NAVY RADON ASSESSMENT AND MITIGATION PROGRAM

GUIDEBOOK

FOR

NAVAL SHORE INSTALLATIONS

June 6, 2015

prepared for
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ABBREVIATIONS, ACRONYMS, AND INITIALISMS

ACH	air change per hour
ASD	active soil depressurization
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
ASTM	American Society for Testing and Materials
ATD	alpha track detector
Bq/m^3	Becquerel per cubic meter
BUMED	US Navy Bureau of Medicine and Surgery
CDC	Centers for Disease Control
cfm	cubic foot per minute
cm	centimeter
COMNAVFACENGCOM	Commander, Naval Facilities Engineering Command
CRM	continuous radon monitor
DoDDS	Department of Defense Dependent Schools
DoDEA	Department of Defense Education Activity
DOE	US Department of Energy
DON	Department of the Navy
DP	differential pressure
EACM	episodic air change measurement
EPA	US Environmental Protection Agency
ER	equilibrium ratio
ERV	energy recovery ventilation
FGS	Final Governing Standards
ft	foot
h	hour
h^{-1}	per hour
HEPA	high-efficiency particulate air
HVAC	heating, ventilating, and air-conditioning
IRAA	Indoor Radon Abatement Act
L	liter
LFE	lateral field extension
LLD	lower level of detection
MERV	minimum efficiency reporting value
NAVFAC EXWC	Naval Facilities Engineering and Expeditionary Warfare Center
NAVFAC Pacific	Naval Facilities Engineering Command Pacific
NAVRAMP	Navy Radon Assessment and Mitigation Program
NRPP	National Radon Proficiency Program
NRSB	National Radon Safety Board
O&M	operation and maintenance
ORNL	Oak Ridge National Laboratory
pCi	picocurie
pCi/h	picocurie per hour

pCi/L	picocurie per liter
PFET	pressure field extension test
ppm	parts per million
PPV	public private venture
QA/QC	quality assurance/quality control
RCP	risk communication plan
RDP	radon decay product
RMP	radon management plan
RPC	radon potential category
RPD	relative percent difference
RRNC	radon-resistant new construction
SAM	supplemental air makeup
SDWA	Safe Drinking Water Act
SMD	submembrane depressurization
SP	shell pressurization
SPT	subslab permeability test
SSD	subslab depressurization
TSCA	Toxic Substances Control Act
UIC	Unit Identity Code
UFC	Unified Facilities Criteria
UFGS	Unified Facilities Guide Specification
USGS	US Geological Survey
USMC	US Marine Corps
WHO	World Health Organization
WL	working level
WLM	working level month

1. INTRODUCTION

This document was developed in support of the Naval Facilities Engineering Command Pacific (NAVFAC Pacific) under US Department of Energy (DOE) Proposal 2172-S515-A1 for the performance of radon technical support. DOE assigned the project to its Oak Ridge National Laboratory (ORNL) Building Technologies Research and Integration Center, managed by UT-Battelle, LLC, to assist with this agreement with NAVFAC Pacific.

1.1 PURPOSE OF THIS DOCUMENT

This document explains current radon policy for Navy and Marine Corps personnel in conducting the Navy Radon Assessment and Mitigation Program (NAVRAMP) and provides guidance for the implementation of radon-resistant new construction (RRNC), radon testing, radon mitigation, and radon system maintenance activities within all buildings except family housing. Also provided in this document (Appendix E) is a more detailed discussion of different aspects of radon (e.g., radon and geology, radon entry into structures, exposure risks, risk communication, radon measurement, US Environmental Protection Agency (EPA) protocols, mitigation diagnostics, and mitigation). This information has been provided to serve as an initial reference for installation personnel involved with NAVRAMP implementation and is also suitable for both internal and public dissemination as circumstances dictate.

1.2 DOCUMENT APPLICABILITY

This document is provided as the primary reference and implementation guide for all Navy and Marine Corps radon projects conducted in nonresidential buildings which for the purposes of this document included bachelor housing, lodges, temporary lodging facilities, and transient quarters. It is applicable to all naval installations worldwide. For radon guidance in family housing, please consult *Navy Radon Assessment and Mitigation Program Guidance Document for Navy Family Housing* (US Navy 2002).

1.3 DOCUMENT ORGANIZATION

The document is organized as follows.

Chapter 1: Introduction

- General overview of radon (Section 1.4)
- Suggested installation starting point (Flowchart 1)

Chapter 2: Overview of radon regulations and Navy/Marine Corps radon policy and implementation guidance

- Regulation (Section 2.1)
- Navy radon policy (Section 2.2)

- Marine Corps radon policy (Section 2.3)
- NAVRAMP implementation strategies
  - Radon testing (Sections 2.5 to 2.7)
  - Required NAVRAMP testing status actions for all Navy and Marine Corps installations worldwide (Section 2.8)

Chapter 3: Guidance and instructions for performing radon testing within nonresidential buildings, which for the purposes of this guidebook include bachelor housing, lodges, temporary lodging facilities, and transient quarters

- Radon testing device selection and procedures (Section 3.2.1 to 3.2.6)
- Measurement and data set validation procedures (Section 3.5)
- Testing contractor qualifications (Section 3.3.4)

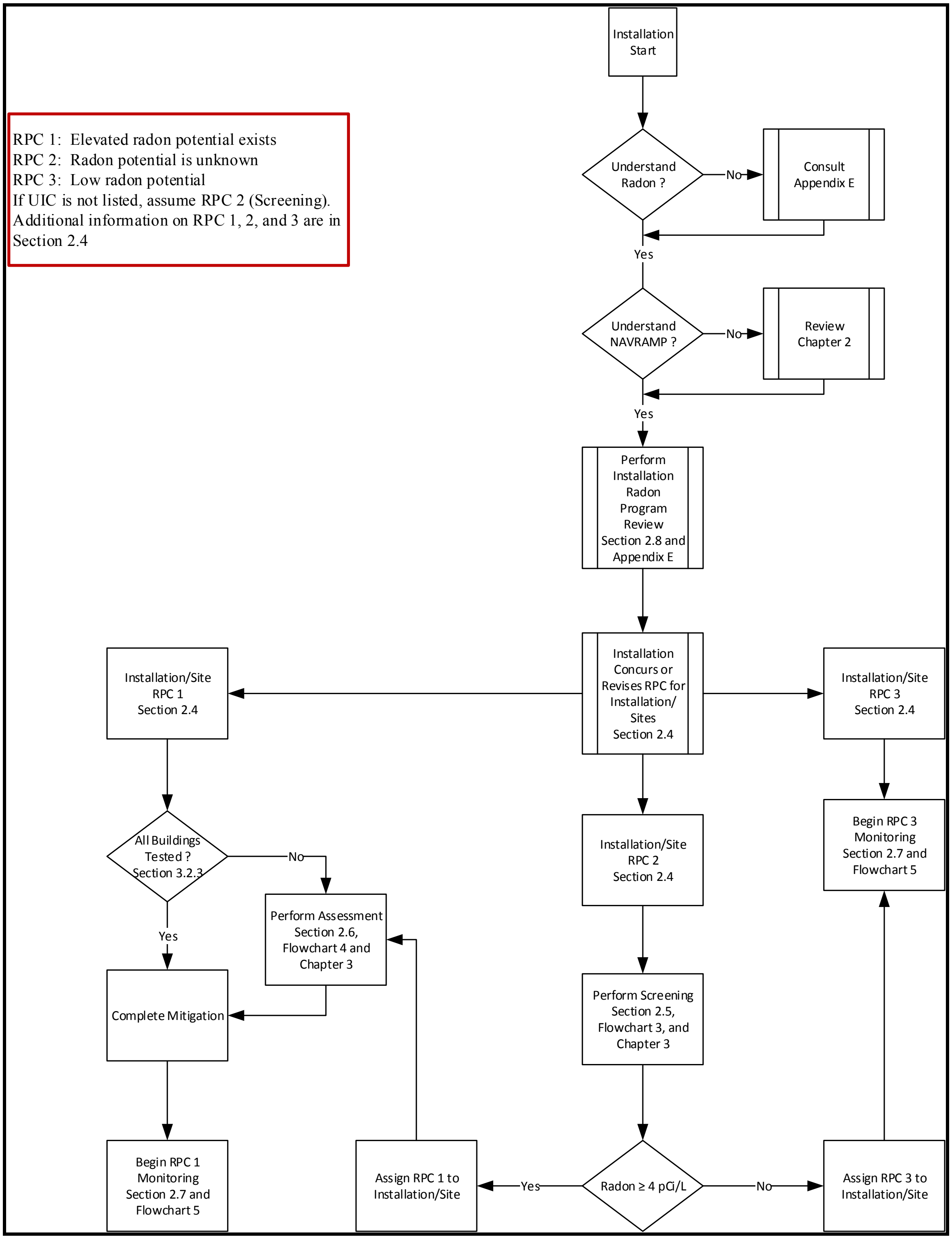
Chapter 4: Guidance and instructions for performing radon mitigation within nonresidential buildings, bachelor housing, lodges, temporary lodging facilities, and transient quarters

- Navy and Marine Corps requirements for radon mitigation systems (Sections 4.1 and 4.2)
- Required maintenance of radon mitigation systems (Section 4.4)
- Mitigation contractor requirements (Section 4.2.6)
- Design considerations for incorporating radon-resistant features in new construction (Section 4.3)

Appendix A: EPA correspondence
Appendix B: Initial radon potential category for naval installations
Appendix C: Example of a radon testing handout
Appendix D: Example of a radon mitigation system inspection form
Appendix E: Radon reference section

- Integration of various EPA, ASTM, and ANSI guidelines, recommendations, and procedures
- Overview of radon and radon entry and retention in structures
- Radon measurement overview
- Radon exposure risk and risk communication information
- Radon mitigation diagnostics and mitigation
- Radon resistance in new construction

Flowchart 1 provides a suggested initial starting point for the installation in the use of this guidebook.



Flowchart 1. Suggested installation starting point for initial use of the document.

1.4 OVERVIEW OF RADON

Radon is a naturally occurring, odorless, colorless radioactive gas that is released from rock, soil, and water as part of the natural decay of uranium. Although radon levels in outdoor air pose a relatively low threat to human health, indoors, radon can accumulate to dangerous levels. Exposure to indoor radon is the second leading cause of lung cancer in the United States and the number one cause among nonsmokers. The EPA estimates that radon causes more than 20,000 lung cancer deaths in the United States each year. Only smoking causes more lung cancer deaths. (EPA 2013, US Surgeon General 1989, BEIR 1998, 1999).

Although elevated indoor radon can come from water supplies or building materials, almost always, the problem comes from radon emanation from the soil under or surrounding a building (EPA 2012). The reason is that radon is chemically inert (it does not interact with other substances), so it can usually move unhindered through 1–2 meters of soil. Once in contact with building components in soil contact (e.g., slab, foundation, wall, crawlspace), it can easily enter into the building through cracks or openings and in some cases diffuse through pores in concrete masonry units or even through solid concrete. It is important to note that after radon enters the building from the soil, many factors influence its retention. Building design, usage, air change rate (a measure of the ventilation rate within a building), occupancy pattern, building shell pressure (buildings under negative pressure typically enhance radon entry), and type and operational patterns of a building's heating, ventilation, and air-conditioning (HVAC) system have all been shown to influence radon levels within a building (EPA April 1994a). Because none of these building factors, including the radon soil gas concentrations under the building, can be accurately measured or estimated, the only way to know for sure if radon is present at unacceptable levels is to test (EPA 2012).

Indoor radon measurements are relatively simple to perform and are essential to assess radon concentration in a building. Performing radon testing is typically not disruptive to the occupants (the most common types of detectors emit no noise or odors) and usually take only a few minutes per testing location to perform. However, radon concentrations within a building do vary from day to day because of episodic weather patterns (e.g., wind, and rain) and can vary significantly from season to season. Because the risk to radon exposure is based on an annualized dose, both the EPA (EPA 2012) and the World Health Organization (WHO 2009) recommend that the radon testing be performed for as long as practical to ensure a representative measurement.

In single-family homes and small commercial buildings (e.g., <5,000 ft ^{2}), one testing location on the lowest occupied level of the building typically is sufficient to determine whether elevated radon is present. Regarding which room to test, studies have shown that most of the time the radon levels do not vary significantly from room to room on the same level in these types of structures. However testing in a centrally located area or room away from outside doors or windows usually gives the most representative results (EPA May 1993). Unlike in these smaller structures, radon levels within large buildings (e.g., >5000 ft^{2}) such as schools and commercial buildings can and do vary significantly from room to room. In fact, most of the time when elevated radon is found in a large building, it is typically limited to only a few rooms and the rest have acceptable levels. The primary reasons are the differences in building structure and construction techniques, occupancy patterns, and HVAC operation (WHO 2009). To address this problem, EPA and the American National Standards Institute (ANSI) recommend that all ground-contact rooms in a large building be tested (EPA July 1993 and ANSI 2014a).

In the United States, radon is measured in picocuries per liter of air (pCi/L). EPA and the Centers for Disease Control and Prevention recommend that corrective actions be taken at 4 pCi/L or higher. In addition, EPA also recommends that Americans consider corrective actions for radon levels between 2 pCi/L and 4 pCi/L as well (EPA 2013). As for how soon corrective action should be taken, historically EPA recommended (EPA 1986) a timeline ranging from a few weeks to years, depending on the radon result (i.e., 4 to <20 pCi/L, a few years; >200 pCi/L, a few weeks). However, currently EPA recommends that corrective action be taken for any test result ≥4 pCi/L (EPA 2012) as soon as possible to lower the lifetime risk of radon-induced lung cancer.

EPA divides radon mitigation into two basic categories: passive and active (EPA August 1988). Passive mitigation is defined as a nonmechanical means of radon abatement or control. Examples include sealing cracks in contact with soil, balancing an existing mechanical system, or increasing the natural ventilation rate of the building substructure (i.e., crawlspace). Active mitigation entails the use of mechanical means, such as a fan or blower, to control radon entry into the inhabited space and can be grouped into two categories: pre-entry and post-entry mitigation. Pre-entry mitigation is a technique that retards radon entry into the building. Common examples of this type are shell pressurization (SP) and active soil depressurization (ASD); these include subslab depressurization (SSD) for buildings with slabs and sub-membrane depressurization (SMD) for buildings with crawlspaces. Post-entry mitigation involves the treatment of the radon-laden air inside the room or building. Examples are energy recovery ventilation (ERV) and supplemental air mitigation (SAM). The selection of the most appropriate mitigation method for a building depends on many factors, the most common being building design and usage, installation and long-term operation costs, and aesthetics. To assist with the selection of a mitigation method, EPA recommends that diagnostics (scientific tests that help with the selection of the most appropriate mitigation method) be performed (EPA April 1994a). After mitigation system installation, it is imperative that the system be routinely inspected and maintained and the building retested periodically (EPA April 1994b) to ensure that effective radon control is still occurring.

For proposed new construction, EPA recommends (EPA June 1994) that radon-resistant new construction (RRNC) techniques be considered for all buildings located within areas of known elevated radon potential. Briefly, RRNC entails placing a radon soil gas piping collection network in the subslab aggregated bed before pouring the concrete slab (ANSI 2013). The piping network is in turn connected to a vent riser, which passively exhausts the collected radon above the building, or stubbed out and capped in a convenient location in case it is needed later. If later testing finds elevated radon, this piping network can be made active with the installation of a fan on the vent riser.

Radon exposure represents about 37% of the annual radiation dose for a typical US citizen (Stanford University 2015). As a result, exposure to indoor radon is the second leading cause of lung cancer in the United States and the number one cause among nonsmokers. Since the precursors of radon (i.e., uranium and thorium) are found to some extent in virtually all soil and rock formations worldwide, varying concentrations of radon gas in soil can be found as well. Given the right combination of radon soil gas concentration, soil permeability, suitable entry pathways, and low indoor ventilation rates, virtually every building in the world has some risk potential for elevated radon (WHO 2009). Therefore, unlike the risks associated with lead-based paint or asbestos, the risk from radon exposure can never be removed—it can only be managed by taking appropriate measures. The only way to abrogate the lung cancer risk from radon exposure is to test and, if appropriate, mitigate. If mitigation is required, diligence in the form of inspection, maintenance, and periodic retesting is essential to ensure long-term risk reduction.

1.5 INDOOR RADON ABATEMENT ACT OF 1988

In recognition of the public health hazard presented by indoor radon, the US Congress passed the *Indoor Radon Abatement Act of 1988* (IRAA) and the President signed it into law. IRAA, part of Title III of the *Toxic Substances Control Act of 1988* (TSCA), declares the national goal to be "that the air within buildings in the United States should be as free of radon as the ambient air outside the buildings" (Public Law 100-551, 1988). In addition, the law stipulates that the head of each federal agency that manages a building will design a study to assess the extent of radon contamination in buildings within its jurisdiction and submit that study to EPA.

1.6 BACKGROUND OF THE NAVY RADON ASSESSMENT AND MITIGATION PROGRAM

In response to IRAA, the US Department of the Navy (DON), with concurrence from the Commandant of the Marine Corps, tasked the Commander, Naval Facilities Engineering Command (COMNAVFACENGCOM) to identify naval installations worldwide with elevated radon potential and take corrective action. As a result, COMNAVFACENGCOM created the Navy Radon Assessment and Mitigation Program (NAVRAMP), the goals of which are to

- identify potential hazards to Navy and Marine Corps personnel from exposure to naturally occurring radon gas,
- prioritize corrective actions, and
- coordinate these actions with the Budget Submitting Offices.

DON Message R 191631Z, dated January 1989, authorized the formation of NAVRAMP with the stated purpose of finding and mitigating all Navy and Marine-occupied structures with confirmed elevated levels of radon. When the program was initiated, dedicated funding was provided to enable completion of program objectives via a centrally managed approach; this funding was subsequently eliminated and the program funding transitioned to being reimbursable and project-specific.

Since the inception of NAVRAMP, the stated overall objective has been to test all Navy and Marine Corps installations worldwide using a sampling protocol that would ensure an overall 95% statistical confidence that no single building would have elevated radon potential. By its conclusion as a centrally funded and managed program in 1994, approximately 31,000 radon measurements had been performed in family housing and 50,000 measurements performed within nonresidential buildings, including billeting and lodging. From those studies, the elevated radon potential of most Navy and Marine Corps installations worldwide was estimated, and the program consequently shifted from a worldwide screening program to more of an ongoing facility environmental program. With these considerations in mind, and relying heavily on lessons learned since the program's inception, COMNAVFACENGCOM has developed and updated implementation strategies to facilitate radon testing at the naval installation level as required under Chapter 25, Section 4 (Periodic Reevaluation and Revision of NAVRAMP) of OPNAV M-5090.1 (US Navy 2014). Therefore, the implementation guidance provided in this guidebook should be considered an extension of the primary policy requirements for full implementation of NAVRAMP at all Navy and Marine Corps installations.

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2. RADON REGULATION, NAVY AND MARINE CORPS POLICY AND GUIDELINES

2.1 REGULATORY OVERVIEW OF RADON

In recognition of the public health hazard presented by indoor radon, the US Congress passed the *Indoor Radon Abatement Act of 1988* and the President signed it into law. IRAA, part of Title III of the *Toxic Substances Control Act of 1988,* declares the national goal to be "that the air within buildings in the United States should be as free of radon as the ambient air outside the buildings" (Public Law 100-551, 1988). In addition, the law stipulates that the head of each federal agency that manages a building will design a study to assess the extent of radon contamination in buildings within its jurisdiction and submit that study to EPA. However, unlike the case for other indoor environmental hazards (e.g., lead-based paint, asbestos), IRAA did not require that any corrective action be taken. With respect to other federal laws, the Occupational Safety and Health Administration regulates radon only at privately owned and operated nuclear facilities under 29 CFR 1910 (CFR 1996). However, for all other types of buildings, at the federal level, radon is still considered a voluntary, nonregulated program.

At the state level, many states (e.g., Illinois, Pennsylvania, and New Jersey) have strict laws requiring that homes be tested and that radon test results be disclosed to the prospective home buyer, and some require radon levels to be reduced to acceptable levels prior to closing. In addition, a number of states (e.g., Pennsylvania, New Jersey, Nebraska, and Rhode Island) have strict laws requiring that the company performing radon services (e.g., testing and mitigation) be licensed within that state. However, at this time, the federal government has not relinquished primacy (e.g., jurisdictional control) to the states for radon.

The *Safe Drinking Water Act* (Public Law 104-102, 1996) directed EPA to make available a multimedia mitigation program to address radon risks in indoor air and from drinking water. However, health risk studies conducted by EPA (http://water.epa.gov/scitech/drinkingwater/dws/radon/proposal.cfm) found that by far, the greatest danger was from the release of radon into the indoor environment by typical water usage (e.g., heating water, cooking, showering). The studies also found that for most water supplies, the cancer risk from the ingestion of radon in drinking water was within the same range as the risk from municipally treated water supplies (e.g., water chlorination). As a result, in 1999 EPA offered the states and federal agencies the opportunity to develop enhanced radon programs to address the health risks from radon in indoor air without necessarily having to test water supplies for radon (EPA 1999). Currently, EPA is encouraging states and sister agencies to adopt this option because it is the most cost-effective way to achieve the greatest radon risk reduction.

More recently EPA (Appendix A) has provided the Navy with clarifications of past EPA protocols and guidelines and made some new recommendations with respect to the management of radon. Recognizing that elevated radon is a highly localized phenomenon, meaning that radon concentrations can vary significantly from building to building, EPA's overall position is biased toward testing every building at all naval installations (i.e., screening is no longer a best practice). In addition, EPA also made the following points:

1. Family housing should be retested every 5 years and large buildings after every mechanical adjustment (e.g., HVAC systems).
2. EPA reemphasizes that mitigated buildings need to be retested at least every 2 years.
3. New residential construction should be tested before occupancy.
4. Radon action levels in the workplace are the same as those recommended in family housing (i.e., ≤4 pCi/L).
5. High-efficiency particulate air (HEPA) filtration is not recommended as a mitigation method.
6. Preconstruction radon predictions (i.e., soil flux measurements) and the use of radon test data from neighboring areas should not be considered substitutes for radon testing after construction has been completed.
7. RRNC practices are recommended for all new construction within EPA Radon Zones 1 and 2 (EPA 2015; map is included in Appendix E, Fig. 4).

2.2 US NAVY RADON POLICY

The current Navy Radon Policy established in Chapter 25, Section 3.2 of OPNAV M-5090.1 (US Navy 2014) provides the framework for the implementation of the radon program within the Navy. Briefly, it does the following:

1. Instructs all Navy installations to implement NAVRAMP worldwide.
2. Establishes 4 pCi/L as the action level for both residential and occupational radon exposures.
3. Limits radon testing to occupied buildings.
4. Requires periodic inspections and preventive maintenance as appropriate on mitigation systems and periodic retesting of buildings with mitigation systems (at least every 2 years) to ensure the systems are operating properly to reduce building radon levels below 4 pCi/L. In addition, retesting within these buildings is required, if the structures have been significantly modified, to ensure levels are still below 4 pCi/L.
5. Requires, where applicable, that radon-resistant features be incorporated into new building construction.
6. Requires installations to evaluate all existing and new lease agreements to ensure that Navy occupants are afforded the same protection from elevated radon as those that are in Navy-owned buildings.
7. Requires US Navy Bureau of Medicine and Surgery (BUMED) to assist COMNAVFACENGCOM in areas of radon public health assessment and risk communication and evaluate the appropriateness of radon action levels and mitigation schedules for Navy installations.

Chapter 25, Section 3.2 of OPNAV M-5090.1 (US Navy 2014) divides radon testing into three phases:

1. Screening: Installations are instructed to select a statistically significant sample of structures (Section 2.5) with priority given to hospitals, bachelor quarters, schools, child-care centers, and brigs. In the case of small activities, a screening becomes an assessment if the minimum statistically significant number of buildings (31 buildings per installation or 31 housing units per housing area) is equal to or greater than the total number of occupied buildings. Under normal circumstances, screening is performed only once and therefore should not be considered a recurring requirement.

2. Assessment: Installations test all occupied/occupiable testable buildings where valid, confirmed elevated radon levels (e.g., one room or building ≥4 pCi/L) were found during screening (Section 2.6).

3. Monitoring: The installation follows EPA recommendations for retesting after every renovation (e.g., weatherization, whole building replacement, and additions), HVAC modification or replacement, or damage by any events such as earthquakes and storms that would alter the building envelope, at installations with known elevated radon potential. In addition, periodic retesting is required within buildings that have radon mitigation systems to ensure that the radon levels are still <4 pCi/L (Section 2.7).

For installations with structures that have valid, confirmed radon levels ≥4 pCi/L, mitigation of those structures is required in accordance with the timeline outlined in Table 1.

Table 1. Corrective action timeline [a]

Category	**Radon level** (pCi/L)	**Action**
1	0 to <4	No action required
2	4 to <20	Mitigation within 2 years
3	20 to <200	Mitigation within 6 months
4	≥200	Mitigation within 3 weeks

[a] The schedule for corrective action (e.g., the mitigation clock) should be based upon the report date. In cases where confirmation is required, mitigation should be based upon the report date of the initial test.

Overseas Navy and Marine Corps installations may be required to meet the country-specific Final Governing Standards (FGSs) prepared by the Department of Defense (DoD) Environmental Executive Agent based on the host nation's environmental requirements and the Overseas Environmental Baseline Guidance Document.

Per OPNAVINST 5090.1D, Naval Facilities Engineering and Expeditionary Warfare Center (NAVFAC EXWC) maintains a central data management system containing results for radon testing conducted per NAVRAMP implementation guidance (this document). Installations shall keep records of all NAVRAMP testing data and mitigation projects and shall provide testing data to NAVFAC EXWC per guidance to be provided separately.

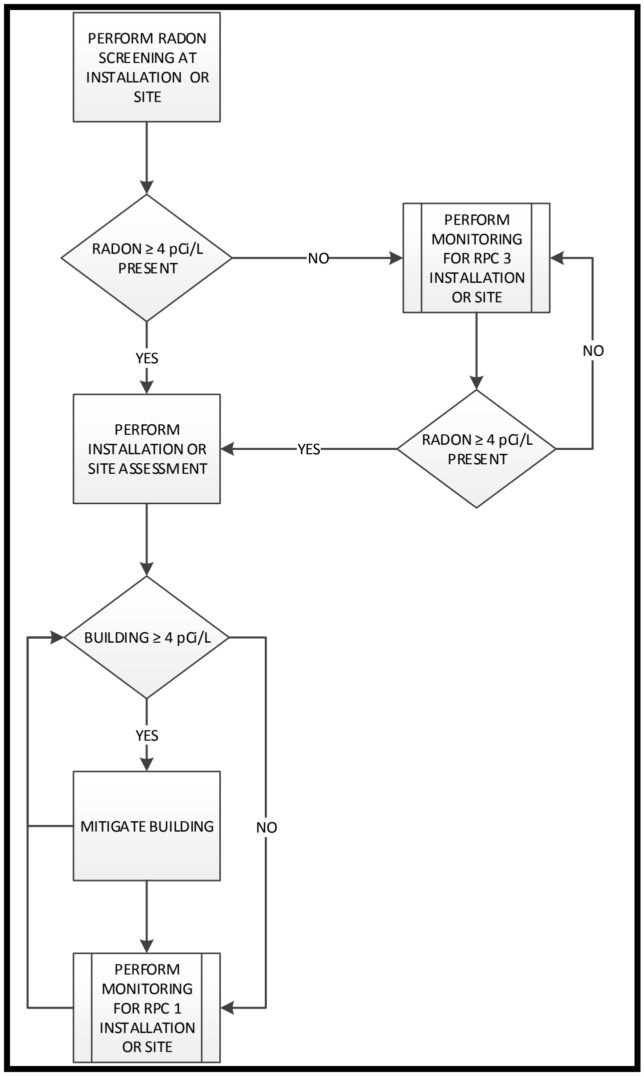
The Navy radon policies in this section have been reviewed and incorporated within NAVRAMP. Therefore any reference to NAVRAMP within this document should be considered synonymous with the policies listed in Chapter 25, Section 3.2 of OPNAV M-5090.1 (US Navy 2014).

2.3 US MARINE CORPS RADON POLICY

Marine Corps policy is established under Section 6207 of US Marine Corps MCO P5090.2A, *Environmental Compliance and Protection Manual* (US Marine Corps 2013). Briefly, the policy states that all Marine Corps installations must implement all phases of NAVRAMP and incorporate radon-resistant designs in new construction where required by historical elevated radon site data, geological conditions, or regulatory requirements.

2.4 NAVRAMP RADON POTENTIAL CATEGORIES

The testing phases listed in Section 2.2 outline a phased approach in which all installations undergo initial screening and, if required, assessment. At the conclusion of these testing phases, each installation is transitioned into a monitoring phase (e.g., screening and assessment under normal circumstances should not be considered a reoccurring requirement) in which additional testing is performed as needed to ensure that radon levels are still below 4 pCi/L (Flowchart 2). Because the monitoring (to some extent radon is found in all soils and geological formations worldwide, so the potential for elevated, indoor radon is always present) needs for each naval installation will ultimately depend on its radon potential, COMNAVFACENGCOM performed a comprehensive review of all Navy and Marine Corps residential and nonresidential radon data reported as of May 2015 (note data on file was collected from 1989 through May 2015). The review found that that a significant number of naval installations had completed the required screening and assessment (Appendix B) and were for all practical purposes in the monitoring phase. At some installations, however, screening and assessment had not been completed; at others, screening, although attempted, was inconclusive. Therefore, it was decided that a simple, easy-to-follow ranking system based on the current radon potential at each installation was needed to better manage the radon program at all levels of the Navy and Marine Corps (e.g., installation, region, and headquarters). The data review also revealed that installations needed additional options for radon management. For this reason, the option of subdividing an installation into smaller, better manageable sites was added (Section 2.4.1).



Flowchart 2. Overview of the NAVRAMP testing and mitigation phases.

Using all historical residential and nonresidential radon data on file as of May 2015, and property information from the Internet Naval Facilities Assets Data Store (iNFADS), COMNAVFACENGCOM assigned each naval installation with shore facilities an initial Radon Potential Category (RPC). The purpose of these assigned codes was twofold: (1) to identify installations in need of initial screening and assessment and (2) to provide an outline for continual monitoring and other actions based on radon potential. Also by design, the RPC designations (listed by unit identification code [UIC] in Appendix B) are changeable by the installation (Section 2.8) for justifiable reasons.

The RPCs are

RPC 1: installations or sites with known elevated radon potential (e.g., elevated radon has been confirmed in one or more rooms)
RPC 2: installations or sites with unknown radon potential

RPC 3: installations or sites with sufficient screening data that indicate low radon potential

For each RPC, the following specific actions are required under NAVRAMP:

- RPC 1 installation or sites
  - All testable buildings (Section 3.2.3) must have been assessed (Section 2.6).
    - Mitigate all buildings with confirmed radon levels ≥4 pCi/L in accordance with the NAVRAMP mitigation timeline (Table 1).
    - Retest all mitigated rooms at least every 2 years,
  - Implement RPC 1 monitoring (Section 2.7.1) at assessment completion.
    - Retest all testable buildings after every 5 years, or after every significant, earthquake, or severe weather event that would alter the building envelope.
    - Test all new or newly acquired buildings and retest significantly modified buildings (e.g., HVAC adjustment or replacement, building envelope modifications).
  - Incorporate RRNC features in all proposed new buildings planned for occupancy.

- RPC 2 installation or sites
  - Complete screening (Section 2.5).
  - Based upon the survey findings, assign as appropriate an RPC 1 or RPC 3 designation for the installation or site.

- RPC 3 installation or sites
  - Implement RPC 3 monitoring (Section 2.7.2).
    - Test all buildings constructed after 2003.
      - The rationale for testing all buildings constructed after 2003 is that some energy-saving features (primarily lower volumes of fresh makeup air, and tighter building envelopes) typically incorporated after this time have been shown to increase the probability of finding elevated radon.
    - Test all recently acquired untested buildings (e.g., newly constructed, or through transfer of ownership).
    - Test all untested Tier 1 buildings (e.g., hospitals, bachelor quarters, schools, child-care centers, brigs).
    - Perform optional monitoring on selected buildings as circumstances dictate (Section 2.7.2).

As was mentioned above, the installation can update the RPC assignments and testing phase (Appendix B) at any time for justifiable reasons. Section 2.8 provides a suggested outline for the installation to follow while conducting the review.

2.4.1 Option of Dividing Installations into Sites for RPC Assignments

During the radon data set review, it was recognized that not all installations are the same. Some naval installations may include just a few buildings at a central location, whereas others have hundreds of buildings distributed over thousands of square miles at numerous locations. Thus the potential exists that a single building with elevated radon at a remote location with respect to the main installation would require the testing of all occupied buildings at the installation. Although doing so is not required for implementing NAVRAMP (i.e., is optional), an installation may find it advantageous if warranted to split a single installation into smaller sites for radon testing and radon program management. The key advantage of this approach is that it would ensure that buildings at sites at the greatest risk from radon would get the required attention, while those with low potential would not be tested or retested unnecessarily.

Valid reasons for creating sites within installation are as follows:

1. Geology varies from location to location; hence, the radon potential could vary as well throughout the installation.
2. Building types vary at the installation. It is not unusual for a naval installation to have distinctly different types of buildings grouped within certain areas of the installation (e.g., shipyards usually have different types of buildings from naval magazines, and the two are usually not intermingled).
3. Administrative reasons may exist in cases of joint basing, for buildings under the jurisdiction of a separate command for which funding or jurisdictional issues may arise, or in cases in which NAVRAMP qualifying leased or international use buildings are involved (Section 2.9).
4. A single building or collection of buildings may not be within the traditional footprint of the installation (i.e., may be located some distance away).
5. A single building or few buildings (atypical buildings) at the installation may have a unique construction style or specialized application (e.g., silos, telecommunication facilities with underground cable vaults, underground facilities, armories, magazines, or other types of atypical structures) that has resulted in elevated radon levels.

If the site option is used, the installation shall assign the most appropriate RPC to each site and implement any required actions for the respective RPC (e.g., complete screening for an RPC 2 site or implement monitoring for an RPC 3 site). The reasons and/or rationale for dividing the installation into sites should also be documented in the installation Radon Management Plan (RMP; see Section 2.10). For administrative purposes, if one or more RPC 1 sites are present, then the installation RPC as a whole will remain RPC 1. However, for installations with combinations of RPC 2 and RPC 3 sites should be assigned the most representative RPC for the installation as a whole. For example, if 8 of 10 sites are RPC 3 and 2 are RPC 2, the installation should pick RPC 3 as the most representative for the installation as a whole (screening would still be need to be completed at the RPC 2 site in this example).

In cases where only one specific building or building type at a site or installation has elevated radon (e.g., an atypical building, see valid reason 5 above), it may be excluded from the installation or site RPC classification to more accurately represent the true radon potential at the site or installation (reason or rationale for using the atypical exception should be documented in the RMP). However, the atypical building will still need to be managed as an RPC 1 structure (i.e., retesting will be required in the future).

2.5 RADON SCREENING

The objective of screening (Section 2.2) is to reach a defensible testing conclusion using a statistically significant sample of structures (i.e., a minimum of 95% confidence that no more than one room has the potential for elevated radon). At the conclusion of the screening, the installation or site (if applicable) would be designated as either RPC 1 (known elevated radon potential) or RPC 3 (low radon potential) and further action taken as required (Section 2.7). Under normal circumstances, an entire installation or site (if applicable) should be screened only once; screening should not be considered a recurring requirement. Therefore, this section applies only to RPC 2 (Section 2.4) installations or sites.

Radon studies (Appendix E, Sections 1.3.3 and 3.1.8) have found that unlike housing, in which room-to-room radon levels are reasonably consistent, radon levels within large buildings may have significant room-to-room variation. Analysis of Navy and Marine Corps radon data in which all rooms in a building were sampled has confirmed this observation. Further analysis of data collected within individual large buildings has also shown that the data cannot be statistically sampled to provide a defensible confidence interval. In addition, within Naval Shore facilities (excluding family housing), studies have shown that buildings vary in size from 1 to over 200 rooms. This level of variation could potentially lead to a case in which a statistically significant number of buildings selected for screening would not offer a comparable and defensible statistical confidence if the total number of testable rooms (a room that is occupied or easily occupiable in a testable building and that is either in ground contact or over an unoccupied ground contact basemen room or crawlspace, see Section 3.2.4) within the population were taken into account. For these reasons, and to be consistent with EPA and ANSI testing guidelines (EPA July 1993, ANSI 2014a), in buildings selected for screening, the testing of all ground-contact, occupied or easily occupiable rooms is required. Additional information on radon testing, data validation, and other testing considerations is presented in Chapter 3.

2.5.1 Radon Screening Sampling Considerations

The primary advantage of screening vs. assessment (testing all buildings) is the presumption of a significant cost savings. Although analysis of past screening projects within the Navy and Marine Corps has demonstrated cost savings at large installations (e.g., >3,000 rooms), the total cost savings for screening at medium or small installation (e.g., <3,000 rooms) has been brought into question. In a screening project, a significant amount of effort must be invested in both the planning and the data analysis portions of the project. Whereas the conclusions in an assessment are mostly self-evident (all buildings tested and no extrapolation is needed for potential rooms >4 pCi/L), a proper screening project requires a representative sampling of all types of buildings and a good geographical distribution at the installation or site (geology, hence radon potential, can vary significantly in small areas). Once testing is completed, calculations must be made to ensure that the 95% confidence interval was met and, in some cases (Section 2.5.2), statistical modeling is performed to estimate the number of rooms >4 pCi/L. The costs for these planning and data analysis efforts may in some cases exceed the actual costs of simply testing all of the buildings. Therefore, during the planning stages, total costs (planning, field testing, data analysis, and reporting) for statistical screening vs. assessment should be compiled and the best overall value for the Navy or Marine Corps selected.

The number of testable buildings (Section 3.2.3) proposed for screening at the installation or site is a consideration as well. Under NAVRAMP (Section 2.2), if the number of buildings is ≤31, all should be tested. Using average historical sample densities in past radon surveys in the Navy and Marine Corps (e.g., average rooms per building), 31 buildings equates to around 500 to 700 rooms. However, cost analysis of projects of this size has found no significant increase in costs for projects of up to 1,000 rooms or about 45 buildings. Therefore, it is recommended that if ≥32 buildings are present, but there are <1,000 testable rooms (Section 3.2.4) present, assessment be performed as well.

An important consideration may be a need for expediency due to potential health concerns or funding cycles for radon testing. In some cases, planning (i.e., the selection of the best method for screening and ultimately the selection of the buildings to test) may take several months to complete, in addition to the time for data analysis after the testing has been completed. Therefore, in these cases, assessment—which has a shorter life cycle compared with screening (typically 3 to 6 months less)—may be the more appropriate choice.

