THE EFFECT OF RAIN AND HVAC SETTING ON RADON LEVELS IN A HOME

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Abstract

This study sought to determine the effect of environmental conditions on radon levels in a home. The two independent variables in the experiment were (1) whether or not it was raining and (2) whether the HVAC system on the main level of the home was set to "ON" for continuous ventilation or "AUTO" for forced air only to maintain temperature. A recently calibrated Radalink AirCat® radon detector was placed in an unfinished basement of a three story house that had recently recorded concentrations at 4.0 pCi/l, the action threshold level. Based on the results it was concluded that an active ventilation system successfully reduces radon. For this particular house, it was also concluded that the presence of rain increases radon concentration levels. The absence of requirements for engineered ventilation in our residential building codes misses the opportunity to achieve safer levels. Accordingly, regulatory measures are recommended for new residential construction.

Introduction

Radon penetrates homes through walls, floors, foundations, and pipes. Radon is the second leading cause of lung cancer, causing 21,000 deaths per year in the United States and many professionals estimate that a reduction of levels to below 2.0 pCi/L nationwide would likely reduce the annual lung cancer deaths attributed to radon by 50% (EPA, 2013). Therefore, even though radon concentrations below 4.0pCi/l are acceptable, for health considerations, lower radon exposure levels would be even safer.

Background

Many factors influence the laws governing radon levels in residential structures. Ensuring public safety is balanced with various financial considerations. For example, in home re-sale situations, the presence of high levels of radon during the inspection could either cost the seller significant radon mitigation costs or perhaps cancel the contractual offer. For new home sales, builders who expect testing below the 4.0 pCi/l threshold in a new neighborhood will unlikely employ mitigation techniques which could reduce radon levels even more. This misses the opportunity to make our homes even safer at a time during new construction when it is much less expensive to implement and less invasive to the homeowner.

One of the most fundamental factors affecting radon levels is the negative pressure differential of the air on the ground floor of a home relative to that of the underlying soil. Higher differentials result in more radon being pulled to the surface and into the home via the so-called "stack effect." Various factors can influence this pressure differential and overall detected radon levels. Even within a given testing period, large fluctuations typically occur and are even expected.

During the course of a 24-hour cycle, homes often exhibit a characteristic signature of rising and lowering radon levels due to the diurnal environmental changes (Cohen, 1992). A minimum 48 hour testing period is required to produce certified results by averaging across at least two of these cycles. Uncontrollable environmental factors such as rain can impact the measurements (Gundersen, 1991). This study shows that the HVAC setting, which can be controlled by the homeowner, also impacts the measurements.

Material and Procedures

A three-story house in metropolitan Atlanta which had recently tested at the 4.0pCi/l action level was identified and served as the subject for this study. Hovering directly on this threshold, changes in the environment could lead to the difference between passing and failing a radon test.

A recently calibrated, professional grade, Radalink AirCat® monitor was placed on a tripod and located in the unfinished basement of the three-story home as shown in Figure 1. This represents standard testing procedures since the lowest story of a home typically has the highest concentrations of radon.

Figure (1): Experimental setup of Radalink AirCat® monitor located in basement of a three story house which had recently tested at the 4.0 pCi/l action level.

The instructions and guidelines provided by Radalink were carefully followed to ensure proper technical usage of the AirCat® monitor. Each test was conducted for a minimum of 52 hours duration (4 hour equalization period + minimum of 2 full days of measurement) with results averaged over the full time period. For each testing period, the HVAC was either set to "ON" for continuous ventilation or "AUTO" for forced air only to maintain the temperature set on the thermostat. The weather conditions, HVAC settings, and other variables were logged from the beginning to the end of each test. The monitor automatically tracked time, radon concentration, barometric pressure, temperature, and humidity. Normal house conditions were followed to test realistic living conditions, however door openings were kept to a minimum and windows were closed.

Results

A total of ten experiments were conducted under different conditions from mid-November 2013 until early January 2014. It was an unusually rainy autumn in the Atlanta area which helped populate a complete matrix of testing conditions. The HVAC setting and environmental factors observed throughout the testing period are noted in Table 1. Also shown are the average radon concentrations and atmospheric pressures measured over the full testing period of each experiment.

