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EPA **Project Summary**

Radon Diagnostic Measurement Guidance for Large Buildings

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The purpose of this study was to develop radon diagnostic procedures and mitigation strategies applicable to a variety of large non-residential buildings commonly found in Florida. The investigations document and evaluate the nature of radon occurrence and entry mechanisms for radon, the effects of heating, ventilation, and air-conditioning (HVAC) system configuration and operation on radon entry and dilution, and the significance of occupancy patterns, building height, and other building construction features. A primary focus of this project was the effect of the HVAC systems of a large building on the transport, entry, and hopefully the minimization of indoor radon in the building. Two buildings were investigated, both of which showed an inverse relationship between dedicated ventilation air and indoor radon concentrations, as was expected. Both also showed signs of unusual HVAC design, operation, and maintenance that presumably adversely affected indoor radon and other indoor air quality (IAQ) variables. The second building showed clear indications of foundation design elements that contributed to radon entry. Some recommendations relevant to building standards can be concluded from this project. First, design and construction should concentrate on elimination of major soil gas pathways such as hollow walls and unsealed utility penetrations. Second, HVAC system design should include strategies designed to minimize depressurized zones adjacent to the soil. Third, while increased supply ventilation is generally helpful for radon control, it is clearly not the most cost-effective solution or prevention tool once the requirements of occupant comfort and general IAQ have been met.

This Project Summary was developed by EPA's National Risk Management Research Laboratory's Air Pollution Prevention and Control Division, 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

This report describes the results of a project conducted by Southern Research Institute and other organizations for the U.S. Environmental Protection Agency on behalf of the Florida Department of Community Affairs. The purpose of this study is to develop radon diagnostic procedures and mitigation strategies applicable to a variety of large non-residential buildings commonly found in Florida. To accomplish this, it was necessary to perform detailed field investigations and parametric studies in a variety of buildings that have elevated levels of radon. The investigations document and evaluate the nature of radon occurrence and entry mechanisms for radon, the effects of HVAC configuration and operation on radon entry and dilution, and the significance of occupancy patterns, building height, and other building construction features.

A primary focus of this project was the effect of the HVAC systems of a large building on the transport, entry, and hopefully the minimization of indoor radon in the building. The full report discusses HVAC systems and their effects and describes case studies in two large buildings in Florida. Conclusions and recommendations address elements of significance to proposed statewide standards for radon resistance in new large building construction.

Case Study 1: Financial Center North

The first large building selected for a radon case study is the Financial Center North (FCN) building in Deerfield Beach, Florida. This is a privately owned building that is being leased to the General Services Administration (GSA) for purposes of housing FCN of the Internal Revenue Service (IRS). Crown Diversified Industries Corporation (CDIC) owns the building. The building is a combination office and warehouse/maintenance facility. It is constructed in two wings in the shape of an L. Each wing has three floors: each floor in the north wing is about 5600 ft^2* (112 x 50 ft), and each east wing floor is about 6200 ft^2 (124 x 50 ft). The warehouse/maintenance portion of the facility is in the crook of the L. It is predominantly a two-story high-bay space. This area of the building is used primarily by a maintenance staff that services an adjacent apartment complex also owned by CDIC. The maintenance/warehouse area is about 10,450 ft^2 (110 x 95 ft). The entire building is about 46,000 ft^2 and can accommodate about 125 occupants.

The HVAC systems are of theUnitary type and rely on 22 separate direct expansion split systems for primary cooling to the office spaces. All of the condensers are frame mounted and located on the roof. The system evaporators are located in ceiling-hung air handlers (AHs) units in/or near the comfort zone being served. In addition to housing the evaporator, all of the AHs contain electric reheat coils that provide space heating. The AHs are also provided with a system of distribution ductwork consisting of supply, return, and outdoor air (OA) connections. Cooling and heating of the occupied space is controlled by wall mounted thermostats. Each AH has its own individual thermostat. The heating and cooling capacities of each split system range in size from 2.91 tons cooling/7.2 kW heating to 9.16 tons cooling/15 kW heating.

Air is exhausted from the building primarily by three roof-mounted power roof ventilators (PRVs), as well as toilet exhaust fans. The original HVAC design called for the OA to be provided through two outdoor air risers (OARs) that, through a system of ductwork, were connected to the suction side of each AH. None of the OARs were originally powered by a fan. The introduction of OA was reliant on the ability of the AH fan to inject OA from the roof level down the OAR and into the intake of the AH. The original design specified that a total of 4500 cfm of OA be introduced to the building. This quantity of OA represents 10% of the total building supply air.

