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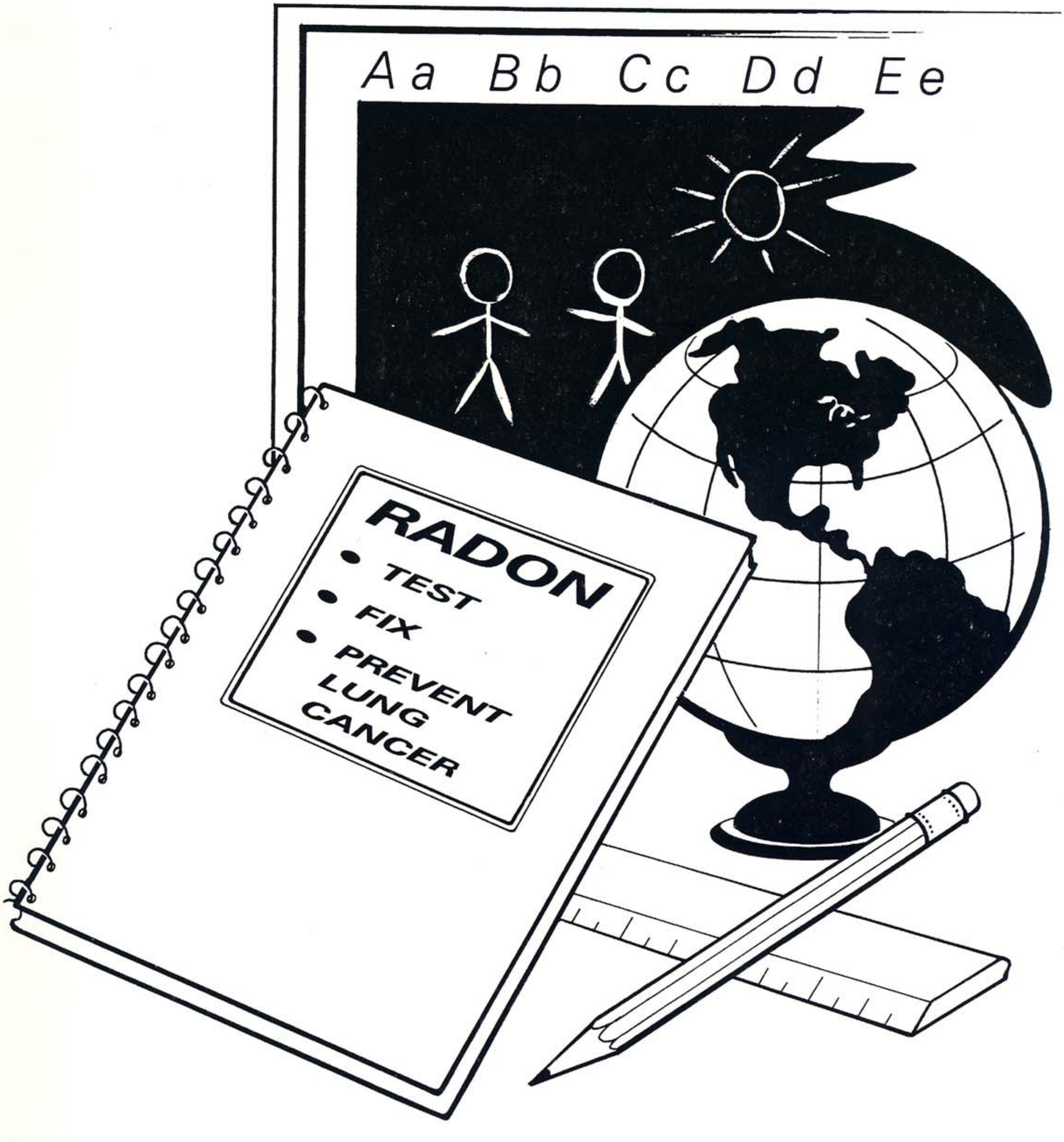
Radon Measurement In Schools

Revised Edition



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Corrections in the Second Printing

page 9 After the third bullet in the subsection on Retesting, the following bullet has been added:

- Retest after major renovations to the structure of a school building or after major alterations to a school's HVAC system. These renovations and alterations may increase radon levels within a school building.

page 10 For the subsection on Recommendations for Specific School Designs, the recommendations for a school with a Basement Design has been further clarified:

(Original)
<u>Basement Design:</u> In addition to measuring all frequently occupied basement rooms, measure all rooms above the basement that have at least one wall with substantial contact with the ground.

(Clarification)
<u>Basement Design:</u> In addition to measuring all frequently occupied basement rooms and rooms with a floor or wall with ground-contact, measure all rooms that have no ground-contact but that are directly above a basement space that is not frequently-occupied.

page 19 For the subsection on Active Sub-slab Depressurization, the sixth line of the first paragraph has been corrected to read:

(Original)
…When radon levels are greater than 20 pCi/L...

(Correction)
...When radon levels are greater than 10 pCi/L...

FOR FURTHER INFORMATION

Radon Measurement in Schools: Self-Paced Training Workbook
(EPA 402-B-94-001)

For a free copy, call 202-260-2080 or write to the US EPA Public Information Center; 401 M. Street, SW (PM 211 B); Washington, DC 20468. Please include your name, address, title of the document, and the EPA number for the document. *Before testing, call your State Radon Contact for information on any State requirements concerning radon testing in schools and on available state training.*

Reducing Radon in Schools: A Team Approach
(EPA 402-R-94-00B)

For a free copy, call your State Radon Contact.

Radon Prevention in the Design and Construction of Schools and Other Large Buildings
(EPA 625-R-92-016)

For a free copy, call the Center for Environmental Research Information at 513-569-7562 or FAX your request to 513-569-7566. Please include your name, address, title of the document, and the EPA number for the document.

SECTION I: INTRODUCTION

The U.S. Environmental Protection Agency (EPA) and other major national and international scientific organizations have concluded that radon is a human carcinogen and a serious environmental health problem. Early concern about indoor radon focused primarily on the hazard posed in the home. More recently, the EPA has conducted extensive research on the presence and measurement of radon in schools. Initial reports from some of those studies prompted the Administrator in 1989 to recommend that schools nationwide be tested for the presence of radon. Based on more recent findings, EPA continues to advise U.S. schools to test for radon and to reduce levels to below 4 pCi/L.

This report has been prepared to provide school administrators and facilities managers with instructions on how to test for the presence of radon. The findings from EPA's comprehensive studies of radon measurements in schools have been incorporated into these recommendations. This report supersedes *Radon Measurements in Schools - An Interim Report* (EPA 520/1-89-010). However, it does not invalidate tests conducted or tests in the process of being conducted under the interim report.

The amount of radon gas in the air is measured in picocuries per liter of air or **pCi/L**. However, sometimes test results are expressed in Working Levels (**WL**), representing radon decay products. EPA recommends that schools take action to reduce the level of radon when levels are **4 pCi/L** (or 0.02 WL) or higher. Testing is the only way to determine whether or not the radon concentration in a school room is below the action level. Measuring levels of radon gas in schools is a relatively easy and inexpensive process compared to many other important building upkeep activities.

Because radon levels in schools have been found to vary significantly from room to room, schools should test all frequently occupied rooms in contact with the ground. If a room is found to have a level of 4 pCi/L or greater, this measurement result should be confirmed with another test. If the second test is also at or above 4 pCi/L, schools should take action to reduce the radon level to below 4 pCi/L.

In addition to radon, some schools may be interested in addressing overall **indoor air quality** concerns. Many schools have poor indoor air quality resulting in part from low rates of ventilation (low outdoor air intake). This is often the result of poor maintenance and improper operation of the HVAC system or limiting the intake of outdoor air to reduce heating (and cooling) costs. EPA is preparing to release practical guidance on improving indoor air quality in school buildings. The guidance entitled *Indoor Air Quality Tools for Schools* will be available in early 1995 through the Superintendent of Documents; P.O. Box 371954; Pittsburgh, PA 15250-7954.

A. RADON FACTS

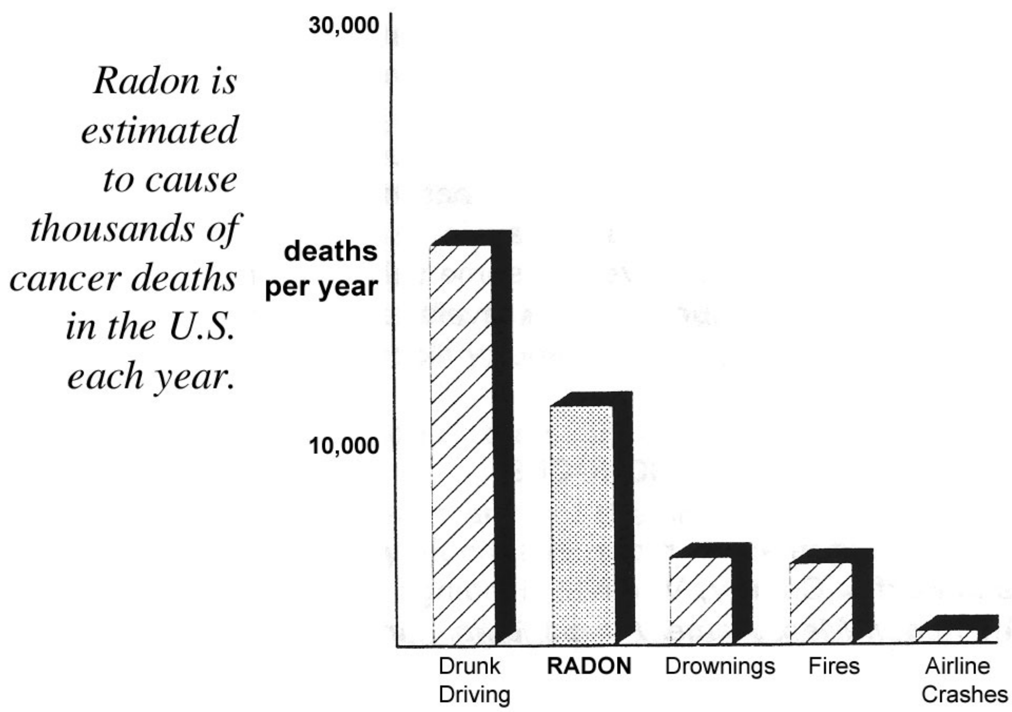
Radon is a naturally occurring **radioactive gas**. It comes from the natural breakdown (decay) of uranium which is found in soil and rock allover the United States. Radon travels through soil and enters buildings through cracks and other holes in the foundation. Eventually, it decays into radioactive particles (decay products) that can become trapped in your lungs when you breathe. As these particles in turn decay, they release small bursts of radiation. This radiation can damage lung tissue and lead to lung cancer over the course of your lifetime. EPA studies have found that radon concentrations in outdoor air average about 0.4 pCi/L. However, radon and its decay products can accumulate to much higher concentrations inside a building.