Table (1): HVAC settings and environmental conditions observed during the ten tests

Test #	Start Date	End Date	Radon Level	HVAC Fan	Environment	% RH	Avg %RH	Pressure Range (InHg)	Avg Press (InHg)
1	11/14/13	11/16/13	4.3	On	Intermittent rain both days	37-44	39	30.1-30.2	30.1
2	12/07/13	12/9/13	3.6	On	Rained throughout	43-47	46	30.0-30.2	30.1
3	12/09/13	12/12/13	4.0	Auto	Rain during first half of testing	40-47	43	29.9-30.3	30.2
4	12/12/13	12/15/13	4.7	Auto	Rain all 1st day / morning 2nd day	37-44	40	29.8-30.2	30.0
5	12/15/13	12/18/13	4.5	Auto	Sunny	37-40	40	30.0-30.2	30.1
6	12/18/13	12/20/13	3.6	On	Sunny/party cloudy both days	37-40	38	30.1-30.2	30.1
7	12/20/13	12/23/13	6.9	On	Heavy Rain throughout test	40-47	44	29.9-30.1	30.0
8	12/24/13	12/27/13	4.1	Auto	Sunny, test began after a big rain	37-40	38	30.1-30.3	30.2
9	12/27/13	12/29/13	3.7	On	Rained second half of testing	37-40	38	29.8-30.3	30.1
10	12/29/13	1/2/14	3.6	On	Cloudy - rain only last few hours	37-44	40	29.8-30.1	30.1

Figure 2 shows an example of the graphical output for Test #10. Even though the detected radon level often rose above the action level of 4.0 pCi/l (red line), the average across the entire testing period was only 3.6 pCi/l (green line) resulting in an overall passing score. Also, the general tendency was for the radon levels to be lower during the time period in the middle of the graph when the barometric pressure (bottom plot) was higher.

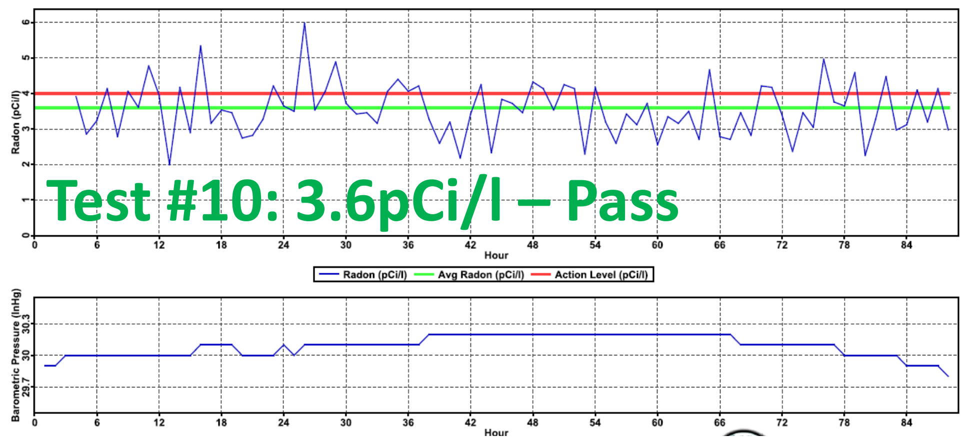

Figure (2): Graphics provided by Radalink for Test #10 showing a passing score of 3.6 pCi/l

Figure 3 shows the opposite extreme for a radon test conducted on the same house which failed. Heavy rain storms were noted during the full testing period and only one data point was collected below the 4.0 pCi/l level (red line). The barometric pressure in the basement dropped after the beginning of the test and this corresponded to a rise in radon later in the test. The average of 6.9 pCi/l level (green line) is well above the 3.6 pCi/l level for the testing shown in Figure 2. The HVAC setting was "ON" for continuous operation during both of these tests, so the large variance is attributed to the extreme difference in weather conditions.

