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MEASUREMENTS ON LOW LEVEL PLUTONIUM SOURCES USING RAD ELEC ELECTRET ION CHAMBERS

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ABSTRACT

This is a technique for measuring gross alpha particle emission from interior contaminated surfaces. The technique utilizes electret ionization chambers (EICs), which consist of a charged Teflon plate (the electret) and an electrically-conductive plastic chamber of 145 ml volume. To measure very low levels of alpha contamination, the EIC is left in place on the surface to be measured for about 48 hours. The change in the surface charge of the electret is a measure of the ionization during the measurement period. The rate of change of the charge is converted into an activity using an appropriate calibration factor. This system has the ability to make accurate gross alpha contamination measurements while being subject to a high airborne radon concentration, such as might occur in certain buildings or during an atmospheric inversion.

Previous studies of the effectiveness of these EIC's focused on levels of alpha contamination much higher than is allowed for unrestricted release of material at the Rocky Flats Environmental Technology Site (RFETS). This study evaluated the performance of EIC's at levels from 100 disintegrations per minute (dpm) per 100 cm^2 to below 20 dpm per 100 cm^2 (all measurements are referenced to a 4π geometry). The EIC's were found to be within 5% accuracy, as compared to a gas flow proportional counter calibrated with a NIST–traceable source. Test results indicate that the EIC, left in place for 48 hours, can detect alpha contamination as low as 6.4 ± 3.0 dpm/100 cm^2 to a 95% confidence level.

I. INTRODUCTION

A major activity associated with the closure of RFETS is the removal of excess property. Property items not designated as waste must be verified free of radioactive contamination prior to being released for unrestricted use. The criteria used to allow release for unrestricted use are derived from Department of Energy (DOE) Orders and implemented on-site via the RFETS Radiological Control Manual (RCM). For transuranic isotopes, the unrestricted release limits for fixed surface contamination are generally 100 dpm per 100 cm^2 and for removable contamination are 20 dpm per 100 cm^2. Verification that items meet these limits requires many hours of Radiological Control Technician effort, which is a severely limited resource. Previous work on the detection of alpha emitting isotopes with the Electret Ion Chamber System, performed at Oak Ridge National Laboratory and described in Reference (1), used sources ranging from several hundred to 27,000 dpm. The intent of the work described here is to produce data on the electret system performance for sources below the 100 dpm range.

The Rad Elec Electret Ion Chamber was identified as a system which has the potential to economically measure surface contamination down to the unrestricted use limits on some objects. By virtue of the fact that the electret chamber can be left in place for an arbitrary period and measured later, for some applications the system appears to offer several advantages over current survey technology. In cases where items have a smooth, flat surface, and it is not necessary to survey the entire surface of the object, technicians could quickly place the chambers, move on to other work, and return later to collect and measure the electrets. The system seems particularly suited to detecting contamination near the unrestricted release levels because of the (typically) long exposure time.

II. THE TECHNIQUE

The technique utilizes electret ionization chambers (EICs), which consist of a charged Teflon plate (the electret) and an electrically-conductive plastic chamber of 145 ml volume. The electret has the property of retaining an electric charge virtually indefinitely (actual voltage loss when stored with its keeper screwed on finger tight is 4

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volts/month), and is initially charged to approximately 700 volts (positive charge) by the manufacturer. Prior to performing a radiation contamination survey, the electret is placed in a surface voltage reader to read the initial voltage. The surface voltage reader can determine the voltage on the electret without affecting the surface charge.

