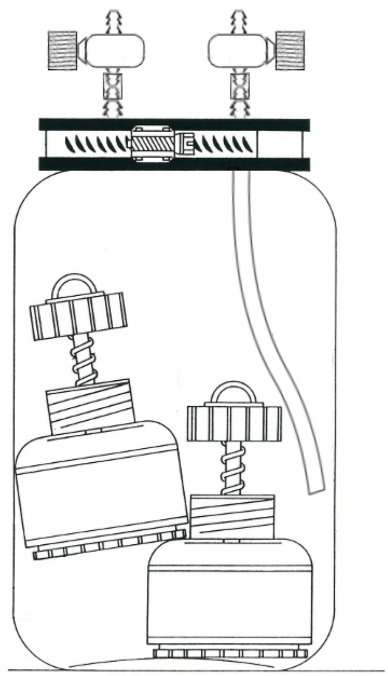
Rad Elec Inc.



Radon in Natural Gas Operator's Manual

Revision 1.1
18 February 2020

Table of Contents

Introduction

Electret ion chambers (known by the trade name E-PERM®) have been extensively used for measuring radon concentrations in both air and water, but this new methodology allows for the characterization and measurement of radon in natural gas. Natural gas has a distinct chemical composition, making it very different from air both in terms of density and ionization potential.

The Radon in Natural Gas E-PERM® Test Kit will allow you to make accurate measurements of the radon concentrations present in natural gas, although care must be given to ensure that the sampling jars are properly sealed to prevent any gas from escaping (which can lead to a negative bias).