Radon is colorless, odorless, and tasteless. The only way to know whether or not an elevated level of radon is present in any room of a school is to test. Each frequently occupied room that is in contact with the ground should be measured because adjacent rooms can have significantly different levels of radon.

B. HEALTH EFFECTS

Radon is a known **human carcinogen**. Prolonged exposure to elevated radon concentrations causes an increased **risk of lung cancer**. Like other environmental pollutants, there is some uncertainty about the magnitude of radon health risks. However, scientists are more certain about radon risks than risks from most other cancer-causing environmental pollutants. This is because estimates of radon risk are based on studies of cancer in humans (underground miners). Additional studies on more typical populations are underway.

EPA estimates that radon may cause about **14,000 lung cancer deaths** in the U.S. each year. However, this number could range from 7,000 to 30,000 deaths per year. The **U.S. Surgeon General** has warned that radon is the second-leading cause of lung cancer deaths. Only smoking causes more lung cancer deaths. The following bar chart displays the estimated deaths caused by radon relative to deaths resulting from other causes. The numbers of deaths from other causes are taken from 1990 National Safety Council Reports.



Not everyone who breathes radon decay products will develop lung cancer. An individual's risk of getting lung cancer from radon depends mostly on three factors: the **level of radon**, the duration of **exposure**, and the individual's **smoking habits**. Risk increases as an individual is exposed to higher levels of radon over a longer period of time. Smoking combined with radon is an especially serious health risk. The risk of dying from lung cancer caused by radon is much greater for smokers than it is for non-smokers.

Children have been reported to have greater risk than adults for certain types of cancer from radiation, but there are currently no conclusive data on whether children are at greater risk than adults from radon.

C. RADON EXPOSURE

Because many people - particularly children - spend much of their time at home, the home is likely to be the most significant source of radon exposure. Parents are strongly encouraged to test their homes for radon and to take action to reduce elevated radon concentrations there. Information to assist them in such efforts is provided in EPA's *A Citizen's Guide to Radon* (EPA 402-K92-001, May 1992).

For most school children and staff, the second largest contributor to their radon exposure is likely to be their school. As a result, EPA recommends that school buildings as well as homes be tested for radon.

EPA recommends reducing the concentration of radon in the air within a school building to below EPA's radon action level of 4 pCi/L. EPA believes that any radon exposure carries some risk - no level of radon is safe. Even radon levels below 4 pCi/L pose some risk, and the risk of lung cancer can be reduced by lowering radon levels. This action level is based largely on the ability of current technologies to reduce elevated radon levels below 4 pCi/L. Depending on the building characteristics, radon levels in some schools can be reduced well below 4 pCi/L. In other schools, reducing radon levels to below 4 pCi/L may be more difficult.

D. THE RADON PROBLEM IN SCHOOLS

EPA's investigations of radon in schools were initiated in 1988 with a study of schools in Fairfax County, Virginia. Findings from that study were used to develop the *Radon Measurement in Schools - An Interim Report* (EPA 520/1-89- 010). Schools have been using this document as a interim guide for measuring radon in schools.

In 1989 and 1990, EPA conducted the *School Protocol Development Study*, a nationwide effort to further examine how best to conduct radon measurements in schools. Results from this study have been used to improve the procedures for testing radon in schools and are incorporated into this document.

The results of this study also suggested that elevated radon levels (levels ≥ 4 pCi/L) may exist in at least some schools in every state. Although most elevated measurements in this study were slightly greater than 4 pCi/L, several schools were found with levels well over 20 pCi/L while some have been found with concentrations over 100 pCi/L.

EPA has conducted a *National School Radon Survey* which provides a statistically valid representation of the levels of radon in schools at the national level but not at the state or local level. The results show widespread radon contamination in schools. EPA estimates that 19.3% of U.S. schools, nearly one in five, have at least one frequently occupied ground contact room with short-term radon levels above 4 pCi/L - the level at which EPA recommends mitigation. In total, EPA estimates that over 70,000 schoolrooms in use today have short-term radon levels above 4 pCi/L. Refer to your State Radon Contact or EPA Regional Office for further information about the results of this surveyor for more information about radon in schools in your area (see **Appendix A and B**).

E. RADON ENTRY INTO SCHOOLS

Many factors contribute to the entry of radon gas into a school building. Schools in nearby areas can have significantly different radon levels from one another. As a result, school officials can not know if elevated levels of radon are present without testing. The following factors determine why some schools have elevated radon levels and others do not:

- the concentration of radon in the soil gas (source strength) and permeability of the soil (gas mobility) under the school;
- the structure and construction of the school building; and
- the type, operation, and maintenance of the heating, ventilation, and air-conditioning (HVAC) system.

Many schools are constructed on adjoining floor slabs which permit radon gas to enter through construction and expansion joints between the slabs. Other features, such as the presence of a basement area, crawl spaces, utility tunnels, subslab HVAC ducts, cracks, or other penetrations in the slab (e.g., around pipes) also provide areas for radon to enter indoor spaces.

Depending on their design and operation, HVAC systems can influence radon levels in schools by:

- increasing ventilation (diluting indoor radon concentrations with outdoor air);
- decreasing ventilation (allowing radon gas to build up); pressurizing a building (keeping radon out); and,

- depressurizing a building (drawing radon inside).

The frequency and thoroughness of HVAC maintenance can also play an important role. For example, if air intake filters are not periodically cleaned and changed, this can significantly reduce the amount of outdoor air ventilating the indoor environment. Less ventilation allows radon to build-up indoors.

An understanding of the design, operation, and maintenance of a school's HVAC system and how it influences indoor air conditions is essential for understanding and managing a radon problem as well as many other indoor air quality concerns in schools. More information on how HVAC systems can affect school radon concentrations is provided in **SECTION III**.

SECTION II: RADON TESTING IN SCHOOLS

A. INTRODUCTION

There are two general ways to test for radon:

1. A **short-term test** is the quickest way to test for radon. In this test, the testing device remains in an area (e.g., schoolroom) for a period of **2 to 90 days** depending on the device. Because radon levels tend to vary from day to day and from season to season, a short-term test is less likely than a long- term test to give an average radon level for a school year.

2. A **long-term test** remains in place for **more than 90 days**. A long-term test (e.g., a test conducted over the school year) will give a result that is more likely to represent the school year average radon level in a schoolroom than a short-term test.

Short-term measurements are most often made with activated charcoal devices, alpha track detectors, electret-ion chambers, continuous monitors, and charcoal liquid scintillation detectors. Alpha track detectors and electret-ion chambers are used for long-term tests. Some general information about radon detectors is given in **Appendix D**. More detailed information can be found in the document entitled *Indoor Radon and Radon Decay Product Measurement Device Protocols* (EPA-402-R-92-004). In order to assure adequate test results, only devices that are used for a measurement period of **at least 48 continuous hours** should be used when testing for radon in school buildings.

Of the short-term tests, a **90-day test** may provide a more representative picture of the average school year radon level in a schoolroom than 2 to 5-day tests. Long-term tests are able to integrate fluctuations of radon concentrations with time. For example, while a 2-day radon measurement might be made during a period of higher than usual radon levels, a 90-day measurement will allow such highs, if they are occurring, to be balanced by periods of moderate or low radon concentrations.

Alternatively, **2 to 5-day tests** indicate the radon level for a shorter period of testing during which radon levels may have been somewhat higher or lower than the school year average. However, EPA research suggests that, on average, these measurements are more likely to reflect the average radon level for a 3-month or longer period when testing is conducted in the coldest months of the year when closed conditions are more likely to be present [see **SECTION II (D)** below].

B. MEASUREMENT STRATEGY FOR SCHOOLS

If a school decides to use a short-term test during initial measurements, EPA recommends the two-step approach described below.

Step 1 Initial Measurements

Take initial measurements using a short-term test. Short-term measurements should be made in **all frequently occupied rooms in contact with the ground** to provide a quick test of whether or not high radon concentrations are present. **All rooms should be tested simultaneously.**

- Do a follow-up test in every room with a short-term, initial test result of 4 pCi/L or greater (**See Step 2**).

Step 2 Follow-up Measurements

All follow-up measurements in a school should be conducted simultaneously. Follow-up measurements should be made in the same locations and under the same conditions as the initial measurements (to the extent possible, including similar seasonal conditions and especially HVAC system operation). This will ensure that the two results are as comparable as possible.

- Use a short-term, follow-up test if results are needed quickly.

The higher the initial short-term test result, the more certain you can be that a short-term test should be used rather than a long-term follow-up test. In general, the higher the initial measurement, the greater the urgency to do a follow-up test as soon as possible. For example, if the initial short-term measurement for a room is several times the EPA's radon action level (e.g., about 10 pCi/L or higher), a short-term follow-up measurement should be taken immediately.

- Use a long-term, follow-up test to better understand the average radon level for a school year.

When a room's initial result is only slightly elevated above 4 pCi/L (e.g., between 4 and 10 pCi/L), a long-term follow-up measurement -preferably taken over the entire nine month school year - is appropriate. The result from such a test may best represent the average radon concentration for the school year in that room. A long-term test should be conducted over the school year immediately following the completion of initial measurements.

Appendix F provides a list of steps to take during a radon-testing program. These steps are not intended to be all-inclusive. However, they may serve as guide through the process of radon testing in a school.

Interpreting Test Results

- If a short-term, follow-up measurement was used, take action to reduce the radon level if the average of the initial and follow-up measurement results is 4 pCi/L or more.

- If the result of a long-term, follow-up measurement is 4 pCi/L or more, take action to reduce radon levels.

Schools can reduce radon levels by proceeding with *diagnostics* and *mitigation*. Diagnostics involve the evaluation of radon entry points and the identification of the appropriate radon reduction technique. Mitigation is the design and implementation of a radon reduction system. *Reducing Radon in Schools: A Team Approach* (EPA 402-R-94-008) will assist schools with the mitigation process. To receive this document, call your State Radon Contact or EPA Regional Office (See **Appendix A and B**). For more information on reducing radon concentrations in schoolrooms see **SECTION III**.