The electret is screwed into the chamber, and the unit is placed in contact with the contaminated surface to be measured. Alpha particles entering the chamber volume ionize the air in the volume, and the negatively-charged ions are attracted to, and deposited on the electret, thereby reducing the electret's surface charge. For accurate measurements, a drop of a minimum of 30 volts is required, so depending on the anticipated contamination level of the surface being measured, the housing is left in contact, and without movement on, the surface for a few minutes to up to 48 hours. The electret is then unscrewed from the chamber, and the final voltage reading is made. The change in the surface charge is a measure of the ionization during the measurement period. The rate of change of the charge is converted into an activity using an appropriate calibration factor. The open end of the plastic chamber (approximately 3 inches in diameter) has a footprint of 48.7 cm^2. It is important to note that the contamination level as determined by the electret only applies to the footprint it "read".

An electret is capable of making many readings, each one reducing its charge, until it needs to be recharged by the manufacturer. Below a surface potential of 200 volts, the ion collection efficiency may not be optimum, and a lower response will result. Thus, the electret should not be used if it will be reduced to less than 200 volts during the exposure, so a minimum initial voltage should be 230 volts or more.

The detectors are sensitive to alpha, beta, and gamma radiation, and to radon. For measurements in mixed fields, two parallel measurements are necessary, one with a bare (or mylar) window electret and the other using a Tyvek-paper screen. The bare (or mylar) window electret response is the sum of its response to alpha, beta, gamma, and radon. The tyvek-paper screen passes gamma radiation, radon, and a significant portion of the incident beta radiation. The difference of the two readings, therefore, is the response due to alpha particles alone.

As with all air filled ionization chambers vented to atmospheric pressure, the electrets are sensitive to atmospheric pressure and temperature. Both of these variables affect the density of the air inside the electret's chamber, and therefore directly affect the number of ionizations inside the chamber. Absolute atmospheric pressure and ambient temperature measurements should be taken prior to deploying the electret and again upon retrieving the electret. The electret should be deployed in an area of relatively stable ambient temperature, if at all possible.

III. DESCRIPTION OF METHOD

A. Tests On Sources From 102 to 40 dpm

Nine different sources with nominal emission rates between 40 and 100 dpm were each measured 20 times. The sources were manufactured by depositing very small quantities of the Pu 239 onto 7/8" diameter, thin, stainless steel discs. The 0.1 N nitric acid carrier was evaporated off with a heat lamp and the residue fixed to the disk with a torch flame. Finished source activities were determined using calibrated windowless 2π gas proportional counters. Source activities refer to emission rates into a 4π geometry.

The sources were placed on a clean, painted metal shelf in a closed steel cabinet. An electret was positioned over the center of the source using the electret holder and exposed over the work day or overnight. A background reading was obtained for each period from an electret/holder placed on the shelf with no source present. Initial and final times and voltages were recorded. Voltage measurements were obtained with the supplied Surface Potential Voltage Reader (SPER) according to the procedure given in the E-Perm System Manual.

Emission rate results were obtained using Equation 1.

(1) Conversion to Activity Measurement (A):

$$A_{(dpm/100cm^2)} = \left(\left(\frac{V_f - V_i}{Time_f - Time_i} \right)_{open} - \left(\frac{V_f - V_i}{Time_f - Time_i} \right)_{fp} \right) \bullet \left(\frac{CF \bullet NL \bullet G \bullet MY \bullet (2.053)}{CAL} \right)$$

Where:

V_f	=	final electret voltage
V_i	=	initial electret voltage
$Time_f$-$Time_i$	=	elapsed time (that is, exposure time) in minutes
open	=	open, or bare electret measurement (or, if a mylar screened electret is used instead of an open electret, use the voltage and time data for the mylar electret in place of the open electret)
fp	=	Tyvek paper-covered electret measurement
CF	=	temperature and pressure correction factor
NL	=	non-linearity correction factor
G	=	geometrical correction factor (for measuring areas less than that covered by the electret, that is, < 48.7 cm^2)
MY	=	mylar attenuation factor, if mylar is used
CAL	=	isotope calibration factor in Volts/disintegration
2.053	=	area conversion factor (to convert from the area of the electret (48.7 cm^2) to 100 cm^2).

