OPTIMIZED 90 DAY LONG-TERM EIC (E-PERM®) MONITOR

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Abstract

This device uses an electret of 15-mil (0.381 mm) thickness, designated as an MT electret, loaded into an L-OO chamber. The L-OO chambers have a slide mechanism, which can be used to turn the device "on" (allowing it to measure ionizing radiation) or "off" (where no ionization can be measured). The L-OO Chamber is already approved by the NRPP Code 8234-25. Using an MT electret loaded into an L-OO chamber, radon concentrations of 4.0 pCi/L are measurable with 6.5% accuracy, and radon concentrations of 1.5 pCi/L are measurable with 10% accuracy, making these detectors ideal for long-term indoor measurements. The maximum measurable integrated radon concentration is about 8,000 pCi-days/L. Using newly-developed calibration equations, MT electrets can be used in a wide range, from 750 volts down to 50 volts. This wider dynamic range provides a large number of 90-day measurements. These detectors have all the attractive features associated with the existing electret ion chamber devices. Characterization of these detectors involved deploying thirty detectors with staggered starting voltages in the Bowser-Morner Radon Test Chamber for radon exposures in a "spike test mode" for 90-day detectors. Experimental data is provided and discussed.

Authors are associated with Rad Elec Inc, which manufactures the devices described herein.

Introduction

Electret ion chambers (EIC) with the trade name of E-PERM® (Electret Passive Environmental Radon Monitor) have been in use for longer than 20 years. These are widely used by radon professionals in many countries, including within the USA and Canada, and a wide variety of configurations are listed by both the National Radon Proficiency Program (NRPP) and the National Radon Safety Board (NRSB). The basic system is fully described in a previous publication (Kotrappa et al., 1990). The most widely-used device for short-term indoor radon measurements, designed for two to seven day measurements, is an ST electret loaded into an S chamber (technically known as an SST). Other E-PERM® devices used for making indoor long-term radon measurements (for exposures lasting longer than 90 days) are designated as SLT (S chamber with LT electrets), and LLT-OO (LT electret in the L-OO chamber). Although these listed devices are usable for long-term measurements, some practical limitations have been observed in their routine use. The SLT configuration can be quite sensitive for a practical long-term indoor radon measurement, rendering it inadequate for areas with extremely high radon concentrations. On the other hand, LLT-OO configurations do not have sufficient sensitivity for a 90-day measurement in areas with low radon concentrations. To overcome this limitation, a new electret designated as the MT electret has been developed, with a thickness of 15-mil (0.381 mm). The thickness of the electret is the defining characteristic in its sensitivity, with larger values increasing this property. In comparison, ST electrets have a nominal thickness of 60-mil (1.524 mm), and LT electrets have a thickness of 5-mil (0.127 mm). Both ST and LT electrets have been fully described in a previous publication (Kotrappa, 2001). When MT electrets are combined with the existing L-OO chamber, this new setup is designated as an LMT-OO configuration. The purpose of this current publication is to fully describe the characteristics of the new MT electret, with a focus on its use in the L-OO chamber. This LMT-OO configuration will be most commonly applicable for measurements lasting between 30 and 120 days, in areas with unknown radon concentrations.

Methods

Description of LMT-OO radon monitors

A useful feature of the L-OO chamber is that the radon professional can use an integrated slide mechanism to turn the unit into an opened or closed position. If the user wishes to send this device to a radon test chamber, one must take the initial reading, slide the mechanism to its "off" position and then mail it. Once it arrives at the radon chamber, the evaluators simply slide the mechanism to the "on" position and expose the unit to a known radon concentration. At the conclusion of the exposure period, the unit is removed and slid into its "off" position, and then returned to the user for analysis. The same procedures can be used for 90-day measurements by the customer. Figures 1, 2, and 3 provide the schematics of the monitors, and assist in describing their proper usage.