The FCN Building has initially exhibited radon levels of approximately 10 picocuries per liter (pCi/L), during GSA screening measurements, which are above the EPA action level guideline of 4 pCi/L. In early 1992, Radon Environmental Testing Corporation was requested to provide radon measurement and mitigation service to the building management. Passive sealing of slab cracks and penetrations was provided as well as increasing the level of OA by installing supply fans. This reduced radon levels down below the 4 pCi/L guideline and generally subjectively improved IAQ.

New OA fans raised the level of OA from 21 to about 66% of design. Using ASHRAE Standard 62-1989, this new quantity of OA would support 200 occupants (3000 cfm at 15 cfm per occupant). Past reports indicate not more than 102 occupants in the building at any time (17 occupants per floor x 6 floors). At the time of our study, the building was being operated in this mode.

Experimental Plan: Outdoor Air Variations

For this part of the study, it was agreed that the primary feature of the HVAC systems in mitigating radon is pressurization of the building.

It was decided to operate the HVAC systems in four different modes of building pressurization while collecting data. These modes of operation were determined by our ability to vary and control the amount of OA allowed to be introduced into the building while maintaining supply and exhaust at known quantities. The four modes consisted of operation of the system(s) to provide 0, 5, 10, 15, and 20 cfm/occupant from the OA supply fans. No changes in the supply or exhaust air quantities were made. These predetermined modes of operation describe situations from complete system shutdown of OA quantities to those recommended in ASHRAE Standard 62-1989. Mode 1, no OA, would be considered the worst case scenario. Under this mode of operation, the building is under complete negative pressure and all OA enters by infiltration. As OA supplied to the AHs increases, infiltration decreases, resulting in no change in supply or exhaust quantities, although increasing OA causes increased pressurization throughout the building. Mode 2 would simulate the OA requirements illustrated in the Florida Administrative Code (FAC) chapter 6A-2 that controls the amount of OA to 5 cfm/occupant. Modes 3 and 4 would be variations on the ASHRAE Standard 62-1989, using 15 and 20 cfm/occupant.

For Mode 1, the OA intakes were closed with polyethylene to ensure a complete nonporous seal. Mode 1 was accomplished over a weekend (July 3-6, 1992) since the building owner would not permit the HVAC systems to be operated without OA during normal working hours. For Mode 2 (July 6-15), the HVAC systems were balanced so that the measured OA intake was actually 5.5 cfm/occupant. Mode 3 (June 16 - July 3) was measured at 13.6 cfm/occupant. Mode 4 (July 15-27) was 19.5 cfm/occupant.

Data were collected from the data stations by downloading data files through the internal modem by telephone connection. The information was converted into usable numbers, calibrated, and put into graphs and tables. Data files were analyzed and compared with other information, such as maintenance practices. The FCN data are limited in scope due to instrumentation difficulties that were corrected for the second case study. FCN results are limited to radon concentrations and some perfluorocarbon tracer (PFT) gas measurements.

By intentionally reducing the OA intake, an increase in radon concentrations was exhibited to a peak level above 4 pCi/L throughout the building. Distinct average levels of radon can be identified from the data for a consistent level of OA intake. A comparison of radon levels versus OA intake flowrate is evident in the averaged continuous radon monitor data. The building average concentration at 0 cfm (per occupant) was 2.6 pCi/L as compared to 1.8 pCi/L at 5.5 cfm, 1.2 pCi/L at 13.6 cfm, and 1.0 pCi/L at 19 cfm. A reduction correlated with increased OA is clearly present; however, due to imprecision in measurement and expected fluctuations in radon concentrations, it is not possible to form quantitative conclusions.