Another consideration is the probability that screening will find elevated radon potential (recall that all buildings will need to be tested if the screening finds one room with elevated radon). In that case, all the remaining buildings would need to be tested, making it necessary to accrue costs for another round of mobilization/demobilization. Therefore, in the initial planning stages of screening, an attempt should be made to ascertain the radon potential of the site or installation from US or host government sources (this would also include Navy, Marine Corps, and other DoD data collected in or near the installation) and past radon surveys at the installation. For naval installations located within the United States or its territories, radon potential information can be obtained online at http://www.epa.gov/radon/zonemap.html (Appendix E, Fig. 4) or from the EPA regional radon point of contact. For overseas locations, the applicable counterpart within the host government should be consulted. If it can be determined via these governmental or other reliable data sources that the installation or site is located within an area of known elevated radon potential (e.g., the installation or site is located within an EPA Radon Zone 1 or 2, see Appendix E, Section 1.2.1), then assessment (testing of all occupied buildings) is recommended over screening.

If the site option is used, it should not be considered unusual for some sites to be selected for screening while others are selected for assessment. Therefore, if doing so is desirable because of cost or other logistical considerations, the entire installation can be tested over several years based on the testing needs of each site (e.g., performing site screening in years 1–2 and site assessments in years 2–3).

In summary, all installations or sites (if applicable) are required to undergo initial screening. However, assessment in lieu of screening of an installation or site should be considered when

- the number of testable buildings is ≤31, or
- the total number of testable rooms is <1,000, or
- reliable data sources have indicated that the installation or site is within an area of known elevated radon potential (i.e., EPA Radon Zone 1 or 2 or the equivalent), or
- because of logistical or other considerations, the cost of screening is comparable to that of assessment.

2.5.2 Statistical Screening Implementation

For an RPC 2 installation or site, if none of the above criteria applies that would warrant assessment (i.e., ≤31 buildings or <1,000 rooms, or known elevated radon potential in the area), then screening should be performed. The following steps are provided as a guide.

Step 1: Estimation of Overall Population Size

In preparation for executing a statistical screening project, a list of all potentially testable buildings (those planned for demolition within the next 2 years should be excluded) should be prepared, including an estimate of the number of testable rooms per building (Section 3.2.4). The list shall also include NAVRAMP-qualifying leased buildings and international agreement buildings (Section 2.9). If applicable, these buildings then should be grouped into their respective sites. If the site option is used, the total number of testable buildings (Section 3.2.3) should be counted and the number of rooms summed. If the total number of testable buildings per site is ≤31 or <1000 rooms, then all buildings at that site shall be tested and removed from further screening consideration.

Step 2: Identification of Priority Buildings to Test

The primary usage of each building should be reviewed, each building placed in one of the following classifications, and the number of testable rooms in each tier totaled.

Tier 1: Includes all hospitals, bachelor quarters, schools, child-care centers, and brigs.

Tier 2: Includes all 24 h manned facilities, such as but not limited to command and communication facilities, fire stations, lodges, and security buildings.

Tier 3: Includes all offices and administrative buildings, exchanges, commissary, shops, recreational facilities (i.e., fitness centers, theaters), warehouses, and other work areas.

Tier 4: Includes atypical buildings such as but not limited to armories, occupied magazines, underground facilities, and buildings with unique construction characteristics.

Step 3: Selection of a Screening Option

Many statistical models are available for estimating sample size. However, it is difficult for most of those models to establish statistical confidence as the number of potential positive results in a population approaches 1 or 0 (DOE 1990). Therefore, the following options are proposed for installation or site screening to achieve the minimal 95% confidence interval that no more than one room contains elevated radon within the population. However, as discussed earlier, estimated costs for full assessment (i.e., testing of all buildings) should be collected as well to ensure that the best overall value for the Navy and Marine Corps is being obtained.

Screening Option 1: Fixed Sample Density

In this approach, a fixed sample density (e.g., percentage of rooms to test) of sufficient magnitude is used to ensure a 95% confidence interval, assuming a low frequency of elevated radon (i.e., 1%). In this approach, no special mathematical or computer skills are required for data analysis. For this option, the selected detectors (Section 3.2.2) must have ≤15% measurement error (accuracy and precision information is available from the manufacturer), and testing must be 1 year in duration (under NAVRAMP, any radon test between 335 and 395 days in duration is considered a 1 year test). To ensure adequate sample density, a minimum of 80% of the total testable rooms at the installation or at each site shall be tested for radon. All Tier 1 buildings will be included, with the remaining balance made up of Tier 2 followed by Tier 3 buildings. Exceeding the 80% minimum to include entire buildings for testing to make up the balance is permitted. Testing all Tier 4 buildings is also recommended (these buildings cannot be included in the 80%) because of the higher-than-expected frequency of elevated radon found in such buildings in other studies. In addition, installation maps should be consulted to ensure good spatial coverage. If required, additional buildings above the prescribed minimum may be added in some areas to ensure adequate coverage.

At the conclusion of the survey (assuming that all data quality objectives of the survey are met; see Section 3.5), RPCs (RPC 1 or 3) can be assigned to the installation or sites (if applicable) based on the highest single average radon result (e.g., RPC 3 if the highest single average result is <4 pCi/L and RPC 1 if the highest single average result is ≥4 pCi/L).

Option 2: Enhanced Statistical Method

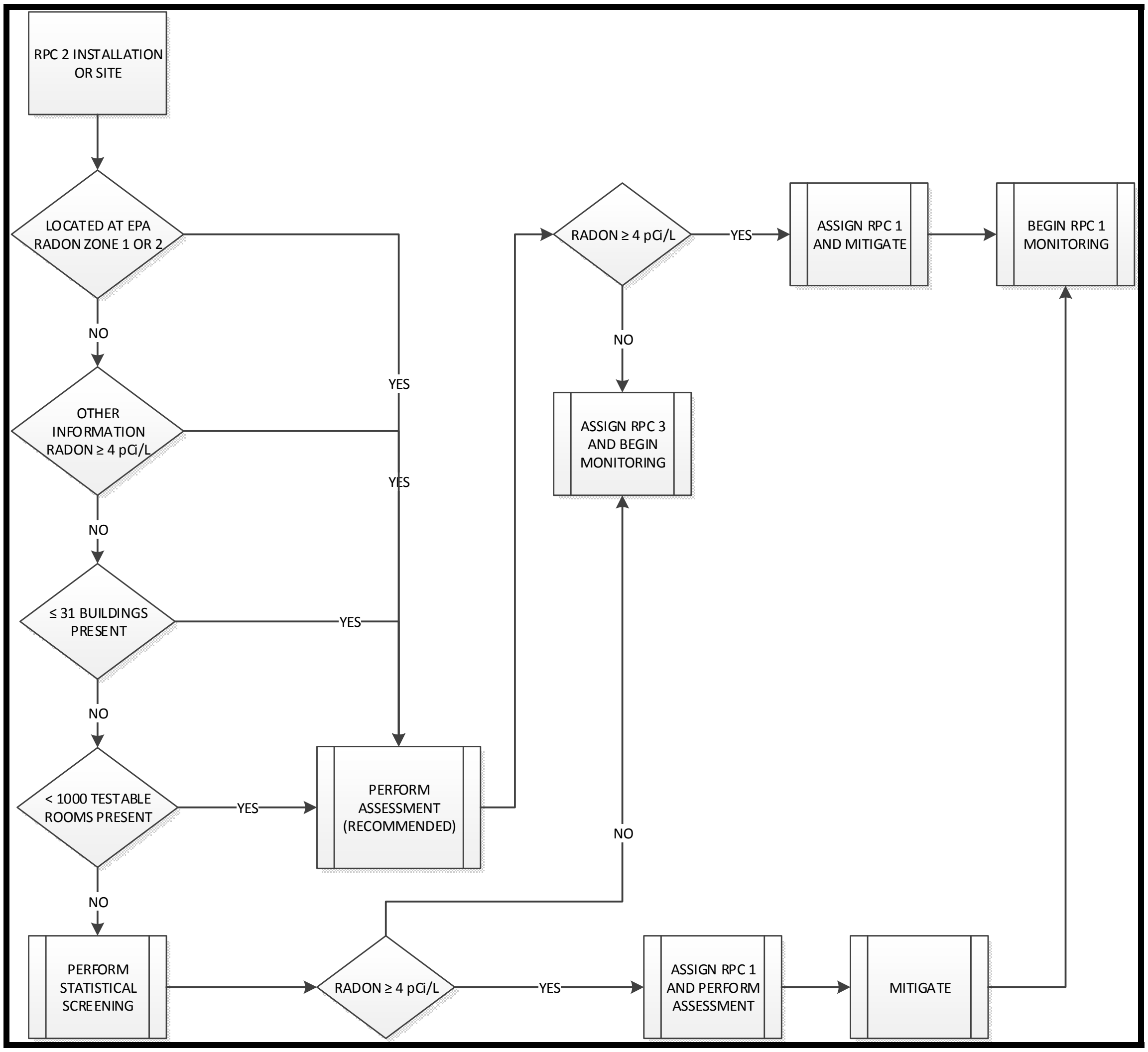
This approach takes advantage of the fact that a superior-quality radon data set (i.e., ≥175 results) collected at a site or installation usually (e.g., 90% of the time) follows a known statistical distribution (lognormal, normal, or exponential). Taking advantage of this fact can significantly reduce the total number of tests required to achieve a 95% confidence level (DOE 1990). However, during data analysis, advanced computer and statistical skills are required to generate the dataset curves for the installation or each site (if applicable) used to estimate the number of rooms ≥4 pCi/L. As a result, the cost per measurement for this approach is sometimes higher than for screening option 1 or for assessment. Therefore, this option should be considered for use only at larger installations or at sites with >3,000 rooms.

For this option, the selected detectors (Section 3.2.2) must have ≤15% measurement error (accuracy and precision information is available from the manufacturer) with no upper limits on the number of blanks and spike detectors (Section 3.3.1). In addition, the duration of the survey must be 1 year (under NAVRAMP, any radon test between 335 and 395 days in duration is considered a 1 year test). Furthermore, all of the sampling at the installation or each site should be performed within the same time period (e.g., detector placement and retrieval cannot be spread out over several months or years).

Sampling of at least 33% of the total testable rooms at the installation or site (excluding Tier 4) is required. However, because of other sampling considerations (e.g., primarily detector accuracy and precision), an accredited, professional statistician (i.e., American Statistical Association accreditation or equivalent) should review the proposed sample density to ensure that the proper minimum number of rooms are tested.

All Tier 1 buildings shall be included, with the remaining balance made up of Tier 2 followed by Tier 3 buildings. Testing all Tier 4 buildings is also recommended (although they should not be included in the model) because of the higher-than-expected frequency of elevated radon found in other studies. In addition, installation maps should be consulted to ensure good spatial coverage. If required, additional buildings may be added in some areas to ensure adequate coverage.

After the data have been collected and validated (Section 3.5), a simple inspection is used to verify that all results are <4 pCi/L. If valid data are found to be ≥4 pCi/L, the installation or site is assigned an RPC 1 Assessment designation and actions are taken as appropriate (Section 2.6). However, if all results are <4 pCi/L, then the results will need to be analyzed by an accredited, professional statistician using nonlinear regression models (as a minimum, lognormal, normal, and exponential) to determine the best fit for the data distribution. Using the best curve fit for the installation or site, estimate the number of rooms ≥4 pCi/L assuming a 95% confidence interval. If the number of rooms estimated is less than one, then the installation or site is assigned an RPC 3 designation. However, if one or more rooms are projected to be >4 pCi/L, then the remaining buildings at the installation or site should be tested before the final RPC assignment. An overview of the screening phase is shown in Flowchart 3.



Flowchart 3. Overview of screening phase.

2.6 RADON ASSESSMENT

Simply stated, the purpose of the radon assessment is to test all testable rooms within all testable buildings (Section 3.2.3 and Section 3.2.4) including applicable leased and international use agreement buildings (Section 2.9) at the installation or site. The only exception to this requirement is buildings proposed for demolition within the next 2 years. Within buildings proposed for significant modification (see definition of significantly modified) that would coincide with the radon testing, the testing should be deferred until after completion. The completion of a radon assessment is mandatory for all RPC 1 installation or sites. In addition, RPC 2 installation or sites may be included in assessments under specific circumstances (i.e., ≤31 buildings or < 1,000 rooms, or known elevated radon potential in the area, or cost considerations if the assessment costs are comparable to those of screening). In preparation for the assessment, a dated list of all testable buildings needs to be compiled, including the estimated number of testable rooms per building (Section 3.2.4). Buildings previously tested may be excluded from the proposed assessment provided all testable rooms in the building have valid radon test data and the testing was performed within the last 5 years. However, consideration should be given to retesting buildings that meet these criteria if they have been significantly modified or if they have been damaged by events such as earthquakes or storms since the previous radon test. If these buildings cannot be included in the assessment, then they will need to be tested later under radon monitoring (Section 2.7).

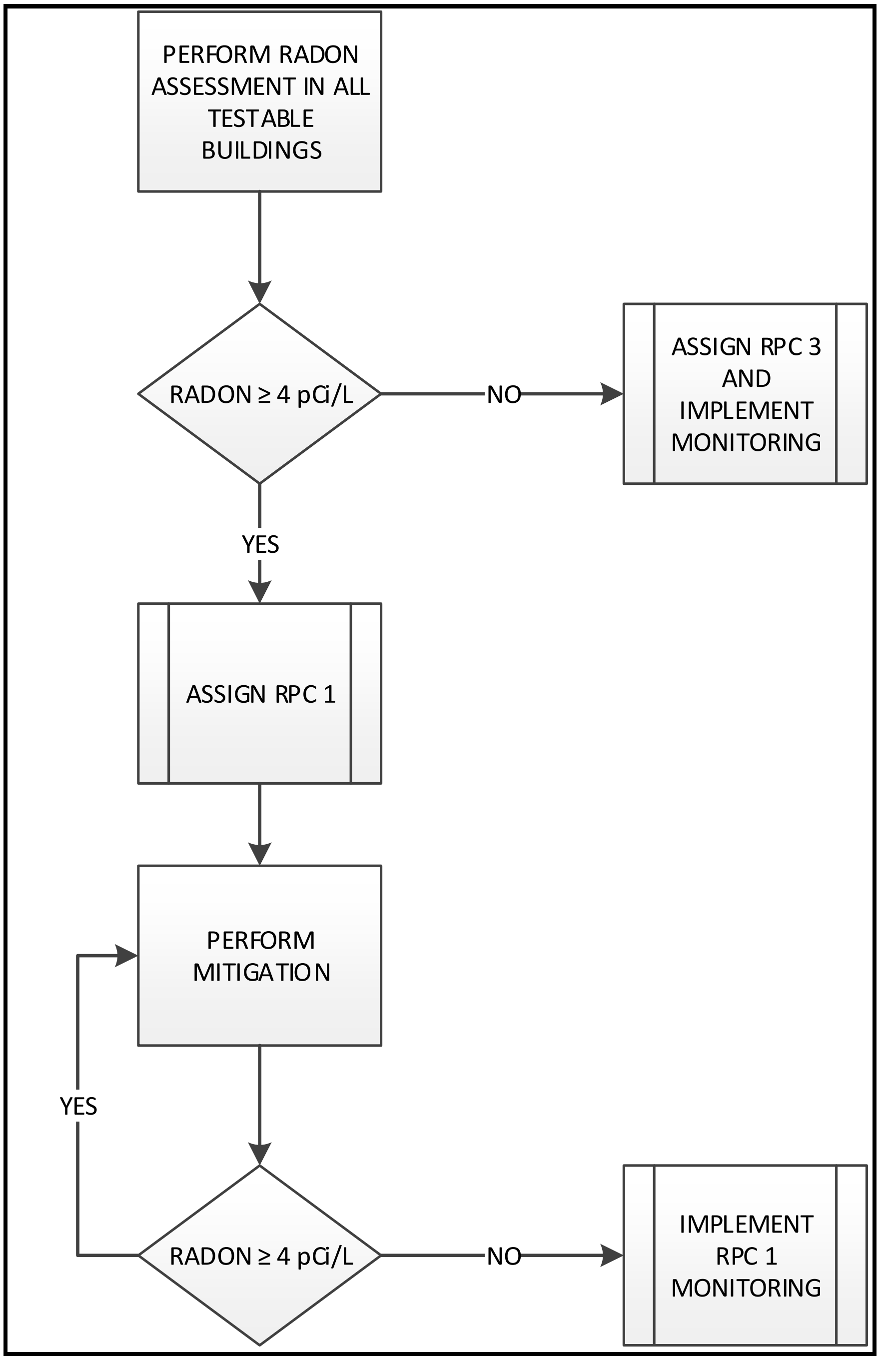
Unlike certain types of screening in which all the testing (e.g., detector placement and retrieval) needs to be performed during the same time period, assessment testing at an installation or site can be performed over extended time periods (e.g., months or years) if needed, provided the minimal testing duration requirements are met (Section 3.2.1).

For assessment testing, the selected detectors (Section 3.2.2) must have ≤25% measurement error (accuracy and precision information is available from the manufacturer), and long-term exposure (i.e., >90 days, with 1 year preferred) is recommended. However, under certain circumstances, short-term testing (e.g., 2 to 90 days) can be used under very stringent testing conditions (Section 3.2.1).

If the assessment is being performed at an RPC 2 installation or site, at the conclusion of the testing (assuming all data quality objectives of the survey are met; see Section 3.5), the appropriate RPC (RPC 1 or 3) is assigned to the installation or site (if applicable) based on the highest single average radon result (e.g., RPC 3 monitoring if the highest single average result is <4 pCi/L and RPC 1 monitoring if the highest single average result is ≥4 pCi/L). Future action is taken as required based on the assigned RPC (Section 2.4).

By design, under normal circumstances, an RPC 1 installation or site is assessed only once. Once the assessment phase has been completed, the installation or site transitions to the monitoring phase (Section 2.7) in which additional testing is performed and actions are taken to ensure that radon levels are maintained <4 pCi/L for all buildings. However, in cases where most of the buildings have been tested, and in particular where mitigation has already occurred, consideration should be given to transitioning to the monitoring phase, with emphasis given to testing the remaining buildings.

Flowchart 4 provides an overview of the assessment phase. Additional information on radon testing, data validation, and other testing considerations is presented in Chapter 3.



Flowchart 4. Overview of the assessment phase.

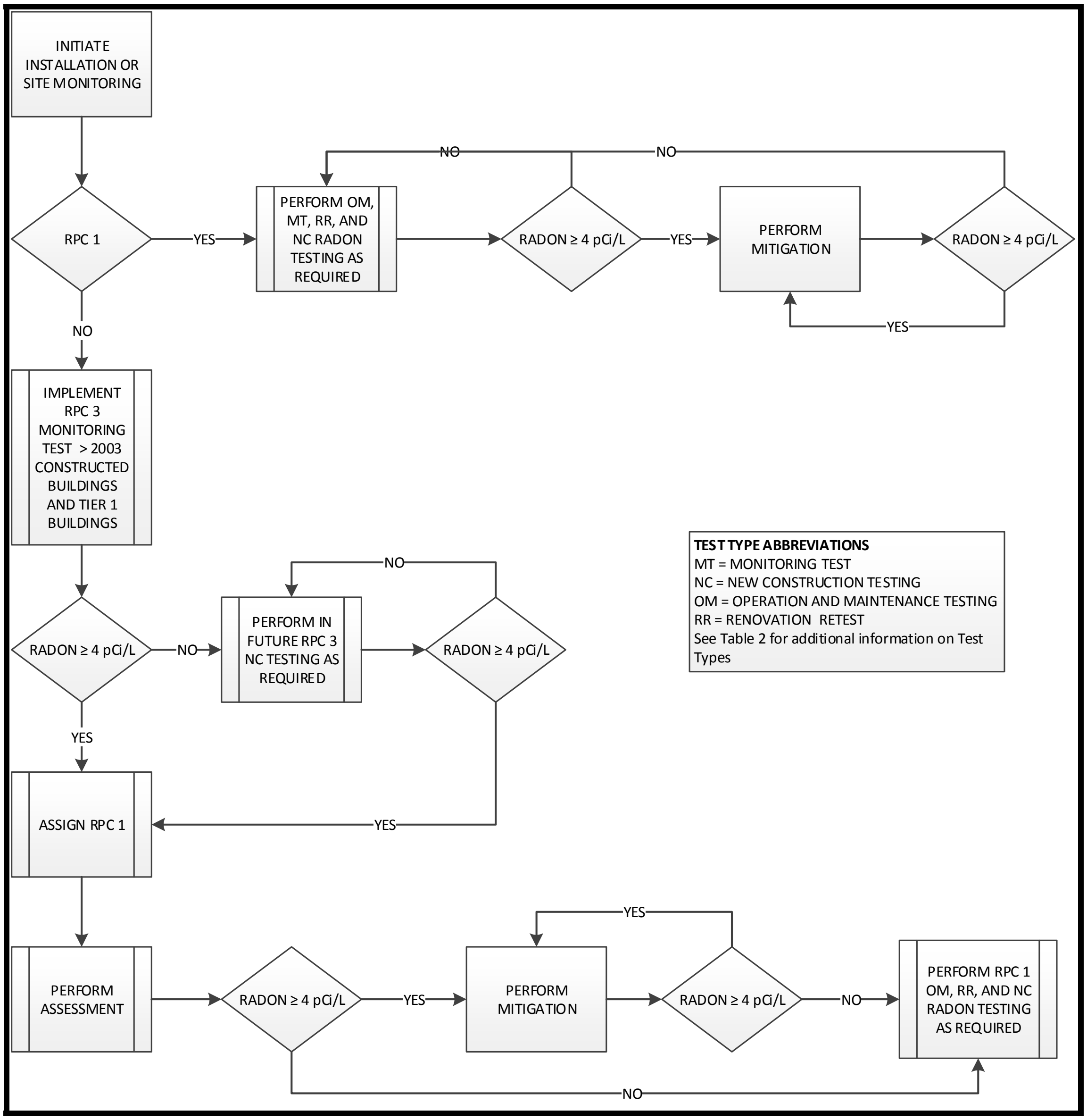
2.7 RADON MONITORING

As was stated in Section 2.4, the purpose is to transition all Navy and Marine Corps installations into a monitoring phase after screening and if applicable assessment has been successfully completed. Because radon emanates from soil and geological formations under the building, unlike the risks associated with lead-based paint or asbestos, the risk from radon exposure can never be removed. It can only be managed by taking appropriate, ongoing measures, including further radon testing at installations or sites with no known potential for radon (see below).

Under NAVRAMP, installations or sites that were successfully screened and were found to have no elevated radon are automatically placed into the monitoring phase and assigned a RPC 3 monitoring designation. However, those that are known to have elevated radon and that have successfully completed assessment are designated RPC 1 monitoring. Because the radon potentials are different (i.e., one has known elevated radon potential and the other does not), each of these monitoring subcategories (i.e., RPC 1 and RPC 3) has its own specific testing requirements (Sections 2.7.1 and 2.7.2, respectively). It is important to note that if the site option is used at the installation, it is not a requirement that the testing requirements for other sites at the installation be completed for a qualifying site to be incorporated into the monitoring phase.

For monitoring testing, the selected detectors (Section 3.2.2) must have ≤25% measurement error (accuracy and precision information is available from the manufacturer), and testing can be either short-term (i.e., <90 days) or long-term exposure (i.e., >90 days). Unless otherwise specified, radon testing within individual testable buildings shall be performed in all testable rooms with the noted exception of diagnostic, postmitigation, and operations and maintenance (O&M) testing (see Section 3.2.1, Table 2, for descriptions of test types). For RPC 3 sites, reassignment to RPC 1 is required if monitoring determines elevated radon potential at the site (e.g., valid, confirmed radon results ≥4 pCi/L). Similar to testing in the screening and assessment phases, all testable rooms are tested in the building (excluding diagnostic, postmitigation, and O&M testing, see Section 3.2.1, Table 2). Flowchart 5 provides an overview of the monitoring phase.

Unlike certain types of screening in which all testing needs to be performed during the same time period, monitoring testing at an installation or site can be implemented by building on an as-needed basis or performed over several years for a larger numbers of buildings. Additional information on radon testing, data validation, and other testing considerations is provided in Chapter 3.



Flowchart 5. Overview of the monitoring phase.

2.7.1 Types of Monitoring at RPC 1 Installations or Sites

Because elevated radon potential is known at an RPC 1 monitoring installation or site(s), periodic monitoring is mandated for all buildings as follows.

- Perform radon assessment (Section 2.6) in any untested, testable building,
- Retest all testable buildings
  - after every renovation (e.g., weatherization, whole building replacement, addition),
  - after every HVAC modification or replacement,
  - after damage by any event such as an earthquake or storm that would alter the building envelope, **<u>or</u>**

    - simply retest every 5 years.
- In buildings with mitigation systems, retest the affected rooms (i.e., those that were identified as having elevated radon and mitigated) at least every 2 years.
- Test all newly acquired buildings before occupancy or within 5 years of occupancy.

2.7.2 Types of Monitoring at RPC 3 Installations or Sites

Because a successful screening has indicated that low radon potential exists at a RPC 3 monitoring installation or site(s), the primary purpose of this type of monitoring is to ensure that Tier 1 buildings (e.g., hospital, bachelor quarter, school, child-care center, brig) are tested, and that all testable building constructed after 2003 are tested to ensure that no elevated radon levels are present. Testing Tier 4 buildings is also recommended because of the above average frequency of elevated radon found within these types of buildings. Because this is not a recurring radon test, the results collected for these buildings as part of previous testing projects (e.g., screening, pre-occupancy clearance testing) can be used to meet this requirement provided they meet or exceed NAVRAMP testing standards (Section 3). In addition, these buildings do not need to be retested after every renovation, HVAC adjustment, and the like. With respect to future new construction, although EPA recommends testing before occupancy, studies have shown that the best time to test is actually 2–3 years later to allow more time for the concrete to settle and dry. Therefore, testing of newly acquired buildings can be performed at any time up to a maximum of 5 years after the occupancy date. However, in recognition of the fact that radon is dynamic, optional (i.e., not required) radon testing may be performed as part of an expanded monitoring program at RPC 3 installations or sites as specific circumstances as defined by the installation dictate. Examples for expanding the radon monitoring program at the installation would include, but would not be limited to, the following circumstances:

1. An existing building or group of buildings was significantly modified in such a way that they are different from the general building population at the installation.
2. Medical or health concerns exist about the indoor air quality within an existing building or buildings.
3. The radon data for selected buildings is >5 years old and there are reasons to suspect that the results are no longer representative of the indoor radon concentration.

For RPC 3 sites, a reassignment to RPC 1 is required if monitoring determines elevated radon potential at the site (e.g., valid, confirmed radon results ≥4 pCi/L).

2.8 INSTALLATION REVIEW OF NAVRAMP TESTING STATUS

As was discussed in Section 2.4, COMNAVFACENGCOM assigned all installations with shore facilities an initial RPC (see Appendix B; if your installation is not listed, assume an RPC 2 initial assignment). In making the initial assignments, all valid, historical and current radon data on file were used (residential and nonresidential collected from 1989 through May 2015). Also taken into consideration was the overall sample density at the installation and within particular buildings based on information provided in iNFADS (e.g., did an installation test a minimum of 31 buildings or at least 31 units per neighborhood, see Section 2.2, 2.5, and 2.6). It is important to note that because of DON installation consolidation, and radon testing performed since the decentralization of NAVRAMP in 1994, the totals in Appendix B may differ from those in official correspondences sent to the installation by ORNL in 1994 and those reported in the NAVRAMP final project report (DOE 1994).

Briefly, the RPCs (Section 2.4) are:

- RPC 1: One or more valid, confirmed radon results ≥4 pCi/L was present at the installation.
- RPC 2: Based on past and present radon policies, insufficient data exist to project the current radon potential for the nonresidential buildings at the installation (this would also include billeting, lodges, and transient quarters).
- RPC 3: Sufficient radon data (including family housing data) exist to conclude that the installation has a low radon potential.

It is also important to note that the RPC (a unique term developed by COMNAVFACENGCOM for NAVRAMP) is not related to the EPA radon map potential zones (http://www.epa.gov/radon/zonemap.html), which are similarly numbered. RPCs are assigned based on actual Navy/Marine Corps radon test data collected at the installation. The EPA radon map zones are based on limited data collected over large geographical areas and lack the resolution needed for Navy and Marine Corps monitoring applications. However, the EPA Zone designation may be used as a justification to skip installation screening and perform assessment if the installation is located in an EPA Zone 1 or Zone 2 area or its host nation's equivalent (Section 2.5).

In the initial part of the installation review, a decision needs to be made whether to implement NAVRAMP as an installation-wide program or as a series of sites (Section 2.4.1). This decision need not be based solely on distance and geological and structure details but can also be based on potential health concerns (e.g., was this area sampled sufficiently) and administrative issues [e.g., a different DoD agency in a joint base–type arrangement, qualifying leased and international use agreement buildings (Section 2.9)]. In addition, from a program management perspective, sites are managed akin to "mini installations" with their own RPCs, testing requirements, and schedules (Section 2.5 to 2.7). Therefore, the use of this option may provide the installation greater flexibility in getting more buildings into the monitoring phase (Section 2.7) in the shortest period of time.

After the site issue has been decided, the next step is to confirm or revise the installation RPC value and, if applicable, assign values to individual sites. The following are suggested steps.

- Consult all the radon data on file for the installation (data for family housing and other residential structures and nonresidential data can be used).
- If needed, consult building inventory information in iNFADs.
- In cases where only screening has been performed, consult installation maps to ensure that the testing had an adequate footprint.
- If the initial RPC is RPC 1, verify that the results ≥4 pCi/L were valid (Section 3.5) and were not collected in atypical buildings.
- If the initial RPC is RPC 2, using the data on file (there may be additional data that were not on file during the review), determine if screening has been completed (Section 2.5).
- If the initial RPC is RPC 3, verify that sufficient screening was performed.
- Assign updated RPCs as appropriate based upon your review.
- Document these findings and conclusions in the installation RMP (Section 2.10) or in a memo to file.

It is also important to note that radon mitigation of one or more buildings at an installation or site does not reduce the radon potential for all other buildings (e.g., mitigating a building does not alter the geological potential, it only controls the radon levels in that particular building or room). Therefore, RPC 1 would still apply.

Examples and rationales for appropriate installation RPC changes at an installation without elevated radon would include, but are not limited to, the following.

1. Changing an RPC 3 to an RPC 2
   a. The screening data were insufficient to arrive at a defensible testing conclusion at this installation.
   b. The screening data were collected at a different site or location from this installation.
   c. The screening data summarized in Appendix B were not collected at this UIC.
   d. The screening data are outdated and the buildings screened are no longer representative of the types of buildings at the installation.
2. Changing an RPC 2 to an RPC 3
   a. Additional valid radon test data that were not included in the COMNAVFACENGCOM database were identified and are sufficient to arrive at a defensible testing conclusion at this installation.
   b. The installation radon program could be better managed as an RPC 3 monitoring installation.
   c. Screening was performed successfully (Section 2.5) and no elevated radon was found.

However, for RPC 1 installations (elevated radon has been detected), the rationale needs to be more specific and defensible, since elevated radon results have already been reported. Therefore, the installation must review the radon data more closely and make a determination based on the elevated results. The following are examples of rationales that would be defensible reasons to disqualify an elevated radon measurement.

1. Valid, confirmation, follow-up, or diagnostic measurements support the absence of elevated radon (historical or more recent).
   a. To be considered as defensible, these subsequent tests must have been performed in the same room and, if the room is >2000 ft^2, at the same location.
      1) If room and location are in doubt, retest the entire building.
   b. The EPA average (Section 3.2.10) was applied to the initial and follow-up measurements and the average was <4 pCi/L.
2. The elevated result is at a location (Section 2.4.1) that is no longer controlled or owned by the Navy or Marine Corps.
   a. Data collected in a former Navy or Marine Corps family housing area that has since been privatized cannot be disqualified unless the neighborhood could be considered a separate site (Section 2.4.1).
3. More recent radon screening (Section 2.5) or assessment (Section 2.6) at the installation found no elevated radon.
4. The elevated results in question were collected within an atypical type room or building (Section 2.4.1).
   a. In this case, the room or building would still be managed as an RPC 1 site, but the overall installation RPC could be changed.

The next step in the installation review is to determine the most appropriate NAVRAMP testing phase (Section 2.2) for the installation or site(s). As was illustrated in Flowchart 2, the objective of NAVRAMP is to transition all naval installations worldwide into the monitoring phase of the program (Section 2.7). Doing so requires that screening and assessment (if applicable) be completed. However, all RPC 3 installations or sites are by default already considered to be in the monitoring phase. Therefore, the only required action is to implement RPC 3 monitoring as needed (Section 2.7.2). Likewise RPC 2 installation or sites are by default considered to be in the screening phase. Therefore, screening (Section 2.5) must be completed, and, if required, assessment (Section 2.6) before the monitoring phase can be implemented. However, RPC 1 installations or sites can be either in the assessment testing phase, meaning that most of the buildings still require testing, or the monitoring phase, which means that most if not all of the testing has been completed. However, in cases in which only a few buildings remain to be tested, particularly where mitigation has already occurred, consideration should be given to transitioning to the monitoring phase with emphasis given to testing the remaining untested buildings.

2.9 IMPLEMENTATION OF NAVRAMP WITHIN LEASED BUILDINGS

Navy (Chapter 25, Section 3.2. Section c of OPNAV M-5090.1 [US Navy 2014]) and Marine Corps policy (MCO P5090.2 [US Marine Corps 2013]) affords the same protection from radon exposure to Navy or Marine Corps personnel (includes military, civilian, and dependents) who are occupying testable buildings that are not Navy or Marine Corps owned. In consultation with appropriate legal counsel, installations must evaluate all current and future lease agreements to determine who has the main responsibility for radon testing and mitigation (if applicable). This requirement also applies to buildings used at overseas facilities under international use agreements, and to public–private ventures. If it is determined that the Navy or Marine Corps is responsible, then those buildings shall be tested and mitigated in accordance with all applicable NAVRAMP requirements. If it is determined that the lessor or host government is responsible, then the installation shall work with these parties to ensure that the buildings are tested and mitigated if required. If the responsibility cannot be determined, then the lease or agreement shall be renegotiated to empower the Navy or Marine Corps to implement NAVRAMP within these buildings. With respect to the construction of new buildings for long-term leases (e.g., leases, limited partnerships, and international use agreements), the naval installation shall consider the incorporation of RRNC features (Section 4.3) if the Navy or Marine Corps will be responsible for implementing NAVRAMP after construction has been completed.

For naval installations located at a non-Department of the Navy Joint Base, it should be determined if the host is in compliance with their respective service radon program. If not, then the installation should consult higher headquarters for further instruction.

2.10 RADON MANAGEMENT PLAN

All installations regardless of radon potential should develop and sustain an RMP. The primary purpose of an installation RMP is to serve as the primary document of the oversight mechanism for the entire radon control program. In addition, the document serves as a major means of maintaining program credibility and provides a quick reference for those who are new to or outside of the radon program at the installation. The RMP should be reviewed and updated every 5 years or as needed to ensure that the information within the document is current.

The following minimal outline is provided to facilitate RMP development; however, additional information or topics may be added by the installation as needed for further clarity.

Section 1: Introduction

- Date finalized
- Name and title of the preparer
- RMP coverage (e.g., all buildings, plus housing)
- Name and title of radon technical lead at the installation
- Suggested optional subsection: overview of roles and responsibilities for potential team members, for example
  - installation maintenance (periodic inspections, maintenance and repair of mitigation systems)
  - installation medical authority (to assist with health questions)
  - engineering design (new construction)
  - contracting (new construction)
  - safety office
  - legal and or public affairs (for release of radon data)
- Suggested optional subsection identifying possible stakeholders
  - family housing (government owned or privatized)
  - DoD Dependents Schools (DoDDS) or DoD Education Installation (DoDEA)
  - representatives of non-Navy or non–Marine Corps tenants at the installation

Section 2: Radon Data Analysis

- Brief overview of past radon surveys at the installation
  - Summary of radon surveys at the installation (e.g., number of buildings, rooms tested, highest results)
- Overall testing conclusions
  - Overall installation RPC
    - If site option is used,
      - RPC 1 if one site has elevated radon
      - RPC 2 if one site has not been screened
      - RPC 3 if all sites have been screened and no elevated radon was detected
  - Site RPCs (if applicable)
    - Include a brief rationale for each site
  - List of any leased or international use buildings at installation (Section 2.9)
    - Document who is responsible for testing and mitigation
  - List of atypical buildings (if applicable)
    - Include a brief justification for each atypical building
- A command-approved procedural plan for the release of radon results to stakeholders

Section 3: Mitigation

- List of mitigation systems by type of mitigation, room, and building at the installation

Section 4: Projects or Items Needing to be Addressed during the Next 5 Years

- List all projects that are required or proposed to meet NAVRAMP (funded and unfunded) over the next 5 years

2.11 HEALTH RISK COMMUNICATION

Under existing federal law (OSHA Hazard Communication Standard, 29 CFR 1910.1200 [CFR 2012]), military personnel, civil service employees, and subcontractors have the right to know the results of radon testing within their respective workplaces or residences. It is therefore in the Navy's and Marine Corps' best interest to be open and transparent about radon testing (see example handout in Appendix C). Prior to the initiation of radon testing, it is recommended that each installation develop a risk communication plan (RCP) and include it in the RMP (if applicable). The purpose of this RCP is to ensure that all stakeholders are informed and understand the installation's purpose for initiating radon testing, what the process is, and what to expect in terms of sharing results and other actions that may be necessary based on those results. This plan should include the procedures for the release of current survey data but also any historical data on file at the installation upon request by legitimate stakeholders. In the early stages of developing a risk communication plan, typically one or more of the following are consulted:

- command authorities
- installation medical office
- public affairs office
- installation legal office

Examples of stakeholders are

- occupants of the buildings
- DoDDS and DoDEA personnel (if schools are involved)
- installation medical support staff who are involved in primary care

Examples of methods by which to release the information include but are not limited to

- notices for building managers to distribute or post
- websites or a radon hotline
- town meetings or building-specific meetings
- base newspaper, all-hands emails

Another type of data dissemination that should be addressed in the RCP are requests through proper channels (e.g., higher headquarters, installation command, or public affairs office) from state, local, federal agencies, or host government officials; educational and research institutions; and news organizations.

