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Project Summary

Follow-up Alpha-Track Monitoring in 40 Eastern Pennsylvania Houses with Indoor Radon Reduction Systems (Winter 1988-89)

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Between June 1985 and June 1987, developmental indoor radon reduction systems 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 for removing radon from well water. The initial reductions in indoor radon concentrations achieved in each house were described earlier. Follow-up alpha-track detector (ATD) measurements of radon concentrations in these houses during the winter of 1987-88 were also described earlier.

The purpose of the current study was to make follow-up ATD measurements in these houses over the Winter of 1988-89, two to four years after the installations were completed, in order to further determine how well the radon reduction performance of the systems was being maintained. The ATD measurements were made over a 4-month period during the winter (December 1988 - early April 1989), to assess system performance when cold weather would be giving the systems a significant challenge. These 1988-89 ATD results are compared with comparable ATD measurements made during the two previous winters and with those made prior to the installation of the radon reduction system.

Of the 34 houses where the radon mitigation system was in operation during the entire measurement period, the radon levels measured in 1989 compared well with those measured in prior years (or any differences appeared explainable) in all but two of the houses. In those two houses, concentrations in the basement had increased by 220 to 360% for no apparent reason, probably because the system performance had been marginal. Well water radon removal was maintained at 97% at the one house that had a charcoal unit designed specifically for radon, but had fallen to 65% at the house with a general-purpose charcoal unit.

Two additional soil ventilation fans failed during the past year, bringing to five the number of fan failures over two to four years of operation in the 34 houses having operating active soil ventilation systems.

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).

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), or 740 Becquerels per cubic meter (Bq/m^3). 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 - was 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 have been made during the winter periods since the installations were completed. Measurements during the winter of 1987-88 were reported earlier; measurements during the winter of 1988-89 are reported here. Winter was chosen for this measurement to determine system performance when the system was facing the challenge of cold weather.

The measurements reported here were completed in the 38 of the 40 houses which still have operating systems. Of the two houses no longer having operating systems, one 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 alpha-track detectors (ATDs). In each house, two ATDs were hung together from a central floor joist in the basement; a second pair was hung in the living area (the story above the basement) from an interior wall or ceiling. Pairs were used to permit identification of outliers.

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

For quality assurance, seven unexposed detectors were returned to Terradex as blind blanks, to determine the zero correction. Also, 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 four houses during some portion of the measurement period. In two houses, the soil ventilation fan failed; in a third house, the soil ventilation fan had been inadvertently unplugged; and in the fourth house, the fan motor in a heat recovery ventilator failed. Thus, in only 34 houses do the ATD results give radon concentrations representative of uninterrupted system operation.

The results from these 34 houses are presented in Table 1. The radon concentrations listed in the column "1989" are from this 1988-89 measurement effort; each number (for the basement and for the living area) is the average of the paired ATDs. Results are also shown for comparable post-mitigation ATD measurements during the previous two winters ("1988" and "1987"). Where available, results are also shown for post-mitigation measurements 3 years before ("1986"). Pre-mitigation results, usually from an ATD measurement during an earlier heating season, are also shown for each house.

An analysis of the data in Table 1 indicates that the mean heating season radon concentration measured in 1989 is similar to that measured the previous year for almost all houses, indicating no overall degradation in system performance. Of the 34 houses in the table, 16 have 1989 ATD results, both in the basement and upstairs, which vary from the 1988 results by less than 1 pCi/ℓ; in 24 of the houses, no one result varies by more than 2 pCi/ℓ from 1988. Considering the variability of radon levels in houses, and the accuracy of the measurement method, this agreement suggests no degradation within our ability to measure. Of the 24 houses in Table 1 which changed by less than 2 pCi/ℓ, most (58%) *decreased* in radon level. The fact that such a large percentage decreased in concentration could be partially due to the fact that, in 1989, the measurement period extended to early April, thus encompassing an additional 2 weeks of possibly mild weather compared to the 1988 period, which extended only to late March. Also, the 1988/89 winter was reported by the homeowners to hav[e] been relatively mild.

Of the 10 houses, where either th[e] upstairs or basement levels changed b[y] 2 pCi/ℓ or more: in three houses (House[s] 4, 15, and 39), levels dropped dramat[-] ically in 1989 because the mitigatio[n] system had been off for part or all of th[e] 1988 measurement period; in two othe[r] houses (Houses 10 and 19), level[s] decreased by about 5 pCi/ℓ for unknow[n] reasons, reflecting the variability of th[e] system and the house dynamics; in thre[e] houses (Houses 2, 9, and 22), level[s] increased by 2.0 to 4.2 pCi/ℓ (an increas[e] of 25 to 32%), either due to syster[m] house dynamics variability or perhap[s] due to some limited degradation; and i[n] the final two houses (Houses 33 and 40[)] there was a significant increase in rado[n] levels in the basements (by 220% i[n] House 33, by 360% in House 40[)] sufficiently large to suggest that som[e] real degradation had in fact occurred.

