United States Environmental Protection Agency

Office of Research and Development Washington, DC 20460

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EPA Radon Mitigation Research Update

Introduction

The *Radon Mitigation Research Update* is the fourth in a series of research summaries intended to provide up-to-date information on EPA's Air and Energy Engineering Research Laboratory's (AEERL's) radon mitigation research programs. The *Updates* summarize recently completed and ongoing research activities intended to achieve the Radon Mitigation Branch's (RMB's) research objectives. Research topics included in this *Update* are listed in the table of contents. If you would like more information about specific research activities or programs, you may contact the appropriate RMB project officer at the number listed on this page.

The first two *Updates*, published in December 1990 and March 1991, summarize RMB's radon mitigation research objectives and RMB's strategic research plan for meeting these objectives. The projects described in the November 1991 *Update* reflect the strategic plan's emphasis on innovative and supporting research and on reducing radon in schools and other large buildings. Copies of these *Updates* may be requested by writing to RMB Research Updates, MD-54, U.S. EPA, AEERL, Research Triangle Park, NC 27711. AEERL plans to publish subsequent *Updates* approximately twice a year.

This *Update* has two main sections. The first is Project Highlights, which contains summaries of completed or ongoing research projects. These summaries are intended to provide the radon mitigation industry with timely and useful information in RMB's four research areas: Existing Houses, New House Construction, Schools and Other Large Buildings, and Innovative and Supporting Research (covering research in the other three areas). Some of this information is based on regional or preliminary findings and should be viewed as such. As research programs progress, RMB will publish the final results as technical reports, manuals, and papers. The second section in this *Update* contains a list of RMB publications completed since the previous *Update*, a list of the EPA Regional Offices, and an announcement of the 1992 International Symposium on Radon and Radon Reduction Technology.

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Section 1: Project Highlights

Existing House Research

Field Testing of a New Pre-Mitigation Diagnostic Approach for Subslab Depressurization Systems (SSD)

Recent field tests in six slab-on-grade houses in New Mexico show that a new diagnostic approach, the "radon entry potential" method, can be useful when designing SSD systems. Radon entry potential testing involves depressurizing the ***house*** (rather than just the subslab region) by 0.004 to 0.12 inch (0.01 to 0.30 cm) water column (WC) with a blower door and measuring the total flow rate and radon concentration of the gas flowing into the house through each test hole drilled in the slab. Test holes with the highest ***radon*** flow rate (total flow rate times radon concentration) indicate the slab areas with the highest radon entry potential. SSD suction pipes should be placed in these areas. Mitigators can use these results, together with other diagnostic information (especially pressure field extension measurements), to design effective SSD systems.

The SSD systems in the New Mexico houses, designed using radon entry potential as a diagnostic tool, performed well. The entry potentials at the perimeter of the slabs were about 10 times greater than the potentials at the central portion (perimeters had lower radon concentrations but higher flows), suggesting that suction pipes should be located near the perimeter in the houses. In addition, the soil beneath the slabs was much more resistant to gas flow than the slab itself, so once soil gas moved into the area beneath the slab, it entered the house relatively easily.

The radon levels in two of the New Mexico research houses also turned out to increase significantly while barometric pressure was dropping, overwhelming the SSD system. This effect has been observed in a few other cases, and suggests that more data are needed on radon entry and control mechanisms. The barometric pressure effect may also influence diagnostic measurements and post-mitigation radon monitoring results.

RMB is continuing to analyze data from this project and will soon publish a final report. A paper was presented at the 1991 Symposium; other papers being prepared will provide further detail.

Effects of Natural and Forced Basement Ventilation on Radon Levels in Single Family Dwellings

EPA's 2-year systematic study of three Princeton University research houses clearly demonstrates that radon entry rates depend directly on basement depressurization. The results also clarify the role of natural ventilation in reducing indoor radon concentrations. Natural ventilation is a simple way to reduce indoor radon levels, but, until now, there has been no information on how much reduction to expect. This work demonstrates that natural ventilation decreases radon levels in two ways: (1) by simple dilution; and (2) by providing a pressure break (any opening in the building shell that reduces the outdoor-to-indoor pressure difference). The pressure break reduces both depressurization and radon entry. Results from one of the research houses are shown in Figures 1 and 2. Figure 1 illustrates the dramatic drop in basement radon levels when two basement windows were opened (at point 0). Figure 2 shows the corresponding drop in differential pressure. For additional information, see *Recent RMB Publications* in Section 2.

