A Study of the Static Discharging Power of a Decaying Alpha Source

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Abstract—**210Po sources have been used for static charge mitigation for nearly half a century. The 5.4 MeV Alpha particles[1] that are emitted from the source collide with air molecules and ionize them along their 3.8 cm average range[2]. The Polonium source has a half-life of 138 days[3] so the number of ions created drops dramatically over the course of the one year advertised life of the ionizer[4].**

An empirical model incorporating recombination is presented. Also, a population of NRD Inc. Nuclespot model P2042 was analyzed using a Charge Plate Monitor to measure the discharge efficiency[5] of the sources at a distance of 2.5 cm to 15 cm. The sources were 5 mCi when manufactured and varied in age from zero to 15 months. The results showed that the source decayed from 5 mCi to 500 μCi over 15 months but the ionizing power as measured by the CPM as Discharge Time degraded much less.

I. INTRODUCTION

Polonium 210 (^{210}Po) encapsulated in an amalgam has been sold as a source of air ions for static electricity control for over 20 years. The technology completely seals the Po inside of a silver substrate which is protected by a gold and nickel foil. See Figure 1. This technique makes it safe against contamination issues while minimizing the amount of material that the alpha particles travel through so that the majority of the alpha's kinetic energy is delivered to the air.

The kinetic energy is deposited as air molecules recoils and as ionization of the air molecules. These air ions are used to neutralize static charge on objects in high technology manufacturing of items and processes which are sensitive to static charge. Alpha ionization is desirable for the most demanding of applications because it is inherently polarity balanced, requiring no adjustment, because it does not collect contamination from the air which must be cleaned and because it does not exhibit the gas to particle conversion process which corona ionizers create.

Since the engine that drives the ionization creation process is the activity of the ^{210}Po source, it is natural to assume that the performance of the ionizer is linearly proportional to the source activity. The manufacturer of these sources, NRD, claims that the source

has a normal lifetime of 1 year. Government regulations require that the source be re-turned to the manufacturer for testing after this time, and NRD claims that the source maintains its performance over this interval. They claim that their experience is that the source does not loose appreciable performance over the year in spite of the fact that the source strength (activity) does decay appreciably over the year. It is well known that the half life of ^{210}Po is 138.4 days[6] so by the end of a year, the activity of a source has dropped by a factor of

$$2^{-365/138.4} = 0.168$$

The purpose of this article is to evaluate the overall performance of the ^{210}Po–based ionizer over a year and to determine a model that helps to explain the performance. Vali-dating the comments made by NRD would require that the ionizer performance remain within ~20% its initial performance in spite of the 83% loss in alpha activity.
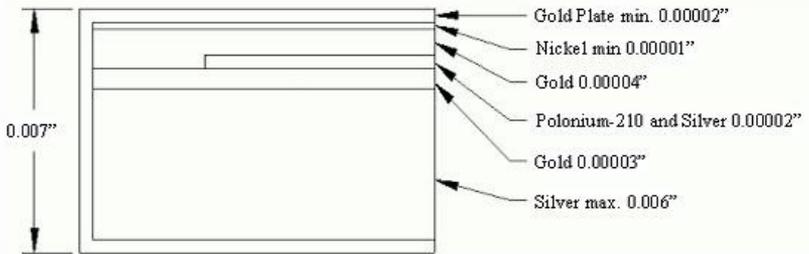

Figure 1. Cross section of a ^{210}Po ionizing alpha source.

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II. POLONIUM ALPHA FACTS

The alpha particles emitted from a ^{210}Po source have a kinetic energy of 5.3 MeV. By the time they exit from the source they have lost 0.49 to 0.63 MeV[7] by collisions within the source. Because of their relatively large mass (4 amu.) these particles travel at rela-tively low speed and thus are highly ionizing. They have a range of only 3.8 cm. in 1 atm. of air. They give up their kinetic energy by collisions with air molecules (O_2 and N_2). The energy causes the air molecules to recoil and to ionize. Approximately 10^5 ion pairs are created for each alpha particle.
Owing to the large number of collisions, each alpha undergoes, the range of the alpha particles is quite consistent. The plot of the energy deposit along the path of each alpha

particle, $\frac{dE}{dx}$, is called a Bragg curve[8] and is shown in Figure 2. The rate of energy transfer to the air increases as the alpha slows and then the particle stops abruptly.
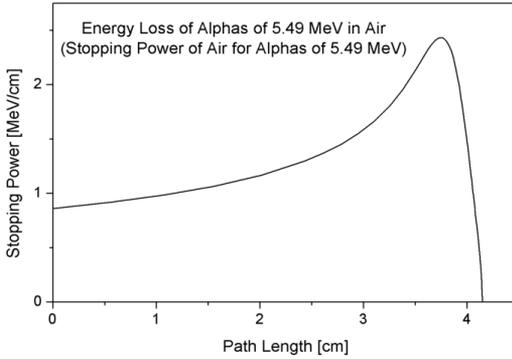

