1995-31

RADON MITIGATION DIAGNOSTICS FOR LARGE NONRESIDENTIAL BUILDINGS

D. L. Wilson, C. S. Dudney, and R. B. Gammage
Health Sciences Research Division
Oak Ridge National Laboratory
Oak Ridge, TN

K. M. Davis
Hazardous Waste Remedial Actions Program
Oak Ridge, TN

ABSTRACT

Recently, considerable attention has been dedicated to ascertaining the best approach to performing radon mitigation in large, nonresidential buildings. Considerations such as localized elevated radon, complex substructures, local building codes, and multiple mechanical systems have greatly complicated mitigation installation. In 1991, Oak Ridge National Laboratory (ORNL) proposed a large building mitigation diagnostic protocol for the purpose of optimizing mitigation method selection. The diagnostic protocol involves performing detailed subslab permeability, building shell integrity, and mechanical system performance measurements. By placing the collected data into a mitigation matrix, the optimal mitigation solution for the building is determined. During 1992-1994, ORNL staff members evaluated this protocol and mitigation matrix in 27 large buildings (10,000 to 200,000 ft^2) nationwide. The evaluation of the protocol and specific problems identified during the investigation will be addressed.

INTRODUCTION

Within residential buildings, understanding the root cause of how the radon enters the house is not really required to perform a successful mitigation. The reasons are that room-to-room radon distribution is fairly uniform, and residential buildings are generally very simple in construction: a single foundation, a monolithic slab, and a single mechanical system. In large buildings, sizable room-to-room variations in radon concentration are common as is complicated construction: multiple foundations, slabs, and mechanical systems (1-2). In addition, research has indicated that large buildings may contain construction features or mechanical systems that would inhibit the installation or operation of a residential-type mitigation system (1). Examples are return air ducts or supply ducts that are routed through the slab. These mechanical components have demonstrated sufficient subslab perturbation to overpower traditional subslab depressurization systems. Also, highly segmented slabs were found to disrupt subslab depressurization fields (1).

Other important issues for consideration during mitigation design are health, safety, and local building code requirements. For example, the best method for mitigation of a building might be subslab depressurization, but the presence of asbestos in building material might prevent the installation of the PVC intake and exhaust piping. Local fire codes are a factor as well. To prevent the release of toxic fumes in the event of a fire, within certain areas of the country, PVC pipe cannot penetrate into occupied areas or through fire walls. Also, roof penetrations for radon exhaust may invalidate the contractor's warranty. All of these factors and more must be considered during the mitigation design.

By definition, radon mitigation consists of the measures taken to reduce human exposure to elevated radon. As stated previously, elevated radon within large buildings can be isolated within certain areas of a building. If these areas are occupied on a regular basis, then mitigation should be considered, but before corrective action is taken, another option should be considered. The key part of the risk associated with radon exposure is that a person must be exposed to be considered at risk. Obviously, if no exposure occurs, no human health risk exists; thus, by restricting or removing a worker from exposure, a more cost-effective mitigation may result. For example, by limiting or controlling access to a room (i.e., locking the door) or relocating occupants to safer areas within the building, the human health risks are eliminated and mitigation has occurred.

MITIGATION DESIGN CONSIDERATIONS

In most cases, the initial installation cost of a radon mitigation system is the basis for mitigation method selection. However, in large buildings, additional concerns may exist that may have significant impact on the system selection and installation. These concerns are:

1. Installation difficulty.

   Is the lead time required for mitigation greater than the guidelines allow?

   Are the chances for successful mitigation acceptable for the most inexpensive system?

   Are hazards present that would require abatement before installation (e.g., asbestos or lead-based paint)?

2. System upkeep and energy operation costs.

   Will it be difficult to maintain the mitigation system once it is operational?

   What are the costs associated for this upkeep and energy operation?

3. Remaining building lifetime.

   What is the remaining lifetime of the building?

   Would it be more cost effective to construct or lease a new building?

4. Short-term options.

   What are the exposure risks?

   Can the space usage be modified to decrease the potential radon exposure?

5. Scheduled mechanical replacements and upgrades.

   Is the building mechanical system scheduled for replacement or upgrade within the mitigation time allotted?

OVERVIEW OF RADON MITIGATION DIAGNOSTIC PROTOCOL

To address these concerns, ORNL proposed the following protocol:

Step 1: Prediagnostic

Perform a radon test in all ground-contact rooms, stairwells, pipe chases, and other interfloor conduits. Record the results on the building floor plan, and classify the radon data pattern as one of the following types:

- Random (no distinct pattern)
- Clustered (grouped together in a certain area of the building)
- Linear (results are in a row)
- Uniform (all data are about the same)

With the radon room map, review the building construction plans noting any building features, modifications, or additions that would enhance radon entry.

