

KOTRAPPA

(E) III-P1-3 (Summers) B-III-1 (E-Risk) EPA/600/9-90/005b January 1990 B-IV-5 (Hopper)

United States
Environmental Protection
Agency

Air and Energy Environmental
Research Laboratory
Research Triangle Park NC 27711

EPA/600/9-90/005b
January 1990

Research and Development



The 1990 International Symposium on Radon and Radon Reduction Technology: Volume II. Preprints

Session III: Radon Measurement
Methods

Session III-P1: Panel Session on
QA/QC of Measurement

Session III-P2: Panel Session on
Short-/Long-term Radon
Measurements

Session B-III: QA/QC of
Measurement—POSTERS

Session B-IV: Short-/Long-term
Radon Measurements—
POSTERS

February 19-23, 1990
Stouffer Waverly Hotel
Atlanta, Georgia

AN E-RPISU (ELECTRET RADON PROGENY INTEGRATING SAMPLING UNIT)
A NEW INSTRUMENT FOR MEASUREMENT OF RADON PROGENY CONCENTRATION IN AIR

by: P. Kotrappa, J. C. Dempsey, L. R. Stieff and R. W. Ramsey
Rad Elec Inc.
5330 J Spectrum Drive
Frederick, MD 21701 USA

ABSTRACT

A RPISU (radon progeny integrating sampling unit) is a generic name given to instruments which collect radon progeny on a filter paper and register the alpha radiation from the deposited progeny during the entire period of collection. An E-RPISU is a variation of this device with an electret located in an electret ion chamber serving as a sensor for registering the ions created by the alpha radiation. A conventional low-flow rate air sampling pump is used to collect the progeny on a one-inch diameter filter which is mounted on the side of the electret ion chamber (220 mL) such that the collected progeny ionizes the air inside the chamber. The negative ions are collected by a positively charged electret (0.127 mm thick) causing the electret voltage to drop. The electret voltage drop which occurs during the sampling period is proportional to the time integrated progeny concentration. The calibration factor for E-RPISU ranged from 1.2 to 1.6 V per mWL-day when sampled at 1 liter per minute. The calibration procedure and the performance of these devices are discussed. These devices have the sensitivity needed for indoor radon progeny measurements.

INTRODUCTION

It is known that the radiation dose to the lungs is almost entirely due to the inhalation of the particulate radon daughter products. These daughter products deposit in the airways of lungs and irradiate the basal cells of tracheobronchial and pulmonary epithelia. These cells receive dose not only from the deposited progeny but also from the alpha emitted by the daughter products formed after the deposition. This led to the concept of relating the inhalation hazard to the ultimate or the potential alpha energy concentration in working level units (WL). One WL is defined as the potential alpha energy concentration of the decay products of radon equivalent to 135,000 MeV per liter of air. Evans (1) has shown that one WL also corresponds to 16844 alpha from progeny contained in one liter of air.

The radon progeny integrating sampling unit (RPISU) is an instrument designed to measure the radon progeny concentration in WL units. These units collect the radon progeny on an air sampling filter paper. The alpha radiation is registered not only during the entire period of collection but also three hours after cessation of sampling. This data along with the volume of the sample collected can readily be converted into the progeny concentration in WL units. RPISU units have been reported which use thermoluminescent dosimeters, alpha track detectors and solid state detectors. Their sensitivities are restricted by the fact that (a) the detectors are small and must be located close to the filter within the range of alpha radiation and (b) the area of filter paper is limited by the size of the detectors.

An electret is a piece of dielectric material carrying permanent electrical charge. Its effective surface charge decreases only by the collection of ions from the ambient air. An electret ion chamber is simply an electrically conducting plastic chamber containing a charged electret located at the bottom of the chamber. Electret ion chambers and their successful use as a passive environmental radon monitor has been described fully (2,3). An E-RPISU uses an electret ion chamber configuration to register the ions produced by the alpha radiation emitted by the progeny collected on the filter paper. The restrictions mentioned in the earlier paragraphs do not apply to these devices. The filter area could be large allowing a low cost pump to be used without worrying about the pressure drop. The detector (electret) need not be in the immediate vicinity of the filter. The chamber size can be relatively large.