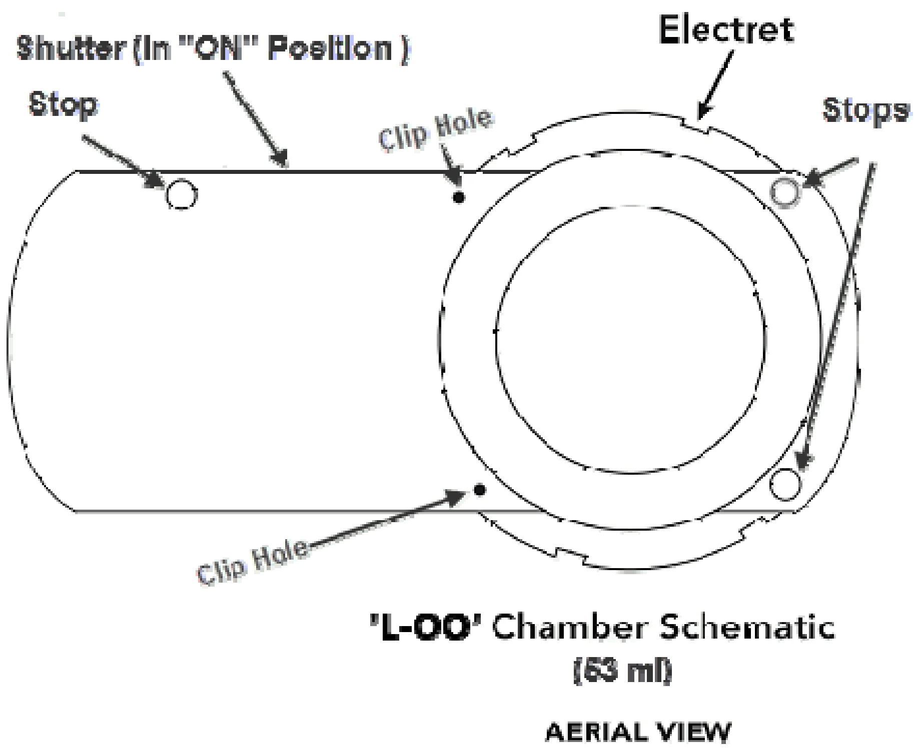

Figure (1): Device is in the "ON" position. A lock clip is inserted through the clip hole to lock the device which prevents accidental movement of the slide mechanism. The "stops" consist of indentations which position the slide mechanism in the correct position.

