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Project Summary

Follow-Up Annual Alpha-Track Monitoring in 40 Eastern Pennsylvania Houses with Indoor Radon Reduction Systems (December 1988 - December 1989)

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Between June 1985 and June 1987, developmental indoor radon reduction techniques were installed in 40 houses in the Reading Prong region of eastern Pennsylvania. Most of these systems involved some form of active soil ventilation, although three involved heat recovery ventilators and two included carbon filters to remove radon from well water. The initial reductions in indoor radon concentrations achieved in each house were described in an earlier report. Follow-up alpha-track detector (ATD) measurements of radon concentrations in these houses during the winters of 1987-88 and 1988-89 were also described earlier.

The purpose of the current study was to make follow-up ATD measurements in the living area of these houses over an entire year (December 1988-December 1989), 2 to 4 years after the installations were completed. Since these figures reflect annual averages in the living area, they are the best measures to date of the effectiveness of the mitigation systems in reducing occupant exposures after several years of operation.

Of the 28 houses where the radon mitigation system was in operation during the entire year, the annual average radon levels measured in the living area were within 1 pCi/L* of the previous winter-quarter averages in all but six. Almost half of the houses were below 2 pCi/L, and three-quarters were below 4 pCi/L. It is believed that most of the residual radon in these houses results from re-entrainment of fan exhaust back into the house, and, to a lesser extent, from radon released from well water. Inadequate treatment of the floor slab by the active soil depressurization system does not appear to be the primary cause of the residual radon in most of these houses.

Of 34 soil depressurization fans operating under this project, 6 have failed to date. Five of these six failures resulted from failure of the capacitor in the fan circuitry.

This Project Summary was developed by EPA's Air and Energy Engineering Research Laboratory, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

*1 pCi/L = 37 Bq/m^3

Introduction

The U.S. Environmental Protection Agency (EPA) is conducting a program to develop and demonstrate cost-effective methods for reducing the concentrations of naturally occurring radon gas inside houses. As part of this program, EPA sponsored the installation of developmental radon reduction measures in 40 existing houses in eastern Pennsylvania having high initial radon levels—above 20 picoCuries per liter (pCi/L). These houses had substructures representative of the region—basements having block or poured concrete foundation walls, sometimes with an adjoining slab-on-grade or crawl-space wing. Active soil ventilation, utilizing a fan—sub-slab suction, drain tile suction, or block wall suction or pressurization—were tested in most of the houses. Heat recovery ventilators (air-to-air heat exchangers) were tested in three houses having only moderately elevated radon levels, and charcoal treatment of well water was tested in two houses. The installations in these 40 houses, and the initial system performances, were reported earlier.

To test the durability of these installations, 3- to 4- month ATD measurements of radon concentrations were made during the winter periods since the installations were completed. Measurements during the winters of 1987-88 and of 1988-89 were reported earlier. Measurements in the living area between December 1988 and December 1989 are reported here. This 1-year measurement period was selected to determine the annual average levels to which the occupants were being exposed.

The measurements reported here were completed in the 38 of the 40 houses which still have operating systems. Of the 2 houses no longer with operating systems, 1 was moved from its original site after the system was installed; in the other, the owner decided to discontinue participation in the project.

Measurement Procedures

The measurements were made using Terradex "Type SF" Track Etch ATDs. In each house, a cluster of two ATDs were hung together in the living area (the story above the basement), from an interior wall or ceiling. Clusters of two were used to permit identification of outliers.

The detectors were deployed in mid-December 1988, and retrieved in mid-December 1989, by an experienced professional. The exposed detectors were returned to the Terradex laboratories for analysis.

For quality assurance, six unexposed detectors were returned to Terradex as blind blanks, to determine the zero correction. Also, as part of the previous winter-quarter measurements, 10 detectors were exposed to known radon environments in a test chamber for a selected duration, and returned to Terradex as blind spikes, to determine the gain correction.

Results and Discussion

Of the 38 houses in which ATDs were deployed, it was found upon retrieval of the detectors that the mitigation system fans had been off in 10 houses during some portion of the measurement period. In three houses, the soil depressurization fan failed; in five other houses, the fan had deliberately been turned off during mild weather when the homeowner usually opened the windows, in the belief that increased natural house ventilation would compensate for the system's being off; in a another house, the soil depressurization fan was inadvertently unplugged; and in another house, the fan motor in a heat recovery ventilator failed. Thus, in only 28 houses do the ATD results give radon concentrations representative of uninterrupted system operation over the year.

The results from these 28 houses are presented in Table 1. The radon concentrations listed in the column "1989 Annual" are from this measurement effort; each number is the average of the two ATDs in the cluster, corrected using the zero and gain corrections from the blanks and spikes. Results are also shown for post-mitigation ATD measurements during the previous winter quarters where available ("1989 Winter" for the winter of 1988-89, etc.). Pre-mitigation results, usually from an ATD measurement during an earlier heating season, are also shown for each house.

