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# Evaluation of Electret Ion Chambers for Measurement of Surface Alpha Contamination in Preparation for SRS-LSDDP



by
S. R. Salaymeh
Westinghouse Savannah River Company
Savannah River Site
Aiken, South Carolina 29808

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# EVALUATION OF ELECTRET ION CHAMBERS FOR MEASUREMENT OF SURFACE ALPHA CONTAMINATION IN PREPARATION FOR SRS-LSDDP


S. K. Dua
Hemispheric Center for Environmental Technology
Florida International University
10555 W. Flagler Street, EAS 2100
Miami, FL 33174
(305) 348 1640

P. Szerszen
Hemispheric Center for Environmental Technology
Florida International University
10555 W. Flagler Street, EAS 2100
Miami, FL 33174
(305) 348 1821

R. Rose
Hemispheric Center for Environmental Technology
Florida International University
10555 W. Flagler Street, EAS 2100
Miami, FL 33174
(305) 348 6623

J. Boudreaux
DRS
PO Box 5298
Oak Ridge, TN 37831
(423) 241 0638

M. A. Ebadian
Hemispheric Center for Environmental Technology
Florida International University
10555 W. Flagler Street, EAS 2100
Miami, FL 33174
(305) 348 3585

C. May
Savannah River Site
Building 773-43A
Room 212
Aiken, SC 29808
(803) 725 4704

S. Salaymeh
Savannah River Site
Building 773-43A
Aiken, SC 29808
(803) 725 1628

K. Kasper
NES Scientific
504 Mary St.
Anderson, SC 29624
(864) 296 2600



## ABSTRACT

Electret ion chambers (EICs) are inexpensive, lightweight, robust, commercially available, passive charge-integrating devices for accurate measurement of different radiations. At Florida International University's Hemispheric Center for Environmental Technology (FIU-HCET), performance of EICs was evaluated with the aims of 1) providing U.S. Department of Energy (DOE) with low-cost and low-risk means of alpha contamination monitoring using an existing commercial technology and 2) demonstrating EIC performance and benefits at DOE sites (e.g., Large-Scale Demonstration and Deployment Project [LSDDP] at Savannah River Site [SRS]) and supporting D&D Focus Area and site users for its potential deployment (e.g., at Oak Ridge [OR]). Ion chambers of two types and electrets of three thicknesses were used for the study. Calibration of the EICs was performed using reference alpha standards of different energies and levels of radioactivity. Effect of various parameters, such as chamber dimensions, electret thickness, alpha particle energy, level of alpha contamination, source dimensions, Mylar window covering the chamber, and ambient radon and gamma radiation, on the response of the EICs was determined. Suitable combinations of chamber and electret to measure surface alpha contamination were determined. HCET's ceramic tile test bed (alpha activity: 33 to 125 dpm/100 $cm^2$) was used for comparative assessment of performance, cost, and risk of EIC with baseline technology.


Electret ion chambers have been used for nearly 10 years for measurement of radon and other radiations. Their application to measure alpha contamination is of recent origin. An EIC consists of an electret (a charged Teflon disk) and an ionization chamber. When the EIC with its aluminized Mylar window facing down is placed on the contaminated surface, alpha radiation from the surface enters the chamber through the window and causes ionization in the chamber air volume. The negatively charged ions formed in the air are attracted to the surface of the positively charged electret, causing reduction of its surface voltage. Such a change in voltage is measured using a portable electret voltage reader. The rate of change of the electret voltage is used with appropriate algorithms to calculate the alpha contamination in units of dpm per 100 $cm^2$. Measurement of alpha contamination involves use of one voltmeter and a large number of inexpensive EICs. These EICs, with recorded initial voltage, can be simultaneously deployed for measurement of alpha contamination in a large facility and picked up for final reading after a predetermined exposure period. The results of study show that the exposure time (varying from minutes to days) depends on the electret-chamber combination used and the level of surface alpha contamination. Since the EIC is a passive, charge-integrating device, the chambers are placed and left in the field. A surveyor's time is not tied up actually taking the measurement. This frees the surveyor to conduct other tasks. Thus, the EIC method for surface alpha contamination measurement provides saving on the labor cost and personal radiation exposures as compared with the baseline technology, which involves holding scintillation or proportional counting-based survey meters in the field during the period of measurement.

