A DETAILED STUDY OF INEXPENSIVE RADON CONTROL TECHNIQUES IN NEW YORK STATE HOUSES

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Abstract

As part of a comprehensive indoor air quality and infiltration field study, radon concentrations were measured in 60 houses in upstate New York using passive integrating monitors. Indoor air radon concentrations ranged from 0.2 pCi/l to 50 pCi/l. Four houses with the highest radon levels were then extensively monitored using real-time continuous instruments for the measurement of radon, radon daughters, respirable particles, infiltration, inside-outside pressure difference, and weather parameters. Several inexpensive radon mitigation techniques were tested in these four houses. Their effectiveness ranged widely. Techniques identified as effective were permanently installed in 14 houses having indoor air radon concentrations above 2 pCi/l. Finally, the long-term effectiveness of the installed control techniques is being tested using passive integrating radon monitors.

Introduction

Recently there has been considerable concern over the indoor air quality effects of energy conservation measures and alternative heating devices (2). This prompted the initiation of an extensive indoor air quality project in 61 houses in New York State, sponsored by NMPC (an electric and gas utility) and NYSERDA. The objectives of the overall project are to investigate the relationship between indoor air quality, air exchange rates, pollution sources, and construction practices; to evaluate the effectiveness of simple, inexpensive methods of controlling indoor air pollution; and to disseminate research results to relevant professional organizations and the general public. The emphasis of this paper will be reporting preliminary radon results.

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Experimental Methods

There are four phases of the project involving radon measurements and mitigation techniques.

In phase 1, 56 homes were monitored for indoor air radon concentrations using four passive radon detectors per home over a period of approximately six months (summer and fall 1982, winter 1983). In addition, careful door fan pressurization measurements were performed, the location of leakage sites noted, and factors that might influence indoor air quality were obtained using a detailed questionnaire on all 61 houses in the study. Approximately half the houses were state-of-the-art, energy efficient houses while the other half represented typical houses in upstate New York.

Phase 2 was conducted in the fall of 1983 using a newly developed passive radon building kit (3). This kit was mailed to each of 58 participating homeowners. Site visits were made to 15 of these homes to ensure that the detectors were properly installed.

Phase 3, detailed real-time radon monitoring, was conducted from mid-October 1983 until January 1984, in four homes with the highest indoor air radon concentrations. The primary purpose of this phase was to evaluate the effectiveness of inexpensive radon control techniques. Weather, particulate, and infiltration variables were also monitored, along with radon and radon-daughter concentrations in order to differentiate between the natural variations in radon levels from those resulting from control techniques. In these four houses, several control techniques were temporarily installed and tested for a period ranging from one day to over a week.

After the real-time evaluation of the various temporary control measures, permanent control techniques were installed in the original four houses and ten additional homes with radon levels above 2 pCi/l.

Phase 4 is currently under way (April 1984) in which three to four passive radon detectors are deployed in each of the 14 home for three months to test the long-term effectiveness of the permanent controls.

Initial Results and Discussion

Table 1 summarizes phase 1 and 2 measurements and indicates the following results:

1) Air exchange rates at 50 pascals varied by a factor of 50 while radon source strengths varied over three or more orders of magnitude. This points to the overwhelming importance of radon source strengths compared to air exchange rates when considering radon control techniques.

2) Indoor air radon concentration below grade was found to be about three times greater than indoor air radon concentrations above grade, indicating that the source of radon was from the soil.

3) The concentration of radon in well water was found to be greater than in municipal reservoir water but even well water concentrations were relatively low and can be ignored for purposes of radon control in locations covered in this study.

The first part of Table 2 displays the short-term effectiveness of temporary radon control techniques tested in houses 05, 21, 31, and 37. The following points highlight some results:

1) In house 05, a filter using 9kg of activated charcoal with a flow rate of 150 l/s did not reduce radon levels but did reduce radon progeny levels by 60%. Sealing, sub-slab ventilation, and crawl space ventilation together were shown to reduce radon and progeny levels by 75%.

2) In house 21, porous cinderblock basement walls and numerous openings in the basement walls and floor reduced the effectiveness of subslab ventilation especially when outside temperatures fell below 10°C. Various experiments were conducted using different air flow rates and sealing techniques to obtain information on the best permanent control methods.

3) House 31 had a finished basement with most cracks inaccessible, so sealing was impractical. The use of an air-to-air heat exchanger was considered only a partial solution. The permanent control involved cutting two holes in the basement floor at opposite ends of the basement and venting the sub-slab to the outside with small fans.

4) In house 37 sealing cracks and holes in the poured concrete basement walls and floor reduced radon levels by 65%. When the sump (connected to sub-slab drain pipes) was vented with a small fan, indoor radon levels fell to outdoor ambient levels.

A listing of the permanent controls installed in all 14 houses is indicated in bold face type in Table 2. Final results showing the long-term effectiveness of the permanent control measures in all 14 houses will be known in May 1984. Using the experience gained in the first four houses, it is expected that all permanent measures should be effective in bringing living space radon levels to below the ASHRAE guideline of 2pCi/l, assuming 50% equilibrium (1). Because of the greater care in installation, it is also expected that the permanent installations will be more effective than the temporary measures.