Case Study 2: Polk County Life and Learning Center

The second case study in this project was conducted at the Polk County Life and Learning Center (LLC). While some

* For readers more familiar with metric units: 1 ft^2 = 929 cm^2, 1 ft = 0.305 m, 1 ton = 907 kg (or 0.907 metric ton), 1°F = 9/5°C + 32, 1 in. = 2.54 cm, 1 in. WG = 249 Pa, 1 cfm = 0.0283 m^3/min, and 1 pCi/L = 37 Bq/m^3.

of the same measurement techniques were used at this building as for the previous study at the FCN, the experimental and analytical sequences were much more detailed. The LLC consists of three buildings: The Center for the Trainable Mentally Handicapped, the Severely Handicapped Center (two classroom addition), and the Greenhouse. The Center for the Trainable Mentally Handicapped and the Greenhouse were designed in 1974 and built in 1975. The Severely Handicapped Center was designed in 1984 and constructed in 1985. This study focuses entirely on the LLC for the Trainable Mentally Handicapped. The LLC building is a single-story training/school building of about 18,000 ft^2. It consists of staff office space, classrooms, a large multipurpose room, a kitchen area, janitorial closets, and a woodshop. The facility houses 103 students daily along with 22 staff members for a total of 125 occupants. Architecturally, the building is constructed as a slab-on-grade. The slab is 4 in. reinforced concrete on compressed fill and provided with a vapor barrier. The vapor barrier is assumed to be polyethylene (the drawings are not specific). The walls of the Center are 8 in. CMUs (concrete masonry units; i.e., blocks) with stucco exterior and 5/8-in. gypsum boards on 1 x 2 in. furring strips on the interior. The roof system consists of wood truss construction with asphalt shingle roof tiles over most of the roof. However, in some areas the roofing consists of rolled mineral roofing material. The interior ceilings are either lay-in tile or painted gypsum board. All windows are either aluminum frame single hung or bay windows. The interior walls are gypsum board on wood studs with interior ceiling heights of typically 9 ft except for the central area used as a cafeteria/auditorium. The LLC is divided into four fire control zones by means of rated 5/8-in. gypsum board that extends to the tectum decking below the roof. However, many openings between zones (some as large as 2 x 4 ft) tend to merge the separate zones into one or two larger zones. Fire walls divide the building into four zones (although the zones appear to be well coupled).

The LLC is heated and cooled by an ALL-AIR system composed of a single main AH. The AH provides cooling to the LLC by means of a 21 ton (252 x 10^6 Btu/hr) direct expansion split system and a distribution system of supply ductwork. The system is low pressure (2.5 in. WG) and uses a single supply duct and a ceiling plenum return air system. The individual rooms and zones are environmentally controlled by variable-air-volume (VAV) boxes mounted above the ceiling in the return plenum. Wall-mounted thermostats control the VAV boxes. The introduction of OA is controlled by a roof-mounted supply fan. This fan initially could provide up to 1200 cfm of unconditioned OA directly to the AH return air plenum. The OA then mixes with the building return air. The AH has the capacity to supply 5620 cfm at conditions of 57°F dry bulb/56°F wet bulb which gives the machine a rating of approximately 21 tons. This is approximately 1.2 tons per 1000 ft^2 which constitutes a greatly oversized capacity. Based on the Florida Administrative Code, Chapter 6A-2 requirements of 5 cfm/occupant, the LLC could house 240 occupants. The actual occupancy of 120 people increases the OA to 10 cfm/occupant (1200 cfm/120 occupants). Heat for the LLC building (via AH) is provided by a 15-kW strip heater. In addition, each VAV box that serves a space that is adjacent to an exterior wall is provided with an additional strip heater. VAV box strip heaters are controlled by room-wall-mounted thermostats. The building is served by 26 VAV boxes that are sized for a full air-conditioning load of 11,305 cfm. The boxes are set for a minimum setting of 40% of full load. The diversity factor (100 times the ratio of the sum of the individual VAV box capacities divided by the AH capacity; i.e., 100 x [5620/11,305]) is calculated to be approximately 50% for the VAV box operation. Exhaust air from the LLC is through 14 exhaust fans located in the toilets, bathrooms, janitor closets, workshop, and kitchen. The total design building exhaust from these 14 fans is 2350 cfm when all are operating.

Initial radon measurements were made at the LLC by the Polk County Health Unit during the 1990-91 and 1991-92 school years. The radon levels averaged 10.4 pCi/L and were fairly independent of the seasons.

Based upon inspection of the design plans for the building, it was easy to see that this building may have been operated in an undesirable HVAC negative pressure mode. Since the maximum OA quantity was 1200 cfm and the exhaust quantity is 2350 cfm, the building may have been operated negative by about 1150 cfm or less. To compound this imbalance, the OA fan was set to shut off when the return air temperature was below 70°F or above 80°F. The fan controls would only allow the OA fan to operate when the return air temperature was in the range of 70-80°F. Further, the OA fan was installed backwards on the motor shaft, and the motorized damper for the OA fan was frozen in the closed position. Other deficiencies identified include: leakage from the supply air on both sides of the VAV boxes, and in the main supply duct feeding all the VAV boxes, several VAV control mechanisms inoperative, and four exhaust fans inoperative. A list of the building deficiencies was sent to school officials on about November 10, 1992. It was agreed that the Polk County School System would fund all "punch list" items and the EPA would fund the test and balance (TAB) fee and fan replacement.

