STUDY OF THE EFFECT OF TAMPERING AND ITS DETECTION DURING SHORT-TERM TESTS

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ABSTRACT

This Study, sponsored by the Pennsylvania Department of Environmental Resources (PA DER) evaluated methods and equipment available in Pennsylvania which could be used to detect or deter test interference. Nineteen different radon or WL instruments were used at four houses of different styles during this Study. Variations in test interference were performed under single-blind conditions during thirty-six of the forty-eight short term test runs. The tests were performed during the fall of 1992 and the winter of 1993. The parameters measured were radon levels, WL levels and their equilibrium, indoor and outdoor temperatures, humidity changes, pressure changes and CO2 levels. This study shows that it is unlikely that the detection of the most common methods of tampering can be determined by one single method. More than likely, only by utilizing a number of tamper controls, can tampering be determined with any degree of certainty.

INTRODUCTION

The largest percentage of radon tests in single family homes in the United States is performed as a short-term test during real estate transactions. Typically, this test is then used as the sole basis for deciding upon the need for mitigation until the house is again tested during the next real estate transaction. There has been growing concern that this short term test can be easily tampered with in order to avoid the cost of mitigation and/or the disruption of the house sale. The most recent EPA Protocols, "Radon and Radon Decay Product Measurements in Homes" states that "The test should include method(s) to prevent or detect interference with testing conditions or with the testing device itself." The objective of this Study was to investigate the ability of a representative selection of the radon/RDP testing devices, methods and anti-tampering controls, used in Pennsylvania in connection with real estate transactions, to detect the existence of non-standard test conditions and to quantify the effect that such conditions have on the results obtained.

NON-STANDARD TEST CONDITIONS

This study investigated the effect of test interference in four individual dwellings during three different seasons. Each house had a round of four short term tests done in three different seasons, for a total of twelve tests per house and forty-eight tests for the whole study. The changes in radon levels were noted, versus the degree of tampering that had taken place. In addition the radon and RDP measurements as well as other interference detecting devices or methods were evaluated without knowledge of what had been done in order to determine if the interference could be determined from the equipment response. To accomplish this, three of the four short term tests done during each round of testing were interfered with by Pennsylvania DER employees after the researchers had placed the equipment and left the dwelling. Before the researchers returned, at the end of the short term test, the interference that had been done was returned to its original condition so that it would be undetected. It was agreed that the first short term test of each run would not be interfered with so that a base line radon and RDP concentration could be obtained and a comparison of the equipment performance could be made. It was also agreed which radon and RDP equipment would be open for interference during each of the interfered with 2nd, 3rd, and 4th short term tests done in each round of testing, so as to allow more concentrated effort on determining the interference detecting capabilities of each detector. The researchers were not told what had been done to the equipment or dwelling until they had reported their conclusions.

The major difference between this study and real world testing is the active radon detectors, especially those that do not use any pumps, used in this study were already in equilibrium with the radon concentration in the area being tested versus real life testing where the detector is brought into the space and has a short period until it reaches equilibrium. In addition the interference method of opening windows before and after the technician arrives was not tried because the set up time for so many pieces of equipment took a few hours rather than the more typical 15 minutes. The response time of the equipment to changes in concentration as well as the changes in the ambient concentration due to ventilation is, however, documented.

EQUIPMENT USED IN THE STUDY

Continuous radon equipment

PY-Rn	Pylon AB5 #261 or #317 w/PRD (Pylon Electronic Dev. Co., LTD)
RAD7-Rn	RAD 7 (Niton Corp.)
F210-Rn	F210 (Femto-TECH Corp)
F510-Rn	F510 #144 (Femto-TECH Corp)
SURV-Rn	Surveyor (Sun Nuclear Corp)

HPRM-Rn Honeywell Professional Radon Monitor (Sun Nuclear Corp)
GEM-Rn Gemini radon monitor (Radonics)
RGM3-Rn RGM3 (Eberline Instrument Corp) NOTE: This was the reference detector

Continuous WL monitors

CIRAS-WL Ciras II (Alpha Nuclear Corp)
PY-WL AB5 #262 with AEP 25 head (Pylon Electronic Dev. Co., LTD)
TN-WL TN-WL-02 (Thompson Neilson, LTD)
EBL-WL WLM #536 and WLR (Eberline Instrument Corp)
GEM-WL Gemini radon monitor (Radonics)

Radon progeny integrating sampling units - RPISU

CAIRS-WL Cairs (Canadian Institute for Radiation Safety)
ER 300 E-RPISU - (Rad Elec, Inc.)
ER 400 E-RPISU - (Rad Elec, Inc.)

Passive detectors and single average electronic monitor

3 - DMA 4" Open faced charcoal canisters (DMA Radtech, Inc.)
3 - ES Ion S chambers with short term electrets (Rad Elec, Inc.)
RA Radon Alarm (Eviralert Corp)

First floor detectors

F510F F510 #145 (Femto-TECH Corp)
PYW2 AB5 #408 w/AEP 47 head (Pylon Electronic Development Co., LTD)
EBLF WLM #324 (Eberline Instrument Corp)

Pressure, ventilation and interference equipment

MODUS T20 Pressure Transmitter (MODUS INSTRUMENTS, INC.)
TELAIRE CO2 MONITOR (GAZTECH INTERNATIONAL CORP)
FURNACE RUN TIME Pressure relay switch (GRAINGER CO.)
RECORDAIRE DATALOGGER (GAZTECH INTERNATIONAL CORP)
TAPE SEALS (EQUITRON, INC)-(RADON ANALYTICAL LABORATORIES) - (RTCA)
CAULK SEALS Clear Zip-A-Way Removable Sealant (RED DEVIL)
Tub and Tile Adhesive Caulk (Poly Seamseal)
TAMPER BOX (SUNN CORP) - (RTCA)

HOUSE DESCRIPTIONS

House A - E - I

The first study house is a 1500 square foot rancher. The garage is separated from the house by an open concrete slab patio. The house is frame, however, the exterior walls and foundation are block. The exterior appears to be a thin brick attached to the block wall. The house has two additions added to the original construction, which were built by the original owner. The heating system is oil-fired hot water with no central air conditioning. There are two window air conditioners on the main floor. The basement is divided into approximately five rooms that are all partially finished. The basement has an outside set of stairs and three windows. The family/TV room in the basement was chosen as the test location because it had the closest proximity to two of the outside windows.