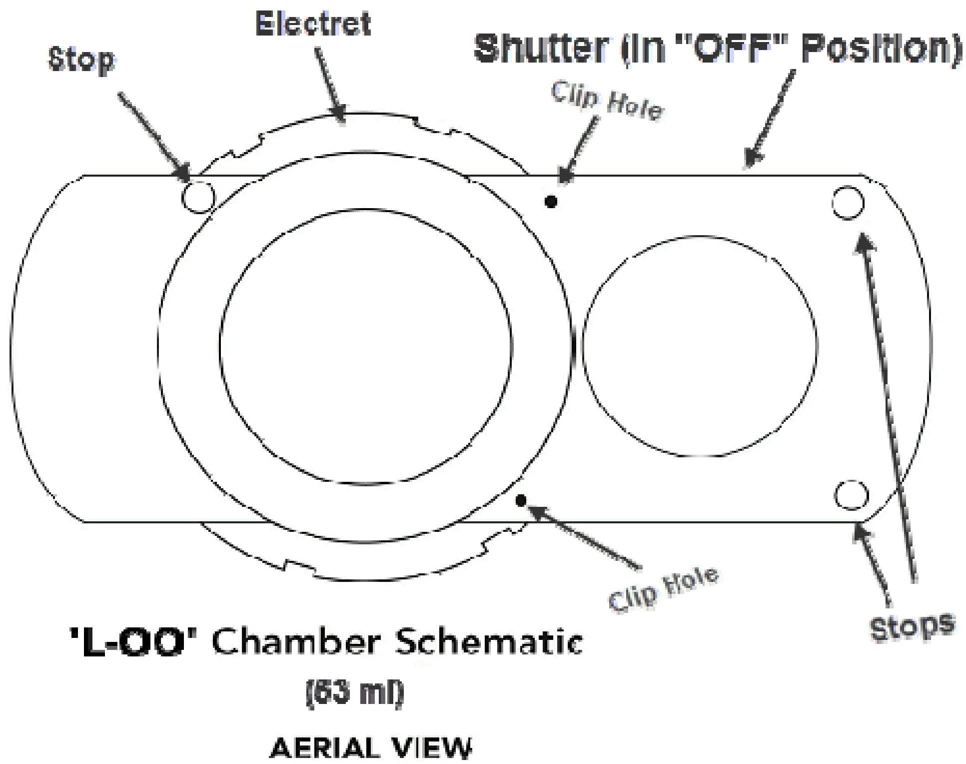

Figure (2): Device is in the “OFF” position. A lock clip is inserted through the clip hole to prevent accidental closure of the device while deployed.

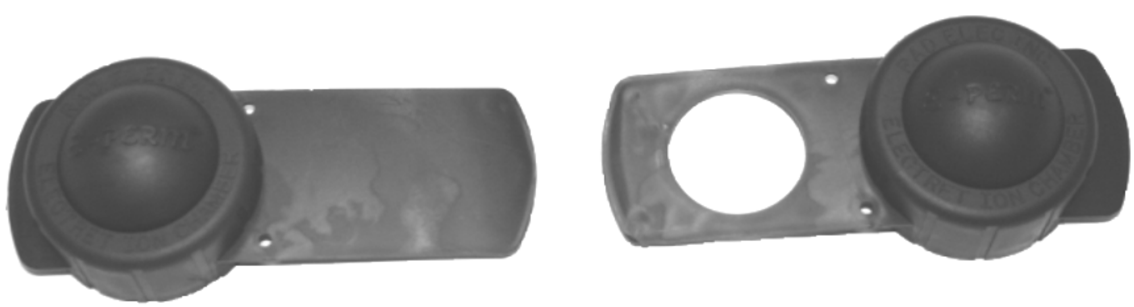

Figure (3): Photograph of an L-OO Chamber
Picture on the left is in the “ON” position. Picture on the right is in the “OFF” position.

Evaluation of LMT-OO Configuration

The purpose of this paper is to fully evaluate the LMT-OO configuration in order to define its characteristics and illustrate its potential application. The LMT-OO configuration is termed as an “optimized” device because it takes into account the limitations of other EIC devices used for long-term measurement of radon. The first step is to derive the calibration equation for LMT-OO radon monitors. The procedure used to calibration E-PERMs® has been fully discussed in previous publications (Kotrappa et al., 2013). The calibration factor thus derived covers electret voltages in a dynamic range, from approximately 750 volts down to 50 volts. A well-calibrated radon test chamber has been used for this study. It is typically operated at about 16 pCi/L for a test duration of 28 days.

The following Equation (1) was derived for the calibration factor applicable to the electret voltages from 750 volt to 50 volts:

$$CF = 0.0135 + 0.0125 \times Ln(MPV) \qquad (1)$$

where CF is the calibration factor in units of volts per pCi-days/L, Ln is the natural logarithm, and MPV is the midpoint voltage (average of initial and final voltages readings).

Equation (2) is used to calculate the unknown long term average radon concentration in pCi/L, measured over T days,

$$RnC = [(IV-FV) / (T \times CF)] - BG \qquad (2)$$

where,
RnC is the average radon concentration in the exposure area,
T is the exposure period in days, and
IV and FV are the initial and final voltages, respectively.
CF is the calibration factor in volts per (pCi-days/L) given by Equation (1).
For this experiment BG is 0.816 pCi/L. This is obtained by multiplying the gamma radiation level at the test area (6.8 µR/h) by 0.12. The constant 0.12 is the radon concentration (pCi/L) equivalent for 1 µR/h.

Appropriate corrections have been made for the elevation of the test area for L-OO chambers. Furthermore, appropriate corrections have been made for inherent discharge of electrets (about 1 volt per month).

Results

Evaluation in radon test chamber for radon exposures in a “spike test mode”.