ASD Exhaust Re-Entrainment Research

The "Radon Contractor Proficiency Program Interim Radon Mitigation Standards" published by EPA's Office of Radiation Programs in December 1991 require the exhaust from active soil depressurization (ASD) systems to meet a "10-foot rule"—to discharge at least 10 feet (3.05 m) above ground level, at least 10 feet away from any opening in the house or an adjacent building, and at least 10 feet from any private or public walkway. The purpose is to ensure that people in or near houses with ASD systems are not exposed to elevated radon levels from the ASD system exhaust. These standards effectively require an exhaust stack inside or outside the house. This increases installation costs by about $100, and owners may object to the appearance of the stack. If stacks were not needed under some conditions, homeowners might be more willing to install ASD systems.

RMB is working with Pennsylvania State University to determine the conditions under which grade-level ASD exhaust may be appropriate. The study will experimentally examine re-entrainment (indoor exposure) and dispersion (outdoor exposure) in relation to exhaust location, configuration, velocity, and wind conditions. The study will also include mathematical modeling to determine whether ASD exhausts increase deposits of radon progeny (including lead-210) on soil surrounding and buildings.

The study is using a "mock" exhaust system (a fan and piping, ***not*** connected to an ASD system) and a tracer gas as a radon substitute. This approach allows RMB to test many different exhaust locations and system configurations without modifying a real ASD system or increasing the amount of radon drawn into a house by re-entrainment. For each test condition, RMB will take gas samples from 12 to 24 sampling points indoors

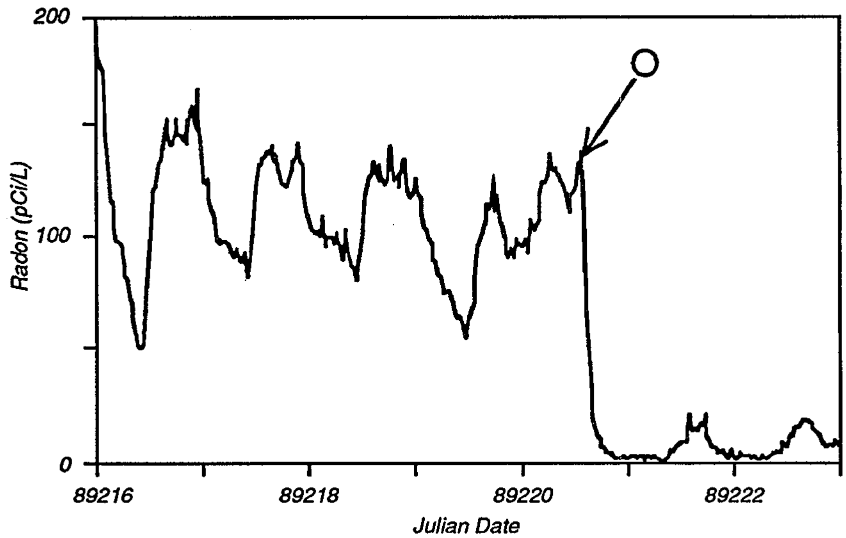

Figure 1. *Effect of opening two basement windows (at point 0) on basement radon levels.*

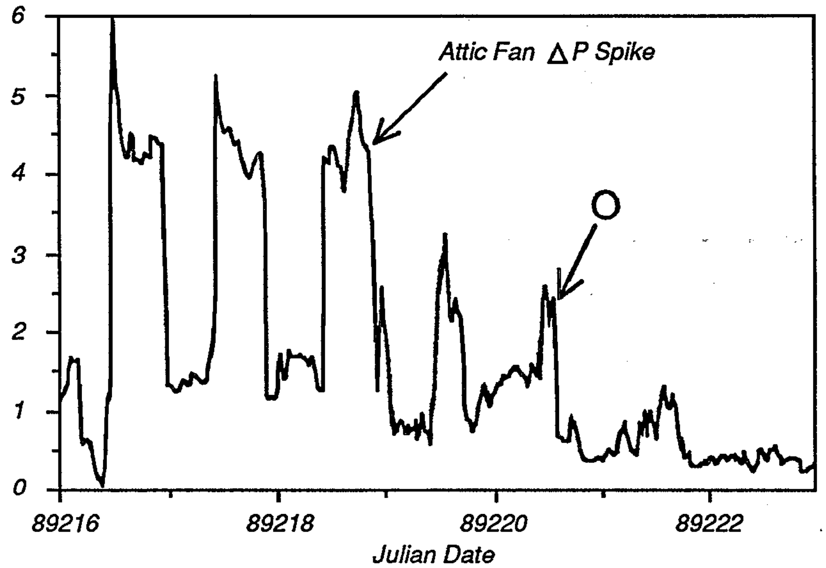

Figure 2. *Effect of opening two basement windows (at point 0) on basement/outdoor differential pressures.*

and around the exhaust point outdoors. The samples will be analyzed for the tracer gas by gas chromatography to measure re-entrainment and dispersion. The observed results will then be checked with mathematical models that consider jet effects.