House B - F - J

The second house in the study is a colonial with a walk-out basement. There is no attached garage. The siding is vinyl with some stone veneer. The foundation is block. The basement is broken into three rooms, separated by doors that were left open for the study. The basement has about 1290 square feet of floor space, with a drop ceiling about eight feet above the floor and a foot of space above the drop ceiling. The heating system is a heat pump with back up gas. The radon detectors were set up in the center room of the basement. This was the only house that had an existing mitigation system. The system was designed by a local EPA official in the radon division and installed by the homeowner. It consisted of a single central suction sub-slab system. The system fan was installed sideways under the main floor deck with the exhaust at the edge of the deck floor above the exterior door of the walkout portion of the basement. The radon system was turned off for the study and the exhaust pipe was sealed with duct tape. An air-to-air heat exchanger, which was not being used, was kept off.

House C - G - K

The third house in the study is a colonial with a partial basement. The foundation is block. The house is frame construction with vinyl siding. A family room has a slab-on-grade floor that is one step down from the wooden first floor over the basement. The basement has about 900 square feet of floor space with a drop ceiling. The basement has one large finished room, and a small furnace and storage room. A small closet contains the electrical panel and an open sump pit with no sump pump. The basement has a dropped ceiling and drywalled walls. A two inch wide canal drain runs around the perimeter of the basement floor but is mostly concealed by a finished frame wall. The heating system is a heat pump with back up gas. The radon detectors were set up in the center room of the basement.

House D - H - L

The fourth house in the study is a split level with a partial basement. The basement has about 700 square feet. A half flight up from the basement is an adjoining slab on grade floor that contains a bedroom, study, and bathroom. On the other side of the basement is a garage that is a full height above the basement. A set of stairs allows direct access from the basement laundry room to the garage. The basement has a small center room that has finished walls with an adjoining laundry room and furnace room. The house is heated with a hot air oil burner and a central air conditioner. The basement has no finished ceiling. The foundation walls are poured concrete. There is a pedestal sump pump in a sump pit. The exterior siding is wood with a stone front veneer. The radon detectors were set up in the center room of the basement.

QUALITY ASSURANCE

To ensure that all the equipment being used was functioning properly, the radon and RDP equipment was exposed at the beginning and at the end of the study in the Department of Energy Environmental Measurement Lab (DOE/EML) facility radon/RDP chamber in New York City. The first short term test in each round, for a total of twelve tests, were not tampered with in order to check the equipment performance as well as to obtain a baseline radon/RDP concentration. In addition, Pennsylvania DER exposed an Eberline RGM3 radon monitor, an Eberline WL monitor, three DER charcoal canisters and three DER E-PERMs during each short term test to be used as background measurements. This equipment was not tampered with. Although these specific instruments were designated to be the reference and were not tampered with, they themselves would occasionally produce results that were suspect.

In general the active monitors had greater precision than the passive detectors. The PYRB, F510B and GEMW were the only monitors to not have any non-tampered measurements greater than +/- 20% different from the reference detector (Eberline RGM3 and Pylon WL) during the whole study. The TN, CIRAS and HPRM had only one measurement each greater than +/- 20% of the reference value after correcting for an bias. 5.3% to 8.5% of the measurements using the RAD-7, EBL-WL, GEM-Rn, F210-Rn, SURV-Rn, and E-PERMs had measurements greater than +/- 20% from the reference. The PYL-WL and EPRIPSU's had 13% and 16% of their measurements greater than 20% from the reference. The CAIRS had a 25% low bias and 23% of its measurements were greater than +/- 20% of the reference. The Radon Alarm had a 55% low bias and over 80% of the measurements were greater than +/- 20% from the reference even with the bias corrected. The DMA canisters were greater than +/- 20% of the reference for 26% of their measurements. The percentage of DMA canisters that were greater than +/- 20% of the reference was only 15.7% before run H, which began on 11/30/92. For runs H through L, from 11/30/92 to 2/17/93, the percentage greater than +/- 20% from the reference increased to 38.3%. This is almost two and a half times worse performance. It was not investigated whether this percentage of in-precision was due to the changing radon concentrations the canisters were exposed to since open face canister are more sensitive to the last twelve hours of their exposure or to the operation of the charcoal laboratory. All of these results support the need for good QA including frequent calibrations and the use of duplicates or comparative measurements. Refer to Reference section for a list of other papers and reports documenting the QA measurements taken during this study..

LOWERING RADON/WL CONCENTRATIONS

Opening Windows and/or Exterior Doors

Opening basement windows was one of the easiest and most effective ways to reduce the radon/WL concentration. Generally the effectiveness depended upon the amount of window area opened. In the two story house, run B4 (fig 6), a 242 square inch (si) opening dropped the radon 85%. In the split level house the radon levels only dropped 29% in run D4 (fig 15) with a 48 si opening, 37% in run H3 (fig 29) with 40 si and 47% drop in run L4 (fig 43) with 140 si opening. The ranch house dropped 74% during run A4 (fig 4) with 720 si opening. The other two story house dropped 84% in run C4 (fig 9 & 10) with a 624 si opening.

The change in basement negative pressure as compared to the outside was inconsistent. In most cases the larger the window opening, the greater the basement to outside pressure reduction but in run C4 with 624 si opening, for no apparent reason, there was not a measurable pressure difference even though the radon levels went down 84%. In run B4 with 242 si opening, the pressure difference was reduced by 66% and the radon levels went down 84%. In run D4 with a 48 si opening, the pressure difference was reduced about in half with a 29% radon reduction.

Large increases from ventilation can typically be detected with continuous monitors as dramatic shifts in radon or WL's. It would be difficult, however, to detect tampering if the basement windows were opened before the test is begun and then only closed for the time the tester is at the house either placing or retrieving the detectors. Window seals were found to be an effective method to detect this type of tampering.

Opening upstairs windows had a much smaller affect upon basement levels. In the four runs where only the first floor windows were opened, the basement reductions were as follows; run A3 (fig 4) -15%, run B3 (fig 6) -20%, run C3 -9%, E2 -0%. The smaller reductions of run C3 and E2 were probably due to the fact that the owner did not keep the first floor windows open consistently. It is obviously more difficult to leave first floor windows open if the building is occupied and the outdoor temperatures are cold.