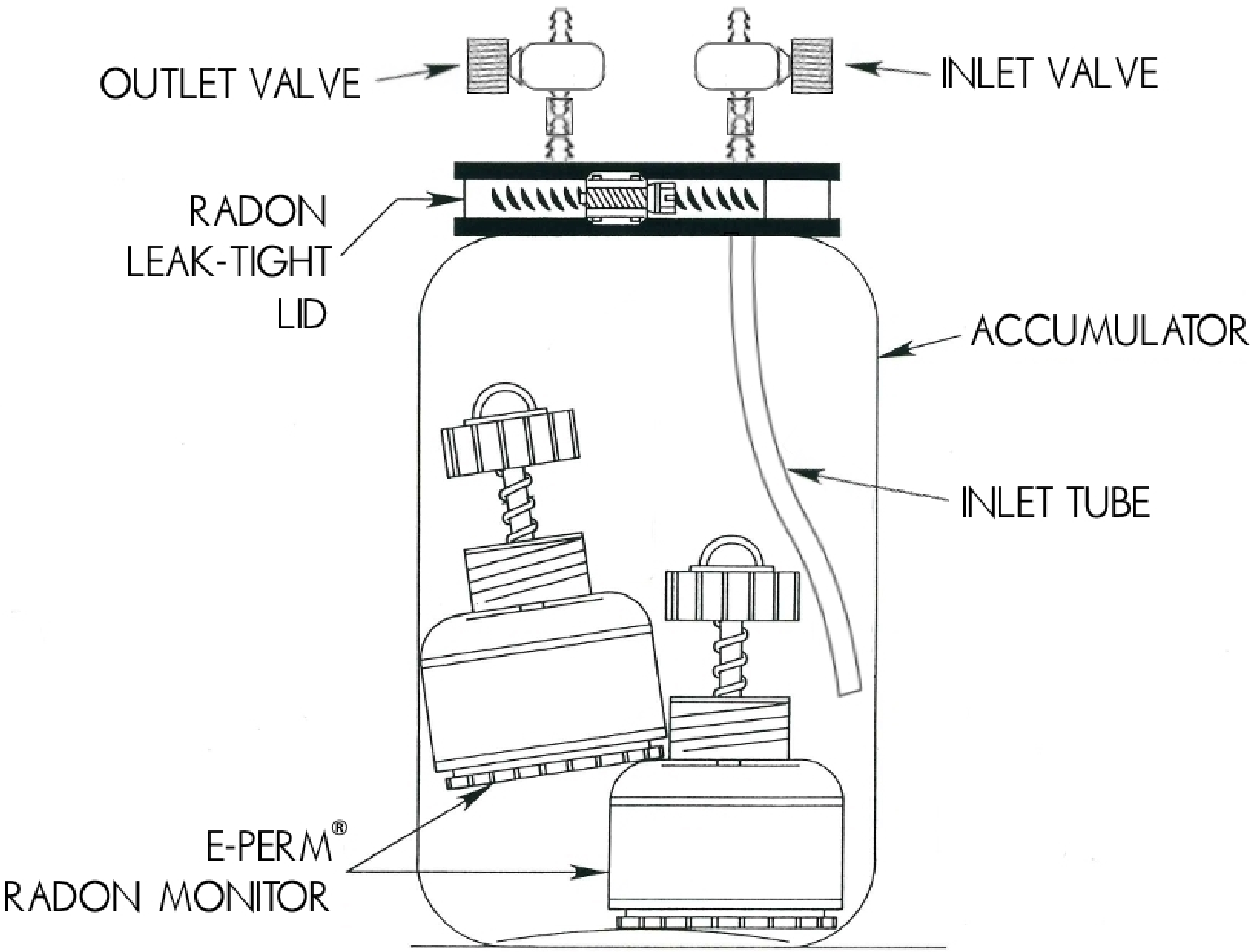
Test Kit Components

Each Radon in Natural Gas E-PERM® Test Kit includes the following:

- **2 Sampling Accumulator Jars** (3.7 Liter)
- **4 Valves**
- **2 Sampling Jar Lids** (replacements can be ordered from Rad Elec, if needed)
- **Valve Wrench** (for removing / replacing valves from sampling jar lids)
- **2 Leak-Tight Adjustable Lid Collars**
- **Manual**
- **Radon in Natural Gas Spreadsheet** (for analyzing results)

The lid valves are modular, making it easy to remove them from the sampling jar lids (if one needs to be replaced).

Sampling Jar Diagram



Overview

This section will discuss the procedures required to conduct measurements of radon gas concentration in natural gas. It goes beyond the scope of this manual to provide instructions on how to safely procure a natural gas flow from a source, as this procedure is not intended for normal residential radon testing. Suffice it to say that you should be very careful when directing the natural gas source into the accumulating jar – natural gas is highly flammable!

Natural gas is highly flammable – please keep this in mind throughout the sampling and exposure periods.

Procedure

1. Record the **initial voltages** of electrets. Short-term (ST) electrets are recommended, but long-term (LT) electrets can be used if the radon concentration is extremely high.

2. Load both electrets into S chambers, then place the electret ion chambers into the sampling accumulator jar.

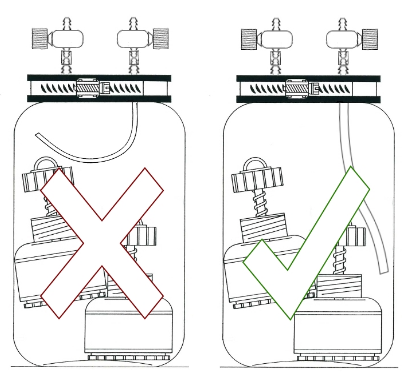
Theoretically, any ion chamber (such as the L or L-OO) can be used, but initial characterization was performed using the S Chamber.

3. Immediately before the exposure commences, ensure that the electret ion chambers are in the "ON" position (by unscrewing the spring-loaded top on the S chamber).

4. Screw the plastic lid onto the sampling accumulator jar. Ensure that the lid is tight.

5. Install the adjustable lid collar once the plastic lid has been screwed onto the accumulator jar; use a screwdriver to fully tighten the collar. A leak-proof accumulator jar is essential for the accurate measurement of radon in natural gas.