Durability of Radon Mitigation Systems

To determine how well radon mitigation systems hold up, this study is measuring radon levels in about 300 homes and schools with radon mitigation systems that have been installed for at least 18 months. Three-month (or longer) alpha track detector (ATD) measurements will be compared with pre- and post-mitigation charcoal canister measurements made when the system was installed. If the post-mitigation ATD measurements are consistent with post-mitigation canister measurements, the system presumably is operating properly. In addition, EPA is physically checking some systems to determine how well they are operating and to see if certain components, such as seals or fans, consistently fail. Results will be included in a final report this fall.

Radon Mitigation in Attached Houses

Because attached houses are common in many areas of the country, blocks of attached apartments located in Cortland, New York, are being researched. RMB is investigating techniques that can be used to mitigate attached structures as well as individual residential units. One focus is on building components common to adjoining housing units, such as exhaust stacks, furnace combustion air intakes, and vacuum fields. Pre-mitigation measurements included subslab communication and double blower-door tests of each unit (individually and in conjunction with adjacent apartments).Mitigation systems include ASD and encapsulation of sump pits. A report on the research will be available later this year.

Applied Research on Design of Sub-Membrane Depressurization (SMD) Systems for Crawl Space Houses

This project will expand the database on radon mitigation techniques for crawl-space dwellings. Possible techniques include 1) SMD, 2) depressurizing the entire crawl space, and 3) ventilating the crawl space. SMD has a lower energy penalty and is typically more effective than the other techniques, but it also costs more to install. This study should answer several questions pertaining to SMD:

- How much membrane sealing is required? What is the effect of sealing on radon levels?
- How should suction be distributed beneath the membrane?
- What portion of the crawl-space floor needs to be covered?
- When should crawl-space depressurization rather than SMD be used?

Much of this testing will be conducted using an existing crawl-space test house.

New House Construction Research

A Simple Procedure to Select Low Air Permeability Concrete Blocks

Air entering a building through concrete blocks can contain radon, moisture, biological agents, and other contaminants that threaten the health and comfort of the occupants and the structure itself. Tests show that the permeabilities between different types of concrete blocks can vary by a factor of 50. The following procedure may help determine the permeability differences between the types of blocks available in an area, permitting a more informed choice of concrete blocks. A general conclusion is that smooth-surfaced blocks may be less permeable than blocks with a rough-looking surface: in short, "if it ***looks*** leaky, it probably ***is*** leaky."

Materials

- aquarium pump ("Whisper" 400 or equivalent)
- concrete blocks to be tested, plus a spare
- 9 feet (2.7 m) of clear aquarium tubing plus 6 inches (15 cm) for each test block, to fit pump
- one tee and one nipple to fit tubing
- one tube of silicone caulk (G. E. "Silicone Clear Household Glue and Seal" or equivalent)
- spatula, 1-1/2 inches (4 cm) wide
- "circular form" (3/8-inch, 1 cm, cross section cut from bottom of spent caulk cartridge)
- clear tape
- sheet of graph paper (10 x 10 grid preferred)
- for each block to be tested, half a cartridge of caulk (Red Devil "Lifetime" or equivalent)
- for each block to be tested, two 3-inch (7.6 cm) plastic funnels

Procedure (see Figure 3)

1. Label each type of block sample and lay it on its side, 1 inch (3 cm) or more apart.
2. Select two identical 3-inch (7.6 cm) plastic funnels. Carefully trim away any tabs. Center one funnel directly on the surface above one core (void) in first test block.
3. Hold funnel down firmly and apply a generous (3/8-inch, 1 cm) bead of cartridge caulk around rim of funnel, touching both funnel and block. Apply two more beads of caulk to the block against first bead. Continuing to hold funnel

firmly, use spatula to spread caulk away from funnel along surface of block to edges, evenly caulking half the block. Repeat using second funnel on other half of block. Repeat entire process with remaining test blocks and funnels.