DOE has requirements of low-cost and low-exposure measurement of low levels of alpha contamination on surfaces after deactivation. Since EIC has been demonstrated to meet these requirements, and since it is an existing commercial technology, the 321-M LSDDP at SRS has planned to use EICs to quantify levels of enriched uranium on surfaces within the surplus building. The successful demonstrations at SRS will enable the EICs to be deployed at other DOE sites. Rocky Flats is considering using these as tools to confirm that, for unrestricted-use property and buildings, release limits are met. FIU-HCET has prepared a test plan for tests and deployment of the EICs at K-1420, East Tennessee Park, Oak Ridge.

## I. INTRODUCTION

As a part of an environment remediation campaign of its nuclear facilities and free release of its properties, the DOE requires cost-effective technologies for measuring low-levels of alpha contamination. At present, surface alpha contamination is measured by hand-held alpha detectors or by wipe test. In wipe test, a known area of the surface is wiped with a filter paper, which is subsequently counted in a counter. This test gives information about the transferable contamination only. Hand-held alpha survey meters are difficult to use on floors, particularly when large areas are to be surveyed and when contamination level is low. Since the technician's time is tied up in making measurements, the technician is not effectively utilized during the time measurements are performed with the survey meters. These measurements also expose technicians to radiations during measuring times. Electret ion chambers (EICs) are an alternate technology for measurement of surface alpha contamination. The EIC is a passive, charge-integrating device. Its integrating property enables it to collect ions produced by alpha radiation over a long time and hence detect very low levels of alpha contamination. The chambers are placed and left in the field. A surveyor's time is not tied up actually taking the measurement. This frees the surveyor to conduct other tasks. Thus, the EIC method for surface alpha contamination measurement provides saving on labor cost and personal radiation exposures as compared with the baseline technology, which involves holding scintillation or proportional counting-based survey meters in the field during the period of measurement.

Electret ion chambers have been used for measurement of radon and other radiations for nearly 10 years. Their application for measuring alpha contamination is of recent origin.[1-5] An EIC consists of an electret (a charged Teflon disk) loaded inside an ion chamber. The electret serves as a source of electrostatic field and collects ions produced by alpha (or any) radiation in the chamber air which reduce the surface charge (voltage). The voltage is measured using a portable volt reader. The rate of reduction of the voltage gives a measure of alpha radiation intensity. EICs are available with chambers in two volumes, 145 ml and 960 ml. Electrets of three thicknesses are commercially available. Thus, six configurations of EIC are possible. Meyer et al.[1] have characterized the 145-ml chamber for surface alpha contamination. Meacham et al.[5] have tested the performance of 145 ml chambers at Oak Ridge. Dua et al.[3] have studied the influence of various factors, namely electret voltage, chamber dimensions, electret thickness, chamber-electret combination, Mylar window, alpha energy, location of contamination, contamination levels, and effect of gamma and radon backgrounds, on the response of the EICs. Dua et al.[4] have also performed comparative assessment of EICs and baseline technology (a 100 $cm^2$ ZnS(Ag) alpha probe) at the FIU-HCET test bed.

The demonstration of the EICs at the 321-M SRS is scheduled for summer 1999. The baseline technology is hand probing with an alpha scintillation probe for total contamination and hand swipes for removable contamination. An EIC will be placed adjacent to the spot where alpha measurements with a probe and swipes are taken so a direct comparison can be made. The present study presents comparative assessment of total alpha contamination on an FIU-HCET test bed performed by side-by-side measurements with EICs and an alpha probe. The study also compares the results of measurements performed with EICs and an alpha counter on wipes taken from the FIU-HCET radiological laboratory.

