

RADON IN WORKPLACE ATMOSPHERES



Method No.:	ID-208
Matrix:	Air
OSHA Maximum Permissible Concentration:	100 pCi/L (29 CFR Part 1910.1096 (c) (1))
Collection Procedure:	A passive monitoring device known as Electret-Passive Environmental Radon Monitor (E-PERM) is used to collect and to measure the ionized particles produced by radon gas.
Recommended Sampling Time:	2 - 7 days (short-term electret)
Analytical Procedure:	The voltage on an electret is read before and after the electret is exposed to the workplace atmosphere. The voltage difference corresponds to the quantity of radon in the workplace atmosphere.
Manufacturers Quoted Detection Limit:	0.7 pCi/L for short-term electret with a two day exposure and 0.4 pCi/L with a seven day exposure.
Manufacturers Quoted coefficient of variation:	The coefficient of variation is 10% (at one sigma) at radon concentrations of 4 pCi/L or greater at the minimum recommended exposure periods. (8.1.)
Method Classification:	Partially Validated Analytical Method
Chemist:	Dixon Cook
Date (Date Revised):	April, 1992 (February, 1993)

Commercial manufacturers and products mentioned in this method are for descriptive use only and do not constitute endorsements by USDOL-OSHA. Similar products from other sources can be substituted.

1. Introduction

This method describes the collection and analysis of radon gas using a standard S chamber E-Perm monitoring device. Workplace atmospheres are passively measured within the device by taking readings of the voltage difference before and after the exposure period.

1.1 History (Refs. 8.2 & 8.3)

Within the Salt Lake Technical Center, radon gas was previously collected on charcoal canisters and analyzed by a private contractor using the method of scintillation counting.

1.2 Principle

E-PERMs are passive devices requiring no power to function. They are integrating detectors and can be used to determine the average radon concentration in the working environment where the device is located during the measurement period. The E-PERM electret radon chamber consists of a plastic shell which has a spring-loaded plastic cap and a replaceable holder at the bottom which holds the electret. The electret has a Teflon surface which has a fixed voltage induced on it. When the E-Perm sampler is open, radon gas will diffuse into the shell through small holes at the top and the particulate radon progeny will be trapped by the filter. The negative ions released during the nuclear decay of radon gas will move to the surface of the electret causing a reduction in its surface voltage. The amount of voltage reduction is directly related to the time integrated average radon concentration to which the electret was exposed.

1.3 Advantages and Disadvantages

- 1.3.1 This method is extremely convenient for both the industrial hygienist and the analyst. No liquids are used either in the sampling or the analysis.
- 1.3.2 The standard S chamber E-Perm cannot be worn as a personal sampler and is to be used as an area sampler only.
- 1.3.3 The analysis can be completed in a few minutes and no digestion or expensive equipment is needed.
- 1.3.4 The E-Perm has adequate sensitivity for measuring workplace radon exposures.
- 1.3.5 There are no errors introduced due to temperature, humidity, air draft, or concentration variations. Corrections for background radiation are available for each state and are applied to each measurement.
- 1.3.6 The E-Perm does not measure radon daughters created outside the chamber. Since radon daughters are particulates and cannot pass through the filter, only radon gas can enter the chamber. The radon will decay into its daughters and the daughters inside the chamber will reduce the voltage on the electret.
- 1.3.7 This method is much cheaper than other methods since an electret can be re-used and since the measurement can be completed at the OSHA Laboratory and no private contractor need be used.

- 1.3.8 The standard S chamber E-Perm does not have adequate sensitivity for measuring an 8 hour workshift and must be deployed for at least 2 days.

1.4 Uses and Occurrence (8.1)

Radon is not used commercially. Radon is formed by the radioactive decay of certain naturally-occurring uranium and thorium isotopes to radon 222 and eventually to lead 206. Because radon diffuses from the soil and from the domestic water supply, it has become a concern in homes and workplaces. In regions with large deposits of radioactive materials in the ground, radon gas seeps into buildings and decays into radioactive radon daughters. In the 1970's the construction of energy-efficient buildings resulted in elevated concentrations of radon and other pollutants, many times over that found outdoors. (8.2)

The only known health effect associated with exposure to elevated levels of radon is an increased risk of developing lung cancer. The risk of developing lung cancer increases as the level of radon and the length of exposure increase. In 1985 the US-EPA evaluated the existing data on the lung cancer risk from radon exposure, and recommended that residents consider taking some kind of remedial action if the radon level in their houses exceeded 4 picocuries (pCi) of radon per liter of air. The EPA projects that if a person is exposed to 4pCi/L of radon and radon progeny for a lifetime there is a 1-5 % chance that the person will die of lung cancer. The EPA does not consider this a safe level of radon concentration, but it is lower than that proposed by some other organizations. The National Council on Radiation Protection & Measurements (NCRP) study says that 8 pCi per L of radon in air is an acceptable level for homes, and others believe the action level should be as high as 20 pCi/L (8.3).