3. NAVRAMP RADON TESTING PROCEDURES

3.1 OVERVIEW OF RADON TESTING PROCEDURES

As outlined in Section 2.2, NAVRAMP consists of three types of radon testing (screening, assessment, and monitoring), each with its own unique objective. Consequently, the types of detectors and the required quality assurance and quality control (QA/QC) procedures for each of the tests are different as well. This chapter outlines those requirements and, where possible, provides standardized procedures and specifications for all three testing categories. For all testing categories, whenever testing is required or performed within a structure, it is assumed that all occupied or potentially occupiable rooms are tested within the building. The only exceptions would be within buildings with installed radon mitigation systems where only the affected rooms would be tested (specifically diagnostic measurement, postmitigation, and O&M testing).

Under NAVRAMP, all installations or sites are required to complete screening and, if applicable, assessment. Once these are completed, installations or sites move into an ongoing monitoring phase to ensure that certain types of building changes or modifications do not result in rooms with radon concentrations ≥4 pCi/L. Because these changes or modifications can result in totally different actions at installations or sites with varying radon potential, COMNAVFACENGCOM has assigned initial RPCs (Section 2.4) to all installations responsible for shore facilities (Appendix B). These initial RPCs can be changed by the installation as circumstances dictate and are intended to be used for guidance as to how to conduct monitoring at the installation or site (if applicable).

Briefly, the testing requirements are as follows.

- For RPC 1 installations and/or sites
  - Ensure that radon testing is conducted in all occupied buildings (Section 2.6).
    - Retest all testable buildings
      - after every renovation (e.g., weatherization, whole building replacement, addition),
      - after every HVAC modification or replacement,
      - after damage by any event such as an earthquake or storm that would alter the building envelope, **<u>or</u>**
      - simply retest every 5 years.
  - Test all new buildings before occupancy or within 5 years of occupancy.
  - Test all mitigated rooms at least every 2 years.
- For RPC 2 installations and/or sites
  - Perform required screening (Section 2.5).
  - Based upon the survey findings, assign either an RPC 1 or RPC 3 designation.
- For RPC 3 installations and/or sites
  - Test all untested buildings constructed after 2003.

        - The rationale for testing all buildings constructed after 2003 is that some energy-saving features (primarily lower volumes of fresh makeup air and tighter building envelopes) typically incorporated after 2003 have been shown to increase the probability of elevated radon levels.
    - Test all recently acquired untested buildings (e.g., newly constructed, or through transfer of ownership) before occupancy or within 5 years of occupancy.
    - Test all Tier 1 buildings (e.g., hospitals, bachelors quarters schools, child-care centers, and brigs) that have not been tested previously.

3.1.1 Basis of the NAVRAMP Testing Protocol

At the inception of NAVRAMP, the stated overall objective was to screen all naval installations worldwide using a sampling protocol that would ensure an overall 95% statistical confidence that no single facility would have elevated radon potential. Since that time, the focus has shifted from an installation screening program to an ongoing environmental program in which the primary focus is the individual building. Because most radon testing in the United States is performed in single-family housing, EPA has focused considerable effort on the development of residential testing protocols. The underlying premise in these protocols is that the resident is genuinely motivated by either health concerns or the desire to sell a house and will do what is required to achieve a defensible testing conclusion. Consequently, the ability to perform a successful short-term radon measurement under the prescribed closed-building conditions presumably is simplified (for short-term tests of <4 days, closed building conditions must be initiated at least 12 h prior to the placement of the detectors and maintained for the duration of the test). With respect to nonresidential buildings, the only available EPA guidance document, *Radon Measurement in Schools* (EPA July 1993), does not adequately address the reality of testing a large population of buildings using its multiple measurement strategy. Consequently, in consultation with EPA and other subject matter experts, the Navy developed its own large building sampling protocol that blends applicable portions of the following EPA documents into a testing protocol:

- *A Citizen's Guide to Radon* (EPA 2012)
- *Home Buyer's and Seller's Guide to Radon* (EPA 2006)
- *Radon Measurement in Schools Revised Edition* (EPA July 1993)
- *Technical Support Document for the 1992 Citizen's Guide to Radon* (EPA May 1992)
- *Indoor Radon and Radon Decay Product Measurement Device Protocols* (EPA July 1992)

3.2 NAVRAMP TESTING PROTOCOL

The following testing procedures apply to all radon measurements performed within Navy and Marine Corps owned, leased, and international agreement buildings (excludes family housing) and for all testing phases (e.g., screening, assessment, and monitoring). For questions about testing family housing, please consult *Navy Radon Assessment and*

Mitigation Program Guidance Document for Navy Family Housing (US Navy 2002) for guidance.

3.2.1 When to Test and Testing Duration

Numerous studies (Appendix E, Section 1.3.2) have shown that indoor radon levels have not only day-to-day variation but also season-to-season variation. Consistent with EPA recommendations, under NAVRAMP, a 1 year test (tests ranging in duration from 325 to 395 days are considered 1 year tests) is required for all types of screening measurements (Section 2.5) and is the preferred method for assessment (Section 2.6) and periodic monitoring (Section 2.7) measurements. However, if 1 year tests are not practical, measurements >180 days are the preferred second choice. For testing of ≤180 days (the third choice), the testing should include the entire season of the year in which the building is under the longest period of closed-building conditions (i.e., typically winter for installations in the northern latitudes and summer for installations in southern latitudes). At installations that experience seasons (e.g., fall, winter, spring, and summer) during which 1 month or more elapses during the mechanical system changeover between heating and cooling configurations, the long-term test should span only one of these transitional seasons during the measurement period. In cases in which this cannot be determined with a high degree of certainty, a 1 year test should be performed.

However, in cases of possible health concerns, limited time, or financial considerations or at sites or installations at which significant elevated radon potential has been demonstrated (e.g., historical, validated radon data have identified rooms ≥20 pCi/L or the installation or site is RPC 1), short-term measurements (e.g., 2–90 days) can be used for assessment and for all periodic monitoring measurements provided that specific conditions are met during the entire test period (see also Section 3.5.6):

1. closed-building conditions
    a. For short-term tests of <4 days, closed building conditions must be initiated at least 12 h prior to the placement of the detectors and maintained for the duration of the testing period.
2. normal HVAC operation
3. testing is not performed during abnormal weather conditions

If one of these conditions was not met, then the short-term test data should be disqualified and the building retested. Validated short-term measurements that do meet these criteria are termed "representative" and are considered suitable for further evaluation (Section 3.5.6).

It is also important to note that testing for >1 year (e.g., 1.5 years) does not enhance or improve the quality of the long-term radon measurement. The sole intent of a 1 year test is to integrate the day-to-day and seasonal variations in radon concentrations found within most buildings to afford a good representation of the annual average (the risk upon which radon exposure is based). Extending the sample period of a 1 year test for more than 30 days (e.g., >395 days) may bias the result (higher or lower) and could impact the overall measurement confidence. Table 2 summarizes the types of radon testing and recommended test durations performed under NAVRAMP.

Table 2. NAVRAMP radon measurement testing types and codes

Type of radon measurement	Testing code	NAVRAMP testing phase	Preferred test type	Description of the test
Screening	SG	Screening (Section 2.5)	Long-term (1 year)	Measurement performed as part of project to determine radon potential at a site or installation
Supplemental screening	SU	Screening (Section 2.5)	Long-term (1 year)	Measurement repeated as a replacement for lost detectors during screening
Assessment	AS	Assessment (Section 2.6)	Long-term [a] (>90 to ≤365 days)	Measurement performed to identify buildings or rooms at a site or installation with elevated radon
Supplemental assessment	SA	Assessment (Section 2.6)	Long-term [a] (>90 to ≤365 days)	Measurement repeated as a replacement for lost detectors during assessment
Confirmation	CN	All phases	Short or long-term	Measurement used to confirm a single elevated radon measurement
Follow-up test	FT	All phases	Short or long-term	A retest of the room where the results are averaged with the pervious radon measurements to reach a conclusion
New construction	NC	Monitoring (Section 2.7)	Short or long-term	A radon test performed in a new building before occupancy or within 5 years of acquisition
Significantly modified or HVAC replacement or modification retest	RR	Monitoring (Section 2.7)	Short or long-term	A retest of a room or building in which weatherization, whole building replacement, additions, HVAC modification or replacement, or damage by any events such as earthquakes and storms that would alter the building envelope has occurred

Table 2 (cont.)

Type of radon measurement	Testing code	NAVRAMP Testing Phase	Preferred test type	Description of the test
Operation and maintenance	OM	Monitoring (Section 2.8)	Short-term	A mitigation performance test performed at least every 2 years within the affected rooms.
Monitoring test	MT	Monitoring (Section 2.8)	Short or long-term	Radon testing performed after the screening and assessment phases have been performed to ensure that levels are <4 pCi/L
Diagnostic measurement	DM	Mitigation	Short-term	A radon test performed as part of a mitigation diagnostic or under exactly known conditions within a room or building of interest
Postmitigation	PM	Mitigation	Short-term	Radon test after radon mitigation within the affected rooms

[a] Under certain circumstances (Section 3.2.1), short-term measurements can be substituted for long-term measurements. See also Section 3.5.6.

3.2.2 Radon Detector Selection

The selection of the most appropriate radon detector for a particular application depends on many factors, such as the type of radon test, the cost of the device, the highest expected radon result, and the logistics of getting the detector analyzed. For testing in Navy and Marine Corps buildings, three types of detectors are approved for short-term measurements (charcoal, electret, and continuous radon monitor [CRM]) and two types of detectors for long-term measurements (alpha track detector [ATD] and electret). It is important to note that NAVRAMP policy does not specify a particular detector manufacturer but does require that the following technical specifications be met:

- The detectors and analysis laboratory must be National Radon Proficiency Program (NRPP) or National Radon Safety Board (NRSB) approved.
- The CRM must be NRPP or NRSB listed.
- The detectors or CRM must be used in accordance with the manufacturer's, NRPP, and NRSB published specifications.
- The data collected must meet minimum NAVRAMP data quality objectives.
- The detector should have an upper reportable limit of at least 30 pCi/L for the projected exposure period.

All detectors used for screening must have ≤15% measurement error, whereas all other detectors (for assessment and monitoring) must have ≤25% (accuracy and precision information is available from the manufacturer).

Another consideration in the selection of the detectors is overall suitability. Most radon detectors are designed for typical indoor environments and have published lower and upper temperature and humidity limits. Testing outside these limits will result in poor data quality and in some cases will be invalidated by the manufacturer (note that not all manufacturers do so). Maximum testing duration is another consideration. Some detectors have extremely short exposure periods (e.g., 2–3 days) which, if exceeded, invalidate the radon measurements. Others (electrets, ATDs) have upper reportable limits because of technological or calibration issues (similar to overexposing a photo). In addition, some detectors have short holding times (the time elapsed between retrieval and analysis of the detectors) which, if exceeded, would invalidate a radon measurement. Therefore, obtaining this information from the manufacturer and examining return shipment options should be a prerequisite in the planning stages of any survey, and testing duration should be adjusted accordingly.

Although EPA, NRPP, and NRSB protocols allow for the reporting of radon results in either picocuries per liter, becquerel per cubic meter (Bq/m^3), or working level months (WLM), uncertainties in particulate concentrations (a key assumption in WLM measurements) within Navy and Marine Corps buildings make using WLM difficult. Therefore, only testing methods that measure radon gas concentration directly in picocuries per liter are permitted. For additional information on WLM see Appendix E Section 2.1.2. Note that gas detectors measuring radon concentrations in international units (Bq/m^3) are allowed provided the laboratory converts the results into pCi/L before reporting (1 pCi/L = 37 Bq/m^3).

3.2.3 Building Testing Requirements

For a building to be considered testable (referred to throughout the document as a testable building), it must first be enclosed, in ground contact (e.g., slab on grade, crawlspaces, basements), occupied or easily occupiable, and not proposed for demolition within the next 2 calendar years. Also included in this category of testable buildings are leased and international use agreement buildings in which it has been determined that the Navy or Marine Corps is responsible for the implementation of NAVRAMP (Section 2.9).

Exceptions to these testing requirements are buildings proposed for renovation, HVAC replacement, or other project or installations that would result in the building being more open than in typical usage. Testing for these buildings should be performed after these occurrences have been completed.

3.2.4 Room Testing Requirements

Within a building selected for radon testing (e.g., screening, assessment, and selected types of monitoring; see Sections 2.5–2.7), all ground-contact rooms (wall, floor, or ceiling) over a crawlspace or directly over a basement space not being tested are considered potentially testable rooms or areas. Selected measurement types (Table 2) excluded from this requirement are postmitigation, diagnostic, O&M, replacement for lost or damaged detectors, follow up, and confirmation testing. In these cases, the option exists to test only the individually impacted room or room of interest.

For a room or area to be considered for radon testing, it should be occupied for ≥4 h/day or easily occupiable (e.g., vacant bachelor quarter room, vacant office, or space that could easily be converted into occupied space). In addition, conference rooms, classrooms, and break areas should be included. Occupied service bays (e.g., motor transport buildings) should be tested only if the bay doors are closed for ≥4 h/day while occupied. Additional rooms for testing at the installation's discretion would include ground-contact hallways, stairwells, and other types of common areas. Rooms that should not be tested (unless for diagnostic purposes) include but are not limited to bathrooms, gear lockers, utility closets, dedicated storage rooms, elevator shafts, and unoccupied mechanical rooms.

3.2.5 Number of Sample Locations per Room

All radon testing using passive detectors shall be performed using 100% collocated duplicate detectors (e.g., two detectors placed side-by-side at the same location). The use of the second detector is not a requirement for CRMs.

Within testable rooms that are <10,000 ft^2, testing shall be performed at a frequency of one testing location per 2,000 ft^2 of floor area. In single testable rooms ≥10,000 ft^2 with a high volume of people usually present (e.g., commissary or exchange sales rooms, gymnasiums), testing locations shall be at an interval of one per 5,000 ft^2 up to a maximum of 50 sampling locations (to the best extent possible, evenly distributed throughout the room). However, for testable rooms ≥10,000 ft^2 with a low density of occupants (e.g., hangar bays, warehouse or storage bays, high-bay repair shops), testing locations shall include all areas (one sampling location per 2,000 ft^2) where the occupants spend the most time (e.g., counter, desk areas, or break areas) plus the less frequently used areas of the room (a maximum of five evenly distributed sampling locations for these infrequently used areas). In addition, all individual, testable rooms within these large rooms shall be tested as independent rooms (i.e., these sampling locations do not count toward the 5 or 50 location maximum for the room).

A noted exception to this testing requirement is cases in which family housing buildings (not including high-rise buildings) have been converted to other uses (e.g., billeting, lodges, transient quarters, offices). In this case, only one centrally located room (former living room or hallway) is tested.

3.2.6 Selecting a Testing Location within a Room

After the rooms for radon testing have been selected, to the best extent possible, the detectors should be placed in accordance with applicable portions of *Indoor Radon and Radon Decay Product Measurement Device Protocols* (EPA July 1992) and *Protocols for Radon and Radon Decay Product Measurements in Homes* (EPA May 1993). Specifically, the following guidelines should be observed.

- Select a testing location that reduces the probability that the device will be disturbed.
- Do not place the devices within 3 ft of drafts caused by fans or heating, air-conditioning, or other ventilation systems.
- Do not place or hang the detectors on light or fire sprinkler fixtures.
- Do not put the detectors inside drawers or cabinets.
- Place the devices between 2 and 8 ft from the floor, 4 in. from other objects, at least 3 ft from exterior doors and windows, and 1 ft from an outside wall.
- Place collocated duplicate detectors (i.e., two detectors per test location), within 4 to 6 in. of each other.

In addition to those requirements, all recommendations provided by the device manufacturer should be followed (e.g., do not use in direct sunlight or in areas of high humidity or temperature).

After the detectors are placed, a sticker bearing the following information should be attached either to the detectors or adjacent to them on the wall:

DO NOT DISTURB
RADON TESTING IN PROGRESS
CALL: (contact phone number)

At the time of detector placement, a handout containing information about radon, the testing device, and so on should be left with the occupant (an example handout is included in Appendix C).

3.2.7 Testing Documentation

After the radon detectors have been placed, specific information needs to be recorded on a data sheet. At a minimum, the following information should be collected:

- placement technician
- building number
- building name
- detector numbers
- types of radon detectors (e.g., ATD, electret, CRM)
- type of radon test (Table 2)
- date placed
- time placed (if applicable)
- room in which placed
- location placed in the room
- comments

In addition, rooms that require radon testing but that, for a valid reason, could not be accessed during detector placement should be recorded and the reason documented.

During detector retrieval, the following information should be collected or verified and recorded on the data form:

- date retrieved
- time retrieved (if applicable)
- detector number
- room and location
- any evidence of tampering
- any evidence of significant modification to the building that could have an impact on the radon level
- whether closed-building conditions were maintained during the test period (short-term only)

After the detectors have been retrieved, they should be returned to the manufacturer for analysis and reporting. Because different devices have different field holding times (the time between detector retrieval and analysis), manufacturer recommendations shall be strictly adhered to at all times. In addition, the QA detectors (blanks and spikes) should be returned at the same time as the field detectors. In surveys in which more than one shipment is required, the QA detectors should be distributed proportionally with each shipment.

3.2.8 Detector Losses and Missed Rooms

For planning purposes, in nonresidential radon surveys, one can usually anticipate detector losses of about 0.5 to 1% per month of the total number of rooms tested. Therefore, during a 6 month, 1,000-room survey, one would expect to lose detectors in between 30 and 60 rooms. Studies have identified the following three major reasons for these losses:

1. An occupant threw the detector away for some reason (15%).
2. Uniformed painters or cleanup crews threw the detector away (75%).
3. The detector fell and was disposed of (10%).

To counter these causes for detector loss, the following precautions should be taken.

1. Affix warning stickers to the detectors with a local number to call for additional information and provide information handouts during detector placement.
2. Inform contractors and base personnel working in the buildings that radon testing is in progress and the testing devices are not to be disturbed.
3. Place detectors in out-of-the-way locations within the room to ensure that they will not be bumped during the test period, and instruct occupants during placement to reattach the detectors if they accidentally fall.

If warranted, rooms in which detectors were lost and rooms that could not be accessed during detector placement can be retested using either long-term (preferred) or short-term measurement devices. However, short-term testing can be performed only if it can be done during nominal closed-building conditions. It is recommended that all rooms without radon results be retested within 1 calendar year of the previous survey's retrieval date. The noted exception is for buildings in which one or more rooms had radon results ≥4 pCi/L. In this case, testing shall be completed as soon as possible so that mitigation planning and implementation can proceed in a timely manner. For all other buildings in which the highest result was <4 pCi/L, retesting in the rooms with missing data should be considered only if losses exceed 20% of the total testable rooms within the building.

3.2.9 Testing Errors

During the test period, things may happen that would have an impact on the validity of the radon measurement. Certain types of these events would result in the test's being classified as invalid or not reportable (commonly referred to as "catastrophic" errors). For example, EPA recommends, as does NAVRAMP, that short-term test data be invalidated if one or more of the following is true:

- Testing was not performed during closed-building conditions.
- HVAC operation during the testing period was not "typical" (e.g., building mechanicals were off or malfunctioning).
- Testing was conducted during periods of abnormal weather conditions.

Typical problems that would invalidate long-term measurements include these:

- significant modifications to the building or HVAC replacement
- nonachievement of the minimum manufacturer's recommended exposure time for the device

Examples of catastrophic errors that would apply to both types of measurements are

- damage to detectors (e.g., vandalism, water, smoke, paint)
- device tampering
- relocation of the detectors to other rooms

For these types of errors, the result is not reported (i.e., the attempted measurement is documented without the radon result and with the error description listed under comments), and retesting is recommended. However, other types of errors need only be recorded and reviewed to see if the resulting error is significant. Examples of these types of conditional errors are

- One or both the detectors fell down (not significant if both results are <2 pCi/L).
- Placement and/or retrieval dates are missing (not significant if substituting the last placement date and/or the first retrieval date for the project yields results of <2 pCi/L).
- Results exceed the maximum reportable limit.

If those qualifying conditions for the conditional error are true, then the result accompanied with the error may be reported. However, if the qualifying conditions for the error are not met, then retesting is required if one or more rooms in the building has elevated radon or if problems were encountered with >20% of the testable rooms.

3.2.10 Follow-up Testing vs. Retesting

Under EPA radon testing protocols and guidance documents, follow-up measurements (defined as measurements performed with the same device, at the same location, under similar testing conditions, and, if applicable, identical HVAC settings) are recommended for all measurements ≥4 pCi/L. The conclusion to take corrective action is then based upon the numeric average of the initial and follow-up measurements (e.g., (initial result + follow-up result)/2). However, under this guidance, any initial measurement ≥8 pCi/L would mathematically require mitigation (e.g., (8.0 pCi/L + 0 pCi/L)/2 = 4 pCi/L). For this reason, under NAVRAMP, the automatic use of the EPA follow-up measurement protocol is not recommended. Under NAVRAMP, if the data set has been validated (i.e., all QA/QC objectives were met) and the measurement was confirmed (e.g., collocated duplicates have a relative percent difference [RPD], Eq. 1, of <36% or other elevated radon was present in the building), it is assumed that the elevated result is valid and representative (Section 3.5.1) of the radon levels within the room or building. More simply stated, from a programmatic level, elevated radon was present within the room during the test period; therefore, if additional testing is required, diagnostic measurements (a series of radon tests performed under known and specifically controlled conditions) are the preferred method to reach a defensible testing conclusion.

$$\textbf{Relative percent difference} = \frac{\textbf{(Highest pCi/L} - \textbf{Lowest pCi/L)} \times \textbf{100\%}}{\textbf{Mean}}$$

Equation 1. Relative percent difference

(Quality Assurance Handbook for Air Pollution Measurement Systems: Volume I, EPA 600/9-76-005 [EPA 1984])

3.3 TESTING QUALITY ASSURANCE AND QUALITY CONTROL

The objective of radon measurement QA is to ensure that data are scientifically sound and of known precision and accuracy. This is accomplished with project QC using unexposed detectors (blanks), collocated duplicates, and controlled exposures (spikes). Additional elements of QA involve using only devices accredited for radon measurements of the type being performed and the use of qualified staff during the field execution phase.

As part of these QA programs, procedures for attaining the defined QA objectives and a system for recording and monitoring should be established. In validating and analyzing a data set (defining a data set as a group of measurements performed at the same time using the same devices by the same organization), all exceptions must be noted and reported and their impact noted in the data report. In addition, the QC measurements shall be permanently linked with the data set to afford independent analysis in the future.

Because, in most NAVRAMP surveys, large number of measurements are performed within a short period of time, plotting daily control charts (Appendix E, Section 2.1.4) would be of only minimal benefit. Instead, NAVRAMP uses an individual measurement tripwire using the EPA control limits (see the second bullet item, for "duplicates," in the following list). Under NAVRAMP, the QC requirements for all passive radon measurements are the following.

- Blanks: Blanks should be at or below the manufacturer's published lower level of detection (LLD).
- Duplicates: Collocated detectors in which both measurements are >4 pCi/L should have an RPD of <36% (see Eq. 1). For collocated detectors in which the measurements are >2 pCi/L and <4 pCi/L, an RPD of <67% is considered acceptable.
- Spikes: Spike results should be within ±25% of the known value (Eq. 2).

To the best extent possible, the blanks and spikes should be returned to the laboratory at the same time as the field detectors. In addition, they should be intermingled with and undistinguishable from the field detectors.

3.3.1 Passive Measurement Quality Assurance and Quality Control

Before a data set can be reported, it must first be validated to ensure that it meets specific QA requirements. Failure to meet any of the minimum QA requirements will require specific reporting actions and, depending on the severity of the failure, possibly retesting. The following sections detail the requirements, analysis procedures, and corrective actions to be taken if needed. Under NAVRAMP, the level of QC for passive detectors (ATDs, charcoal canisters, and electrets) depends upon the type of testing (i.e., screening, assessment, or monitoring) and the number of locations (e.g., rooms) being tested at a given time. The minimum QC levels follow.

- <10 locations:
  - one blank detector and
  - 100% collocated duplicates
- 10 to <33 locations:
  - three blank detectors,
  - 100% collocated duplicates, and
  - three spike detectors at four times the number of days of the projected exposure (e.g., for a 365 day exposure, the spike should be 1460 pCi/L-days)
- ≥33 locations:
  - blank detectors: 3% of the total number of locations tested, or up to 30 blanks (2/3 field blanks, 1/3 laboratory blanks), whichever quantity is less;
  - 100% collocated duplicates; and
  - spike detectors: 5% of the total number of locations tested or up to 50 spikes, whichever quantity is less; spike concentration of four times the number of days of the projected exposure (e.g., for a 365 day exposure, the spike should be 1460 pCi/L-days)

For screening using the enhanced statistical method option (Section 2.5.2), there are no upper limits for the number of blanks and spikes.

For blank ATDs, an acceptable blank measurement would be any reported measurement ≤60 pCi/L-day. For charcoal canisters, an acceptable blank measurement would be any reported measurement ≤1 pCi/L-day. For electret-based detectors, an acceptable blank measurement would be any measurement ±3 V from the original measurement

Under NAVRAMP, all spikes must be performed in an NRPP- or NRSB-accredited chamber or within a US governmental calibration chamber. NAVRAMP requires that the mean spike result (the average of all spike results at a given concentration) be ±25% of the known concentration (Eq. 2). With respect to ordering spikes from the private accredited chambers, it is highly recommended that contractual arrangements be made with the laboratory prior or shortly after the initiation of detector placement.

$$\textbf{Relative percent Error} = \frac{\textbf{(Measured Value – Reference Value}^{a}\textbf{)} \times \textbf{100\%}}{\textbf{(Reference Value)}}$$

([a] Reference value can be in either pCi/L-days or pCi/L)

Equation 2. Individual relative error.

Reference: (EPA 1997)

In all cases in which one or more of the QC requirements are not met, the testing contractor shall first inform the laboratory of the problem(s). If the laboratory can correct the problem, then the corrected results for the data set shall be resubmitted by the laboratory. However, if the laboratory is unwilling or unable to correct the QC problem(s), then the installation shall perform an in-depth analysis of the impact of the QC failure on the radon measurements. At a minimum, the impact analysis shall address the overall measurement uncertainty at 4 pCi/L and the likelihood of false positive and/or negative measurements. Using these measurement uncertainties, a review of the individual field measurements should be performed and all measurements in which the conclusion (e.g., the need to perform mitigation) is in question should be identified. For these individual measurements, retesting would be required. Individual measurements that fall outside the range of interest should be documented, and retesting would be at the discretion of the Navy or Marine Corps. It is important to note that EPA testing guidelines do not permit the end user to compensate or correct for laboratory identified QC deficiencies (e.g., blanks or spikes out of compliance) in the survey, these corrections can only be made by the laboratory (see also Section 3.5.1).

3.3.2 Precision Calculations for Passive Detectors

All radon testing currently performed under NAVRAMP using passive radon detectors is performed using 100% collocated duplicates. To determine if a data set meets overall precision requirements, the RPD for each measurement is calculated (Eq. 1) and then the results are sorted into two ranges based upon the average radon concentration of the measurement (>2 pCi/L and <4 pCi/L, and ≥4 pCi/L). No RPD requirement is needed for radon measurements for which both collocated results are <2 pCi/L.

The arithmetic average of the RPDs of each range is then calculated. A data set (i.e., a group of radon measurements performed at approximately the same time using identical detectors, the same QC, and so on) is considered to have acceptable precision if both of the following requirements are met:

- an average RPD of <67% is achieved for all average radon results >2 pCi/L and <4 pCi/L
- an average RPD of <36% is achieved for all average radon results ≥4 pCi/L

However, if one or both of the RPD precision requirements are not met, then further analysis is required using the following steps:

Average radon measurements >2 pCi/L and <4 pCi/L with RPD ≥67%

- Using Student's *t*-test or other appropriate statistical method, eliminate all statistical outliers and recalculate the average RPD.
  - If the average RPD without the statistical outliers is <67%, then the abbreviated data set is considered to have acceptable precision in the lower range.
    - Retesting of the rooms that failed the RPD test is not required.
  - If after the exclusion of the statistical outliers, the average RPD is >67%, then the laboratory should be consulted to see if the problem can be corrected.
    - If the problem cannot be corrected, then retesting should be considered for all rooms with RPDs ≥67%.

Average radon measurements ≥4 pCi/L with RPD ≥36%

- Using Student's *t*-test or other appropriate statistical method, eliminate all statistical outliers and recalculate the average RPD.
  - If the average RPD without the statistical outliers is <36%, then the abbreviated data set is considered to have acceptable precision in the upper range.
    - For the statistical outliers excluded from the RPD analysis, retesting is recommended for results with an arithmetic average ≥4 pCi/L to <20 pCi/L, and not recommended for statistical outliers where both measurements are ≥20 pCi/L.
- If after the exclusion of the statistical outliers, the average RPD is >36%, then the RPD should be recalculated excluding all outliers and measurements in which both radon results are ≥10 pCi/L.
  - If the average RPD is <36%, then the abbreviated data set is considered to have acceptable precision in the upper range.
    - For the results excluded from the RPD analysis, retesting is recommended for those in which both results are <10 pCi/L, and not recommended for those in which both results are ≥10 pCi/L.

If both methods using the abbreviated data set fail to achieve a <36% RPD using the abbreviated data sets, then the rooms should be confirmed before mitigation.

3.3.3 Continuous Radon Monitor Quality Assurance and Quality Control

At a minimum, all CRMs used under NAVRAMP must have ±10% resolution at 2 pCi/L and be able to record the levels hourly. The device used in the field must have a current manufacturer's calibration certificate and shall be maintained in accordance with manufacturer specifications. For every tenth radon measurement performed, a duplicate measurement performed with another CRM or an approved electret or charcoal canister shall be performed. The acceptance criterion for the CRM is that the result be within ±25% of the collocated duplicate measurement.

If this condition is not met, then the test should be repeated using either collocated duplicate passive detectors or collocated duplicate CRMs. If the CRM is found to be in error, then all rooms previously tested by the CRM since the last performance check should be retested.

3.4 RADON MEASUREMENT REPORTING REQUIREMENTS

For all radon testing conducted, a report shall be generated and submitted to the designated NAVRAMP point of contact. It shall contain at a minimum the following information:

Contractor information

- contractor name
- address and phone number
- contract number
- NRPP or NRSB testing certification number

Device information

- manufacturer's name, address, and phone number
- device type and model number
- manufacturer's NRPP and/or NRSB certification number

The following information should be submitted by building and room tested:

- report date
- site, if applicable
- building name
- sample room and location
- type of detector
- type test (short-term or long-term)
- detector identification number
- duplicate identification number
- date placed and retrieved
- measured radon concentration in picocuries per liter
- duplicate radon concentration in picocuries per liter
- average radon concentration in picocuries per liter
- occupied rooms that could not be tested
- testing exceptions and losses and comments

For each building tested, a summary listing should include the following:

- number of measurements completed
- number of detectors lost

- list of rooms in which testing was unsuccessful
- number of rooms 0 to <4 pCi/L
- number of rooms 4 to <20 pCi/L
- number of rooms 20 to <200 pCi/L
- number of rooms ≥200 pCi/L or greater
- highest measurement in picocuries per liter
- rooms requiring radon mitigation
- recommendations for future actions

Depending on the size, complexity, and needs of the project, additional deliverables (e.g., electronic format, maps, and local geological conditions) may also be requested.

3.5 DATA ANALYSIS

3.5.1 Data Set Validation

When a radon measurement data set is received, the data must be validated before any conclusions are drawn. All deficiencies in the data set need to be documented and corrective actions taken, if warranted. For QA detectors, the following acceptance criteria should be verified:

- The appropriate number of blanks were used (Section 3.3.1), and all blanks are at or below the reported manufacturer LLD.
- RPD calculations (a measure of precision) were done for all duplicate measurements and met the requirements listed in Section 3.3.2.
- The appropriate number of spikes were used, were exposed at the correct concentration (Section 3.3.1), and are within ± 25% of the known concentration.

Data sets that meet these QA criteria are considered validated and are suitable for further processing. However, for data sets with QA deficiencies, further analysis is required.

For all QA deficiencies, the manufacturer of the testing devices should be consulted to determine if corrections can be performed. In cases in which corrections cannot be performed, or the corrections still do not meet NAVRAMP QA requirements, two options exist: redo the radon survey or perform an error impact analysis. For small radon surveys, retesting will probably be the option of choice. However, for larger surveys, time, funding, and logistics may preclude retesting. The objective of error impact analysis is to determine if a defensible conclusion can be reached for measurements at or near the action level using conservative assumptions. The conclusions reached using these methods can be reported provided that the appropriate disclaimer is provided. For example, in cases in which the blanks are above the LLD but all radon test results are <4 pCi/L, the impact is minimal. The overall conclusion, no elevated radon is present, can be reached and results reported. Conversely, in cases of significantly elevated results, a conclusion can also be reached (e.g., elevated radon is present) provided the difference between the reported measurement and the background is ≥4 pCi/L. However, in cases for which the background correction yields a result between 3 and 5 pCi/L, the rooms should be retested.

Conclusions as to accuracy can be reached provided that the data set has acceptable precision (Section 3.3.2). For example, if the bias is ±2 pCi/L and the highest measured result is 1.0 pCi/L, the overall conclusion that no elevated radon is present can be reached. However, in cases in which the bias could result in some individual results being ≥4 pCi/L, or some marginally elevated results being <4 pCi/L, retesting should be performed. The same is also true for significantly elevated radon results for which subtracting the bias still provides a result of ≥4 pCi/L and the conclusion that radon is elevated is evident.

However, poor precision is much more difficult to work around within the area of interest. For example, if the average RPD for results for all survey data <4 pCi/L is twice the NAVRAMP limit (e.g., 134%), any result over 1.7 pCi/L is potentially above the action level. Therefore, redoing the survey is warranted. Conversely, an elevated result of 5.6 pCi/L is also potentially suspect if its RPD is twice the NAVRAMP >4 pCi/L limit (e.g., 72%). Therefore, confirmation measurements are needed. At higher radon concentrations (e.g., >10 pCi/L), poor precision does not alter the conclusion that elevated radon is present; therefore, confirmation testing is not needed.

3.5.2 Data Set Quality Factor

Historically, within the Navy and Marine Corps, tens of thousands of individual radon results have survived in one form or another for decades. However, when they are reviewed decades later (Section 2.4), in a significant number of cases, the blank and spike data are incomplete or missing, creating the possibility of having to retest tens of thousands of rooms. To assist future reviewers of the data—who may not have the benefit of process knowledge of a particular survey—at the conclusion of each data set validation, a data set quality factor (DSQF) is assigned. These values will provide future reviewers of the data some insight into the data set quality and ensure that the validation process need not be repeated. The DSQF values and meanings follow.

- **DSQF 1: Meets NAVRAMP Criteria**
  - The data set meets or exceeds all historical or current NAVRAMP data quality requirements. Data sets with this assignment can be used or cited without further qualifications. However, NAVRAMP confirmation rules for elevated results must be followed as applicable for each measurement before taking correction action.
- **DSQF 2: Meets EPA Criteria**
  - The data set did not have sufficient blanks or spikes to meet the applicable NAVRAMP requirements in force at that time. However the data set has at least 10% duplicates, and the duplicates are within the acceptable RPD range provided by EPA. Data sets with this assignment can be cited; but in cases in which single radon measurements are ≥4 pCi/L, the result must contain the statement "Pending Confirmation." In addition, before corrective action is taken, all single elevated results must be confirmed. The sole exception is if

the elevated measurement was performed using collocated duplicates and the measurement had an acceptable RPD. In this case, mitigation could proceed without confirmation.

- **DSQF 3: Data Set Quality Is Unknown**
  - The data set has insufficient QC to make a determination. All elevated results, including those with collocated duplicates, must be confirmed before corrective action is taken. All citations of the data ≥4 pCi/L should include the comment "Pending Confirmation."
- **DSQF 4: Unusable Data**
  - The data set has sufficient QC to determine that it does not meet NAVRAMP or EPA data set quality standards. The data set or individual result should not be cited or distributed, and the entire survey should be repeated. In addition, no conclusions should be drawn from the data with respect to the absence or presence of elevated radon at the installation or site.

3.5.3 Data Set Completeness

The overall objective of NAVRAMP testing is to test all testable rooms (Section 3.2.4) within a building. However, detector losses, inaccessible areas, and other errors will inevitably result in some rooms not having radon data. The necessity of retesting these rooms depends upon many factors, such as the total number of rooms in which data are available, the potential for elevated radon at the installation or site, and the highest result in the building. Within each building tested, a check should also be performed to ensure that all occupied areas required to be tested under NAVRAMP actually were tested (Section 3.2.4). Any areas or rooms that were missed should be documented and reasons provided for their being missed. Under NAVRAMP, retesting of testable rooms with missing data (not the entire building) shall be performed for any building in which a confirmed elevated measurement was found. For all other buildings in which the highest result was <4 pCi/L, retesting in the rooms with missing data should be considered only if losses exceed 20% of the total testable rooms.

3.5.4 Elevated Radon Results

The objective of this section is to reach a defensible testing conclusion for each room tested using a validated data set following standardized procedures. Because EPA and NAVRAMP guidelines require that any measurement ≥4 pCi/L be confirmed before corrective action is taken, the measurements need to be segregated by room into two types of measurements: those performed individually and those performed using collocated duplicates.

For rooms tested with a single long-term measurement (e.g., only one detector was used), results ≥4 pCi/L are considered confirmed if one or more of the following is true:

- One or more rooms in the building are ≥4 pCi/L.
- Prior testing in the room has been ≥4 pCi/L.
- The average of sequential measurements employing similar test devices for a similar duration in the room is ≥4 pCi/L.

For all other rooms, a single measurement of ≥4 pCi/L will need to be confirmed by independent measurement using either long-term or short-term devices before corrective action is taken.

For measurements performed using collocated duplicates, results in which the arithmetic average is ≥4 pCi/L are individually reviewed to determine if confirmation is required. The measurement is considered confirmed if one or more of the following is true:

- The RPD is <36%.
- One or more rooms in the building are confirmed as ≥4 pCi/L.
- Prior testing in the room has been ≥4 pCi/L.
- The average of sequential measurements employing similar test devices at a similar duration in the room is ≥4 pCi/L.

For the remaining cases, the single ≥4 pCi/L measurement will need to be confirmed by independent measurement using either long-term or short-term devices before corrective action is taken.

The only exception to these rules is for cases in which both radon results are >30 pCi/L. For both technical and business reasons, all commercially available radon measurement devices have upper limits for radon exposure. After those limits are exceeded, precision and accuracy tend to widen and drift, respectively. In such cases, the device manufacturer should be consulted. In cases of high radon concentrations, obtaining a measurement within the NAVRAMP control limits is a secondary concern to mitigation.