## II. FIU-HCET TEST BED

Ceramic floor or wall tiles, commonly used in bathrooms, toilets, and kitchen, have been reported to contain zircon,[6] which contains naturally occurring radioactive materials thorium and uranium. These materials, including their decay products, decay by emission of alpha, beta, and gamma radiations. These tiles can serve as large-area alpha calibration sources if it could be demonstrated that they have uniform surface-alpha emission rate. Test beds of different types of tiles were set up at FIU-HCET (Figure 1). Electret ion chambers (EICs) and a large-area alpha detector probe were used for measurement of alpha contamination. Measurements made with 100 $cm^2$ area alpha probe show that FIU-HCET ceramic test bed tiles have uniform alpha emanation over the entire cross-sections of the tiles (type A: 33-cm x 33-cm; type B: 40-cm x 40-cm), thus confirming HCET's configuration as an excellent, inexpensive, large-area radioactive test bed for evaluation, comparative assessment and calibration of instruments.

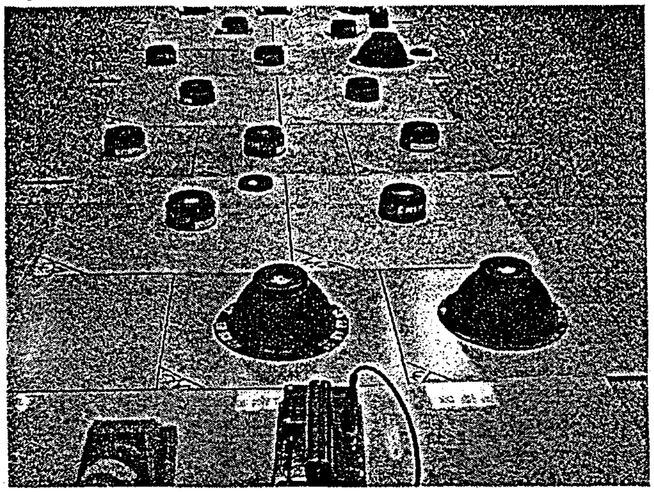

Figure 1. FIU-HCET Test Bed

Calibration of the EICs was previously performed using reference alpha standards of different energies and radioactivities. Two measurements were performed on a tile, one with a Mylar window (density thickness: 0.8 mg $cm^{-2}$) and another with a Mylar and Tyvek window (density thickness: 7 mg $cm^{-2}$). The first reading gives the contribution of alpha and beta-gamma radiation, whereas the second reading gives the beta-gamma contribution. The difference between the two readings (net change in volts per minute) is converted into alpha contamination using a suitable algorithm.[3] Table 1 shows the results of measurements performed with EIC and alpha probe for three types of tiles. From these measurements and alpha probe readings the following observations are made:

* Tiles of a particular make have uniform contamination and can serve as test beds for calibration of instruments.
* Different types (makes) of tiles have different surface alpha activity. Thus, it is possible to have sources of various fixed alpha contamination levels needed for instrument calibration.
* The measurements performed with EICs are comparable with those made using an alpha probe from Ludlum Measurements, Inc.

The following conclusions can be drawn from these observations:

* Ceramic tiles can serve as fairly uniform, inexpensive, large-area, fixed contamination test beds for calibration of instruments, unlike conventional calibration sources, which are expensive, not easily available in desired large geometries, require radioactive material license, and are subject to deterioration due to improper handling.
* EICs are easy-to-use devices for accurate measurement of low-level alpha contamination.

Table 1. Comparative Assessment of Alpha Contamination on Tiles

| Description of Tiles | Alpha contamination (dpm/ 100$cm^2$) | |
|---|---|---|
| | Alpha Probe | EIC |
| White 33 cm x 33 cm Décor Vitro Tiles | 126.27 ± 2.04 | 122.43 ± 13.80 |
| Beige Marble 40 cm x 40 cm (Prima) Stylnu Tiles | 59.01 ± 2.05 | 65.88 ± 12.06 |
| White 30 cm x 30 cm Tiles | 36.98 ± 3.20 | 33.22 ± 7.56 |

## III. LARGE-SCALE DEMONSTRATION AND DEPLOYMENT PROJECT (LSDDP) AT SAVANNAH RIVER SITE (SRS)

The purpose of the LSDDP is to locate and quantify alpha-emitting surface contamination in the form of highly enriched uranium (HEU) on selected 321-M Facility surfaces including floors and equipment.

