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THE MEASUREMENT OF VERY HIGH LEVELS OF ^{222}Rn CONCENTRATIONS USING ELECTRET ION CHAMBERS

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ABSTRACT

Electret ion chambers are normally standardized for measurement of relatively low ^{222}Rn (radon) concentrations usually found in indoor and outdoor environments. However, there are situations when very high levels need to be measured. For example in unventilated uranium and other mines, radon therapy caves, acute inhalation experiments and waste storage silos. Concentrations of 50,000 to 100,000 pCi l^{-1} (2 to 4 MBq m^{-3}) are not uncommon in these situations. At such high levels, exposure periods must be necessarily short (less than one hour) to avoid total discharge of electret. Such short intervals does not allow equilibrium to reach between radon and the associated progeny inside the chamber. For this reason the standard calibration does not hold good. There are two ways of achieving the equivalent steady state. One method is called as "delayed final" method and the other is called "initialization method". The theoretical basis for the equivalence of the two procedures is presented in the paper. Such procedures were successfully used in radon therapy caves in Badgastein (Austria), in using NIST radon emanation standard with high radium content and in some special studies conducted in UK. The procedures devloped in this work expands the horizon of EICs to new and difficult to measure areas.

INTRODUCTION

The Electret Ion Chamber (EIC) is an integrating ionization chamber wherein the electret (a charged Teflon Disc) serves both as a source of electrostatic field and as a sensor. It consists of an electret mounted inside a small chamber made of electrically conducting plastic. These are passive devices. The ions produced inside the chamber are collected onto the electret causing a reduction of the charge on the electret. the reduction in charge is a measure of the total ionization produced during that period in that volume of the chamber. The charge on the electret before and after the exposure is measured by a sensitive electret voltage reader. The sensitivity and dynamic range depends upon the thickness of the electret and on the volume of the chamber. Figure 1 gives a schematic view of different commercially available chambers. The volume of these chambers range from 50 ml to 960 ml. The "S" type of chamber has an on/off mechanism which can be used to close and open the electret from outside. Electrets of two different thicknesses are commercially available. The electret with the 1.542 cm is usually referred to as "short term" or "high sensitivity" electret and the electret with 0.127 mm is referred to as "long term" or "low sensitivity" electret. the scientific basis and the design features are described in publications cited (1,2).

A commercial version of the EIC known as E-PERM $^{(TM)}$ (electret passive environmental radon monitor) is widely used for making indoor and outdoor radon measurements (1,2,3,4). Currently, US EPA (United States Environmental Protection Agency) listed radon laboratories form the largest and most successful group in USA compared to the laboratories using other devices (5).

EIC, A TRUE INTEGRTAOR

Figure 2 gives details of how an EIC works as a radon monitor. The radon enters the chamber by passive diffusion. The electret collects only the ions produced inside the chamber and not the radon it self. Radon freely diffuses in and out and the concentration of radon inside the chamber will be the same as that in the room, at any time. These devices, therefore, function as true integrator of changing radon concentrations usually found in homes. Alpha track detectors also function as true integrator where as the activated charcoal detectors do not function as true integrator "because charcoal allows continual adsorption and desorption of radon "(6).

LIMITATION OF EIC

As a passive integrating unit, the electret inside the EIC unit may be completely discharged if used for sufficiently long time or at high concentration of radon. Manufacturer provides the dynamic ranges of time integrated concentrations for different combinations of chambers and electrets. The most popular combination termed as SST (S chamber used with short term electret)is recommended for use for 2 to 7 days in typical indoor measurement. Similarly the combination termed as SLT (S chamber with long term electret) is recommended for use from one month to one year in typical indoor measurements. Being true integrator, the SST can be used for measurement periods longer that 2 to 7 days, if the concentration is low and similarly the SLT can be used for shorter than one month measurement period if concentration is high. In principle, one can measure very high concentration when exposed for very short time. However, there are limitations when used for times shorter than 2 days. The purpose of this paper is to describe procedures applicable for very short exposure period.