4. While caulk sets, assemble aquarium pump and tubing. Cut 2 feet (0.6 m) of tubing; connect one end to pump and other end to tee arm. Cut 2-1/2 feet (0.8 m) of tubing and connect one end to tee leg. Shape this tubing into a "U" with the open-ended leg slightly shorter to allow for filling with water in Step 9. To prevent kinking, place the "circular form" inside the bottom of the U tubing. Tape the tubing together just above the circular form and near the tee so the arrangement lies flat. Position the tee and U tubing on the face of the spare block and use silicone caulk to hold the tee, circular form, and tubing to the block. Leave the center 6 inches (15 cm) of tubing free of caulk or tape but flat against block.
5. While U tubing caulk sets, cut a 3-inch (8 cm) length of tubing for each funnel plus one extra. Apply a generous bead of silicone caulk 1/2-inch (1 cm) from one end of a piece of 3-inch tubing and insert into tip of a funnel so about 2 inches (5 cm) of tubing extends from tip. Be sure to use enough caulk to completely seal tubing to tip of funnel, spreading excess caulk over top edge of funnel tip and along tubing to ensure a complete seal. Repeat with remaining tubing and funnels.
6. Connect one end of the remaining length of tubing (about 4 feet, 1.2 m, long) to the tee and insert the nipple into the free end.
7. Seal all connections at the tee, the pump, and the nipple with silicone caulk.
8. Allow time for all silicone caulk to cure (at least 4 hours; preferably overnight).
9. Lift the block with the attached U tubing to a vertical position and fill the U tubing half full with water (coloring improves visibility). Mark the center horizontal line (reference line) on a piece of graph paper about 4 inches (10 cm) square and slide it between the center of the U tubing and block.
10. Place the reserved 3-inch length of tubing on the nipple.
11. Turn on pump. Slide the graph paper "reference line" to the water level in the side of the U tubing that is open at the top.
12. Remove 3-inch tubing from nipple (do not pinch tubing closed; this may blow water out of U tube) and insert nipple into the first block funnel tubing. Wait 30 seconds. Read amount of change in water level in open side of U tubing. Remove nipple from funnel and replace 3-inch tubing. Check that water level returns to reference line. If not, repeat this step. Record reading. Repeat with second funnel on first block.
13. Continue until all blocks are tested and readings are recorded.
14. Review results, and select the block with the highest U tubing readings. Higher readings indicate better resistance to air infiltration (low air permeability). Generally, blocks with the smoothest surface texture have the best resistance.
15. If all results are "low," less than 0.1 to 0.2 inch (0.2 to 0.5 cm), then you may want to consider other sources of concrete block, another material, or coating the surface of the constructed block wall with a cementaceous block filler/coating, or other durable coating that fills the pores of the block.

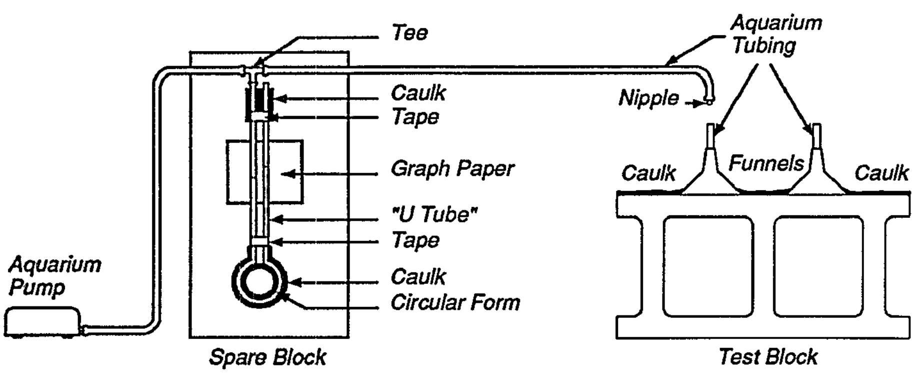

Figure 3. *Concrete block permeability test assembly.*

Feasibility Study of Basement Pressurization Using a Forced-Air Furnace

In a previous project, RMB demonstrated that a typical forced-air furnace system could be installed to pressurize a basement to reduce radon entry. This research project, in the same Pennsylvania house, will determine the most effective configuration for this type of furnace installation. EPA is collecting continuous data on indoor conditions (temperature, humidity, radon levels, pressure relationships, and equipment operation) and outdoor conditions (temperature, humidity, radon levels, wind speed and direction, and barometric pressure) for each operating mode of the furnace system. The system reduced radon levels from 19.3 to 1.5 pCi/L in summer (cooling) conditions, and data are now being collected under winter (heating) conditions. A report should be available in the fall of 1992.