Diverting Outdoor Air to Detector

Three of the continuous radon monitors and all of the WL monitors have pumps for sampling the air. If the detector's inlet can be easily connected to additional tubing such as with the Surveyor, RAD7, and RGM3, a piece of tubing can be run from the detector inlet to an outside source of air. It is actually not even necessary with this technique to open the basement window which may have a tamper seal in place. The tubing inlet can be simply placed close to a crack around a window that is letting outdoor air in. The tubing will effectively be sampling outdoor air without disturbing the window seal. This type of tampering could be detected by observing a dramatic drop in the levels at the beginning and or end of the exposure. During run J3 (fig 35), the Surveyor inlet was connected to tubing that was run to the outside. Although the initial drop was not dramatic, you can see a sharp climb up with the Surveyor during the last two hours of the sampling. This caused a 73% drop in the reported results although it still averaged 6.1 pCi/l which is well above ambient. During run A4, tubing was run from both the RAD7 and the Surveyor through the rear window to the outside covered porch. At the same time the basement windows were opened. The RAD7 and the Surveyor compared to the RGM3 dropped 12% and 20% as compared to their previous relationship to the RGM3 in the previous run. This reduced effect is partially due to the fact that all the monitors dropped because of the windows being opened but this does not explain why these two monitor did not reach ambient radon levels. It appears that some basement air was still entering the monitors.

Running tubing from the inlet of a monitor to the outside is more than a typical homeowner would manage to do to tamper with radon monitors. It would be unlikely that he would have the correct tubing size available nor the resourcefulness or desire to go to such extreme.

Moving Detector to Low Radon Environment

Obviously if you move a radon detector to the outside you will achieve a large reduction in the radon result. This was tried four times with E-PERM's and produced a 49% to 87% reduction. During run I2, a charcoal canister result was 66% low from being moved outside and its moisture gain was not significantly different from the non-tampered canisters. During run G3 a canister was moved in front of a basement window that was open a crack. This resulted in a 29% drop in its average although the weight gain was 5.8 grams compared to the average of the other non-tampered canisters gain of 3.2 grams. Canister weight or gain may be an indicator of tampering. The Surveyor (fig 32), F210 (fig 36) and HPRM (fig 40) were moved to the outside causing a drop exceeding 90% in each case. This movement could be typically detected with continuous radon monitors that report hourly averages because the radon levels would change dramatically at the beginning and end of the exposure. The HRPM would depend on its tilt indicator to detect this type of tampering since its four hour interval would tend to mask the sudden change. During run A4 (fig 3) even the HPRM, with its four hour intervals, showed a sudden rapid changed from its first interval to the next two that would have possible indicated tampering by a window being opened The newer one hour interval HPRM were not available for the study. During run I2 (fig 31) a PY-Rn was moved to the first floor, causing it to average 43% low compared to the basement reference radon levels. During run E2 (fig 16), an F510 was moved to the first floor and averaged 43% lower than the basement.

During run D4, the canister was exposed to the outdoor air for 55 minutes and then returned to the basement for another hour before it was sealed up at the end of the run. This only caused a 10% reduction. During run F2 and F3, single canisters were taken outside and aired out for a few minutes and then sealed up. These canisters were 15% and 10% lower than the other non-tampered canister that was sealed up normally in the basement. The 5% difference in results may be due to the fact that the radon levels had been dropping through run F3 which only had a 10% reduction. There was not a significant decrease in moisture weight gain from this airing out of the canister. A passive detector would required tamper seals or tamper box in order to flag that it had been moved.

Agitating Air

The WL concentration can be reduced by agitating the air in order to increase the plateout of RDP's. The effect of agitating the air with a standard room fan varied from as little as a 4% reduction during B2 (fig 5) with the fan on the floor, to as high as a 26% reduction during run C2 (fig 8). In the seven times this was tried a typical reduction of the WL was 4% to 39%. There was 20% reduction in run A2 and a 37% in run E4 (fig 18) when two fans were used. Using two fans appears to improve the reduction in WL compared to using one fan. No method could be thought of to detect the use of a window fan in the room other than the sometimes apparent initial drop in WL and upward slope at the end of the measurement.

Twice the furnace fan was set to continuous on operation. In run J2 (fig 33 & 34) this reduced the WL by 35%. In run K4 it made no significant reduction to the WL's at all. This may be due to the fact that house K uses a heat pump system with the furnace fan running far more continuously than if it had a combustion fuel furnace. It appears that the furnace operation only increased from 76% to 96% in run K4 and thus there was a very limited increase in agitation of the air. During run G2 (fig 23) a fan was directed at the EBL WL monitor from five or six feet away but it did not appear to affect its performance as compared to the other WL monitors. The overall basement EQR did decrease from 48% to 23% which is a 52% reduction. During run H3 (fig 29), a fan was directed at the TN monitor causing it to average 42% low. The EQR dropped (fig 30) from a previous average of 24% to 17% which is a 29% reduction. This house is difficult to understand because the first floor EQR was often twice that of the basement.

Filtering Room Air

No air purification filters were run in the same room as the detectors during the study.

ALTERING EQUIPMENT PERFORMANCE

Bags, Buckets, and Coverings

Different bags, buckets and coverings were placed over or around the different detectors. In general, all the WL monitors were dramatically affected if they were placed within a confined space because the detector's air sampling acted like a filtering system and quickly reduced the RDP's.

The effect of covering the WL monitors ranged from a 30% reduction with the EBL during run A2 (fig 1) when it was placed in a garbage bag to a 93% reduction for the TN during run D3 (fig 13) and a 93% reduction for the EBL-WL in run I2 (fig 31) when they were sealed in a five gallon bucket to the table. When the TN was placed under the bucket without sealing it to the table during run D2 (fig 12), it caused a 70% reduction. Even sealing a WL monitor under a metal garbage can as with the CIRAS during run E4 (fig 18) was enough to drop the WL by 66%. One of the CAIRS detectors was placed in a tyvek bag which is porous to radon but not WL during run I3 (fig 32) and it dropped the response by 76%.

The charcoal detectors were covered in all manners and fashions during the study. In general charcoal detectors are very susceptible to being placed in a confined space because of their characteristic of adsorbing radon out of the surrounding air. During run L3 and L4, charcoal canisters were carefully sealed in various size containers. The initial radon concentrations in the air were noted at the time of sealing. If the container was as small as 12 or even 39 ounces, the radon average decreased 98 to 99%. Even with containers as large as 68 liters, the radon average was decreased by almost 80%. It appears from a rough calculation that charcoal adsorbs about 2000 times its volume from the surrounding air. To check if the adsorption of radon would be affected if canisters were placed next to each other, five canisters were placed side by side while still being open to the room air. The adsorption of radon by the canisters did not however appear to affect each others adsorption of radon although there was a slight less moisture take up from the middle canister. This slightly less moisture take up may have contributed to the center canister averaging 11% more than the average of the canisters that were placed around it.

Overall any covering or bagging of the charcoal canisters caused a significant drop in its performance. The least drop caused from covering the canister was 40% during run A3 when just a magazine was laid on top of the canister. Typical reductions from covering or bagging the canister was from 64% to 85% reduction.