EPA does not recommend that schools use a single short-term test as the basis for determining whether or not action needs to be taken to reduce radon levels. A follow-up measurement to confirm an initial short-term measurement of 4 pCi/L or higher should be conducted before making such a decision. Indoor radon levels depend upon a number of variables and can fluctuate significantly from day to day. Short-term tests (particularly tests of 2 to 5-days) may in some cases reflect an unusual peak in the radon concentration thus indicating a need for remedial action which may not be necessary. In addition, EPA studies have shown that the averaging of two such short-term measurements reduces the possibility of misrepresenting the average radon concentration.

Retesting

In addition to initial and follow-up measurements, EPA recommends that schools retest sometime in the future especially after significant changes to the building structure or the HVAC system. Suggested times for retesting are as follows:

- If no mitigation is required after initial testing (e.g., all rooms were found to have levels below 4 pCi/L), retest all frequently occupied rooms in contact with the ground sometime in the future. As a building ages and settles, radon entry may increase due to cracks in the foundation or other structural changes.

- If radon mitigation measures have been implemented in a school, retest these systems as a periodic check on any implemented radon reduction measures.

- If major renovations to the structure of a school building or major alterations to a school's HVAC system are planned, retest the school before initiating the renovation. If elevated radon is present, radon-resistant techniques can be included as part of the renovation.

- Retest after major renovations to the structure of a school building or after major alterations to a school's HVAC system. These renovations and alterations may increase radon levels within a school building.

C. WHAT ROOMS TO TEST

EPA's research in schools has shown that radon levels often vary greatly from room to room in the same building. A known radon measurement result for a given classroom cannot be used as an indicator of the radon level in adjacent rooms. Therefore, EPA recommends that schools conduct initial measurements in *all frequently occupied rooms in contact with the ground.*

Frequently occupied rooms are usually classrooms, offices, laboratories, cafeterias, libraries, and gymnasiums. Areas such as rest rooms, hallways, stairwells, elevator shafts, utility closets, and storage closets need not be tested (Note: these areas may be important areas for diagnostic testing if elevated radon is found). EPA studies indicate that radon levels on upper floors are not likely to exceed the levels found in ground-contact rooms. Testing rooms on the ground-contact floor is sufficient to determine if radon is a problem in a school.

Recommendations for Specific School Designs

Slab-on-Grade Design: Measure only frequently occupied rooms in contact with the ground.

Open-Plan or Pod Design: If sections of a pod have moveable walls that can physically separate them from other sections, measure each section separately. If moveable walls are absent or inoperable, measure the pod as one room placing detectors every 2000 square feet.

Crawl Space Design: If classrooms are above an enclosed crawl space, measure rooms directly above the crawl space.

Basement Design: In addition to measuring all frequently occupied basement rooms and rooms with a floor or wall with ground-contact, measure all rooms that have no ground-contact but that are directly above a basement space that is not frequently occupied.

Placing Detectors in a Room

- Do not place detectors near drafts resulting from heating, ventilating vents, air conditioning vents, fans, doors, and windows.
- Place detectors where they are least likely to be disturbed or covered up.
- Do not place detectors in direct sunlight or in areas of high humidity.
- Place detectors at least approximately 50 centimeters (20 inches), from the floor and 10 centimeters (4 inches) from other objects and away from the exterior walls of the building.
- Place detectors about every 2,000 square feet for large spaces.
- Do not disturb the test device at any time during the test.

D. WHEN TO CONDUCT RADON MEASUREMENTS

Recommendations

The purpose of initial testing is to identify rooms that have a potential for elevated radon levels (e.g., levels of 4 pCi/L or greater) during the school year. To achieve this purpose, EPA recommends that initial measurements be conducted:

- under closed conditions (closed windows/doors except for normal exit/entry).
- after 12-hours of closed conditions when using a 2 to 5-day test (e.g., initiate testing after a weekend).
- during colder months (October through March, depending on geographical location).
- during weekdays with HVAC systems operating normally when conducting a 2 to 5-day test.

The EPA recommends that schools *avoid* conducting initial measurements under the following conditions:

- during abnormal weather or barometric conditions (e.g., storms and high winds).
- during structural changes to a school building and/or the renovation or replacement of the HV AC system.

An Explanation of the Recommendations

Closed conditions: Short-term tests should be made under closed conditions in order to obtain more representative and reproducible results. Open windows and doors permit the movement of outdoor air into a room. When closed conditions in a room are not maintained during testing, the subsequent dilution of radon gas by outdoor air may produce a measurement result that falls below the action level in a room that actually has a potential for an elevated radon level. Closed conditions should be maintained for at least 12-hours prior to the start of 2 to 5-day measurements. When using a short-term test of 90-days, schools should also maintain closed conditions to the extent possible. Although brief periods of open windows will not seriously jeopardize the results, they should be avoided during testing.

Colder months: Because testing under closed conditions is important to obtain meaningful results from short-term tests, schools should schedule their testing during the coldest months of the year. During these months, windows and exterior doors are more likely to be closed. In addition, the heating system is more likely to be operating. This usually results in the reduced intake of outside air. Moreover, EPA has studied seasonal variations of radon measurements in schools and found that short-term measurements may more likely reflect the average radon level in a room for the school year when taken during the winter heating season.

Weekday testing: When using 2 to 5-day short-term tests, EPA recommends that testing be conducted on weekdays with HVAC systems operating normally. This approach has the important advantage of measuring radon levels under the typical weekday conditions for that school. This also eliminates the burden of weekend testing and non-routine adjustments to the HVAC systems as previously recommended in EPA's interim school guidance. Based upon EPA studies, this recommendation to conduct 2 to 5-day tests on weekdays does not invalidate radon measurements that were conducted on weekends with HVAC system operating continuously as recommended in the interim school guidance (See **SECTION IV (B)**, page 22).

Weather conditions: If major weather or barometric changes are expected, EPA recommends postponing 2 to 5-day testing. EPA studies show that barometric changes affect indoor radon concentrations. For example, radon concentrations can increase with a sudden drop in barometric pressure associated with storms.

E. WHO MAY CONDUCT TESTING

Introduction

There are two options that EPA recommends to school officials when testing their school for radon:

- testing may be conducted by a measurement service that has demonstrated proficiency in EPA's *Radon Measurement Proficiency* (RMP) *Program*.
- testing may be conducted by qualified, trained school personnel.

Schools may choose to hire a testing service to supervise and conduct initial and follow-up measurements. EPA operates a voluntary program to ensure that radon measurement *services* with their selected test devices provide quality test results. This program is called the *Radon Measurement Proficiency* (RMP) *Program*. EPA recommends that schools use only RMP-listed (or State-listed) companies for radon measurement services. Call your State Radon Contact or EPA Regional Office for more information. General guidelines to consider when hiring a company to perform school radon testing are given in **Appendix C**.

School and school district personnel may choose to design and implement the radon testing program themselves if they are willing to devote the needed effort to achieve a successful testing program. Radon testing requires careful planning, record keeping, and logistical preparation which requires attention to the selection of appropriate test locations and the handling of large numbers of devices. This option has the advantages of reducing costs and providing in-house experience and awareness to address future radon needs (e.g., such as retesting).

EPA recommends that school personnel use only radon testing devices from a company listed with EPA's RMP Program or your State. EPA also recommends that school personnel receive training to ensure the quality of their work when electing to do testing themselves.

Recommended level of Training

EPA recommends two different levels of training for school personnel depending on the measurement method chosen:

- Use of devices that are returned to a *RMP-listed laboratory* for determination of the test result. In this case, school personnel are not involved in determining the level of radon in pCi/L (or in WL) that is present in a room. For most devices, the purchase price generally includes payment for the laboratory analysis. For others, an additional fee may be charged when the device is returned to the laboratory.

School personnel using devices which will be analyzed by an RMP-listed service should receive training to introduce them to the major components of a school testing program. At a minimum, school personnel who will supervise the measurement process should receive training, but demonstrated proficiency in the RMP is not necessary.

- Use of devices purchased from a RMP-listed company where the measurement in pCi/L or WL can be determined directly from the device with either special portable equipment or directly from a self-contained measurement device. In this case, school personnel are able to *measure directly* the radon concentration and determine the test result immediately (i.e., without a RMP-listed laboratory).

EPA strongly recommends that school personnel who plan to use measurement devices or equipment which **provide immediate results** (i.e., the radon level) demonstrate proficiency in the RMP Program or a State Certification Program. Alternatively, school personnel could be directly supervised by someone who is RMP-listed (e.g., State officials). Because school personnel, rather than an RMP- listed firm, are providing the measurement analysis, EPA believes that it is important that these school personnel demonstrate proficiency in the measurement of radon via the RMP. A certain level of technical knowledge and demonstrated capability is necessary to ensure the quality of such test results.

EPA recommends that you call your State Radon Contact for more information on available training and for information on any state requirements before you begin to test your school (see **Appendix A**). EPA supports several regional *Radon Training Centers* (RTC) that currently provide courses in radon measurement, diagnostics, and mitigation including courses associated with the Radon Measurement Proficiency Program. EPA and the RTCs have also developed self-instructional training for radon testing in schools. This training is presented in the document *Radon Measurement in Schools: Self-Paced Training Workbook* (EPA 402-8-94-001). For directions on how to obtain this workbook, refer to the box containing further information located at the beginning of this document.

F. QUALITY ASSURANCE MEASUREMENTS

To ensure that measurement results are reliable, EPA strongly recommends that quality assurance measurements accompany initial and follow-up measurements. The term **quality assurance** refers to maintaining minimum acceptable standards of precision and accuracy in your testing program. Quality assurance measurements include side-by-side detectors (**duplicates**) and unexposed control detectors (**blanks**). **Appendix E** provides the procedure to help you evaluate the results of the quality assurance measurements.

Assessing the Precision of Your Measurements

Duplicates are pairs of detectors deployed in the same location side-by-side for the same measurement period. Duplicates should be placed in 10 percent of all measurement locations in a school building (they need not exceed 50 extra detectors). They are stored, deployed, placed, removed, and shipped to the laboratory for analysis in the same manner as the other devices so that the processing laboratory cannot distinguish them.

Since duplicates are placed side-by-side, the measured values for radon should be the same. For duplicate pairs where the average of the two measurements is greater than or equal to 4 pCi/L, they should not differ by more than 25%. If they do, each measurement is questionable. Problems in handling the detectors during the measurement process, in the laboratory analysis, or in the detector may introduce error into the test results. Consistent failure in duplicate agreement should be investigated.

