CPM Test Limitation Study for AC, Pulsed AC and High Frequency AC Ionizers vs. DC Based Ionizers

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Abstract – There are some technical limitations with current charge plate monitor (CPM) technology for voltage switching type of ionizers such as AC, pulsed AC and high frequency AC ionizers. Technical limitations are mainly related with lack of response speed of CPM and other simpler portable ionizer testing instruments. ANSI/ESD S20.20 and IEC 61340-5-1 standards requires offset value for ionizer balance testing. CPM manufacturer provides average test data, and this isn't match with offset value and provide different measurement value. Current CPM technology has limited to indicate risk of various types of ionizers and these ionizers can cause of ESD event rather than neutralize charged energy. This paper studied various type of ionizers and measurement value differences with CPM and high-speed oscilloscope.

I. Introduction

Many ionizer users and vendors expect that ionizer can neutralize charge on insulator and isolated conductor such as plastic mold of ICs, printed circuit board and glass substrate of flat panel display (FPD)s. Charged plate monitor (CPM) is the instrument for evaluation and testing ionizer performance. Also, CPM testing is part of ESD control program that ionizer can meet limited value less than ±35V in both polarities.

It has known that AC ionizer can make ESD damage to ultra-sensitive devices such as MR head of disk industry. Instead of AC ionizer, steady-state of DC ionizer will give less impact to such sensitive devices due to no switching voltages from ionizers. Main cause of problem was switching high voltage from AC ionizers.

Over a decade, new technology developed using bipolar AC high voltage source with compressed air assist designed. This new ionizer is switching polarity on single emitter point with multiple nozzle configuration and adjustable output parameters such as voltage, frequency and duty cycles etc. This is more enhanced ionization technology than conventional AC ionizer based on high voltage transformer designed which has fixed high voltage around 4-7kV and frequency at 50/60Hz.

Due to enhanced bipolar AC ionizer and their changeable capability of output parameters along with the limited or slower speed response of CPM measurement technology, their measurement result looks achievable ANSI/ESD S20.20 ionizer requirement such as less than ±35V. This test result is limited by current CPM instrument technology. ANSI/ESD STM 3.1 document does not address of response speed of CPM instrument and all other documents.

In this study, several experiments revealed that CPM measurement is limited by its own operating response speed to measure balance value for AC, enhanced bipolar pulsed AC and high frequency AC ionizers compare with steady-state DC ionizer.

II. Ion balance measurement compliance to ANSI/ESD S20.20 requirement study

Ion balance measurement is one of the important parameters of ESD control program in EPA when using ionizers. ANSI/ESD STM 3.1 provide various types of ionizer testing set up and figures. But it doesn't include detail information how to test several types of ionizers such as soft X-ray, alpha, alternative room and air assist bar ionizers. With this reason, WG3 Ionization committee recognized the needs of the new test procedure for these new ionizers and working on new document release as SP3.5 for Test Methods for Air Assist Bar Ionizer, Soft X-ray and Room Ionizer Alternative. STM 3.1 and other ionizer related documents address how to make measurement ionizers and recommend taking peak value against ESD risk for pulsed ionizers.

As part of the ESD control program, ANSI/ESD S20.20 has limited target for ionizer balance measurement and offset value less than ±35V. AC and enhanced AC ionizers claims to meet this requirement. But this has concluded limited CPM technology and missing important information of measurement value. Several experiments will indicate that the offset value can be expressed in several ways what it could really mean.

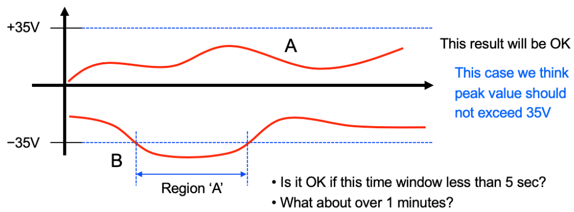

Figure 1: Offset Voltage

Operators and testing personnel may expect and understand that the measured value from ionizer should be lower than ±35V in always such waveform A in Figure 1. It is still also possible to accept waveform B if the offset voltage is exceeded shortly. It would not be acceptable if this offset value was more constantly over the limit.

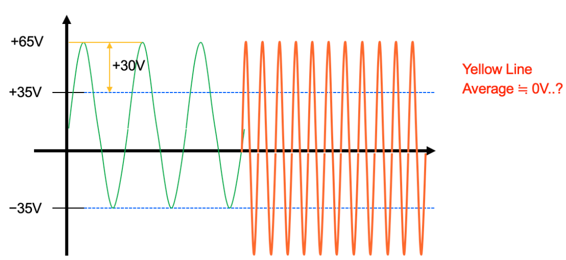

Figure 2: Offset Voltage from AC signal

Another concern is the signals that are not stable DC but fast AC instead. In this case, we may have much different test result for offset voltage measurement. If the measurement like green waveform in Figure 2, we can conclude +30V offset voltage and device will have only have 30V ESD risk from the ionizer. But if we measured high frequency AC signal and measured peak value ±65V and offset voltage almost 0V theoretically. In this case, we may accept this ionizer compliance to ANSI/ESD S20.20 program in place. But this significantly ignored switching voltage risk from ionizers rather than neutralize charged energy to ESDS items.

