FOUR INCHES! TOO CLOSE, TOO FAR, JUST RIGHT?

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INTRODUCTION

The July 1992 Indoor Radon and Radon Decay Product Measurement Device Protocols, EPA 402-R-92-004 (EPA 1992) provides five measurement device location selection criteria that should be followed when placing a device within a room for measurement of the radon concentration. These criteria include: (1) a place where the device will not be disturbed and there is adequate room for the device, (2) away from drafts caused by heating, ventilating and air conditioning vents, doors, fans, and windows, and areas of high heat, such as near fireplaces or in direct sunlight, and areas of high humidity should be avoided, (3) the device should be at least three feet from windows and other potential openings in the exterior wall and if there are no potential openings the device should be at least one foot from the exterior wall, (4) the device should be at least 20 in. above the floor and at least **four inches from other objects**, and (5) the device should not be placed in a kitchen, laundry room, closet or bathroom.

These location selection protocols along with the measurement condition protocols help to ensure a more standardized and reproducible testing environment within the home or building environment from one test to the next and from one home to another. They in part also help to produce a worst-case scenario-testing environment.

The EPA protocols do leave open some room for interpretation. If a device is lifted off of a shelf to dust under would this invalidate or even introduce any additional error into the result? If a device is placed on top of a television set that happens to be on for several hours each night, would that be considered excessive heat? Would a different result be obtained if a device were placed 30 in. above the floor instead of 20 in.? EPA did not consider this to be a significant difference! Would two devices that were touching each other interfere with the diffusion of radon into one or the other of the devices?

Some of these protocol requirements may be more sensitive to deviation than others. For instance, Gray and Windham 1989, found a 24% over response for open-faced charcoal canisters exposed to an air velocity of 30 linear feet per minute. They advised strict conformance to protocols for this device. Charcoal canisters are also sensitive to temperature and humidity. At 50% relative humidity a raise in temperature from 50° to 80° F resulted in a 26% decrease in charcoal collection efficiency (Ronca-Battista and Gray, 1987). High humidity will also decrease charcoal collection efficiency, particularly after two days of exposure. Thus the reason for avoiding kitchens, bathrooms, and laundry rooms. However, deviations for some devices to some of the requirements may not have any adverse effect on test results. A change in the most recent EPA protocols (1992) for placement of the device from the floor from 30 in. to 20 in. was not thought to be critical. Additionally, would placing two devices closer than four inches to one another or to any other object adversely affect their result?

The intent of this experiment was to examine one small part of the current device placement protocols. This examination is by no means exhaustive with only four devices examined under a limited number of scenerios. Hopefully, others will provide additional information on this topic as well as other research related to the device protocols. This type of information may be very useful to future AARST working groups involved in the update, revision, or adoption of new radon device standards.

Diffusion

According to kinetic theory, the molecules in a gas are continually moving and colliding with each other. This motion and these collisions produce a random and uniform distribution of a substance in a given volume. This distribution will follow a concentration gradient, whereby the gas will diffuse from a region of high concentration to a region of lower concentration. The rate at which this diffusion occurs is dependent upon temperature and the molecular or atomic mass. For the specific case of Radon-222, atoms in a typical basement environment will be traveling at about 400 mph, but only over very short distances. This point is brought up only so that it is realized that radon gas diffusion will fairly quickly produce a uniform concentration within the basement environment. Point sources such as open bottom sump pits and HVAC system air flows could certainly cause perturbations to this uniform distribution. However, as Dr. Kearney said "except for thermal, radioactive decay, and non-steady-state ("puffs") effects, radon concentration in an enclosed volume is, for health physics purposes, uniform. Consider the uniformity of the salinity of ocean water, top to bottom, side to side. Elementary kinetic theory explains it all" (Health Physics Newsletter, 1991, Vol. 19, No. 3).

It would seem reasonable to assume that diffusion would work to produce a uniform exposure to various radon test devices whether they were four inches apart or touching, or whether they were touching something else such as a table top or some sort of enclosure.