The building should then be divided into diagnostic zones of the following types: slab, interior, or mechanical. A slab diagnostic zone is area beneath the slab enclosed by footers or foundation. An interior diagnostic zone is area defined by rooms enclosed by fire walls, masonry construction. Consideration should be given to normal room door positions (open or closed) when defining this type of zone. A mechanical diagnostic zone is defined only if a forced air system is present. For each forced air mechanical system present, locate the supply and return ducts. Identify the supply air zone(s) and return air zone(s). In a properly balanced system, the zones should overlap. Note any ductwork that is in ground contact or that passes through low ventilated or confined areas in soil contact such as crawl spaces or storage rooms.

A visual inspection of the building should then be conducted to confirm the accuracy of the building plans, and to collect information on individual room usage and occupancy patterns. If present, information on the building heating and ventilation system (HVAC) and the duty cycle should be noted as well. After the walkthrough inspection, an interview of the building maintenance staff should be conducted to review the collected information and discuss future diagnostics work. The building manager should also be interviewed to collect additional nonstuructual information. Examples of nonstructural information are: future renovation plans, building expansion plans, and potential for relocation.

Step 2: Active Diagnostics

Based on the information collected in Step 1, perform up to 7 different active mitigation diagnostics. Examples of active diagnostics are listed in Table 1.

Table 1. Mitigation diagnostics performed

Mitigation Diagnostic	Description
Air change	Measure zonal ventilation rates
Blower door	Measure zonal leakage area
Subslab	Measure subslab permeability and lateral field extension
Continuous radon monitoring	Monitor impact of mechanical cycles on radon concentration
Flow hood	Mechanical system balance
Radon entry pathway	Identify major entry pathways
Differential pressure	Mechanical system balance

Evaluation of the Mitigation Diagnostic Protocol

From 1992 to 1994, a total of 27 buildings were evaluated using this protocol. The population diversity was quite good from structural, chronological, and geographical standpoints. Table 2 lists the sites and building characteristics.

Table 2. Sites for 1994 radon mitigation diagnostics study

Location	Area (ft^2)	Levels	Year Built	Mechanical System
Abilene, Texas	154,560	4	1936	HVAC
Ada, Oklahoma	40,000	4	1935	HVAC
Allentown, Pennsylvania	80,902	3	1934	None
Big Springs, Texas	31,137	2	1969	HVAC
Clovis, New Mexico	11,858	2	1966	HVAC
Dallas, Texas	212,970	5	1929	HVAC
Eastport, Maine	8,500	3	1890	None
Eldora, Iowa	9,500	2	1939	HAC
Enid, Oklahoma	85,000	3	1940	HVAC
Florissant, Missouri (Leased)	59,531	2	1971	HVAC
Griffin, Georgia	32,403	2	1975	HVAC
Lancaster, Ohio	22,500	2	1910	HVAC
Lawerenceburg, Tennessee	13,338	2	1935	None
Lowville, New York	13,500	2	1939	HVAC
Machias, Maine	15,000	2	1967	HVAC
Marion, Indiana	63,000	2	1941	HVAC
Mercer, Pennsylvania	6,190	2	1939	None
Okmulgee, Oklahoma	55,497	3	1933	None
Paris, Kentucky	13,500	2	1965	HAC
Pueblo, Colorado	68,000	2	1898	HVAC
Raton, New Mexico	19,000	2	1966	HVAC
Rockland, Maine	19,000	2	1967	HVAC
Scott City, Kansas	18,000	2	1965	HVAC
Talladega, Alabama	18,000	2	1970	HAC
Willimantic, Connecticut (Leased)	24,000	1	1966	HAC
Waynesville, North Carolina	19,000	2	1966	HAC
Wrightsville, Georgia	4,600	2	1938	HVAC

RESULTS AND DISCUSSION

During the mitigation diagnostic evaluation study, up to 7 different diagnostics were performed (Table 3) in 27 buildings. As required by the project sponsor, the type of diagnostic measurements performed were limited to established residential diagnostics and had to be nondisruptive to worker activities. However, limitations were observed for each of these tests that have an impact on their usefulness. Table 3 lists the diagnostics performed, limitations, and recommendations.