In some cases, the detectors may have been exposed to higher levels of radon than can be accurately reported by the laboratory. (This should not be confused with exceeding the exposure duration of the detector, in which case retesting is warranted.) Typically, these results are coded by the manufacturer and reported as "measurement exceeds upper limit" or the result is greater than or equal to some value. Although the conclusion is self-evident (elevated radon is present, mitigation is needed), attempts should be made to work with the manufacturer to determine if the result could be over the respective NAVRAMP threshold timelines (in Table 1, for example is the result >20 pCi/L or >200 pCi/L). In cases in which the result cannot be bracketed by the manufacturer, mitigation should be performed as soon as practical.

With respect to elevated, confirmed short-term tests, the following must be true for the entire test period:

1. The entire test was performed during nominal closed-building conditions.
    a. For short-term tests of <4 days, closed building conditions must be initiated at least 12 h prior to the placement of the detectors and maintained for the duration of the test.
2. HVAC operation was as normal.
3. Testing was not performed during abnormal weather conditions.

At a minimum, if these three conditions cannot be met or maintained during the proposed test period, then the testing should not be performed at that time. If the testing was performed and one of these conditions was not met, the data should be disqualified and the building retested. Measurements that do meet these criteria are termed by NAVRAMP "representative radon measurements" and can be used for further evaluation.

3.5.5 Averaging Sequential Radon Measurements

Under the EPA testing protocol, sequential measurements (sometimes referred to as sequential duplicates) are performed as a means to judge the variability of the indoor radon concentration at different test conditions (e.g., different seasons or HVAC settings). To perform sequential averaging, the results to be averaged must all be from the same category (e.g., all long-term or all short-term). When similar types of radon measurements are averaged, the average of each individual measurement event is calculated first and then the average of these results is calculated. In the example shown in Table 3, over a 1 year period, a room had three short-term testing events, each performed with collocated duplicate detectors. The average result and RPD of each measurement event were calculated. Because all of the RPDs were within acceptable limits, the overall average of all three measurement events was then calculated. The result, 3.5 pCi/L, indicates that mitigation would not be required in this room. However, if one of the three measurement events had an unacceptable RPD, it would be discarded, the average of the two remaining results would be taken, and a conclusion would be drawn from the result.

Table 3. Sequential testing averaging example

Measurement	Detector 1 (pCi/L)	Detector 2 (pCi/L)	Average (pCi/L)	RPD (%)
1	3.9	4.5	4.2	14.3
2	2.0	2.4	2.2	18.2
3	3.8	4.3	4.1	12.3
Average			**3.5**	

In some buildings, seasonal HVAC settings may have a direct impact on the radon concentration. Examples include variation in the volume of makeup air, physically turning the HVAC off during transient seasons, and changes in the supply air volume, to name a few. In these cases, a time-weighted-average method can be employed to determine if mitigation is required. For this determination, detailed HVAC operational information is required—specifically, when the changes occur and for what duration—in addition to representative, good-quality radon measurement data collected during these periods. To perform the time-weighted average, the number of days is first estimated for each specific HVAC condition found throughout the year. The individual estimated days are then multiplied by their respective radon results (pCi/L) for this period. The pCi/L-days are then summed and the sum divided by the total number of days (ideally, 360 to 365 days). The result in pCi/L would be an estimate of the annual average for the building (see Table 4 for examples).

In cases where the estimated annual average is ≤2 pCi/L, mitigation is not recommended. For an annual average, ≥4 pCi/L, mitigation should be performed in accordance with the NAVRAMP timeline (Table 1). However, for estimated results >2 and <4 pCi/L, retesting using a 1 year measurement should be considered.

Table 4. Examples of time-weighted averaging

Example 1	**Winter (HVAC on)**	**Spring (HVAC off)**	**Summer (HVAC on)**	**Fall (HVAC off)**	**Total**
Number of days	120	60	120	60	360
Radon level (pCi/L)	8.0	1.0	4.0	0.5	N/A
pCi-L-days	960	60	480	30	1530
Average radon level	4.3				
Conclusion	Mitigate				
Example 2	**Winter (HVAC on)**	**Spring (HVAC off)**	**Summer (HVAC on)**	**Fall (HVAC off)**	**Total**
Number of days	180	N/A	180	N/A	360
Radon level (pCi/L)	8.0	N/A	0.1	N/A	N/A
pCi-L-days	1440	N/A	18	N/A	1458
Average radon level	4.1				
Conclusion	Mitigate				
Example 3	**Winter (HVAC on)**	**Spring (HVAC off)**	**Summer (HVAC on)**	**Fall (HVAC off)**	**Total**
Number of days	90	90	90	90	360
Radon level (pCi/L)	6.0	0.5	0.8	0.5	N/A
pCi-L-days	540	45	72	45	702
Average radon level	2.0				
Conclusion	Mitigation is not required, but 1 year testing should be considered				

3.5.6 Analysis of Short-Term Radon Data

Under NAVRAMP, if 1 year tests are not practical, radon tests of >90 days are preferred for assessment and supplemental assessment measurements rather than short-term measurements (e.g., 2–90 days). However, in cases of possible health concerns, limited time, or financial considerations, or at sites or installations at which significant elevated radon potential has been demonstrated (e.g., historical, validated radon data has identified rooms ≥20 pCi/L or a RPC 1 site or installation), short-term measurements (e.g., 2–90 days) can be used for assessment and supplemental assessment measurements provided that specific conditions are met during the entire test period (Section 3.2.3).

Unlike long-term tests (e.g., 91–365 days), short-term measurements can be biased (higher or lower) by episodic and seasonal weather (Appendix E, Fig. 6). Consequently, extra care must be taken to document periods of heavy rain or high winds during the test period and the HVAC conditions of the building (e.g., is the HVAC operating normally; if applicable, what are the seasonal settings; are there any setbacks for nights and weekends). For these reasons, a validated, elevated short-term result is treated differently under NAVRAMP from a long-term result of similar quality. For example, under NAVRAMP, if an elevated 1 year measurement has been validated and confirmed, mitigation should proceed without additional testing. Conversely, validated and confirmed, representative elevated short-term measurements require a review of the indoor testing conditions and may require additional radon testing before mitigation is considered.

In large buildings, radon levels can be significantly affected (up or down) by the operation of the building's mechanical systems (e.g., HVAC and exhaust blowers). Under the expedited testing protocol, all rooms with validated, confirmed, representative elevated radon are treated initially as "rooms of interest," meaning that the possible impact of the building HVAC system should be evaluated before recommending mitigation. Specifically, what needs to be determined is whether any seasonal adjustments were made during the year (e.g., fresh-air dampers opened and closed, heating and cooling cycles turned off for certain times of the year). If any of these has occurred, then the overall potential impact of these adjustments or cycles on the building's ventilation rate needs to be determined. This information can typically be obtained by consulting the installation's HVAC maintenance group or contractor.

In cases where seasonal changes in HVAC condition would not reduce or significantly change the ventilation rate, or in cases where there is no mechanical contribution (e.g., buildings with split systems with no allowance for fresh air, radiator heater/cooling, and so on), Table 5 should be consulted to extrapolate the radon levels needed for the remainder of the year to provide an estimated <4 pCi/L/year. Consideration should be given to periods of possible open-building conditions during transition seasons (e.g., spring and fall). For radon results between 4 and 6 pCi/L, or if the extrapolation is uncertain, consideration should be given to performing a short-term test during the opposite season and then doing a time-weighted estimated annual average (Flowchart 6). However, in cases where no significant change in radon concentration is expected, mitigation within the NAVRAMP guidelines should proceed.

However, for cases in which seasonal HVAC fresh-air volume adjustments are made, it should be determined whether the changes might reduce the radon levels either through dilution or pressurizing the building. To determine if retesting is needed, the first step is to estimate the number of days/year on which these HVAC conditions are prevalent. Rounding off to the nearest pCi/L, consult Table 5 to determine what the radon concentration would need to average for the remaining days of the year to average to

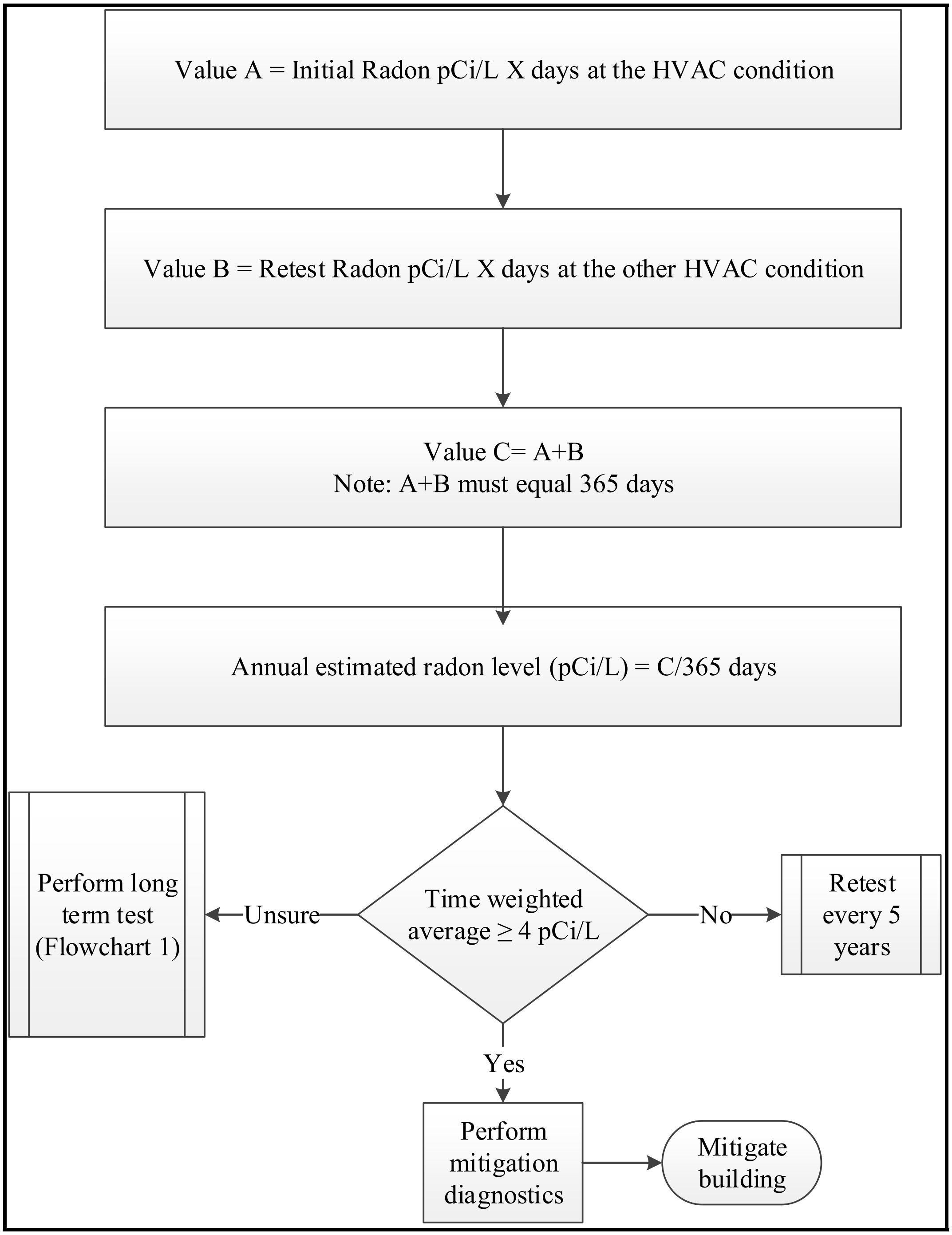
3.9 pCi/L. For example, if the initial radon result was 20 pCi/L and the duration of the HVAC condition was 30 days, the radon level would have to average ≤2.5 pCi/L for the remaining 335 days for the integrated annual average to be ≤3.9 pCi/L. In this example, a short-term retest during the other HVAC condition would be recommended if the seasonal HVAC changes had the potential to pressurize the building or significantly increase the building ventilation rate. However, in this example, if the duration of the tested HVAC condition was 90 days, mitigation should proceed in accordance with the NAVRAMP recommended guidelines, since negative levels of radon are an impossibility. If a valid and representative retest was performed, then the time weighted average should be calculated using Flowchart 6.

Table 5. Time-weighted averages to obtain annualized 3.9 pCi/L [a]

	30 days at HVAC or climate condition	**60 days at HVAC or climate condition**	**90 days at HVAC or climate condition**	**120 days at HVAC or climate condition**	**180 days at HVAC or climate condition**	**270 days at HVAC or climate condition**
Initial radon result (pCi/L)	**Average for remaining 335 days (pCi/L)**	**Average for remaining 305 days (pCi/L)**	**Average for remaining 275 days (pCi/L)**	**Average for remaining 245 days (pCi/L)**	**Average for remaining 185 days (pCi/L)**	**Average for remaining 95 days (pCi/L)**
4.0	3.9	3.9	3.9	3.8	3.8	3.6
5.0	3.8	3.7	3.5	3.4	2.8	0.8
6.0	3.7	3.5	3.2	2.9	1.9	–2.1
7.0	3.6	3.3	2.9	2.4	0.9	–4.9
8.0	3.5	3.1	2.6	1.9	–0.1	–7.8
9.0	3.4	2.9	2.2	1.4	–1.1	–10.6
10.0	3.4	2.7	1.9	0.9	–2.0	–13.4
15.0	2.9	1.7	0.3	–1.5	–6.9	–27.7
20.0	2.5	0.7	–1.4	–4.0	–11.8	–41.9
25.0	2.0	–0.3	–3.0	–6.4	–16.6	–56.1
30.0	1.6	–1.2	–4.6	–8.9	–21.5	–70.3
35.0	1.1	–2.2	–6.3	–11.3	–26.4	–84.5
40.0	0.7	–3.2	–7.9	–13.8	–31.2	–98.7
45.0	0.2	–4.2	–9.6	–16.2	–36.1	–112.9
50.0	–0.2	–5.2	–11.2	–18.7	–41.0	–127.1
100.0	–4.7	–15.0	–27.6	–43.2	–89.6	–269.2
200.0	–13.7	–34.7	–60.3	–92.2	–186.9	–553.4

[a] Radon levels < 0.0 pCi/L are an impossibility. The negative values were included for reference purposes only.

Another option is to perform a series of short-term, diagnostics radon measurements (radon measurements performed during radon mitigation diagnostics under known, precise conditions) at the different fresh-air settings. These measurements can be performed using short-term passive detectors or CRMs, and the data can be processed using a similar time weighted process as illustrated in Flowchart 6.



Flowchart 6. Estimation of the annual average using two results.

3.5.7 Confirmation Measurements

Consistent with current EPA recommendations for follow-up testing, NAVRAMP requires that all rooms with a single reading (e.g., one detector) ≥4 pCi/L be confirmed by additional radon testing (short- or long-term) or by other means before mitigation. If NAVRAMP QA/QC has been followed and the data set validated (Section 3.5.1), then the likelihood of an erroneous radon measurement is very small. In cases in which seasonal weather patterns or cyclic HVAC operation is known or suspected to have caused an error, testing should be performed using sequential measurements (Section 3.5.5).

In all other cases using a valid data set, the only reasons to confirm an elevated measurement are

- The measurement in question failed to meet the RPD requirements (Section 3.3.2).
- The measurement was not performed using collocated duplicates.
- A specific event occurred during the testing that might have resulted in an elevated radon reading.

The perception of "testing until I find a result that I like" should be avoided at all times.

For a single, valid, elevated radon measurement (e.g., no collocated detector), retesting must be performed if there are no other results in the building ≥4pCi/L. If the initial measurement was short-term, then another short-term measurement can be used if similar test conditions can be obtained (e.g., if it is the same season). If not, then a long-term measurement will be required. If the retest of a short-term measurement is performed using short-term devices, under similar conditions, the initial measurement is considered confirmed if

- the average of the test and the retest is ≥4 pCi/L
- the average of the retest is <4 pCi/L but ≥50% of the initial measurement (e.g., a retest value of 2.0 pCi/L confirms 4.0 pCi/L).

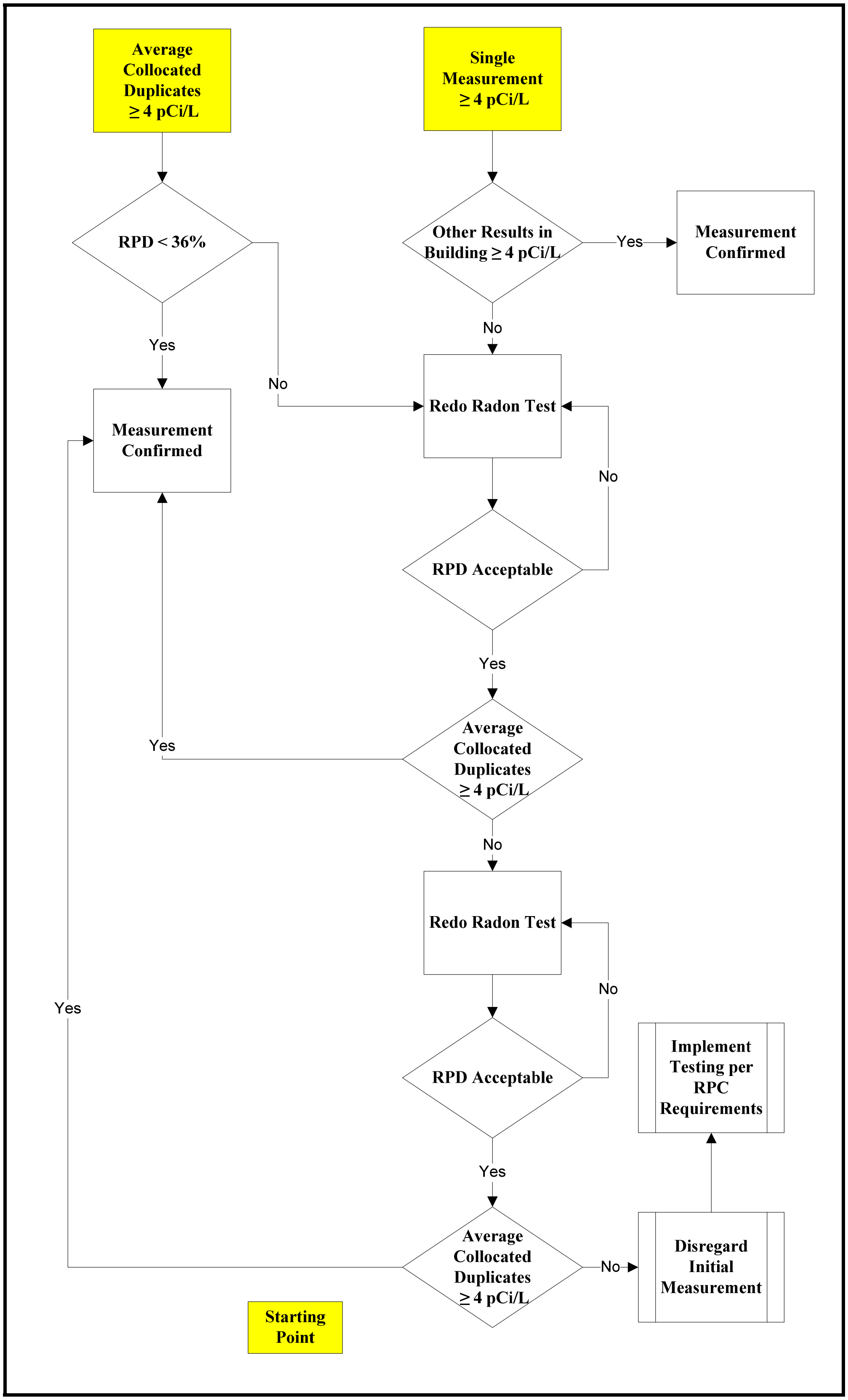
If the measurement is not confirmed, then a third test is employed using the same criteria as above. If the elevated measurement cannot be confirmed, it should be error-coded and not used.

Ideally, to confirm a long-term measurement, another long-term measurement would be performed during the same season. Unfortunately, time and/or financial considerations may require a follow-up test using a shorter measurement interval in a different season. Extrapolating from EPA guidance and programmatic lessons learned, a few general rules have been developed to assist in interpreting independently measured long-term tests and short-term data. The following is a summary of the confirmation algorithm:

1. If both the short-term and long-term measurements are ≥4 pCi/L, then the long-term result is considered confirmed (e.g., initial long-term = 4.0 pCi/L and average short-term confirmation = 30 pCi/L).

2. If the short-term measurement result is <4 pCi/L but >50% of the long-term result, then the long-term result is confirmed (e.g., initial long-term = 4.0 pCi/L and short-term confirmation = 2.0 pCi/L).

In cases of disagreement, a second confirmation measurement should be performed using either a short-term or long-term confirmation (the latter is preferred) during similar initial testing conditions. If the second follow-up measurement is >4 pCi/L, then the initial conclusion is kept (e.g., elevated radon is present). If the second follow-up agrees with the first follow-up measurement, then a new conclusion is reached based on the most recent short-term measurements. In addition, consideration should be given to any changes (usage, structural, or mechanical) that may have occurred since the initial long-term test was performed. The occurrence of any one of these events can cause significant increases or decreases in the radon levels. The confirmation algorithm is shown in Flowchart 7.



Flowchart 7. Elevated radon measurement confirmation process.

3.5.8 Postmitigation and O&M Measurements

For postmitigation testing, EPA requires only that the measurement be performed using an approved device/method and be conducted within 30 days of the mitigation installation (EPA 1994b). A successful mitigation is evident if the measurement is <4 pCi/L. Similar guidance is provided for O&M testing, with the exception that the test is to be performed at least every 2 years after mitigation. Under NAVRAMP, these measurements are performed using collocated duplicates (duplicates are not required for CRMs) and the results validated by calculating the RPD (Eq. 1). The measurement is considered valid if either of the following is true:

- An average RPD of <67% is achieved for average radon results >2 pCi/L and <4 pCi/L.
- An average RPD of <36% is achieved for average radon results ≥4 pCi/L.

RPD validation is not required if both results are <2 pCi/L.

3.5.9 Analysis of Radon Test Data from Other DoD Sources

Recently, as a cost savings measure, DoD combined separate DoD facilities into a common administrative entity to save on both administration and maintenance costs. At naval installations where joint basing has occurred and the Navy or Marine Corps has been designated as the administrative lead (e.g., implementation of NAVRAMP would be required for this population of buildings), a review of all available radon data for the acquired buildings will be required. Because of difference in the respective DoD radon testing programs, it will be very unlikely that the supplied data will meet all of the NAVRAMP requirements. Therefore, the data provided will need to be validated (Section 3.5.1) and then assigned a DSQF (Section 3.5.2) before an appropriate RPC can be assigned (Section 2.4). For data set analysis purposes, the provided data set should initially be processed as a separate site (Section 2.4.1) until an appropriate RPC has been determined for this population of buildings. However, if no individual radon test data are available (summary reports, sometimes referred to as circumstantial data, cannot be used), then RPC 2 shall be assigned to the site.

In the initial analysis step, determine if one or more of the following statements are **true** for the provided data set:

- The testing device information (e.g., manufacturer and type of testing device) was not provided or it is has been determined that they do not meet the minimal NAVRAMP requirements (Section 3.2.2).
  - Note: WLM or progeny measurements cannot be accepted under NAVRAMP.
- The measurements were **not** collected using the respective services radon testing program guidelines **or** one of the following standards were **not** followed.
  - *Protocols for Radon and Radon Decay Product Measurements in Homes*, (EPA May 1993),
  - *Radon Measurement in Schools* (EPA July 1993)

    - *Protocols for Measuring Radon and Radon Decay Products in School and Large Buildings* (ANSI 2014a), or
    - EPA testing requirements for federal agencies (Appendix E, Section 2.1.4).
- One or more of the following information is missing from the provided data set:
    - Detector id numbers,
    - placement and retrieval dates,
    - building numbers and tested room names, or
    - individual radon results for each room tested.

If any of the above statements are **true**, the data set should be assigned DSQF = 4, and the site RPC = 2. However, if the testing devices **do meet** the minimal NAVRAMP testing device requirements, and **at least one** of the testing guidelines listed above, then a review of the available QC data (duplicate, blank and spike results) should be performed and the appropriate DSQF assigned (Section 3.5.2).

For DSQF equal to 2 or 3 (if the data set was assigned a DSQF = 4, assign an RPC = 2 to the site), an RPC 1 is assigned to the site for any confirmed radon results ≥4 pCi/L (Flowchart 7) or if more than one result at the site was found to be ≥4 pCi/L. If confirmation testing is required, then the assignment of the RPC should be deferred until the confirmation or follow-up testing has been completed (Section 3.5.7). However, in this case, if expediency is desired for the RPC assignment, consideration can be given to other mitigating factors such as the main naval installation or other sites are known RPC 1.

If the data set is validated (e.g., DSQF 2 or 3) but the highest radon result is <4 pCi/L, a determination needs to be made whether sufficient testing has been performed. If at least 25% of the ground-contact occupied rooms at the site were tested, then an RPC 3 designation (Section 2.4) is assigned. However, if <25% of the rooms were tested, then an RPC 2 designation (Section 2.4) shall be applied.

After the initial RPC has been assigned to the site, the installation will need to decide as to whether to continue to manage this population of buildings as a separate site, integrate it into an existing naval site, or incorporate it into the existing population of buildings at the naval installation as a whole. If the decision is make to incorporate these buildings into the existing site, or the entire installation building population, then the RPC for the site or UIC as a whole would apply (Section 2.4) and any additional testing implemented as required (Section 2.4).

3.5.9.1 Analysis of Radon Test Data From Other Sources

Another source of radon data may be the current occupant of a building. Because of the availability and relatively low cost of “do-it-yourself” radon test kits, occupants may be tempted to perform the radon testing themselves. Under no circumstances are these data to be used to draw any testing conclusions.

3.5.10 Radon Testing Records Management

Under NAVRAMP, all installations are required to maintain a central data management system containing all valid data collected at the installation (this requirement includes current and former Navy/Marine Corps–owned family housing, and nonresidential buildings that are either owned or leased) that were tested under NAVRAMP. At a minimum, the information on file should contain the information specified in Section 3.4 and can be maintained in either hard copy or electronic format. Consistent with current EPA and BUMED recommendations, all radon test results collected under NAVRAMP shall be kept on file by the installation indefinitely, the rationale being that the manifestation of lung cancer after radon exposure can be decades. However, the installation is not required to maintain radon testing records from public private venture (PPV) housing collected by the partnering private company. Additional guidance on this subject will be provided by COMNAVFACENGCOM separately in the future.

3.6 RADON TESTING PROVIDER QUALIFICATIONS

For all field placement and retrieval activities, the radon team must be under the supervision of an on-site field supervisor. Qualifications of the field supervisor are

- Training: Radon testing training certified by NRPP or NRSB
- Experience: 3 years of documentable radon testing experience
- Certification: Current NRPP or NRSB certification

Personnel other than the on-site field supervisor who are placing and retrieving radon detectors are called “field technicians.” Qualifications for the field technician are

- Training: Radon testing training certified by NRPP or NRSB
- Experience: 1 year of documentable radon testing experience
- Certification: Current NRPP or NRSB certification

Personnel who perform data analysis, validation, and certification of the radon testing results are called radon testing analysts. Qualifications for the radon testing analyst are

- Training: Radon testing training certified by NRPP or NRSB
- Experience: 5 years of documentable radon testing experience
- Certification: Current NRPP or NRSB certification

Under EPA guidelines for implementation of the IRAA, government employees and military personnel may perform the radon testing at their facilities without accreditation, although appropriate training is recommended. However, the remaining requirements for the testing (e.g., use of NRPP- or NRSB-listed devices and laboratories, testing locations, documentation) remain unchanged.

3.6.1 Testing Subcontractor Health and Safety Plan

Before any testing project begins, the subcontractor shall prepare a project health and safety plan. At a minimum, the plan shall list the expected potential hazards to the personnel performing the testing, the workers, and building occupants and the proposed measures to control the hazards.

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4. NAVRAMP RADON MITIGATION

Within tested and proposed new construction buildings, NAVRAMP requires the following.

- All buildings with valid radon test results ≥4 pCi/L shall be mitigated following a prescribed schedule (Table 1 of this document).
- Installed mitigation systems shall be periodically inspected and retested.
- RRNC shall be included where appropriate (Section 4.3).

This chapter provides the NAVRAMP installation specifications for the mitigation systems, RRNC, and mitigation system O&M. Additional information on these topics can be found in Chapter 4 in Appendix E.

4.1 NAVRAMP RADON MITIGATION SYSTEM REQUIREMENTS

The only mitigation techniques allowed under NAVRAMP are those that prevent radon gas from entering the building or those that dilute the gas by use of supplemental ventilation (see EPA August 1988 and EPA October 1993 for a complete list of mitigation techniques). Mitigation methods using HEPA filtration or progeny removal are not allowed (see EPA letter to Douglas County School Board in Appendix A). All ASD mitigation systems in existing building shall be in accordance with ASTM E2121-12 (ASTM 2012) and UFGS-31-21-13 (UFGS 2011) and shall be equipped with performance indicators and contact information to report system failure. In addition, all mitigation shall be performed by qualified personnel (Section 4.2.6). The schedule (Table 1) for corrective action (e.g., the mitigation clock) should generally be based upon the testing report date. In cases in which confirmation is required, the mitigation schedule should be based upon the report date of the initial test. In order to ensure protection of human health, specific mitigation schedules should be coordinated with command leadership, BUMED personnel, and others as appropriate. See also communication guidance provided in Section 2.11. In addition NAVRAMP requires the following.

- The installed mitigation system shall consistently maintain radon levels at <4 pCi/L when operating.
- Each active mitigation system regardless of type shall be equipped with a performance indicator and contact information to report system failure.
- All mitigation shall be performed by qualified personnel (Section 4.2.6).

4.2 RADON MITIGATION SPECIFICATIONS AND REQUIREMENTS

EPA divides radon mitigation into two basic categories: passive and active. Passive mitigation is defined as a nonmechanical means of radon abatement or control by the use of sealing cracks, balancing an existing mechanical system, installing a passive stack vent pipe during construction, or increasing the natural ventilation rate of the building substructure (i.e., the crawlspace). The other category, active mitigation, entails using mechanical means, such as a fan or blower, to either dilute or control the entry of radon into the living area. Examples of active mitigation include, but are not limited to, SP, ERV, SSD, and SAM. For further information on these types of mitigation systems please consult Chapter 3 in Appendix E.

Because of the diversity in style and construction of naval installation buildings, a single mitigation approach for all buildings at an installation is highly unlikely. Therefore, building-specific mitigation diagnostics (measurements that assist in the selection of a mitigation system) should be conducted to ensure that a proper mitigation system selection is made. Mitigation method selection criteria always include costs (installation and O&M), probability of success, and direct impact on the building occupants. Other considerations might be

- energy consumption
- security concerns
- aesthetics
- noise generation
- loss of indoor functional space
- proposed and pending renovations
- projected remaining lifetime of the building
- understanding of the occupants' concerns
- life-cycle cost

As a general rule, because of their long-term cost-effectiveness, passive, SSD, and SAM should always be considered first. If these methods are not viable, then other mitigation methods (e.g., ERV, SP) should be considered. However, under no circumstances should HEPA systems or other methods that alter the radon decay product equilibrium be used, because their efficacy in reducing risk is uncertain.

Upon completion of a mitigation system installation, postmitigation radon testing shall be performed by the mitigation contractor to ensure that radon levels are <4 pCi/L. All postmitigation testing shall be short term and in accordance with NAVRAMP testing policies, guidelines, and procedures and EPA 402-R-92-004 (EPA July 1992). Postmitigation testing shall be performed no sooner than 24 h and no later than 30 days after system activation or, in the case of passive mitigation, completion. Within 30 days of the reporting of the postmitigation test results and at the discretion of the installation, an independent postmitigation test may be performed to verify that radon mitigation has indeed occurred. The extent and frequency of this follow-up postmitigation testing are at the sole discretion of the installation.

4.2.1 Passive Mitigation Specifications and QA

For existing construction, passive mitigation is divided into two categories: sealing and mechanical balance and repair. Although simple in concept (e.g., no moving parts), it can in the long term be difficult to inspect passive mitigation measures and ascertain current system performance. EPA applies the same O&M inspection and testing criteria as for active systems (e.g., periodic inspection, retesting at least every 2 years).

In passive sealing, various sealants are applied to cracks, expansion joints, and other potential radon soil gas entry points in an effort to reduce radon entry or, ideally, eliminate it entirely. Passive sealing should be attempted as a mitigation means only if the repair would potentially last for >20 years. Therefore, the selection of the most appropriate sealant is critical. According to the American Adhesive and Sealant Council, the choice of a sealant should be based on the type and size of the opening, the opening substrate, the environment in which the sealant would be used, and the potential for deterioration, among other criteria. For most sealants on the market, specification and instruction sheets provided by the manufacturer are a good source of this type of information. In addition, the Material Safety Data Sheet should be consulted to see if any precautions need to be taken during installation and post-application curing.

Passive sealing is highly application-specific and thus does not easily fit a standard checklist for post-installation QA. Therefore, a customized QA checklist must be developed for each post-installation inspection and for future O&M checks. Questions that should always be included on the post-installation checklist are

- Was the use of this particular sealant appropriate for this application?
- Was the sealant applied according to the manufacturer's instructions?

In mechanical balance and repair, the building's mechanical systems (e.g., supply and exhaust) are modified or restored to the original design specifications. This includes, but is not limited to, replacing makeup air and exhaust components, adjusting supply and return air, adjusting the fresh-air and exhaust dampers, and modifying duct components that are in ground contact (e.g., subslab return or supply ducts). As with passive sealing, this technique is very much application-specific and does not easily fit into a standardized QA checklist. Therefore, a customized form must be developed for the post-installation check and future O&M inspections. Questions that should always be included on the post-installation check list are

- Did the adjustment, modification, or repair keep the building temperature and humidity within the design specifications?
- Did the adjustment, modification, or repair have any significant impact on occupant comfort?

Within 30 days of the passive mitigation installation, the installation or its designee should perform independent inspections of the passive mitigation installation to verify that the system meets the design requirements and was installed properly.

4.2.2 Shell Pressurization Specifications and QA

SP, although the oldest and best understood of all radon mitigation methods, should be considered the mitigation method of last resort. To be brief, compared with other forms of radon mitigation, SP has higher maintenance and energy costs and, depending upon the type of SP system installed, may be more expensive to install. SP systems consist of two basic types differentiated by how the required volume of outdoor air is supplied.

A Type 1 SP system uses either an existing or an installed fresh-air damper to supply the fresh air. In this design, the air is conditioned by the building's existing mechanical system before discharge into the building. Therefore, before the SP system is installed, it is necessary to evaluate the current mechanical system and calculate the load to determine if it could condition the added volume of air (e.g., heat, cool, and dehumidify). If the existing mechanical system lacks the capacity for conditioning the required makeup air, then a Type 2 SP system (an independent mechanical system to condition the outdoor air before it enters the structure) will be required. Load calculations must be performed to ensure that the unit will adequately condition the supply air year around.

Specifications for SP mitigation systems are building- and application-specific—the design for one building will not be readily interchangeable with another. Many considerations go into the design of an SP system to ensure that the current mechanical system(s) can handle the added conditioning load and that the possible increase in humidity would not place the building within the range for inducing mold growth (≥60% RH). Therefore, if SP is selected as the mitigation method, the design will need to be reviewed and approved by a qualified mechanical engineer before the mitigation system is installed. From this final design, a QA checklist can be generated for possible inspection. Examples of typical features and conditions to check after installation are

1. The quarters, room(s), or building is between (+) 4 and 8 Pa relative to the outdoors.
2. Installed filters have a minimum efficiency reporting value (MERV) rating of 8 or greater (ASHRAE 2007, 52.2-2007) and are accessible.
3. The relative humidity in the room(s) or building is ≤60% or meets the specific building requirements.
4. Wall penetrations to the exterior are sealed.
5. To the best extent possible, the system meets fresh-air intake requirements of *DoD Minimum Antiterrorism Standards for Buildings* (UFC October 2003, UFC 4-010-01, updated 22 January 2007).

Within 30 days of the mitigation installation, the SP system should be independently inspected to verify that it meets the design requirements and was installed properly. In addition, pressure, temperature, and humidity should be measured in the supply air and in the rooms or building to verify that the tolerances listed in the design were met.

4.2.3 Energy Recovery Ventilation Specifications and QA

ERV is a post-entry mitigation technique that reduces the indoor radon concentration by increasing the air exchange in the building or room(s). An ERV unit typically consists of two fans, one exhausting a known volume of indoor air and the second bringing in an equal volume. During operation, the two air streams (in separate compartments of the unit) pass over an inter-compartmental heat exchanger (for energy recovery) and a desiccant wheel (for humidity control). Although heat recovery is high for most units (ranging from 60 to 80%), the units are not well suited for use as dehumidifiers in climates with hot, humid summers. Consequently, as part of the mitigation design, it is necessary to evaluate the existing building mechanical system to determine if it can handle the added cooling and heating load and the increase in humidity. If that capability is in question, optional features (available on most commercial units) for conditioning the incoming outdoor air should be included.

The design specifications of all ERV systems for use within naval installation buildings must have been evaluated using either ASHRAE Standard 84-2008 (ASHRAE 2008) or AHRI Standard 1060-2005 (AHRI 2005).

The proposed ERV unit should have a rated capacity of at least 10% above the required cubic feet per minute to allow for some performance degradation between air filter changeouts. Also, the supply air volume should be at least 5% greater than the exhaust volume to prevent room depressurization. In addition, on average the unit should recover at least 70% of the conditioned temperature year round (as determined by either ASHRAE Standard 84-2008 [ASHRAE 2008] or AHRI Standard 1060-2005 [AHRI 2005]). The unit should be equipped with an insect screen and MERV 8 filters (ASHRAE 2007, 52.2-2007). In addition, unit operation should not cause room(s) or the building to exceed 60% RH or the specific building requirements for any extended period of time. Also, to the best extent possible, the system should meet fresh-air intake requirements *of DoD Minimum Antiterrorism Standards for Buildings* (UFC October 2003, UFC 4-010-01, updated 22 January 2007).

Within 30 days of the ERV installation, the installation should be independently inspected to verify that the system meets the proposed contract design requirements and was installed properly. In addition, temperature and humidity should be measured in the supply air and in the room(s) or building to verify that the tolerances listed in the design are met.