6. Open both the inlet and outlet valves. You can identify the inlet valve (where the natural gas will flow *into* the accumulator jar) by the piece of tubing that extends downward into the jar. The tube assists in ensuring that the original air is entirely displaced by the incoming natural gas flow.



7. Connect the inlet valve to the stream of natural gas.

8. Ensure that the natural gas stream has a flow rate of approximately 20 LPM (or greater). This provides sufficient volume exchange to fully displace original air with the sampling gas.

9. Continue to flow the natural gas for approximately two (2) minutes; it will displace the existing air in the sampling accumulator jar. Check for the flow rate by observing the outlet valve.

It's important to wait a few moments before closing the outlet valve. This is to avoid the possibility of creating an abnormally high pressure inside the accumulator jar, which would necessitate a calibration correction.

10. After the sample acquisition period is concluded, terminate the natural gas stream and close the inlet valve.

11. Wait a few seconds, and then close the outlet valve on the sampling accumulator jar. Both valves should now be closed. The sampling accumulator jar should now represent a sealed environment.

Electrets below 100 volts should be retired from service.

12. Record the beginning date and time of the exposure period.

13. After the desired exposure period – usually one (1) to three (3) days – unscrew the adjustable rubber collar and remove it from the accumulator jar. Unscrew the lid, and unseal the jar.

14. Close the electret ion chambers, and be sure to record the ending date and time of the exposure period. If an elevation correction is needed (for elevations above 4000 feet or 1219 meters when using S chambers), make note of this.

Note that any potential elevation should be recorded at where the sampling accumulator jar was ***exposed***, not necessarily where the sample was collected.

15. Remove the electrets from the ion chambers, and record their **final voltages**.

The **initial radon concentration** represents the radon concentration in the gas when the sample was collected. This is the value you want.

16. Input the initial voltages, final voltages, dates and times into the spreadsheet. It will provide you with the **initial radon concentration** of the natural gas.

Calculating Results

Although the spreadsheet can be used to analyze results quickly and easily, this section will demonstrate how to calculate results manually. In short, this section is intended for those with the personal curiosity and/or professional need to see the "nitty gritty" mathematical details behind using electret ion chambers to calculate radon concentrations in natural gas.

Results can be calculated quickly using the spreadsheet (which can be found on the flash drive).

1. At the conclusion of the test, make sure that you have the start/end dates and times, in addition to the initial and final electret voltages for each detector.

2. Look up Constants (A, B, and G) for the specific E-PERM® configuration, as shown in the table below. The most common configuration to use for measuring radon in natural gas is the SST (short-term electret loaded into an S chamber).

E-PERM® Configuration	Constant A	Constant B	Constant G
SST	0.314473	0.260619	0.087
SLT	0.031243	0.021880	0.087
LST	0.124228	0.040676	0.12
LLT	0.010189	0.003372	0.12
LST-OO	0.074671	0.037557	0.12
LLT-OO	0.011965	0.002079	0.12
LMT-OO	0.013497	0.012499	0.12

3. Calculate the Electret Ion Chamber Calibration Factor (EIC CF) using Constants A and B from Step 1, with the following equation:

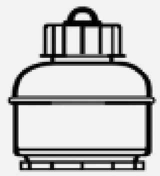
$$\text{EIC CF} = A + \left(B \times \ln\left(\frac{IV + FV}{2}\right)\right)$$

Where...

A = Constant A
B = Constant B
$\ln$ = Natural Logarithm ($\log_e$)
IV = Initial Voltage
FV = Final Voltage

4 Note the elevation of the exposure site (in feet), and calculate the Elevation Correction Factor (ElevCF). If you are measuring the election in meters, this value can be converted to feet by dividing it by 3.28084.