Figure 2. The stopping power curve for a 5.4 MeV alpha source.

III. IONIZER PERFORMANCE MEASUREMENTS

The most common way to benchmark the performance of an ionizer is with an instrument called a Charge Plate Monitor (CPM). See Figure 3. The device uses a 150 mm x 150 mm electrically isolated plate as a sensor. The plate is arranged with respect to ground to have an electrical capacitance of 20 pF. The plate is charged to ±1000 V and exposed to the air ionizer. The instrument measures the time for the voltage on the plate to drop to ±100 V. For the purposes of this paper, the time to discharge from +1000 V to + 100 V (the positive discharge time) and the time from -1000 V to -100 V (the negative discharge time) were averaged and used as a figure of merit for the ionizer tested.

Figure 3. A typical commercial charge plate monitor.

The ionizer employed for the test consisted of a small disk (see Figure 4) with an activity of 5 mCi. The source itself is clearly visible as a gold foil behind a protective screen.

Figure 4. The P2042 alpha source.

The source was placed in a laminar flow field of approximately 25 cm/s with the CPM located at various distances from the source. The distance ranged from 25 mm to 150 mm. The discharge times were measured for each distance for each source. Six sources were studied, each once a month for two successive months. Sources varied in age from new to 15 months. The activity tolerance for newly manufactured sources was typical-ly<10% so it was reasonable to use multiple sources to span the age range studied. The measured Discharge Times (± averaged) as a function of source age are shown in Figure 5 below.
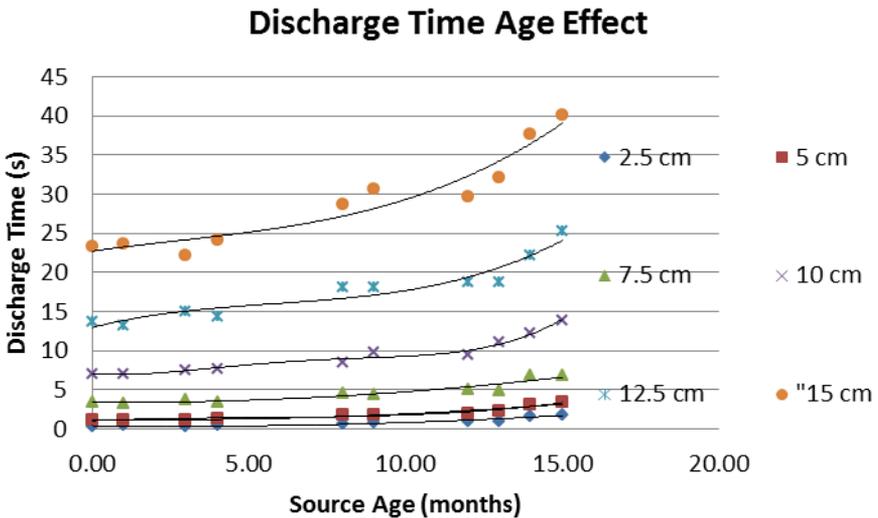

Figure 5. Effect of source age air ionizer performance at several distances.

As can be seen from the figure, the data indicate that the discharge time stays relatively constant over the course of a year in spite of the continuously decaying alpha activity. Because the data varies so much in amplitude (discharge time) for different values of

source-CPM distance, the data were re-plotted with each data set normalized to its age=0 months value. This graph is shown in Figure 6.