MEASURING VERY HIGH LEVELS OF RADON

There are situations when very high levels need to be measured. For example in unventilated uranium and other mines, radon therapy caves, acute inhalation experiments and waste storage silos. Concentrations of 50,000 to 100,000 pCi l^{-1} (2 to 4 MBq m^{-3}) are not uncommon in these situations. At such high levels, exposure periods must be necessarily short (as small as one hour) to avoid total discharge of electret.

The calibration of EIC is usually done by exposing the units in radon chambers for periods in excess of two days at suitable steady radon concentrations (2). Such calibration can not be directly used for measurements done at shorter period. This becomes clearer when the dynamics are examined.

DYNAMICS OF RADON IN AN EIC

When a detector is placed in the radon atmosphere,

1. The radon diffuses into the chamber.
2. Radon decays in the chamber by an emission of alpha particle forming the first decay product. This decays further to the second decay product and so on. Eventually there are three alpha emissions for every radon atom. Because of the relatively small effective half life (40 minutes) of the radon progeny, an equilibrium is reached between the progeny and radon in about three hours. The rate of ionization reaches a maximum and stays steady after three hours. However, the rate of ionization during this growth period (3 hours) is made up of constant ionization rate due to radon and the growing ionization rate due to the progeny deposited on the wall. This is usually called as "ramp up". During the "ramp up" the total ionization due to deposited radon progeny is somewhat lower than what it would have been if there was a complete equilibrium to start with. Let us call this as "deficiency" during ramp up. When the detector is removed the radon diffuses out and ionization continues for another three hours from the progeny deposited on the wall. This is usually called as "ramp down". It can be shown that the total ionization during "ramp down" is quantitatively the same as the "deficiency" during "ramp up" if the radon concentration has stayed the same through out the measuring period. The signal from "the deficiency" is quantitatively less than 2 % of the total signal for sampling periods of two days and decreases further for longer periods. However, the relative signal from "deficiency" becomes significant when sampling periods are less than 2 days.

Measurement and addition of the "deficiency" is the principle used for making short duration measurement. The following two procedures correct for this deficiency.

A. Delayed final method
1. Take initial reading of electret (I volts).
2. Locate the EIC in test area.
3. At the end of sampling period (D days), move the EIC to low radon area, wait for three hours and read the electret (DF). Such reading is called "delayed final" or DF to distinguish it from the "immediate final" that is usually measured when tests are conducted for periods longer than two days.
4. The signal now includes the "ramp down" or "deficiency"
5. Use I, DF and D to calculate the radon concentration using standard calibration equations.

B. Initialization method
1. Take the reading of electret (I volts).
2. Leave the open chamber without electret in the test area for three hours. At the end of this period, progeny deposition and growth is complete.
3. Load the premeasured electret into the chamber and start the exposure. At the end of the test period (D days), simply remove the electret and make "immediate final" voltage (F volts) measurement.
4. The signal now includes the "deficiency"
5. Use I, F and D to calculate the radon concentration using standard calibration equations.

RECOMMENDATION

Both procedures correct for the deficiency and any method can be used depending upon the convenience. For example, when we participated in measuring radon concentration in radon therapy cave in Badgastein (Austria) as a part of the international intercomparison exercise, we were asked to start at 8 AM and end at 10 AM. In such situation the first procedure was more practical. We entered the cave at 8 AM and took the detectors out at 10 AM and measured the delayed final voltage at 11 AM. This principle was also used when EICs are used with NIST source in accumulation mode (7), indirectly verifying this analysis.

CONCLUSIONS

If sampling periods are more than 2 days, standard procedures of measuring initial and "immediate final" voltages and using standard calibration factors is perfectly alright. For some reason if one wishes to use EIC for periods shorter than 2 days, the procedures should be to use the "delayed final" voltage measurements for obtaining the correct results. The need for measuring radon for less than 2 days arise in following typical cases :

Radon concentrations are very high as is in radon therapy caves, in mines etc., When quick (one day or less) pre and post mitigation tests are to be done by using high sensitive EIC such as "HST" device.

