CHARACTERIZATION AND USE OF AN ACCUMULATING TYPE OF RADON TEST CHAMBER

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Abstract

There are two general types of radon test chambers. One type can be described as a "flow-through" radon chamber while the second type can be described as an "accumulation" type of radon chamber. The Bowser-Morner, Inc. radon test chamber is an example of a "flow-through" type. These are generally used for "performance testing" by certified radon professionals. By comparison, an "accumulation" chamber is typically much smaller (ranging in size up to approximately 125 liters), and are relatively inexpensive to fabricate and operate. The radium source and radon detectors are introduced into an "accumulation" chamber through a sealable port, after which the port is sealed. When a NIST Radon Emanation Standard is used as a radium source, it is possible to calculate the expected radon concentration after a specified accumulation period. This paper describes a typical "accumulation" chamber, provides the equations needed to calculate the radon concentration at any specified accumulation time, and highlights some practical and unique applications of such test chambers.

Introduction

There are two general types of radon test chambers. One type can be described as a "flow-through" radon chamber while the second type can be described as an "accumulation" radon chamber. The Bowser-Morner, Inc. Radon Chamber in Dayton, OH and USEPA radon test chamber in Las Vegas, NV are examples of a "flow-through" type chambers. These are generally used for "performance testing" by radon professionals. Flow-through test chambers are generally larger in size, more expensive to build and maintain, and maintain traceability to NIST. Parameters such as humidity and temperature, as well as the radon levels (and radon progeny concentrations), can be varied as needed. By comparison, an "accumulation" type radon test chamber is typically much smaller (ranging in size up to approximately 125 liters), and are relatively inexpensive to fabricate and operate. The radium source and radon detectors are introduced into an "accumulation" chamber through a sealable port, after which the port

[1] The Authors are the developers of, and have a commercial interest in, the accumulating radon test chamber discussed. in this paper.

is sealed. When a NIST Radon Emanation Standard is used as a radium source, it is possible to calculate the expected radon concentration after a specified accumulation period. This paper describes a typical "accumulation" radon test chamber, and provides the equations needed to calculate the radon concentration at any specified accumulation time, as well as highlighting some practical and unique applications of such test chambers.

Accumulation type of radon test chamber

<u>Features</u>

Accumulating type radon test chambers are sealable and have an air volume of approximately 5 to 125 liters. They have ports, through which a radium source and radon detectors can be inserted, after which the port is resealed. Reference detectors and CRMs can also be inserted at the same time that other radon detectors are introduced into the chamber. The main feature of an accumulating chamber is that the radon continues to accumulate inside the chamber and provides continuously increasing radon concentrations. Equation (1a) gives the radon concentration at any time T (days). Equation (2a) is obtained by integrating equation (1a) and dividing by the accumulation time (Reference 1) to calculate the integrated average radon concentration. The factor $\frac{Ra\ f}{V}$ is a constant that depends upon the source and the volume of the accumulator and may be referred to as a "chamber constant". Equations (1b) and (2b) are derived after naming this as K. The derivation of these equations is also given in Reference 1 (1994).

$$C(Rn) = \frac{Ra\ f\{(1 - e^{-0.1814T}\}}{V} \quad \text{----- 1a}$$

$$C(Rn) = K(1 - e^{-0.1814T}) \quad \text{----- 1 b}$$

$$C(Rn)_{Av} = \frac{Ra\ f}{V}\left[1 - \left(\frac{1 - e^{-0.1814T}}{0.1814T}\right)\right] \text{---- 2a}$$

$$C(Rn)_{Av} = K\left[1 - \left(\frac{1 - e^{-0.1814T}}{0.1814T}\right)\right] \text{---- 2b}$$

V is the volume of the chamber in m^3

Ra is the radium content in Bq

Where *C (Rn)* is the radon concentration (Bq/m^3) at the stated accumulation time of T days

Where $C\ (Rn)_{Av}$ is the average radon concentration (Bq/m^3) at the stated accumulation time of T days,