Houses 33 and 40 have larg[e] unexplained increases in the baseme[nt] which possibly suggest some degrad[a-] tion. In both these houses, radon upstai[rs] did not increase nearly so dramatically. [In] fact, in House 33, the upstairs co[n-] centration went *down*. House 33 was [a] small basement house with poure[d] concrete foundation walls and r[no] adjoining living wing. Suction is drawn [on] a concrete-lined, concrete-bottom sum[p] pit having no drain tiles; holes we[re] drilled through the concrete walls of t[he] pit to provide access to the sub-sla[b]. While communication under the slab h[as] not yet been measured, diagnost[ic] smoke stick testing after installation [of] the system had suggested that t[he] distribution of the suction under the sl[ab] was ambiguous. Thus, one possib[le] explanation for the observed increase [is] that the system might have be[en] marginal to begin with, and somethi[ng] happened prior to or during this particu[lar] measurement period to reduce syste[m] effectiveness, increasing radon from [3.5] pCi/ℓ in 1988 to 11.2 pCi/ℓ in 19[89]. House 40 was a very large basem[ent] house with poured concrete walls, havi[ng] multiple slab pours and extremely p[oor] sub-slab communication. Twenty s[ub-] slab suction pipes penetrate the slab a[nd] connect to a single Kanalflakt K6 f[an;] most of the 20 pipes have soil gas fl[ows] of less than 1 cfm (0.5 L/s). Although [the] system has many suction pipes, it m[ay] be marginal due to the very p[oor] communication, and this could be [an] explanation for the increase in basem[ent] concentrations from 1.9 pCi/ℓ in 198[8 to] 8.8 pCi/ℓ in 1989.

With two fan failures this year, fans have now failed in five of the 34 houses with active soil ventilation systems over an operating period of two to four years. Failure has usually been due either to bearing failure, or to failure of the capacitor. All of the failed fans have been (or are being) replaced under warranty. The failure of the fan motor in the heat recovery ventilator this year is the first failure among the three heat recovery ventilators installed under this project; this unit has been repaired.

Radon concentrations were measured in the well water at Houses 2 and 30, entering and leaving the charcoal treatment unit. In House 30, water concentrations were being reduced from 156,000 pCi/ℓ to 4,360 pCi/ℓ (from 5.77 to 0.16 MBq/m^3), for a removal efficiency of 97%, consistent with the removals being achieved when the unit was first installed over 2 years previously. Thus, there was no apparent degradation in the performance of this unit, which contains a charcoal specifically selected for radon removal. However, in House 2, water concentrations were being reduced from 57,200 to 19,900 pCi/ℓ (2.12 to 0.74 MBq/m^3), a removal of only 65%; this represents a continuing degradation from the removals of up to 95% observed mmediately after installation two years previously. This unit was not designed specifically for radon removal but was being marketed for organics removal.

Overall earlier conclusions still appear to be valid. Reductions of 90-99+% are still being achieved with the active soil ventilation systems. Heat recovery ventilators give lower, less predictable reductions, usually no greater than about 50%; the apparent reduction of about 80% in House 28 is questioned, since this ventilator gave reductions of only 15-45% during short-term back-to-back measurements with the ventilator on and off. Carbon filtration can remove 95-99% of the radon in water, at least over this 28-month test period, if the charcoal is appropriately selected for radon removal.

Table 1. *Summary of Results to Date for Houses with Mitigation Fans Operating Throughout the 1989 Measurement Period*