A review of the data for all 28 houses in Table 1 shows that the annual average concentration in the living area measured throughout 1989 is not as greatly different from the 1988-89 winter-quarter average as might have been expected. Within a tolerance of ± 0.3 pCi/L: 10 of the 28 houses have annual averages in the living area equal to the Winter 1989 value, ± 0.3 pCi/L; 8 houses have annual averages lower than the winter-quarter value; and 10 houses have annual averages greater than the winter-quarter value. This is a fairly uniform distribution. When the band of allowable difference is increased to ±1.0 pCi/L (not an unreasonable allowance, given the variability of radon levels in a given house, and given the accuracy of the ATD measurement method at these low concentrations): 22 of the 28 houses have annual averages equal to the Winter 1989 quarterly value; 2 have lower annual averages (Houses 18 and 28, both with HRVs); and 4 have higher annual averages (Houses 10, 25, 27, and 39). Among that group of four houses having annual averages greater than their winter-quarter means, all but House 27 are among the group having annual averages above 4 pCi/L. In summary, in only six houses does the 1988-89 winter-quarter concentration in the living area differ from the annual average by more than 1.0 pCi/L, and in four of those cases, the winter-quarter concentration is *lower* than the annual average. Similar results are obtained when this analysis is expanded to include winter-quarter data for the prior winters.

Since radon measurements have often been made in the winter with the expectation of maximizing the radon concentration, it is to be noted that, more often than not among these houses, the winter-quarter post-mitigation average can be lower than the annual average. There are thought to be two reasons why the annual average is commonly higher. First, opened windows during mild weather probably increased the amount of fan exhaust re-entrained back into the house. Second, there are probably additional, unreported cases where the occupant turned off the system during periods of mild weather when the windows are opened. (Of the five houses where it is known that the fan was turned off when windows were opened, radon levels in the living area increased significantly in four of these, probably due to the very high source term in this region, and to the likelihood that the windows were not constantly open.)

Almost half of the 28 houses with continuously-operating systems have been reduced to below 2 pCi/L in the living area on an annual average, compared to pre-mitigation (cold-weather) values in the hundreds of pCi/L in many cases. Over three-quarters are below 4 pCi/L on an annual average.

Based upon testing conducted after this year-long measurement period was completed, it is believed that most of the residual radon in many of these houses is due to re-entrainment of fan exhaust, and, to a lesser extent, airborne radon resulting from radon in the well water. Most of the active soil depressurization systems in this project are maintaining at least a marginal (and sometimes a very good) suction field beneath the floor slabs; thus, the residual radon is often not the result of poor sub-slab communication and insufficient suction field extension, as had previously been thought. Care in the design of the fan exhaust, to reduce re-entrainment, is clearly important when the exhaust contains such high radon concentrations as commonly encountered in eastern Pennsylvania (often greater than 1,000-2,000 pCi/L). It is believed that essentially all of these houses could be reduced below 2-4 pCi/L if the re-entrainment and well water contributions were addressed.

The generally consistent performance of these mitigation systems over the two to four years since installation demonstrates the durability of these systems over that time period. Only where the soil depressurization fan failed, or where the system had been turned off by the occupant, did radon levels show a significant increase. Five of the six fan failures to date have resulted from failures of the electrolytic capacitor in the fan circuitry. It was learned from the fan manufacturer that the capacitors installed in most of the fans in this project were rated at a 40,000-hour lifetime, which would correspond to 4 to 5 years of continuous operation. If this lifetime rating is accurate, more fan failures might be anticipated in the near future as some of these systems approach 5 years of operation.

In House 40, where the capacitor failed while the fan was operating, the fan continued to operate, at greatly reduced suction and flow, for up to a year following the capacitor failure. (If the fan had been turned off during that period, it would not have restarted.) To the occupant, the fan sounded as if it were operating normally. The fact that the fan can continue to operate, but at greatly reduced performance, following capacitor failure is further indication that pressure- and/or flow-actuated alarms are necessary on active soil depressurization systems.

The performance was checked of the two activated charcoal water treatment units installed in 1986 under the original project. The one unit containing a charcoal specifically selected for radon removal was still achieving 97% removal, within the range (95-99%) that has been observed since installation. However, the radon removal efficiency of the second unit—containing a generally available charcoal not specifically selected for radon—continued a steady decline, now down to 38%.