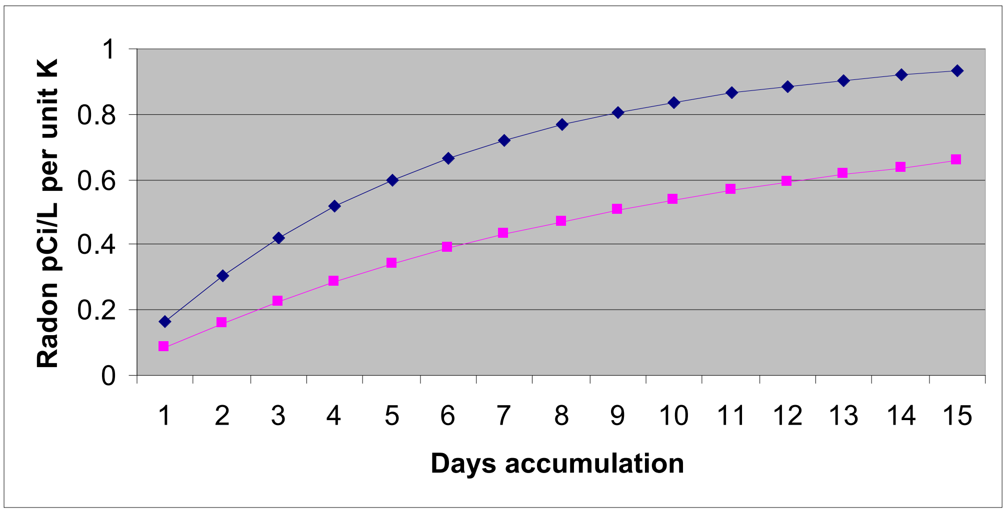
f is the emanation coefficient of the NIST source used
0.1814 is the decay constant of radon in day^{-1} units
K is a constant that depends upon source and chamber volume

Table 1 depicts the expected radon concentration after a stated accumulation time and the average radon concentration for stated accumulation periods (days) for unit K.
Figure 1 depicts the graphic representation of the radon concentration at any stated time (square black) and the average radon concentration at the stated time (Rectangle red) per unit K.

Table 1 - Expected radon concentration at stated accumulation time and the average on concentration for stated accumulation periods (days), for unit K

Accumulation Time	Expected radon Concentration at stated Acc time per unit *K*	Expected average radon concentration at stated Acc time per unit *K*	Expected average radon at stated Acc time for *K* of 404 Bq/m^3
days	pCi/L	pCi/L	pCi/L
1	0.165732	0.085367	34.48824
2	0.303996	0.161159	65.10811
3	0.419346	0.228576	92.34487
4	0.515579	0.288661	116.619
5	0.595862	0.342315	138.2953
6	0.662841	0.390323	157.6905
7	0.718719	0.433366	175.0798
8	0.765336	0.472037	190.7028
9	0.804227	0.506851	204.7679
10	0.836673	0.53826	217.457
11	0.863741	0.566656	228.929
12	0.886324	0.592382	239.3225
13	0.905163	0.61574	248.7589
14	0.920881	0.636991	257.3444
15	0.933993	0.656367	265.1724

Figure 1 - Graphic representation of radon concentration at any stated time (Diamond, blue) and the average radon concentration at stated time (Rectangle, red) per unit K



<u>Practical Accumulating Type of Radon Test Chamber</u>
A practical accumulating type of radon test chamber is described by Kotrappa and L. Stieff (Kotrappa et al., 1994). NIST standard sources are used as radium sources. The Radium sources used were NIST 880 Bq standards (Volkovitsky, 2006). These were used inside the 127 liter sealable chamber. Knowing the characteristics of NIST standards and the air volume of the chamber, it is possible to calculate the chamber constant K, the average radon concentration at any accumulation time, and the average radon concentration at the end of the accumulation time. Such calculated radon concentration varied from1.3 pCi/l to 53.5 pCi/l with an accumulation time ranging from 1 h to 48 h. The average concentration builds to 220 pCi/l for an accumulation time of 15 days. Certified NIST standards are available with Ra content from 5 Bq to 5000 Bq. These are fully described by Volkovitsky (Volkovitsky, 2006). The technical paper by P. Kotrappa et al., 1994) fully describes the design and methodology of using such a chamber for calibrating electret ion chamber (EIC) types of radon monitors and Femto tech continuous radon monitors (CRM).