The scientific basis of this type of RPISU was first established by Kotrappa(4). His goal was for determining the progeny concentrations in mine atmosphere during a short period of sampling. The key for the application of the devices for long duration integration required for indoor monitoring was the recent development of very stable electrets (2,3).

DESIGN FEATURES OF E-RPISU

Figure 1 shows the design features of an E-RPISU. A standard one-inch filter head is fitted to the side of a standard electret ion chamber (2,3). Small openings (2 mm diameter) are provided for air entry. A spring-loaded electret cover is used to cover the electret when the E-RPISU is either in storage or in transit. The left half of the figure shows the electret closed position and the right half shows the electret open position. The filter head is connected to a pump with a flowmeter. An alternate way is to use a pump with a calibrated critical orifice.

OPERATION OF E-RPISU

The initial surface voltage of the electret is measured using an electret surface potential voltmeter (2,3). It is fitted into the bottom of the chamber. The device is placed at a location where measurement has to be

doi
sc
th
Aft
pos
the
be
lab
fin

E-R
CH.
clo

FLOW
AND F

Figur

T
proge
in a
all o
were
proge
electr
additi
were
dropp
follow

where

done. Bring the E-RPISU chamber to the open position by unscrewing the top screw cap (Figure 1). Turn on the power to the air sampling pump. Note down the time and date of the start of the pump. Note down the air flow rate. After the desired period of sampling, bring the E-RPISU chamber to a closed position (Figure 1). Note down the final air flow rate, time and date. Stop the pump. The final surface voltage of the electret is measured. This can be done either at the place of measurement or after taking the device to the laboratory. The data to be noted are: (a) initial electret voltage, (b) final electret voltage, (c) air sampling duration, (d) the average flow rate.

E-RPISU™

Electret-Radon Progeny Integrating Sampling Unit (Schematic)

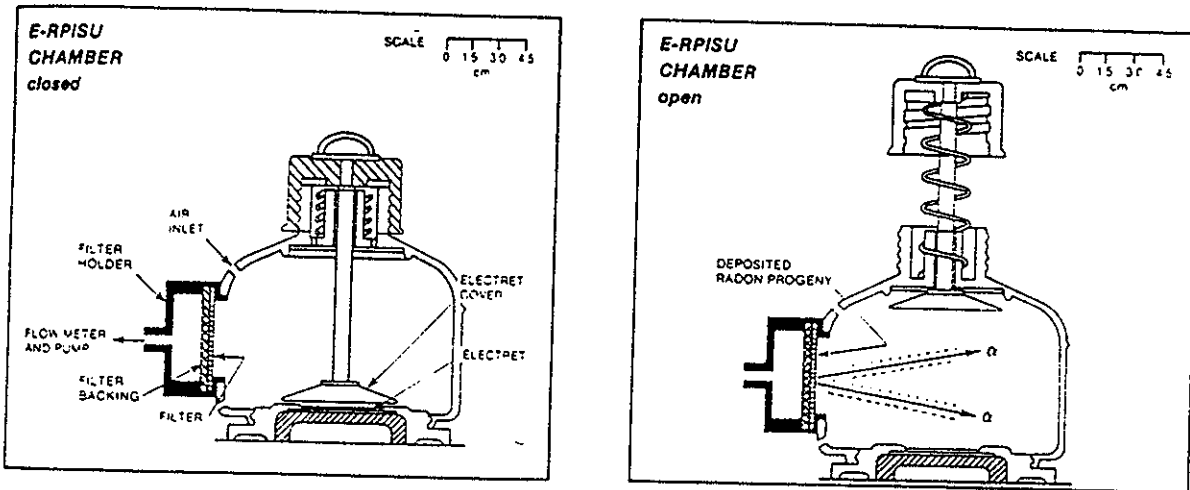


Figure 1. Schematic of the electret radon progeny integrating sampling unit.