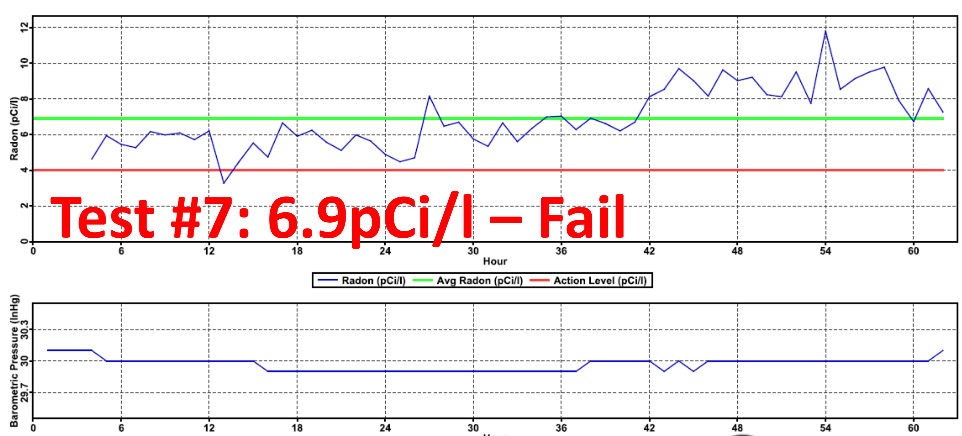

Figure (3): Graphics provided by Radalink for Test #7 showing a failing score of 6.9 pCi/l

Table 2 summarizes the official results certified by Radalink. The tests are categorized by the HVAC setting ("AUTO" or "ON") and weather ("Rain" or "No Rain") for direct data analysis and interpretation. Tests which had rain for only a small fraction of the testing period were designated as "No Rain." To further facilitate interpretation, the results are sub-categorized into "PASS" and "FAIL" by comparing the average radon level of each test to the 4.0 pCi/l action level. The average barometric pressure recorded for each test (in inches of mercury, InHg) is also included so that its influence and general correlation toward overall results can be deduced.

Table (2): Summary of test results

	HVAC "AUTO" (pCi/l, InHg)		**HVAC "ON" (pCi/l, InHg)**	
	PASS	**FAIL**	**PASS**	**FAIL**
No Rain	-	Test #5: (4.5/30.1) Test #8: (4.1/30.2)	Test #6: (3.6/30.1) Test #10 (3.6/30.1)	-
Rain	-	Test #3: (4.0/30.2) Test #4: (4.7/30.0)	Test #2: (3.6/30.1) Test #9: (3.7/30.1)	Test #1: (4.3/30.1) Test #7: (6.9/30.0)

Analyzing the data in the convenient format of this table provides direct interpretation. For this house, which had initially measured at the borderline 4.0pCi/l action level:

- with the HVAC set to “AUTO” the radon test was always a “FAIL”
- with the HVAC set to “ON” and “No Rain” the radon test always a “PASS”
- with the HVAC set to “ON” and “Rain” the radon test passed half the time
- within each category, lower barometric pressures tended toward higher radon levels

Conclusions

Rainier days resulted in higher radon levels, as they were accompanied by lower barometric pressure as measured in the basement. The higher pressure in the ground relative to the lower pressure in the basement caused the radon gas to seep upward from the soil and into the house through the concrete slab of the basement. On clearer days, however, the higher pressure in the basement resulted in less radon infiltrating the house as evidenced by the lower detected levels.

When the HVAC system was turned to the “ON” position, the detected radon levels were noticeably lower than the “AUTO” position since there was more air ventilation and circulation between the basement and the other stories of the house as well as its exterior.

It has been shown that severe weather conditions can result in testing results almost double those observed during other tests. While a single test needs to be averaged over a minimum of 48 hours to count as an official result, any random two-day period is not representative of the radon levels in the home during all weather and ventilation conditions. Therefore, a more conservative government standard should be set if it is serve as the litmus test that a single result is to be compared against.

Recommendations

The absence of requirements for engineered ventilation in our residential building codes misses the opportunity to reduce radon levels in new homes. This study shows that even the most standard ventilation provided by an HVAC system can reduce levels. The impact of radon is statistical and improvements can continue to be gained at levels below the current 4.0 pCi/l action level. For example, values of 2.0 pCi/l will likely reduce the yearly lung cancer deaths attributed to radon by 50%. Thus, the lower the level the better. Even the World Health Organization (WHO) recommends action levels at 2.7pCi/l (100Bq/m3 in their units) (Zeeb, 2009). Rather than failing to meet this recommendation, the United States should exceed these standards and lead by example to improve overall air quality and reduce health risks. Additionally, with radon recognized as the second leading cause of lung cancer, regulatory measures are recommended to include engineered ventilation for new residential construction to reduce levels even further. During construction, mitigation techniques are easier to implement, more cost effective, and less invasive to future homeowners.

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