Hair spray was sprayed on top of the charcoal canisters at the beginning of a number of runs in order to slow down the diffusion into the canister. During run A2, a five second spray of hair spray was sprayed into both DMA canisters. They both gained extra moisture as the previous average gain of 5.5 grams went to 8.6 and 10.9 grams in this run. This caused a 29% drop in the average compared to the previous run. A 3 second spray (although from the moisture gain it was probable longer) at the start of run H2 caused the moisture gain to go from 1.6 grams to 5.4 grams and dropped the average result by 42%. During run G4, static guard was sprayed onto a canister for 3 to 5 seconds which caused the canister average to drop by 67%. This canister, however, did not appear to gain any additional weight from this. During run F3, so much hair spray was applied to the canister that its weight gain was 14.3 grams compared to the average 4 gram weight gain of the other non-tampered canisters. This large amount of hair spray caused this canister to average 94% low.

The use of a hair dryer for ten minutes on high at the end of an exposure blowing onto the charcoal was tried during run G2. This caused an 11% reduction. During run I4 the hair dryer was again used but for twenty minutes. This time the canister averaged 50% low.

E-PERM's were placed in zip-lock bags, wrapped in foil, placed under metal cans, moved into drawers. In most cases this appeared to have no affect upon their performance. If the container that the E-PERM was placed into was able to be completely sealed from radon entry or exit, then sealing it is the equivalent of a grab sample. A grab sample over a two day exposure will lose approximately one quarter of the radon, which would give an average reduction of approximately 13%. It appeared that the zip-lock bags could seal out radon while aluminum foil and tape over the inlet was not effective at stopping diffusion. If the container was radon tight, the initial radon levels at the time of sealing are significant. During run K3 and L2 the tampered E-PERM's were taken outdoors and sealed in Tupperware containers and returned to the basement. This caused a 72% to 76% reduction in the final average.

Numerous coverings and seals were used on the continuous radon monitors to determine if their performance could be altered. In general, if the monitor was placed in a bag or had its inlets blocked it made little difference upon the performance. In run E3 (fig 18) the PY-Rn and the F210-Rn had their openings covered with tape or foil with no apparent affect. In run G4 (fig 25) the RAD7-Rn was covered with a tub and the F210-Rn had its inlets taped shut. The F210-Rn showed no apparent affect. The RAD7-Rn did not respond to changing radon levels. In run H2 (fig 27) the PY-Rn had its inlet sealed with no affect. In run G2 (fig 22) the PY-Rn and the HPRM-Rn were sealed in a plastic bag that had been filled with outdoor air. The PY-Rn only showed a delayed response while the HPRM-Rn dropped to one third its initial levels and then slowly recovered. Since an active radon monitor removes no radon from the air, it does not take much of a hole to allow radon to enter its chamber and replace what small amount has decayed away. During run A4 (fig 3) the radon levels took a sudden drop. The Pylon, with the PRD attachment, had its inlet covered during this run with Saran wrap which caused a 16 hour delay before it caught up with the changing radon that the other radon monitors were measuring, indicating its slowed response. During run F3 (fig 20), the F510 was taken outside and placed in a bag and then returned to the basement. This caused a 28% reduction of the F510 average which did finally catch up with the other continuous radon monitors. In general the radon and WL monitors responded to changing radon/RDP levels at about the same rate.

Charcoal or Paper Filters

During run F4 (fig 21), the RAD7 inlet had a charcoal filter placed in line. This caused the RAD7 to average 95% low.

Paper filters of different capacities were placed in front of the inlets to the WL monitors. Coffee filters were placed over the inlet to the Pylon WL monitor during run A4 and B2 (fig 5), and were installed with tape on the TN WL monitor during C3 (fig 11). This caused an 11% and 36% reduction for the Pylon and a 22% reduction for the TN WL monitor. During run C2 (fig 7), the coffee filter attached to the Pylon WL monitor caused it to average 46% low. Paper towels were used as pre-filters for the TN and CIRAS during run L3 (fig 41), which reduced the WL average by only 9% and 22%. A paper towel was taped over the EBL WL monitor during run K2 (fig 37) and it reduced the level 52%.

One" foam was placed over the Pylon WL monitor inlet during run F2 (fig 19) and over the

CIRAS during run G3 (fig 24). The average was reduced 31% for the Pylon but 0% for the Ciras as compared to the previous run. This difference might be explained by the fact that the filter fits tightly into the Pylon WL head adaptor and the air flow for the Pylon was set at 1 lpm. The CIRAS inlets in front of the monitor are more difficult to cover with a filter and the air may have been by-passing around the filter. Another possible explanation might be that the air flow for the CIRAS is only 0.125 lpm which would tend to capture less RDP's. During run J4, 1" foam was taped over a rear port of the GEMWL monitor but this must not be the actual intake because their was no reduction in its performance.

A piece of dish cleaning steel wool was placed in front of the CIRAS for run J2 and it only reduced the WL by 11%. Regular filter paper was placed or sealed over the inlet ports during the following runs with the following WL monitors. The Pylon WL monitor averaged 28% and 83% low in run E2 (fig 16) and D4 (fig 14). The CIRAS averaged 27% and 76% low during run K3 (fig 38) and run I3 (fig 32). For an unexplained reason the TN in run A4 and run I3 (fig 32) averaged only 16% and 7% low compared to the reference WL monitor. The EBL WL monitor averaged only 14% low in run A3 with a pre-filter. The difference in reductions in the above results is probably due to how complete the inlet opening is sealed with the additional filter or possibly with the quality of the filter used rather than the type of monitor the extra filter was added to. Tampering could be determined from the continuous printout only when actual WL filter paper was carefully sealed over the inlet openings and produced a reduction greater than 75%. None of the other filter tampering could be determined by looking at the continuous printouts.

<u>Removing Tubes or Connecting Exhaust Ports to Inlets</u>

The EPRPISU box could not be closed because the electrical cord was in the way. The most recent version of this unit has changed that deficiency. It is possible to now place a tamper seal on the edges of the lid to keep someone from removing the electret or any one of the tubings. This type of tampering can easily cause a 90% reduction in the result, which without the tamper seal, would go undetected.

The exhaust port of the TN WL monitor was connected to its inlet during run F3 (fig 20). This caused the average to be 74% low. The ramp up and the decrease at the beginning of this run was not dramatic enough to be suspicious. The final two hours of the run did revealed a ramp up in WL that was still not distinct enough to definitely highlight possible tampering.