Table 1. *Living Area ATD Results to Date Houses with Mitigation Fans Operating Throughout the 12/88-12/89 Annual Measurement Period*

House ID#	Type*	Final Mitigation System	Average Radon Concentration (pCi/L) Premitigation**	Post-Mitigation*** 1989 Annual	1989 Winter	1988 Winter	1987 Winter	1986 Winter
3	1	Wall + sub-slab suction	350	1.8	1.9	2.3	2.1	1.7
4	1	Sub-slab suction	25	0.5	1.0	3.1[a]	0.8	—
5	1	Wall pressurization	(110)	4.0	4.4	4.4	4.3	—
6	1	Sub-slab suction	60	2.3	2.7	3.2	4.9	—
8	1	Wall suction	183	1.1	1.0	1.5	1.8	1.3
10	1	Drain tile suction	626	12.1	8.9	9.9	6.5	3.0
12	1	Drain tile suction	(11)	1.3	2.1	2.2	2.5	—
15	1	Drain tile suction	(18)	0.9	1.3	11.0[a]	1.0	—
16	2	Wall suction	395	1.5	1.1	2.5	1.7	—
18	1	Heat recovery ventilator	12	3.6	5.1	3.4	2.1	—
20	2	Sub-slab + wall suction in bsmt; suction under crawl-space slab	210	10.0	9.3	10.0	9.9	—
21	1	Sub-slab suction	172	3.7	2.7	2.7	2.6	—
23	3	Sub-slab suction (basement + slab)	98	1.6	1.5	1.6	—	—
24	4	Sub-slab suction	66	3.2	3.7	3.8	4.6	—
25	4	Sub-slab suction	122	6.4	5.3	6.0	3.0	—
26	1	Drain tile suction	(89)	1.0	1.1	1.6	1.5	—
27	1	Drain tile suction	21	3.9	2.1	2.2	2.2	—
28	1	Heat recovery ventilator	21	3.6	5.1	4.4	5.3	—
29	5	Drain tile suction (interior sump)+ suction under crawl-space liner	61	3.0	2.3	2.0	1.4	—
30	1	Carbon adsorption treatment of well water	17	1.9	2.1	1.6	1.3	—
32	1	Sub-slab suction	(6)	4.0	3.2	4.4	3.2	—
33	4	Sub-slab suction	82	0.6	0.7	1.2	1.1	—
34	4	Sub-slab suction	470	5.8	5.5	5.5	3.7	—
35	4	Sub-slab suction	144	0.7	1.0	0.9	0.7	—

(continued)

Table 1. (Continued)

House ID#	Type*	Final Mitigation System	Permitigation**	Average Radom Concentration (pCi/L) Post-Mitigation*** 1989 Annual	1989 Winter	1988 Winter	1987 Winter	1986 Winter
36	3	Sub-slab suction (basement + slab	300	0.7	0.7	1.0	0.7	—
37	3	Sub-slab suction (basement only)	87	0.9	0.5	0.7	1.7	—
38	1	Sub-slab suction	309	6.6	7.3	7.2	—	—
39	1	Sub-slab suction	111	4.1	1.8	17.5[a]	—	—

*House Type:
1 = Block basement walls
2 = Block basement walls + paved crawl space
3 = Poured concrete basement walls + slab on grade
4 = Poured concrete basement walls
5 = Block basement walls + unpaved crawl space

**Many of these pre-mitigation radon concentrations were probably obtained in the basement, and thus might not be directly compa rable to the living-area post-mitigation results in the remainder of the table. Pre-mitigation concentrations reported here represent a single Terradex Track Etch alpha-track detector measurement arranged by the Pennsylvania Department of Environmental Resources during a heating season prior to installation of EPA's radon mitigation system. The exact location of these detectors is not always known; in some cases, this pre-mitigation measurement might have been made in the basement. Where it is known that the pre-mitigation ATD was not placed in a representative location, or where the ATD result was clearly not representative of subsequent Pylon measurements made by EPA, the pre-mitigation concentration shown here is the average of at least 48 hours of hourly radon measurements made in the basement during cold weather using a Pylon AB-5 continuous radon monitor. (Pylon measurements were generally not made in the living area during this early testing.) Where Pylon measurements have been used, the pre-mitigation value is shown in parentheses. The Pylon measurements were made during the 1985-87 system installation period.

***Post-mitigation living-area radon concentrations reported here represent the average of clusters of two (1989) or three (pre-1989) ATDs. The 1989 annual detectors were exposed between December 1988 - December 1989; the values shown in this table are the corrected averages. The Winter 1989 detectors were exposed for 4 months (December 1988 -April 1989); the Winter 1988 detectors were exposed for 3 months (December 1987 - March 1988). The Winter 1987 ATD measurements (December 1986 - March 1987) and the Winter 1986 ATD measurements (December 1985 - March 1986) were reported in the final report on the original project. All results in this table have been corrected using the zero and gain corrections.

[a] A superscript "a" indicates that the ATD measurements in that house during that year are not representative of an operating mitigation system, because the system fan was off for part or all of that measurement period.

—Absence of results for 1986 or 1987 for a given house indicates that: alpha-track measurements were not made in that house that winter; or the radon mitigation system was changed significantly between that winter and the following winter; or the alpha-track measurement was made significantly outside the December - March window due to the system installation schedule.

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The complete report, entitled "Follow-Up Annual Alpha-Track Monitoring in 40 Eastern Pennsylvania Houses with Indoor Radon Reduction Systems (December 1988-December 1989)," (Order No. PB91-127 779/AS; Cost: $15.00, subject to change) will be available only from:
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