The baseline technology at SRS makes use of an alpha scintillation probe (50 $cm^2$ probe surface) for direct readings (fixed plus removable alpha contamination). Levels of removable contamination are determined using 100 $cm^2$ swipes in conjunction with a gas flow proportional swipe counter. The electrets will be demonstrated side-by-side with the baseline readings by hand probes and swipes.

Prior to placing the electrets for measurement, a predetermined exposure time will be set for the area being surveyed. The electret will be placed at the measurement location when the baseline measurements are made. After the exposure period, electrets will be removed, voltage readings taken, and contamination levels determined. To account for beta, gamma, and radon contribution, another reading with Tyvek window will be taken and its contribution will be subtracted from the first reading, as described earlier. EIC-measured alpha contamination will be compared to the adjacent baseline measurements.

Surface alpha activity measurements will be made in several areas and on components to be released. Current release criteria, specified by the DOE's Radiological Control Manual, is 1000 dpm/100 $cm^2$ for removable uranium contamination and 5000 dpm/100$cm^2$ for total (fixed + removable) uranium contamination. The EICs integrate (sum) activity and can not distinguish between fixed and removable contamination. To be conservative, EIC measurements will be treated as removable levels of contamination. However, if the surface area under the EIC is determined to meet the removable contamination limit, it will also meet the requirement for fixed activity. The EIC system will be used to verify measurements acquired through baseline monitoring processes. It is expected that EIC measurement will provide alpha contamination levels comparable with those obtained from alpha probe. Further, EIC measurements are expected to be equal or greater than the removal contamination values obtained from wipe counts. If measurements show that EIC values are at least equal to those obtained from wipe counts, and these are less than 1000 dpm/100 $cm^2$ for uranium, then the area will be considered to meet the release limit for removable contamination.

To add credibility to EIC performance, the following measurements are desired:

- Demonstration of comparable results of alpha contamination levels between EIC and alpha probe on large areas. This was shown to be valid from the measurements on tiles (Table 1).
- Demonstration of comparable results on wipe samples taken from radioactive area and measured with EICs and alpha scintillation counter or gas flow proportional counter. This will be shown following.

The following considerations apply with respect to alpha contamination measurements on wipes:

- For performing a comparison of removable contamination, wipes should be counted in a standard counting setup, such as gas flow proportional counter or ZnS (Tl) scintillation counter measuring only alpha radiation. The same wipe should be measured with an electret ionization chamber. Since response of the EIC depends on the position of the source of radiation (contamination) and since wipe samples are usually smaller in area (< 4 $cm^2$) than the area of the EIC window (48.5 or 180 $cm^2$), the wipe should be placed in line with the chamber center and appropriate calibration factor[3] should be used for this position.

- Response of the electret depends also on the energy of alpha radiation, which means the source of radiation should be known and an appropriate calibration factor[3] should be used. These calibration factors are presented in Table 2 for 1.524 mm thick electrets, called short-term (ST) electrets, loaded in 960 ml chamber having 0.8 mg $cm^{-2}$ aluminized Mylar window. This table shows responses of the EIC for different alpha sources placed in line with the chamber centerline. It also shows the ratio of the response for uniformly distributed large area alpha source to that of a small source at the chamber base center.

Using this table, an EIC initially calibrated for a large area source can also be used for small area sources, such as wipe samples.

Comparative assessment was done at FIU-HCET by collecting wipes from its radiological laboratory (K-65 silo material) by using factors appropriate to wipe sample dimensions. Table 3 gives the results. There is agreement between the EIC and alpha probe readings. The EIC/Alpha probe ratio is >1, mainly because two EIC readings were significantly higher and because the contamination on the filter was from radionuclides with mean alpha energy of about 4.96 MeV and the calibration factor corresponding to Np-237 (alpha energy = 4.79 MeV) was used. The difference between alpha energies should account for nearly a 4% difference in the ratio.