Application of Small Fans for Active Soil Depressurization in New Construction

EPA's proposed model standards for controlling radon in new buildings include placing a layer of aggregate and barrier under the slab. By meeting these standards and sealing the slab, it may be possible to use smaller ASD fans than those now used for ASD systems in existing houses. Smaller fans cost less to install and operate, require less space, and may be quieter. In addition, it might be possible to power them with a simple photovoltaic system. This project involves an initial survey of at least 20 new slab-on-grade or basement houses that meet the requirements of the proposed model standards. At each house, RMB will measure radon levels under three ASD operating conditions, conduct blower door and tracer gas tests, and obtain data on subslab aggregate size and depth, soil permeability, and foundation size and shape. RMB will use these data, together with information on weather patterns, to predict the fan size required and ASD performance characteristics. Based on these results, RMB will select about six houses to study how well small ASD fans actually perform.

Schools and Other Large Buildings Research

Estimated Costs of Radon Diagnostics and Mitigation in Schools

To date, school facility managers with responsibility for radon mitigation have had little information on the costs of radon diagnostics and mitigation in school buildings. The most common approaches to radon mitigation in schools are ASD and heating, ventilating, and air conditioning (HVAC) system control. The costs of HVAC control are very school-specific, depending on the design capabilities of the existing HVAC system in the building. To provide guidelines that school officials can use to estimate the cost of reducing radon levels with ASD systems, seven radon mitigators with extensive experience in schools were surveyed. The mitigators were asked to provide cost data for two scenarios of "typical" school buildings with elevated radon levels. The mitigators provided cost and labor-hour estimates for five work elements associated with conducting radon diagnostics and mitigation in these two typical schools:

- reviewing construction plans;
- conducting diagnostic measurements;
- designing an ASD system;
- purchasing ASD materials; and
- installing and checking out the ASD system.

Based on the results of the survey, it is estimated that radon diagnostics and mitigation in a typical school would cost roughly $0.50 per square foot ($0.05 per square m). It is estimated that about 20 percent of this cost is for diagnostics and 80 percent for materials and installation. The cost would be higher in schools with extensive subslab walls, very poor pressure field extension (PFE), and building code and/or asbestos complications. Costs would be lower in simple schools with very good PFE and no subslab barriers to communication. For additional information, see *Recent RMB Publications—Papers* in Section 2.

Effect of Suction Pit Volume on Pressure Field Extension

Research in a Kentucky school has helped to quantify the effect of suction pit size on subslab depressurization. Figure 4 shows the average subslab differential pressure in the school with no suction pit and with three pits with increasing size. Subslab differential pressure measurements under these four conditions were grouped into four distance ranges from the suction point: less than 100 feet (30.5 m), 100 to 149 feet (45.4 m), 150 to 200 feet (45.7 to 61.0 m), and over 200 feet. For all four ranges, the negative pressure under the slab increased with increased suction pit volume. Based on the results of this experiment and on other research, EPA recommends that a suction pit 3 feet (0.9 m) in diameter and 1 foot (0.3 m) deep be used for maximum PFE in schools. PFE measurements in the school showed that one ASD point depressurized the entire 50,000-square-foot (4645-square-m) slab, the greatest PFE coverage yet measured by RMB in an existing building. The construction characteristics of this school were "ideal" for installation of an ASD system: post and beam construction, no internal barriers to subslab communication, and 4 inches (10 cm) of coarse aggregate under the slab.

HVAC Systems in Schools

A report describing the various types of HVAC systems found in schools across the country describes how each system type operates, how the systems are controlled, and how system operation should affect building pressures, ventilation, and

