PASSIVE E-PERM RADON FLUX MONITORS FOR MEASURING UNDISTURBED RADON FLUX FROM THE GROUND

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ABSTRACT

The measurement of radon flux (radon emanated from a unit surface area per unit time, expressed in pCi $m^{-2}sec^{-1}$) from the ground or other surfaces without interfering with the physical nature of the soil or the surface is of interest for several practical applications: (1) to determine the radon emanating potential of the ground at a building site, (2) to meet the EPA compliance limits of radon flux at uranium mill tailings piles or phosphogypsum stacks, and (3) to determine the radon flux from the building materials and other surfaces. The passive radon flux monitor consists of 1000 ml volume vented electret ion chamber (EIC) with a 180 cm^2 electrically conducting Tyvek widow. The principle of passive flux measurements, the calibration. the applications, and sensitivities are discussed.

INTRODUCTION

The measurement of radon flux from the ground or other surfaces is useful (a) for determining the radon emanating potential of a building site, (b) to meet the regulatory requirements for uranium mill tailings or phosphogypsum stacks, and (c) to determine the radon flux from building materials such as bricks, concrete and other surfaces. A dynamic, flow through method using E-PERM electret ion chambers has been described (Ref: 1, 2, and 3). This method consists of measuring equilibrium radon concentration inside an inverted, rectangular basin placed on the surface of the ground where flux needs to be determined. The equilibrium radon concentration depends upon the air flow rate, the radon flux and the open area of the basin and requires the operation of a pump and the measurement of the air flow rate. The time averaged equilibrium radon concentration is measured. This method has been successfully used in several projects requiring precise radon flux measurements. The dynamic method is not always easy in the field. The purpose of the current work is to develop a passive flux monitoring electret ion chamber that can be used in the field without any need for an air pump. However, such passive flux monitors require calibration whereas the dynamic method is based on first principles and does not require calibration.

THE PASSIVE FLUX MONITOR

The E-PERM H electret ion chamber has been modified to feature a large, 180 cm^2, electrically conducting diffusion window made of 70 um thick Tyvek sheet (Fig. 1). The chamber is vented by four filtered outlets so that it will not accumulate radon. When the flux monitor is placed on a radon emanating surface, the radon enters through the Tyvek barrier and exits through the vents. The semi-equilibrium radon concentration established inside the chamber is representative of the flux from the surface. Because of the equilibrium between the radon from the ground and radon in the outside air through the vents, the flux emanation from the ground is not disturbed. A measure of the semi-equilibrium radon concentration is a measure of the radon flux. The discharge rate of the electret is, in turn, a measure of the radon flux. The discharge rate is simply the voltage drop divided by the exposure time in hours. Fig. 1 is a schematic of such monitor.

CALIBRATION

The E-PERM flux monitor has been calibrated on radon flux beds at CANMET (Canada). This National Reference Standard Flux Beds in Canada is used for calibrating flux monitoring instrumentation. These beds consist of ^{226}Ra bearing material (well characterized uranium tailings) 5.5 cm thick and 5 meter in diameter. The bed has been precisely characterized by CANMET to provide a radon flux of 7.7 +/- 1.1 pCim^{2}sec^{-1} (7.7 flux units). Through out this paper 1 pCim^{2}sec^{-1} is referred to as one FU.

The monitor uses the same type of electrets and the reading device used in all of the E-PERM electret ion chamber systems. The high sensitivity electrets (termed ST) are used for low fluxes and the low sensitivity (termed LT) are used for high fluxes. The units were p[laced on the flux beds from 1 to 2 days when the flux monitor was used with ST electrets and placed from 4 to 7 days when flux monitors were used with LT electrets. A similar flux monitor was positioned on the flux bed, separated by a radon barrier (mylar sheet) to serve as a blank that responds to all the other environmental contributors (gamma and radon in the atmosphere) except flux from the bed. The differential discharge rates were correlated with the reference flux values. The calibration factors based on the data from CANMET are given below:

<u>For ST electrets</u> the calibration factor (CF) is given by the equation:

$$CF = \underline{10.4 +/- 1.0} \text{ VPH per unit flux } (\text{pCim}^2\text{sec}^{-1}) \tag{1}$$

<u>For LT electrets</u> the calibration factor (CF) is given by the equation:

$$CF = \underline{0.60 +/- 0.12} \text{ VPH per unit flux } (\text{pCim}^2\text{sec}^{-1}) \tag{2}$$

This means that a discharge rate of 10.4 volts in one hour corresponds to 1 FU when the monitor is used with ST electrets and a discharge rate of 0.60 volt in one hour corresponds to 1 FU flux when the monitor is used with LT electrets.

LINEARITY CORRECTION COEFFICIENTS

It is well known that the discharge rate of the electret in electret ion chambers is not the same for unit flux for all the operating voltages of the electret (Ref: 4). Depending upon the operating electret voltages, the result should be multiplied by a linearity correction coefficient given by equation (3). This is applicable both for ST and LT electrets. Such coefficients are derived by exposing monitors with different starting electret voltages in a radon test chamber.

$$LLC = 0.7727 + 0.0004568 \times \{(I+F)/2\} \tag{3}$$

where I and F are the initial and final electret voltages.