The RAD7 during run H4, the Surveyor during F3 had their inlets hooked to the exhaust and neither result was significantly different from the previous run. During run J4 (fig 36), the RAD7 had its inlet hooked to the Surveyor exhaust without any significant alteration in its performance. During run K4 (fig 39), the RAD7 had its desiccant column unattached. This caused the average to fall by 23% from the RGM3 average. The printout revealed that the internal moisture level went above the recommended level and this moisture change may have flagged the tester that a problem had occurred which would affect the test results. No sign of tampering was seen with the caulk and noodle seals.

Turning off or Changing Pump Flows

The EPRPISU and the CAIRS were easily tampered with during run C2 and L2 and during K3, by removing the plug or turning off the power to the outlet. This deficiency has been corrected with new versions of the EPRIPSU by installing a timer clock that records the number of hours that the pump operates. The pump was turned off on the Pylon WL monitor during run H2 (fig 27) and L2 (fig 40). The pylon printout, however, records pump on time so this type of tampering can be spotted. It is also highly suspicious when the WL drops to 0 for all of the run except the very beginning and end. The TN also had its pump turned off during run G3 (fig 24). Although the TN printout does not indicate pump on time there was almost no measurable WL while the pump was off, with steep climbs at the beginning and end of the run.

The pump flow rate on the TN, PYLW, EPRPISU WL monitors can be reduced by turning the flow adjustment screw unless a tamper seal is placed over the adjustment screw or knob. During run I4 and K4, the EPRIPSU had its normal pump flow rate of 1.33 lpm reduced to 0.5 and 0.0 lpm and this caused the average to be 68% and 89% low. The TN had its pump flow rate reduced from 1.0 to 0.5 lpm during K3 (fig 38) and this caused the monitor to average 60% low.

The Pylon WL monitor showed no loss of performance when its high voltage switch was adjusted from 600 volts to 300 volts in run K2 (fig 37). During run L2 (fig 40) the Pylon radon monitor's voltage was turned down to 200 volts which caused it this time to average 50% less. It appears there is a threshold were voltage adjustment makes a significant difference on the monitor performance.

The EPRPISU shell was closed during run J4 and the average result dropped 87%. A clip seal had to be broken for this to happen. The new version of the EPRIPSU would have had a broken lid seal. All the EP's had clip seals through the spring closures to keep the lid from being closed. During run F3, the clip seal was cut and the EP closed to give an average that was 64% low. Careful inspection of the broken clip seal upon retrieval would reveal that it had been cut. During run L3, two of the EP's were closed down as far as possible without breaking the clip seal by using duct tape to hold the lid down. This caused the EP's to average 27% and 35% low. A tamper seal of the EP to the table may or may not be broken by such a method. During run G3, the EP lid was closed down half way and this caused a 20% reduction in the final average in comparison to the other non-tampered EP's.

During run K2, the electret was removed from the bottom of the EPRIPSU and placed upside down on the table. This caused the EP averages to be 71% low. The caulk seal was found missing between the electret and the shell which indicates some tampering had taken place. During run K4 the electret was removed and covered with a metal can. This caused the EP average to be 91% low. The caulk seal was again found missing.

TAMPER RESISTANT TECHNIQUES

Tape seals

Tape seals can be an effective method for ensuring that windows are not opened, radon detectors are not moved, and unused doors are not opened. A number of tape seals were tried. Some worked well while others did not. It is important that the surface that the tape is sealed to is clean. Some furniture polishes or a silicone oil spray will leave a slick film on the surface that makes it difficult to attach the tape or for the void wording of the void tapes to attach itself to the surface. The tapes will, however, stick to most surfaces although the surface around a typical basement window will need to be cleaned first. Basement exterior doors can also be sealed, since no one should be using this door during the test. It is questionable if all the first floor windows should be sealed if the test is being run in the basement. Opening the first floor windows reduced the radon levels in the basement only 10 to 20 percent while opening basement windows caused as much as an 85% reduction.

The Equitron tape is manufactured just for tamper detection. It is partially sliced so that after it is in place, any attempt to remove it would cause it to be easily torn. It works well as a tamper seal, however, it has a major fault. Once it is firmly pressed into place, it does not come easily off. The extra effort to remove it might end up damaging the surface it is attached to.

Both the void tape sold by RAL and RTCA was used. Any attempt to remove this type of tape after it is in place will cause part of the glue to separate from the tape spelling the word "void" on the surface. Even if an attempt is then made to replace the tape in its exact location, the word "void" still reads through the tape. It is helpful to use a flashlight to carefully inspect the condition of the tape upon retrieval of the detectors. The void lettering that is left on the detector and the surfaces after the tape is removed can be rubbed off the surface with a rubber eraser.

There are numerous types of tapes that are sold in office supply stores that could be possibly used for a tamper seal. A number of these types of tapes or seals were used. Plan scotch tape was tried. If it is carefully sliced in the middle so that only a small portion is left, it is difficult to remove without tearing. This type of tape, however, can be duplicated easily. Other more unusual seals were tried. One tape was in the shape of a small dumbbell. The smaller center section of the seal made it likely to be torn if removed. This tape can however be removed and replaced without marking the tape if one is extra careful. To reduce the possibility of someone removing the dumb bell seal, a small amount of white acrylic latex caulk was laid over both edges of the tape. Although this made it more difficult to remove, it was removed on two occasions without being detected. A better caulk might remedy this situation.

Tape seals can also be fabricated out of a fragile paper such as small piece of tissue that is sealed to the window edges with glue. The test company can obtain a small stamp with their company name to code the tissue. The main detriment to this method is the glue can sometimes be difficult to remove or leave marks upon the woodwork.

Standard double stick tapes can be used to reduce the chance that a charcoal canister will have something placed directly on top of it. If two separate loops are arched over the canister so that one loop is higher than the other and not touching, it is difficult to place anything on top of the canister and still maintain the tape in its original condition. This method does not however prevent someone from placing a container over the tape and the canister.

Caulk seals

Acrylic caulk was used to seal the office supply tape seals. It was also tried as a stand alone window/door seal. Although it was effective for this, it was difficult to get off the woodwork after being in place for 2 to 3 days.

Weatherstrip caulk is used to weather seal openings such as around double hung windows. The caulk sticks lightly to the surface but can be removed easily without damaging any existing woodwork, even if it has been in place all winter. The weatherstripping caulk used in this study is manufactured by Red Devil although there are other companies that manufacturer similar products.

Its easy application and removal makes it ideal as a window, door, and monitor seal. A small amount is placed on the surface the detector is to be placed on and the detector is pushed into the caulk. For windows and doors, a small amount is spread across the window or door frame. Upon retrieval of the detector, each seal is gently pressed to ensure the caulk is still adhered to both surfaces. It is then simply pulled away. The caulk that is removed is checked for consistence to determine if fresh caulk was attempted to be reapplied. This caulk did not appear to leave any marks on any of the surfaces during the study.