Assessing the Accuracy of Your Measurements

Blanks can be used to determine whether the manufacturing, shipping, storage, or processing of the detector has affected the accuracy of your measurements. They are called "blanks" because they are not deployed in a room during the measurement period. As a result, blanks should give a result at or near to 0.0 pCi/L. Blanks are unwrapped (but not opened) and immediately rewrapped at the end of the exposure period. They are then shipped with the exposed devices so that the laboratory cannot distinguish the two sets of devices. The number of blanks should be 5% of the detectors deployed or 25 whichever is less.

Since blanks are not exposed to radon, their measurement value should theoretically be 0.0 pCi/L. Any value other than 0.0 is a measure of the accuracy of your measurements. For example, if a blank yields a result of 2 pCi/L, this indicates some problem with the measurement device or the laboratory analysis.

G. SUMMARY OF EPA RECOMMENDATIONS

- Initial short-term tests should be made in all frequently occupied, ground-contact rooms.
- Initial testing should be conducted during the coldest months when the heating system is operating and windows and doors are closed (except for normal exit/entry).
- If a school uses a short-term test of 2 to-5 days, the tests should be conducted on weekdays with the HVAC system operating normally.
- If the short-term test shows that the radon level in a room is 4 pCi/L or greater, schools should conduct either a second short-term test or a long-term test to confirm the presence of an elevated radon level.
- EPA does not recommend that schools use a single short-term test result as the basis for determining if action needs to be taken to reduce radon levels.
- Duplicates and blanks should accompany all testing programs (conducted by school personnel or a measurement firm) to provide assurance of the quality of the measurements.

- Trained school personnel or a RMP-listed measurement service should supervise and/or conduct a radon-testing program.

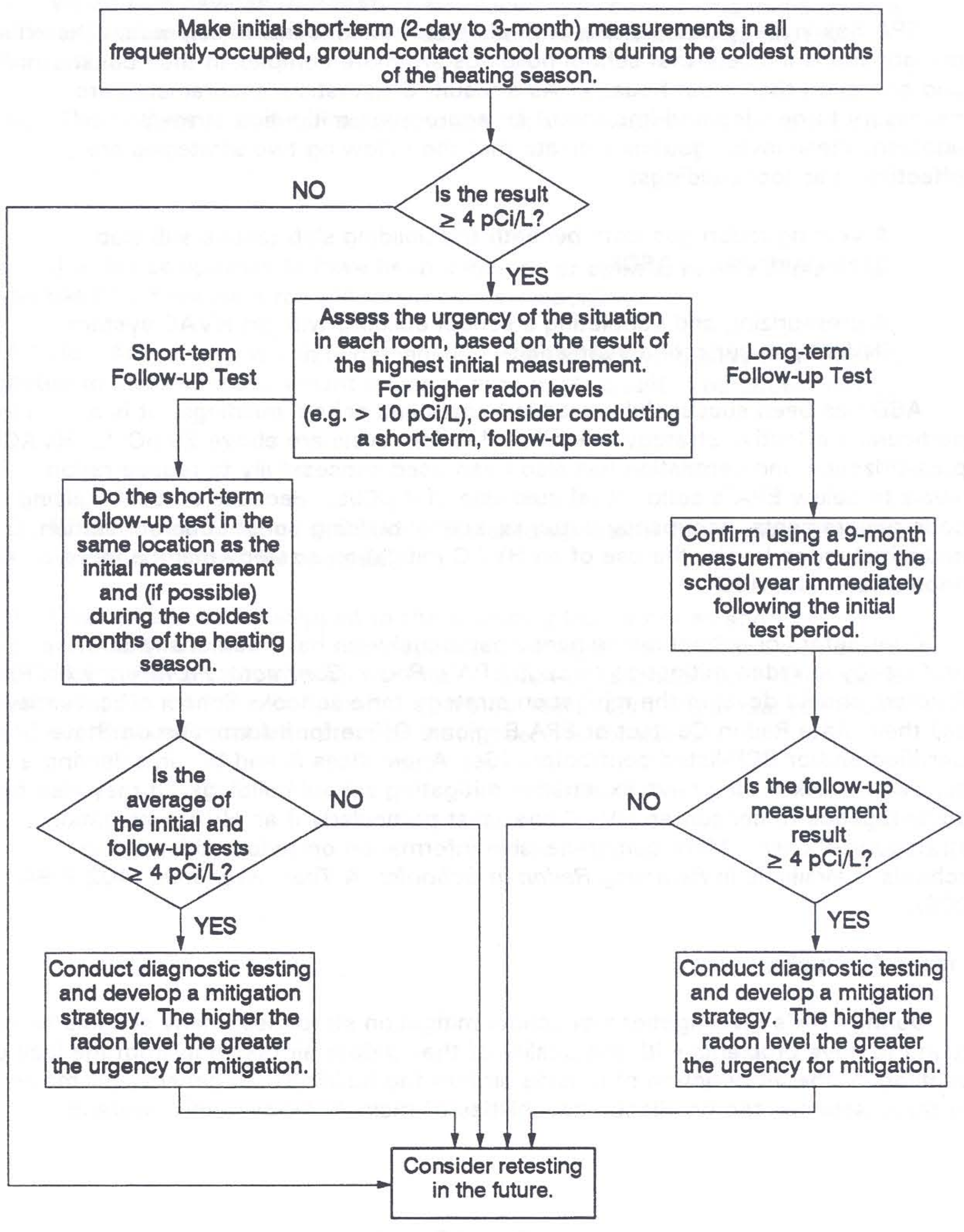
H. DECIDING HOW QUICKLY TO MITIGATE

How quickly to begin the diagnostic measurements that precede mitigation will depend on the urgency of the situation as dictated by the radon level detected. Very elevated radon concentrations (e.g., several times the action level or around 10 pCi/L) demand a quicker response. In addition, if radon levels are near 100 pCi/L or greater, school officials should call their State Radon Contact and consider relocating until the levels can be reduced.

I. DECISION-MAKING FLOW CHART

The decision-making flow chart on the following page summarizes the t testing guidelines from initial measurements through the decision to mitigate.

Decision-Making Flow Chart



SECTION III: REDUCING RADON CONCENTRATIONS

Introduction

EPA has investigated schools with elevated radon levels nationwide. These investigations indicate that school buildings are more complex in their construction and operation than most houses. As a result, diagnostic measurements are necessary to develop and implement an appropriate mitigation strategy. In addition, these investigations indicate that the following two strategies are effective in school buildings:

- venting radon gas from beneath the building slab (active sub-slab depressurization - **ASD**)

- pressurizing and ventilating a school building with an HV AC system (**HVAC pressurization/ventilation**)

ASD has been successfully used in homes and school buildings. It is a particularly effective strategy when initial radon levels are above 20 pCi/L. HVAC pressurization and ventilation has also been used successfully to reduce radon levels to below EPA's action level guideline of 4 pCi/L. Because of local building code requirements, occupancy patterns, school building construction/operation, and initial radon levels, the use of an HVAC mitigation strategy may be more appropriate than ASD.

Contractors or school maintenance personnel who have demonstrated proficiency in radon mitigation through EPA's *Radon Contractor Proficiency* (RCP) *Program* should develop the mitigation strategy for a school. School officials may call their State Radon Contact or EPA Regional Office for information on State-Certified and/or RCP-listed contractors (See **Appendices A and B**). In selecting a contractor, ask if they have experience mitigating school buildings. It may also be advantageous to consult an HVAC specialist particularly if an HVAC mitigation strategy is chosen. More comprehensive information on radon mitigation in schools is available in *Reducing Radon in Schools: A Team Approach* (402-R-94-008).

Indoor Air Quality

During EPA's investigations of school mitigation strategies, many schools were found to have problems with the quality of their indoor air resulting from the lack of ventilation (the introduction of outside air into the building). In general, for many of these schools, the ventilation capabilities of their HVAC system(s) were in disrepair or blocked to reduce heating and/or cooling costs. When considering the indoor air quality of high occupancy buildings like schools, proper ventilation is a significant part of an overall approach to its improvement.

Active Sub-slab Depressurization

ASD creates a lower air pressure beneath the slab to reverse the flow of air through the building foundation thus preventing radon entry. This is accomplished by installing a series of pipes that penetrate the slab or foundation walls. A high suction fan is attached to these pipes to draw and vent the soil gas (containing radon) from beneath the building foundation before the gas has a chance to enter into the building. When radon levels are greater than 10 pCi/L, ASD will probably be needed to lower levels below EPA's action level of 4 pCi/L. Although ASD is an effective strategy for controlling radon entry into buildings, it has no other demonstrable effect on the overall quality of indoor air within a school building other than its effects on radon levels.

The installation of an ASD system should be accompanied by the sealing of radon entry routes. Sealing will increase the effectiveness of the system and reduce the energy costs associated with operation of an ASD system. EPA does not recommend the use of sealing alone to reduce radon levels. EPA studies indicate that sealing will not lower radon levels consistently.

HVAC Pressurization/Ventilation

The HVAC system(s) in school buildings can directly influence radon entry by altering air pressure differences between the radon laden soil and the building interior. Depending on its type and operation, a school's HVAC system may produce positive or negative air pressure conditions within the building. Positive pressure within the building can prevent radon from entering a building while negative pressure can permit or, in some cases enhance, radon entry into the building.

The pressurization of a school building is accomplished when sufficient quantities of outdoor air are introduced into the building producing a positive air pressure within the building. Pressurization may require additional heating, cooling, and/or dehumidification that may exceed the capacity of the existing HVAC equipment. In addition, routine operation and maintenance will be necessary for this type of mitigation strategy to consistently reduce radon levels.

Restoring the ventilation capacity of an existing HVAC system to meet its original design specifications will, in some cases, achieve the appropriate level of building pressurization. If possible, ventilation rates should be increased to meet current ventilation standards. Proper ventilation through the introduction of outdoor air can reduce radon levels by diluting the radon that has entered the building. Some older schools may not have a mechanical ventilation system (HVAC). For these schools, consideration should be given to the installation of a ventilation system when addressing radon problems especially since such a system may contribute to an improvement in the overall indoor air quality of the school.

Because schools vary in their design, construction, and operation, there is no standard HVAC pressurization and ventilation strategy for all schools. As a result, an HVAC engineer may need to be consulted when considering HVAC pressurization and ventilation as a mitigation strategy.

SECTION IV: FREQUENTLY-ASKED QUESTIONS

A. RADON AND RADIATION:

Q: **Does radon cause headaches, eye irritation, or sick-building syndrome?**

A: No.