PROTOCOLS FOR MEASUREMENT

Following are the suggested protocols for using the flux monitor.

1. Clear the surface of the ground of any debris or pebbles over an area of 0.3m x 0.6m, sufficient to locate two flux monitors. Level the area.
2. Choose two flux monitors for used at each site. Read two ST electrets and note down the initial readings, call these I1 and I2. Carry theses in their storage covers separately to the site of measurement.
3. At the site load the electrets into the flux monitors.
4. Spread a paper towel or any filter (transparent to radon) over one half of the cleared area and locate one flux monitor (Monitor A in Figure). This is the radon flux monitor.
5. Locate a radon barrier (sheet of Al on the other half of the area, and locate another flux monitor (Monitor B in Figure). This is blank.
6. Put some weight on the monitors to prevent physical movement.
7. Leave these in position for about 8 hours or longer if necessary (T hours).
8. After the desired period of exposure, take out the monitors, the paper towel and Al sheet.
9. Remove the electrets from the monitors and load them into the storage caps.
10. Measure the final electret voltages of the electrets in the laboratory. Call these F1 and F2.
11. Let I1 and F1 correspond to the blank and let I2 and F2 correspond to radon flux monitor.

CALCULATIONS

<u>Step 1. Calculate the radon flux for the blank flux monitor.</u>

The discharge rate is:	(F1-I1)/T VPH
The flux is:	{(F1-I1)/T}/10.4
The correction flux:	{{(F1-I1)/T}/10.4}x[0.7727+0.0004568x((I1+F1)/2)]
	X flux units

<u>Step 2. Calculate the radon flux for the radon flux monitor.</u>

The discharge rate is:	(F2-I2)/T VPH
The correction flux:	{{(F2-I2)/T}/10.4}x[0.7727+0.0004568x((I2+F2)/2)]
	Y flux units

<u>Step 3. Calculate the net flux.</u>

Net Flux is = (Y-X) flux units.

<u>EXAMPLE</u>

Let I1 and F1 be 425 and 375 volts. Electret discharge rate is 50/8 = 6.25 VPH. Let I2 and F2 be 700 and 500 volts. Electret discharge rate is 100/8 = 25.00 VPH. Time be 8 hours. ST electrets are used.

Step 1: Flux = 6.25/(10.4x0.9545) = 0.6296 flux units
Step 2: Flux = 25/(10.4x1.0455) = 2.2992 flux units

DISCUSSION

Flux unit A measures contribution from radon, environmental gamma and environmental radon. Flux unit B (Fig. 2) measures contribution from environmental gamma and environmental radon. The difference is due to radon flux from ground only.

For measuring radon flux as a measure of the radon potential at a building site, it is recommended that a 5 cm deep rectangular channel be made and the detectors located as described in the protocol. This is to remove the surface artifact.

One flux unit corresponds to 0.037 $Bqm^{-2}sec^{-1}$ in SI units.

For higher fluxes or for extended measurements a LT electret can be used.

SENSITIVITY ANALYSIS

Assuming that 20 volt net drop is measurable with 10% precision, measurements are done either for 8 hours or 24 hours, sensitivity analysis can be made.

A 20 volt drop in 8 hours corresponds to 2.5 VPH, and is equivalent to 0.24 FU. A 20 volt drop in 24 hours corresponds to 0.83 VPH and is equivalent to 0.08 FU.

Therefore, using ST flux monitor, minimum measurable fluxes are 0.24 FU for 8 hour measurement, and 0.08 FU for 24 hour measurement. Similarly, the minimum measurable fluxes are 2.88 FU for 8 hour and 0.96 FU for 24 hours.

Using suitable combinations, it is possible to cover fluxes from 0.1 to 20 FU, normally need to be measured. Minimum measurable fluxes (with 10% accuracy) are 0.24 FU in 8 hours and 0.08 FU in 24 hours using ST electrets. For larger flux measurements an LT electret is used. Currently, these passive flux monitors are being used for research at the Ona Agricultural Research Center of the University of Florida (2) where comparative field measurements with flow through flux monitors and charcoal canisters are being made.