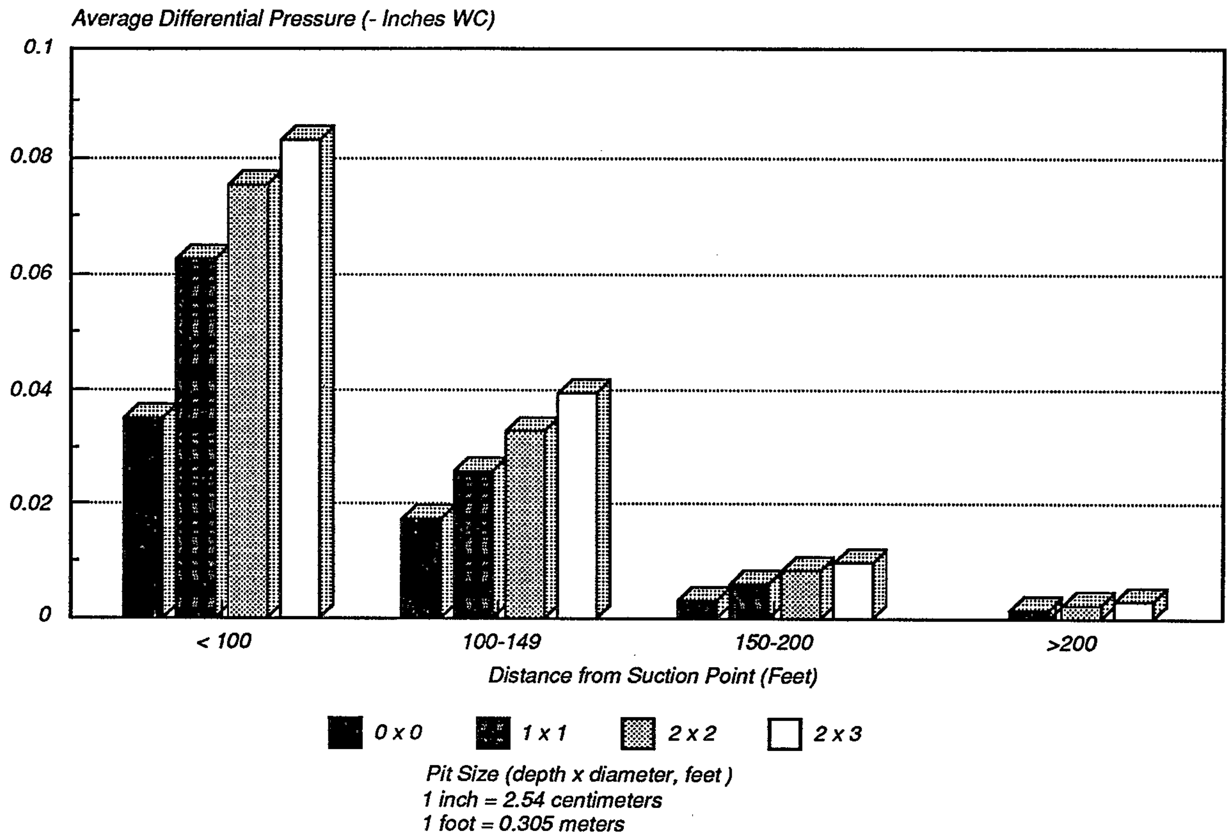

Figure 4. Effect of suction pit size on PFE .

radon concentrations. The report entitled "A Study of HVAC Systems in the Current Stock of U. S. K-12 Schools" is scheduled for publication later this year.

School Program Peer Review

A review of RMB's School Research Program took place in May in Research Triangle Park, North Carolina. The purpose of the review was to present school research results to a panel of four experts and obtain feedback for future research. Research topics covered included: ASD control, HVAC system control, comparison of ASD and HVAC control, radon reduction in crawl space schools, and radon prevention in the construction of schools and other large buildings.

Innovative and Supporting Research

A Simple Model for Describing Radon Migration and Entry Into Houses

The relative importance of physical mechanisms such as diffusion, dilution, and radon decay may be helpful when designing radon mitigation systems. This model uses simplified assumptions about the distribution of radon entry routes and driving forces to relate indoor radon levels to soil characteristics. Under these assumptions the model shows that:

- soil permeability is the most important influence on indoor radon concentrations because soil permeability varies naturally by five to six orders of magnitude;
- the area of the radon entry route is not very important;
- 90 percent of the total soil gas flow occurs in a band surrounding the house with a width six times the depth of the basement; and
- because radon decays, only the volume of soil within a band of width about two times the basement depth actually contributes to indoor levels (this volume may be much smaller at low permeabilities).

The simplified model provides realistic predictions of indoor radon concentrations for permeabilities higher than 10^{-11} square meters. RMB plans to extend the model to cover transport by both advective flow and diffusion. For additional information on this model see *Recent RMB Publications* in Section 2.

Modeling the Influence of Active Subslab Depressurization (ASD) Systems on Airflows in Subslab Aggregate Beds

When the total soil gas flow rate and the average size, thickness, porosity, and permeability of a subslab gravel bed are known, this model predicts the pressure in the aggregate bed as a function of distance from a suction point. Mitigators can use the model to design an ASD mitigation system when pressure field extension (PFE) measurements are not available. Builders should find the model helpful when designing a mitigation system based on a specified gravel bed, as well as selecting the type of fan needed to provide a required flow rate. The model is based on calculating the distances at which the soil gas flow changes from Darcian (lower velocities near the perimeter), through a "transition zone," to turbulent (higher velocities) near the center of the bed. So far, results from the model compare well with PFE measurements in three basement houses and especially well with measurements made in larger buildings. For additional information on this model, see *Recent RMB Publications* in Section 2.