Materials and Methods

A series of radon gas exposures was carried out on different radon measurement methods, both passive and active, in both a well-controlled radon chamber and a basement environment. During all exposures a control device(s) were deployed strictly according to EPA radon testing protocols. The control device(s) served to provide the reference radon value against which the other device results were compared.

Various deviations of the protocols were tested including devices touching one another, devices less than four inches from other objects, devices in closed containers, devices in buckets, and devices in sealed Tyvek Bags (Figures 1 & 2). The closed containers were plastic boxes provide by Rad Elec, Inc. They are designed to hold two E-Perms in the open position. There is a foam insert within the box that holds the two E-Perms in place. The interior volume of the box is 240 cubic in., with 67 cubic in. taken up by the foam insert. With the lid of the box closed there are two circular openings on each side to allow for air movement into and out of the box. These two openings provide for 1.6 sq. in. of open space. The Tyvek Bags are 10" wide by 14.5" long with a sealable flap. Tyvek, manufactured by DuPont, is a 100% high-density polyethylene fiber. It is vapor-permeable. Tyvek is virtually non-linting, plus its tight pore structure keeps even the smallest particulates from dusting through the package. The bucket used was a 1.5 gal. standard plastic bucket.

Devices tested were F&J R40VDB four-inch diffusion barrier charcoals, Rad Elec short-term electret ion chambers, Landauer's Radtrak Alpha Track Detectors (ATD), and Pylon AB-5/PRD.

Devices tested in the radon chamber were kept under constant conditions of temperature, relative humidity, and radon concentration throughout the exposures. Two separate exposures were carried out in the chamber at concentrations of 10 and 16 pCi/L, 68°F, 31% relative humidity, and 9 microR/hour. Two separate exposures were also carried out in the basement environment at around 8 pCi/L, 70°F, 37% and 45% relative humidity, and 8 microR/hour. Radon concentration, temperature, and relative humidity did vary somewhat in this basement environment during the exposure period.

Results and Discussion

Four separate exposures were performed; the first exposure took place in the radon chamber and deployed two E-Perms in the open box, two E-Perms in the closed box, two E-Perms in only the foam insert, two E-Perms in the sealed Tyvek Bag, eight E-Perms in the bucket, four E-Perms touching one another, and four E-Perms as controls. The second exposure took place in the basement environment and consisted of all the same scenarios as above except for the four E-Perms touching. The third exposure took place in the radon chamber and deployed four charcoals touching one another, four charcoals in sealed Tyvek Bag, two charcoals touching in a closed box, eight charcoals in 1.5 gal bucket, four charcoals as controls, four ATDs touching, four ATDs touching and in sealed Tyvek Bag, four ATDs touching and in closed box, four ATD controls, four Pylon AB-5/PRD's as controls, and four Pylon AB-5/PRDs with detectors ½" from each other. The fourth and final exposure took place in the basement environment and deployed two charcoals as controls, two charcoals in closed box, and two charcoals in closed box but with foam insert removed.

Listed in Tables 1-4 are the configurations, sample size, and mean radon concentration plus or minus one standard deviation from the four different exposures.

An analysis of variance was used to judge whether the population means were statistically different from one another or not. The analysis of variance does not tell which specific populations means are different, just that they are different or not. A paired T-test was used to look at the data from the Pylons and the two charcoal configurations in the fourth exposure, since there were just two population means and there was equal sample size.

Table 5 provides the primary conclusion from this study. A difference in the population means was only seen in the third and fourth exposures involving charcoal canisters, all other exposures with all other devices showed no difference of the population means under the various configurations.

Conclusions

Even an intuitive examination of Tables 3 and 4 show that charcoals contained in a closed, small volume (240 cubic in.) box underestimate the radon concentration as compared to the controls by 35% and 47%, respectively. It is possible that due to the limited volume there may be a depletion zone around the charcoals that is limiting uptake.