Q: **Do children have a greater risk than adults for certain types of cancer caused by radon exposure?**

A: Children have been reported to have greater risk than adults of certain types of cancer from radiation, but there are no conclusive data on whether children are at greater risk than adults from radon.

Q: **What is a picocurie of radiation and why are radon levels reported in units of picoCuries per liter?**

A: All radioactive substances are unstable and undergo radioactive decay. The amount of radioactivity can be assessed by the number of particles which decay each minute. A picocurie (pCi/L) of radiation is equal to 2.2 radioactive decays per minute. A measurement result of 1 pCi/L of radon gas means that in each liter of air there is enough radon to produce 2.2 radioactive decays each minute.

Q: What is a "Working Level"?

A: The working level (WL) is a unit used to measure radon decay products. The concentration of radon decay products suspended in the air can be measured and expressed in terms of working levels. Working levels, in turn, can be converted to the concentration of radon gas in pCi/L. The measurement of radon decay products is most frequently performed with continuous working level monitors (see **Appendix D**).

Q: Is radon in water a problem in schools? If so, how do we test for it?

A: The primary entry route of radon into schools is through the soil. However, radon can also enter through the water supply. It can then be released into the air while using water. While radon in water is not a problem for most public water supplies, it has been found in well water. Research suggests that swallowing water with high radon levels may also pose risks although these risks are believed to be much lower - in most cases - than those from breathing air containing radon. EPA has proposed regulations which would require the testing of public water supplies for radon and other radionuclides. These regulations also include requirements to reduce elevated levels of radon in the water supply. These requirements are scheduled to become final in October 1993.

If your school is serviced by a public water supply, the water will be tested for elevated radon levels. If an elevated radon concentration is detected, it will be reduced under the above requirements. If your school is on a well system and you have found elevated levels of radon in the indoor air, you should have the water tested for radon. For more information, call EPA's Drinking Water Hotline (1-800-426-4791) or your State Radon Contact.

Q: Is there any hazard involved in handling radon measurement devices?

A: No.

Q: How does background gamma radiation affect measurements?

A: Of the devices commonly used to make initial measurements in schools, only electret-ion chambers (EICs) are sensitive to and require correction for gamma radiation. Gamma correction is a simple calculation made by the service analyzing the devices. If a gamma radiation measurement is not made, a background value is assumed.

Q: Are building materials likely to contain or emit radon?

A: Radon emission from soil gas and its subsequent entry through the building foundation is the major source of radon contamination for schools. However, phosphogypsum wall board has been identified as a potential source of radon in building structures. The presence of phosphogypsum wall board in American buildings is very rare. Studies show that when phosphogypsum is present its contribution to the overall indoor radon concentration is quite small. EPA has not identified the presence of radon emanations from wall board in measurements conducted during field studies. In very rare cases, cinder blocks or concrete may contain enough radium to emit radon. However, the concentrations are likely to be insignificant.

B. PLANNING FOR TESTING:

Q: In *Radon Measurements in Schools - An Interim Report*, EPA recommended that 2-day tests be conducted over a weekend with HVAC operating continuously (i.e., at maximum setting). Are these test results still valid given the changes in the school measurement guidance?

A: Yes. EPA studies indicate that these two testing protocols generally yield similar results when conducted during the coldest months of the year. Therefore, schools which have tested according to the interim guidance do not need to retest using the revised guidance. EPA's revised recommendation to test on weekdays with normal HVAC operation does not require school personnel to deviate from the usual schedule of adjustments to HVAC controls and is designed to reflect, as much as possible, normal weekday conditions.

Q: Should testing be delayed if a school is planning major renovations to the building structure or to the HVAC system?

A: Initial and follow-up tests should be conducted prior to major HVAC or building structure renovations. If the test results indicate a radon problem, radon-resistant techniques can be inexpensively included as part of the renovation. Because major renovations can change the level of radon in any school, school officials should test again after the completion of the renovation to determine if the radon-resistant techniques are effective.

Q: EPA does not recommend testing the upper floors of a school. Does this mean that upper floors never have elevated levels?

A: Upper floors may have elevated radon levels. However, EPA studies indicate that a radon level for an upper floor room is not likely to exceed levels found on the first floor. Therefore, if all measurements in ground-contact rooms are below the action level, radon concentrations on upper floors are likely also to be below 4 pCi/L. Furthermore, mitigation of school rooms on the ground floor, if necessary, will also serve to reduce radon levels on upper floors.

Q: In schools with a basement level (below ground), the first floor is often built at grade level and, therefore, is in contact with the ground only along its outside edge. Should this floor be tested?

A: Although such a floor may have limited contact with the ground, the outside rooms may have openings permitting radon entry and should be tested if they are frequently occupied. If any of the rooms in the basement are frequently occupied or may be in the future (for example, if extra classroom space is anticipated), these basement rooms should also be tested. In addition, schools with crawl spaces between the ground and first floor should test all frequently-occupied first-floor rooms.

Q: Some schools and homes near us have reported finding no elevated radon levels. Do we still need to test?

A: Yes. Since radon levels in buildings vary with local geology, building structure, and HVAC system, schools in close proximity can exhibit dramatically different radon levels. The only way to know if the rooms in your school have elevated radon levels is to conduct radon testing in your school.

Q: What are the costs involved in testing for radon in schools?

A: The costs of testing are primarily dependent on the number of rooms to be tested, the type of measurement device used, and whether school personnel or a measurement company conduct the testing. As in the procurement of any equipment or services, it is best to get several estimates (see **Appendix C**).

C. CONDUCTING INITIAL MEASUREMENTS:

Q: If a room's short-term, initial test result is very high (for example, near 100 pCi/L), should remedial action be delayed to allow time for a follow-up measurement?

A: Schools should conduct a follow-up measurement before deciding to take remedial action. EPA's studies of radon measurements show that the results from short-term tests become more accurate as radon levels rise above 4 pCi/L. Therefore, under these circumstances, a school should consider doing a follow-up short-term test of 2 to 5-days to quickly confirm a high radon level and to eliminate the possibility of laboratory error. Consult your State Radon Contact or EPA Regional Office if you discover radon levels near or greater than 100 pCi/L in your schools (see **Appendices A or B**). It may be appropriate to relocate staff and students until the radon level is reduced.

Q: Should initial or follow-up measurements be conducted only during the hours when a school is occupied?

A: No. EPA recommends that both initial and follow-up measurements be conducted for a minimum of 48 *continuous* hours. This will measure the effects of daily fluctuations in radon levels in a room and include periods when radon levels may be at their highest. This provides a more conservative measure (i.e., more protective) of the radon levels. If elevated radon is found in a room, the diagnostic phase of mitigation can provide a more definitive picture of occupied hour levels. This will be part of the information used to decide how best to reduce radon levels.

D. TAMPERING/DETECTOR PLACEMENT:

Q: Should a room be retested if there is evidence of detector tampering?

A: Another test should be conducted under conditions which insure that tampering has not affected the measurement results.

Q: How do you place radon detectors in large, open areas such as cafeterias, gymnasiums, or auditoriums?

A: Since flat surfaces elevated from the floor are rare in gymnasiums and auditoriums, detectors may be hung from walls in these rooms. However, refer to the manufacturer's instructions for any restrictions on the deployment of their device. Hanging radon detectors from walls should only be done when absolutely necessary.

Q: How should we test partitioned classrooms?

A: Classrooms with moveable partitions should be individually tested if the partitions extend from the floor to ceiling.

E. WEATHER CONDITIONS:

Q: What should be done if unusual weather conditions (e.g., heavy rain, snow or wind) arise just before a planned 2 to 5-day winter testing period?

A: EPA recommends that schools avoid testing under these conditions. Therefore, testing should be postponed.

F. CONDUCTING FOLLOW-UP MEASUREMENTS:

Q: Why does EPA suggest a long-term, follow-up measurement of 9 months rather than a full year?

A: Schools generally conduct classes over a nine-month school year which excludes summer months. In such a case, the summer months should be excluded from the measurement period. If your facilities are used continually throughout the calendar year, and you plan to do a long-term test as a follow-up measurement, a 12-month test may be more appropriate.

Q: Is a long-term follow-up measurement of any duration greater than three months recommended?

A: EPA uses "long-term" to refer to any measurement over 90 days in duration. The longer the follow-up test, the better the picture of the average radon concentration for the school year. If circumstances prohibit testing over the full school year, consider testing for a measurement period of 6, 7, or 8 months if possible. If the initial test result was about 10 pCi/L or higher, a short-term follow-up test is more appropriate.

Q: Is it acceptable to use short-term follow-up tests for all rooms even though EPA's recommendation is to use a long-term follow-up test when the initial measurement for a room is slightly elevated above 4 pCi/L and to use a short-term follow-up test if the initial test is much higher (e.g., about 10 pCi/L or greater)?

A: Yes, it is acceptable. EPA recognizes that there can be a range of initial test results for rooms in a school and this approach may simplify follow-up testing. Both short-term and long-term radon tests can be used for making mitigation decisions.

Q: Should quality assurance measurements be made during the follow-up testing phase?

A: Yes. However, in most schools, there will be fewer follow-up measurements than during the initial measurement phase since only rooms with elevated initial measurement results receive follow-up tests. Even if only a few follow-up measurements are needed, a minimum of one duplicate and one blank should still be part of a testing plan.

Q: Is the use of continuous monitors ever appropriate for follow-up testing?

A: Continuous monitors, as well as any other radon devices, may be used for follow-up testing as long as they are used to measure a period of no fewer than 48 continuous hours - EPA's minimum acceptable duration for initial and follow-up measurements. Continuous monitors may be used in accordance with EPA's measurement protocols for periods of time less than 48 hours only as part of the diagnostic process.

G. QUALITY ASSURANCE:

Q: When two devices (duplicates) are placed in a room during initial testing for quality assurance purposes, which measurement result is taken as the test result for that room?

A: The arithmetic average serves as the initial measurement result for that room.

Q: If a device appears to have been damaged or opened before deployment, may it be used to measure a room's radon concentration?

A: No. Any device which is damaged or opened before deployment cannot be expected to yield a measurement result of acceptable quality and should not be deployed.

Q: What should be done if a device is picked up late or found after the other devices have been shipped for analysis?

A: Devices should be shipped to the analyzing laboratory as soon as possible, preferably within one or two days after testing ends. Devices that are not returned quickly may produce invalid results. If a device is picked up or discovered after two days, record the serial number of the device, record the actual retrieval time, and call the analytical laboratory or testing service for advice.