B. Tests On Sources From 21.8 to 6.4 dpm/100 cm^2

The original research described above demonstrated that there was significant potential for use of the EIC system at RFETS. To improve on this research, large area sources less than 20 dpm/100cm^2 were necessary. A source with at least the area of the footprint of the EIC would allow the elimination of the geometrical correction factor from the activity equation, and sources less than 20 dpm/100 cm^2 would conclusively show that the EIC system could be applied to surveys for the unconditional release of property from RFETS.

The large area source was made from a glazed floor tile from a lot that was known to be a Thorium-232 emitter in the 50-60 dpm/100 cm^2 range. This tile was cut into a circle the exact dimension of the EIC footprint, and was shaved on the back so that it could fit into the gas flow proportional counter. This round tile was covered with 2 layers of 0.7 mg/cm^2 aluminized mylar to reduce the alpha energy emission, thereby simulating a lower activity source. This source was then counted for 18 hours in the gas flow proportional counter (calibrated by a NIST-traceable Pu-239 source), and after applying a correction factor for the lower-energy thorium source, the activity of the tile source was determined to be 21.78 dpm/100 cm^2.

This source was then counted for exposures of 3 days each using the EIC's. The exposure of 3 days was selected to ensure at least a 30 volt drop during the measurement period. At the same time, the rest of the 12 inch square tile was marked off into grids, and was counted with other bare window and mylar window EIC's that had varying numbers of layers of the 0.7 mg/cm^2 mylar. The purpose of these other measurements was to determine quite accurately the attenuation factor of the 0.7 mg/cm^2 mylar. After 77 measurements, the mylar was found to have an attenuation factor of 1.85 per layer. This allowed tailoring the round tile source, by varying the number of layers of mylar, to a source with varying equivalent activity levels. Source activities refer to emission rates into a 4π geometry.

IV. RESULTS

A. Tests On Sources From 102 to 40 dpm

The mean, standard deviation, standard deviation of the mean, and percent error for the measurements on each source are summarized in Table 1.

Table 1

Source ID	Source dpm	Mean of Results (dpm)	Std Dev of Results (dpm)	Std Dev of Mean	% Error
601459	40 +/- 2	38.5	2.69	0.90	-3.6
600720	48 +/- 1	47.1	3.36	0.84	-2.0
600722	52 +/- 2	53.2	2.87	0.68	1.8
601484	54 +/- 2	54.2	3.75	0.87	0.4
600708	60 +/- 2	56.7	2.23	0.64	-5.5
601552	72 +/- 2	71.46	5.02	1.15	-1.2
600428	80 +/- 2	76.27	8.10	1.91	-4.7
600717	92 +/- 3	92.04	5.80	1.33	0.4
600410	102 +/- 3	99.70	8.30	1.91	-2.5

A. Tests On Sources From 21.8 – 6.4 dpm

These test are still in process, and the preliminary data shown below consists of a total of only 22 measurements.

Table 2

Source (dpm/100 cm^2)	Mean of Results (dpm/100 cm^2)	Std Dev of Results (dpm/100 cm^2)	Std. Dev of Mean	% Error
21.8	21.7	1.77	0.38	-0.5%
11.8	12.1	-	-	-
6.4	6.5	0.71	0.28	1.6%

V. CONCLUSIONS

The electret ion chamber system provides consistent, repeatable results that are, on average, within 5% of the stated value of plutonium emitting sources with nominal emission rates between 40 and 100 dpm, and large area alpha sources with emission rates between 21.8 and 6.4 dpm/100 cm^2. The performance demonstrated with this work indicates the system should receive serious consideration for approval as a tool to confirm that unrestricted use property release levels are met.

ACKNOWLEDGEMENTS

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REFERENCES

1. K.E. Meyer et. al., *Utilization of Electret Ionization Chambers for Characterization of Gross Alpha Emission from Indoor Surfaces*, Oak Ridge National Laboratory, 1994.