Given adequate air space all test devices, even charcoals, did not seem to be effected by violation of the four inch separation distance as required by EPA protocols. This finding would seem to be particularly consistent with devices such as alpha tracks, E-Perms, and continuous monitors that do not have adsorptive properties.

Based on this initial study, placement of alpha track detectors, E-Perms, continuous monitors, or charcoal canisters within four inches of "other" objects would not appear to adversely effect measurement results. "Other" objects should be kept in the context of the present study. Charcoal canisters should not be enclosed in a "limiting volume".

The question that remains is, "should the test device protocols be changed, should they be left alone, or could there be specific requirements germane to only certain test devices?" Further study will be needed to provide the answer.

Additional, interesting protocol questions remain, should crawl space vents be closed or open during testing, what is a good definition of lowest-livable level, and is the requirement for 10% duplicates necessary?

Note: The mention of specific product names within this report does not represent endorsement by the Department. These products are commonly used in the industry and were available to the Radon Division for this study.

References

Gray, D. and Windham, S., EPA Develops New Canister, Radon News Digest, April 1989.

Health Physics Newsletter, March 1991, Volume XIX, No. 3, page 12.

Marion, J. B., General Physics with Bioscience Essays, John Willey & Sons, Inc., 1979.

Ronca-Battista, M. and Gray, D., The Influence of Changing Exposure Conditions on Measurements of Radon Concentrations with Charcoal Adsorption Technique, USEPA.

United States Environmental Protection Agency, Indoor Radon and Radon Decay Product Measurement Device Protocols, EPA 402-R-92-004, July 1992.

Table 1, First Exposure, Radon Chamber, ST E-PERMs

Configuration	**Sample Size**	**Mean (pCi/L)**	**+/- 1 Std. Dev.**
E-Perm box, open	2	11.3	0.6
E-Perm box, closed	2	11.2	0.8
Foam only	2	11.3	0.2
Sealed Tyvek Bag	2	10.4	0.8
1.5 Gal Bucket	8	11.3	0.4
Touching	4	11.2	0.5
Controls	4	11.2	0.2

Table 2, Second Exposure, Basement, ST E-PERMs

Configuration	**Sample Size**	**Mean (pCi/L)**	**+/- 1 Std. Dev.**
E-Perm box, open	2	8.7	0.3
E-Perm box, closed	2	8.3	0.8
Foam only	2	8.0	0.4
Sealed Tyvek Bag	2	8.3	0.4
1.5 Gal Bucket	8	7.8	0.6
Controls	4	8.0	0.5

Table 3, Third Exposure, Radon Chamber, Char/ATD/Cont. Mont.

Configuration	**Sample Size**	**Mean (pCi/L)**	**+/- 1 Std. Dev.**
Touching (Char.)	4	15.7	0.5
Touching in sealed Tyvek Bag (Char.)	4	16.7	0.8
Touching in closed E-Perm box (Char)	2	11.2	0.6
1.5 Gal Bucket (Char.)	8	14.6	1.2
Controls (Char.)	4	**15.9**	0.8
Touching (ATD)	4	15.9	2.8
Touching in sealed Tyvek bag (ATD)	4	16.1	3.3
Touching in closed E-Perm box (ATD)	4	17.2	1.7
Controls (ATD)		**15.3**	4.5
½" separation (Pylon)	4	15.6	0.1
Controls (Pylon)	4	**15.6**	0.2

Table 4, Fourth Exposure, Basement, Charcoals

Configuration	Sample Size	Mean (pCi/L)	+/- 1 Std. Dev.
E-Perm box, closed (Char.)	2	5.2	0.1
Controls	2	**8.4**	0.3

Table 5, Results of Statistical Tests on Population Means

Exposure	Number of Configurations	Test Device	Any Difference in the Means?	Probability of Type I Error
First	7	ST E-PERMS	No	0.05
Second	6	ST E-PERMS	No	0.05
Third	5	Charcoal	Yes	0.05
Third	4	ATD	No	0.05
Third	2	Cont. Monitor	No	0.025
Fourth	2	Charcoal	Yes	0.025