Two of the most difficult detectors to protect against serious tampering are the WL monitors and the charcoal canisters. A completely satisfactory method of protecting the WL monitor inlet was not found. If the WL inlet is pre-filtered or diverted to outside air, large reductions are possible in its performance. To try to safe guard against this, the weatherstrip caulk was used to hold Japanese sorba noodles in place. The noodles are inexpensive, very thin and tend to break easily. The idea is that any attempt to hook a pre-filter or fresh air tube to the inlet would cause the noodle to be touched and most likely broken. This worked with limited success although it tended to look a bit strange.. The exact location and length of the noodles needs to be documented each test so that any small changes can be noted upon retrieval of the detector.

Detecting or preventing someone from placing an object on top of a charcoal canister or a container over it was a difficult. One rather awkward solution was to place a small amount of caulk on the side of the canister and run sorba noodles straight up and to the side. This made it difficult to cover the canister or place something on top of it. A container larger than the height and width of the noodles might however be used unless the canister was hung over the edge of the table, chair or stand that the canister was attached to. Careful notation of the location and position of the noodles was necessary to ensure accurate analysis upon retrieval.

Detector placement

Placing the detector in a certain location or on top of a grid pattern that is attached to the table or detector stand can be a method of detecting movement of the detector. If the placement indicator is visible, it might also discourage someone from attempting to move the detector. The location of the detector must be carefully noted after it is placed and checked carefully when it is retrieved. If the detector is also susceptible to being covered, it should be placed over the edge of the table or stand. One alternative method was to place the canister on top of two light weight styrofoam venting strips that are available from any building supply house. The canister has a tape seal attached to the stand. Attempts to tamper with this arrangement caused the canisters to fall from the stand and actually spill the carbon onto the floor.

Lock ties

Equitron also supplies a locking clip called a "home buyer seal" that has an individual serial number. Once it is snapped in place, it creates a small 3/4 inch circle that cannot be opened except by cutting it. This type of clip works very well with E-PERM's. If the clip is inserted through the drilled hole in the shaft portion of the E-PERM, it is impossible to close the cap without cutting the clip. If the clip is just hooked through the spring of the E-PERM, then the E-PERM can only be partially closed. During run L3 two of E-PERMs had the cap forced down on the clip that was just run through the spring and held in place with duct tape. This reduced the average by 27% and 35% and would be difficult to detect.

Equitron also makes a hanging strip that has holes punched in either end. The strip is ideal for hanging E-PERMs. Simply loop the strip over a metal water pipe or similar object and attach an E-PERM with the lock clip. Note that the electret still needs to be sealed to the chamber in case someone was to try and remove the electret and cover it during the exposure. The object the E-PERM is attached to needs to be secure. On a few occasions the drop ceiling was disassembled in order to remove an E-PERM without breaking the clip seal. During run I3 an E-PERM was hung from the ceiling and it was sealed in place in a zip-lock plastic bag. This caused the E-PERM to average 12% low. The tape used to seal the zip-lock bag frayed the hanging strip and it was noted as being tampered with. The hanging strip and lock clip can also be used with other passive detectors. A plastic fish net was used to hang a charcoal canister with the hanging strip and lock tie. In order to tamper with this method it is, however, only necessary to wrap the whole hanging net and canister in a plastic bag. This was done in run I3 and caused the charcoal to average 84% low. The hanging strip was found torn upon retrieval of the detector.

The E-PERM can also be placed inside a tyvek envelope and hung from the ceiling with a lock clip and hanging strip in order to prevent someone from moving it, closing it or removing the electret. This method would not work with the charcoal because the tyvek slows down the radon entry just enough to bias the results slightly low.

Multiple test locations

Multiple test locations can reveal unusual ratios between them that might indicate tampering. If only the basement room that the detectors are in is ventilated, first floor levels often reach or exceeded basement levels. Since the basement is usually from 2 to 4 times higher than the first floor in the winter and from 2 to 10 times higher in the summer, any significant variation from this could indicate tampering. One needs to take into consideration the run time of the air handler of a forced air system in evaluating this data.

During run A1 and A2, the first floor to basement radon ratio was 38%. When the first floor windows were opened during run A3 (fig 4) the ratio only dropped slightly to 34%. This is probable due to the lack of much stack effect because the outdoor temperature was very warm. When the basement windows were opened during run A4 the ratio went to 91%. The outside average temperature was 72 degrees.

During run B1 and B2 the first floor to basement radon ratio was 61%. The ratio dropped to 24% when the first floor windows were opened during run B3 (fig 6). During run B4 when the basement windows in the test room were wide open, the ratio went to 222%. The first floor had more than twice the average radon of the basement. This would definitely raise some suspicion. The outside average temperature was 65 degrees.

During the run G1 through G3 (fig 23 & 26) the first floor to basement radon ratio averaged from 29% to 77%. When the basement windows were opened, the ratio went to 129%. The outside average temperature was 42 degrees.

During run L1 through L3 (fig 43), the first floor to basement radon ratio averaged 47%. When the basement windows were opened during run L4, the ratio went to 97%. The outside average temperature was below freezing.

Hourly measurements

Hour by hour measurements were only instrumental in determining that tampering had taken place when drastic changes or unusual levels were recorded. During run J4, the F210 was moved outside. Within two hours the monitor had dropped from 30 pCi/L to 0 pCi/L and in one hour at the end of the measurement the levels had recovered half way to the other detectors. In general the non-interfered with radon and WL monitors had similar response performance to changing radon and RDP levels, taking about two to three hours to be in equilibrium with the new concentration. Run J4 (fig 36) is a good example of the RAD7, SURV, and RGM3 having equal response to changing radon levels.

Tampering would occasionally produce a clearly defined sloped decline during the first hour or two of the measurements and a corresponding climb back up at the end. Under real test conditions if the tampering took place immediately after placement the initial decline would not be recorded accurately because the monitor would be brought in from the outside and therefore only coming into equilibrium during the first two to three hours. If the windows were also opened before the tester arrived this would further reduce the chance of detecting any drastic change in the concentration. During this project the radon monitors were always in equilibrium with the room when tampering was begun. A tester might have better success seeing the climb of radon or WL's at the end of the measurement when his instrument was in equilibrium with the test area. At the end of run G3 the open basement windows which had reduced the radon levels by 51% were closed and the last two hours showed a steep climb back up for both the radon and WL monitors. One method to enhance the visibility of any steep climb in levels at the end of the measurement is to delay the pick up of the detectors to allow for this ramp up. A tester could tell the client that he would be returning within a two hour window and then return at the end of that period since the owner would most likely have to close the windows before the earliest return time.