CALIBRATION OF E-RPISU

The E-RPISU unit has to be calibrated in a standard chamber where the progeny concentration is precisely known. Most of the work was carried out in a well calibrated QC chamber (5). A set of three E-RPISU units were used, all of them with a starting initial electret voltage of about 750 V. These were run for a period of one day with a flow rate of 1 liter per minute at a progeny concentration of about 0.075 WL or 75 mWL. The final voltages of the electrets were recorded after allowing the registration of ions for an additional period of three hours after cessation of the sampling. Experiments were continued for several days until the final voltages of the electrets dropped to about 150 V. The calibration factors were determined using the following equation (1):

$$PC = (IV - FV) / (CF \times F \times D) \text{ --- (1)}$$

where PC is the progeny concentration in mWL
 IV is the initial voltage of the electret
 FV is the final voltage of the electret

F is the flow rate in liter per minute
 D is the duration of sampling in units of days
 CF is the calibration factor

Figure 2 shows such a calibration curve. The CF is on vertical axis and the average of the initial and final voltages of each measurement (also called the midpoint voltage or MPV) is on the horizontal axis. Equation (2) is a linear regression equation relating CF and MPV. The correlation coefficient is 0.89.

$$CF = 1.0744 + 0.000685 \times (MPV) \quad \text{--- (2)}$$

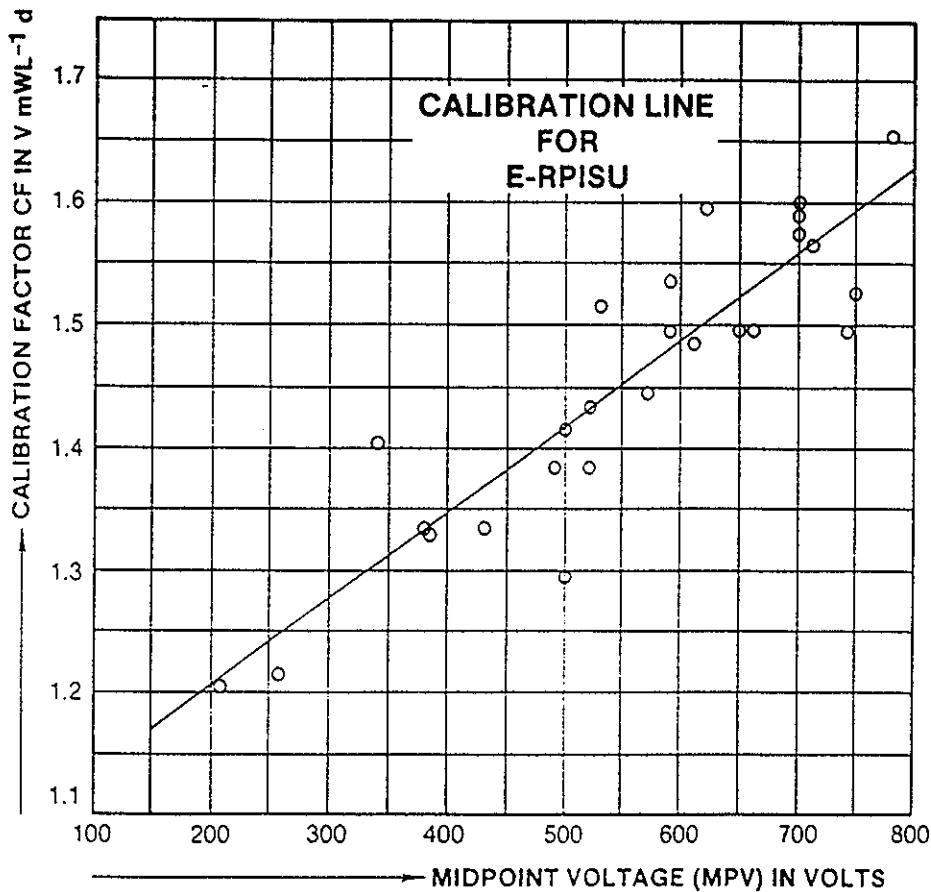


Figure 2. Calibration line for electret progeny integrating sampling unit. The air sampling rate is 1 liter per minute.