The procedure developed in this paper expands the application of EIC to a new horizon.

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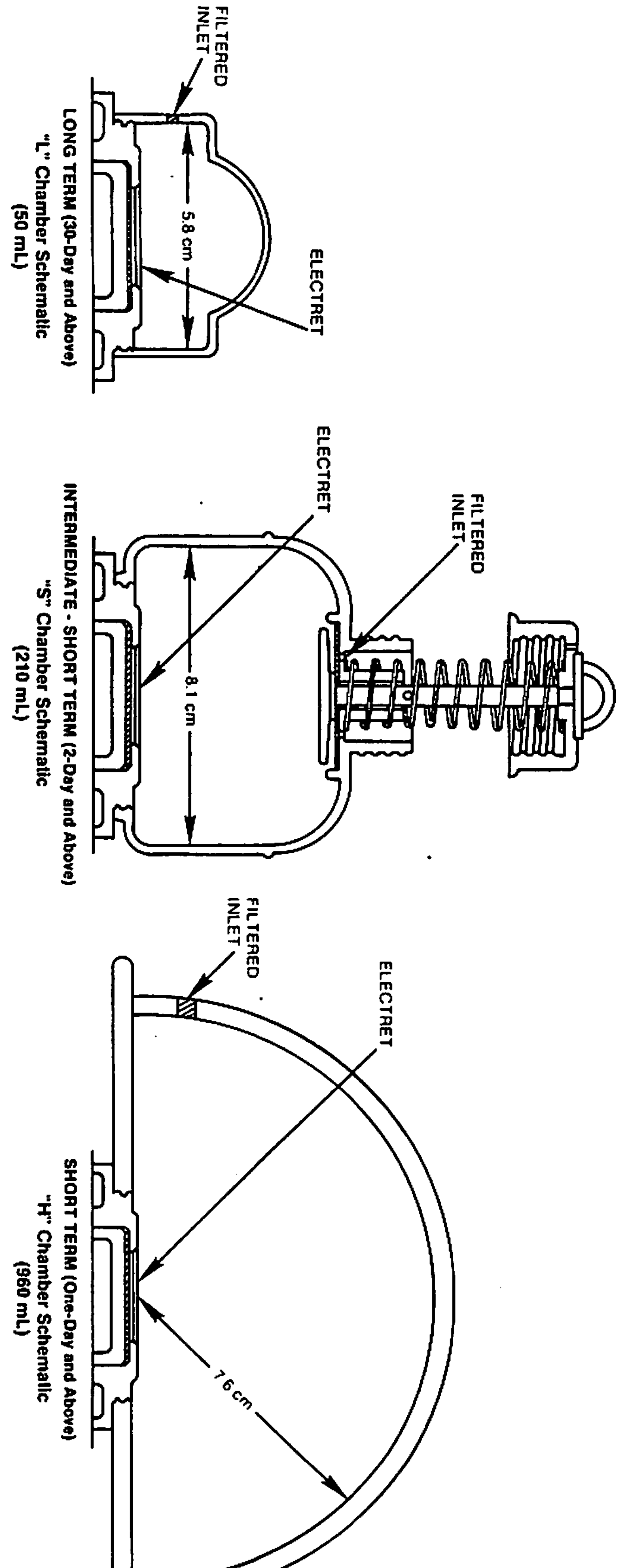
FILTERED INLET
ELECTRET
5.8 cm
LONG TERM (30-Day and Above)
"L" Chamber Schematic
(50 mL)
FILTERED INLET
ELECTRET
8.1 cm
INTERMEDIATE - SHORT TERM (2-Day and Above)
"S" Chamber Schematic
(210 mL)
FILTERED INLET
ELECTRET
7.6 cm
SHORT TERM (One-Day and Above)
"H" Chamber Schematic
(960 mL)

E-PERM ELECTRET ION CHAMBER