III. Ionizer Measurement by CPM Instruments

A. CPM Test Instrument Specification Comparison

Four different type of CPM instruments has taken to make comparison test measurements. Model 300 from Monroe Electronics' is fieldmeter based CPM instrument and Model 288 is voltage following technology instrument. Trek's Model 157 and Model 156A/1 are equivalent instruments. These instrument's specification summarized in Table 1.

Model #	Speed of Response	Accuracy from manufacturer
Model 300	6Hz	2%
Model 157	80Hz	1% (-3dB)
Model 288	1kHz to 20Vp-p 10Hz to 2000Vp-p	0.1% (-3dB)
Model 156A/1	1kHz to 20Vp-p 10Hz to 2000Vp-p	0.1% (-3dB)

Table 1: CPM Specification Comparison

B. Ionizer & CPM Test Setup

Enhanced pulsed AC ionizer was installed in enclosed environment made of transparent static dissipative material to minimize external source of measurement error of CPM instrument. ANSI/ESD SP3.5 is a new ionizer test document for air assist bar ionizers and Core Insight's Model 7110-600 air assist bar ionizer has installed at 200 mm distance from 15 cm x 15 cm CPM plate. See Figure 3.

Figure 3: Air assist bar ionizer installation with CPM plate

Ionizer needed small adjustment from the factory set due to humidity and temperature differences in test area. With some output adjustment an average of ion balance can be achieved less then ±35 V.

C. CPM Test Results with Pulsed AC Bar Ionizers

Initial testing was conducted with Model 300 CPM which has 6 Hz response speed and enhanced AC ionizer was set 12 Hz output with 5.5 kV positive and 4.8 kV negative outputs. Test result with Model 300 CPM are -31 V average with +24 V and -81 V peak value recorded. Figure 4 shows the test result.

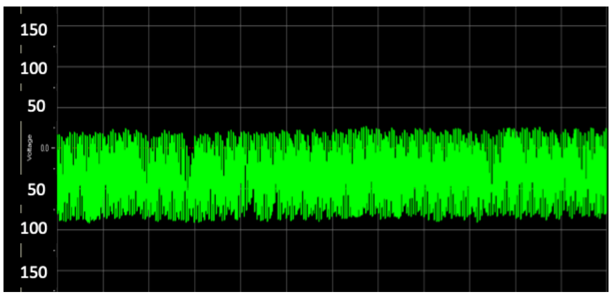

Figure 4: Model 300 CPM test result

Model 300 has its own software that displays and remote control for testing ionizers. Captured waveform image from computer screen shows a lot of noise signals from ionizers. The reason for noisy signal is multi-nozzle configuration with different corona discharge times given frequencies at 12 Hz. CPM response speed is 6 Hz and half of response speed.

When frequency of ionizer changed from 12 Hz to 30 Hz and the signal captured by CPM that software shows the waveform dramatically reduced. Measured average value was +7 V and peak values are -4 V and +17 V. Figure 5 shows the measured changes.

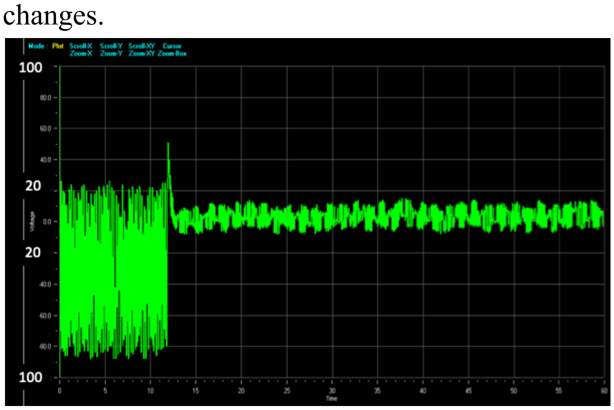

Figure 5: CPM measurement changes waveform when frequency from 12Hz to 30Hz

Test result indicates that the S20.20 requirement of less than ±35 V can be successfully achievable.

Then Model 288 CPM was replaced at the exact same location. Ionizer frequency was set up back to 12 Hz from 30 Hz. Model 288 CPM can measure at 1 kHz bandwidth 20 Vp-p with -3 dB. In Figure 6, second CPM instrument measurement result shows AC swing peak voltages are from +393 V and -305 V with average value -39.4 V which is just slightly higher than ANSI/ESD S20.20 requirement. With this response speed of CPM, user can see repeatable high peak swing voltages than slower CPM.

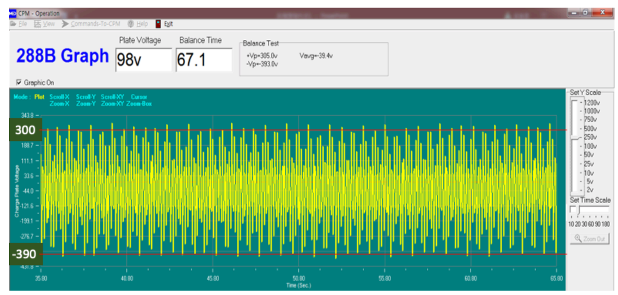

Figure 6: Model 288 CPM measurement result with 12Hz output of enhanced AC air assist bar ionizer.