1.5 Physical and Chemical Properties (8.4)

Radon	CAS No. 7647-01-0
Atomic formula	Rn
Atomic weight (longest-lived isotope)	222.0
Specific gravity	9.73 g/L
Melting point	-71. °C
Boiling point	-61.8 °C

2. Working Range and Detection Limit

- 2.1 An electret is a Teflon disk across which a voltage of approximately 750 volts has been applied. The dynamic range for a electret in an "S" chamber has a 200 V to 750 V range limitation which translates to a limitation of about 270 pCi/L-days (see calculation of radon concentration in Section 7). In other words, the voltage would fall from 750 V to 200 V if exposed for one day to about 270 pCi/L or if exposed for 10 days to about 27 pCi/L. The upper range can be extended by exposing the electrets for shorter than the recommended times. (8.1)
- 2.2 The manufacturer's quoted minimum measurable levels for radon analysis at 25% error using the E-PERM short-term electrets in an S-chamber are 0.7 pCi/L for a two day measurement, and 0.4 pCi/L for a seven day measurement. The minimum measurable level for an electret may be improved by using a longer sampling time.
- 2.3 The coefficient of variation is 10% (at one sigma) at radon concentrations of 4 pCi/L or greater at the minimum recommended exposure period of 2 days. (8.1)

3. Method Performance (8.1)

- 3.1 The error associated with the system component imperfections, which includes uncertainty in chamber volumes, electret thicknesses and other component parameters, was experimentally measured to be about 5% for the E-PERMs by Rad Elec Inc.
- 3.2 The error in the electret voltage reading can be as much as 1 volt which gives a percent error of 100

$X = 1.4 / (I - F)$. Where I = initial voltage and F = final voltage.

- 3.3 The maximum error introduced by using the EPA-listed state average background values to correct measurements made in various locations within a state is about 0.1 to 0.2. pCi/L. Background error can be minimized by using the precise gamma background level at the site of measurement. However even if there is a 20% error from the state average level, the error introduced is only about 0.2 pCi/L.
- 3.4 The total error is the square root of the sum of the squares of individual error components listed in 3.1. to 3.3. $ET = (E_1^2 + E_2^2 + E_3^2)^{1/2}$, where E_1 is 5%, E_2 is the error referred to in 3.2. and E_3 is the background error referred to in 3.3.
- 3.5 The error depends upon the type of E-PERM device and the measurement period.
- 3.6 No validation of this method was performed by the OSHA-SLTC - a full validation was performed by Rad Elec, Inc. (8.1).

4. Interferences

No interferences exist.

5. Sampling

5.1 Equipment

- 5.1.1 E-PERM ion chamber: The "S" (standard-volume) chamber consists of a plastic shell which has a spring-loaded plastic cap.
- 5.1.2 Electrets: Removable plastic discs containing an electrically charged wafer of Teflon. The white surface electrets are short-term samplers which can be used to sample for one to 14 days. [Chambers and electrets are available from Rad Elec, Inc., 7499 Whitepine Rd., Richmond, VA 23237.]

5.2 Sampling Procedure

- 5.2.1 The measurement should not be made if the occupant is planning remodeling; making changes in the heating, ventilating and air conditioning system; or performing other modifications that may influence the radon concentration during the measurement period. The E-PERM should not be deployed if the occupant's schedule prohibits terminating the measurement at the time selected for returning it to the Laboratory.
- 5.2.2 The building should be closed, with all windows and external doors shut (except for normal entrance and exit) for at least 12 hours prior to and during the sampling period. For this reason, measurements should be made during the winter whenever possible.
- 5.2.3 E-PERMs should be deployed into workplaces as soon as possible after their initial voltage is measured. Until an E-PERM is deployed, its electret cover should remain in place over the electret to minimize background effects.
- 5.2.4 To select the proper location of an E-PERM within a room, the following must be considered. The E-PERM must not be disturbed during the measurement period. The E-PERM should not be placed near drafts caused by high volume air conditioning vents, windows, and doors. Avoid locations near excessive heat, such as direct strong sunlight. The E-PERM should be placed flat on a shelf or table at least 50 centimeters (20 inches) above floor level and with the detector's top face at least 10 centimeters from other objects. Nothing should impede air flow around the E-PERM. The E-PERM should not be placed close to the outside walls of the building. (8.1)

- 5.2.5 When retrieving the E-PERM, care should be taken to inspect the device for damage during handling. The information called for on the 91A should be accurately recorded. The E-PERM serial number should be recorded in a log book along with a description of the location in the building where it was placed. The most important information is the day and time the E-PERM was opened and the day and time the E-PERM was closed.
- 5.2.6 After sampling is completed be sure the E-PERM is securely closed. Wrap the E-PERM top-to-bottom with a sample seal (OSHA 21 or equivalent).
- 5.2.7 E-PERMs should be deployed for a 2 to 7 day measurement period. The E-PERM is turned off by screwing down the "pop-up" lid on the top of the canister.
- 5.2.8 Ship the samples to the laboratory using appropriate packing materials. The E-PERM must be sent to the laboratory as soon as possible, preferably within a few days following exposure termination.