House			Pre-	Average Radon Concentration (pCi/ℓ)							
				Post-Mitigation***							
				1989		1988		1987		1986	
ID#	Type*	Final System	Mitigation**	B	LA	B	LA	B	LA	B	LA
2	1	Wall + sub-slab pressurization (baseboard duct) + carbon adsorption on well water	413	5.5	8.7	4.8	6.7[a]	2.6	5.2	-	-
3	1	Wall + sub-slab suction	350	3.0	1.9	3.5	2.3	3.5	2.1	4.4	1.7
4	1	Sub-slab suction	25	1.2	1.0	7.3	3.1[a]	0.7	0.8	-	-
5	1	Wall pressurization	(110)	5.0	4.4	5.0	4.4	4.3	4.3	-	-
6	1	Sub-slab suction	60	3.2	2.7	4.1	3.2	3.3	4.9	-	-
8	1	Wall suction	183	2.9	1.0	3.5	1.5	3.9	1.8	3.1	3.1
9	1	Wall + sub-slab pressurization (baseboard duct)	533	12.4	17.1	10.4	12.9	11.6	14.5	-	-
10	1	Drain tile suction	626	10.4	8.9	15.2	9.9	9.0	6.5	3.3	3.0
12	1	Drain tile suction	(11)	1.6	2.1	2.2	2.2	3.7	2.5	-	-
13	1	Sub-slab suction + drain tile suction	64	2.7	2.8	2.6	3.9	2.3	2.0	-	-
15	1	Drain tile suction	(18)	1.3	1.3	19.7	11.0[a]	1.1	1.0	-	-
16	2	Wall suction	395	4.8	1.1	5.7	2.5	5.4	1.7	-	-
18	1	Heat recovery ventilator	12	12.7	5.1	13.5	3.4	8.8	2.1	-	-
19	1	Wall suction	32	28.5	0.6	33.5	0.8	32.0	0.6	-	-
20	2	Sub-slab + wall suction, + suction under crawl space slab	210	8.3	9.3	6.5	10.0	5.8	9.9	-	-
21	1	Sub-slab suction	172	1.9	2.7	2.0	2.7	3.1	2.6	-	-
22	3	Sub-slab suction (basement + slab)	24	10.8	4.0	8.6	4.4	7.6	2.7	-	-
23	3	Sub-slab suction (basement + slab)	98	2.4	1.5	2.6	1.6	-	-	-	-
24	4	Sub-slab suction	66	4.3	3.7	3.6	3.8	4.3	4.6	-	-
25	4	Sub-slab suction	122	7.2	5.3	7.7	6.0	5.4	3.0	-	-
26	1	Drain tile suction	(89)	0.6	1.1	1.1	1.6	2.1	1.5	-	-
27	1	Drain tile suction	21	5.6	2.1	4.0	2.2	3.8	2.2	-	-
28	1	Heat recovery ventilator	21	3.6	5.1	4.1	4.4	2.4	5.3	-	-
29	5	Drain tile suction (interior sump) + suction under crawl space liner	61	2.1	2.3	1.6	2.0	1.9	1.4	-	-
30	1	Carbon adsorption treatment of well water	17	3.9	2.1	4.0	1.6	3.0	1.3	-	-
32	1	Sub-slab suction	(6)	0.5	3.2	1.2	4.4	1.0	3.2	-	-
33	4	Sub-slab suction	82	11.2	0.7	3.5	1.2	2.2	1.1	-	-
34	4	Sub-slab suction	470	5.1	5.5	5.4	5.5	5.5	3.7	-	-
35	4	Sub-slab suction	144	2.4	1.0	1.0	0.9	0.8	0.7	-	-
36	3	Sub-slab suction (basement + slab)	300	0.8	0.7	1.1	1.0	1.6	0.7	-	-
37	3	Sub-slab suction (basement only)	87	0.9	0.5	1.2	0.7	0.6	1.7	-	-
38	1	Sub-slab suction	309	7.0	7.3	8.7	7.2	-	-	-	-
39	1	Sub-slab suction	111	7.5	1.8	46.1	17.5[a]	-	-	-	-
40	4	Sub-slab suction	148	8.8	2.5	1.9	1.2	-	-	-	-

Table 1. *Notes*

* *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

** *Pre-mitigation radon concentrations reported here represent a single Terradex 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. 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. 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 radon concentrations reported here represent the average of clusters of two or three alpha-track detectors exposed for a 3- to 4-month period during the winter. 1989 measurements were made during this study (December 1988 - April 1989). 1988 measurements made during the period December 1987 - March 1988; 1987 measurements generally made during the period December 1986 - March 1987; 1986 measurements generally made during the period December 1985 - March 1986. All results corrected for gain and zero where needed.*

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 was off for part or all of the 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.

B = Track Etch measurements in basement

LA = Track Etch measurements in living area (story above basement)

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The complete report, entitled "Follow-up Alpha-Track Monitoring in 40 Eastern Pennsylvania Houses with Indoor Radon Reduction Systems (Winter 1988-89)," (Order No. PB 90-134 172/AS; Cost: $15.00, subject to change) will be available only from:
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