Table 3. Mitigation diagnostic measurement summary

Diagnostics Test	Limitations	Recommendations
Air change	Measurements must be performed for both on and off forced air	Perform at all sites
Blower door	Buildings or areas larger than 8,000 ft^2 yield inconclusive results	Limit to buildings < 8,000 ft^2
Subslab	Multistory buildings hamper subslab depressurization systems	Limit only to buildings in which a subslab mitigation system can be installed
Continuous radon measurements	Continuous measurements are expensive when compared with passive measurements	Perform in all buildings with forced air systems
Flow hood	Accessibility to many supply vents complicates the measurements	Differential pressure measurement is better imbalance indicator
Radon entry pathway	In 26 on-site investigations, only one significant pathway was encountered	Perform only for obvious entry pathways
Differential pressure	Cyclic and seasonal forced air systems may not be operational during diagnostics	If seasonal or cyclic forced air system is present, 2 measurements (on/off) must be performed

Of the 27 buildings investigated, 22 had a Forced Air System (FAS). In all 22 buildings, the operational impact of the FAS was found to be significant. Even if radon above the action level is detected, the possibility may exist for certain types of buildings that the elevated radon may not be present during the normal work hours, specifically, buildings with a FAS that is reduced or shut down during the nonwork hours. An example of this type of problem was discovered within a building in Griffin, Georgia (Fig. 1). During normal work hours, the HVAC system provides adequate radon mitigation. However, in the evening, the capacity of the HVAC is greatly reduced. In this case, passive testing indicated levels above the action level, but the continuous measurements indicated a problem only during the off-shift hours. In order for radon to be a risk, people must be exposed to the radon. If no one is present, then the risk is nonexistent. In buildings such as this, the recommendation is made that before radon mitigation, continuous radon measurements be performed in areas that have tested above the action level. Based on the data collected, the duration of the test should be a minimum of 21 days. Integrated resolution of the instrument should be on the order of one measurement for per 0.5 hr. If elevated radon is confirmed during the work hours, then the next step of the premitigation process should entail the inspection of the mechanical system. Table 4 summarizes important questions to address during the inspection. In addition to these questions, the inspector should try to correlate elevated radon concentration to areas of the building that have poor ventilation (e.g., no FAS service). For seasonal FAS, continuous radon measurements should be performed in both on and off cycle, weather permitting.

Table 4. Questions for mechanical inspections

Questions
Is the forced air system continuous, seasonal or intermittent?
Is the system within specifications?
Can the system be upgraded?
Should the system be continuous?
Can the system be modified to provide year-round service?
Is localized ventilation possible?
Can the system be adjusted?
Should the system be replaced?

During the mitigation diagnostic study, it became apparent that although subslab mitigation diagnostics could be performed, certain building characteristics made installation of a subslab depressuriztion system (SSD) moot. Therefore, the first step for SSD mitigation diagnostics should be an assessment of whether an SSD system is practical. Reasons that would potentially disqualify a building from SSD mitigation are as follows:

- Buildings with more than 3 stories (e.g., >40 ft from slab to roof).
- Historical buildings that cannot have exterior modifications and for which vertical penetration is not practical.
- Building interiors that do not have an easy access to the roof (e.g., single-fan pipe runs of over 100 ft).
- Buildings constructed over shallow water tables (e.g., water table <4 ft from the slab).
- Buildings with extra thick (e.g., 1 ft) or steel reinforced slabs that would increase installation cost greatly.

If one or more of the above statements are true, then performing SSD diagnostics is not recommended.

If the building has been found suitable for potential SSD mitigation, the building plans should then be reviewed. During the review, all subslab utilities (e.g., water, sewer, and electrical) should be identified on the building plans. A walkthrough of the building is then conducted to verify drawing accuracy. Hazards such as asbestos in floor tile need to be documented during the visual inspection as well. In addition to reviewing the building plans, the building maintenance staff should be consulted. Concurrent with the subslab utilities inspection, avenues for running SSD pipe should be documented as well.

After the walkthrough inspection, SSD diagnostics can then be performed in areas where a potential suction pit could be installed. The exact number of SSD diagnostics to perform for a given building is dependent upon many variables: the size of the slab, subslab complexity, the measured field extension, the detail of the building plans, and the number of areas in which SSD diagnostics can be performed are just a few. For reference purposes, one SSD diagnostic should be performed for each foundation present. For example, a single, perimeter, rectangular foundation with a monolithic slab could be characterized with only one SS diagnostic if the building plans indicate homogenous subslab fill. In cases where more than one foundation (e.g., multilevel basement or building additions) or inhomogeneous subslab fill exists, then one SSD diagnostic should be performed per section (provided elevated radon is present in those areas).

The second structural mitigation diagnostic, radon entry pathway (REP) measurements, should be performed in all buildings. The exact number of measurements will vary from building to building. All major ground-contact blemishes (or a representative sample) should have an REP performed. Examples of blemishes are: holes or breaks in the slab with visible subslab material, sumps, loose-fit slab penetrations, expansion joints, etc. Small slab and wall cracks (e.g., <3/8-in. cross section) can be omitted. The significance of the measurement is dependent upon the volume of the room, the room air change rate, the concentration of the soil gas, and the estimated radon flux.