In general continuous monitoring was most effective in determining tampering when the tampering was too effective and thus displaying an usually low and stable period during the test. If a continuous monitor is placed in a garage or a WL monitor has its pump turned off, inlet filtered or the monitor covered, the results appear so low as to be suspicious. During run D3, the TN result dropped so low that it was obvious something had been done to the monitor. In this case a bucket was sealed over the monitor. No other tampering seal or motion indicator would have indicated any disturbance with this type of tampering. The lack of any diurnal variation is also a give away that the monitor has been disrupted from measuring any radon or RDP's.

Movement indicators

Some of the continuous monitors and the passive detector tamper cages had movement indicators. These devices were obviously helpful in determining if tampering had taken place. The continuous monitor movement indicators were significantly more helpful then the cage movement indicators because they could record each time and hour that the movement took place. With a single indicator the homeowner can easily say that he just bumped the detector or table it was on and the indicator tripped. A tape or caulk seal would not trip as easily, but both of these would not detect if the detector and movement indicator were covered.

The Gemini monitor has a built in infrared motion detector as well as a number of other internal sensors. When this monitor was covered with a plastic bag during run A3 (fig 2), the internal temperature rose, the infrared detector indicated movement, the WL went down to zero while the radon levels varied with the basement concentrations. All of this information easily flagged a tampering situation with a probable action of the detector being covered. A recent passive detector cage built by RTCA also includes an infrared motion detector that can determine if the monitor or cage has been covered with a large bucket or box. A room motion detector cannot, however, distinguish someone coming into the room and walking innocently by, from someone who is trying to interfere with the detector. The RTCA room movement indicator only detects movement directly above the detector.

Since a tape or caulk seal cannot be used on an active door there is no way to be sure that the door is left open or has a fan placed in the doorway, especially if the test device is a passive detector. RAL has developed a door motion detector that records any door or window opening that is longer than a specified amount of time. The information is not only stored in the combination receiver and computer but is also faxed to the tester so that he can correct the situation before it voids the test.

Moisture gain

The charcoal lab provided the weight gain of each canister with the final result. This information often showed a variation of the tampered canisters to the non-tampered canister. Tampering with the radon uptake into the canister also restricted the uptake of moisture. The addition of hair spray was also detected as additional weight gain even though the spray may in fact be blocking the moisture uptake of the canister. The key to using this method is knowing what the expected weight gain should be. The charcoal detector lab should be able to determine the typical moisture uptake if the humidity, temperature, and exposure length are known. The tester would be required to measure the humidity and temperature of the test area at the placement and retrieval of the detector and then compare the final weight gain with the expected weight gain. A charcoal lab might consider having its computer predict the weight gain automatically if the humidity and test area temperature are also given.

Temperature changes

Charcoal canisters are the only detectors that are very sensitive to being heated. To detect being heated, a small heat dot can be purchased that changes color when a specified temperature is reached. This could be located on the tamper box or placed on each canister that is used.

The temperature of the basement was continuously recorded to determine if opening the basement windows could be detected by changes in the basement temperature. When the basement windows were opened, the basement temperature would, however, typically only fall a few degrees. The furnace appeared capable of maintaining the basement temperature even with large increases in the basement ventilation. If the outdoor temperature is mild, there is little hope of seeing changes in basement temperature due to ventilation. During run G3 (fig 24), the basement temperature dropped from an average of 72 degrees to 68 degrees. During run L4 (fig 43) when the outside average temperature was below freezing, the basement average dropped from the previous run average of 70 degrees to 63 degrees. If, however, only run L4 was viewed, this lower temperature would be inconclusive because 63 degrees is not an unusual basement temperature.

Humidity

Humidity measurements in the basement did not change enough to indicate that the basement windows were opened. During run L3 and L4, which had very cold outside temperatures, the basement average humidity which had been 48% during run L1 and L2, dropped to 32% and 33%. The basement windows were, however, only opened during run L4. During run B1 through B4, the basement humidity averages were 83%, 82%, 79% and 80%. The basement windows were opened during run B4 and CO2 levels indicated that there was at least a tripling of the ventilation rate and still the humidity did not change much. The outside average temperature was a mild 63 degrees during run B4. This lack of change combined with the fact that the pre-existing humidity measurements are not typically available for comparison make using humidity for tamper indicating very questionable.

Pressure measurements

Pressure measurements are difficult to make. Small amounts of wind can play havoc with results. Data loggers tend to only make one measurement per time interval rather than collecting the average pressure reading for the interval. Since the pressure reading can be fluctuating wildly during any windy period, single measurements are always questionable. Basement to outdoor measurements are especially sensitive to any wind because the house acts like a giant sail that creates pockets of pressure that vary not only with wind speed but with wind direction. Basement to sub-floor measurements are much more stable but their strength or correlation with basement to outdoor measurements is dependent upon the tightness of the basement slab and foundation in comparison to the soil porosity. In run L1 to L3 the basement to outside averages - 0.012" while the basement to sub-floor is only - 0.001". This indicates a leaky floor.

The changes in the basement pressures produced by opening the windows can often be seen but only if the pressure has been measured for a reasonable period when the windows were closed. During run L1 to run L3, the basement to outside pressure average was - 0.012". When the windows were opened during run L4, the basement to outside pressure average decreased to - 0.005".

Equilibrium measurements

The measurement of the equilibrium ratio between radon and radon decay products was thought to be a possible indicator of increased ventilation. This was not found to be the case during any of the runs when the basement or first floor windows were opened. Sometimes the EQR went up, other times it went down. The inability to see a correlation may also be due to the fact that so many instruments were sampling the air in the test rooms. Occasionally EML would also have numerous pieces of equipment taking air samples at the same time. Even during run J2, when the furnace fan was run continuously, the EQR ratio decreased some but not to the degree where it could be observed as tampering.

CO2 measurements

The CO2 measurement detectors that were used appear to be fairly accurate and to have good precision. This sensitivity allows them to be more useful than pressure measurements even though they are affected by occupancy. The results need to be plotted on a computer in order to be worthwhile. CO_2 measurements were made during the first eight house runs with a tank supplying a steady rate of CO_2 so that the ventilation rate might be determined. The data obtained was difficult to interpret because of the many variables in each house. Ventilation changes could, however, be seen but occupancy in the test area complicated the analysis. During the last four house runs, the CO_2 measurements were made without adding additional CO_2 to the air. During run L1 and L2, three EML personnel were in the house and the average CO_2 was 756 PPM. During run L3 (fig 42), without the three EML persons the CO_2 level averaged 610 PPM. When the windows were opened during run L4 the average CO_2 level fell to 447 PPM, which is a 27% reduction although considering that the outdoor CO_2 level is about half this amount the ventilation change might be double this amount. The 37% decrease in radon levels can be due to increased ventilation as well as the reduced pressure difference between the basement and the sub-soil.