Then the frequency of enhanced pulsed AC ionizer was changed from 12 Hz to 30 Hz. Test result shows obvious smaller waveform similar like previous slower CPM test results.

Figure 7: Model 288 CPM measurement result with 30Hz output of enhanced AC air assist bar ionizer.

Peak value immediately drops down to ±121 V ranges and average is only +5.1 V. Figure 7 shows swing voltage and peak value changes. Rate of drops are 60 % – 70 %.

With above four measurements that all peak values are different and not quite sure which data is accurate based on CPM specification information.

D. CPM Test Results with Conventional AC Bar Ionizers

Comparison testing was conducted with conventional AC bar ionizer at 150 mm without air assist with Trek Model 156A/1 which has 1 kHz frequency range at 20 Vp-p and conventional AC bar ionizer connected with high voltage AC power supply and output was fixed 5 kV with 60 Hz frequency fixed output. Figure 8 shows the test setup.

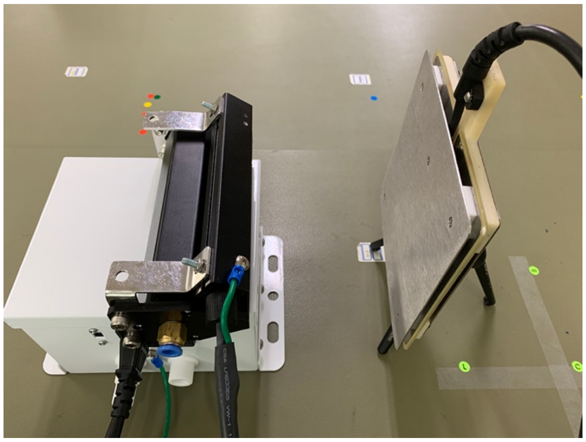

Figure 8: Model 156A/1 CPM measurement setup with conventional AC bar ionizer

Initial measurement was conducted with computer software and it is quite similar like noise type of signals as previous study.

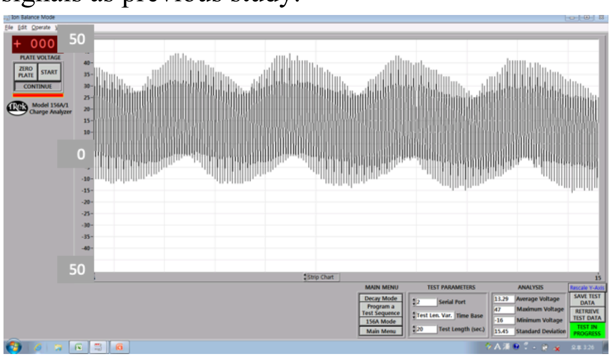

Figure 9: Model 156A/1 CPM measurement result with steady-state DC blowers.

Measurement result shows us small signal from CPM instrument within +42 V and -16 V only. Due to no output adjustment capability, this output was fixed. Figure 9 shows repeated waveform from AC bar ionizer and several color ranges could be observed. The thick colored area may cause of different corona discharge timing on multiple emitter pin construction on AC bar ionizer.

E. CPM Test Results with High Frequency AC Ionizers

High frequency AC ionizer was installed at the same distance of 200 mm to the CPM plate. Relatively small average value was measured within ±35 V by Trek Model 156A/1 CPM. Similar noise waveform and unstable balancing was observed with the conventional AC testing experiment. Figure 10 shows test setup. Figure 11 shows unstable waveform from high frequency AC ionizers.

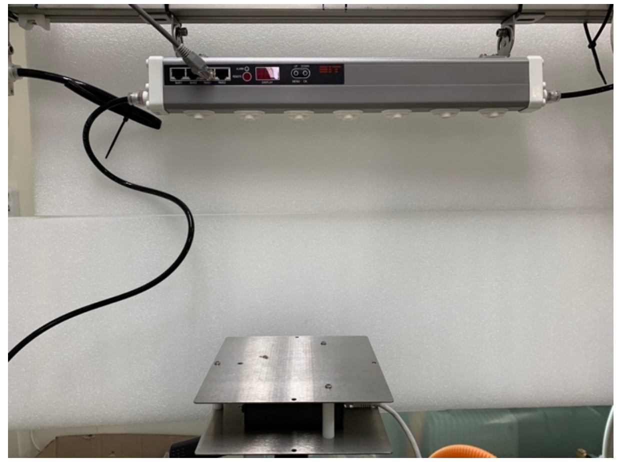

Figure 10: Model 156A/1 CPM measurement setup with high frequency AC bar ionizer

Peak value was +40 V and -35 V in unstable waveform. This unstable signal may cause of limited speed of response of CPM and randomly captured signal from ionizer. High frequency AC ionizer operating about 30 kHz and this is too fast to measure by 1 kHz CPM instrument for 20 Vp-p ranges.