If yes, then can the replacement system installation be accelerated and be designed to mitigate the problem?

From these considerations, costs and issues, a primary and secondary mitigation method is selected.

CONCLUSION

In summary, early indications based on the buildings examined indicate that increased ventilation will be the mitigation solution for well over half of the buildings. This does not mean that other mitigation methods should be disqualified. As a general rule, SSD systems cost $800 per suction pit and less than $100 per year to operate. In buildings for which it is well suited, SSD is still the most cost effective long-term solution.

REFERENCES

1. Wilson, D., et al., Radon in Nonhousing, WATTec, Knoxville, Tennessee, 1991.

2. Wilson, D., et al., Testing for Radon in the Work Place: The Development of a Protocol, American Industrial Hygiene Association Conference, Boston, Massachusetts, 1992.

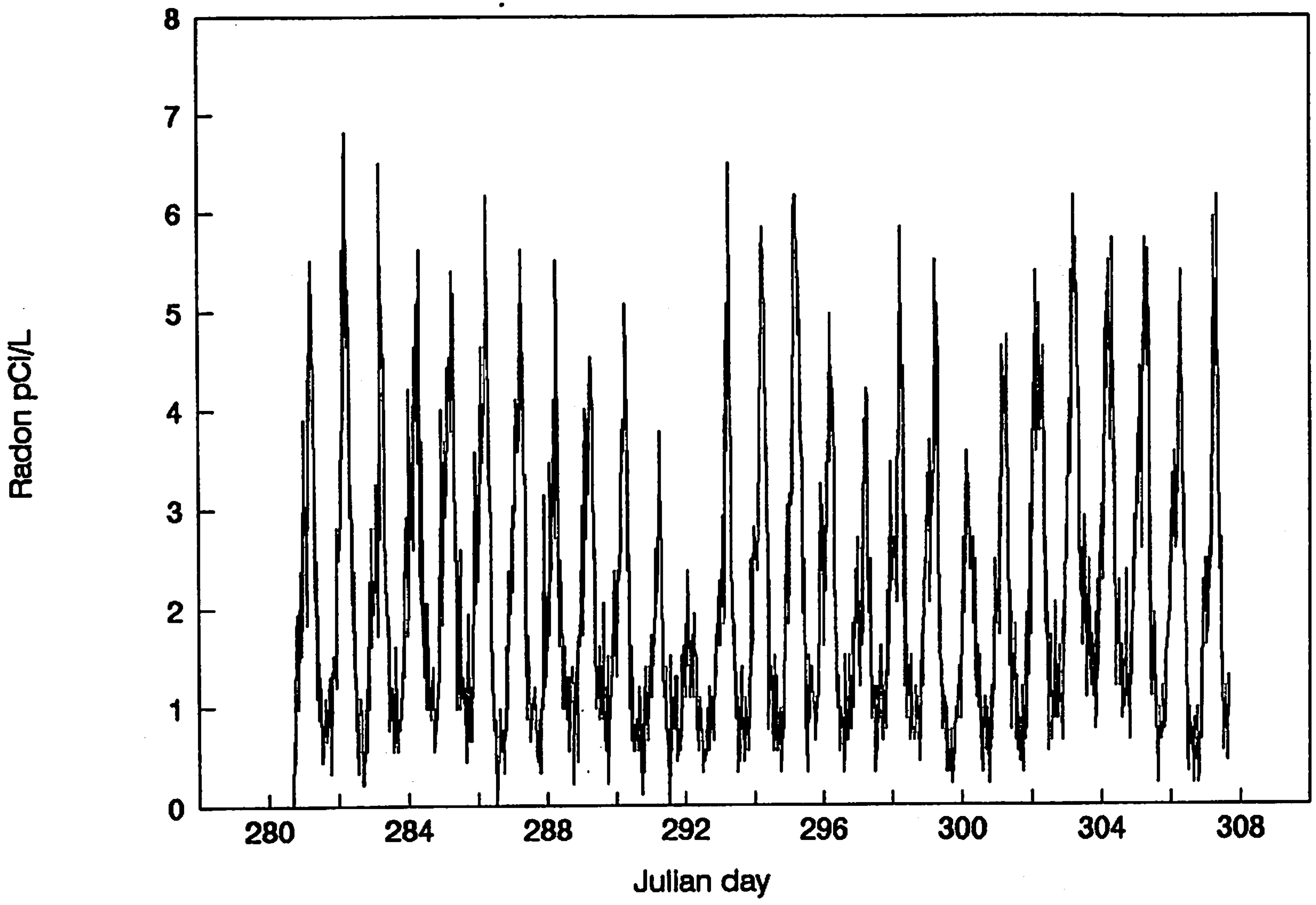

Fig. 1. Impact of ventilation system energy cycle on radon levels.