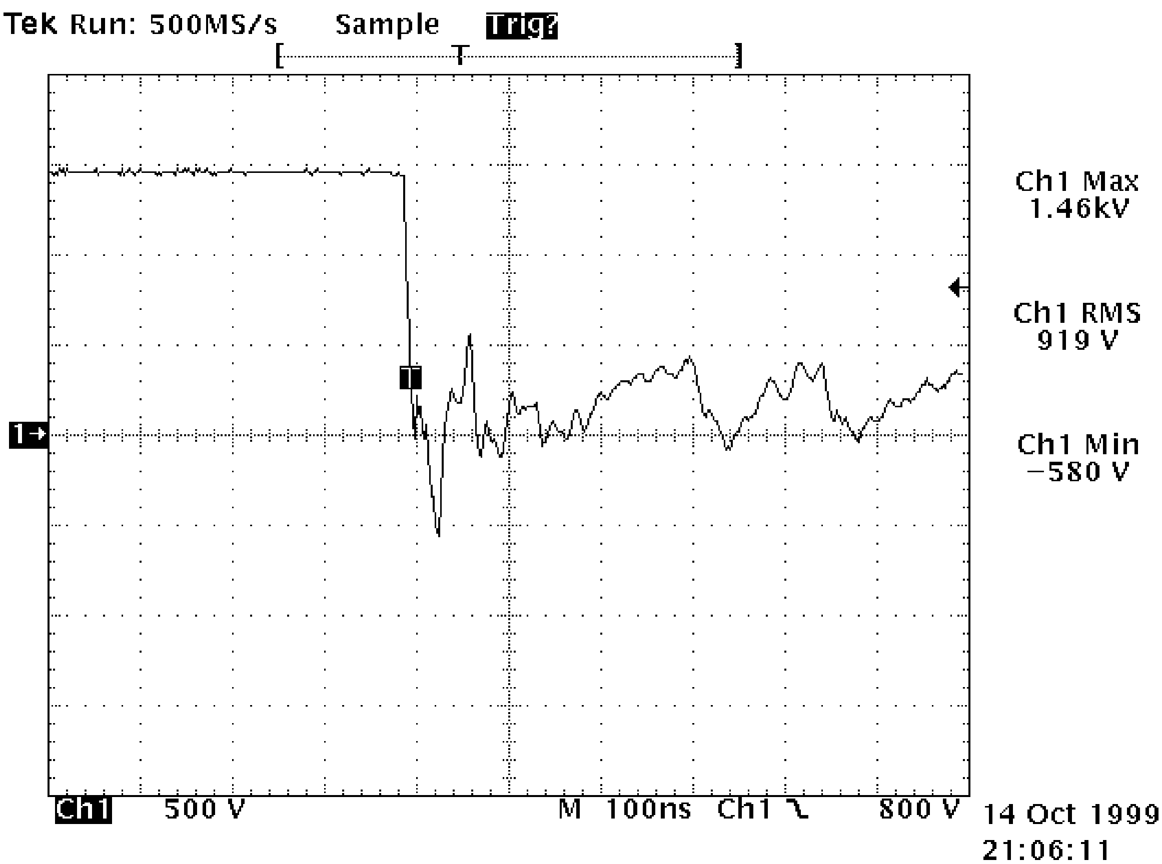

Figure 7 - DC Voltage Breakdown: First 600 ns

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ONCLUSION

In this paper, I have presented various waveforms to show the following interesting facts about dielectric withstand testing:

1. AC RMS values of waveforms do not properly illustrate their effects on dielectric withstand testing. Dielectric breakdowns occur at the peaks of AC waveforms.

2. The peak voltage of the AC waveform is 1.414 times the RMS voltage.

3. If peak voltages are equal, DC dielectric tests will give identical results of AC dielectric tests.

4. In order for the peak voltages to be equal, the DC voltage used in a dielectric withstand test must be 1.414 times the AC RMS voltage used.

5. Finally, the question of AC vs. DC dielectric testing has nothing to do with the fact that the insulation being tested is normally subjected to 120Vac. A dielectric breakdown will occur in nanoseconds. All of these events happen so quickly, that a 60 Hz voltage is "stopped" in comparison. If the peak voltages of an AC and DC dielectric withstand test are the same, similar results will be achieved.