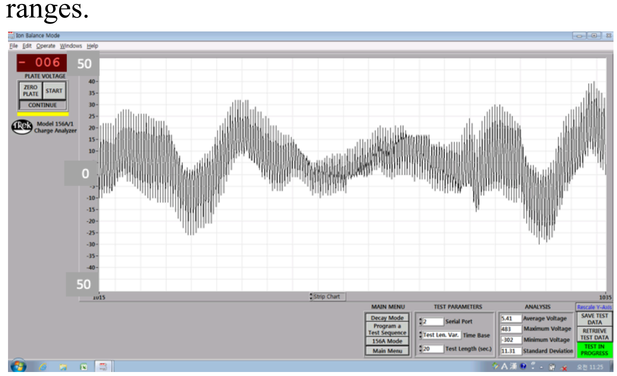

Figure 11: Model 156A/1 CPM measurement result with steady-state DC blowers.

F. CPM Test Results with Steady-State DC Blowing Ionizers

In comparison with AC switching type of ionizers, Core Insight's Model 310E steady-state DC ionizer was placed at 300 mm on workstation for testing balance measurement. The result shows clearly that the steady-state DC ionizer do not have such high voltage swings and low peak value. Figure 12 and

13 shows a setup and results of the ion balance measurement of the steady-state DC ionizers. The peak values were +12 V and 0 V only. Average was 10.3 V.

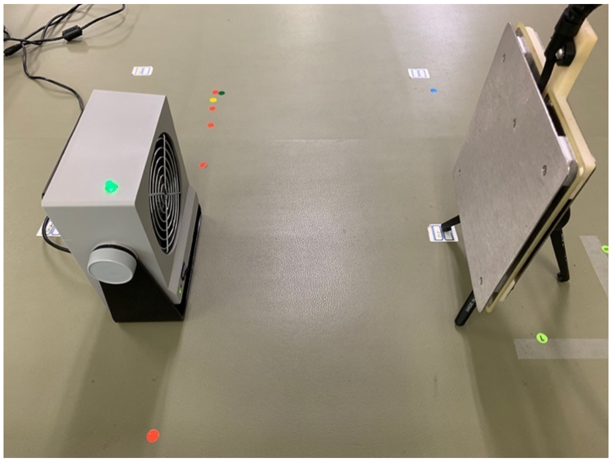

Figure 12: Model 156A/1 CPM measurement setup apparatus with steady-state DC blowers.

So, it is clear that the balance requirement of less than ±35 V are intended to get similar result from steady-state DC ionizer and they are clearly not useful for voltage switching AC ionizers.

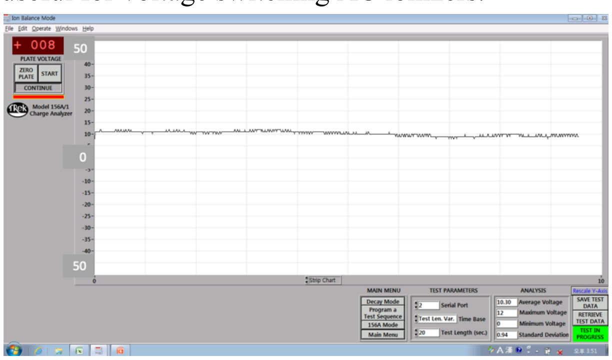

Figure 13: Model 156A/1 CPM measurement result with steady-state DC blowers.

The result indicates even enhanced voltage switching AC type of ionizer can increase the ESD (or spark discharge) risk for voltage or field sensitive devices or electrical circuit in narrow gap. Current CPM technology does not cover the measurements of fast signals and therefore it is not capable to verify such ionizers.

IV. Ionizer Measurement by CPM Plate with Oscilloscope

It is clearly shown that CPM response speed is not fast enough to catch full scales of peak voltage ranges. Tektronix TDS2022C oscilloscope is replaced with CPM instrument and connected with isolated plate of CPM connect to scope to measure peak values as alternative way overcome frequency issues from enhanced AC ionizers.

A. Oscilloscope Test Measurement with Pulsed AC Bar Ionizers

Pulsed AC ionizer setup has the same measurement setup than with CPM, but in this case the CPM plate connect to oscilloscope input channel.

Peak to peak values at 12 Hz were 1.05 V p-p. This value is then converted to 1 kVp-p according to the attenuation ratio of 1:1000. Figure 14 shows initial test measurement result. When the ionizer frequency changed from 12 Hz to 30 Hz, it measured 29.97 Hz with same 1.02 V pk-pk. Figure 15 shows 30 Hz frequency measurement.

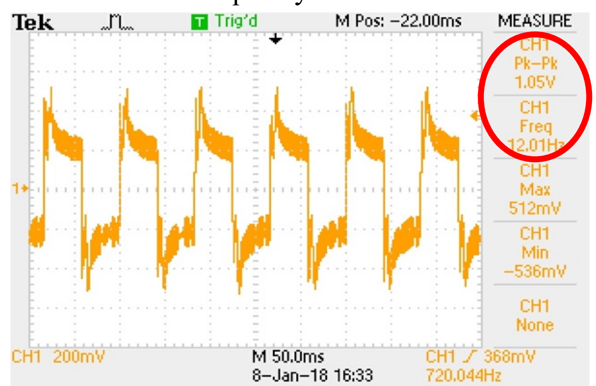

Figure 14: CPM plate with oscilloscope measurement for 12Hz output of enhanced pulsed AC ionizer

In this measurement, it is clear that CPM has lack of response speed to be measured with relatively fast frequency ranges of voltage switching from pulsed AC ionizer.