APPENDIX A

STATE/INDIAN NATION RADON CONTACTS

ALABAMA	800-582-1866
ALASKA	800-478-8324
ARIZONA	602-255-4845
ARKANSAS	501-661-2301
CALIFORNIA	800-745-7236
COLORADO	800-846-3986
CONNECTICUT	203-566-3122
DELAWARE	800-554-4636
D.C.	202-727-5728
FLORIDA	800-543-8279
GEORGIA	800-745-0037
HAWAII	808-586-4700
IDAHO	800-445-8647
ILLINOIS	800-325-1245
INDIANA	800-272-9723
IOWA	800-383-5992
KANSAS	913-296-6183
KENTUCKY	502-564-3700
LOUISIANA	800-256-2494
MAINE	800-232-0842
MARYLAND	800-872-3666
MASSACHUSETTS	413-586-7525
MICHIGAN	800-723-6642
MINNESOTA	800-798-9050
MISSISSIPPI	800-626-7739
MISSOURI	800-669-7236
MONTANA	406-444-3671
NEBRASKA	800-334-9491
NEVADA	702-687-5394
NEW HAMPSHIRE	800-852-3345 X4674
NEW JERSEY	800-648-0394
NEW MEXICO	505-827-4300
NEW YORK	800-458-1158
NORTH CAROLINA	919-571-4141
NORTH DAKOTA	701-221-5188
OHIO	800-523-4439
OKLAHOMA	405-271-1902
OREGON	503-731-4014
PENNSYLVANIA	800-237-2366
RHODE ISLAND	401-277-2438
SOUTH CAROLINA	800-768-0362
SOUTH DAKOTA	800-438-3367
TENNESSEE	800-232-1139
TEXAS	512-834-6688
UTAH	800-536-4250
VERMONT	800-640-0601
VIRGINIA	800-468-0138
WEST VIRGINIA	800-922-1255
WISCONSIN	800-267-4795
WYOMING	800-458-5847

PUERTO RICO	809-767-3563

All Indian Pueblo Council	505-881-2254
Cherokee Nation	918-458-5496
Chickasaw Nation	405-436-2603
Hopi Tribe	602-734-2441
Inner Tribal Council	602-248-0071
Jicarilla Apache Tribe	505-759-3242
Navajo Nation	602-871-7754
Oneida Indian Nation	315-361-6300
Seneca Nation	716-532-0024
St. Regis Mohawk Tribe	518-358-3141

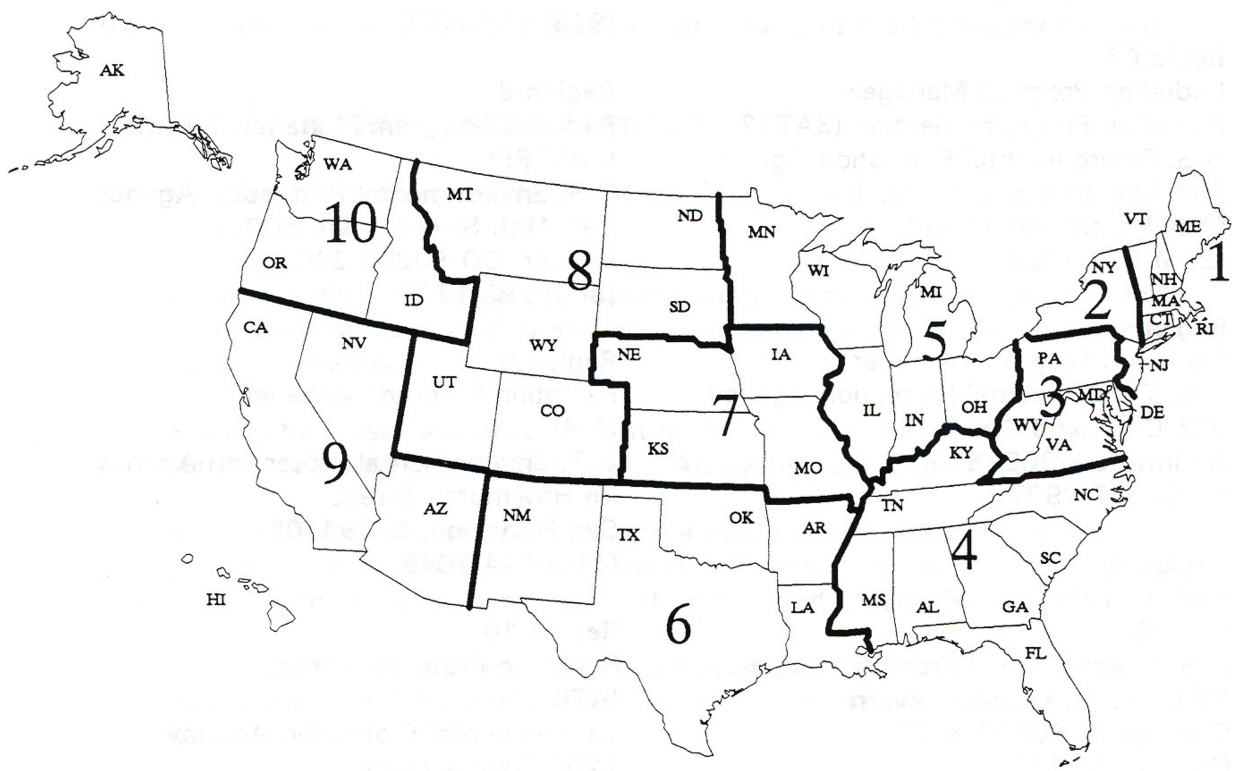
For Indian Nations in the States of MN, WI, MI, IL, IN, and OH 312-886-6063

APPENDIX B

EPA REGIONAL OFFICES AND RADON TRAINING CENTERS

Map of EPA Regions

Each of the 50 United States, as well as the District of Columbia, the Virgin Islands, and Puerto Rico, has been assigned to one of 10 Federal Regions. This map shows the Regional assignments for the 50 States. Puerto Rico and the Virgin Islands are assigned to Region 2. The District of Columbia is in Region 3. Identify your Region on the map below and refer to next page for a telephone number and address.



EPA REGIONAL RADIATION (RADON) PROGRAM MANAGERS

Region 1
Radiation Program Manager
U.S. Environmental Protection Agency
John F. Kennedy Federal Building
Boston, MA 02203-2211
(617) 565-4502

Region 2
Chief, Radiation Branch (2AWM-RAD)
U.S. Environmental Protection Agency
Federal Plaza, Room 1005A
New York, NY 10278
(212) 264-4110

Region 3
Radiation Program Manager
Radiation Programs Section (3A T12)
U.S. Environmental Protection Agency
841 Chestnut Street
Philadelphia, PA 19107
(215) 597-8326

Region 4
Radiation Program Manager
U.S. Environmental Protection Agency
345 Courtland Street, N.E.
Atlanta, GA 30365
(404) 347-3907

Region 5
Radiation Program Manager
(AT-18J)
U.S. Environmental Protection Agency
77 West Jackson Boulevard (A T -082)
Chicago, IL 60604-3507
(312) 886-6175

Region 6
Radiation Program Manager
U.S. Environmental Protection Agency
1445 Ross Avenue (6T -AG)
Dallas, TX 75202-2733
(214) 665-7223

Region 7
Radiation Program Manager
U.S. Environmental Protection Agency
726 Minnesota Avenue
Kansas City, KS 66101
(913) 551-7020

Region 8
Radiation Program Manager
(8ARTRP)
U.S. Environmental Protection Agency
999 18th Street, Suite 500
Denver, CO 80202-2405
(303) 293-1709

Region 9
Radiation Program Manager
(A-1-1)
U.S. Environmental Protection Agency
75 Hawthorne Street
San Francisco, CA 94105
(415) 744-1048

Region 10
Radiation Program Manager
(AT-082)
U.S. Environmental Protection Agency
1200 Sixth Avenue
Seattle, WA 98101
(206) 553-7660

RADON TRAINING CENTERS

Eastern Regional Radon Training Center (EERTC)
Rutgers University
Livingston Campus, Bldg. 4087
New Brunswick, NJ 08903

(908) 932-2582
FAX 908-932-4918

Southern Regional Training Center (SRRTC)
Auburn University
107 Ramsay Hall
Auburn University, AL 36849-5332

(800) 626-2703 or (205) 844-5719
FAX 205-844-5715

Western Regional Radon Training Center (WRRTC)
Department of Industrial Sciences
IS Bldg. Room 200-B
Colorado State University
Fort Collins, CO 80523

(800) 462-7459 or (303) 491-7742
FAX 303-491-7801

Midwest Universities Radon Consortium (MURC)
University of Minnesota
1985 Buford Avenue (240)
St. Paul, MN 55108-6136

(612) 624-8747
FAX 612-624-3113

APPENDIX C

USING A MEASUREMENT SERVICE

Although school personnel may design and implement a radon testing program, some schools may prefer to contract with an organization that provides radon measurement services. For example, in addition to supplying measurement devices and analytical services, a qualified measurement contractor could supervise the entire measurement procedure including the selection of sampling locations, the placement of measurement devices, and the implementation of a quality assurance program. Alternatively, a school may choose to place and collect measurement devices while the contractor selects the sampling locations and implements the quality assurance plan. Regardless of the degree of contractor involvement, the following guidelines may be useful when employing a radon measurement contractor:

Selecting a Measurement Service

- Invite the measurement service to walk through your school building before formulating their estimate.
- Select a measurement service that is listed with your State Certification Program or with EPA's *Radon Measurement Proficiency* (RMP) *Program*. Verify RMP-listing by requesting a copy of the current listing letter or an I.D. card.
- Request references and check contractor's service history with your State Radon Contact, Better Business Bureau, and State Department of Consumer Protection.
- Obtain several written proposals with bids for radon measurement services.
- Request written estimates which give the total number of devices needed in addition to their total costs. This will enable you to determine if the proposed quantity will be sufficient to measure all sampling locations and to conduct quality assurance measurements.

Evaluating Proposals from RMP-listed Services

- Review the quality assurance plan (QAP) of the measurement service. For companies providing measurement and/or analytical services (**primary services**), QAPs should contain procedures for the following:

  ___ calibration of instruments;

____ chain of custody for specific devices;

____ assessing contamination from background radiation; and

____ assessing accuracy and precision using spikes, blanks, and duplicates.

For companies providing measurement services only (**secondary services**), QAPs should contain:

____ testing procedures consistent with this document;

____ procedures for device deployment and retrieval consistent with manufacturer's instructions;

____ quality assurance procedures consistent with this document; and -use of State or RMP-certified analysis lab.

Developing a Contract

After selecting a contractor, request that they prepare a contract detailing the terms described in the proposal. Carefully read the contract before signing. Consider including the following in the contract:

- A limit on the time required to report the measurement results (EPA's RMP program requires reporting of results within 30 calendar days after completion of testing).