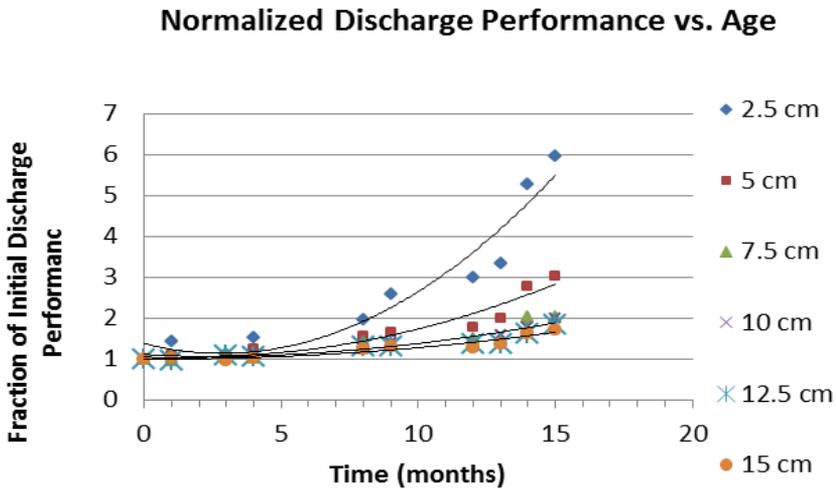**Normalized Discharge Performance vs. Age**

Figure 6. Fractional ionizer performance (~discharge time)   versus ionizer age.

As can be seen from the data, the ionizer performance is quite stable as the device ages but it is most stable in performance for distances of 4 inches (10 cm) or more.

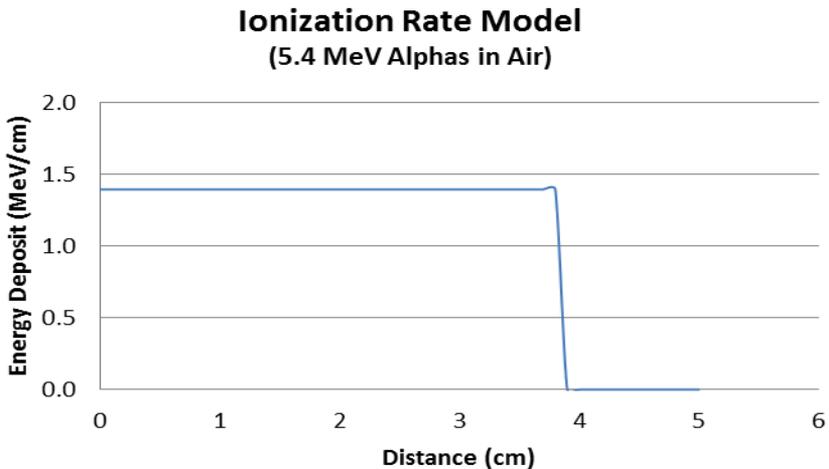**Ionization Rate Model**
(5.4 MeV Alphas in Air)

Figure 7. Alpha energy deposit approximation used for numerical simulation.

IV. NUMERICAL SIMULATION OF IONIZER PERFORMANCE

In an attempt to understand why the age of the source plays such a weak role in the ionizer performance, a model was constructed. The model makes the simplifying assumption that the alpha energy deposit, $\frac{dE}{dx}$, is a flat distribution as compared with Figure 2. See Figure 7.

The 2 dimensional model also assumes that the ions are moved toward the CPM on the laminar air flow and that the positive and negative ions recombine at a rate which is proportional to the ion density, ρ. Therefore, as the ions move away from their creation point (0 to 3.8 cm from the source), they are attenuated in population by a factor of

$$f = e^{-\lambda \rho}$$

for each 100 μm differential element traversed. The parameter λ was determined from the experimental data to be 1.5 x 10^{13} ions/100 μm. The current calculated for the CPM discharge time was compared to the charge laid down by the ionizer. The speed at which ions recombine is extremely high at the magnitude of ion density created by the source.