The LLC was instrumented with five of the EPA Data logging systems on October 27-29, 1992. School maintenance personnel implemented a repair procedure at the LLC to correct the deficiencies detected in the building during the walk-through on November 5, 1992, and as described in the building pre-balance survey carried out by the TAB company. These repairs were completed during the latter part of January 1993. During December, the Phoenix Agency, Inc. (PAI) replaced the OA supply fan and damper. The as-found condition of the building was such that little or no OA was being supplied to the building. The only ventilation was through openings in the building shell. This was evident from the odors that persisted in several rooms; in particular, in Room 105. The new OA fan can supply 3000 cfm of OA.

1993 Parametric Study

Testing at the LLC was carried out using the following conditions. OA flowrates of 0,750, 1500, 2250, and 3000 cfm (0, 5, 10, 15, and 20 cfm/person) were used. Generally, each OA flowrate condition occupied a week of testing. The exhaust fan-on condition was maintained over 1-1/2 days of the weekend, and the exhaust fan-off condition was maintained at night and the remainder of the weekend. Typically, the HVAC fan operated on a 12 hour on/12 hour off cycle each day.

The radon levels in the LLC building were significantly reduced from the levels first measured in December 1992. Averaged radon levels were measured in Rooms 102, 109, the Cafeteria, the Audiology room, and the Conference room with the Femto-Tech continuous monitors attached to the EPA data loggers. Several aspects of the data are apparent. First, the levels measured during December 1992 and January 1993 were much higher than those measured by the Polk County Health Unit. The reasons for this large difference are not known. Second, the overall levels show a steady decrease as shown by the 5-day moving (un-weighted) average line. This is due primarily to the replacement of the OA fan and damper, and to the consistent operation of this fan. Also, the new OA fan greatly reduced the level of offensive odors noticed in Room 105 in October 1992. The second interesting aspect of the data is the fine structure or daily variations in the radon levels. These are caused primarily by the daily cycling of the HVAC system from daytime use to nighttime setback. Several aspects of the radon time series data were readily apparent:

1. The radon levels generally increase overnight until the HVAC system comes on.
2. Once the HVAC system turns on, the levels drop rapidly.
3. As the HVAC system operates, the levels drop but seldom go below 4-5 pCi/L. The rate of drop and the limiting radon level depend as expected on the OA flowrate.
4. When the exhaust fans are run continuously, the radon levels do not increase to nearly as high levels with the HVAC system off as they do when the fans are left off.
5. The radon levels in the Audiology room do not always follow the rest of the building. The levels here are usually higher than the building as a whole.

From these observations several conclusions appear obvious. The HVAC system is assisting in lowering the radon levels even without the intentional introduction of OA. A significant factor is almost certainly the enhanced ventilation rate induced by the system. Pressure differences across the building shell will enhance infiltration through shell openings, especially when exhaust fans are active. This infiltrating air is difficult to measure and changes the definition of “no OA” to mean, “no OA actively supplied by the OA supply fan.” The peak radon levels reached in the building just before the HVAC system comes on do depend somewhat on the amount of OA introduced into the system during the previous HVAC operation cycle and on the length of time that has transpired since the HVAC system was last operated. The main reasons for the persistently higher radon levels in the Audiology room were thought to be due to the isolation of the room combined with a major entry path such as an open (or extremely leaky) expansion joint located under the room.

In an effort to understand why the radon levels remain at 4 pCi/L or greater, two additional Pylon AB5 continuous radon monitors with PRD-1 passive cells were placed outside the building in the sheltered workshop area on the north side of the building. One monitor was located at ground level and the other about 8 ft off the ground. The locations were open and sheltered only from rain. Over the 4-week period the ground level radon averaged 4.1 pCi/L with a weekly high of 5.3 pCi/L (4/30-5/7) and a weekly low of 2.8 pCi/L (4/16-4/23). These results were of obvious concern since, if the radon source strength is sufficiently high, the indoor levels can never be reduced below the average ground level outdoor levels.