Conclusions

Variations of indoor radon source strengths overwhelm variations in air exchange rates so methods of radon control in houses with high radon cannot rely totally on ventilation. Filtration with activated charcoal is also of limited value. However, in very tight houses with relatively low radon source strengths, whole house ventilation with heat recovery may reduce radon to acceptable levels. Basement ventilation would be preferred to whole house ventilation if the radon source is in the basement (not in the water) and the basement is separated from other parts of the house. Ventilation of a crawl space can also be an effective control. Sealing cracks and holes in basement walls and floors and ventilating the sub-slab can cause substantial reductions in indoor radon concentrations. In fact, of the several radon control techniques tested, the combination of sealing cracks and venting the sub-slab provided the greatest reduction in indoor radon concentration.

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References

(1) ASHRAE Standard 62-81. Ventilation for Acceptable Indoor Air Quality. New York: ASHRAE, 1981.

(2) National Academy of Sciences-National Research Council, Indoor Pollutants. Washington, D.C.: National Academy Press, 1981.

(3) Wadach, J.B. Detection of Radon Concentration in Air, Water, and Soil Using Track-Etch Detectors and Liquid Scintillation. MSc Thesis. Orono, ME: University of Maine at Orono, 1983.

Table 1. Summary of integrated radon measurements in sixty houses before controls.

House	House volume (m)	Airchange at 50 Pa (h)	Radon concentration (pCi/l): Indoor air below grade**	Radon concentration (pCi/l): Indoor air above grade**	Radon concentration (pCi/l): Water***
01	315	8.5	1.2±0.7	1.0±0.5	1M
02*	473	3.7	6.1±2.4	5.8±3.3	307W
03	289	2.5	11.0	0.6±0.2	175W
04	773	9.3	1.2±0.4	0.7±0.3	2M
05*	472	5.4	16.4±0.3	7.5±1.5	3M
06	870	6.2	1.8±0.7	0.9±0.4	237W
07	477	6.3	1.7±0.9	1.7±1.0	101W
08	211	5.4	---	1.9±0.2	18W
09	265	3.3	3.9	1.5±0.6	470W
10	690	1.5	1.6±0.4	0.4±0.1	3M
11	311	6.7	0.5	0.6±0.1	---
12*	696	4.7	18.3	9.2±5.3	1M
13	293	8.5	0.7	0.4±0.1	1M
14	350	6.9	0.9±0.5	0.6±0.4	0M
15	353	6.1	---	1.2±0.4	325W
16*	508	5.0	---	1.3±1.1	2M
17	682	5.3	2.4	0.3±0.2	---
18	441	15.1	0.9±0.1	0.8±0.4	14M
19*	515	12.3	18.8±1.6	2.0±0.6	340M
20	468	6.1	---	0.3±0.1	38W
21*	379	7.5	49.8	14.7±1.8	1M
22	697	3.5	2.1±0.3	1.0±0.1	148W
23	429	5.0	0.7±0.2	0.3±0.2	1M
24	329	8.0	0.9±0.2	0.8±0.5	1M
25	733	1.8	2.3±0.1	1.0±0.2	455W
26*	545	4.2	8.6±3.8	6.1±2.2	30W
27	658	5.7	0.3±0.1	0.6±0.8	36M
28*	720	6.8	9.3±1.0	3.1±1.8	115W
29*	438	2.4	5.2±3.8	4.5±3.7	14M
30	880	3.1	2.7±1.7	1.4±0.9	1028W
31*	1020	2.6	17.2	14.7±0.5	2M
32	701	7.3	2.4±0.5	1.5±0.5	33M
33	579	7.5	2.2±1.1	1.4±0.7	---
34	329	7.4	3.0	1.5±0.7	1M
35	429	8.9	---	---	---
36	455	5.7	0.8±0.5	0.3±0.1	1M
37*	340	10.9	30.4±2.1	4.9±0.1	1M
38	798	5.0	1.8	0.7±0.3	1M
39	800	6.7	0.9	0.9±0.6	1M
40	422	5.6	---	0.5±0.2	---
41*	544	3.8	8.0	1.7±1.3	10M
42	544	6.8	1.8±1.1	0.7±0.4	---
43	652	6.4	0.9±0.4	0.5±0.1	1114W
44	606	2.0	5.3±7.6	1.5±0.2	422W
45	483	3.5	1.5±0.1	0.9±0.6	9W
46	464	2.3	2.9±1.8	1.1±0.3	5W
47	433	6.9	2.9±0.3	0.9±0.1	20W
48	764	2.7	1.0	0.5±0.1	---
49	528	5.7	---	1.7±0.7	93M
50	644	2.4	---	0.6±0.2	10M
51*	443	0.9	1.4±0.7	---	206W
52	450	2.2	0.7±0.3	---	72W
53	278	3.0	---	0.9±0.2	105W
54	75	0.3	---	0.5±0.4	30M
55	270	2.1	1.8±0.9	---	66W
56*	588	6.5	3.4±1.2	1.3±0.4	828W
57	394	9.6	---	0.5±0.1	---
58	181	13.4	---	0.3±0.1	12M
59	490	5.1	3.0	2.3±0.7	1M
60	468	2.2	1.1±0.2	0.7±0.4	---
61	480	5.2	4.7	1.4±0.2	1M

* Controls installed later (see Table 2). ** Air measurements taken over two time periods in various locations in the house below grade level and above grade level before controls were installed. Data indicates mean and standard deviation of the measurements. *** M municipal surface water, W well water.