4.2.4 Supplemental Air Mitigation Specifications and QA

SAM is used to correct elevated radon problems in a single room by providing additional forced-air ventilation (Fig. 18). Although relatively easy to install and maintain (a typical SAM system consists of a blower, ductwork, and a switch), the technique is not widely employed because of its limited application. For example, the criteria for the room to be mitigated by SAM are that it must

- have radon levels <20 pCi/L
- be no larger than 3,500 ft^3
- have an ACH rate of <0.2
- be located near a large room or common area from which the desired volume of low-radon conditioned air can be withdrawn without a significant risk of depressurization

In addition to these criteria, particular attention must be paid to noise and occupant comfort. Because these systems are usually used in single or double offices, the noise generated by the discharge of the supply air may pose an inadvertent distraction to the occupant(s). Therefore, the supply diffuser, in addition to being aesthetically pleasing, must produce as little noise as possible. Another important consideration is the location of the discharge point. The discharge air velocity from a typical SAM system is comparable to that of a forced-air system. So to the best extent possible, the discharge needs to be in a location that would not appreciably increase the air velocity in the primary work area.

Within 30 days of the SAM installation, the system should be independently inspected to verify that the system meets the proposed contract design requirements and was installed properly.

4.2.5 Subslab Depressurization Specifications and QA

For SSD mitigation systems, minimum specifications are that the systems comply with

- *Radon Mitigation Standards for Schools and Large Buildings,* ANSI RMS-LB 2014 (ANSI 2014b)
- *Standard Practice for Installing Radon Mitigation Systems in Existing Low-Rise Residential Buildings*, ASTM E2121-12 (ASTM 2012)
- *Radon Mitigation,* UFGS-31-21-13 (UFGS 2011)

In addition, the following requirements must be met:

1. All electrical work shall meet or exceed the most current National Electrical Code and installation requirements and shall use solid 12 AWG wire.
2. The electrical circuit for the radon fan shall be clearly labeled in the breaker panel.
3. All mitigation fans shall be hard-wired unless they are in an attic where corded fans (with cords shorter than 6 ft) are allowed.
4. A wet location–rated electrical switch shall be located within 6 ft of the fan unless it is an attic installation where corded fans are permitted.
5. All vent pipes and fittings shall be white 4 in. PVC Schedule 40.
6. All metal components of the system (e.g., fasteners, pipe straps, channel) shall be stainless steel or be corrosion resistant.
7. All fans shall be rated for exterior use and be designated by the manufacturer for use as radon mitigation fans.

8. Every vent stack shall be covered with a vent cap.
9. Every system shall have a performance indicator located within 6 ft of the primary slab penetration point. Instructions regarding how to read the indicator and a contact phone number shall be posted adjacent to the indicator.
10. Where applicable, all radon fans shall be covered by a fan cover attached to a fan cover base plate.
11. All exterior clamps and fasters shall be stainless steel, galvanized, or corrosion resistant.

Contractor-requested exceptions to these standards shall be submitted to the installation in writing for consideration at least 2 weeks before the mitigation installation.

Within 30 days of the mitigation installation project, an independent inspection should be performed on a randomly selected section of the radon system to verify that the system meets the proposed design specifications. The frequency of the random checks and the number of systems to verify are at the sole discretion of the installation. An example data form for SSD inspection is included in Appendix D.

4.2.6 Radon Mitigation Subcontractor Qualifications

For all field mitigation diagnostics and installation activities, the radon team must be under the direct supervision of an on-site field supervisor. Qualifications for the field supervisor follow.

- Training: Radon mitigation training certified by EPA, NRPP, or NRSB
- Experience: 3 years of documentable radon mitigation experience in nonresidential or other large buildings
- Certification: Current NRPP or NRSB certification

Personnel other than the on-site field supervisor who are involved in mitigation diagnostics or installation are called field technicians. Qualifications for the lead field technician follow.

- Training: Radon mitigation training certified by EPA, NRPP, or NRSB
- Experience: 1 year of documentable radon mitigation experience
- Certification: Current NRPP or NRSB certification

Personnel who perform mitigation design are called radon mitigation analysts. Qualifications for the radon mitigation analyst follow.

- Training: Radon mitigation training certified by EPA, NRPP, or NRSB
- Experience: 5 years of documentable radon mitigation experience in nonresidential or other large buildings
- Certification: Current NRPP or NRSB certification

Under EPA guidelines for implementation of the IRAA, government employees and military personnel may perform radon mitigation at their facilities without accreditation, although appropriate training is recommended.

4.2.7 Mitigation Subcontractor Health and Safety Plan

Before any mitigation project begins, the subcontractor shall prepare a project health and safety plan. At a minimum, the plan shall list the expected potential hazards to the mitigation personnel, workers, and building occupants and the measures to control the hazards.

4.3 RADON-RESISTANT NEW CONSTRUCTION REQUIREMENTS

As was discussed in Section 2.4, RRNC is required for all new construction at RPC 1 installations or sites and within the construction of new, long-term lease buildings (e.g., leases, limited partnerships, and international use agreements; see Section 2.9) in which the Navy/Marine Corps will be responsible for NAVRAMP implementation. The basic design considerations for buildings that will incorporate radon-resistant features in new construction are as follows.

- If possible, the aggregate bed under the slab should not be compacted.
- One riser should be installed for every 3,000–5,000 ft^2 of slab (see also ASTM E1465-08a).
- There should be provision for 3–4 ft of clearance in the attic to allow for easy access to install and maintain the fan.
- The electrical outlet should be located within 6 ft of the radon vent riser in the attic.

In addition to the requirements listed, the passive sealing portions of Unified Facilities Criteria (UFC) 3-490-04A (UFC May 2003) and the subslab gas collector specifications from ASTM E1465-08a should be incorporated.

4.3.1 RRNC Design Overview

For all new construction incorporating radon-resistant features, all gaps/joints and slab penetrations should be sealed. However, the installation of other RRNC features and components will depend upon the design of the building. It is recommended that to the best extent possible, one of the following three RRNC methods be incorporated into the building design:

- Method 1 uses a preinstalled vent pipe to route radon from under the slab to above the roof. This method is commonly referred to as “passive stack.”
- Method 2 uses a subslab soil gas collection piping network that is connected to a vent pipe that penetrates the roof. This technique is commonly referred to as “mitigation-ready passive stack.”
- Method 3 uses an identical subslab soil gas collection piping network, but the vent piping is stubbed out and capped in either the living area or the attic or on the

exterior of the building. This technique is commonly referred to as "mitigation ready."

Additional information about RRNC is included in Appendix E, Chapter 4.

4.3.1.1 Slab Sealing Specifications

All gaps/joints and all floor slab penetrations must be sealed to prevent air leakage into the building (EPA 402-K/11-002 [EPA 2012], ASTM E1465-08a [ASTM 2008], or UFC 3-490-04A, inactive with no replacement [UFC May 2003]). Gaps can be filled with polyethylene backer rod or comparable filler material as required and sealed with polyurethane caulk or other elastomeric sealant. Caulks and sealants shall be applied according to the manufacturer's instructions. All penetrations into the building exterior should be inspected to ensure they are watertight. All work should be coordinated with the contracting officer.

4.3.1.2 Method 1: Passive Stack (Option)

Operational Principle

This design uses an RRNC technique to potentially retard radon entry into the building by passively redirecting the radon soil gas from under the slab to a vent pipe.

Specifications

Just before the slab is poured, at an interval of one pipe for every 2,000 ft^2 of slab, a 4 in. Schedule 40 PVC vent pipe (or pipes) equipped with a tee will be inserted into a noncompacted aggregate bed (minimum 4 in. layer of clean coarse gravel [½–¾ in. mesh]). After the concrete has been poured, the gap around the pipe will be sealed with polyurethane caulk or another elastomeric sealant. The vent pipe will then be routed vertically through the building and through the roof in a manner that would not interfere with the daily operations and functions of the building occupants. The exhaust end of the pipe shall be left uncapped, and the vent stack pipe discharge location shall be as specified in ASTM E1465-08a (ASTM 2008).

Within 6 ft of the location of a proposed fan (the fan cannot be mounted in or directly under living or occupied space), an electrical outlet on a dedicated circuit shall be installed. If needed, multiple fans can be wired to the same dedicated circuit. All components of the radon system piping shall drain their condensed water vapor and collected rain completely to the ground beneath the slab. If the intent is to mount the proposed fan in the attic, then a minimum of 3–4 ft of vertical clearance will be required to allow for easy access to install and maintain the fan. To the best extent possible, the visibility of the system should be kept to a minimum, and all operating components should be accessible for maintenance and repair.

4.3.1.3 Method 2: Mitigation-Ready Passive Stack (Option)

Operational Principle

This design uses an RRNC technique to potentially retard radon entry into the building by passively redirecting the radon soil gas through a network of underground pipes to a vent pipe.

Specifications

A network of Schedule 40 perforated PVC pipes (Type 1 soil gas collector; flexible corrugated drain tile may be substituted) will be buried in a gas-permeable layer of crushed stone (minimum 8 in. layer of clean coarse gravel [½–¾ in. mesh]) and manifolded to effect coverage under all rooms. A tee assembly shall be positioned so that the suction-point pipe that attaches to it penetrates the slab in an unobtrusive place and so that the suction-point pipe can be attached to the vent stack (one riser for every 3,000–5,000 ft^2 of slab). Perforated, corrugated drain tile can be substituted for the Schedule 40 PVC provided it is inspected for deformations (e.g., crushing) and repaired just before the slab is poured. The radon system vent piping (4 in. Schedule 40; corrugated drain tile ***cannot*** be substituted) shall be routed so as not to interfere with the daily operations and functions of the building occupants. The exhaust end of the pipe shall be left uncapped, and the vent stack pipe discharge location shall be as specified in ASTM E1465-08a (ASTM 2008).

Within 6 ft of the location of a proposed fan (the fan cannot be mounted in or directly under living or occupied space), an electrical outlet on a dedicated circuit shall be installed. If needed, multiple fans can be wired to the same dedicated circuit. If the intent is to mount the proposed fan in the attic, then a minimum of 3–4 ft of vertical clearance will be required to allow for easy access to install and maintain the fan. All components of the radon system piping shall drain their condensed water vapor and collected rain completely to the ground beneath the slab. To the best extent possible, the visibility of the system should be kept to a minimum, and all operating components should be accessible for maintenance and repair.

4.3.1.4 Method 3: Mitigation-Ready (Option)

Operational Principle

This design uses a mitigation-ready approach to ensure that if elevated radon is found, mitigation can be successfully performed at a lower cost.

Specifications

A network of Schedule 40 perforated PVC pipes (Type 1 soil gas collector; flexible corrugated drain tile may be substituted) will be buried in the gas-permeable layer of crushed stone (minimum 8 in. layer of clean coarse gravel [½–¾ in mesh]) and manifolded to effect coverage under all rooms. In the design, allowances should be made for one riser (see paragraphs below) for every 3,000–5,000 ft^2 of slab. If perforated, corrugated drain tile must be substituted for the Schedule 40 PVC soil gas collection network, it must be inspected for deformations (e.g., crushing) and repaired just before the slab is poured.

For interior risers, a tee assembly shall be positioned so that the suction-point pipe that attaches to the soil gas collection network penetrates the slab in an unobtrusive place and so that the suction point can be attached to the vent stack. The capped riser should extend a minimum 6 in. above the floor (proposed route of the optional vent pipe should be included in the building plans) and should be located in an area that is readily accessible (e.g., the capped end of the riser cannot be enclosed inside a wall).

For exterior-mounted risers, a branch of the soil gas collection network should extend through the foundation using 4 in. Schedule 40 pipe and should have a 90° elbow attached. From the top of the elbow, a minimum 6 in. section of 4 in. Schedule 40 pipe shall be attached and a cap installed on the end. The riser should be located in an area that is readily accessible, and the building plans should contain the proposed route of the optional vent pipe. In addition, the location of the riser and optional vent pipe should not interfere with the daily operations and functions of the building occupants.

Within 6 ft of the location (either type of riser) of a proposed fan (fan cannot be mounted in or directly under a living or occupied space), an electrical outlet on a dedicated circuit shall be installed. If needed, multiple fans can be wired to the same dedicated circuit. If the intent is to mount the proposed fan in the attic, then a minimum of 3–4 ft of vertical clearance will be required to allow for easy access to install and maintain the fan. All components of the radon system piping shall drain their condensed water vapor and collected rain completely to the ground beneath the slab. To the best extent possible, the visibility of the system should be kept to a minimum, and all operating components should be accessible for maintenance and repair.

4.3.1.5 Design Specification for Radon Fan Assembly

For all passive stack and mitigation-ready options, designs and specifications shall be provided for the installation of the radon fan. In addition, the proposed fan shall be installed in a vertical section of the vent stack pipe and in a vertical orientation to prevent condensed water and precipitation from accumulating in the fan. As a minimum, the design shall contain

- the proposed fan location and type of fan
- the proposed electrical hook-up and wiring specification
- the location and type of the system performance indicator
- any additional hardware needed for fan activation

4.3.1.6 Labeling of System

System components shall be labeled as specified in ASTM E1465-08a (ASTM 2008) for all passive stack and mitigation-ready options. This would include but not be limited to labels that identify the vent piping as part of a radon reduction system in visible, inside walls and attics.

4.3.1.7 Radon Testing of Mitigation-Ready Building

Upon building completion or within 5 years of occupancy, an initial radon gas test shall be performed as specified in accordance with the NAVRAMP testing protocol.

4.3.1.8 Activation of Radon Mitigation-Ready System

If radon testing finds rooms within the building ≥4.0 pCi/L, then the mitigation fan and any remaining vent pipe should be installed per design and activated by a certified radon mitigator under the supervision of the responsible system designer. Upon completion of fan installation and activation, postmitigation testing shall be performed no sooner than 24 h after fan activation to ensure that radon levels in occupiable spaces are <4.0 pCi/L. All testing should be performed under closed-building conditions (for short-term tests of <4 days, closed building conditions must be initiated at least 12 h prior to the placement of the detectors and maintained for the duration of the test). In addition, all mechanical equipment that will be operating during normal human occupancy (normally, exhaust blowers and central air-conditioning system operating in a typical fashion) should be operating at least 24 h before an initial radon test is conducted. If elevated radon is still present, the contract officer should be consulted for further instruction.

4.3.2 Radon-Resistant New Construction Designer Subcontractor Qualifications

For all RRNC designs, the designer shall have as a minimum

- Training: Radon mitigation training certified by EPA, NRPP, or NRSB
- Experience: 5 years of documentable radon mitigation experience
- Certification: Current NRPP or NRSB certification

Personnel responsible for the installation, oversight, or activation of the RRNC system shall have as a minimum

- Training: Radon mitigation training certified by EPA, NRPP, or NRSB
- Experience: 1 year of documentable radon mitigation experience
- Certification: Current NRPP or NRSB certification

4.4 O&M OF RADON MITIGATION SYSTEMS

To maintain effective long-term radon control, radon systems will require periodic maintenance and retesting. Therefore, EPA recommends (EPA 402-R-93-078 [EPA 1994b]) that in addition to periodic performance checks, a detailed system inspection be performed at least every 2 years, followed by radon testing of the mitigated rooms. The following sections outline recommended O&M by system type.

4.4.1 O&M of Passive Mitigation Systems

Passive sealing is very much application-specific and thus does not easily fit a standard O&M checklist. Therefore, a customized O&M checklist must be developed. For passive mitigation involving mechanical balance and repair, the building mechanical system (e.g., supply and exhaust) is modified or restored to the original design specifications. This includes, but is not limited to, replacing makeup air and exhaust components, adjusting supply and return air, adjusting the fresh-air and exhaust dampers, and modifying duct components that are in ground contact (e.g., subslab return or supply ducts). Therefore, the O&M checklist should include those items. In addition, in cases where the repairs or adjustments involve bring in more fresh air, the building temperature and humidity should be included as well. In cases where sealing is involved, all joints should be inspected to verify that the caulk is still adhering to the substrate.

4.4.2 O&M of Shell Pressurization Systems

An SP system retards radon entry by mechanically introducing sufficient outdoor air to induce a positive pressure across the slab (typically 4 to 6 Pa) and into the soil. Applying pressure across the building shell reverses the natural flow of radon from the soil into the living area. Therefore, the air flows from the living area into the subslab, preventing radon entry. The downside of an SP system is that all windows and doors must be kept closed to maintain mitigation. Small openings, such as an entry door left ajar or a window left cracked open, will result in the radon levels reverting to their unmitigated levels. Also, as door and window seals deteriorate over time, additional fresh air must be drawn in to maintain mitigation.

The following routine maintenance is recommended for an air intake SP system on a quarterly basis or as required by the manufacturer:

1. Clean or replace the air intake grill air filter as needed.
2. Clean in-house return air filter.
3. After cleaning both filters, verify that shell pressure (indoor to outside) is between 4 and 6 Pa, using a digital micromanometer.

Table 6 lists troubleshooting techniques for air intake SP mitigation systems if, in the future, mitigation failure occurs or the building can no longer be pressurized to 4 Pa.

Table 6. Troubleshooting SP mitigation systems

Problem	Possible solutions
Building is <4 Pa shell pressure (indoor to outside)	1. Verify that the mechanical blower is running continuously and properly 2. Inspect intake grill for blockage 3. Clean intake grill air filter 4. Adjust air intake damper to increase outdoor airflow. 5. Inspect the mechanical collar for leakage. Repair leak as needed 6. Inspect shell for any significant leaks around windows and exterior doors. As appropriate, replace door seals or caulk any cracks around windows and doors
Building is >6 Pa pressure (indoor to outside)	1. Adjust air intake damper to decrease outdoor airflow 2. Clean central mechanical return air filter 3. Inspect mechanical collar for leakage. Repair leak as needed
Building is >4 pCi/L	1. Verify that the blower is running continuously and properly 2. Check shell pressure with digital micromanometer 3. Verify that occupants are not leaving windows and doors open for extended periods of time
Building is >4 pCi/L and shell pressure is between 4 and 6 Pa	1. Repeat differential pressure diagnostic for all major air exhaust systems. Discuss with occupants the frequency of usage of the exhaust systems. Increase airflow accordingly to compensate for largest and/or most frequently used air exhaust system

4.4.3 O&M of Energy Recovery Ventilation Mitigation Systems

ERV systems are commercially available package systems that reduce radon levels by increasing the natural ventilation rate in a building or room(s). Because of differences in design, installation, and materials, no two manufacturers' O&M requirements are exactly the same. Therefore, it is important to review the owner's manual and draft a system-specific O&M plan. Common O&M elements to address are

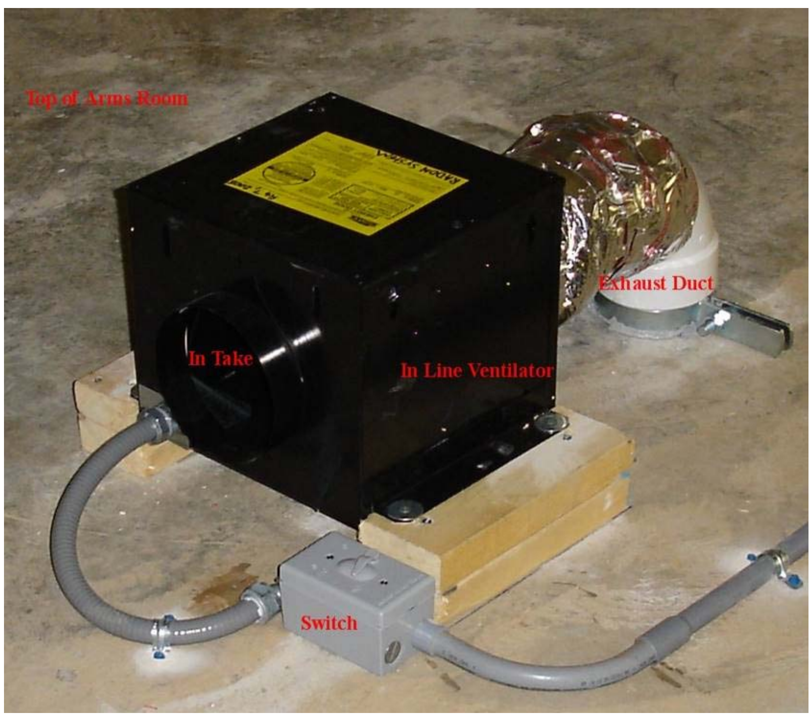
1. the frequency of changing the air filters and drive belts
2. lubrication of the drive and blow motors
3. maintenance of the desiccant wheel
4. the recommended frequency for checking the pressure balance of the system

It is important to note that for ERV systems, O&M is not just a good idea—it is mandatory. For example, if the system filters are not changed, the building or room may become depressurized (i.e., the ERV exhausts more air than it is bringing in), resulting in a potential increase in the room's radon levels. In addition, on some ERV models, lack of maintenance of the desiccant wheel could result in a sudden uncontrollable increase in the humidity of the supply air. This condition could result in a catastrophic condensation release followed by the onset of mold.

4.4.4 O&M of Supplemental Air Mitigation Systems

In general, SAM systems are easy to operate and maintain. The system consists of two basic parts, the electric fan and the duct, neither of which requires any scheduled maintenance. However, periodically, the intake (Pictures 1 and 2) should be inspected and cleaned and it should be confirmed that the unit is exhausting (e.g., smoke test, strip of paper). To determine if a SAM is working, an illuminated light box (Picture 3) can be installed. Fan operation is indicated by the green LED light (Picture 3).

Every 2 years, it is recommended that the exhaust rate of the blower be checked using a pitot tube, face velocity probe, or other suitable measuring device to confirm a minimum of 150 cfm of makeup air or the volume specified by the installer. If the air volume is found to be less, the blower should be replaced.



Picture 1. SAM components with box fan.

Picture 2. SAM components with centrifugal fan.

Picture 3. SAM performance indicator.

4.4.5 O&M of Subslab Depressurization Mitigation Systems

SSD mitigation uses a pipe inserted through the slab and connected to a fan (Fig. 1, Pictures 4 to 6). When the fan is activated, the area beneath the slab (subslab) is depressurized. The resulting depressurization prevents radon entry into the living area by redirecting the subslab radon into the pipe for discharge into the atmosphere, where it is harmlessly diluted. Generally speaking, an SSD system consists of two major components: the exhaust pipe and the mitigation fan. Of these two components, only the fan will normally need to be replaced during the remaining lifetime of the building. To determine if the fan is working properly, it is recommended that the occupant perform a monthly visual inspection of the U-tube on the fan. If the oil level reads between 0.3 and 4.0 on the scale, then the fan is operating properly (Fig. 2). If the oil level is reading 0, then the occupant should contact the phone number on the decal. A decal placed next to the U-tube provides detailed instructions and contact phone numbers. The only required maintenance of the U-tube is the infrequent addition of oil. If oil is needed, common cooking oil (e.g., Mazola® oil or the equivalent) may be used or the U-tube can be replaced. Petroleum-based oils or fluids should not be used because of the potential for poisoning small children. Before oil is added to the U-tube, the fan should be turned off either at the exterior switch or by tripping the circuit breaker. Using an eyedropper or plastic drinking straw, oil can then be added a drop at a time until the level equals 0, or the U-tube can simply be replaced. Pictures 7 and 8 show typical U-tube installations. The illuminated light box (Picture 9) relies on an electrical pressure sensor to trigger one of two LED lights (red indicating fan is off, and green indicating fan is on). Maintenance for an illuminated light box is limited to infrequent replacement of the 10-year LED bulbs and pressure sensor.

Depending upon the orientation of the building and the type of system installed, the U-tube can be mounted on the exterior of the building inside a manometer box (Picture 7) or mounted on the pipe near the floor penetration (Picture 8). An illuminated light box (Picture 9), on the other hand, can be located near the system or at a convenient location some distance from the system for remote viewing. In the private sector, routine maintenance of the mitigation system is the responsibility of the individual homeowner or building owner, and maintenance is usually performed by qualified personnel after system failure. Evaluation of the SSD systems installed at other military facilities identified several critical parts and components that should be checked on a regular interval. This maintenance is recommended to prevent water leakage into the building and loss of exterior components during high winds. With these considerations in mind, it is recommended that each component and part listed in Table 7 be inspected in accordance with the proposed schedule. To assist with the identification of the components, a "typical" SSD system has been broken into three assemblies (pipe, fan, and roof flashing) and is illustrated in Figs. 3, 4 and 5).

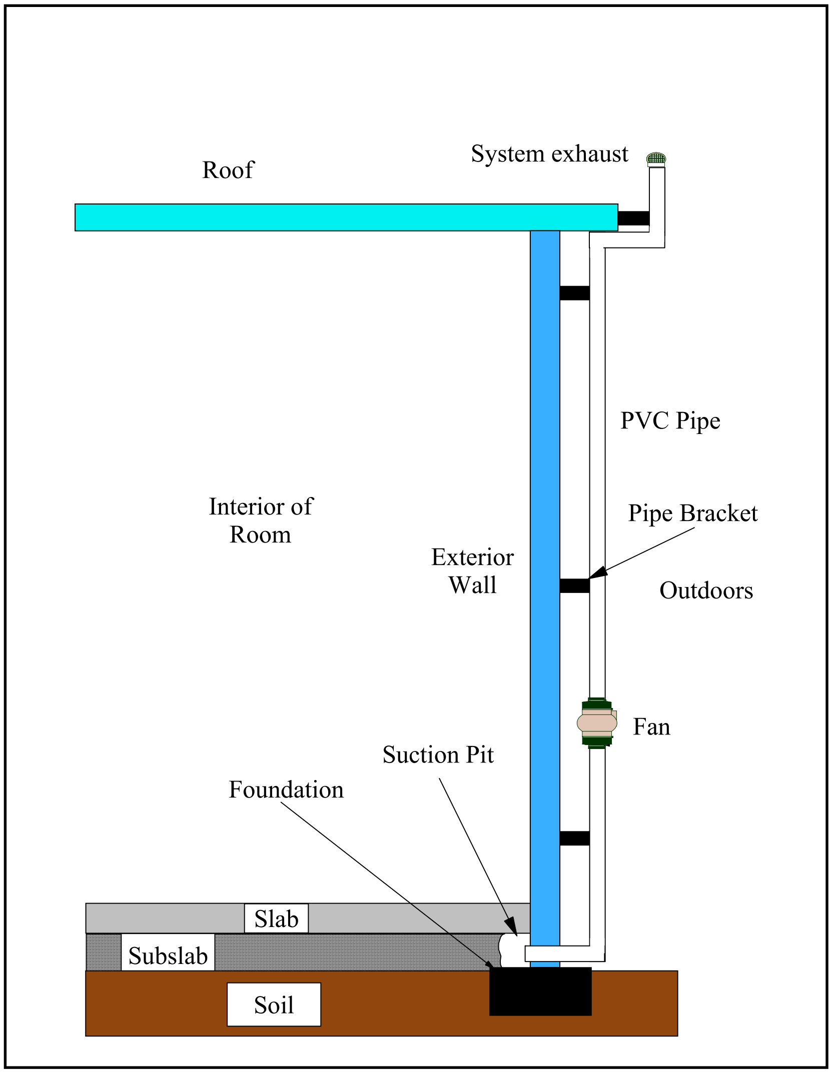
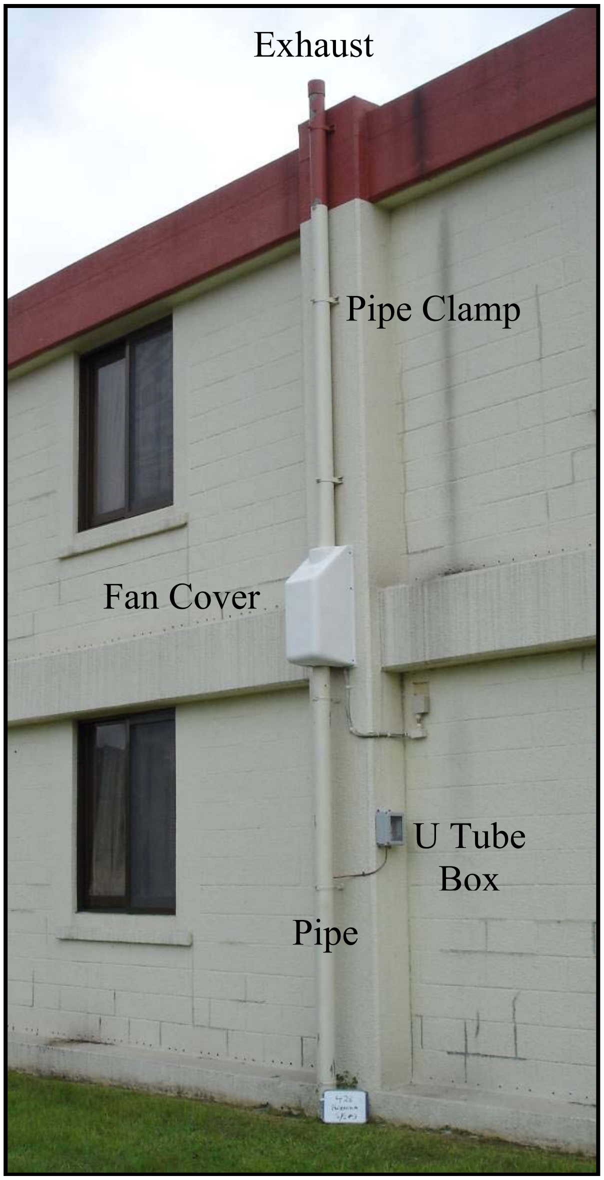
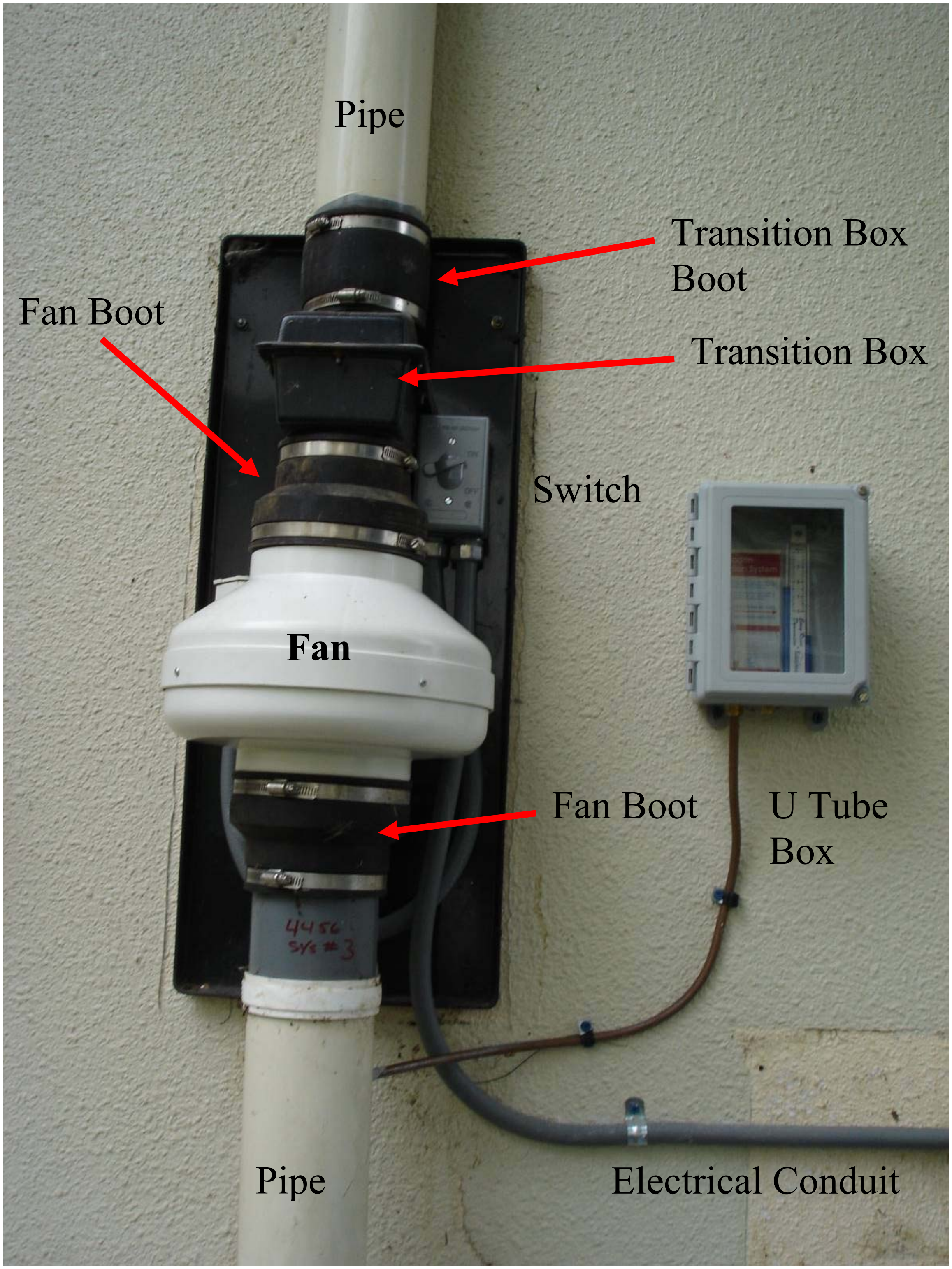


Fig. 1. Basic components of an SSD mitigation system.

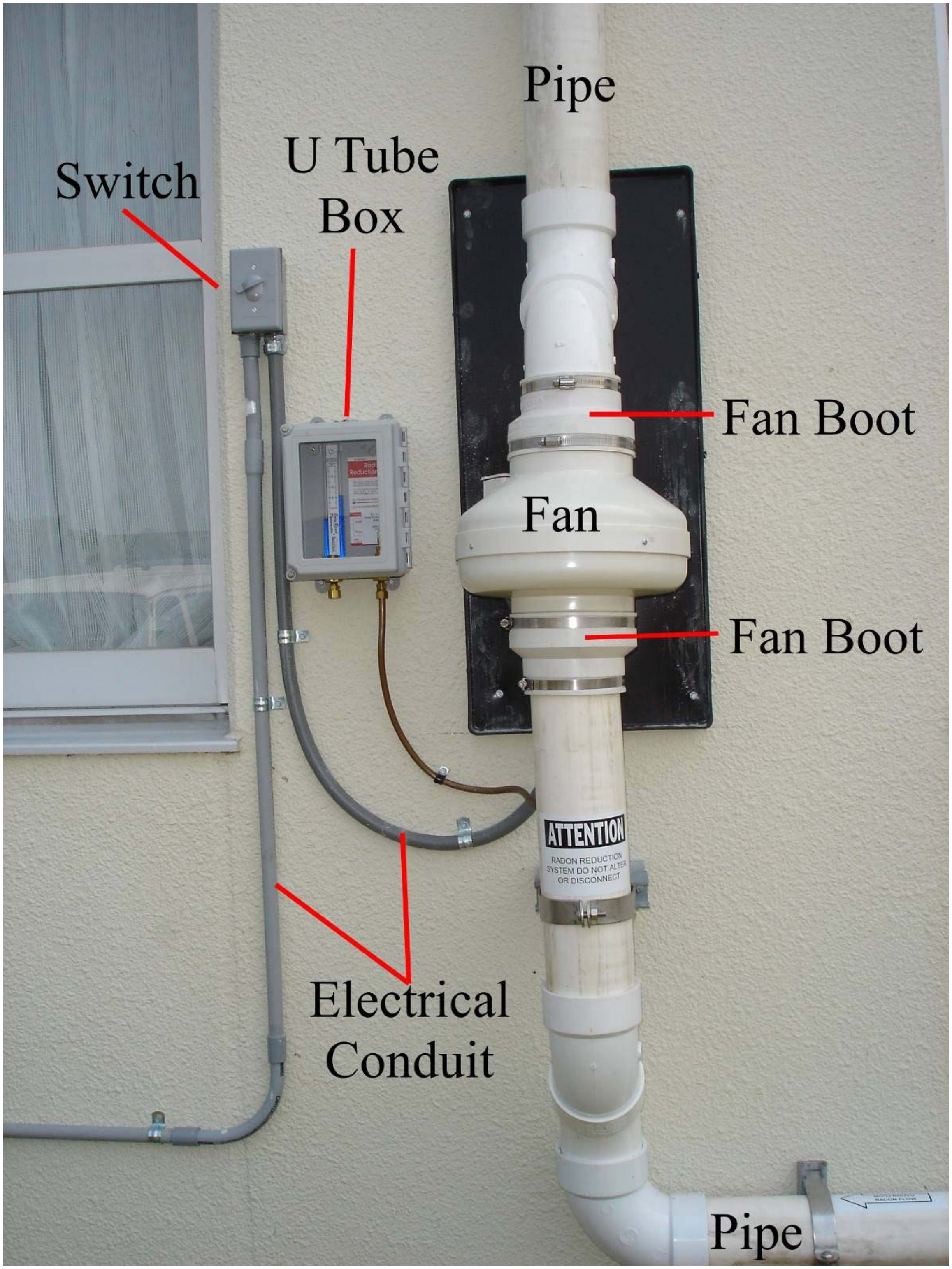
Problems in an SSD mitigation system generally are caused by failure of the mitigation fan or the loss of vacuum under the slab. Table 8 summarizes the most common problems and proposed corrective actions for SSD mitigation systems.



Picture 4. Typical SSD mitigation system.



Picture 5. SSD mitigation system with transition box.



Picture 6. SSD mitigation system without transition box.

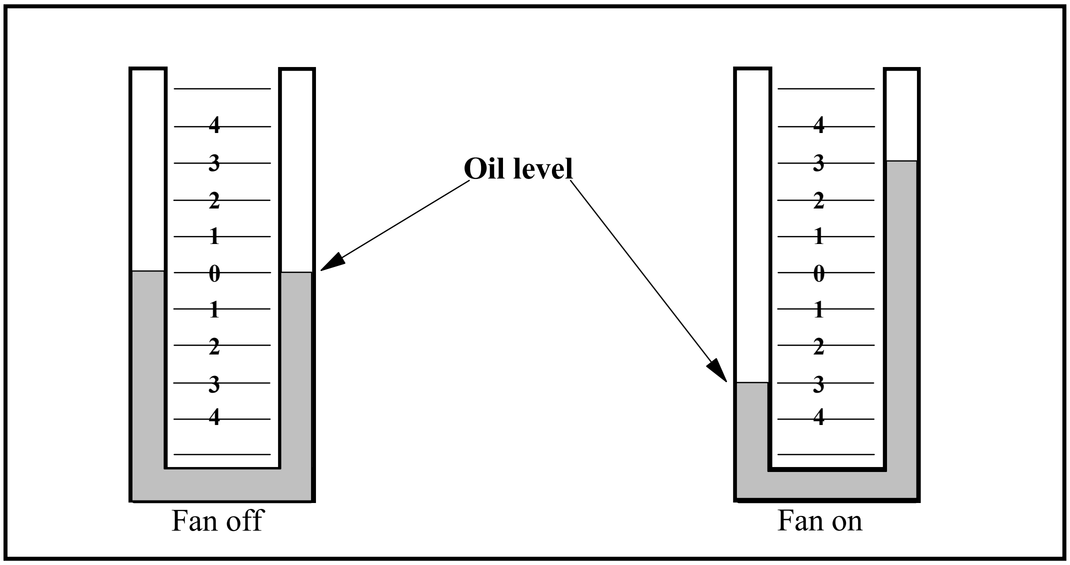


Fig. 2. Typical U-tube.