Table 2. Response of ST electret in 960-ml chamber having 0.8 mg $cm^{-2}$ Mylar window for different alpha energy sources; source centers aligned with chamber centerline; ratio of the response of uniformly distributed source of size equal to or greater than the chamber window at the chamber base to that of small area source at the chamber centerline

| MPV | Response (mV/disintegration) | | | | Ratio of the response for uniformly distributed source to that in line with centerline |
|---|---|---|---|---|---|
| | Source center aligned with chamber centerline | | | | |
| | Np-237 | Pu-239 | Am-241 | Cm-244 | |
| 750 | 0.542 | 0.640 | 0.726 | 0.814 | 0.682 |
| 700 | 0.536 | 0.631 | 0.717 | 0.804 | 0.677 |
| 650 | 0.529 | 0.621 | 0.709 | 0.793 | 0.672 |
| 600 | 0.523 | 0.611 | 0.699 | 0.782 | 0.666 |
| 550 | 0.515 | 0.600 | 0.689 | 0.769 | 0.659 |
| 500 | 0.507 | 0.588 | 0.677 | 0.755 | 0.651 |
| 450 | 0.498 | 0.574 | 0.665 | 0.740 | 0.643 |
| 400 | 0.488 | 0.559 | 0.651 | 0.723 | 0.632 |
| 350 | 0.477 | 0.542 | 0.635 | 0.704 | 0.620 |
| 300 | 0.463 | 0.522 | 0.617 | 0.682 | 0.605 |
| 250 | 0.448 | 0.499 | 0.595 | 0.656 | 0.586 |
| 200 | 0.429 | 0.470 | 0.568 | 0.623 | 0.561 |

## IV. COST COMPARISON WITH BASELINE TECHNOLOGY

Table 4 shows a comparison between the features of EIC and the baseline technology. It also shows a comparison between the capital cost and the cost per measurement, as well as risk from the radiation exposure. Measurements were performed on FIU-HCET test beds. A SPER1 electret voltage reader was used for reading electret voltage. This reader is a manual reader, which means initial and voltages as well as exposures times are manually recorded. SPER2 reader stores these in memory. Every reading was also manually recorded with alpha contamination monitor. Use of programmed readers such as SPER2 will save time on recording the data. Time for reading initial and final voltages, loading into chamber, deploying EIC for measurement, removal and recording the data was approximately 3 minutes per measurement averaged over 200 measurements. Work with EICs can be started in the afternoon, electrets deployed by the end of the day and picked up the next day for final measurements. Alpha measurements with alpha probe require nearly 10 minutes (time will depend on the alpha contamination level and accuracy desired). Nearly two minutes per measurement are needed for covering the unit to avoid contamination, deploying, and taking the reading. The technician gets fatigued after a doing monotonous and non-challenging job. The additional time spent (~ 9 min. per measurement) in a radioactive environment exposes the technician to radiation level, which is usually small— a small fraction of a mR/h.

## V. DISCUSSION

An Electret Ion Chamber (EIC) is a simple, inexpensive, easy-to-use technology for accurate measurement of surface alpha contamination. It requires only one reader and a large number of electrets and chambers for making a large number of simultaneous measurements. It is light-weight (~ 150 g maximum weight for 960-ml chamber) and can be placed flush with any surface (floor, walls, ceiling, etc.) using an adhesive tape. It can easily be decontaminated and damage of Mylar due to uneven surfaces does not affect its performance. The main advantage of the EIC is that it can be left in place unattended for measurement thus freeing the technician for other jobs. The technician does not get fatigued making measurements. Its measurement performance is comparable with the baseline technology. The results of the study show that the EIC is a mature technology for demonstration at the SRS-LSDDP and deployment at Oak Ridge and other DOE sites. The EIC system is completely safe. No hazardous materials are employed in the process.