- The contract should include a description of exactly what work will be done prior to and during the testing period, the time required to complete the work, and the total cost of the job including all applicable taxes, permit fees, down payment (if any), and date of payment.

- A guarantee that the measurements will meet the standards required by EPA's RMP Program and the quality assurance guidelines outlined in this document. The guarantee should include provisions in the event that measurements do not meet these standards (e.g., to reconduct testing or portions thereof at no cost to the school).

- A statement that liability insurance and applicable worker's compensation coverage is carried by the organization in the event of injury to persons or damage to property during the measurement process.

APPENDIX D

MEASUREMENT DEVICES

This appendix contains brief introductory descriptions of the various measurement devices mentioned in this guidance document. Further information on each device, including EPA's approved protocols for their use and specific quality assurance requirements, may be found in EPA's document entitled *Indoor Radon and Radon Decay Product Measurement Protocols* (EPA 402-R-92-004). All devices used for measuring radon in schools should meet EPA *Radon Measurement Proficiency* (RMP) *Program* requirements and should be used in strict accordance with manufacturer's instructions.

Passive Device: A radon measurement device which requires no electrical power to perform its function. Passive devices are exposed to indoor air by being "uncapped" or similarly activated, then left in place for a length of time known as the measurement period. All of the devices described below are passive devices, except continuous monitors which are active devices.

Active Device: A measurement device which requires an electrical power source and which is capable of charting radon gas or radon decay product concentration fluctuations throughout the course of a given measurement period (usually by producing integrated periodic measurements over a period of two or more days).

Activated Charcoal Adsorption Devices (AC)

ACs are passive devices. The charcoal within these devices has been treated to increase its ability to adsorb gases. The passive nature of the activated charcoal allows continual adsorption and desorption of radon. During the entire measurement period (typically two to seven days), the adsorbed radon undergoes radioactive decay. This technique does not adsorb radon uniformly during the exposure period; as a result, these devices are not true integrating devices. Moreover, ACs should be promptly returned to the laboratory after the exposure period (by mail service that guarantees delivery within two to three days at maximum).

As with all devices that store radon, the average concentration calculated is subject to error if the radon concentration in a room varies substantially during the measurement period. Therefore, the recommendations discussed in **SECTION II (D)** should be followed when using AC devices.

Variations of AC are presently available. A device used commonly contains charcoal packaged inside an air-permeable bag. Radon is able to diffuse into this bag where it can be adsorbed onto the charcoal. Another device used commonly consists of a circular, 6 to 10-centimeter (cm) container that is approximately 2.5 cm deep and filled with 25 to 100 grams of activated charcoal. One side of the container is fitted with a screen that keeps the charcoal in but allows air to diffuse in the charcoal. For some of these devices, the charcoal container has a diffusion barrier over the opening. For longer exposures, this barrier improves the uniformity of response to variations of radon concentration with time.

Charcoal Liquid Scintillation (CLS) Devices

Charcoal liquid scintillation (CLS) devices are passive detectors which function on the same principle as charcoal canisters. CLS devices retain radon on 1 to 3 grams of charcoal in a glass vial approximately 1 inch in diameter and 2 ½ inches in height. They are called "liquid scintillation" devices because they are analyzed by transferring the charcoal with radon to a fluid and placed in a scintillation counter where the radon level is determined from the rate of scintillations (flashes of light) that result from the interaction of the radon decay products with the scintillation fluid. Like AC devices, CLS devices are not true integrating devices and sometimes contain a diffusion barrier. In addition, CLS devices must be resealed and sent to the laboratory for analysis promptly after the exposure period (by mail service that guarantees delivery within two to three days).

Electret-Ion Chambers (EICs)

Electret-ion chamber detectors (EICs) are passive devices which function as true integrating detectors measuring the average radon gas concentration during the measurement period. EICs take advantage of the fact that the radiation emitted from the decay of radon and its decay products imparts an electrical charge on the airborne particles that are released during the decay of these particles. These charged particles (ions) are attracted to an electret (electrostatically charged disk of Teflon®) in the EIC housing which reacts to their presence by losing some of its voltage. The amount of voltage reduction is directly related to the average concentration of radon within the chamber during the exposure period.

EICs may be designed to measure for short periods of time (e.g., 2 to 5 days) or for long periods of time (e.g., 9 months). The type of the electret (i.e., short or long-term) and chamber volume determine the usable measurement period. The electret is removed from the canister and its voltage measured with a special surface voltmeter both before and after the exposure period. The difference between these two voltage readings is used to calculate the average radon concentration. The devices may be sent to a laboratory for measurement, or a school can purchase special equipment (i.e., voltmeter) that can measure the radon concentration soon after its detection. Schools that purchase voltmeters for reading electrets should enroll in the Radon Measurement Proficiency Program or have special training for operating these instruments.

Alpha Track Detectors (ATDs)

An alpha track detector (ATD) is a passive device consisting of a small piece of plastic or film (the sensor) enclosed in a housing with a filter-covered opening. Radon diffuses through the filter into the housing where it undergoes radioactive decay. This decay produces particles of alpha radiation which strike the sensor and generate submicroscopic damage called alpha tracks. Alpha tracks on the sensor can be counted under a microscope in a laboratory. The number of tracks counted determines the average radon level over the exposure period. ATDs have no bias toward a specific part of the exposure period; therefore, they function as true integrating devices. In addition, they are most commonly used for measurements of three to nine months in duration.

Continuous Radon Monitors and Working Level Monitors

Continuous monitors are the only active devices mentioned in this list. They utilize various types of sensors. Some collect air for analysis with a small pump while others allow air to diffuse into a sensor chamber. All have electrical circuitry capable of reporting (and usually recording) integrated radon concentrations for periodic intervals (e.g., every hour or every five minutes). Continuous radon monitors measure radon gas. Continuous working level monitors, on the other hand, measure radon decay product concentrations. Schools that purchase continuous monitors should participate in the Radon Measurement Proficiency Program or have special training to operate these instruments.

APPENDIX E

QUALITY ASSURANCE PROCEDURE

After receiving the results from the analysis of your initial or follow-up tests, take the following steps to evaluate whether or not these measurements were conducted with adequate quality. To perform these steps, you will need your completed Device Placement Log (See **Appendix F**).

Analysis of Duplicates

The following steps are for activated charcoal adsorption devices, electret-ion chamber devices, charcoal liquid scintillation devices, and alpha track devices. See **SECTION II (F)** for a brief discussion on the use of duplicates to evaluate the precision of your measurements.

____ 1 Identify your duplicate measurements on the Device Placement Log. Each row containing a "D" in the "Room #" column represents the <u>second duplicate</u> pair (hereafter, D_2). The device listed in the row immediately above the "D" listing is the first duplicate pair (hereafter, D_1).

____ 2 Transfer the results for each duplicate pair to the **Duplicate Log** (see sample at the end of this appendix). Place the first duplicate in the " D_1" column. Place the second duplicate in the " D_2" column. Repeat this step for all duplicate pairs.

____ 3 Calculate the average (mean) for each duplicate pair using the following equation:

$$\text{average } (\mathbf{M}) = \frac{D_1 + D_2}{2}$$

____ 4 Record the average of the pair in the "M" column of the **Duplicate Log**.

____ 5 Place an "**X**" in the "M ≥ 4" column for duplicate pairs that have an average of 4 or greater. The following steps should only be conducted for those duplicate measurements where the average of the two measurements is greater than or equal to 4 pCi/L. If the average for every duplicate pair is below 4, see the footnote at the end of this appendix.

____ 6 Count the total number(**N**) of "**X**'s" in the "M ≥ 4" column. Write this total in the space indicated at the bottom of the "M ≥ 4"column.

____ 7 Calculate the **relative percent difference (RPD)** for each duplicate pair that has an "**X**" in the "M ≥ 4" Column using one of the two formulas below:

a) If D_1 is greater than D_2, then the

$$\text{relative percent difference } (\mathbf{RPD}) = \frac{D_1 - D_2}{\mathbf{M}} \times 100 = \_\_\_\_\_\_\_\_ \%$$

b) If D_2 is greater than D_1, then the

$$(\mathbf{RPD}) = \frac{D_2 - D_1}{\mathbf{M}} \times 100 = \_\_\_\_\_\_\_\_ \%$$

____ 8 Record the relative percent difference in the "RPD" column.

____ 9 Determine the **total relative percent difference (TRPD)** by adding together all the "RPD" values in the "RPD" column. Record the **TRPD** in the space indicated at the bottom of the "RPD" column.

____10 Determine the **average relative percent difference (ARPD)** for all duplicate pairs by dividing the **TRPD** (from step 9) by the N (from step 6). Record this result here **ARPD** = ________ (see the example calculation using data from the sample duplicate log on the next page).

$$(\mathbf{ARPD}) = \frac{\text{TRPD}}{\text{N}} = \frac{49.0}{4} = 12.3\%$$

____11 If the ARPD for all duplicate pairs exceeds 25%, then the quality of the measurements is questionable. Contact the laboratory analyzing the devices or the measurement service for assistance in determining if there is a problem and if any retesting is necessary.

Analysis of Blanks

The following two steps are for all passive measurement devices. See **SECTION II (F)** for brief discussion on the use of blanks to evaluate the accuracy of your measurements.

____1 Identify your blank measurements on the Device Placement Log. Note each row containing a "B" on the Room #/Name column represents a blank.

___ 2 If any of the blank measurements is equal to or greater than 1.0 pCi/L, contact the analyzing laboratory or measurement service and request an explanation for the inaccuracy in the blank result.

DUPLICATE LOG

D_1	D_2	M	M≥4 *	RPD
			N =	TRPD =

SAMPLE

D_1	D_2	M	M≥4*	RPD
1.4	1.2	1.3		
0.8	1.1	1.0		
3.9	3.5	3.7		
4.6	5.1	4.9	X	10.2
4.1	3.8	4.0	X	7.5
0.3	2.0	1.2		
0.8	0.5	0.7		
6.4	7.2	6.8	X	11.8
4.2	2.5	3.4		
1.8	2.4	2.1		
3.0	2.3	2.7		
4.5	3.7	4.1	X	19.5
0.5	0.6	0.6		
			N = 4	TRPD = 49.0

* Duplicate pairs with an average less than 4 are not considered because of the inherent limitations of measurement devices at radon concentrations below 4 pCi/L of air. If the average of each duplicate pair is below 4, assume that the precision of the duplicate measurements is acceptable given the measurement device's limitations and proceed to the *Analysis of Blanks* section.