Picture 7. Typical external U-tube box.

Picture 8. Interior-mounted U-tube.

Picture 9. Typical illuminated light box.

Table 7. SSD components requiring routine inspection

Component	Check for	Corrective action	Recommended frequency of inspection
U-tube (Fig. 2)			
U-tube	Fan operation	Call Trouble Desk if fan is not operational	Monthly by occupant
U-tube	Oil level	Add oil	2 years
Pipe assembly (Fig. 3)			
Pipe/slab seal	Leakage	Apply additional polyurethane caulk	2 years
Interior wall/pipe seal	Leakage	Apply additional polyurethane caulk	2 years
Exterior wall/pipe seal	Leakage	Apply additional polyurethane caulk	2 years
Clamp nut	Tightness	Tighten nut	2 years
Pipe-mounted fan assembly (Fig. 4)			
Rubber boot	Cracking or sagging, fan seated level	Replace boot	2 years
Fan operation	Excessive noise, vibration, or not operating	Replace fan	2 years
Rubber boot/pipe seal	Leakage	Replace boot	2 years
Flex conduit electrical condition	Cracking of conduit and deterioration of liquid-tight connectors	Replace conduit and liquid-tight connectors	2 years
Switch and switch and switch cover gasket	Functional switch and seal of box gasket	Replace switch and gasket	2 years
Conduit C clamp	Tightness and corrosion	Tighten or replace C clamp	2 years
Hose clamp	Tightness	Tighten	2 years
Roof flashing (Fig. 5)			
Flashing	Water leaks and cracking	Replace flashing	2 years

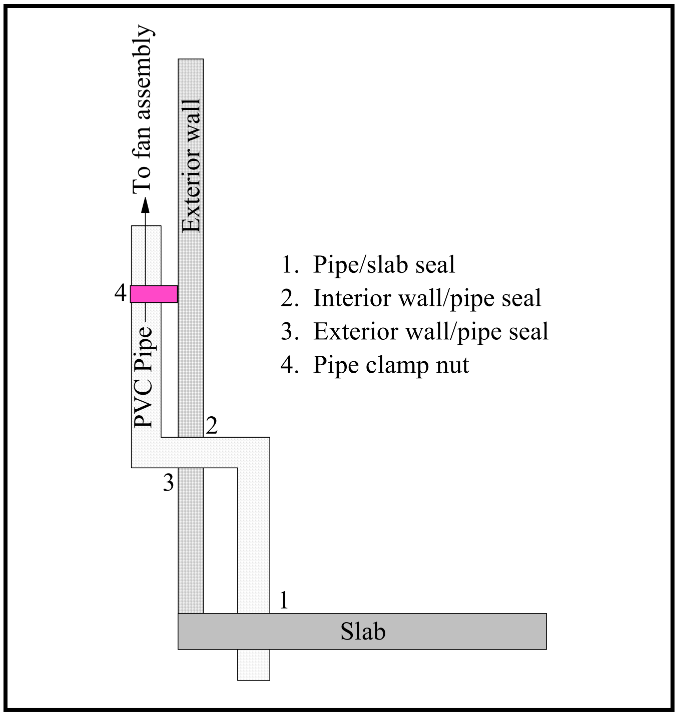


Fig. 3. Components to inspect in an SSD system pipe assembly.

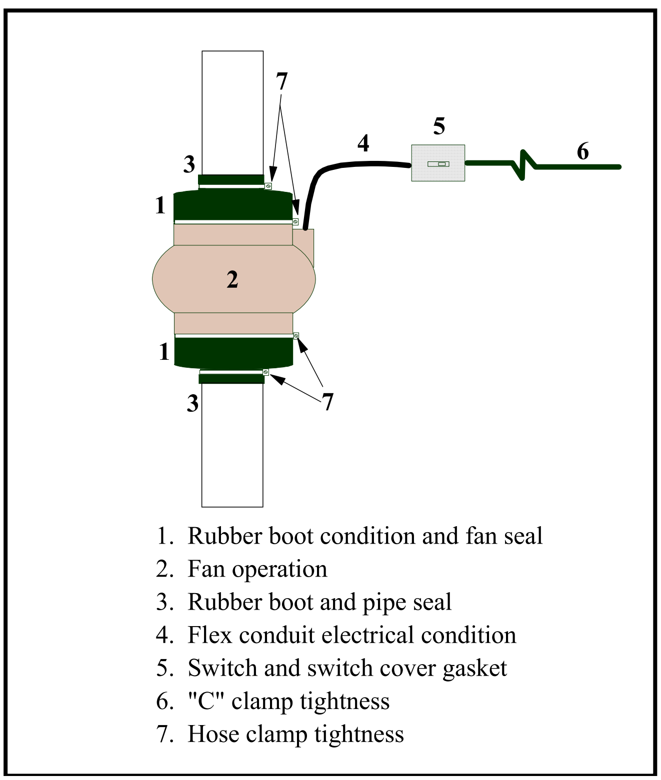


Fig. 4. Components to inspect in an SSD system pipe-mounted fan assembly.

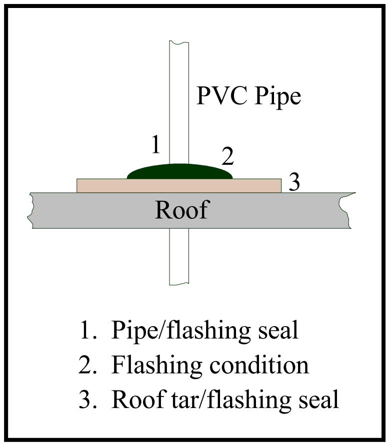


Fig. 5. Components to inspect in an SSD system roof flashing assembly.

Table 8. Troubleshooting SSD mitigation systems

Problem	Possible solution
Fan is not operating	1. Verify that the switch is on and the circuit breaker has not tripped 2. Check electrical connections from the switch box to the fan 3. Replace mitigation fan
Pipe has a noticeable vibration sound	1. Make sure that the fan is level 2. Verify that the base of the fan is not in contact with the pipe. If boot is sagging, replace boot 3. Replace fan
Fan is vibrating	1. Make sure that the fan is level 2. Replace fan
Fan is operating, but U-tube reads <1.5	1. Verify that additional oil is not needed in the U-tube 2. Inspect the U-tube and verify that it is connected to the pipe and that the tubing has not been crimped 3. Verify that no obstructions are present in the system exhaust 4. Inspect the boot/fan seals for air leaks 5. Check floor/pipe seals for air leakage 6. Inspect PVC pipe for holes 7. Replace mitigation fan

Table 8 (cont.)

Problem	Possible solution
Fan appears to be operating within normal parameters, but building/roomt is no longer <4 pCi/L	1. Verify that U-tube has sufficient oil 2. Verify that no obstructions are present in the system exhaust 3. Inspect the boot/fan seals for air leaks 4. Check floor/pipe seals for air leakage 5. Inspect PVC pipe for holes 6. Repeat radon test 7. Replace fan 8. Review repair and renovation history of building since the system was last verified to be functioning properly. Have renovations occurred that may have reduced the air change rate? Has a new air exhaust system been added? If the answer is yes to either question, a supplemental suction point may be required 9. Perform lateral field extension measurements to determine if vacuum gradient has changed. Install new suction point in area without vacuum
System has audible whistling sound while operating	1. Inspect pipe for holes 2. Inspect PVC joints for leakage 3. Inspect pipe/slab seal for leakage
During heavy rains, water leaks around pipe	1. Inspect wall/pipe seal for leakage 2. Inspect pipe/floor seal for leakage 3. Inspect flashing assembly for cracks or holes

Appendix D contains an example of a data form used for O&M inspection.

4.4.6 Qualifications of O&M Subcontractor

4.4.6.1 Subcontractor Qualifications for O&M Testing

For all field placement and retrieval activities, the radon team must be under the supervision of an on-site field supervisor. Qualifications of the field supervisor follow.

- Training: Radon testing training certified by EPA, NRPP, or NRSB
- Experience: 3 years of documentable radon testing experience
- Certification: Current NRPP or NRSB certification

Personnel other than the on-site field supervisor who are placing and retrieving radon detectors are called field technicians. Qualifications for the field technician follow.

- Training: Radon testing training certified by EPA, NRPP, or NRSB
- Experience: 1 year of documentable radon testing experience

- Certification: Current NRPP or NRSB certification

Personnel who perform data analysis, validation, and certification of the radon testing results are called radon testing analysts. Qualifications for the radon testing analyst follow.

- Training: Radon testing training certified by EPA, NRPP, or NRSB
- Experience: 5 years of documentable radon testing experience
- Certification: Current NRPP or NRSB certification

4.4.6.2 Subcontractor Qualifications for O&M Inspection

For all O&M inspection activities, the radon team must be under the direct supervision of an on-site field supervisor. Qualifications of the field supervisor follow.

- Training: Radon mitigation training certified by EPA, NRPP, or NRSB
- Experience: 5 years of documentable radon mitigation experience
- Certification: Current NRPP or NRSB certification

Personnel other than the on-site field supervisor who are involved in mitigation diagnostics or installation are called field technicians. Qualifications for the field technician follow.

- Training: Radon mitigation training certified by EPA, NRPP, or NRSB
- Experience: 1 year of documentable radon mitigation experience
- Certification: Current NRPP or NRSB certification

DEFINITIONS AND TERMS

Abnormal weather: Any type of severe weather (e.g., high wind, heavy rain or snow) that would be considered out of the ordinary while performing a short-term radon test. For long-term tests, examples of severe weather would be hurricanes, tropical cyclones, tropical storms and typhoons.

Assessment: The testing of all testable rooms at an installation or site for radon.

Atypical building: A building with unique construction that is different from all other buildings at the installation or site (e.g., underground command bunker).

Becquerel per cubic meter (Bq/m^3): The international unit of radon measure. 1 pCi/L = 37 Bq/m^3. See picocurie per liter (pCi/L) definition below.

Blank: A radon detector that is returned to the laboratory unexposed in order to measure the background of the device as part of NAVRAMP QA/QC.

Closed-building conditions: During the radon test, the building's windows and exterior doors are closed except for routine entrances and exits. For short-term tests of <4 days, closed building conditions must be initiated at least 12 h prior to the placement of the detectors and maintained for the duration of the test period.

Collocated: Radon test devices are placed within 12 in. of each other during a simultaneous measurement.

Duplicate: Radon measurements that are performed using two radon testing devices at the same time as part of NAVRAMP QA/QC.

Karst: Landscape underlain by limestone that has been eroded by dissolution, producing ridges, towers, fissures, sinkholes, and other characteristic landforms.

Mitigation: The corrective action taken in buildings or rooms that have been found to have radon levels ≥ 4 pCi/L.

Mitigation system. Any system or steps designed to reduce radon concentrations in the indoor air of a building.

Monitoring: Ongoing radon testing performed at an installation or site with known radon potential (low or elevated) which will alert the installation to any future elevated radon problems.

Nonresidential building: Simply put, a building that is not considered family housing. For the purposes of NAVRAMP and this document, other types of residential buildings such as bachelor officer quarters/bachelor enlisted quarters, Navy/Marine Corps lodges, temporary lodging, and transient quarters are also included in this definition.

Normal building testing conditions: The building is occupied, and the building's mechanical systems (e.g., heating and cooling systems) are operating under typical seasonal conditions.

Occupied: A room or building in which one or more people spend >4 h/day on average per year.

Occupiable: A room not currently occupied but that could be occupied easily. Examples are bachelor quarter rooms, vacant offices, or offices currently used as storage rooms that could easily be converted to office space.

One year test: Under NAVRAMP, any radon test between 335 and 395 days duration is considered a 1 year test.

Picocurie per liter (pCi/L): A common unit of measurement of the concentration of radioactivity in a fluid (liquid or gas). A picocurie per liter corresponds to 0.037 radioactive disintegrations per second in every liter of fluid. For radon testing purposes, pCi/L is the unit of measure of radon gas. EPA and NAVRAMP have set an action level of 4 pCi/L.

Picocurie per liter per day (pCi/L-day): A measure of the detector dose; 1 pCi/L-day is the dose a detector receives if it is exposed to 1 pCi/L for 1 day.

Radon: A colorless, odorless, radioactive gas formed by the decay of uranium. It exists in varying amounts in all soils, rocks, and some groundwater supplies worldwide. Under certain conditions, it can infiltrate into and concentrate to unacceptable levels in buildings.

Radon potential category (RPC): A dynamic category assigned by COMNAVFACENGCOM, based on historical radon testing data to a naval installation or site which designates its potential for having elevated radon. Briefly the designations are

- RPC 1 means proven elevated radon potential exists
- RPC 2 means the potential is unknown
- RPC 3 means a low potential for elevated radon exists

Radon progeny: Radon particles that can be breathed into the lungs, where they continue to release radiation as they further decay. Also known as radon decay products or radon daughters.

Representative short-term radon measurement: A short-term radon measurement performed during closed-building conditions; normal HVAC system operation; and typical seasonal weather patterns.

Room of interest: a room with valid test data that indicate the presence of elevated radon.

Screening: Radon testing in a representative statistical subset of testable rooms at a site or installation.

Significantly modified: A building occupied or to be occupied, altered, or renovated either by changing mechanical systems (e.g., HVAC) or by making modifications (e.g., changing the original number or type of windows, doors, ground slabs, walls) in any manner that significantly changes the air change or flow into and within the building.

Site: The subdivision of an installation into smaller geographical areas based on geology, building types, or remoteness.

Spike: A radon detector exposed at a laboratory to a known radon concentration as part of NAVRAMP QA/QC. When used in conjunction with field testing, spikes measure the accuracy of the survey radon results.

Testable building: A building that is enclosed, occupied/occupiable, and in ground contact.

Testable room: An occupied or easily occupiable room in a testable building either in ground contact or over an unoccupied ground contact basement room or crawlspace.

Test type code: A two-letter code assigned to a specific radon measurement to document the reason why the radon test was performed (example: PM = postmitigation).

Tier 1 buildings: Includes all hospitals, bachelor quarters, schools, child-care centers, and brigs.

Tier 2 buildings: Includes all 24 h manned facilities, such as but not limited to command and communication facilities, fire stations, lodges, and security buildings.

Tier 3 buildings: Includes all offices and administrative buildings, exchanges, commissary, shops, recreational facilities (i.e., fitness centers, theaters), warehouses and other work areas.

Tier 4 buildings: Includes atypical buildings such as but not limited to armories, occupied magazines, underground facilities, and buildings with unique construction characteristics.

Valid radon test: Radon test that meets the requirements of NAVRAMP (e.g., type of radon detection device; sampling strategies, procedures, and intervals; QA and QC).

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APPENDIX A: EPA CORRESPONDENCE

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UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

December 1, 2011

Mr. David Wilson
Research Staff
Oak Ridge National Laboratory/Sobran
115D Flint Road
Oak Ridge, Tennessee 38731

Dear Mr. Wilson:

This letter is in response to your recent request for additional information pertaining to radon and the testing intervals, action levels and standards, filtration, and radon-resistant new construction. EPA's understanding is that this information is pertinent to the NAVFACENGCOM effort to complete an update of the U.S. Navy's Radon Testing and Mitigation Guidebook.

Radon is a highly localized phenomenon. Identical buildings (or dwelling units within a building) that are adjacent to one another can have very different radon levels. Geologic and soil conditions, building design and materials, operation and maintenance, and the aging of the building are key variables that affect the radon concentration. Atmospheric conditions also play a significant role temporally in determining a building's radon concentrations. Buildings should be tested in accordance with the appropriate and approved protocol.

1-Testing Interval for Buildings or Spaces Not Mitigated. Homes that initially test below 4pCi/L should be retested periodically. In addition to the regular testing required by OSHA, EPA and the radon community of practice believe it prudent to test residential buildings every five years, consistent with current consensus standards of practice.[1] Furthermore, a radon test should be conducted following any activity with the potential to affect the air dynamic of any building. Changing a building's air flow dynamic has the potential to affect the radon concentration. For example, upgrading or replacing the HVAC system or windows, or adding a family room to the building.

2-Testing Interval for Mitigated Buildings. All buildings, once mitigated, should be tested within 30 days to confirm the mitigation system's initial effectiveness. Periodic testing should be conducted to confirm the continuing effectiveness of the mitigation system. More specifically, previously mitigated spaces in schools and other large buildings should be retested annually or every two years, consistent with current consensus standards of practice.[2]

3-Testing in New Residential Construction. Test for radon after the building is completed and all systems are operating properly, and prior to occupancy or the issuance of an occupancy certificate. In the case of passive radon mitigation systems, a radon vent fan should be added when the test result exceeds the EPA action level of 4 pCi/L.

4-Radon Action Level and Workplace Standards. For homes, including multi-family buildings, and schools, we recommend that these buildings be mitigated when the measurement or test result is 4pCi/L or more. If non-residential buildings are workplaces, they would be subject to the DOL-OSHA standard, i.e., the Maximum Permissible Concentration (MPC) of 100pCi/L for an adult worker's exposure in 40-hours over a consecutive 7-day period (work week). In addition, OSHA has posting (notice) requirements for radon concentrations below the 100 pCi/L standard.

[For details see http://www.osha.gov/dts/sltc/methods/inorganic/id208/id208.html, and http://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=STANDARDS&p_id=10098]

However, we strongly encourage you to consider a more protective approach to your workplaces. In Appendix A to its recent publication, *Indoor Air Quality in Commercial and Institutional Buildings* (OSHA 3430-04 2011), OSHA does note EPA's 4pCi/L action level. Presuming that the OSHA MPC is a minimum standard of protection, health & safety officers, and facility managers could as a matter of prudent policy choose to meet the more protective EPA action level.

5-High Efficiency Particulate Air (HEPA) Filtration. We don't recommend filtration or HEPA filtration as a radon control measure or mitigation technique. There is some evidence that filtration can reduce radon progeny concentrations. However, many factors can affect filtration's effectiveness in maintaining reduced progeny concentrations, including: (1) a potential increase in ultra fine particles available for progeny attachment and deposition in the lung; (2) a potentially larger percentage of progeny as an unattached fraction available to be deposited in the lung; (3) uncertainties with filter loading, consistency and cost of filter replacement, and maintaining a consistent air volume setting; (4) human interference with filtration device operation; and (5) the frequency (and cost) of radon progeny measurements needed to confirm that the desired progeny concentration is being maintained.

6-Pre-construction Radon Prediction. Soil flux measurements or measurement results from neighboring areas are not reliable methods for predicting a given building's radon level. Individual buildings should be tested in accordance with an appropriate and approved protocol.

7- Radon Resistant New Construction. We recommend that all homes, including multi-family buildings and schools, be built radon-resistant when located in high radon potential areas (Zone 1 on the EPA Map of Radon Zones). EPA also recommends that homes and schools built in medium radon potential areas (Zone 2 on the EPA Map of Radon Zones) consider using radon-resistant construction. Currently, the most appropriate standards are Appendix F of the ICC IRC, or ASTM E1465-08a.

We strongly encourage you to consider building non-residential buildings in accordance with a green building standard, e.g., the ICC International Green Construction Code (IgCC), or adapted from a closely relevant standard to offer occupants an increased level of protection from radon exposure and other health benefits. Please contact me (2020.343.9733, Long.Bill@epa.gov) or Phil Jalbert of my staff (202.343.9431, Jalbert.Philip@epa.gov) if you have questions regarding this letter.

Sincerely,

Bill Long, Director
Center for Radon and Air Toxics

cc: Philip Jalbert, EPA/ORIA/IED

[1]ANSI-AARST Protocol for Conducting Radon and Radon Decay Product Measurements in Multifamily Buildings (MAMF-2010; EPA 402-K-11-002).
2 MAMF-2010; EPA 402-K-11-002) - (see section II.G., page II:2.), and Reducing Radon in Schools: A Team Approach (EPA 402-R-94-008, April 1994) – (Section 9.1, page 9-1).

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UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460
Office of Radiation and Indoor Air
Indoor Environments Division

March 6, 2008

Ms. Teri Jamin, President
Douglas County School Board
1638 Mono Avenue
P.O. Box 1888
Minden, Nevada 89423

Dear Ms. Jamin:

Thank you for your letter of February 19, 2008 requesting assistance in answering questions posed by you and Ms. Luna with regard to the Zephyr Cove Elementary School (ZCES). We also received additional information from Mr. Greg Felton. He provided the minutes of the School Board Meeting (February 12, 2008) and a detailed email (March 4, 2008) on his observations and five questions related to radon risk. We normally refer such requests to our Regional offices. However, in this case, the EPA Region 9 office (San Francisco) has asked us to respond directly to your request.

Please be aware that this response is based only on the information we have received. Therefore, in the absence of complete information or a site inspection, we've limited our response to several general observations and recommendations. Our response addresses measurement, risk, mitigation and technical assistance. EPA's policies on radon measurement and mitigation are necessarily conservative and protective, and based on many years of research and experience in a wide variety of buildings, including schools. EPA's guidance on radon is a prudent and cost-effective long-term approach to risk reduction that is protective of students and staff alike.

Radon measurement. EPA's recommended action level has always been primarily defined as a radon gas measurement, i.e., 4 picocuries per liter of air (pCi/L). The Fallon report incorrectly claims that EPA views working level (WL or progeny) measurements as equally acceptable to radon gas (pCi/L) measurements. Radon gas measurements should always be preferred, especially when the measurement result will be used in mitigation decisions.

Since the actual radon gas measurements from the ZCES are available, they should be used in mitigation decisions, provided the measurements were obtained in accordance with the EPA Radon Measurement in Schools Protocol (EPA 420-R-92-014, July 1993). The Schools protocol allows for initial short-term measurements to be conducted in every ground contact room. Measurement results at or above 4 pCi/L (e.g., 4-10 pCi/L) should be verified with follow-up measurements which can be long-term or short-term. Long-term measurements (90-days+) give a more accurate estimate of the average annual radon level.

Making a good working level or progeny measurement is more difficult than making a radon gas measurement. Because of the uncertainties associated with progeny measurements, the state of New Jersey and the American Association of Radon Scientists and Technologists (AARST) do not recommend making mitigation decisions based on working level measurements. Working level (WL) measurements are mentioned very briefly in EPA documents. The main reason for their inclusion is that in the early years of EPA's radon program there were some devices being used in the market to measure working level (progeny). The use of WL devices has declined over time due to the difficulty and expense of making such measurements.

For the reasons above, EPA's recommendation is to base a mitigation decision on a gas measurement, which we consider a conservative and protective, as well as practical way to evaluate potential risk. More simply put, "no radon gas, no risk." Of course, there is rarely, if ever, "no" radon gas. Background concentrations of radon in outdoor air can vary from place to place and time of day. The available data suggest that the outdoor average is about 0.4 pCi/L, or 1/10th EPA's action level.

Radon health risk. To our knowledge, lung cancer is the only health effect from exposure to radon in air. There are no data to suggest that children are at greater risk from exposure to radon in air than are adults. Recent radon risk assessments confirm that the risk at relatively low levels of radon is significant. For this reason, EPA recommends that mitigation be considered at levels even below our action level of 4 pCi/L (and specifically between 2 and 4 pCi/L) for residential structures. As you know, the 2003 EPA risk assessment estimated 20,000 annual radon-related lung cancer deaths. It's important to remember that this estimate is based on exposure to 1.25 pCi/L, which is the average U.S. indoor radon level. It is for these reasons that the International Commission on Radiation Protection (ICRP) recommends that radon be reduced to a level as low as reasonably achievable (ALARA).

Mitigation. EPA's principal recommendation for mitigating radon levels in school buildings is to control the source, i.e., to minimize or prevent radon entry. The technique used most often and successfully is sub-slab or sub-membrane Active Soil Depressurization (ASD). From the Fallon report we reviewed, it appears that the existing ZCES ASD systems have not been adequately evaluated for their effectiveness.

A complete and thorough evaluation of the existing ASD systems should be conducted. The evaluation should identify needed upgrades to, or extensions of, the existing radon mitigation systems. Any upgrades or new systems should conform to EPA's guidance. We recommend that school ASD systems be operated continuously. For the school's slab-on-grade footprint not served by an existing ASD system, if measurement results warrant mitigation, additional diagnostics should be done to determine whether ASD can be employed. These evaluation/diagnostic activities should be conducted by a qualified professional with experience in large, low-rise, slab-on-grade/crawlspace school/commercial buildings. Evaluations and diagnostics can be conducted independent of weather conditions and when convenient.

EPA does not recommend filtration as a radon control measure; the use of High Efficiency Particle Air (HEPA) filtration devices is not recommended as a mitigation technique. While there is evidence that filtration can reduce progeny concentrations, many factors can impinge on the effectiveness of filtration in maintaining reduced progeny concentrations with an attendant reduction in radon dose.

Some of these complicating factors include: a potential increase in ultra fine particles available for progeny attachment and deposition in the lung; a potentially larger percentage of progeny as an unattached fraction available to be deposited in the lung; maintaining a consistent air volume setting; human interference with filtration device operation; uncertainties with filter loading and progeny reductions; and the frequency of radon progeny measurements needed to maintain the target progeny concentration.

Technical assistance. Further technical assistance may be available to assist you in your ZCES deliberations. Radon professionals at EPA and the State of Nevada are available to support you through letters like this, via conference calls, etc. Also, onsite technical assistance may be available through the Conference of Radiation Control Program Directors (CRCPD). For such a request you should contact Adrian Howe with the Nevada State Radon Program (775-687-7531, ahowe@health.nv.gov).

We acknowledge the good offices of the State of Nevada Radon Program in addressing this issue to date. Thank you for the opportunity of joining in the effort to assist the Douglas County School District in resolving this important public health issue.

Sincerely,

Phil Jalbert [signed]
Radon Team Leader
202-343-9431
jalbert.philip@epa.gov

Gene Fisher [signed]
Health Physicist
202-343-9418
fisher.eugene@epa.gov

cc:
Ms. Holly Luna, Director, Business Services, Douglas County School District
Ms. Carol Lark, Superintendent, Douglas County School District
Dr. Susan Conrath, MPH, PhD, U.S. Public Health Service, EPA
Mr. Bill Long, Director, EPA Center for Radon and Air Toxics, EPA
Mr. Adrian Howe, State of Nevada Radon Program
Ms. Louise Hill, EPA Region 9 Radon Coordinator
Ms. Kelly Krolicki
Mr. Greg Felton

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UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

April 21, 2014

OFFICE OF
AIR AND RADIATION

Mr. David Wilson
Research Staff
Oak Ridge National Laboratory/Sobran
115D Flint Road
Oak Ridge, Tennessee 38731

Dear Mr. Wilson:

This letter is in response to your recent email request for information pertaining to radon and the Agency's recommended residential testing protocol. The Agency's policy and recommendations are that at a minimum, every ground contact dwelling unit be tested, whether it be a multi-unit residential building or a single-family home. This approach is consistent with standards of practice and consensus based standards.

The most relevant protocol for testing multi-unit residential buildings is the ANSI-AARST* *Protocol for Conducting Radon and Radon Decay Product Measurements in Multifamily Buildings* (MAMF-2010; EPA 402-K-11-002).

The most relevant protocol for testing single-family homes is *Protocols for Radon Measurement in Homes Standard* (MAH 9/2005), issued by AARST.

The protocol contained in Section 25-3.2.b.(1)(a) of OPNAV M-5090.1 (10-Jan 2014) for making screening measurements will almost certainly result in overlooking units within buildings or entire buildings that exceed the 4pCi/L action level. This result, and the attendant risk, is likely since radon is such a localized phenomenon. Adjacent buildings can have very different radon levels. Ground contact dwelling units within a building can have varying radon levels. Geologic and soil conditions, building design and materials, operation and maintenance, and the aging of the building are key variables determining the radon concentration. Atmospheric conditions also play a significant role temporally.

Please contact me with any questions you might have (202.343.9431, Jalbert.Philip@epa.gov). Thank you.

Sincerely,

Philip Jalbert†
Center for Radon and Air Toxics
Indoor Environments Division

*American National Standards Institute (ANSI), and American Association of Radon Scientists and Technologists (AARST)
†Executive Secretary, Federal Interagency Committee on Indoor Air Quality (CIAQ)

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APPENDIX B: RADON POTENTIAL CATEGORIES (RPCs) AT NAVAL AND MARINE CORPS INSTALLATIONS

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NAVY INITIAL RPCs

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Navy Initial Radon Potential Categories

Navy Region	UIC	UIC Name	Total Number Radon Measurements	Number of Measurements at UIC ≥ 4 pCi/L	Highest Radon Result at UIC	Radon Potential Category	Radon Testing Phase	Comments
BUMED	N44852	NAVMEDRSCHU SIX LIMA PE	0	0	N/A	2	Screening	FORMER NAVMEDRSCHCEN DET LIMA PERU
BUMED	N61751	NAVMEDRSCHU THREE CAIRO EGYPT	1	0	0.3	2	Screening	
EURAFSWA	N32960	FORMER NAVSUPPACT LA MADDALENA IT	363	69	12.5	N/A	Does not apply	NO LONGER NAVY OWNED
EURAFSWA	N3379A	CAMP LEMONNIER DJIBOUTI	0	0	N/A	2	Screening	
EURAFSWA	N57032	FORMER NAF MILDENHALL UK	0	0	N/A	N/A	Does not apply	NO LONGER NAVY OWNED
EURAFSWA	N62585	FORMER NAVACT LONDON UK	107	2	4.0	N/A	Does not apply	NO LONGER NAVY OWNED
EURAFSWA	N62588	NAVSUPPACT NAPLES IT	1724	28	35.6	1	Monitoring	RADON DATA FROM 1989-1992 NOT INCLUDED IN TOTALS, ONLY 2013-2015 DATA.
EURAFSWA	N62590	NSA NAPLES	0	0	N/A	N/A	Does not apply	SEE N62588
EURAFSWA	N62745	FORMER OICC MED MADRID SP	0	0	N/A	N/A	Does not apply	NO LONGER NAVY OWNED
EURAFSWA	N62863	NAVSTA ROTA SP	274	0	2.6	3	Monitoring	
EURAFSWA	N62995	NAS SIGONELLA IT	21	0	2.7	3	Monitoring	
EURAFSWA	N63005	NAVSUPPACT BAHRAIN	81	0	1.9	2	Screening	FORMER ADMINSUPPU BAHRAIN
EURAFSWA	N63032	FORMER NAS KEFLAVIK IC	246	0	3.1	N/A	Does not apply	NO LONGER NAVY OWNED

RPC 1: Elevated radon potential exists
RPC 2: Radon potential is unknown
RPC 3: Low radon potential
If UIC is not listed, assume RPC 2 (Screening).
N/A: Not applicable
Radon data summary includes residential and nonresidential data collected from 1989 through 2015

Navy Initial Radon Potential Categories

Navy Region	UIC	UIC Name	Total Number Radon Measurements	Number of Measurements at UIC ≥ 4 pCi/L	Highest Radon Result at UIC	Radon Potential Category	Radon Testing Phase	Comments
EURAFSWA	N63073	FORMER NAVSECGRUACT EDZELL UK	325	11	6.3	N/A	Does not apply	NO LONGER NAVY OWNED
EURAFSWA	N63182	NCTAMS LANT DET ROTA SP	0	0	N/A	2	Screening	FORMER NAVCOMMSTA ROTA SP
EURAFSWA	N63395	FORMER NAVCOMSTA THURSO UK	2	0	0.7	N/A	Does not apply	NO LONGER NAVY OWNED
EURAFSWA	N64981	FORMER NAVWPNSFAC ST MAWGAN UK	0	0	N/A	N/A	Does not apply	NO LONGER NAVY OWNED
EURAFSWA	N65995	FORMER NAVSUPPACT HOLY LOCK UK	0	0	N/A	N/A	Does not apply	NO LONGER NAVY OWNED
EURAFSWA	N66096	NAVHOSP NAPLES IT	27	0	1.6	N/A	Does not apply	NEW HOSPITAL DATA IN N62588
EURAFSWA	N66101	NAVHOSP ROTA SP	2	0	0.8	2	Screening	
EURAFSWA	N66691	NAVSUPPACT SOUDA BAY GR	73	0	1.2	3	Monitoring	
EURAFSWA	N68165	FORMER NAVFAC BRAWDY WALES UK	0	0	N/A	N/A	Does not apply	NO LONGER NAVY OWNED
EURAFSWA	N70294	NAVCOMTELSTA NAPLES IT	0	0	N/A	N/A	Does not apply	SEE N62588
EURAFSWA	N70295	FORMER NAVCOMMSTA GREECE NEA MAKRI GR	0	0	N/A	N/A	Does not apply	NO LONGER NAVY OWNED
Far East	N43666	NAVJNTSERVACT NS TOKYO JA	8	0	0.4	2	Screening	

RPC 1: Elevated radon potential exists
RPC 2: Radon potential is unknown
RPC 3: Low radon potential
If UIC is not listed, assume RPC 2 (Screening).
N/A: Not applicable
Radon data summary includes residential and nonresidential data collected from 1989 through 2015

Navy Initial Radon Potential Categories

Navy Region	UIC	UIC Name	Total Number Radon Measurements	Number of Measurements at UIC ≥ 4 pCi/L	Highest Radon Result at UIC	Radon Potential Category	Radon Testing Phase	Comments
Far East	N61054	COMFLEACT YOKOSUKA JA	120	0	3.7	3	Monitoring	MAIN BASE RADON STATUS BASED ON NFEC FE YOKOSUKA NWCF (UIC N65115) RADON DATA; OUTLYING AREAS - NO DATA; DATA FROM UIC N65115 MOVED TO THIS UIC
Far East	N61056	COMFLEACT OKINAWA JA	1548	343	98.1	1	Monitoring	DATA INCLUDES KADENA AND OUTLYING AREAS; FORMER UIC N62254 - DATA MOVED TO THIS UIC
Far East	N61057	NAF ATSUGI JA	242	0	2.9	3	Monitoring	FORMER UIC N62507; DATA MOVED TO THIS UIC
Far East	N61058	COMFLEACT SASEBO JA	1146	14	9.1	1	Monitoring	DATA INCLUDES MAIN BASE AND OUTLYING AREAS
Far East	N61060	NAF MISAWA JA	0	0	N/A	2	Screening	FORMER UIC N68212; DATA MOVED TO THIS UIC
Far East	N61078	FORMER NAVSUPPFAC DIEGO GARCIA IO	0	0	N/A	N/A	Does not apply	DATA LOCATED IN UIC N68539
Far East	N61581	NMC EAD DET YOKOSUKA JA	0	0	N/A	2	Screening	
Far East	N62254	NAVY MUNITIONS COMMAND EAD UNIT OKINAWA JA	0	N/A	N/A	N/A	Does not apply	DATA PART OF COMFLEACT OKINAWA UIC N61056

RPC 1: Elevated radon potential exists
RPC 2: Radon potential is unknown
RPC 3: Low radon potential
If UIC is not listed, assume RPC 2 (Screening).
N/A: Not applicable
Radon data summary includes residential and nonresidential data collected from 1989 through 2015

Navy Initial Radon Potential Categories

Navy Region	UIC	UIC Name	Total Number Radon Measurements	Number of Measurements at UIC ≥ 4 pCi/L	Highest Radon Result at UIC	Radon Potential Category	Radon Testing Phase	Comments
Far East	N62507	NAVY MUNITIONS COMMAND EAD DET ATSUGI ANNEX	0	0	N/A	N/A	Does not apply	DATA PART OF COMFLEACT NAF ATSUGI UIC N61057
Far East	N62649	FISC YOKOSUKA JA	0	0	N/A	N/A	Does not apply	FORMER NSD YOKOSUKA; RADON STATUS BASED ON YOKOSUKA COMPLEX DATA
Far East	N62735	NAVY MUNITIONS COMMAND EAD DET SASEBO	0	0	N/A	N/A	Does not apply	PART OF COMFLEACT SASEBO UIC N61058; DATA PART OF COMFLEACT SASEBO
Far East	N62758	NAVSHIPREPFAC YOKOSUKA JA	0	0	N/A	N/A	Does not apply	RADON STATUS BASED ON YOKOSUKA COMPLEX DATA
Far East	N65115	NFEC FE YOKOSUKA JA NWCF	139	0	3.1	3	Monitoring	FORMER PWC YOKOSUKA
Far East	N66319	SHIP SUPPOFF HONG KONG	9	2	5.8	1	Assessment	
Far East	N68212	NAVY MUNITIONS COMMAND EAD DET MISAWA ANNEX	0	0	N/A	N/A	Does not apply	DATA MOVED TO NAF MISAWA UIC N61060
Far East	N68292	NAVHOSP YOKOSUKA JA	6	0	0.9	2	Screening	RADON STATUS BASED ON NFEC FE YOKOSUKA JA NWCF UIC N65115
Far East	N68470	NAVHOSP OKINAWA JA	932	34	28.4	1	Assessment	
Far East	N68539	NAVSUPPFAC DIEGO GARCIA IO	129	0	0.7	3	Monitoring	FORMER UIC N61078

RPC 1: Elevated radon potential exists
RPC 2: Radon potential is unknown
RPC 3: Low radon potential
If UIC is not listed, assume RPC 2 (Screening).
N/A: Not applicable
Radon data summary includes residential and nonresidential data collected from 1989 through 2015

Navy Initial Radon Potential Categories

Navy Region	UIC	UIC Name	Total Number Radon Measurements	Number of Measurements at UIC ≥ 4 pCi/L	Highest Radon Result at UIC	Radon Potential Category	Radon Testing Phase	Comments
Far East	N70278	NAVCOMTELSTA FAR EAST	26	0	2.4	3	Monitoring	FORMER NAVCOMMSTA YOKOSUKA; RADON STATUS ALSO BASED ON UIC N65115 NFEC FE YOKOSUKA
Far East	N70284	FORMER NAVSECGRUACT HANZA OKINAWA JA	217	73	40.7	N/A	Does not apply	NO LONGER NAVY OWNED
Hawaii	N00311	NAVSHIPYD AND IMF PEARL HARBOR	164	0	0.7	3	Monitoring	FORMER NSY PEARL HARBOR
Hawaii	N00314	NAVSTA PEARL HARBOR HI	114	0	2.2	3	Monitoring	FORMER SUBASE PEARL HARBOR
Hawaii	N00334	FORMER NAS BARBERS PT	746	4	15.2	N/A	Does not apply	FORMER NAS BARBERS POINT HI
Hawaii	N00604	FISC PEARL HARBOR HI	133	2	11.7	1	Assessment	FORMER NSC PEARL HARBOR
Hawaii	N00950	NCTAMS PAC HONOLULU HI	558	1	5.6	1	Assessment	FORMER NAVCAMS EASTPAC HONOLULU
Hawaii	N0534A	PACMISRANFAC HAWAIIAN AREA	29	0	1.2	3	Monitoring	
Hawaii	N0545A	NAVEPVNTMEDU NO 6 PEARL HARBOR HI	23	0	0.2	3	Monitoring	
Hawaii	N43456	NAVY INFO OPERATIONS CMD HI	184	1	5.2	1	Assessment	FORMER NSGA KUNIA