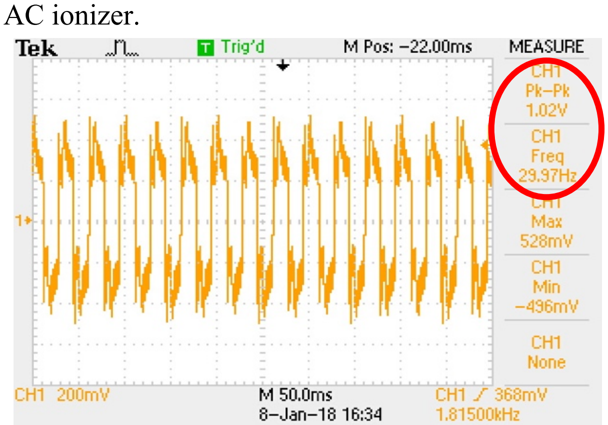

Figure 15: CPM plate with oscilloscope measurement for 30Hz output of enhanced pulsed AC ionizer

CPM instrument has limited speed to measure high voltage signals with frequency changes, but oscilloscope can measure full range of frequencies and it clearly shows voltage signal doesn't drop as CPM measurement indicated.

This means that ESD sensitive items will see the voltage switching with frequency changes without voltage drops. And if voltage exceeded breakdown level between I/O pad on wafers or circuit pattern on glass substrate of flat panel displays, ESD event can occur by ionizers rather than neutralize charge.

B. Oscilloscope Test Measurement with Conventional AC and High Frequency AC Bar Ionizers

This was the similar measurement than above with Pulsed AC bar ionizer. Oscilloscope with CPM plate measurement was conducted for conventional AC and high frequency AC ionizers.

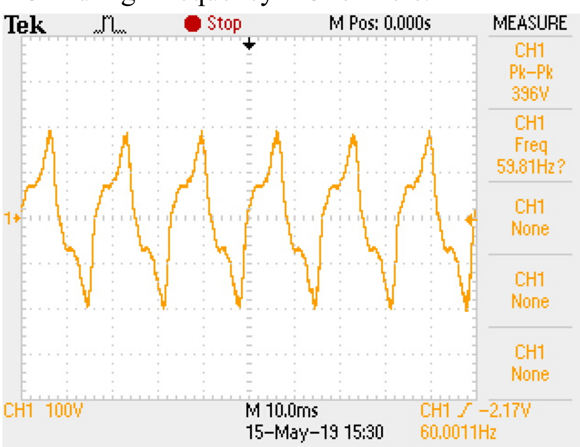

Figure 16: CPM plate with oscilloscope measurement for 60Hz output of conventional AC bar ionizer

Figure 16 test result shows signal frequency of 60 Hz measured by oscilloscope with the CPM plate setup. Peak to peak value was 396 Vp-p. The peak values were +42 V and -16 V by CPM instrument described above. This is obvious different result and much bigger voltage switching value than with CPM instrument test result.

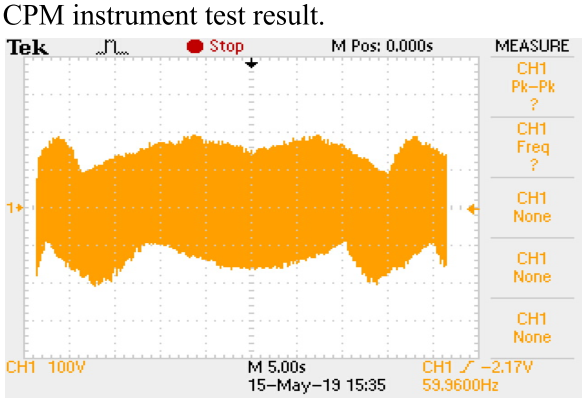

Figure 17: CPM plate with oscilloscope measurement for 60Hz output of conventional AC bar ionizer at wider time slot

Figure 17 shows similar waveform with CPM instrument measurement result, but not just peak to peak value at longer time scale 5 sec per division. This is very similar waveform pattern with CPM instrument measurement describe above in section D of part III for AC ionizer test result.

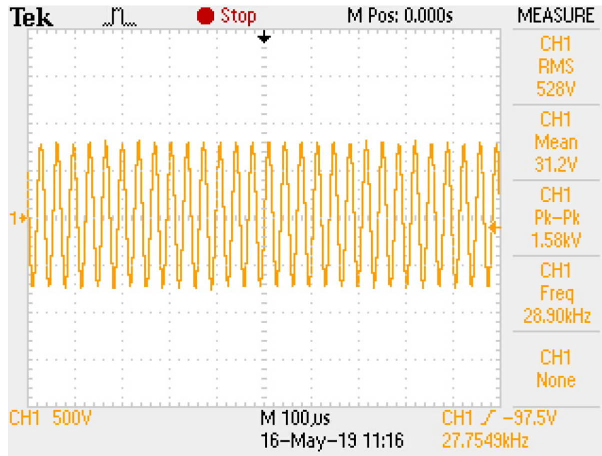

Figure 18: CPM plate with oscilloscope measurement for high frequency AC bar ionizer

Then, ionizer was changed to the high frequency AC ionizer which is 30 kHz output with fixed voltage 5 kVp-p. CPM results were +40 V and -35 V as shown in Figure 18. The CPM plate with the oscilloscope resulted in 28.9 kHz waveform with 528 Vp-p value.