Unfortunately the dramatic change in CO_2 at the beginning and end of runs that have the basement windows open, such as L4 are partially due to the tester being in the test area at the beginning and end of the test period. More testing of this device as a measurement of ventilation changes is necessary to confirm its effectiveness.

GENERAL TAMPER RECOMMENDATIONS

These recommendations are not in any way meant to limit an individual from developing alternative methods, equipment and techniques that accomplish the same goals.

Informing the client

Tampering often takes place unknowingly because the client was not adequately informed about the necessary test conditions before the test was begun. The tester must make sure that he clearly communicates to the responsible person or person the necessary test conditions. To help ensure the information is fully understood, a non-interference agreement should be signed by the responsible person. This agreement documents that the responsible person has indeed been instructed in the proper test conditions and that he agrees to abide by those test conditions.

Discouraging test interference is preferable to detecting interference. All of the non-interference methods that would discourage tampering should be explained to the dwelling occupants and be left in writing near the detector. If the occupants know that the test will be invalidated if they cause a seal to be broken or an indicator to be tripped then they will take extra precautions to ensure that the test conditions are maintained.

Inspection of the house

The tester should make a careful inspection of the home to be tested in order to locate the best test location, ensure that the necessary test conditions are being maintained, and to be able to document any important features such as the condition of crawl space vents or that the furnace fan is set on automatic operation. It is recommended that the tester walk around the outside of the house to be tested before entering to place and also when retrieving the detectors in order to check that all windows and doors are closed.

Detector placement & movement

The test location should be in the most frequently used room of the lowest level occupied or is suitable for occupancy and be at least three feet from a window and one foot from any exterior walls. If the detector requires an electrical source, the tester should carry an extension cord so that the optimal test location is not limited by proximity to an outlet.

Often the proper test location does not have a piece of furniture in the room. To avoid haphazardly using what is available, the tester should have his own test stand that is tamper resistant. If the detector does not have a motion detector the stand should allow a caulk or tape seal to be attached from the stand to the floor so that both cannot be moved to a low radon environment. Weatherstrip caulk or void tape are the recommended seals to use. An alternative approach is to use the commercially available hanging strips with the locking clips.

Opening windows and/or doors

In order to ensure that closed house conditions are being maintained, all the lowest level windows and doors should have a caulk or tape seal from the window to the window frame or over the window latch. The lowest level doors should also be sealed unless they are the primary entrance. The detector should be located as far as possible from a primary entrance door. The next level windows and doors need only be sealed if the tester feels that there is a likely chance they will be opened and they will significantly influence the test results. In general, window and door seals can be installed so easily and inexpensively that they should be included even if a continuous monitor is being used. If the window or door seal is broken, then the tester can more carefully study the changing concentrations reported by the detector. Without a broken seal unusual changes in concentrations may go un-noticed.

Turning detectors off or changing pump flow rates

Testing equipment that only provides one average measurement can be susceptible to tampering if it can be turned off. This includes E-PERMs and RIPSUs. E-PERMs in the S-chamber should have a locking clip placed through the drilled hole in the plunger shaft. The locking clips do not need to be cut after each test if the electrets are returned to their keeper caps.   Keep in mind that E-PERM shells and electrets must be kept free of dust.

RPISU detectors that do not have a timing mechanism to record the power on time should include a tamper seal on all plugs, switches and circuit breakers that control power to the unit.

Most continuous WL monitors will have some indication that the power or the pump has been turned off. If the detector cannot determine that it has lost power or the flow rate of the pump has been changed, then a caulk seal should be used on the detector controls. It may be unlikely that a homeowner would tamper with an electronic device but this added step is easily accomplished.

It is also highly recommended that any WL device include a flow measurement before and after the exposure period. Changing flow rates was a common occurrence for the WL monitors during this study.

Covering detectors

Charcoal canisters and WL monitors are especially susceptible to being covered. Charcoal detector results are also easily reduced by spraying a solvent into the charcoal. To prevent a canister, tamper box with a canister or a continuous WL monitor from having a container placed over it, place the testing equipment so that it extends over the edge of a stand. Unfortunately a plastic garbage bag partially sealed over this arrangement would be difficult to detect. Double stick tape or noodles placed in caulk may prevent the plastic bag from being used. An infrared room movement indicator may be the only effective solution to this type of tampering

Hair spray or similar solvents sprayed into a canister could be used as a method of reducing the canister result. If a charcoal canister is chosen that provides the weight gain, one can learn from the manufacturer what typical weight gains are for different humidities, temperatures and exposures. The humidity and temperature would need to be measured at the placement and retrieval of the detector. Any unusual weight gains may indicate tampering with the detector has taken place.

Filtering inlets

Filtering WL monitor inlets can be effective at reducing the final result even if a coffee filter is used. The type of filter that gives a 90% reduction would rarely be available to a homeowner and he would typically not know how to properly install it. The only method used with limited success in this study to detect filtering of inlet air was the use of caulk and sorba noodles protruding out from the inlet. This was, however, a clumsy method. One of the monitors, the Gemini WL, had the ability to measure changes in airflow that would most likely take place because of the restriction of an added filter.

Altering equipment performance

If equipment performance can be easily altered by adjusting a dial such as the flow rate of a WL monitor, without detection, then it should have a caulk or tape seal or other form of non-interference control.

Charcoal canisters are susceptible to being heated with a hair dryer to reduce their response. A heat dot that changes color at 120 degrees, laid on top of the canister, could be reused until such time that someone tampers with the canister by heating it.

CONCLUSION

In many cases the tampering only reduced the result less than 20%. How many houses have levels around 5 pCi/l that would now pass a radon test from this much tamper effectiveness? A level of 10 pCi/l would require a tamper technique that reduces the radon by 70%. If the radon levels are at 20 pCi/l then a technique that gives an 85% reduction is necessary. Considering the limited cases that tampering takes place and is effective, a tester should consider only the minimum methods which are easily accomplished and effective. Of course minimum to most of us is that which we already are used to doing. What would appear complicated to one person is easy for another who does it regularly. The EPA in the "Home Protocols" is directing testers, however, to take the necessary steps to ensure that the test conditions are being maintained. Non-interference methods such as using caulk or void seals can be low cost and effective, while adding assurance that the measurements were properly done.

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