Characterization of these detectors involved deploying thirty detectors with staggered starting voltages in the Bowser-Morner (BM) Radon Test Chamber in a "spike test mode" for 90-day detectors. A total of 30 pre-measured units with staggered voltages were sent to the BM chamber, where they were exposed to a known radon concentration. At the conclusion of this exposure period, these devices were measured and compared with the target concentration.

The "% Error" is calculated using the following equation: absolute value of ((Measured RnC - Target RnC) / (Target RnC) x 100)). Table1 provides the summary for the test environment, while Tables 2 through 4 provide the individual results of each group, including the % Error, group average radon concentration, and standard deviation. Table 5 provides a concise summary of the group data.

Table 1: Bowser-Morner Radon Test Chamber Environment

Exposure Days	Gamma Micro R/h	Elevation Feet	Elevation Corr. factors	Decay Corr. (V/month)	Target pCi/L
30	7	820	1.04	1	26.6

Table 2: Results for 300-Volt LMT-OO Detectors

Electret#	IV	FV	CF	Radon pCi/L	% Error
LAA601	299	231	0.0832	**27.1**	1.9
LAA370	297	229	0.0832	**27.1**	1.9
LAA486	300	232	0.0833	**27.1**	1.9
LAA596	298	235	0.0833	**25.0**	6.0
LAA582	297	225	0.0831	**28.8**	8.3
LAA833	299	236	0.0834	**25.0**	6.0
LAA616	300	228	0.0832	**28.8**	8.3
LAA834	299	234	0.0833	**25.8**	3.0
LAA711	299	233	0.0833	**26.2**	1.5
LAA663	297	235	0.0833	**24.6**	7.5
			Avg. RnC	**26.55±1.50**	

Table 3: Results for 500-Volt LMT-OO Detectors

Electret#	IV	FV	CF	Radon pCi/L	% Error
LAA482	499	422	0.0902	**28.4**	6.8
LAA409	497	430	0.0902	**24.5**	7.9
LAA524	496	428	0.0902	**24.9**	6.4
LAA379	497	428	0.0902	**25.3**	4.9
LAA531	497	422	0.0901	**27.7**	4.1
LAA714	500	425	0.0902	**27.6**	3.8
LAA769	497	424	0.0902	**26.9**	1.1
LAA785	498	425	0.0902	**26.9**	1.1
LAA626	499	423	0.0902	**28.0**	5.3
LAA902	496	426	0.0902	**25.7**	3.4
			Avg. RnC	**26.59±1.39**	

Table 4: Results for 700-Volt LMT-OO Detectors					
Electret#	IV	FV	CF	Radon pCi/L	% Error
LAA508	696	615	0.0994	**27.1**	1.9
LAA518	696	615	0.0994	**27.1**	1.9
LAA480	697	622	0.0994	**25.0**	6.0
LAA468	696	619	0.0994	**25.7**	3.4
LAA377	695	624	0.0994	**23.6**	11.3
LAA692	698	621	0.0994	**25.7**	3.4
LAA814	698	626	0.0995	**23.9**	10.2
LAA840	698	625	0.0995	**24.3**	8.6
LAA792	699	623	0.0995	**25.3**	4.9
LAA860	699	623	0.0995	**25.3**	4.9
			Avg. RnC	**25.30±1.19**	

Table 5: Group Summary			
Group Number	Average pCi/L	Standard Deviation	Average % Error
300-Volt	26.55	1.50	4.62
500-Volt	26.59	1.39	4.47
700-Volt	25.30	1.19	5.64

Conclusions

After analyzing the entire set of results, the following observations were noted:
The percentage error for group averages ranges from 4.62% to 5.64%.

- Only two individual results (10.2 % and 11.3%) out of 30 exceeded 10% error.
- The exercise included group of electrets with staggered voltages, from 300 to 700 volts.
- The errors associated with these results are considered quite good for long-term measurements.

Appendix 1 and Appendix 2

Appendix 1 provides the technical specifications of the LMT-OO configuration, including the following important parameters:

Radon concentration of 4.0 pCi/L is measurable with 6.5% accuracy.

- Radon concentration of 1.5 pCi/L is measurable with 10% accuracy.
- Maximum measurable concentration is about 8,000 pCi-days/L.