Another interesting phenomenon was observed. About every 100 ms steps voltage dropped close to zero. This can cause of ESD stress to sensitive devices due to the voltage changes.

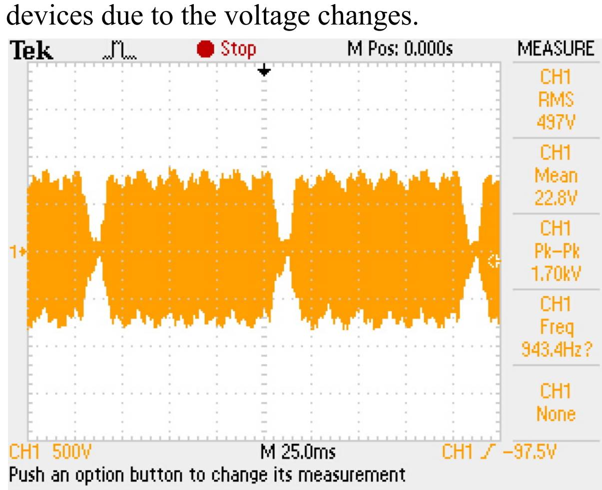

Figure 19: CPM plate with oscilloscope measurement for high frequency AC bar ionizer at 25ms step

C. Oscilloscope Test Measurement with Steady-State DC Ionizer

On the contrary of the above study, CPM plate with oscilloscope measurement resulted in very similar result with CPM instrument measurement. Figure 13 shows oscilloscope results with only approximately 10 V and polarity got shifted oppositely. The reason why this polarity changes may cause of calibration issue either CPM instrument or oscilloscope.

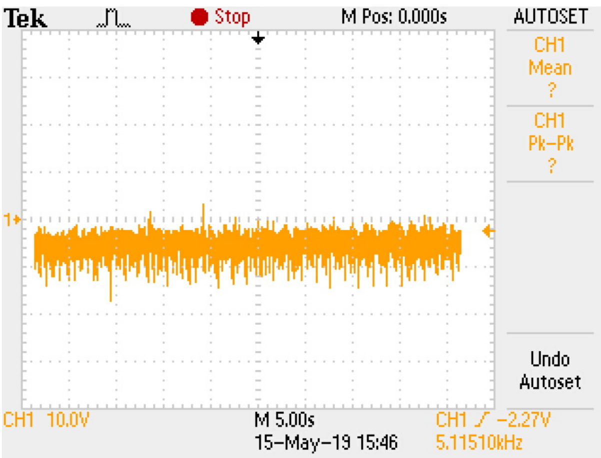

Figure 20: CPM plate with oscilloscope measurement with steady-state DC ionizer

Figure 20 shows very low offset voltage or peak value in this measurement and no high voltage switching.

For more accurate measurement, 5sec per division time scale changed to 1 ms and Figure 21 shows 40 Vp-p value at 300 mm from blower. In accordance with other measurements, time scale limited or shows peak value differences.

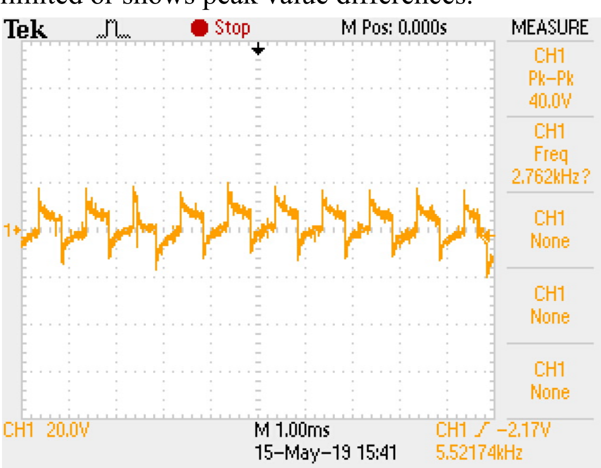

Figure 21: CPM plate with oscilloscope measurement with steady-state DC ionizer at 1ms division

Then, it was interesting to find what happens if distance get shorter in half. The switching voltage could be higher or more than a double. So, with the same time scale at 1 ms division, steady-state DC ionizer was relocated at 15 cm distance to CPM plate. Figure 22 shows relocated set up and Figure 23 shows the the result of peak values with this change.