APPENDIX F

PROCEDURAL CHECKLIST FOR RADON TESTING

The following checklist presents a step-by-step guide for conducting a radon testing program for a school building. The issues discussed in **SECTION II** of this document have been incorporated into this checklist in chronological order. The reader should be familiar with the issues discussed in this section before using this checklist. In addition, the reader should review and understand each section of this checklist before proceeding through the steps.

A **Device Placement Log** has been included at the end of this appendix. Several copies of this log sheet should be made before initiating a testing program. You will use these log sheets to record relevant information as you proceed through these steps.

<u>Planning a Testing Program</u>

____ 1 If possible, plan to test in the early part of the cold weather testing season in your area (e.g. October to March) so that follow-up measurements (if needed) may be conducted under similar conditions. If using 90-day measurements, start early in the heating season.

____ 2 Early in the planning phase, count the rooms to be tested (e.g., all frequently-occupied, ground-contact rooms). Add an additional 15 percent of this total to account for the duplicates (10%) and blanks (5%) but do not exceed 50 duplicates and 25 blanks. This will give you the number of detectors that you will need to conduct a testing program.

____ 3 Your selected measurement device should be listed with EPA's *Radon Measurement Proficiency* (RMP) *Program*. To insure that a device is RMP-listed check its packaging for the phrase "meets EPA RMP-requirements" or "meets EPA proficiency requirements". If these phrases are not on the packaging call your State Radon Contact (see **Appendix A**).

____ 4 Use a floor plan to identify the rooms where initial testing will be conducted. Simple diagrams like the **Sample Floor Plan** provided at the end of this appendix are adequate for this purpose. Make a check in each room to be tested. If you do not have standard room numbers for all of these rooms, assign numbers to them.

These numbers will be used to match devices with the rooms where they were deployed. Record these numbers on your floor plan.

____ 5 A few days before the beginning of the test period, go to each room and choose a location for the detectors. Note these locations (e.g., south wall filing cabinet) on the **Device Placement Log** (see example at the end of this appendix). This will prevent excessive delays during device deployment. Follow the guidelines for detector placement in **SECTION II (C)** of this document.

____ 6 The walk-through described in step 5 is also the best time to select rooms in which duplicate devices will be deployed. Mark these rooms with a large "D" on your floor plan. Approximately 10% of the rooms tested should contain duplicates placed side-by-side.

____ 7 Randomly mark with a "B" on your floor plan as many rooms as the number of blanks you will need. This will enable you to intersperse the duplicates and blanks on the Device Placement Log (hereafter, log sheet) that you send to the analyzing laboratory so that the lab will not be able to tell which of the recorded measurements are duplicates and blanks. Make copies of your completed floor plan and log sheets and keep it in a file that documents your testing program.

____ 8 When the measurement devices arrive from shipment, count them to make sure that there will be enough. Carefully read all the information provided by the manufacturer and/or supplier regarding detector handling, deployment procedures, shipping, detector shelf life, etc. **It is very important that you understand and follow all instructions provided with your detector.** Should you have any questions, call the manufacturer, State Radon Contact, or EPA Regional Office for assistance.

<u>Deploying the Measurement Devices</u>

____ 9 Notify students and staff about testing and provide educational materials on radon before the testing period begins. This will help to prevent inadvertent tampering, damage and/or loss of detectors. Emphasize to students and teachers that a reliable test result depends on their cooperation because any disturbance with the test device or interference with the closed conditions, especially during short-term test, will invalidate the test results.

___10 Other information to be recorded for each device includes: room number and/or name, deployment location, device number (the manufacturer's serial number), date and time of deployment ("start date and time"), date and time of pickup ("stop date and time"), and comments (for noting any special circumstances, such as evidence of tampering, late pickup, etc.). The **Device Placement Log** (hereafter, log sheet) may be used to record this information. The first four columns of the form may be filled out a day or two early in order to save time during deployment.

___11 Remember to intersperse locations for duplicates and blanks on the log sheet (see steps 13 and 15 below). The **Sample Floor Plan** and **Sample Device Placement Log** at the end of this appendix provide an example of how rooms on the floor plan are recorded on the log sheet.

___12 All radon detectors should be deployed in a school on the same day. On the day of deployment, place detectors in the preselected locations in each room and carefully note the time of deployment (for example, "5:42 P.M."). Since the recorded time of deployment should not be off by more than about ten minutes, make certain to record it immediately after opening and deploying the device. This is particularly important for 2 to 5-day measurements.

___13 Duplicate devices should be placed in all rooms marked earlier with a "D" on your floor plan. Duplicate pairs are placed **side-by-side** in the same room so that they will measure the same air. Both devices of a duplicate pair should be given separate entry lines in the log sheet. Place a "D" in the "Room #/Name" and "Location" columns for the second device of the pair so that duplicate pairs will be easy to distinguish from the other measurements on the log sheet. These columns will later be covered so that the analyzing laboratory will be unable to distinguish the duplicates from the other measurements.

___14 Record the serial numbers for the two devices of a duplicate pair as you would for the other measurements but add a few minutes (e.g., 2 to 5) to the deployment time for the second device of the pair so that the lab will not know that they were duplicates deployed at the same time and location. See the completed log sheet at the end of this appendix for an example of how to record duplicates on a log sheet. Pause for a few minutes before deploying the detector in the next room to avoid having similar "start times" between the duplicate and the detector in the next room.

___15 **Blank devices should not be deployed**. Instead, they are kept in safe storage, unopened, throughout the measurement period. Blanks should be recorded in the log sheet as separate entries immediately following the listings for rooms marked earlier on the floor plan with a "B". Carefully record on the log sheet the serial number of the blank device before setting it aside.

___16 Place a "B" in the "Room #/Name" and "location" columns of the log. Although the blanks are not actually deployed, it is still important to record deployment dates and times for these blank devices. Do this by adding a few minutes (e.g., 2 to 5) to the deployment time that you recorded for the device listed just prior to the blank's listing. A completed log sheet at the end of this Appendix has an example on how to record blanks on the log sheet.

___17 Depending on the type of radon detector you purchase, there might be a label on each device for recording the dates and times of deployment and retrieval. If so, record this information on the labels as well as the Device Placement log. This redundancy assures that the laboratory will use the correct dates and times in calculating room radon levels.

<u>Record Keeping During Testing</u>

___18 During testing, particularly if you are conducting 2-day to 5-day tests, note in the "Comments" column of the log sheet any unusual or extreme weather conditions (such as snow storms, heavy rain or high winds) that occur just before or during the measurement period.

<u>Retrieving the Measurement Devices</u>

___19 On the last day of the deployment period, all devices must be retrieved. Make sure that you have read all manufacturer's instructions about retrieving, closing, and resealing the detectors since each type of device has its own procedures.

___20 When picking up each device, check its location and serial number with what was recorded during deployment. Note any discrepancies in the "Comments" column of the log sheet. If the serial number does not agree with the one listed, change the number in the log to the "new" one and note the change as a comment.

___21 Record the date and time of retrieval in the log sheet for each device. Do the same for duplicates and blanks, adding a few minutes (e.g., 2 to 5) to the retrieval time that you recorded for the device listed just above. It may be necessary to pause for a few minutes before retrieving the detector in the next room to avoid time entries too close together. Finally, print your name in the space provided at the end of the log sheet. The Sample Device Placement Log at the end of this appendix provides an example of how to record this information.

Preparing the Devices for Analysis

___22 After retrieving the deployed detectors, blank devices must be prepared and mixed in with these detectors for shipment. In preparing the blanks, remember that the laboratory analyzing the devices should not be able to recognize them as blanks. Therefore, any seals on the blanks must be broken (in some cases, the device must be opened and immediately reclosed) and resealed in the same manner as the deployed detectors.

___23 When devices have been retrieved and prepared for shipment, make sure that all the necessary information for each device has been recorded on the log sheet.

___24 ***Make a special copy of the log sheet for the analyzing laboratory by covering the "Room #/Name" and "Location" columns*** with a blank piece of paper before copying. Be careful not to cover any of the other columns particularly the device serial number and the start/stop dates and times. This special copy of your log sheet keeps the identities of the duplicates and blanks masked from the lab.

___25 ***Include this special copy of the log sheet with the shipment of detectors that were deployed in the school.***

SAMPLE **DEVICE PLACEMENT LOG**

SCHOOL: Oldtown High School

Room # / Name	Location	Serial #	Start Date	Start Time	Stop Date	Stop Time	Comments	Result
100	S wall cabinet	65093	11/1/93	7:22 AM	11/5/93	4:34 PM		
102	bookshelf	93277	"	7:26 AM	"	4:37 PM		
104	file cabinet	17349	"	7:31 AM	"	4:42 PM		
106	file cabinet	84758	"	7:33 AM	"	4:44 PM		
B	B	09543	"	7:35 AM	"	4:46 PM		
108	teacher's desk	69299	"	7:37 AM	"	4:49 PM		
110	on lockers	59021	"	7:40 AM	"	4:51 PM	slight damage	
112	above shelves	48770	"	7:45 AM	"	4:53 PM		
114	storage cabinet	56673	"	7:47 AM	"	4:56 PM		
116	N wall	80173	"	7:50 AM	"	4:58 PM		
115	bookshelf	28556	"	7:52 AM	"	5:01 PM		
113	shelf (SE side)	74305	"	7:55 AM	"	5:03 PM		
D	D	97033	"	7:58 AM	"	5:06 PM		
111	2nd file cab.	86848	"	8:02 AM	"	5:08 PM		
109	hung from ceil.	96026	"	8:05 AM	"	5:12 PM		
107	on shelf	19485	"	8:08 AM	"	5:14 PM		
105	fire ext. case	67809	"	8:12 AM	"	5:17 PM	device fell	
103	desk (W corner)	32289	"	8:14 AM	"	5:19 PM		
101	N wall shelves	65617	"	8:17 AM	"	5:21 PM		
D	D	22021	"	8:20 AM	"	5:24 PM		

NAME: ____________________

DEVICE PLACEMENT LOG

SCHOOL:________________________

Room # / Name	Location	Serial #	Start Date	Start Time	Stop Date	Stop Time	Comments	Result

NAME: ________________________

SAMPLE FLOOR PLAN

SCHOOL: Oldtown High School