1994 Phase II Study

In order to address some of the uncertainties in the 1993 results, permission was obtained for a series of follow-up tests at the LLC. Continuous measurements by Southern Research Institute replicated some of the conditions studied in 1993. Significant changes included:

- Three outdoor air radon monitors were installed to investigate the distribution and time variability of outdoor radon.
- Since the indoor radon was known to be well-mixed outside the Audiology room, only one indoor radon monitor (in the Cafeteria) was used. An additional monitor was installed in the Mechanical room.
- In order to investigate the significance of the load-bearing block walls as an entry route, a pumped radon monitor was used to sample the air within one section of the block wall cavity. Another pumped radon monitor was used to sample subslab radon concentrations.
- Pressure differentials (with respect to the Cafeteria) were monitored in the following zones: the Mechanical room, outdoors, subslab, and the block wall section.
- Sulfur hexafluoride (SF_{6}) was continuously injected into the Cafeteria (and generally found to be uniformly distributed in the building).
- In addition to operation of the HVAC during several week-long periods at each of the OA damper positions used previously, several periods of depressurization (using the exhaust fans) were scheduled on weekends. One period of pressurization (with the HVAC off) was performed using a blower door. Out of deference to the energy management concerns of the school district, the customary setback schedule (8 hr on/16 hr off, 5 days/ week) was used in the 1994 study.

The outdoor radon experiments indicate that outdoor radon was not a significant source of the indoor radon at the LLC. The monitor sampling at ground level (3 in.) failed early in the study and was removed. The other monitors (at 4 ft and on the roof level at the OA intake) continued to operate throughout the study period. Both monitors showed low values during the day (typically ≤0.5 pCi/L) followed by peaks of 2-6 pCi/L or higher at night, when turbulent mixing is low. The OA contribution is seen to be minimal, since the OA concentration is at background levels during the day when the building ventilation rate is significant. In the early morning hours when the outdoor radon concentration is highest, the indoor concentrations are several times higher; furthermore, the infiltration rate is quite low at these times.

Examination of differential pressure data suggests further insights into the normal operating state of the building. These data cover week-long periods of normal operation with the OA damper set at positions corresponding to nominal flowrates of 3000, 750, 2250, and 1250. First, the Cafeteria runs at positive pressure with respect to outdoors when the AH is operating. The mean pressurization varies from about 0.3 Pa at 750 cfm nominal OA to about 1 Pa at 3000 cfm nominal OA. During weekdays, this pressure differential undergoes dramatic fluctuations. These may be partly due to changes in the building load (VAV operation), or in the OA fan operation, as they are not present during periods with the HVAC off, even when the building is mechanically pressurized or depressurized. However, since these fluctuations are also characteristic of occupied periods, they may result from occupant activity (i.e., opening doors or windows). During HVAC off periods, the Cafeteria-outdoor pressure drops to low values, and a slight depressurization is observed on many nights. This depressurization is most likely explained by the observation that a few exhaust fans were often left in operation after the staff left at the end of the day. These unmonitored changes in building operation were unfortunate, since they leave some uncertainty as to the exact operating mode of the building.

The Mechanical room is depressurized relative to the Cafeteria by 1.5-2.0 Pa when the AH is operating. This difference is greater than the pressurization of the Cafeteria, so the Mechanical room is negative with respect to outdoors for all but brief portions of the normally occupied periods. Pressures in the other zones monitored (subslab, block wall, and Mechanical room during periods without AH operation) track the Cafeteria pressure, but tend to be slightly lower in magnitude during mechanical pressurization or depressurization.

Examination of continuous radon data reveals several trends with implications for radon entry in the building. First, the radon concentrations in the Mechanical room are consistently higher than in the Cafeteria under all HVAC and mechanical ventilation conditions, although the differences grow smaller for periods of mechanical depressurization or of low OA damper setting. Since ventilation rates between the two zones are expected to be high, and inleakage of OA is expected to be much higher into the Mechanical room as compared to the Cafeteria, the higher concentration suggests a significantly higher radon entry rate into the Mechanical room. This is not surprising in light of the pressure measurements showing the Mechanical room to be the most highly depressurized portion of the building.