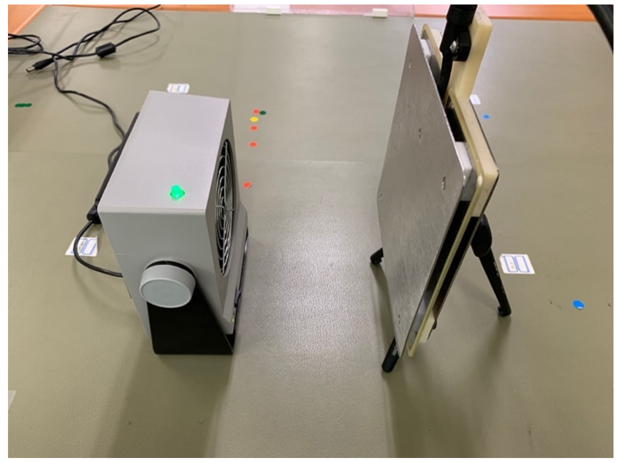

Figure 22: CPM plate relocate 15cm distance to steady-state DC ionizer

But the values were not much higher compared to the AC switching type of ionizer test results. Only 56 Vp-p was measured. This means that the differences between CPM instrument and oscilloscope measurements are very small with the steady-state DC ionizers.

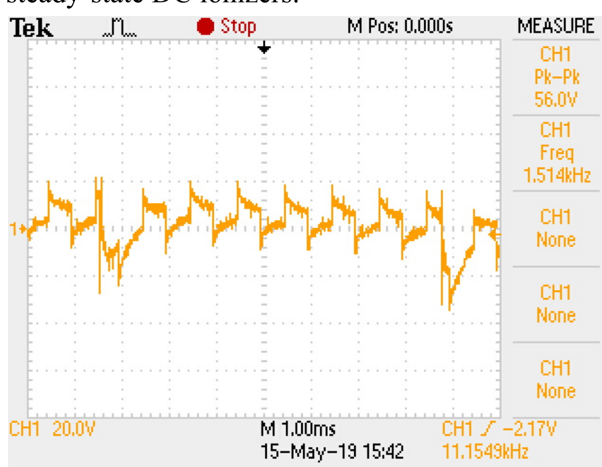

Figure 23: CPM plate with oscilloscope measurement at 15cm from steady-state DC ionizer

V. Direct High Voltage Measurement by Scope

To make sure actual voltage drop, Tektronix P6015A high voltage divider attached to TDS 2022C oscilloscope. It measured directly on emitter point to see the voltage changes when frequency changes from 12Hz to 30 Hz. High voltage dividing rate is 1000:1. The actual voltage was measured 12.3 kV pk-pk with 12 Hz at same output voltage set up at initial 5.5 kV positive and 4.8 kV negative. Figure 24 shows the result.

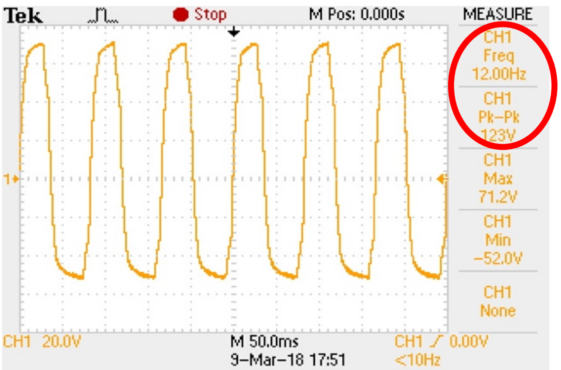

Figure 24: Direct high voltage measurement at 12Hz

Then, frequency was changed to 30Hz again and measured direct voltage on emitter point. The result was 30Hz with very low voltage drops from 12.3 kV to 11.4 kV which is only 7 % drops. Figure 25 shows the test result for 30 Hz frequency ranges.

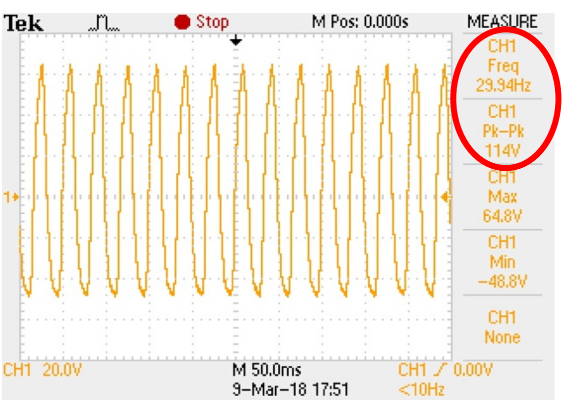

Figure 25: Direct high voltage measurement at 30Hz

VI. Decay Time Measurement

Comparison decay time testing was conducted at the same configuration as described above. Decay time was observed.

First, enhanced pulsed DC bar ionizer was tested by Monroe's Model 300 CPM. Positive decay time is shown in Figure 26. As described above, Model 300 CPM has slow operating speed at 6 Hz. It displays linear discharge from 1000 V to 100 V and decay time is just 1.0 sec.