Table 3. Comparison of EIC and Alpha Counter on Wipes

| Alpha Contamination dpm/ 100 Sq cm | | | Ratio EIC/Alpha Probe | |
|---|---|---|---|---|
| Alpha probe | EIC 145mL | EIC 960mL | 145 mL/Alpha Probe | 960mL/Alpha Probe |
| 125.84 | 177.36 | 148.19 | 1.41 | 1.18 |
| | 118.03 | 149.75 | 0.94 | 1.19 |
| | 171.26 | | 1.36 | |
| 141.38 | 149.17 | 179.33 | 1.06 | 1.27 |
| | 148.07 | 178.40 | 1.05 | 1.26 |
| | 146.70 | | 1.04 | |
| 241.37 | 306.54 | 248.81 | 1.27 | 1.03 |
| | 294.04 | 246.89 | 1.22 | 1.02 |
| 237.86 | 269.43 | 242.03 | 1.13 | 1.02 |
| | 261.53 | 237.27 | 1.10 | 1.00 |
| | Average Ratio | | 1.16 | 1.12 |
| | Std. Dev. | | 0.15 | 0.12 |

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Table 4. Comparison between Baseline Technology and EIC Technology

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**<u>Baseline Technology</u>**<br>
**Alpha Probe and Scaler**

<u>Description</u>

- Hand-held alpha monitors: gas flow/filled proportional counters, scintillation counters. These are sensitive instruments for detection of low levels of alpha contamination. Measurement time (for instrument with a scaler) depends on the level of alpha contamination and accuracy desired. The technician needs to be present for each measurement.
- Floor monitors have low sensitivity.
- Wipe test gives measure of transferable contamination only.

<u>Alpha measurement constraints</u><br>
Alpha particles small range (~ 5 mg cm$^{-2}$, i.e., ~4 cm in air or ~0.004 cm in tissue/paper). So, the detector window must be thin, and the detector should be placed in close contact with floor. This may result in contamination/ damage/ puncture/ of the detector window.

<u>Measurement accuracy</u>

- Comparable with that of EIC

<u>Cost</u><br>
Capital Cost:<br>
Cost per unit: ~ $ 1,600.<br>
Cost of 200 units: $ 320,000, if simultaneous readings are desired.<br>
Cost of 2 units: $ 3,200, two persons making measurements

- Cost per Measurement: $ 3.75

Labor Cost: $ 3.75<br>
Time needed for deployment, entering data and removal for 200 measurements = 400 min<br>
Measurement time for 10 min. reading = 200 x 10 min = 2000 min<br>
Total time for 200 measurements = 2400 min. = 40 hours ~ 5 person.days ~ $ 750 = $ 3.75 per measurement

<u>Risk:</u><br>
Extra exposure time per measurement in field: 9 min., for 200 measurements: 30 h

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**<u>Electret Ion Chamber Technology</u>**<br>
**EIC and Reader**

<u>Description</u>

- EIC is a passive charge integrating measurement device. Measurement time depends on the chamber-electret configuration used, the level of contamination and the accuracy. Electrets can be placed on surface (floor, walls, etc.) for long time and picked up after known exposure time.
- EIC measures total alpha contamination.

<u>Alpha measurement constraints</u>

- Reusable chamber, chamber rim can be decontaminated.
- Not affected by puncturing/ damage of Mylar

<u>Measurement accuracy</u>

- Comparable with that of alpha probe

<u>Cost</u>

- Capital Cost:<br>Cost per unit: < $ 3000 (Reader + EICs)<br>Cost of 200 units: < $ 15,000.<br>(1 reader + 200 EICs)
- Cost-per-Measurement: $ 2.50
- Labor cost: $ 1.50<br>2 technicians (@ $ 150 per person per day) perform 200 measurements per day.<br>Cost of 200 measurements = $ 300<br>(Time needed for initial voltage reading, deployment, removal, final reading per measurement = 3 min )
- Electret Cost: < $ 1.00 per measurement.

Cost saving ~ $ 1 per measurement over baseline technology

<u>Risk:</u><br>
Less time spent in radioactive area, less personnel exposures

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