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Navy Initial Radon Potential Categories

Navy Region	UIC	UIC Name	Total Number Radon Measurements	Number of Measurements at UIC ≥ 4 pCi/L	Highest Radon Result at UIC	Radon Potential Category	Radon Testing Phase	Comments
Hawaii	N57026	NAVSEA INACTSHIPMAINTO PH HI	9	0	0.1	2	Screening	RADON STATUS ALSO BASED ON OTHER PEARL HARBOR DATA
Hawaii	N61064	CNIC PMRF BARKING SANDS HI	0	0	N/A	N/A	Does not apply	
Hawaii	N61449	NAVSTA PEARL HARBOR	2	0	0.1	2	Screening	FORMER COMNAVREG PEARL HARBOR HI; RADON STATUS ALSO BASED ON OTHER PEARL HARBOR DATA
Hawaii	N61845	NAVOPSPTCEN HONOLULU HI	42	0	0.5	3	Monitoring	FORMER NAVMARCORESCEN HONOLULU HI
Hawaii	N62363	NAVMARFCSTCEN PERAL HARBOR HI	0	0	N/A	2	Screening	FORMER NAVWESTOCEANCEN PEARL HARBOR; RADON STATUS BASED ON PEARL HARBOR DATA
Hawaii	N62707	DPS DET PEARL HARBOR HI	24	15	17.1	1	Assessment	FORMER NPPS PEARL HARBOR; DET IS LOCATED IN GUAM
Hawaii	N62755	NAVFAC HAWAII PEARL HARBOR HI	138	0	0.5	3	Monitoring	FORMER PWC PEARL HARBOR

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Navy Initial Radon Potential Categories

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Hawaii	N62813	JBPHH PEARL HARBOR - NAVSTA PEARL HARBOR	21	0	0.8	2	Screening	FORMER NAVSTA PEARL HARBOR; RADON STATUS BASED ON PEARL HARBOR DATA
Hawaii	N68098	NAVMEDCLINIC PEARL HARBOR HI	0	0	N/A	N/A	Does not apply	RADON STATUS BASED ON PEARL HARBOR DATA
Hawaii	N68297	NAVY MUNITIONS COMMAND EAD DET PEARL HARBOR	498	19	14.3	1	Assessment	FORMER NAVY MAGAZINE PEARL HARBOR; ALSO FORMER WEST LOCH AND NAVMAG LUALUALEI
Korea	N32778	FLEET ACTIVITIES CHINHAE ROK	699	89	40.8	1	Monitoring	
Korea	N44990	COMNAVFORKOREA DET POHANG	17	0	3.3	3	Monitoring	
Marianas	N41557	NSA ANDERSEN GUAM	963	112	71.4	1	Assessment	ALSO KNOWN AS ANDERSEN AIR FORCE BASE
Marianas	N60872	NAVAL MUNITIONS GUAM	0	0	N/A	N/A	Does not apply	FORMER NAVMAG GUAM GQ. NOW PART OF NAVBASE GUAM N61755; DATA PART OF NAVBASE GUAM

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N/A: Not applicable
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Marianas	N61119	FISC GUAM	0	0	N/A	N/A	Does not apply	FORMER NSD GUAM; NOW PART OR NAVBASE GUAM N61755; DATA PART OF NAVBASE GUAM
Marianas	N61577	AGANA GUAM NAS (CLOSED)	188	20	19.8	N/A	Does not apply	FORMER NAS AGANA GUAM; NOW PART OF NAVBASE GUAM N61755; INCLUDES MAIN BASE DATA; HOUSING DATA PART OF NAVBASE GUAM
Marianas	N61755	NAVBASE GUAM	9637	1705	230.0	1	Assessment	FORMER CNRM; DATA INCLUDES MAIN BASE AND OUTLYING AREAS
Marianas	N62328	BRDENCLINIC GUAM	0	0	N/A	N/A	Does not apply	FORMER NAVY DENTAL CLINIC GUAM; NOW PART OF NAVBASE GUAM N61755; DATA PART OF NAVBASE GUAM
Marianas	N62395	NAVFAC MARIANAS	0	0	N/A	N/A	Does not apply	FORMER PWC GUAM; NOW PART OF NAVBASE GUAM N61755; DATA PART OF NAVBASE GUAM
Marianas	N62586	NAVBASE GUAM MAIN BASE (FORMER SRF GUAM)	0	0	N/A	N/A	Does not apply	PART OF NAVBASE GUAM N61755; DATA PART OF NAVBASE GUAM

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N/A: Not applicable
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Navy Initial Radon Potential Categories

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Marianas	N66125	FORMER NAVFAC GUAM (RITIDIAN POINT)	0	0	N/A	N/A	Does not apply	NO LONGER NAVY OWNED
Marianas	N68096	NAVHOSP GUAM	185	8	19.3	1	Assessment	HOUSING DATA PART OF NAVBASE GUAM N61755
Marianas	N69143	AGANA GUAM NAS CSO	0	0	N/A	N/A	Does not apply	CLOSED
Marianas	N70243	NAVAL TELECOMMUNICATIONS STATION GUAM	0	0	N/A	N/A	Does not apply	FORMER NAVCOMTELSTA GUAM; PART OF NAVSTA GUAM N61755; DATA PART OF NAVSTA GUAM
Mid-Atlantic	N00034	DEFENSE FINANCING & ACCOUNTING	0	0	N/A	2	Screening	FORMER NAVFINCEN CLEVELAND OH
Mid-Atlantic	N00101	NAS SOUTH WEYMOUTH MA	93	0	2.6	3	Monitoring	
Mid-Atlantic	N00102	PORTS NSYD PORTS NH (STU ONLY)	306	34	13.3	1	Assessment	FORMER NSY PORTSMOUTH NH
Mid-Atlantic	N00104	NSA MECHANICSBURG PA	N/A	N/A	N/A	N/A	Does not apply	DATA RELOCATED TO N32414 NAVSUPPACT MECHANICSBURG PA
Mid-Atlantic	N00105	NBHC PORTSMOUTH NH	0	0	N/A	2	Screening	FORMER NAVMEDCLINIC PORTSMOUTH NH
Mid-Atlantic	N00109	NMC DET YORKTOWN VA	425	2	6.2	1	Assessment	FORMER WPNSTA YORKTOWN VA
Mid-Atlantic	N00124	NAVWARCOL NEWPORT RI	0	0	N/A	2	Screening	
Mid-Atlantic	N00128	GREAT LAKES NAVAL STATION	0	0	N/A	2	Screening	

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N/A: Not applicable
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Navy Initial Radon Potential Categories

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Mid-Atlantic	N00129	NAVSUBASE NEW LONDON CT	5665	90	26.4	1	Assessment	
Mid-Atlantic	N00151	PHILADELPHIA NAVAL YARD ANNEX	78	0	2.1	3	Monitoring	FORMER NSY PHILADELPHIA PA
Mid-Atlantic	N00158	NAS JRB WILLOW GROVE PA	397	3	9.0	1	Assessment	
Mid-Atlantic	N00163	FORMER NAVAIRWARCENACDIV INDIANAPOLIS	5	0	2.5	N/A	Does not apply	DIS-ESTABLISHED
Mid-Atlantic	N00164	NAVSURFWARCENDIV CRANE	63	16	6.6	1	Assessment	FORMER NAVWPNSUPPCEN CRANE IN
Mid-Atlantic	N00181	NSY NORFOLK VA	5	0	0.2	2	Screening	FORMER NSY PORTSMOUTH VA
Mid-Atlantic	N00183	NAVMEDCEN PORTSMOUTH VA	22	0	2.2	3	Monitoring	FORMER NAVHOSP PORTSMOUTH VA
Mid-Atlantic	N00188	NAS OCEANA AIR DET NORFOLK VA	0	0	N/A	2	Screening	FORMER NAS NORFOLK VA
Mid-Atlantic	N00189	NAVSUP FLC NORFOLK VA	0	0	N/A	2	Screening	FORMER FISC NORFOLK VA
Mid-Atlantic	N00197	FORMER NAVSURFWARCEN ORDSTA KY	6	0	1.9	N/A	Does not apply	DIS-ESTABLISHED
Mid-Atlantic	N00210	NSTC GREAT LAKES IL	2844	13	11.3	1	Assessment	FORMER NTC GREAT LAKES IL
Mid-Atlantic	N00211	NAVHEALTHCLINIC GREAT LAKES IL	474	0	2.6	3	Monitoring	FORMER NAVAL HOSPITAL GREAT LAKES IL

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N/A: Not applicable
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Mid-Atlantic	N00274	NAF DETROIT MI	0	0	N/A	N/A	Does not apply	DIS-ESTABLISHED
Mid-Atlantic	N00275	NAVAIRESCEN CHICAGO	1202	2	4.2	1	Assessment	FORMER NAS GLENVIEW IL
Mid-Atlantic	N00281	TRASUPPCEN HAMPTON ROADS	28	0	0.4	3	Monitoring	FORMER FLECOMBATTRACENLANT DAM NECK VA
Mid-Atlantic	N00288	NASOPUBFORMCEN PHILADELPHIA PA	0	0	N/A	2	Screening	
Mid-Atlantic	N00383	NSA PHILADELPHIA	11	0	0.7	3	Monitoring	FORMER NAVICP PHILADELPHIA PA
Mid-Atlantic	N00702	NAVSECGRUACT WINTER HARBOR ME	308	7	8.6	1	Assessment	
Mid-Atlantic	N08912	NMCB 13 PEEKSKILL NY	0	0	N/A	2	Screening	FORMER RNMCB 13 PEEKSKILL NY
Mid-Atlantic	N30316	NAVSOC DET ALPHA PROS HB	13	0	1.1	3	Monitoring	
Mid-Atlantic	N30530	NOSC-MCRC COLUMBUS OH	0	0	N/A	2	Screening	FORMER NAVAIRESCEN COLUMBUS OH
Mid-Atlantic	N31188	NIOC SUGAR GROVE WV	252	1	6.8	1	Assessment	TO BE CLOSED IN 2015
Mid-Atlantic	N31260	NRLCHESBAYDET CHESAPEAKE BEACH MD	47	9	6.7	1	Assessment	

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Mid-Atlantic	N32185	NAVHLTHCLINIC NEW ENGLAND RI	234	8	8.6	1	Assessment	INCLUDES DATA FROM: NAVDENCLINIC NE NEWPORT RI UIC N66023 AND NAVAMBCARECEN NEWPORT RI UIC N68086
Mid-Atlantic	N32411	NAVAL STATION NEWPORT RI	96	19	7.8	1	Assessment	
Mid-Atlantic	N32414	NAVSUPPACT MECHANICSBURG PA	1988	597	33.2	1	Assessment	INCLUDES FORMER N00104 NSA MECHANICSBURG DATA
Mid-Atlantic	N32443	NSA NORFOLK NAVY SHIPYARD	0	0	N/A	2	Screening	
Mid-Atlantic	N32446	NSS PORTSMOUTH NAVY SHIPYARD	1200	23	19.3	1	Assessment	
Mid-Atlantic	N32510	BRMEDCLINIC NAVAL STATION NORFOLK SP	0	0	N/A	2	Screening	FORMER NAVMEDCLINIC NORFOLK VA UIC N68722
Mid-Atlantic	N3567A	CENTER FOR SURFACE COMBAT SYSTEMS (CSCS) DET EAST	0	0	N/A	2	Screening	FORMER STU FLETRACEN NORFOLK UIC N61797
Mid-Atlantic	N39029	AEGIS TECH REP	0	0	N/A	2	Screening	FORMER AEGIS CSEDS MOORESTOWN NJ; NOT PHYSICALLY LOCATED ON NAVAL WEAPONS STATION EARLE AND DOES NOT SUPPORT EARLE MISSION

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N/A: Not applicable
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Navy Initial Radon Potential Categories

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Mid-Atlantic	N40085	NFEC MLANT NORFOLK VA	826	3	5.7	1	Assessment	FORMER PWC NORFOLK UIC N00187
Mid-Atlantic	N4148A	NEPMU FD 2 EAST DET	0	0	N/A	2	Screening	FORMER NAVENPVNTMEDU-2 UIC N63117
Mid-Atlantic	N50092	JNTEXPBASE LITTLE CREEK FS VA	0	0	N/A	2	Screening	
Mid-Atlantic	N57023	COMOPTEVFOR NORFOLK VA	0	0	N/A	2	Screening	
Mid-Atlantic	N57039	NAVFAC NANTUCKET MA	0	0	N/A	2	Screening	
Mid-Atlantic	N57041	NAVFAC CAPE HATTERAS NC	0	0	N/A	2	Screening	
Mid-Atlantic	N57095	NAVSUPPACT NORFOLK VA	0	0	N/A	2	Screening	FORMER LANTFLTHEADSUPPACT NORFOLK VA
Mid-Atlantic	N60087	NAS BRUNSWICK ME	498	2	5.3	1	Assessment	
Mid-Atlantic	N60138	NAVAL AIR SUPPORT EQUIPMENT FACILITY	16	1	7.9	1	Assessment	FORMER FISC CHEATHAM ANNEX
Mid-Atlantic	N60191	NAS OCEANA VA	108	0	1.1	3	Monitoring	

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Navy Initial Radon Potential Categories

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Mid-Atlantic	N60478	NMC DET EARLE NJ	596	0	3.5	3	Monitoring	FORMER WPNSTA EARLE COLTS NECK NJ; TENANT GEOGRAPHICALLY LOCATED ON NAVAL WEAPONS STATION EARLE; RADON STATUS BASED ON WEAPONS STATION EARLE UIC N69213
Mid-Atlantic	N61011	NSA SARATOGA SPRINGS NY	0	0	N/A	2	Screening	
Mid-Atlantic	N61018	NAVAL SUPPORT ACTIVITY CRANE	0	0	N/A	2	Screening	
Mid-Atlantic	N61174	NAVSTA NEW YORK NY	67	0	3.2	3	Monitoring	FORMER NAVSTA BROOKLYN NY
Mid-Atlantic	N61189	NAVSTA PHILADELPHIA PA	13	0	0.6	3	Monitoring	
Mid-Atlantic	N61414	NAVPHIBASE LITTLE CREEK VA	113	0	2.1	3	Monitoring	
Mid-Atlantic	N61797	CENTER FOR SURFACE COMBAT SYSTEMS DETACHMENT EAST	0	0	N/A	N/A	Does not apply	FORMER STU FLETRACEN NORFOLK; DATA MOVED TO NEW UIC N3567A CENTER FOR SURFACE COMBAT SYSTEMS (CSCS) DET EAST NORFOLK VA
Mid-Atlantic	N61801	NAVMARCORESCEN LAWRENCE MA	10	1	7.7	1	Assessment	
Mid-Atlantic	N61803	NAVRESCEN QUINCY MA	9	1	15.6	1	Assessment	

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Mid-Atlantic	N61804	NAVRESCEN PORTLAND ME	10	0	1.0	2	Screening	
Mid-Atlantic	N61805	NOSC BANGOR ME	0	0	N/A	2	Screening	FORMER NAVRESCEN BANGOR ME
Mid-Atlantic	N61808	NAVRESCEN NEW BEDFORD MA	0	0	N/A	2	Screening	
Mid-Atlantic	N61809	NAVOPSPTCEN MANCHESTER NH	0	0	N/A	2	Screening	FORMER NAVMARCORESCEN MANCHESTER NH
Mid-Atlantic	N61814	NAVRESCEN PORTSMOUTH NH	0	0	N/A	2	Screening	
Mid-Atlantic	N61815	NAVOPSPTCEN WORCESTER MA	8	0	3.5	2	Screening	FORMER NAVMARCORESCEN WORCESTER MA
Mid-Atlantic	N61818	NAVRESCEN PITTSFIELD MA	9	0	0.8	2	Screening	
Mid-Atlantic	N61821	NAVOPSPTCEN NEWPORT RI	0	0	N/A	2	Screening	FORMER NAVMARCORESCEN PROVIDENCE RI; LOCATED IN NEWPORT RI
Mid-Atlantic	N61822	NAVOPSPTCEN WHITE RIVER JCT	11	0	0.6	2	Screening	FORMER NAVRESCEN BURLINGTON VT
Mid-Atlantic	N61823	NAVRESCEN PERTH AMBOY NJ	7	0	1.0	2	Screening	
Mid-Atlantic	N61833	NAVRESCEN BINGHAMTON NY	0	0	N/A	2	Screening	
Mid-Atlantic	N61834	NAVOPSPTCEN HORSEHEADS NY	0	0	N/A	2	Screening	

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Mid-Atlantic	N61835	NAVOPSPTCEN PLAINVILLE CT	10	0	0.8	2	Screening	FORMER NAVMARCORESCEN PLAINVILLE CT
Mid-Atlantic	N61837	NAVRESCEN JAMESTOWN NY	10	0	1.3	2	Screening	
Mid-Atlantic	N61839	NAVOPSPTCEN ROCHESTER NY	66	1	6.3	1	Assessment	FORMER NAVMARCORESCEN ROCHESTER NY
Mid-Atlantic	N61842	NAVOPSPTCEN BUFFALO NY	11	0	1.0	2	Screening	FORMER NAVMARESCEN BUFFALO NY
Mid-Atlantic	N61843	NAVOPSPTCEN NEW YORK CITY NY	0	0	N/A	2	Screening	FORMER NAVMARCORESCEN BRONX NY
Mid-Atlantic	N61844	NAVRESCEN WHITESTONE NY	0	0	N/A	2	Screening	
Mid-Atlantic	N61846	NAVMARCORESCEN NEW ROCHELLE NY	0	0	N/A	2	Screening	
Mid-Atlantic	N61848	NAVRESCEN POUGHKEEPSIE NY	10	0	1.8	2	Screening	
Mid-Atlantic	N61851	NAVOPSPTCEN FORT DRUM NY	0	0	N/A	2	Screening	FORMER NAVRESCEN WATERTOWN NY
Mid-Atlantic	N61860	NAVRESCEN WEST TRENTON NJ	0	0	N/A	2	Screening	
Mid-Atlantic	N61861	NAVOPSPTCEN ALBANY NY	0	0	N/A	2	Screening	FORMER NAVMARCORESCEN ALBANY NY

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Mid-Atlantic	N61863	NAVOPSPTCEN SYRACUSE NY	8	0	0.7	2	Screening	FORMER NAVRESCEN SYRACUSE NY
Mid-Atlantic	N61864	NAVOPSPTCEN FRANKFORT NY	0	0	N/A	2	Screening	FORMER NAVRESCEN ROME NY
Mid-Atlantic	N61866	NAVOPSPTCEN NEW LONDON	9	0	0.6	2	Screening	FORMER NAVMARCORESCEN NEW HAVEN CT
Mid-Atlantic	N61868	NAVRESCEN FREEPORT NY	0	0	N/A	2	Screening	
Mid-Atlantic	N61869	NAVMARCORESCEN HUNTINGTON NY	0	0	N/A	2	Screening	
Mid-Atlantic	N61870	NAVRESCEN PHILADELPHIA PA	8	0	0.4	2	Screening	
Mid-Atlantic	N61876	NAVOPSPTCEN WILMINGTON DE	12	0	1.6	2	Screening	FORMER NAVMARCORESCEN WILMINGTON DE
Mid-Atlantic	N61878	NAVOPSPTCEN ERIE PA	10	0	1.2	2	Screening	FORMER NAVMARCORESCEN ERIE PA
Mid-Atlantic	N61880	NAVOPSPTCEN LEHIGH VALLEY PA	10	8	10.8	1	Assessment	FORMER NAVRESCEN LEHIGH VALLEY PA
Mid-Atlantic	N61881	NAVOPSPTCEN READING PA	2	0	1.5	2	Screening	FORMER NAVMARCORESCEN READING PA
Mid-Atlantic	N61882	NAVRESCEN ATLANTIC CITY NJ	0	0	N/A	2	Screening	

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Mid-Atlantic	N61883	NAVRESCEN ALTOONA PA	11	1	7.2	1	Assessment	
Mid-Atlantic	N61884	NAVMARCORESCEN FOLSOM PA	0	0	N/A	2	Screening	
Mid-Atlantic	N61886	NAVOPSPTCEN EBENSBURG PA	9	0	1.0	2	Screening	FORMER NAVMARCORESCEN EBENSBURG PA
Mid-Atlantic	N61889	NAVRESCEN MCKEESPORT PA	10	0	1.4	2	Screening	
Mid-Atlantic	N61893	NAVRESCEN WILLIAMSPORT PA	0	0	N/A	2	Screening	
Mid-Atlantic	N61897	NAVOPSPTCEN BALTIMORE MD	0	0	N/A	2	Screening	FORMER NAVRESCEN BALTIMORE MD
Mid-Atlantic	N61900	NAVOPSPTCEN RICHMOND VA	12	0	1.3	2	Screening	FORMER NAVMARCORESCEN RICHMOND VA
Mid-Atlantic	N61902	NAVRESCEN CUMBERLAND MD	1	0	1.2	2	Screening	
Mid-Atlantic	N61903	NAVOPSPTCEN ELEANOR WV	0	0	N/A	2	Screening	FORMER NAVRESCEN HUNTINGTON WV
Mid-Atlantic	N61904	NAVOPSPTCEN MOUNDSVILLE WV	9	0	1.3	2	Screening	FORMER NAVMARCORESCEN WHELLING WV
Mid-Atlantic	N61905	NAVOPSPTCEN ROANOKE VA	10	1	4.6	1	Assessment	FORMER NAVMARCORESCEN ROANOKE VA

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Mid-Atlantic	N61906	NAVRESCEN LYNCHBURG VA	0	0	N/A	2	Screening	
Mid-Atlantic	N61917	NAVOPSPTCEN CHARLOTTE NC	0	0	N/A	2	Screening	FORMER NAVRESCEN CHAROLTTE NC
Mid-Atlantic	N61920	NAVOPSPTCEN ASHEVILLE NC	10	0	0.7	2	Screening	FORMER NAVRESCEN ASHVILLE NC
Mid-Atlantic	N61921	NAVOPSPTCEN GREENSBORO NC	10	0	2.6	2	Screening	FORMER NAVRESCEN GREENSBORO NC
Mid-Atlantic	N61923	NAVOPSPTCEN RALEIGH NC	10	0	1.3	2	Screening	FORMER NAVRESCEN RALEIGH NC
Mid-Atlantic	N61989	NAVOPSPTCEN GREEN BAY WI	10	0	0.7	2	Screening	FORMER NAVMARCORESCEN GREEN BAY WI
Mid-Atlantic	N61996	NAVOPSPTCEN ROCK ISLAND	8	0	1.7	2	Screening	FORMER NAVMARCORESCEN ROCK ISLAND IL
Mid-Atlantic	N61999	NAVOPSPTCEN TOLEDO OH	0	0	N/A	2	Screening	FORMER NAVMARCORESCEN TOLEDO OH
Mid-Atlantic	N62028	NAVMARCORESCEN WEST TRENTON NJ	56	0	2.0	3	Monitoring	
Mid-Atlantic	N62031	NAVOPSPTCEN INDIANAPOLIS IN	0	0	N/A	2	Screening	FORMER NAVMARCORESCEN INDIANAPOLIS IN

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RPC 3: Low radon potential
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N/A: Not applicable
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Navy Initial Radon Potential Categories

Navy Region	UIC	UIC Name	Total Number Radon Measurements	Number of Measurements at UIC ≥ 4 pCi/L	Highest Radon Result at UIC	Radon Potential Category	Radon Testing Phase	Comments
Mid-Atlantic	N62033	FORMER NAVRESCEN OSHKOSH WI	10	0	1.7	N/A	Does not apply	DIS-ESTABLISHED
Mid-Atlantic	N62034	FORMER NAVMARCORESCEN DETROIT MI	0	0	N/A	N/A	Does not apply	DIS-ESTABLISHED
Mid-Atlantic	N62035	NAVOPSPTCEN MILWAUKEE WI	9	0	3.3	2	Screening	FORMER NAVMARCORESCEN MILWAUKEE WI
Mid-Atlantic	N62037	NAVOPSPTCEN PEORIA IL	0	0	N/A	N/A	Does not apply	RADON DATA MOVED TO UIC PWC-GL
Mid-Atlantic	N62046	FORMER NAVRESCEN GARY IN	9	0	0.4	N/A	Does not apply	DIS-ESTABLISHED
Mid-Atlantic	N62048	FORMER NAVRESCEN PORTSMOUTH OH	10	0	1.1	N/A	Does not apply	DIS-ESTABLISHED
Mid-Atlantic	N62052	FORMER NAVRESCEN SHEBOYGAN WI	9	0	0.5	N/A	Does not apply	DIS-ESTABLISHED
Mid-Atlantic	N62053	FORMER NAVRESCEN CADILLAC MI	10	0	0.7	N/A	Does not apply	DIS-ESTABLISHED
Mid-Atlantic	N62055	FORMER NAVMARCORESCEN DAYTON OH	11	0	3.5	N/A	Does not apply	DIS-ESTABLISHED
Mid-Atlantic	N62060	FORMER NAVMARCORESCEN DANVILLE IL	9	1	4.5	N/A	Does not apply	DIS-ESTABLISHED
Mid-Atlantic	N62062	NAVOPSPTCEN DECATUR IL	0	0	N/A	2	Screening	FORMER NAVRESCEN DECATUR IL

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N/A: Not applicable
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Navy Initial Radon Potential Categories

Navy Region	UIC	UIC Name	Total Number Radon Measurements	Number of Measurements at UIC ≥ 4 pCi/L	Highest Radon Result at UIC	Radon Potential Category	Radon Testing Phase	Comments
Mid-Atlantic	N62063	FORMER NAVRESCEN MANSFIELD OH	0	0	N/A	N/A	Does not apply	DIS-ESTABLISHED
Mid-Atlantic	N62066	FORMER NAVOPSPTCEN LACROSSE WI	10	0	1.0	N/A	Does not apply	DIS-ESTABLISHED
Mid-Atlantic	N62073	FORMER NAVMARCORESCEN FORT WAYNE IN	10	0	3.0	N/A	Does not apply	DIS-ESTABLISHED
Mid-Atlantic	N62075	FORMER NOSC GRISSOM ARB IN	0	0	N/A	N/A	Does not apply	DIS-ESTABLISHED
Mid-Atlantic	N62076	FORMER NAVRESCEN TERRE HAUTE IN	10	0	2.4	N/A	Does not apply	DIS-ESTABLISHED
Mid-Atlantic	N62078	NAVOPSPTCEN LOUISVILLE KY	0	0	N/A	2	Screening	FORMER NAVMARCORESCEN LOUISVILLE KY
Mid-Atlantic	N62080	NAVOPSPTCEN DETROIT MI	11	0	0.6	2	Screening	FORMER NAVRESCEN SOUTHFIELD MI
Mid-Atlantic	N62082	NAVOPSPTCEN GRAND RAPIDS	10	0	1.3	2	Screening	FORMER NAVMARCORESCEN GRAND RAPIDS MI
Mid-Atlantic	N62084	NAVOPSTCEN BATTLE CREEK MI	43	3	6.1	1	Assessment	FORMER NRC FORT CUSTER MI
Mid-Atlantic	N62085	NAVOPSTCEN LANSING MI	5	0	0.9	2	Screening	FORMER NAVMARCORESCEN LANSING MI

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N/A: Not applicable
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Navy Initial Radon Potential Categories

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Mid-Atlantic	N62086	FORMER NAVRESCEN MUSKEGON MI	0	0	N/A	N/A	Does not apply	DIS-ESTABLISHED
Mid-Atlantic	N62088	NAVOPSPTCEN SAGINAW MI	10	0	0.5	2	Screening	FORMER NAVRESCEN SAGINAW MI
Mid-Atlantic	N62092	NAVOPSPTCEN AKRON OH	0	0	N/A	2	Screening	FORMER NAVMARCORESCEN AKRON OH
Mid-Atlantic	N62094	NAVOPSPTCEN CINCINNATI OH	0	0	N/A	2	Screening	FORMER NAVMARCORESCEN CINCINNATI OH
Mid-Atlantic	N62095	NAVOPSPTCEN COLUMBUS OH	10	1	4.2	1	Assessment	FORMER NAVMARCORESCEN COLUMBUS OH
Mid-Atlantic	N62098	NAVOPSPTCEN YOUNGSTOWN OH	10	0	0.9	2	Screening	FORMER NAVMARCORESCEN YOUNGSTOWN OH
Mid-Atlantic	N62100	NAVOPSPTCEN MADISON WI	10	0	0.2	2	Screening	FORMER NAVMARCORESCEN MADISON WI
Mid-Atlantic	N62153	NAVRESCEN FORT WADS S I NY	5	0	0.8	2	Screening	
Mid-Atlantic	N62268	NAVOPSPTCEN GLENS FALLS	9	0	0.2	2	Screening	FORMER NAVRESCEN GLENS FALLS NY
Mid-Atlantic	N62269	NAVAIRWARCENACDIV WARMINSTER	686	13	55.7	1	Assessment	

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N/A: Not applicable
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Navy Initial Radon Potential Categories

Navy Region	UIC	UIC Name	Total Number Radon Measurements	Number of Measurements at UIC ≥ 4 pCi/L	Highest Radon Result at UIC	Radon Potential Category	Radon Testing Phase	Comments
Mid-Atlantic	N62276	NAVRESCEN STAUNTON VA	0	0	N/A	2	Screening	
Mid-Atlantic	N62364	NAVRESCEN AUGUSTA ME	9	1	9.2	1	Assessment	
Mid-Atlantic	N62367	NAVCLOTEXTRSCHFAC NATICK MA	0	0	N/A	2	Screening	
Mid-Atlantic	N62376	NAVAIRWARCENACDIV TRENTON NJ	96	0	2.0	3	Monitoring	FORMER NAVAIRPROPCEN TRENTON NJ
Mid-Atlantic	N62378	FORMER NAVOPSPTCEN CLEVELAND OH	9	0	0.3	N/A	Does not apply	DIS-ESTABLISHED
Mid-Atlantic	N62578	CBC DAVISVILLE RI	182	12	8.8	1	Assessment	
Mid-Atlantic	N62661	OFF TRNG CMD NEWPORT	1697	15	10.0	1	Assessment	FORMER NETC NEWPORT RI
Mid-Atlantic	N62688	NAVSTA NORFOLK VA	6	0	2.3	3	Monitoring	
Mid-Atlantic	N62757	FORMER NAVOPSPTCEN FOREST PARK IL	0	0	N/A	N/A	Does not apply	DIS-ESTABLISHED
Mid-Atlantic	N62789	SUPSHIP GROTON CT	0	0	N/A	2	Screening	
Mid-Atlantic	N62793	SUPSHIPNEWPORT NEWS VA	0	0	N/A	2	Screening	
Mid-Atlantic	N62952	NAVOPSPTCEN PITTSBURGH PA	10	4	5.4	1	Assessment	FORMER NAVMARCORESCEN PITTSBURGH PA
Mid-Atlantic	N62986	NAVNUPWRTRAU BALLSTON SPA NY	0	0	N/A	2	Screening	
Mid-Atlantic	N62990	FORMER SUPSHIP NO DET STURGEON BAY WI	0	0	N/A	N/A	Does not apply	DIS-ESTABLISHED

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Navy Initial Radon Potential Categories

Navy Region	UIC	UIC Name	Total Number Radon Measurements	Number of Measurements at UIC ≥ 4 pCi/L	Highest Radon Result at UIC	Radon Potential Category	Radon Testing Phase	Comments
Mid-Atlantic	N63038	NCTAMSLANT DET CUTLER	59	0	1.5	3	Monitoring	FORMER NAVCOMMU CUTLER ME
Mid-Atlantic	N63039	NAVOPSPTCEN ADELPHI MD	9	0	2.0	2	Screening	FORMER NAVRESCEN ADALPHI MD
Mid-Atlantic	N63063	AFEXPTRAACT CAMP PEARY VA	108	3	4.9	1	Assessment	
Mid-Atlantic	N63117	FORMER NEPMU FD 2 EAST DET	0	0	N/A	N/A	Does not apply	FORMER NAVENPVNTMEDU-2 NORFOLK VA; DATA LOCATED IN UIC N4148A NEPMU FD 2 EAST DET
Mid-Atlantic	N63159	NAVDAMCONTRACEN PHILADELPHIA PA	9	0	0.2	3	Monitoring	
Mid-Atlantic	N63238	NAVSURFWPNCENDET FT MONROE VA	0	0	N/A	2	Screening	
Mid-Atlantic	N63401	FORMER NASC SWM SITE	0	0	N/A	N/A	Does not apply	DATA LOCATED IN NEW UIC N66046 CNATTU NORFOLK VA
Mid-Atlantic	N63423	FORMER NAVMATDATSYSGRP MORGANTOWN WV	14	0	2.5	3	Monitoring	
Mid-Atlantic	N63438	NAVOPSPTCEN NORFOLK VA	7	0	0.1	2	Screening	
Mid-Atlantic	N63458	NAVRESFAC LOWER BURRELL PA	0	0	N/A	2	Screening	

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N/A: Not applicable
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Navy Initial Radon Potential Categories

Navy Region	UIC	UIC Name	Total Number Radon Measurements	Number of Measurements at UIC ≥ 4 pCi/L	Highest Radon Result at UIC	Radon Potential Category	Radon Testing Phase	Comments
Mid-Atlantic	N63465	NAVRESCEN PARKERSBURG WV	0	0	N/A	2	Screening	
Mid-Atlantic	N63500	FORMER NAVRESFAC STEVENS POINT WI	0	0	N/A	N/A	Does not apply	DIS-ESTABLISHED
Mid-Atlantic	N63891	NAVSECGRUACT NWEST CHESAPKE VA	92	0	3.3	3	Monitoring	
Mid-Atlantic	N64281	FORMER NAVUNSEAWARCEN DET NORFOLK VA	0	0	N/A	2	Screening	UNIT DOES NOT EXIST AT NORFOLK ANY LONGER
Mid-Atlantic	N64356	JFSC NAVADMINCOM NORFOLK	0	0	N/A	2	Screening	FORMER NAVADMINCOM AFSC NORFOLK VA
Mid-Atlantic	N65113	NFEC MW NWCF	1978	57	15.2	1	Assessment	FORMER PWC GREAT LAKES
Mid-Atlantic	N65540	NAVSURFWARCEN SHIPSYSENGSTA PA	0	0	N/A	2	Screening	FORMER NAVSSES PHILADELPHIA PA
Mid-Atlantic	N65908	NEX SCOTIA NY	6	0	2.5	2	Screening	FORMER RESALEACT SARATOGA SPRINGS NY (OR SCOTIA NY); CHANGED FROM SCOTIA TO SARATOGA SPRINGS
Mid-Atlantic	N66023	FORMER NAVDENCLINIC NE NEWPORT RI	0	0	N/A	2	Screening	NOW PART OF NAVAL HEALTH CLINIC NEW ENGLAND UIC N32185;
Mid-Atlantic	N66046	CNATTU NORFOLK VA	0	0	N/A	2	Screening	FORMER UIC N63401 NASC SWM SITE

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N/A: Not applicable
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Navy Initial Radon Potential Categories

Navy Region	UIC	UIC Name	Total Number Radon Measurements	Number of Measurements at UIC ≥ 4 pCi/L	Highest Radon Result at UIC	Radon Potential Category	Radon Testing Phase	Comments
Mid-Atlantic	N66094	NAVHEALTHCLINIC CHERRY POINT	2	0	0.9	2	Screening	FORMER NAVHOSP CHERRY PT NC
Mid-Atlantic	N66231	NAVOPSPTCEN CHICAGO IL	0	0	N/A	2	Screening	FORMER NAVRESCEN GREAT LAKES IL
Mid-Atlantic	N66315	NAVOPSPTCEN AVOCA PA	0	0	N/A	2	Screening	FORMER NAVRESCEN AVOCA PA
Mid-Atlantic	N66604	FORMER NAVUNSEAWARCENDIV NEWPORT RI	0	0	N/A	N/A	Does not apply	DATA MOVED TO NEW UIC N68934
Mid-Atlantic	N68086	FORMER NAVAMBCARECEN NEWPORT RI	0	0	N/A	N/A	Does not apply	PART OF NAVAL HEALTH CLINIC NEW ENGLAND UIC N32185; DATA MOVED TO THAT UIC
Mid-Atlantic	N68093	NAVHOSP CAMP LEJEUNE NC	3	0	3.2	2	Screening	
Mid-Atlantic	N68101	FORMER NAVMEDCLINIC PHILADELPHIA PA	9	0	1.2	N/A	Does not apply	CLOSED AND DEMOLISHED
Mid-Atlantic	N68317	NAVSUPPU SARATOGA SPRINGS NY	36	0	2.2	3	Monitoring	FORMER NAVADMINU SARATOGA SPRINGS (OR SCOTIA NY); CHANGED FROM SCOTIA TO SARATOGA SPRINGS
Mid-Atlantic	N68329	FORMER NAVRESREDCOM REG 5 RAVENNA OH	0	0	N/A	N/A	Does not apply	DIS-ESTABLISHED

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Navy Initial Radon Potential Categories