The attenuation factor for each 100 μm bin was integrated to the end of the ionization creation region and summed with the other contributions. Beyond 3.8 cm, the model uses no ion creation, only recombination. The results of the model for a zero age, 6 months and 12 months source are shown in Figure 8. As can be seen, if the source is very close, the dependence with age is strong but beyond 5 cm, this is not a face. At a distance of <6 cm, some small fraction of the alphas will survive and contact the object being protected. Beyond this distance, the source works well but and no alphas survive to contact the product.
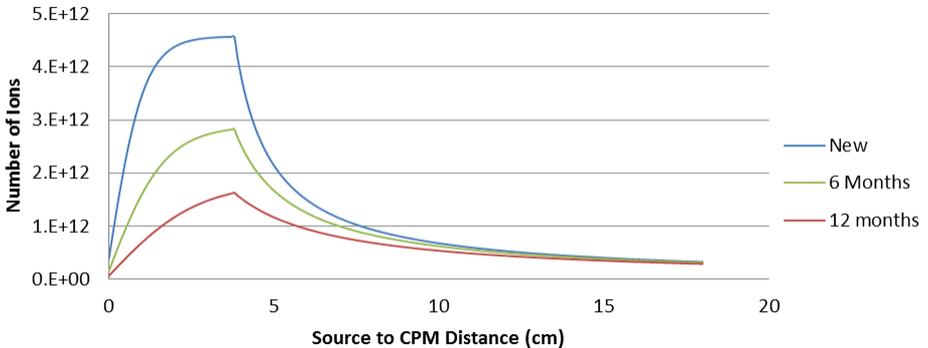

Figure 8. Results of numerical simulation for ions surviving over distance. Note the discontinuity at the alpha range (3.8 cm) .

The experimental data described above was the Discharge Time which is inversely proportional to the number of ions delivered. Therefore to compare the prediction of the model to that of the experimental data, the inverse of the ion delivery predicted by the

model was computed for source ages varying from new to 15 months old. Calculations are shown in Figure 9 for distances of 3.8 cm to 18 cm. corresponding to Figure 6.
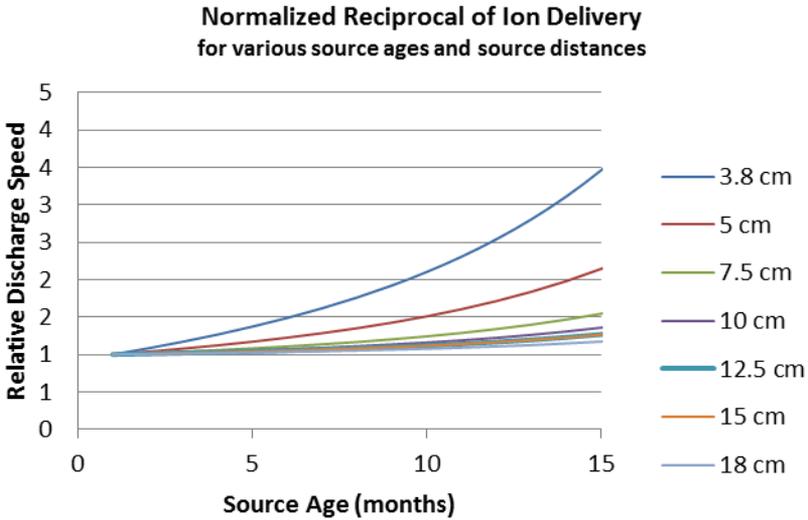

Figure 9. Results of numerical simulation. To be compared to experimental data shown in Figure 6.

V. CONCLUSIONS

An alpha source based ionizer delivers only a small fraction of the ions it creates. The majority of the air ions created are lost to recombination. The rate of recombination is sufficiently aggressive that a new source loses a much larger fraction of its ions to recombination than does a source which has been in existence for a full year. This is a sort of self limiting performance which has the action of regulating the output of the unit. Indeed, the NRD assertion that the ionizer maintains its discharge performance for a full year has been shown to be the case and that an ionizer placed ≥7.5 cm. from the object being protected will offer consistent performance over a year or more in spite of the decaying activity of the source.

REFERENCES

[1] Argonne National Laboratory EVS, Polonium, Human Health Fact Sheet, August 2005
[2] E. Rotondi*, K.W. Geiger **The Measurement Of The Range-Energy Relation And Straggling Of α-Particles In Air Using A Solid State Detector**, Nuclear Instruments and Methods, Volume 40, Issue 2, March 1966, Pages 192‑ 196, Elsevier B.V.
[3] Argonne National Laboratory EVS, Po, Human Health Fact Sheet

[4] http://www.nrdstaticcontrol.com/FAQ.html
[5] ANSII/ESDA SP3.3-2006,
[6] Argonne National Laboratory EVS, Po, Human Health Fact Sheet
[7] Spieler, Helmuth, http://www-physics.lbl.gov/~spieler/physics_198_notes/PDF/IV-E-Deposition.pdf
[8] http://en.wikipedia.org/wiki/File:Bragg_Curve_for_Alphas_in_Air.png