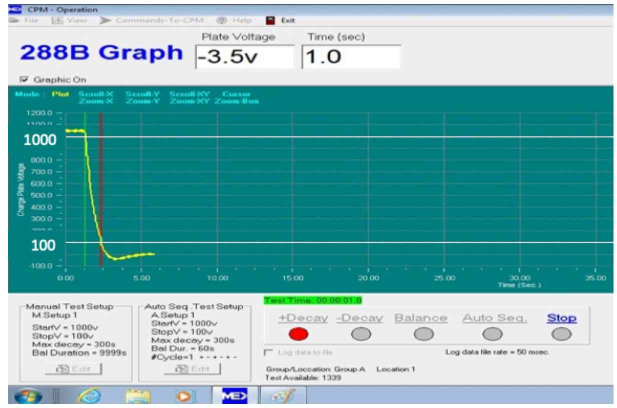

Figure 26: 6Hz CPM instrument decay time measurement

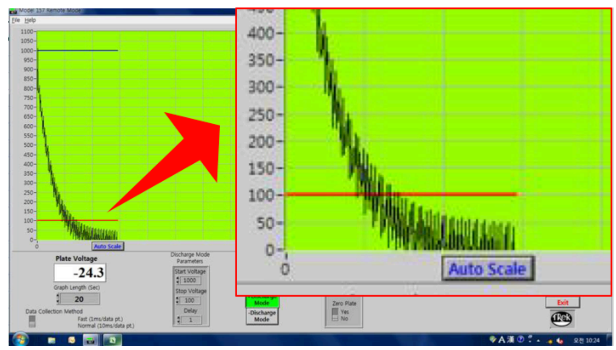

Figure 27: 1kHz CPM instrument decay time measurement

Second, CPM instrument was replaced with Trek Model 156A/1. Measurements was made for pulsed AC bar ionizers at the same distance. Switching voltage was higher than 100 Vp-p, around 100 V or below after discharge finished.

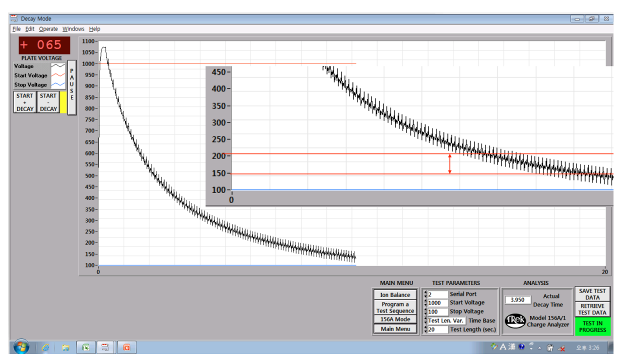

Figure 28: 1kHz CPM instrument decay time measurement for conventional AC bar ionizer

Third, decay time of conventional AC ionizer also shows about 50 V swing voltage before and after 100 V area. This means that CPM is limited to measure accurate voltage over 500 V around and signal getting bigger lower than 300 V. This is exact meaning of small signal 1kHz for 20 Vp-p on product specification.

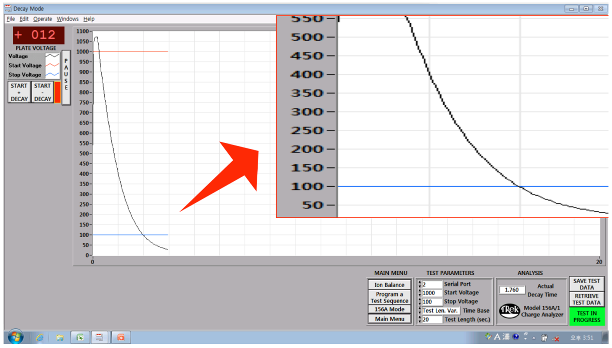

Figure 29: 1kHz CPM instrument decay time measurement for Steady-State DC Ionizer

Finally, steady-state DC ionizer was measured. Discharge time was 1.7 sec with straight line type of waveform without swing voltage. Figure 29 shows this waveform.

V. Conclusion

Various types of ionizers are often installed at short distance from ESD sensitive devices, such as inside of equipment or loading/unloading areas of automated handlers due to fast movement of ESDS items in process applications. Ionizers are intended to neutralize charge on ESDS items such as wafers, device, printed circuit board assemblies, flat panel displays etc.

In this paper, all experiments demonstrate that current CPM technology is suitable for DC based ionizers and relatively slow pulsed DC ionization. Current CPM technology is very limited to evaluate performance and disadvantages of high voltage switching AC, pulsed AC and high frequency AC ionizers due to their response times aren't fast enough to catch voltage ranges. CPMs measure only low frequencies allowing small voltage for balance and residual decaying voltage on CPM plate. Standard CPM test results shows significant voltage drops at short distance applications. Current CPM technology will give incorrect information to users that it is suitable to meet ANSI/ESD S20.20 based ESD control program requirement for ionizers less than ± 35 V ranges.

Experiments demonstrate that it is not recommended to install voltage switching ionizers at short distance applications in automated process tools for ESDS items and voltage sensitive devices. To avoid ESD risk at short distance, if users installed at longer distance with voltage switching type of AC ionizers in fast move automated process tool, it will be less risk to avoid ESD risk from ionizers. But it will also be less efficient to neutralize charge on ESDS items due to their process speed, ion recombination and distances.

To make suitable measurement for such high voltage switching ionizers by CPM, it needs to increase response speed up to 5 times faster than ionizer frequencies follow by Nyquist's data sampling theory or should allow to alternative measurement technique such as CPM plate attached to high speed oscilloscope.

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