Method number:	ID-208
Version:	3.0
OSHA maximum permissible concentration:	100 pCi/L (29 CFR Part 1910.1096 (c) (1))
Procedure:	An Electret-Passive Environmental Radon Monitor (E-PERM) is used to collect and measure the ionized particles produced by radon gas. The voltage on an electret is read before and after the electret is exposed to the workplace atmosphere. The voltage difference is proportional to the concentration of radon in the workplace atmosphere.
Recommended sampling time:	2 - 7 days (short-term electret)
Manufacturers quoted detection limit:	0.8 pCi/L for short-term electret with a two day exposure and 0.4 pCi/L with a seven day exposure.
Manufacturers quoted measurement error:	The measurement error is 5% (at one sigma) at radon concentrations of 100 pCi/L or greater at the minimum recommended exposure periods.
Status:	Partially validated analytical method.

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1. General Discussion

For assistance with accessibility problems in using figures and illustrations presented in this method, please contact Salt Lake Technical Center (SLTC) at (801)233-4900. These procedures were designed and tested for internal use by OSHA personnel. Mention of any company name or commercial product does not constitute endorsement by OSHA.

1.1 Background

1.1.1 History[1]

Prior to about 1992, OSHA collected radon gas on charcoal canisters and analyzed by a private contractor using the method of scintillation counting. Around 1992 OSHA began using the E-PERM system for monitoring radon exposures. E-PERMs are diffusive sampling devices that require 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 consists of a plastic shell which has a spring-loaded plastic cap and a replaceable holder at the bottom which holds an 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. If the radon atom decays in the sampler the particulate radon progeny will be trapped inside by the filter. The negative ions created during the radioactive decay of radon gas, or radon progeny, 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.

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. The recommended methodology for calculating average radon concentration using E-PERM data has been updated. This revision reflects the latest update to that methodology.

1.1.2 Hazardous effects[2] (This section is for information only and should not be taken as the basis of OSHA policy.)

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.

1.1.3 Workplace exposure

Radon is not used commercially. Radon is formed by the radioactive decay of the uranium series isotope ^{226}Ra. Because radon diffuses from the soil and from the

[1] Radon and Radon Daughter Field Measurements, George, Andreas C., Environmental Measurements Laboratory, US-DOE, Presented at the NBS Seminar on Traceability for Ionizing Radiation.
[2] Radon Tagged as Cancer Hazard By Most Studies, Researchers, C&EN Feb. 6, 1989, Pg 7.

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 diffuses into buildings and decays into radioactive radon progeny. In the 1970s the construction of energy-efficient buildings resulted in elevated concentrations of radon and other pollutants, many times over that found outdoors.

1.1.4 Physical properties and other descriptive information[3]

IMIS[4]:	R100
CAS number:	10043-92-2
atomic formula:	Rn
atomic weight:	222
specific gravity:	9.73 g/L
melting point:	-71.0 °C
boiling point:	-61.8 °C

2. Sampling Procedure

All safety practices that apply to the work area being sampled should be followed.

2.1 Apparatus

E-PERM ion chamber: The “S” (standard-volume) chamber consists of a plastic shell which has a spring-loaded plastic cap.

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 2 to 7 days.

2.2 Reagents

None required

2.3 Technique

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 and should be deployed in a tamper resistant container. 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.[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

[3] CRC Handbook of Chemistry and Physics, 52nd. Edition, The Chemical Rubber Co., 1971-1972.

[4] Radon (OSHA Chemical Sampling Information), 2010. United States Department of Labor, Occupational Safety & Health Administration (OSHA) Web site. https://www.osha.gov/chemicaldata/chemResult.html?recNo=883 (accessed June 2018).

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.

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).

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.

The E-PERM must be sent to the laboratory as soon as possible, preferably within a few days following exposure termination using the provided shipping container.

3. Analytical Procedure

3.1 Apparatus

A standard volume E-PERM (S Chamber).

E-PERM tamper resistant container.

An instruction sheet for the industrial hygienist, and a shipping container for returning the E-PERM(s) to the laboratory.

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.)

Set of reference electrets.

3.2 Reagents

None required

3.3 Sample preparation

No sample preparation is required. All samples are analyzed as received.

3.4 Analysis

Refer to the E-PERM system user's manual[5]. All E-PERMs should be analyzed in the Laboratory as soon as possible following removal from the workplace.

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.

[5] E-PERM System User's Manual, Version 3.1, Rad Elec, Inc.

Before using an E-PERM in the field, the initial voltage must be taken. If an initial voltage is less than 100 volts the E-PERM must be discarded.