S Chambers



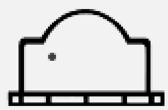
For Elevations <= 4000 feet

ElevCF = 1

For Elevations > 4000 feet

$$\text{ElevCF} = 0.79 + \left(\frac{6 \times \text{Elevation(ft)}}{100000} \right)$$

L / L-OO Chambers



For Elevations <= 200 feet

ElevCF = 1

For Elevations > 200 feet

$$\text{ElevCF} = 1.005 + \left(\frac{4.5526 \times \text{Elevation(ft.)}}{100000} \right)$$

5 Estimate (or measure) the environmental background radiation of the exposure site. The background gamma units should be in µR/hr (microroentgens per hour). If you are measuring the background gamma in nGy/hr (nanograys per hour), these units can be converted to µR/hr by taking the nGy/hr value and dividing it by 8.7. If you are estimating the environmental background radiation, please refer to the chart of average gamma radiation levels for each US state and Canadian province located in the E-PERM® System User's Manual.

6 Calculate the exposure duration in days, to the thousandths decimal place. For example, a 50 hour exposure duration is 2.083 days.

7

Calculate the **average** (overall) radon concentration using the values that you've determined in Steps 1 through 6.

$$\text{Radon Concentration (pCi/L)} = \left(\left(\frac{(IV - FV) - (IVD \times Days)}{EIC\ CF \times Days} \right) - (\gamma \times G) \right) \times (Elev\ CF)$$

$$\text{Radon Concentration (Bq/m}^3\text{)} = \left(\left(\frac{(IV - FV) - (IVD \times Days)}{EIC\ CF \times Days} \right) - (\gamma \times G) \right) \times (Elev\ CF) \times 37$$

Where...

IV = Initial Voltage
FV = Final Voltage
IVD = Inherent Voltage Discharge
Days = Exposure Duration
EIC CF = EIC Calibration Factor
γ = Estimated or Measured Gamma
G = Constant G
Elev CF = Elevation Correction Factor

0.066667 for short-term electrets

0.022223 for long-term electrets

8

When measuring radon in natural gas, the results must be divided by a correction factor. This correction factor is **1.10** for natural gas, and is a composite value representing the decreased *W* value in natural gas (the energy in electron volts required to produce an ion pair) along with the decreased density of natural gas (relative to air). When factoring in both of these properties of natural gas, electret ion chambers will over-respond by approximately 10%. Therefore, **we need to divide the average radon concentration by 1.10 to properly account for the differences between natural gas and air**. If you are measuring a different gas (such as propane), this correction factor will be different.

9 The radon concentration calculated in the previous step represents the **average** radon concentration in natural gas. This is the overall radon concentration of the natural gas throughout the exposure period, during which radioactive decay has occurred. In order to calculate the **initial radon concentration** of the natural gas at the time the sample was collected, use the following equation:

$$\text{Initial Radon Concentration} = \frac{\text{AvRnC} \times \lambda \times \text{Days}}{1 - e^{(-\lambda \times \text{Days})}}$$

Where...

AvRnC = Average Radon Concentration
Days = Exposure Duration
λ = 0.1814 (decay constant of radon in days)

10 At this point, you will have calculated the **initial radon concentration** of the natural gas sample that was collected.

The initial radon concentration represents the concentration at the moment the sample was collected – this is very likely the value that you're seeking to measure!

Afterword

If you've made it this far, thanks for reading our Radon in Natural Gas User's Manual. We at Rad Elec are dedicated to listening to our customers' suggestions, so please contact us if you have any feedback (critical or otherwise) to improve our instruments or this document. We hope that you find this methodology to be an accurate, robust, and cost-effective addition to the catalog of Rad Elec radon measurement equipment.

If you'd like to learn more about the research behind measuring radon in natural gas, you can find the article entitled "Measurement of Radon in Natural Gas and in Propane Using Electret Ion Chambers" on our website (www.radelec.com), located in the Publications section.

Please contact us (using the information below) if you have any questions, concerns, or bright ideas!

Rad Elec Inc.

5716-A Industry Lane
Frederick, Maryland 21704
(800) 526-5482
info@radelec.com