A second observation is that the ratio of indoor radon to SF_6 tracer is significantly higher in the daytime (with HVAC in operation) and during depressurization, indicating higher radon entry rates during those periods. (Since the ventilation rate is also increased, these periods tend to be periods of lower radon concentrations.) The increased entry rate when the AH is turned on also helps explain the slower rate of fall of radon concentration than would be expected from the air change rate. Indeed, the SF_6 tracer gas does drop much more rapidly to its limiting daytime value. The slower decay time of the radon is partially explained by the larger measurement time constant of the radon monitors due to decay times of the radon progeny, but is also an indication of the change in entry rate as the HVAC cycles between normal and setback operation.

The block wall radon concentrations suggest this to be a major pathway for radon entry. During periods of AH operation, the block wall radon rapidly rises to levels of 600-1000 pCi/L, then drops back to lower levels during the evening setback period. Inspection of the block wall pressure at the section tested reveals that, while it is generally positive with respect to outdoors during HVAC on periods, it is generally negative with respect to both the subslab test point and the Cafeteria. This depressurization may be due to coupling with the plenum, and would suggest one path for transport of radon into the return air system. This pressure coupling would explain the rapid influx of soil gas into the block wall cores as the AH starts in the morning, as is clearly seen in the continuous data. The rapid drop in block wall radon as the AH goes off in the afternoon can be attributed to the relief of this driving pressure gradient combined with transport of the accumulated radon back into the soil or, more probably, into the building. The likelihood that the block walls provide a major entry path has been discussed before, since the cores of these walls penetrate the slab to the block courses in direct contact with the soil. Since the pores of the block are highly permeable, a low resistance pathway exists directly from the soil to indoors.

Two cautions must be observed regarding any quantitative interpretations from these results, however. The block wall section tested was a 4 ft wide interior wall segment bordering the Cafeteria and Room 109. Horizontal communication within the wall segment will presumably be limited by the reinforced filled core sections specified every 4 ft in this building. There are exhaust fans in Room 109, which may enhance entry in this section over walls adjacent to rooms with no mechanical exhausts. On the other hand, entry into the walls of the Mechanical room might easily be much higher, and could represent the major source of radon entry into the building. In any event, the results of the present study clearly indicate that the wall construction detail used in the LLC is highly vulnerable to radon entry, and alternatives must be provided for a radon-resistant building standard.

Conclusions and Recommendations

The two case studies in this report present some insight which can be generalized to other structures. The first building was a structure that had apparently been successfully mitigated by passive techniques, so would not normally be considered a “problem” structure. In this building, variations in OA flow control dampers produced ventilation rate changes within the typical range (0.2 to 0.6 of an air change per hour) resulting in variations in indoor radon concentrations over a comparable range (a factor of 2.6). The second building had much higher radon levels, which could not be reduced below the 4 pCi/L radon standard without introducing OA at a rate in excess of ASHRAE standard requirements, not to mention the energy management priorities of the owner. Both buildings demonstrated an inverse relationship between dedicated ventilation air and indoor radon concentrations, as was expected. Both also showed signs of unusual HVAC design, operation and maintenance which presumably adversely affected indoor radon as well as other IAQ variables. The second building showed clear indications of foundation design elements which contributed to radon entry; elimination of these entry paths at the time of construction would have been by far the most cost-effective remedy for the building.

Some recommendations relevant to building standards can be concluded from this project. First, design and construction should concentrate on elimination of major soil gas pathways such as hollow walls and unsealed utility penetrations. It is clear from this study how much benefit can be derived from sealing of minor cracks and joints. Second, HVAC system design should include strategies designed to minimize depressurized zones adjacent to the soil. Such zones could be caused by flow imbalance in the air distribution system, inadequate sealing of major duct leaks, or imbalance of supply and exhaust ventilation airflow. The combination of depressurized areas and poor barriers is particularly undesirable, especially if the depressurizing element is the return air portion of the AH system. Third, while increased supply ventilation is generally helpful for radon control, it is clearly not the most cost-effective solution or prevention tool once the requirements of occupant comfort and general IAQ have been met.

The information base needs to be extended. In particular, monitoring of the radon in new buildings constructed on high radon potential soil according to radon control guidelines could provide useful information.

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The complete report, entitled "Radon Diagnostic Measurement Guidance for Large Buildings, Volumes 1 and 2,)," (Order No. 600/R-97/046A [Volume 1] PB97-189716 and 600/$-97/064B [Volume 2] PB97-189724; Cost: Volume 1 $31.00, Volume 2 $35.00, subject to change) will be available only from:

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