6. Analysis

6.1 Precautions

Refer to instrument and Standard Operating Procedure (8.1) manuals for proper operation.

6.2 Equipment

- 6.2.1 A standard volume E-PERM (SSTB or SSTG).
- 6.2.2 An instruction sheet for the industrial hygienist, and a shipping container for returning the E-PERM(s) to the laboratory.
- 6.2.3 Electret Reader from Rad Elec, Inc. for reading the electret voltages before and after exposure. (The reader is portable and can be used either in the field or in the Laboratory.)
- 6.2.4 Set of reference electrets.

6.3 Reagents - None are required.

6.4 Analytical Procedure (8.1)

Analyze the samples in accordance with the Standard Operating Procedure (8.1). All E-PERMs should be analyzed in the Laboratory as soon as possible following removal from the workplace.

- 6.4.1 The analyst must take every precaution to assure E-PERM custody continuity throughout the analysis. In particular, extreme care must be taken to assure that the identification number of each exposed electret remains traceable to the E-PERM shell identification number in which it was exposed whenever an electret is removed from an E-PERM.
- 6.4.2 Before using an E-PERM in the field, the initial voltage must be taken. If an initial voltage is less than 200 volts, the E-PERM must be discarded.
- 6.4.3 Place the closed E-PERM into the circular electret receptacle on the read-out instrument. Rotate the E-Perm in the electret reader to assure that it is well seated in the receptacle.
- 6.4.4 Open and close the shutter repeatedly until the same voltage reading appears twice in sequence (this usually takes 3 openings). The twice repeated voltage observed in this sequence is the true electret blank voltage. The voltage must be between -001 and +001 volts before taking a reading, if not, re-seat the E-Perm and reread the voltage.
- 6.4.5 Carefully unscrew and remove the bottom piece from the E-PERM. The bottom piece

holds the electret (the Teflon disk on the bottom piece). Do not touch the electret surface or the electret will discharge.

- 6.4.6 Carefully place the electret face down into the circular electret receptacle on the read-out instrument. Rotate the electret a little to assure that it is well seated in the receptacle.
- 6.4.7 Open and close the shutter repeatedly until the same voltage reading appears twice in sequence. The twice repeated voltage observed in this sequence is the true electret voltage. This value must be recorded in the proper place in the analyst's notebook. The E-PERM is now ready to be sent into the field.
- 6.4.8. Upon receiving the E-PERM from the industrial hygienist, read the final voltage from the electret following the previous procedure. After reading the final voltage, carefully remove the electret and replace it in the storage mode in an E-PERM (closed) or with its shipping cover.
- 6.4.9. Check the accuracy of the analysis by reading the E-PERM reference electrets once during the analysis and check against previous readings. Reference values should agree within 5% of their stated values. Record reference values in your notebook.

7. Calculations

- 7.1 In order to determine the average radon concentration (C) during the exposure period, the following equation is to be used:
where:

$$C = \frac{(CV)}{(K) \times (d)} - B$$

- C = Average radon concentration in pCi/L
- CV = initial electret voltage minus final electret voltage
- K = $1.88 + (0.006 \times (CV/2))$ (This is the calibration factor supplied by manufacturer)
- d = The number of days exposure
- B = a correction for background gamma radiation - generally 1 pCi/L. More accurate background corrections can be made by using the background gamma correction by state table found in 8.1, Part I Appendix-3, Page 5.

- 7.2 The concentration of radon in each air sample is expressed in pCi/L.

7.3 Reporting Results

- 7.3.1 Report results to the industrial hygienist as pCi/L radon, using two significant figures.
- 7.3.2 The estimated detection limit is reported when no analyte is detected. The detection limit for a short-term electret in an "S-Chamber" (assuming 25% error) is 0.7 pCi/L with an exposure of 2 days and 0.4 pCi/L with an exposure of 7 days (8.1, Part I Appendix-4, page 3).

8. References

- 8.1 E-PERM system Manual, Rad Elec, Inc.
- 8.2 Radon and Radon Daughter Field Measurements, George, Andreas C., Environmental Measurements Laboratory, US-DOE, Presented at the NBS Seminar on Traceability for Ionizing Radiation.
- 8.3 Radon Tagged as Cancer Hazard By Most Studies, Researchers, C&EN Feb. 6, 1989, Pg 7.

- 8.4 CRC Handbook of Chemistry and Physics, 52nd. Edition, The Chemical Rubber Co., 1971-1972.
- 8.5 Chemical Hygiene Plan, OSHA Laboratory.