Place the closed E-PERM into the circular electret receptacle on the voltage read-out instrument. Rotate the E-PERM in the electret reader to assure that it is well seated in the receptacle.

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.

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.

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.

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 to the field.

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.

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.

3.5 Calculations

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

$$C = \left(\frac{Vi - Vf - 0.066667 \cdot D}{K \cdot D} - B \cdot G\right) F$$

where C is the average radon concentration in pCi/L
Vi is the initial electret voltage in volts
Vf is the final electret voltage in volts
D is the number of days exposure
K is the calibration factor, and is determined from the following equation from Vi and Vf:

$$K = 0.314473 + 0.260619 \cdot ln\left(\frac{V_i + V_f}{2}\right)$$

B is the correction for background gamma radiation - background gamma correction by state table found in footnote reference 5, Part I Appendix-3, Page 5.

G is gamma conversion constant
and F is elevation correction factor, and is equal to 1.0 for elevations ≤ 4000 feet, but is otherwise determined from the following equation using $E,$ the elevation above sea level in feet:

$$F = 0.79 + \left(\frac{6 \cdot E}{100{,}000}\right)$$

The concentration of radon in each air sample is expressed in pCi/L. Report results to the industrial hygienist as pCi/L radon, rounded to the nearest 0.1 pCi/L. The estimated detection limit is reported when no radon 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.

4. Method Validation

Limited validation of this method was performed by the OSHA-SLTC - a full validation was performed by Rad Elec, Inc.[5]

4.1 Detection limit

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 0.8 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.

4.2 Measurement error

The error depends upon the type of E-PERM device and the measurement period.

Error component number 1 (E1): 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.

Error component number 2 (E2): The error in the electret voltage reading can be as much as 1 volt which gives a percent error of:

$$\%\ error = \frac{100 \cdot \sqrt{2}}{Vi - Vf}$$

Where Vi is the initial electret voltage in volts
Vf is the final electret voltage in volts

Error component number 3 (E3): 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 a measured gamma background level at the site of radon measurement. However even if there is a 20% error from the state average level, the error introduced is only about 0.2 pCi/L. Rad Elec Inc recommends using a value of 0.1 pCi/L for the estimating the error associated with background gamma radiation.

The total error (ET) is the square root of the sum of the squares of individual error components listed above.

$$ET = \sqrt{E1^2 + E2^2 + E3^2}$$

where ET is the total error
$E1$ is the system error
$E2$ is the voltage reader error
and $E3$ is the background gamma approximation error

The measurement error for several radon exposures and sample durations is provided in Table 4.2.

Table 4.2
Measurement Error for E-PERM for Several Exposure Times and Concentrations

days	measurement error (%) 4 pCi/L	25 pCi/L	100 pCi/L
2.0	10.9	5.3	5.0
3.4	7.8	5.1	5.0
7.0	6.2	5.0	*

*It is not possible to measure 100 pCi/L radon with a 7 day exposure. The maximum exposure time for measuring 100 pCi/L is 3.4 days.

4.3 Working range

An electret is a Teflon disk across which a voltage of approximately 750 volts has been applied. The dynamic range for an electret in an "S" chamber is 100 V to 750 V, which translates to a limitation of about 342 pCi/L-days (see calculation of radon concentration in Section 3.5). In other words, the voltage would fall from 750 V to 100 V if exposed for one day to about 342 pCi/L or if exposed for 10 days to about 34 pCi/L. The upper limit of airborne radon concentration can be extended by exposing the electrets for shorter than the recommended times.

4.4 Interferences

Background gamma radiation interferes with sample collection because it affects the voltage on the electret. This interference is typically insignificant and can be corrected mathematically (see Section 3.5). If gamma radiation is expected to be abnormally high during sampling separate measurements of gamma radiation can be made to adjust results accordingly.

4.5 Reproducibility

Six standard S chamber E-Perm monitoring devices were sent to Bowser-Morner to be spiked for 4 days with 53.0 pCi/L of radon (212 pCi/L-days). The samples were returned to the OSHA Salt Lake Technical Center for analysis. Results are provided in Table 4.5. The samples were analyzed after being stored for 2 days.

Table 4.5
Reproducibility Data for Radon Using E-PERM

sample number	theoretical (pCi/L)	recovered (pCi/L)	recovery (%)	deviation (%)
1	53.0	53.0	100.0	0.0
2	53.0	49.3	93.0	-7.0
3	53.0	54.2	102.3	2.3
4	53.0	52.1	98.3	-1.7
5	53.0	53.0	100.0	0.0
6	53.0	52.6	99.2	-0.8