Evaluation of Radon Movement Through Soil and Foundation Substructures

To design and install improved mitigation systems, EPA, mitigators, and builders need detailed information on how radon moves through soil and enters buildings. RMB is currently conducting pilot studies on radon movement using a large steel chamber. This study will also help complement the modeling work described above. The chamber contains 21 cubic yards (16 cubic m) of elevated-radium soil with known permeability, moisture retention, density, and particle distribution characteristics. The soil is placed in the chamber to match typical moisture and density conditions as closely as possible. A central perforated pipe under vacuum simulates a driving force, and probes collect radon grab samples at varying depths and distances from the suction point. When the first series of experiments are completed later this year, part of a foundation wall and a floor slab will be installed in the chamber to measure convective and diffusive radon entry characteristics. Final results will be included in a future *Update.*

National Concrete Survey and Assessment

This two-phase project is developing a database on the radon transmission characteristics of typical concrete used in building slabs across the country. EPA will use the results to support the development of American Society for Testing and Materials (ASTM) protocols for testing concrete for permeability and diffusivity. The nationwide survey will collect and analyze 40 to 50 samples from different climatic and construction regions to determine how widely they vary in permeability and diffusivity. Results will be included in a future *Update.*

Effects of Leakage Distribution and Neutral Pressure Level (NPL) on Indoor Radon Concentrations

RMB is investigating the effect of leaks in building envelopes (such as around windows and through electrical outlets) on differential pressures across the slab. The effects of leakage distribution on the NPL will be tested under a variety of stack effect conditions. Results of this study will help determine the best places to seal the superstructure of a house to reduce the driving forces for radon entry. Studies are now underway in a test house constructed on radium-rich soils in Bartow, Florida. RMB is collecting radon data and measuring the pressure differentials at floor level, across the slab, and at various heights under both heating and cooling conditions. The results will be analyzed by Lawrence Berkeley Laboratory and will help to validate newly developed air infiltration models. A report should be available in the fall of 1992.

Section 2: Additional Information

Recent RMB Publications

This section lists RMB reports, manuals, papers, journal publications, and symposium proceedings published since the last *Update.* All publications with NTIS numbers are available (prepaid) from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161 [(703) 487-4650]. If you would like more information on these publications or explanations concerning information contained in them, you may contact your EPA Regional Office (addresses and phone numbers are given after the publications) or the appropriate RMB project officer.

EPA Reports:

Recommended Foundation Fill Materials Construction Standard of the Florida Radon Research Program. D. Sanchez (project officer), EPA-600/8-91-206 (NTIS PB92-105865), October 1991.

Recommended Sub-slab Depressurization Systems Design Standards of the Florida Radon Research Program. D. Sanchez (project officer), EPA-600/8-91-208 (NTIS PB92-105626), October 1991.

Development of Alternate Performance Standard for Radon Resistant Construction Based on Short-Term/Long-Term Indoor Radon Concentrations. Volume 1: Technical Report. D. Sanchez (project officer), EPA-600/8-91-210a (NTIS PB92-115211), October 1991.

Development of Alternate Performance Standard for Radon Resistant Construction Based on Short-Term/Long-Term Indoor Radon Concentrations. Volume 2: Appendices. D. Sanchez (project officer), EPA-600/8-91-210b (NTIS PB92-115229), October 1991.

Standard Measurement Protocols: Florida Radon Research Program. D. Sanchez (project officer), EPA-600/8-91-212 (NTIS PB92-115294), November 1991.

Proceedings of the Workshop on Radon Potential Mapping: Florida Radon Research Program. D. Sanchez (project officer), EPA-600/9-91-044 (NTIS PB92-115278), November 1991.

Natural Basement Ventilation as a Radon Mitigation Technique. R. Mosley (project officer), EPA-600/R-92-059 (NTIS PB92-166958), April 1992.

Manuals:

Durability of Performance of a Home Radon Reduction System - Sub-slab Depressurization Systems, Assessment Protocols. D. Sanchez (project officer), EPA-625/6-91-032, April 1991.

Handbook: Sub-slab Depressurization for Low-permeability Fill Material—Design and Installation of a Home Radon Reduction System. D. Sanchez (project officer), EPA-625/6-91-029, July 1991.