<u>Replacement for NIST Source</u>
The use of a NIST Radium source requires a complicated licensing procedure in the USA. In an effort to eliminate these licensing problems, Rad Elec implemented a more

practical type of radium source. The chamber remains identical to the one described earlier (Kotrappa, 1994), however the NIST radium source has been replaced with several tyvek envelopes containing approximately 50 grams of uranium mill tailing sand. Several of these 50 gram tyvek envelopes are placed along the interior perimeter of the chamber. A meshed pedestal stand serves as a platform to hold the detectors to be tested. The number of envelopes containing uranium mill tailings to be used depends upon the testing requirement.

Average radon concentration ($C(Rn)_{Av}$) is given by equation (3), after an accumulation period of T days (Kotrappa, 1994).

T is the accumulation time in days

Note that the term within large parenthesis has no dimensions and is universal for any accumulator and is a function of the accumulation time only. This is called the *accumulation parameter*.

The constant *K* is usually not known. This depends upon a number of parameters of the chamber including characteristics of Ra content, volume of the chamber etc. This can be computed for NIST sources, but needs to be determined when using other sources.

Determination of *"K"*

Calibrated integrating radon monitors such as ATDs or EICs are used for this purpose. For the current chamber, the concentration is measured to be 34.5 pCi/L for an accumulation time of 1 day. The term in the bracket for T of one day calculates to: 0.085367

$$K = 34.5/0.085367 = 404.1 \text{ pCi/L}$$

Equation (1) can be rewritten as equation (2)

$$C(Rn)_{Av} = 404.1 \left[1 - \left(\frac{1 - e^{-0.1814T}}{0.1814T}\right)\right] \text{---------- (2)}$$

Equation (2) can now be used for calculating the expected radon concentration at any accumulation time. Column 4 of Table 1 gives the predicted average radon concentration after stated periods. For 15 days, the average radon concentration is 265 pCi/L and an equivalent of about 4000 pCi/L-days. Such exposure levels are sufficient to test or calibrate ATDs and EICs.

Advantages of an Accumulating Radon Test Chamber

1. Provide a predictable continuously increasing radon concentration.
2. Are useful for testing integrating detectors such as ATD detectors, EIC detectors, and CRMs. (Every hourly reading of the CRM can be compared with the expected radon concentration, providing a rigorous evaluation of CRMs.)
3. Being a small closed volume, it is easy to provide constant known humidity.
4. From Table 1, it is observed that an integrated radon exposure as high as 4050 pCi/l-day in 15 days. If a higher concentration is needed in 15 days, additional envelopes containing radium sources can be added.
5. Can be very useful to manufacturers for verifying new production batches of long term detectors in a reasonable time period.

Disadvantages of Accumulating Radon Test Chamber

1. Accumulating radon test chambers must be leak tight to obtain accurate results. (This is easily checked by testing the chamber with calibrated EICs or a CRM at different accumulation times and comparing results with the expected growth curve.)
2. The calibration constant needs to be determined for each configuration of sources. (After the satisfactory leak tests, only one measurement for one accumulation time, with a calibrated detector is sufficient to derive the calibration constant.)

References

1. P.Kotrappa and L.R.Stieff "Application of NIST ^{222}Rn Emanation source standards for calibrating ^{222}Rn monitors Radiation Protection Dosimetry 55:211-218(1994).

2. Peter Volkovitsky. "NIST ^{222}Rn emission standards" Applied Radiation and Isotopes 64, 1249-1252 (2006)