PROCEDURE FOR ACTUAL MEASUREMENT

In practice it is not always convenient or possible to wait an additional three hours after the cessation of the sampling for the registration of the alpha radiation of the tail end. It is possible to apply

a correction for this part. If DV is the voltage drop over a sampling period of DT days, then the average rate of change of voltage is DV/DT, which can be taken as constant and hold good at the end of sampling. Then the total expected tail-end voltage drop (TD) during the tail-end portion is given by equation (3).

$$\begin{aligned} TD &= (DV)/(DT) \times \exp(-\lambda t) dt \\ &= (DV)/(DT) \times 0.03 \quad \text{--- (3)} \end{aligned}$$

where λ is the decay constant for the deposited radon progeny is about 33.3 per day. This is arrived at by assuming the half-life of the deposited progeny as about a half-hour or 0.0208 days.

Therefore, the total corrected voltage drop (CDV) is given by equation (4).

$$CDV = DV + (DV)/(DT) \times 0.03 \quad \text{--- (4)}$$

Let us assume the following values for a typical measurement:

IV=700 V; FV=650 V; DT=1.25 days; F=1.00 liter per minute.

Calculated parameters are:

MPV=675 V; CF=1.537; DV=50 V; CDV=51.2 V.

Result is:

$$\begin{aligned} PC &= 51.2 / (1.537 \times 1.25 \times 1.00) = 26.6 \text{ mWL} \\ &= 0.0266 \text{ WL} \end{aligned}$$

The average radon progeny concentration is 0.0266 WL.

Note that FV is the final voltage measured without waiting for the registration of tail-end ionization.

PERFORMANCE TEST

The performance of this device has been tested by the U.S. Environmental Protection Agency as part of the services provided by them for a new device. A unit was sent by mail to the EPA evaluation branch in Las Vegas and was evaluated at different progeny concentrations, at different humidities and at different condensation nuclei counts. The report concluded that the instrument gave a satisfactory performance and a measurement was never more than 12% off from the chamber value (6).

Two radon measuring companies entered the U.S. EPA (RMP6) program with these devices for single blind testing. The E-RPISU units were sent and received by mail. Measuring companies sent their results to the EPA where these results were compared to the chamber values. Table-1 gives these

results. The absolute value of relative errors were in the range of about 5%, much better than the EPA requirement of 25%.

As part of the international intercomparison study (blind test) conducted by the Department of Energy Environmental Measurements Laboratory (DOE-EML), four E-RPISU units were entered. Results are also shown in Table-1. As can be seen the absolute value of the relative errors were in the range of 2% to 3%.

TABLE-1. PERFORMANCE EVALUATION OF E-RPISU

E-RPISU RESULTS OF SINGLE BLIND TEST CONDUCTED BY EPA-RMP-ROUND 6 (1989)*				
Company Code	Detector Number	Measured Value (MI)	Target Value (TI)	Absolute Value of Relative Error [(MI-TI)/TI]
HJTLJ RP	793975	0.029	0.031	0.065
	793976	0.031	0.031	0.000
	793977	0.000	0.000	Blank
	793978	0.033	0.034	0.029
	793979	0.031	0.034	<u>0.088</u>
			Mean	0.0455
HFMEH RP	883570	0.030	0.031	0.032
	883571	0.045	0.047	0.043
	883572	0.049	0.044	0.114
	883573	0.000	0.000	<u>Blank</u>
				Mean
SINGLE BLIND TEST CONDUCTED BY DOE-EML (NEW YORK) AS PART OF INTERNATIONAL INTERCOMPARISON (1989)*				
RTI	571	0.136	0.137	0.007
	610	0.144	0.137	0.051
	547	0.135	0.137	0.015
	603	0.134	0.137	<u>0.021</u>
			Mean	0.024

* NOTE: These results are in the process of publication by the U.S. EPA and DOE-EML, respectively.