The following two manuals are currently being prepared:

- Radon Prevention in the Design and Construction of Schools and Other Large Buildings. This manual will provide designers, builders, and school officials with information on how radon prevention techniques work and how to incorporate them during the design and construction stage at lower costs than retrofit systems. Expected publication is summer 1992.
- Radon Reduction Techniques for Existing Houses. The existing version of this manual, the second edition, is EPA-625/5-87-019 (NTIS PB88-184908). Expected publication of the third edition is fall 1992.

Papers:

Modeling the Influence of Active Subslab Depressurization (ASD) Systems on Airflows in Subslab Aggregate Beds, EPA-600/D-91-226 (NTIS PB91-242925). Mosley, R. B. Presented at the 5th International Symposium on the Natural Radiation Environment, Salzburg, Austria, September 1991.

The U.S. EPA Office of Research and Development Overview of Current Radon Research, EPA-600/D-91-259 (NTIS PB92-121250). Dyess, T. M., and M. C. Osborne. Presented at the 1991 Annual AARST National Fall Conference, Rockville, MD, October 1991.

Update on Radon Mitigation Research in Schools, EPA-600/D-91-229 (NTIS PB91-242958), Leovic, K. W., A. B. Craig, and D. B. Harris. Presented at the 1991 Annual AARST National Fall Conference, Rockville, MD, October 1991.

The Florida Radon Research Program: Technical Support for the Development of Radon Resistant Construction Standards, EPA-600/D-91-235 (NTIS PB92-108109) Sanchez, D.C., R. Dixon, and M. Madani. Presented at the 1991 Annual AARST National Fall Conference, Rockville, MD, October 1991.

A Simple Model for Describing Radon Mitigation and Entry into Houses, EPA-600/D-91-021 (NTIS PB91-176743). Mosley, R. B. Presented at the 29th Hanford Symposium on Health and the Environment, Richland, WA, October 1990.

Costs of Radon Diagnostics and Mitigation in School Buildings. Leovic, K. W., H. Rector, and N. Nagda. Presented at the 85th Annual AWMA Conference, Kansas City, MO, June 1992.

Journal Publications:

Cost Analysis of Soil Depressurization Techniques for Indoor Radon Reduction. EPA-600/J-91-320 (NTIS PB92-120443), *Indoor Air*, Vol. 1, No. 3, pp. 337-351, 1991. Henschel, D.B.

Radon Prevention in the Design and Construction of Schools and Other Large Buildings. *Architecture/Research*, Vol. 1, No. 1, pp. 32-33, October 1991, Leovic, K. W., A. B. Craig, and D. B. Harris.

Case Study of Radon Diagnostics and Mitigation in a New York State School. *Indoor Air*, Vol. 1, No. 4, 1991, pp. 531-538, Leovic, K. W., D. B. Harris, M. Clarkin, and T. Brennan.

Symposium Publications:

Proceedings: The 1991 International Symposium on Radon and Radon Reduction Technology. Volume 1. Symposium Oral Papers (Opening Session and Technical Sessions I-V). T. Dyess (project officer), EPA-600/9-91-037a (NTIS PB92-115351), November 1991.

Proceedings: The 1991 International Symposium on Radon and Radon Reduction Technology. Volume 2. Symposium Oral Papers (Technical Sessions VI-X). T. Dyess (project officer), EPA-600/9-91-037b (NTIS PB92-115369), November 1991.

Proceedings: The 1991 International Symposium on Radon and Radon Reduction Technology. Volume 3. Symposium Panel and Poster Papers (Technical Sessions I-V). T. Dyess (project officer), EPA-600/9-91-037c (NTIS PB92-115377), November 1991.

Proceedings: The 1991 International Symposium on Radon and Radon Reduction Technology. Volume 4. Symposium Poster Papers (Technical Sessions VI-X). T. Dyess (project officer), EPA-600/9-91-037d (NTIS PB92-115385), November 1991.

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1992 International Symposium

The 1992 International Symposium on Radon and Radon Reduction Technology will be held September 22-25, 1992, at the Sheraton Park Place Hotel in Minneapolis, Minnesota [(800) 542-5566]. The purpose of this Symposium is to provide a forum for exchanging technical information on radon and radon reduction technology in the indoor environment. The major topics to be covered at the Symposium are: experience in applying radon reduction and radon-resistant construction techniques, measuring radon and radon progeny, and assessing radon-derived health impacts. For information on the Symposium, contact Tim Dyess at (919) 541-2802.

1992 Radon Symposium Information Card

Yes, I am interested in attending the 1992 International Symposium on Radon and Radon Reduction Technology to be held September 22-25, 1992, in Minneapolis, Minnesota. Please send me a registration form.

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