Figure 1

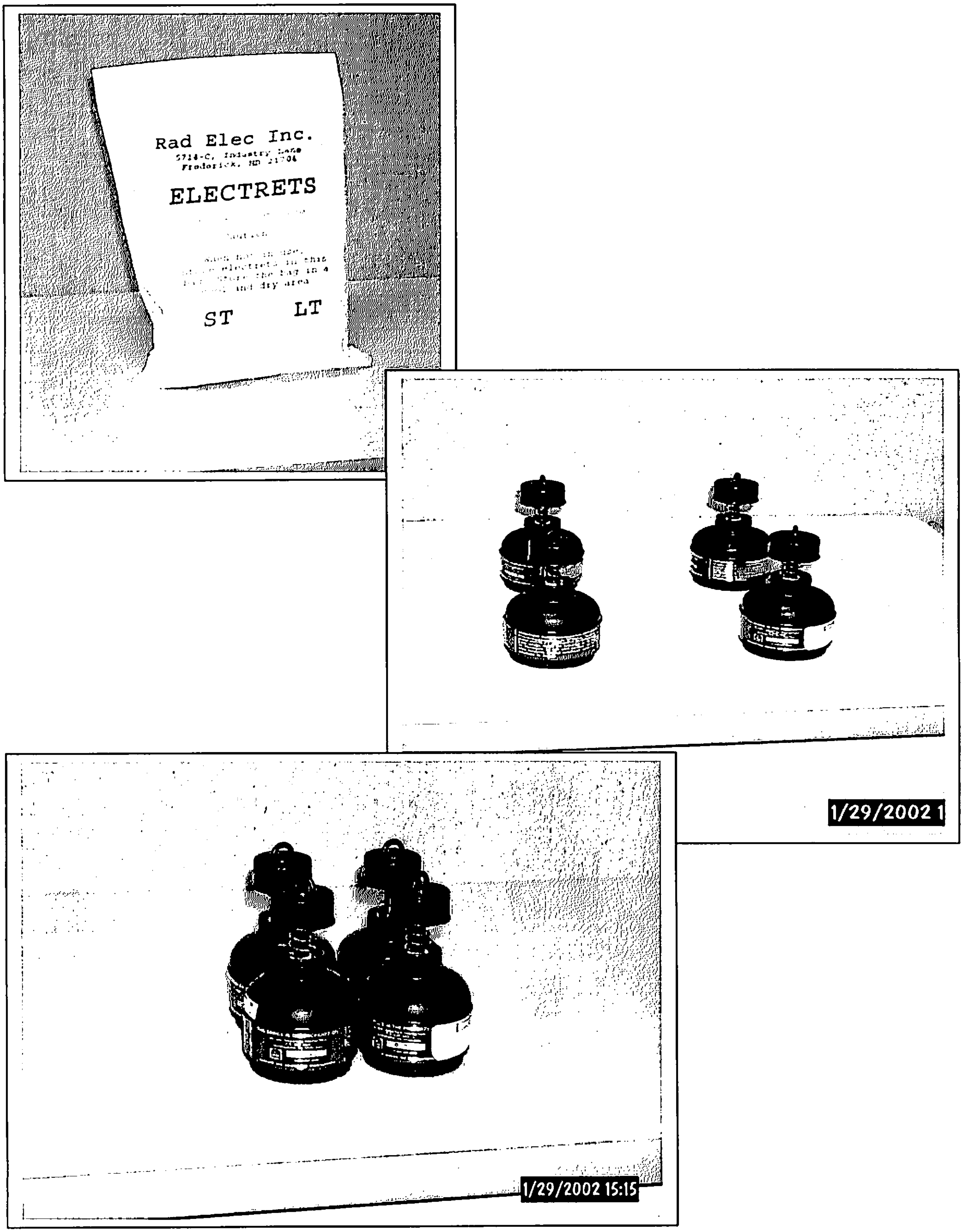

Figure 2