Table 2. Effectiveness of radon control techniques.

House	Control technique*	Monitoring period	Indoor air concentration: Below grade Radon (pCi/l)	Below grade Progeny (mWL)	Above grade Radon (pCi/l)	Percent reduction from no control: Below grade Radon (pCi/l)	Below grade Progeny (mWL)	Above grade Radon (pCi/l)	Comments
05	N	11/23/83-11/28/83	12	30	11	0	0	0	
05	F	11/28/83-12/02/83	12	12	10	0	60	10	
05	VS	12/02/83-12/05/83	11	26	6	10	15	45	VS 50 l/s fan
05	S,VS	12/05/83-12/08/83	5	10	4	60	70	65	VS 50 l/s fan
05	S,VS,VC	12/08/83-12/12/83	3	8	2	75	75	80	VC 115 l/s fan
21	N	08/16/82-12/30/82	50	250**	15	0	0	0	Phase 1 data
21	VD	07/01/83-07/08/83	-	26	-	-	90	-	VD 24 l/s fan
21	VD	07/08/83-07/13/83	-	38	-	-	85	-	VD 24 lf/s fan
21	VD	10/18/83-10/20/83	-	120	-	-	50	-	VD 24 l/s fan
21	VD	10/31/83-11/02/83	10	60	4	80	75	75	VD 165 l/s fan
21	S,VD	11/02/83-11/04/83	2	15	3	95	90	80	VD 165 l/s fan
21	S,VD	11/04/83-11/09/83	6	65	2	90	75	90	VD 50 l/s fan
31	N	12/20/83-12/28/83	12	50	-	0	0	0	
31	VH	01/11/84	5	19	-	60	60	-	VH 70 l/s ht.ex
37	N	11/10/83-11/14/84	40	200	4	0	0	0	
37	S	11/14/83-11/16/83	15	65	-	65	70	-	
37	S,VD	11/16/83-11/21/83	4	5	4	100	100	100	
02	N	09/09/83-11/19/83	9	-	12	0	-	0	VD 50 l/s fan
02	VS	04/02/84-***	***	-	***	***	-	***	
05	N	08/24/83-11/15/83	16	-	9	0	-	0	VS 50 l/s fan
05	S,VS,VC	03/23/84-***	***	-	***	***	-	***	
12	N	09/18/83-11/19/83	18	-	9	0	-	0	VS,VC 50 l/s fa
12	S,VD,VC	03/23/84-***	***	-	***	***	-	***	
16	N	09/05/83-11/09/83	-	-	2	-	-	0	VD 50 l/s fan
16	VA	04/02/84-***	-	-	***	-	-	***	
19	N	08/06/83-11/01/83	20	-	2	0	-	0	Existing ht.ex.
19	VB	03/23/84-***	***	-	***	***	-	***	
21	N	08/16/82-12/30/82	50	-	15	0	-	0	
21	S,VD	04/02/84-***	***	-	***	***	-	***	
26	N	08/24/82-04/08/83	11	-	7	0	-	0	VD 60 l/s fan
26	S,VA	03/23/84-***	***	-	***	***	-	***	
28	N	08/25/82-04/09/83	-	-	6	0	-	0	Pressurization
28	VB	04/03/84-***	***	-	***	***	-	***	
29	N	08/26/82-04/19/83	7	-	8	0	-	0	
29	VH	03/23/84-***	***	-	***	***	-	***	
31	N	10/07/83-11/26/83	17	-	15	0	-	0	
31	VS	04/03/84-***	***	-	***	***	-	***	
37	N	08/17/83-11/16/83	28	-	5	0	-	0	VS two 50 l/s fa
37	S,VD	04/03/84-***	***	-	***	***	-	***	
41	N	09/20/82-04/29/83	5	-	3	0	-	0	VD 50 l/s fan
41	S	03/23/84-***	***	-	***	***	-	***	
51	N	10/01/82-01/18/83	2	-	-	0	-	0	
51	S,VA	04/03/84-***	***	-	-	***	-	***	
56	N	08/22/83-11/22/83	4	-	1	0	-	0	Existing ht. ex.
56	S,VB	04/03/84-***	***	-	***	***	-	***	VB 20 l/s ht. ex

* Bold face type indicates permanent installation. F filtration, N no control technique, S sealants, VA ventilation adjustments to existing system, VB ventilation of basement with heat recovery, VS ventilation of sub-slab without sub-slab drainpipes, VD ventilation of sub-slab with sub-slab drainpipes, VH ventilation of who[le] house with heat recovery. ** Assumes 50% equilibrium. *** Data not available at time of writing.