REFERENCES

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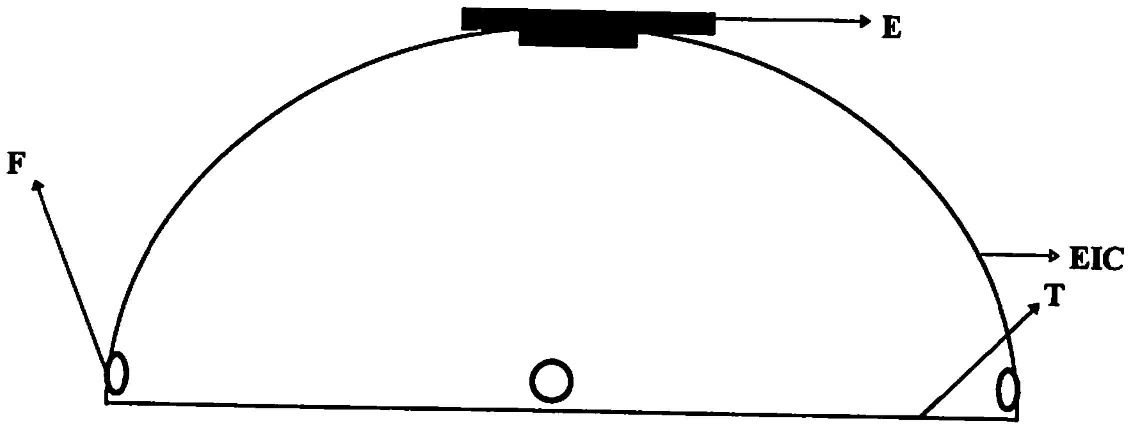
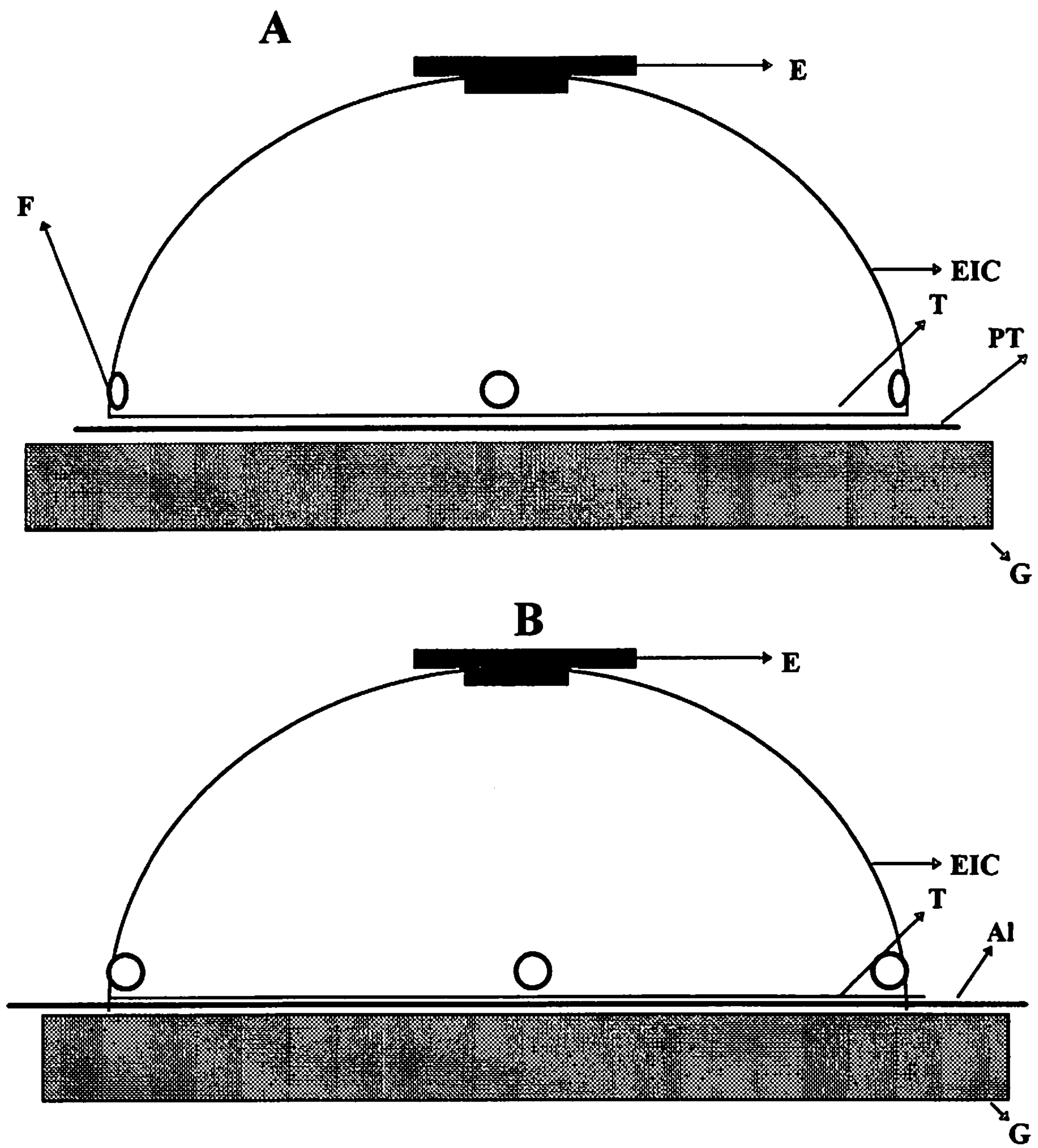


Fig. 1 The schematic view of the 960 ml EPERM$^{(R)}$ Passive Flux Monitor.
EIC : electret ion chamber; E: electret; F: Filtered openings; T: Tyvek window;



E : Electret
G : Ground or tailings
PT : Paper Towel to allow radon to pass
T : Tyvek Window
EIC : Electret Ion Chamber
Al : Al sheet to stop radon
F : Filtered openings

NOTE
The Chamber A allows radon
The Chamber B stops radon

Fig 2. Schematic of measuring radon flux from the ground