ERROR ANALYSIS

There are two sources of possible error. One is the random error associated with the dimensional variations, flow rate variations and other system errors. As seen from the performance (Table-1), this appears to be small and can be taken as about 5%. This was confirmed by running a large number of units in the same location. Another error is in the measurement of surface voltages. The measurement can be done only to within an accuracy of 1 V. When a difference between the two measurements is taken, as is always the case, the expected error is 1.42 V (square root of 2). This error can be substantial if the total measured voltage difference is small. Let us sample for one day at a concentration of 5 mWL at a flow rate of 1 liter per minute. The expected voltage drop is about 7.5 V, and the error in voltage measurement itself is 19%. This combined with the system error using the principle of quadrature comes out to be about 20%. This error can be reduced by sampling for a longer period or by sampling at a higher flow rate. Similarly at a concentration of 20 mWL, the error is about 7%.

SHORT DURATION MEASUREMENT

If one wishes to make a short-duration measurement -- less than one day -- then it is necessary to allow the tail-end portion of the ionization to be registered by allowing a delay of at least three hours. The correction equation (4) becomes less accurate.

It is possible to increase the sensitivity of the device by using a different electret of larger thickness (2,3). If another available 1.524 mm thick electret is used, the sensitivity is increased by a factor of 11. If a short duration sampling is desired at a low concentration, then this electret can be used in the same way. The CF will be 11 times the CF computed by using the equation (2).

DYNAMIC RANGE AND ECONOMICS

The electret can be used down to a surface voltage of about 150 V. The calibration factor does not hold good thereafter. The upper limit of the surface voltage is about 750 V (2,3) in the chamber used in this work. This leaves a headroom of 600 V. Therefore, an E-RPISU goes out of range when the total sample exceeds about 400 mWL-day. This corresponds to a sampling time of 20 days at a concentration of 20 mWL. In other words, one can use one electret for about 20 measurements in the case considered.

DISCUSSION

From the results of blind tests, it can be seen that the E-RPISU can be used to make an accurate measurement of radon progeny concentration. The units can be used as a mailable unit similar to the other passive monitors such as charcoal detectors or E-PERMs. Electret ion chambers are known to give good performance even at extreme temperatures and humidities encountered

in the indoor environment.

The electrets and the measuring device used with standard E-PERM radon monitors (2,3) are usable with the E-RPISU and hence, at a modest additional cost, it can be a useful addition to the laboratories already using E-PERMs.

The electrets have to be handled with some care which is described in our earlier work (2,3). Proper air flow calibration has to be ensured as is the case with other RPISU units.

Kotrappa et al (4) have described how these devices can be used to measure both radon and thoron progeny concentrations. Further, a method is also presented (4) to measure the effective radon progeny concentration taking into account the contribution from the thoron progeny. That methodology is equally applicable to the present instrument.

Pr
Ag

AC
re
ava
th

1.
dau

2.
ele
mea

3.
prac
Acc

4.
Meas
dau
1983

5.

6.
elec

8

ACKNOWLEDGEMENTS

The work described in this paper was not funded by the U.S. Environmental Protection Agency, and therefore the contents do not reflect the views of the Agency and no official endorsement should be assumed.

The work was performed under partial support under DOE Contract No. DE-AC07-861D12584 for the U.S. Department of Energy, Grand Junction. A detailed report (DOE/ID/12584-UNC/GJ-TMC-5, May 1989) on the developmental work is available as a publication from the U.S. Department of Commerce. We are thankful to Mrs. Lu Markland for editorial assistance.

REFERENCES

1. Evans, R. D. Engineers guide to the elementary behavior of radon daughters. Health Physics 17:229, 1969.
2. Kotrappa, P., Dempsey, J. C., Hickey, J. R. and Stieff, L. R. An electret passive environmental 222-Rn monitor based on ionization measurement. Health Physics 54:47, 1988.
3. Kotrappa, P., Dempsey, J. C., Ramsey, R. W and Stieff, L. R. A practical passive environmental monitor for indoor radon measurement. Accepted for publication in Health Physics 1990.
4. Kotrappa, P., Dua, S. K., Gupta, P. C., Pimpalle, N. S. and Khan, A. H.. Measurement of potential alpha energy concentration of radon and thoron daughters using an electret dosimeter. Radiation Protection Dosimetry 5:49, 1983.
5. QC chamber. Operated by Radon QC, Palmer, PA 18043 USA.
6. Personal communication from Richard Hopper. Operational evaluation of electret radon progeny integrating sampling unit. Feb 1989.