Appendix 2 gives step-by-step procedures for using the LMT-OO configuration.

References

Kotrappa, P., Dempsey, J.C., Ramsey, R.W., and Stieff, L.R., 1990. A Practical E-PERM™ (Electret passive environmental radon monitor) System for Indoor 222Rn Measurement, Health Physics 58:461-467.

Kotrappa, P., Stieff, A., Stieff, F., 2013. Advanced Calibration Equations for E-PERM Electret Ion Chambers, International Radon Symposium, Springfield, IL.

Appendix 1

Technical Specifications for LMT-OO E-PERM®

Purpose: To make long-term radon measurements for 90 days.

- Radon concentration of 4.0 pCi/L is measurable with 6.5% accuracy.
- Radon concentration of 1.5 pCi/L is measurable with 10% accuracy.
- Maximum measurable concentration is about 8,000 pCi-days/L.
- MT Electrets can be used in a wide range, from 750 volts down to 50 volts.
- This wider range provides a large number of 90-day measurements.
- For example, approximately 20 measurements can be made at 4.0 pCi/L.
- These detectors have all the attractive features associated with the existing EIC devices, given below.

Not affected by: (under normal conditions typically found in homes)

- Relative Humidity
- Temperature
- Dust
- Air flow
- Sunlight
- Environmental ions
- Magnetic fields up to 10,000 Gauss
- Electric voltages up to 5,000 volts
- Normal shocks while handling and shipping
- Less than 3% response for thoron
- Corrections are available for elevation and for gamma radiation levels of test site.

Errors are estimated by using the published algorithms used in calculations, taking into account all possible errors.

Device-specific templates are provided for the respective devices to help performing the calculations.

Detailed Manual for using the LMT-OO monitor is available to users.

Electret Voltage Reader: CE certified – recommended to be used in air-conditioned rooms with relative humidity of less than 80%.

E-PERM® User's Manual and Technical Publications: available on the web site at www.radelec.com or by request.

Appendix 2

Procedure for Making a Radon Measurement Using an LMT-OO E-PERM®

A simple "clip" or wire tie is used to prevent accidental movement of the slide mechanism during shipping and/or during the actual radon measurement. The slide mechanism is used for turning the unit to an opened or closed position. To turn the device "on", the slide mechanism is pulled until the "stops (small indentations) restrict the slide, which causes the "aperture" to be centered over an electret that has been loaded into the bottom of the chamber. There are also small holes in the slide mechanism where a "clip" or wire-tie can be inserted which will prevent movement or manipulation of the slide during the testing period. To turn the device "off", the shutter is pulled in the opposite direction until the "stops" are engaged, which causes the solid part of the slide to be positioned over the electret. There are small holes which allow a "clip" to be inserted to restrict movement of the slide during transit.

The following steps are used when making a measurement with the LMT-OO chambers.

1. Take an Initial Voltage reading of the electret that is going to be used and load the electret into the bottom of the chamber. Turn the chamber to the "Off" position by pulling the slide mechanism until the "stops" engage (the aperture should be visible) and insert the "clip". The device can now be transported or shipped.

2. At the test location remove the "clip" from the chamber, and turn the unit "On" by pulling the slide mechanism until the "stops" are engaged. The aperture will now be centered over the electret (and will not be visible). Insert the "clip" to lock the slide mechanism in position. Deploy the unit according to recommended protocols.

3. At the conclusion of the testing period remove the "clip" from the chamber, and turn the unit "Off" by pushing the slide mechanism in the opposite direction until the "stops" are engaged (the aperture should be clearly visible again). Insert the lock "clip". The device is now ready for transport or shipment.

4. When ready to analyze, unscrew the electret and measure the Final Voltage. The electret can be stored in the L-OO chamber (in the "Off" position) or in the electret "keeper cap" until the next use.

5. The following information is required:
    a. The test site address
    b. The location of the device in the room
    c. The Initial Voltage (IV) and Final Voltage (FV) of the electrets
    d. The Start-Stop dates and times
    e. The gamma radiation level at the test site
    f. The elevation at the test site

6. Use the appropriate Software or Template for calculations.