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Mid-Atlantic	N68335	NAWCAD LAKEHURST NWCF	235	3	6.1	1	Assessment	FORMER NAVAIRENGCEN LAKEHURST NJ; NOT PART OF NAVAL WEAPONS STATION EARLE, LOCATED ON JOINT BASE MCGUIRE DIX LAKEHURST
Mid-Atlantic	N68524	FORMER NAVRESCEN BROOKLYN NY	0	0	N/A	N/A	Does not apply	DATA IS IN UIC N68527 NAVRESCEN BROOKLYN NY
Mid-Atlantic	N68527	NAVMARCORESCEN BROOKLYN NY	9	0	0.1	2	Screening	
Mid-Atlantic	N68722	FORMER NAVMEDCLINIC NORFOLK VA	0	0	N/A	N/A	Does not apply	DATA LOCATED IN NEW UIC N32510
Mid-Atlantic	N68759	DOD FAM HSG FAC NIAGARA NY	30	0	0.9	3	Monitoring	
Mid-Atlantic	N68777	NAVRESFAC LEWES DE	10	0	0.4	2	Screening	
Mid-Atlantic	N68815	FORMER NAVOPSPTCEN MARQUETTE MI	0	0	N/A	N/A	Does not apply	DIS-ESTABLISHED
Mid-Atlantic	N68846	NAVOPSPTCEN EARLE NJ	0	0	N/A	2	Screening	FORMER NAVRESCEN KEARNY NJ; RADON STATUS BASED ON NAVAL WEAPONS STATION EARLE UIC N69213
Mid-Atlantic	N68859	NAVRESCEN MANHATTAN NY	0	0	N/A	2	Screening	

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Mid-Atlantic	N68934	NAVUNSEAWARCENDIV NEWPORT RI	1038	8	7.6	1	Assessment	FORMER NUSC NEWPORT RI UIC N66604
Mid-Atlantic	N69124	PHILADELPHIA PA NH CSO	0	0	N/A	N/A	Does not apply	CLOSED
Mid-Atlantic	N69126	DAVISVILLE RI CBC CSO	0	0	N/A	N/A	Does not apply	CLOSED
Mid-Atlantic	N69138	JAMESTOWN NY NRC CS	0	0	N/A	2	Screening	
Mid-Atlantic	N69139	PITTSFIELD MA NRC CS	0	0	N/A	2	Screening	
Mid-Atlantic	N69148	PHILADELPHIA PA NS CSO	0	0	N/A	N/A	Does not apply	CLOSED
Mid-Atlantic	N69160	WARMINSTER PA NAWC-AD CSO	0	0	N/A	N/A	Does not apply	CLOSED
Mid-Atlantic	N69170	SOUTH WEYMOUTH MA NAS CSO	0	0	N/A	N/A	Does not apply	CLOSED
Mid-Atlantic	N69212	NAVAL WEAPONS STATION YORKTOWN	0	0	N/A	2	Screening	
Mid-Atlantic	N69213	NAVAL WEAPONS STATIN EARLE NJ	24	0	1.8	2	Screening	MAIN INSTALLATION
Mid-Atlantic	N70272	NCTAMS LANT NORFOLK VA	0	0	N/A	2	Screening	FORMER NAVCAMSLANT NORFOLK VA
Mid-Atlantic	N70310	FORMER NAVRADSTA /R/ SUGAR GROVE	0	N/A	N/A	N/A	Does not apply	CLOSED 10/1/1992, DATA MOVED TO N31188
Mid-Atlantic	N90691	NIROP ROCHESTER NY	0	0	N/A	2	Screening	
Mid-Atlantic	N90845	NWIRP BETHPAGE NY	0	0	N/A	2	Screening	
Mid-Atlantic	N91041	NIROP PITTSFIELD MA	0	0	N/A	2	Screening	

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Mid-Atlantic	N91571	ALLEGANY BALLISTICS LAB	169	0	2.7	2	Screening	FORMER NIROP CUMBERLAND MD; INSTALLATION GEOGRAPHICALLY LOCATED IN ROCKET CENTER WV
Mid-Atlantic	N91780	ORD RESEARCH LAB UNIV PARK PA	0	0	N/A	2	Screening	
Mid-Atlantic	N92782	NWIRP BLOOMFIELD CT	65	0	0.7	3	Monitoring	
Mid-Atlantic	N93880	NWIRP BEDFORD MA	29	0	1.0	2	Screening	
Mid-Atlantic	N94151	KNOLLS APL SCHENECTADY NY	0	0	N/A	2	Screening	
Mid-Atlantic	N96095	NWIRP CALVERTON NY	0	0	N/A	2	Screening	
Mid-Atlantic	PWC-GL	FORMER PWC GREAT LAKES IL	32	12	7.3	1	Assessment	FORMER UIC N62037
N/A	N00651	FORMER NSD SUBIC BAY RP	0	0	N/A	N/A	Does not apply	NO LONGER NAVY OWNED
N/A	N00927	FORMER NAVCOMTELSTA CUBI PT RP	14	0	0.8	N/A	Does not apply	NO LONGER NAVY OWNED
N/A	N30851	FORMER DJAKARTA NMRD	0	0	N/A	N/A	Does not apply	NO LONGER NAVY OWNED
N/A	N55418	FORMER NAVANTARCTICSUPU CHRISTCHURCH	2	0	1.4	N/A	Does not apply	NO LONGER NAVY OWNED
N/A	N57075	FORMER NAVFAC ARGENTIA NFLD CANADA	31	0	1.2	N/A	Does not apply	NO LONGER NAVY OWNED

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N/A: Not applicable
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N/A	N61552	FORMER NAVSTA SUBIC BAY RP	28	0	1.2	N/A	Does not apply	NO LONGER NAVY OWNED
N/A	N62494	FORMER NAF MIDWAY ISLAND	116	0	0.2	N/A	Does not apply	NO LONGER NAVY OWNED
N/A	N62770	FORMER NAVSHIPREPFAC SUBIC BAY RP	0	0	N/A	N/A	Does not apply	NO LONGER NAVY OWNED
N/A	N62807	FORMER NAVMAG SUBIC BAY RP	0	0	N/A	N/A	Does not apply	NO LONGER NAVY OWNED
N/A	N62808	PWC SUBIC BAY PHILIPPINES	0	0	N/A	N/A	Does not apply	NO LONGER NAVY OWNED
N/A	N62814	NAVMEDRSCHUNIT TWO PACIFIC	0	0	N/A	N/A	Does not apply	
N/A	N62864	OICC SOUTHWEST PAC MANILA	0	0	N/A	N/A	Does not apply	NO LONGER NAVY OWNED
N/A	N62876	FORMER NAS CUBI POINT RP	1	0	1.5	N/A	Does not apply	NO LONGER NAVY OWNED
N/A	N63427	NAVCOMMSTA HE HOLT EXMOUTH AS	1	0	1.5	N/A	Does not apply	NO LONGER NAVY OWNED
N/A	N65491	FORMER NAVHOSP SUBIC BAY	0	0	N/A	N/A	Does not apply	NO LONGER NAVY OWNED
N/A	N91982	FORMER JHU APPLIED PHYSIC LAB	0	0	N/A	N/A	Does not apply	DIS-ESTABLISHED
NDW	N00014	CHIEF OF NAVAL RESEARCH ARLINGTON VA	0	0	N/A	2	Screening	
NDW	N00161	USNA ANNAPOLIS MD	139	11	8.9	1	Assessment	

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NDW	N00162	NAVHEALTHCLINIC ANNAPOLIS	2	0	1.5	2	Screening	FORMER NAVMEDCLINIC ANNAPOLIS MD
NDW	N00166	NAF WASHINGTON DC	75	0	0.5	3	Monitoring	
NDW	N00167	NATNAVMEDCEN BETHESDA MD	145	5	8.3	1	Assessment	FORMER DTNSRDC BETHESDA MD
NDW	N00168	COMNAVDIST WASHINGTON DC	14	0	3.6	3	Monitoring	FORMER NAVMEDCOMNATCAPREG BETHESDA
NDW	N00171	NRL WASHINGTON DC	2	0	0.5	2	Screening	FORMER COMNAVDIST WASHINGTON DC
NDW	N00173	NRL WASHINGTON DC	130	1	6.0	1	Assessment	
NDW	N00174	NAVSURFWARCENDIV INDIAN HEAD	44	0	3.5	3	Monitoring	FORMER NAVORDSTA INDIAN HEAD MD
NDW	N00178	NAVSURFWARCENDIV DAHLGREN VA	13	0	1.6	3	Monitoring	
NDW	N00231	NAVHEALTHCLINIC QUANTICO VA	228	0	1.1	3	Monitoring	
NDW	N00421	NAVAIRWARCENACDIV PATUXENT MD	181	0	3.6	3	Monitoring	FORMER NAVAIRTESTCEN PATUXENT RIVER MD
NDW	N00424	NOLSC FORT BELVOIR VA	0	0	N/A	2	Screening	FORMER NAVPETOFF ALEXANDRIA VA
NDW	N00693	HPS SITE DAHLGREN	0	0	N/A	2	Screening	FORMER NTC BAINBRIDGE MD

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N/A: Not applicable
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NDW	N00788	NAVCOTELSTA DET CHELTENHAN	87	0	2.4	3	Monitoring	FORMER NAVCOMMU WASHINGTON DC
NDW	N0417A	NAVSUPPFAC THURMONT MD	21	0	2.3	3	Monitoring	
NDW	N08863	NMCB 23 FT BELVOIR VA	0	0	N/A	2	Screening	
NDW	N33355	NAVSUPPACT BETHESDA MD	0	0	N/A	2	Screening	
NDW	N35328	RADTRANF ANNAPOLIS MD	33	0	1.3	3	Monitoring	
NDW	N47608	NAVAL AIR STATION PAX RIVER	0	0	N/A	2	Screening	
NDW	N60921	NAVSUFWARCEN WHITE OAK DET MD	247	2	9.9	1	Assessment	FORMER NSWC DAHLGREN VA
NDW	N61142	JBAB ANACOSTIA BOLLING	0	0	N/A	2	Screening	
NDW	N61150	NSA NORTH POTOMAC	0	0	N/A	2	Screening	
NDW	N61151	NSA SOUTH POTOMAC	0	0	N/A	2	Screening	
NDW	N61152	NAVSUPPACT ANNAPOLIS	0	0	N/A	2	Screening	
NDW	N61533	NAVSURFWARCEN DET ANNAPOLIS MD	5	3	4.3	1	Assessment	FORMER NSRDC ANNAPOLIS MD
NDW	N61894	FORMER NAVMARCORESCEN WASHINGTON DC	8	0	0.2	2	Screening	
NDW	N62285	NAVOBSY WASHINGTON DC	112	8	48.6	1	Assessment	
NDW	N62477	FORMER NAVFAC EFA CHESAPEAKE	0	0	N/A	N/A	Does not apply	DIS-ESTABLISHED

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N/A: Not applicable
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Navy Initial Radon Potential Categories

Navy Region	UIC	UIC Name	Total Number Radon Measurements	Number of Measurements at UIC ≥ 4 pCi/L	Highest Radon Result at UIC	Radon Potential Category	Radon Testing Phase	Comments
NDW	N63138	NAVSPACESURCEN DAHLGREN VA	0	0	N/A	2	Screening	FORMER NAVSPACESURSYS S DAHLGREN VA
NDW	N68469	NAVAL SUPPORT ACTIVITY WASH	0	0	N/A	2	Screening	
NDW	N70092	FORMER NAVSECSTA WASH DC	112	0	2.7	N/A	Does not apply	DIS-ESTABLISHED
Northwest	N00251	NAVSHIPYD PUGET SOUND WA	4	0	0.3	2	Screening	
Northwest	N00253	NAVUNSEAWARCENDIV KEYPORT WA	3	0	0.9	2	Screening	
Northwest	N00255	NAVSTA PUGET SOUND WA	15	0	0.6	3	Monitoring	
Northwest	N00276	FORMER NAS TWIN CITIES MN	0	0	N/A	N/A	Does not apply	DIS-ESTABLISHED
Northwest	N00406	FISC PUGET SOUND BREMERTON WA	96	0	0.3	3	Monitoring	FORMER NSC PUGET SOUND BREMERTON WA
Northwest	N00620	NAS WHIDBEY ISLAND WA	184	0	1.7	3	Monitoring	
Northwest	N30178	NAVOPSPTCEN HELENA MT	22	0	1.4	3	Monitoring	FORMER NRC HELENA MT
Northwest	N30315	NAVSPACECOM DET BRAVO VANDENBG	26	0	2.0	3	Monitoring	FORMER ASTROGRPDET B ROSEMOUNT MN
Northwest	N30531	NAVOPSPTCEN MINNEAPOLIS MN	95	0	2.8	3	Monitoring	FORMER NAVRESCEN TWIN CITIES MN
Northwest	N32013	FORMER NAVMAG INDIAN ISLAND WA	0	0	N/A	N/A	Does not apply	DIS-ESTABLISHED
Northwest	N57055	NAVFAC COOS HEAD OR	20	0	0.3	3	Monitoring	

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Navy Initial Radon Potential Categories

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Northwest	N57056	FORMER NAVFAC PACIFIC BEACH WA	43	0	0.7	3	Monitoring	
Northwest	N57099	NAVAL OCEAN PROCESS FAC ADAK AK	0	0	N/A	N/A	Does not apply	NO LONGER NAVY OWNED
Northwest	N60462	FORMER NAF ADAK AK	261	0	0.7	N/A	Does not apply	NO LONGER NAVY OWNED
Northwest	N61066	CNI NAVMAG INDIAN ISLAND	0	0	N/A	2	Screening	
Northwest	N61987	FORMER NAVOPSPTCEN CEDAR RAPIDS IA	0	0	N/A	N/A	Does not apply	DIS-ESTABLISHED
Northwest	N61998	NAVOPSPTCEN OMAHA NE	10	0	1.2	2	Screening	FORMER NAVMARCORESCEN OMAHA NE
Northwest	N62042	NAVMARCORESCEN WATERLOO IA	33	4	8.9	1	Assessment	
Northwest	N62043	FORMER NOSC SIOUX CITY IA	0	0	N/A	N/A	Does not apply	DIS-ESTABLISHED
Northwest	N62044	NAVOPSPTCEN DES MOINES IA	5	0	1.5	2	Screening	FORMER NAVMARCORESCEN DES MOINES IA
Northwest	N62047	FORMER NAVOPSPTCEN DUBUQUE IA	10	1	4.3	N/A	Does not apply	DIS-ESTABLISHED
Northwest	N62057	NAVOPSPTCEN DULUTH MN	10	0	2.0	2	Screening	FORMER NAVRESCEN DULUTH MN

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N/A: Not applicable
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Navy Initial Radon Potential Categories

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Northwest	N62058	FORMER NAVMARCORESCEN ST PAUL MN	0	0	N/A	N/A	Does not apply	DIS-ESTABLISHED
Northwest	N62068	NAVOPSPTCEN SIOUX FALLS SD	0	0	N/A	2	Screening	FORMER NAVRESCEN SIOUX FALLS SD
Northwest	N62069	FORMER NAVOPSPTCEN LINCOLN NE	0	0	N/A	N/A	Does not apply	DIS-ESTABLISHED
Northwest	N62091	NAVOPSPTCEN FARGO ND	0	0	N/A	2	Screening	FORMER NAVRESCEN FARGO ND
Northwest	N62134	FORMER NAVRESCEN SEATTLE WA	22	0	0.8	N/A	Does not apply	DIS-ESTABLISHED
Northwest	N62135	FORMER NAVOPSPTCEN TACOMA WA	26	0	0.9	N/A	Does not apply	DIS-ESTABLISHED
Northwest	N62138	NAVOPSPTCEN BILLINGS MT	38	1	4.5	1	Assessment	FORMER NAVMARCORESCEN BILLINGS MT
Northwest	N62139	NAVOPSPTCEN BOISE ID	26	0	2.2	3	Monitoring	FORMER NAVMARCORESCEN BOISE ID
Northwest	N62142	NAVOPSPTCEN CHEYENNE WY	10	0	0.7	2	Screening	FORMER NAVRESCEN CHEYENNE WY
Northwest	N62143	NAVRESFAC BUTTE MT	10	3	4.9	N/A	Does not apply	DIS-ESTABLISHED
Northwest	N62144	NAVOPSPTCEN EVERETT WA	26	0	0.4	3	Monitoring	FORMER NRC EVERETT WA

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Northwest	N62145	NAVOPSPTCEN PORTLAND OR	36	0	2.3	3	Monitoring	FORMER NAVMARCORESCEN PORTLAND OR
Northwest	N62146	NAVOPSPTCEN SPOKANE WA	66	0	3.3	3	Monitoring	FORMER NAVMARCORESCEN SPOKANE WA
Northwest	N62182	DAVID TAYLOR RESCEN BAYVIEW ID	11	10	50.2	1	Assessment	
Northwest	N62250	FORMER NAVMARCORESCEN SALEM OR	10	1	4.4	N/A	Does not apply	DIS-ESTABLISHED
Northwest	N62298	NAVOPSPTCEN SPRINGFIELD OR	54	0	1.0	3	Monitoring	FORMER NAVMARCORESCEN EUGENE OR
Northwest	N63402	SWFPAC BANGOR WA	105	0	0.7	3	Monitoring	
Northwest	N63533	NAVOPSPTCEN BANGOR WA	24	0	0.3	3	Monitoring	FORMER NAVRESCEN BANGOR WA
Northwest	N63538	NAVRESCEN GREAT FALLS MT	11	1	4.7	1	Assessment	
Northwest	N63543	FORMER NAVOPSPTCEN CENTRAL POINT OR	20	0	1.4	N/A	Does not apply	DIS-ESTABLISHED
Northwest	N63545	NAVRESCEN MISSOULA MT	0	0	N/A	2	Screening	
Northwest	N63548	FORMER NAVRESCEN RICHLAND WA	0	0	N/A	N/A	Does not apply	DIS-ESTABLISHED

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N/A: Not applicable
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Northwest	N63550	FORMER NAVOPSPTCEN POCATELLO ID	0	0	N/A	N/A	Does not apply	DIS-ESTABLISHED
Northwest	N63886	NAVSECGRUACT ADAK AK	2	0	0.5	N/A	Does not apply	NO LONGER NAVY OWNED
Northwest	N65198	FORMER NAVADMINU IDAHO FALLS ID	0	0	N/A	N/A	Does not apply	DIS-ESTABLISHED
Northwest	N65226	FORMER NAVARCLAB BARROW AK	0	0	N/A	N/A	Does not apply	NO LONGER NAVY OWNED
Northwest	N66135	NAVOPSPTCEN ANCHORAGE AK	26	1	4.0	1	Assessment	FORMER NAVRESCEN ANCHORAGE AK
Northwest	N68095	NAVHOSP BREMERTON WA	66	0	0.5	3	Monitoring	
Northwest	N68328	NAVREG NW RCC EVERETT	14	0	0.8	3	Monitoring	FORMER REDCOM22 EVERETT WA
Northwest	N68349	FORMER NAVRESREDCOMREG16	0	0	N/A	N/A	Does not apply	DIS-ESTABLISHED
Northwest	N68436	NAVAL BASE KITSAP BREMERTON WA	0	0	N/A	2	Screening	FORMER SUBASE BREMERTON WA
Northwest	N68437	TRITRAFAC BANGOR WA	164	0	1.3	3	Monitoring	
Northwest	N68438	NAVIMFAC BANGOR WA	115	0	0.5	3	Monitoring	FORMER TRIREFFAC BANGOR WA
Northwest	N68660	NCTAMS PAC DET PUGET SOUND WA	0	0	N/A	2	Screening	FORMER NAVCOMMSTA PUGET SOUND SUBSE
Northwest	N68967	NAVSTA EVERETT WA	0	0	N/A	2	Screening	

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Northwest	N69169	CSO NAF ADAK AK	0	0	N/A	N/A	Does not apply	NO LONGER NAVY OWNED
Northwest	N70273	NCTS PAC DET PG/NRS TJC OSO WA	2	0	0.9	3	Monitoring	FORMER NAVRADSTA/T/JIM CREEK WA
Northwest	N81997	MIUW UNIT 101	0	0	N/A	2	Screening	
Northwest	N91192	NIROP MINNEAPOLIS MN	0	0	N/A	2	Screening	
Northwest	N91741	FORMER NIROP ST PAUL MN	0	0	N/A	N/A	Does not apply	DIS-ESTABLISHED
Northwest	N94166	APPLIED PHYSICS LAB SEATTLE WA	0	0	N/A	2	Screening	
Singapore	N61077	SINGAPORE AREA COORDINATOR/NAVREGCEN SINGAPORE	338	3	8.6	1	Monitoring	FORMER NRCC SINGAPORE UIC N68047
Singapore	N68047	NAVREGCEN SINGAPORE	0	0	N/A	2	Screening	FORMER NRCC SINGAPORE; DATA IN UIC N61077
Southeast	N00065	COMNAVMETOCCOM STENNIS SPACEN	0	0	N/A	2	Screening	FORMER COMNAVMETOCCOM BAY ST LOUIS MS
Southeast	N00153	AF RET HOME GULFPORT	0	0	N/A	2	Screening	FORMER NAVAL HOME GULFPORT MS
Southeast	N0017A	FORMER LANTFLTWPNTRAFAC ROOS RDS PR	0	0	N/A	N/A	Does not apply	DIS-ESTABLISHED
Southeast	N00191	NSY CHARLESTON SC	140	1	7.3	1	Assessment	

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Southeast	N00193	NMC DET CHARLESTON SC	7	0	2.2	2	Screening	FOMER WPNSTA CHARLESTON SC
Southeast	N00196	NAS ATLANTA GA	13	0	2.8	2	Screening	
Southeast	N00203	NAVHOSP PENSACOLA FL	5	0	0.2	2	Screening	
Southeast	N00204	NAS PENSACOLA, FL	6	0	0.6	2	Screening	
Southeast	N00205	FORMER NSA NEW ORLEANS LA	109	1	4.7	1	Assessment	FORMER NAVSUPPACT NEW ORLEANS LA
Southeast	N00206	NAS JRB NEW ORLEANS LA	76	0	2.3	3	Monitoring	FORMER NAS NEW ORLEANS
Southeast	N00207	NAS JACKSONVILLE FL	57	0	1.5	3	Monitoring	
Southeast	N00213	NAS KEY WEST FL	425	0	3.5	3	Monitoring	
Southeast	N00215	NAS DALLAS TX	24	5	6.7	1	Assessment	
Southeast	N00216	NAS CORPUS CHRISTI TX	69	0	0.6	3	Monitoring	
Southeast	N00232	NAVHOSP JACKSONVILLE FL	0	0	N/A	2	Screening	
Southeast	N00267	NAVMEDCLINIC KEY WEST FL	3	0	1.5	2	Screening	
Southeast	N00285	NAVHEALTHCLINIC CORPUS CHRISTI	3	0	0.1	2	Screening	FORMER NAVHOSP CORPUS CHRISTI TX
Southeast	N00306	NAS GUANTANAMO BAY	0	0	N/A	2	Screening	
Southeast	N00389	FORMER NAVSTA ROOSEVELT ROADS PR	58	0	1.1	N/A	Does not apply	DIS-ESTABLISHED
Southeast	N00612	FISC JAX DET CHARLESTON	0	0	N/A	2	Screening	FORMER NSC CHARLESTON SC

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Southeast	N00639	NAVSUPPACT MIDSOUTH MEMPHIS TN	609	1	9.1	1	Assessment	FORMER NAS MEMPHIS TN
Southeast	N00743	FORMER NAVCOMMSTA ROOSEVELT ROADS RQ	65	0	2.7	N/A	Does not apply	DIS-ESTABLISHED
Southeast	N08864	NMCB 24 HUNTSVILLE AL	0	0	N/A	2	Screening	FORMER RNMCB 24 HUNTSVILLE AL
Southeast	N08868	NMCB 28	5	0	0.2	2	Screening	FORMER RNMCB 28 BARKSDALE AFB LA
Southeast	N08914	NMCB 15 RICHARDS-GEBOUR AFB	0	0	N/A	2	Screening	
Southeast	N30924	FORMER NAVAIRESCEN OLATHE KS	0	0	N/A	N/A	Does not apply	DIS-ESTABLISHED
Southeast	N40003	NAVAL ACTIVITY PUERTO RICO	0	0	N/A	2	Screening	
Southeast	N40282	CNI NAVAL METOC	0	0	N/A	2	Screening	NEW UIC REPLACING N68462 NRL DET STENNIS SPACE CTR MS
Southeast	N42237	SUBASE KINGS BAY GA	63	0	3.3	3	Monitoring	
Southeast	N44466	TRIREFFAC KINGS BAY GA	0	0	N/A	2	Screening	
Southeast	N45610	NAVAL CON BRIG CHARLESTON SC	4	0	0.1	2	Screening	
Southeast	N45719	NCFSU THREE FT JACKSON SC	0	0	N/A	2	Screening	FORMER NRCF UNIT THREE CHARLESTON SC
Southeast	N50173	NAVSUPPFAC BEAUFORT SC	0	0	N/A	2	Screening	

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Southeast	N57038	NAVOCEANPROFAC DET BERMUDA	0	0	N/A	2	Screening	FORMER NAVFAC BERMUDA
Southeast	N57049	NSF ANTIGUA, WEST INDIES	17	0	3.6	3	Monitoring	FORMER NAVSUPFAC ANTIGUA AC
Southeast	N60002	BR MED CLINIC MILLINGTON TN	6	0	0.9	2	Screening	FORMER NAVHOSP MILLINGTON TN
Southeast	N60200	FORMER NAS CECIL FIELD FL	69	0	1.0	N/A	Does not apply	DIS-ESTABLISHED
Southeast	N60201	NAVSTA MAYPORT FL	146	0	2.1	3	Monitoring	
Southeast	N60241	NAS KINGSVILLE TX	63	0	1.4	3	Monitoring	
Southeast	N60376	NAS CHASE FIELD TX	4	0	1.1	2	Screening	
Southeast	N60508	NAS WHITING FLD MILTON FL	263	0	2.9	3	Monitoring	
Southeast	N60514	NAVSTA GUANTANAMO BAY	78	0	2.2	3	Monitoring	
Southeast	N61006	FORMER NAVAL SUPPORT ACTIVITY ATHENS	0	0	N/A	N/A	Does not apply	DIS-ESTABLISHED
Southeast	N61007	NAVAL SUPPORT ACTIVITY ORLANDO	0	0	N/A	2	Screening	
Southeast	N61008	NAVAL SUPPORT ACTY PANAMA CITY	0	0	N/A	2	Screening	

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Southeast	N61035	NAVOPSPTCEN NEW ORLEANS	9	0	0.3	2	Screening	OLD UIC N61954; NEW UIC FORMED WITH MERGER OF NAVY AIR RESERVE AND NAVAL RESERVE CENTER; MAIN ELEMENTS PHYSICALLY LOCATED AT NAS JRB NEW ORLEANS UIC N00206
Southeast	N61165	NAVSTA CHARLESTON SC	4	0	0.9	2	Screening	
Southeast	N61331	NAVSURFWARCENDIV PANAMA CITY FL	25	0	0.9	3	Monitoring	FORMER NAVCOASTSYSCEN PANAMA CITY FL
Southeast	N61337	NAVHOSP BEAUFORT SC	98	1	4.0	1	Assessment	
Southeast	N61339	NAVAIRWARCEN TSD (N-NWCF) ORLA	97	0	0.9	3	Monitoring	FORMER NAVTRASYSCEN ORLANDO FL
Southeast	N61564	NAVHOSP GUANTANAMO	0	0	N/A	2	Screening	
Southeast	N61910	NAVOPSPTCEN AUGUSTA GA	0	0	N/A	2	Screening	FORMER NAVMARCORESCEN AUGUSTA GA
Southeast	N61911	NAVOPSPTCEN CHARLESTON SC	9	0	0.7	2	Screening	FORMER NAVRESCEN CHARLESTON SC
Southeast	N61912	NAVOPSPTCEN COLUMBIA SC	10	0	0.3	2	Screening	FORMER NAVMARCORESCEN CLOUMBIA SC
Southeast	N61913	NAVRESCEN MACON GA	10	0	0.9	2	Screening	

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Southeast	N61915	NAVMARCORESCEN ATLANTA GA	0	0	N/A	2	Screening	
Southeast	N61919	NAVOPSPTCEN COLUMBUS GA	8	0	0.7	2	Screening	FORMER NAVRESCEN COLUMBUS GA
Southeast	N61926	NOSC-MCRC JACKSONVILLE FL	10	0	2.3	2	Screening	FORMER NAVMARCORESCEN JACKSONVILLE FL
Southeast	N61927	NAVOPSPTCEN MIAMI FL	0	0	N/A	2	Screening	FORMER NAVRESCEN MIAMI FL
Southeast	N61929	NAVOPSPTCEN ORLANDO FL	10	0	1.5	2	Screening	FORMER NAVMARCORESCEN ORLANDO FL
Southeast	N61930	NAVOPSPTCEN ST PETERSBURG FL	10	0	1.6	2	Screening	FORMER NAVRESCEN ST PETERSBURG FL
Southeast	N61931	NAVOPSPTCEN WEST PALM BEACH FL	10	0	0.6	2	Screening	FORMER NAVRESCEN WEST PALM BEACH GARDENS FL
Southeast	N61933	NAVOPSPTCEN TAMPA FL	76	1	5.6	1	Assessment	FORMER NAVRESCEN TAMPA FL
Southeast	N61934	NAVOPSPTCEN CHATTANOOGA TN	8	0	0.2	2	Screening	FORMER NAVMARCORESCEN CHATTANOOGA TN
Southeast	N61935	FORMER NAVRESCEN GULFPORT MS	10	0	0.2	2	Screening	

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Southeast	N61937	NAVRESCEN FORT SMITH AR	10	0	0.5	N/A	Does not apply	FORMER NAVRESCEN FORT SMITH AR, NO LONGER NAVY OWNED
Southeast	N61938	NAVOPSPTCEN TULSA OK	10	0	0.5	2	Screening	FORMER NAVMARCORESCEN BROKEN ARROW OK
Southeast	N61940	NAVOPSPTCEN BATON ROUGE LA	2	0	0.1	2	Screening	FORMER NAVMARCORESCEN BATON ROUGE LA
Southeast	N61942	NAVOPSPTCEN BESSEMER AL	6	0	2.0	2	Screening	FORMER NAVMARCORESCEN BESSEMER AL
Southeast	N61944	NAVOPSPTCEN SHREVEPORT LA	0	0	N/A	2	Screening	FORMER NAVMARCORESCEN SHREVEPORT LA
Southeast	N61945	NAVOPSPTCEN MOBILE AL	8	0	0.7	2	Screening	
Southeast	N61947	NAVMARCORESCEN MONTGOMERY AL	0	0	N/A	2	Screening	
Southeast	N61948	NAVOPSPTCEN KNOXVILLE TN	10	1	5.1	1	Assessment	FORMER NAVMARCORESCEN KNOXVILLE TN
Southeast	N61949	FORMER NAVRESCEN PENSACOLA FL	0	0	N/A	2	Screening	
Southeast	N61951	NAVRESCEN WICHITA FALLS TX	0	0	N/A	2	Screening	

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N/A: Not applicable
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Navy Region	UIC	UIC Name	Total Number Radon Measurements	Number of Measurements at UIC ≥ 4 pCi/L	Highest Radon Result at UIC	Radon Potential Category	Radon Testing Phase	Comments
Southeast	N61954	NAVOPSPTCEN NEW ORLEANS LA	0	0	N/A	2	Screening	FORMER NAVMARCORESCEN NEW ORLEANS LA
Southeast	N61955	NAVOPSPTCEN MERIDAN MS	10	0	0.6	2	Screening	FORMER NAVRESCEN JACKSON MS
Southeast	N61956	FORMER NAVRESCEN KINGSPORT TN	0	0	N/A	N/A	Does not apply	DIS-ESTABLISHED
Southeast	N61958	FORMER NAVRESCEN STILLWATER OK	0	0	N/A	N/A	Does not apply	DIS-ESTABLISHED
Southeast	N61959	NAVOPSPTCEN AMARILLO TX	14	0	0.5	3	Monitoring	FORMER NAVMARCORESCEN AMARILLO TX
Southeast	N61962	NAVOPSPTCEN MEMPHIS TN	1	0	0.5	2	Screening	FORMER NAVRESCEN MEMPHIS TN
Southeast	N61967	NAVMARCORESCEN LAFAYETTE LA	0	0	N/A	2	Screening	
Southeast	N61968	NAVOPSPTCEN HOUSTON TX	19	0	0.4	3	Monitoring	FORMER NAVMARCORESCEN HOUSTON TX
Southeast	N61971	NAVOPSPTCEN NASHVILLE TN	10	4	12.9	1	Assessment	FORMER NAVRESCEN NASHVILLE TN
Southeast	N61972	NAVRESCEN EAST GADSDEN AL	10	0	1.1	2	Screening	
Southeast	N61973	NASRESFAC ALEXANDRIA LA	1	0	0.2	2	Screening	

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RPC 3: Low radon potential
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N/A: Not applicable
Radon data summary includes residential and nonresidential data collected from 1989 through 2015

Navy Initial Radon Potential Categories

Navy Region	UIC	UIC Name	Total Number Radon Measurements	Number of Measurements at UIC ≥ 4 pCi/L	Highest Radon Result at UIC	Radon Potential Category	Radon Testing Phase	Comments
Southeast	N61979	FORMER NAVRESCEN DALLAS TX	6	0	0.3	2	Screening	
Southeast	N61980	NAVOPSPTCEN EL PASO TX	7	0	0.3	2	Screening	FORMER NAVMARCORESCEN EL PASO TX
Southeast	N61982	NAVOPSPTCEN SAN ANTONIO TX	0	0	N/A	2	Screening	FORMER NAVMARCORESCEN SAN ANTONIO TX
Southeast	N61988	FORMER NAVOPSPTCEN CAPE GIRARDEAU MO	10	0	0.6	N/A	Does not apply	DIS-ESTABLISHED
Southeast	N61992	NAVOPSPTCEN ST LOUIS MO	10	1	5.5	1	Assessment	FORMER NAVMARCORESCEN ST LOUIS MO
Southeast	N62032	FORMER NAVRESCEN HUTCHINSON KS	10	0	2.0	N/A	Does not apply	DIS-ESTABLISHED
Southeast	N62039	FORMER NAVRESCEN JOPLIN MO	2	0	0.6	N/A	Does not apply	DIS-ESTABLISHED
Southeast	N62040	NAVOPSPTCEN WICHITA KS	11	0	0.3	2	Screening	FORMER NAVRESCEN WICHITA KS
Southeast	N62041	FORMER NAVMARCORESCEN TOPEKA KS	0	0	N/A	N/A	Does not apply	DIS-ESTABLISHED
Southeast	N62054	NAVOPSPTCEN KANSAS CITY MO	10	0	0.9	2	Screening	FORMER MANVARCORESCEN KANSAS CITY MO

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N/A: Not applicable
Radon data summary includes residential and nonresidential data collected from 1989 through 2015

Navy Initial Radon Potential Categories

Navy Region	UIC	UIC Name	Total Number Radon Measurements	Number of Measurements at UIC ≥ 4 pCi/L	Highest Radon Result at UIC	Radon Potential Category	Radon Testing Phase	Comments
Southeast	N62090	FORMER NAVRESCEN ST JOSEPH MO	0	0	N/A	N/A	Does not apply	DIS-ESTABLISHED
Southeast	N62154	NAVMARCORESCEN SAVANNAH GA	10	0	1.1	2	Screening	
Southeast	N62190	NAVUNSEAWARCEN DET	0	0	N/A	2	Screening	FORMER NRL UWS REF DET ORLANDO FL
Southeast	N62247	NAVRESCEN HUNTSVILLE AL	0	0	N/A	N/A	Does not apply	FORMER NAVRESCEN HUNTSVILLE AL, NO LONGER NAVY OWNED
Southeast	N62248	NAVOPSPTCEN LUBBOCK TX	11	1	4.5	1	Assessment	FORMER NAVMARCORESCEN LUBBOCK TX
Southeast	N62257	NAVMARCORESCEN ABILENE TX	8	0	0.4	N/A	Does not apply	DIS-ESTABLISHED
Southeast	N62306	NAVOCEANO STENNIS SPACE CNTR	0	0	N/A	2	Screening	FORMER NAVOCEANO BAY ST LOUIS MS
Southeast	N62375	NAVOPSPTCEN GREENVILLE SC	9	4	10.0	1	Assessment	FORMER NAVMARCORESCEN GREENVILLE SC
Southeast	N62481	NAS BERMUDA	474	8	12.2	N/A	Does not apply	BRAC
Southeast	N62604	CBC GULFPORT MS	41	0	0.7	3	Monitoring	
Southeast	N62681	FORMER SUPSHIP SAN JUAN PR	0	0	N/A	N/A	Does not apply	DIS-ESTABLISHED

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N/A: Not applicable
Radon data summary includes residential and nonresidential data collected from 1989 through 2015

Navy Initial Radon Potential Categories

Navy Region	UIC	UIC Name	Total Number Radon Measurements	Number of Measurements at UIC ≥ 4 pCi/L	Highest Radon Result at UIC	Radon Potential Category	Radon Testing Phase	Comments
Southeast	N62701	NAVSUFWARCEN DET DANIA NWCF	2	0	0.2	3	Monitoring	FORMER NAVSURFWPNCENDET FT LAUDERDALE
Southeast	N62741	NAVSCSCOL ATHENS GA	509	12	6.7	1	Assessment	NAVY SUPPLY SCHOOL MOVED TO NEWPORT RI
Southeast	N62748	NAVOPSPTCEN WACO TX	10	1	7.6	1	Assessment	FORMER NAVMARCORESCEN WACO TX
Southeast	N62795	FORMER SUPSHP PASCAGOULA MS	146	0	1.5	N/A	Does not apply	DIS-ESTABLISHED
Southeast	N62841	NAVORDTESTU CAPE CANAVERAL	0	0	N/A	2	Screening	FORMER NAVORDTESTU PATRICK AFB FL
Southeast	N62892	NAVSECGRUACT HOMESTEAD FL	1	0	1.8	3	Monitoring	
Southeast	N63028	SWFLANT DET CHARLESTON SC	0	0	N/A	2	Screening	
Southeast	N63043	NAS MERIDIAN MS	57	0	2.4	3	Monitoring	
Southeast	N63082	CENINFODOM CORRY STA PCOLA FL	2	0	0.2	2	Screening	FORMER NAVTECHTRACENCRST PENSACOLA FL
Southeast	N63248	NAVRESFAC FAYETTEVILLE AR	10	0	1.1	N/A	Does not apply	FORMER NAVRESFAC FAYETTEVILLE AR
Southeast	N63249	FORMER NAVRESCEN HARLINGEN TX	6	0	0.1	2	Screening	
Southeast	N63257	NAVRESCEN MONROE LA	0	0	N/A	2	Screening	

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N/A: Not applicable
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Navy Initial Radon Potential Categories

Navy Region	UIC	UIC Name	Total Number Radon Measurements	Number of Measurements at UIC ≥ 4 pCi/L	Highest Radon Result at UIC	Radon Potential Category	Radon Testing Phase	Comments
Southeast	N63267	FORMER NAVRESCEN TYLER TX	11	0	0.3	N/A	Does not apply	DIS-ESTABLISHED
Southeast	N63322	SUBTRAFAC CHARLESTON SC	0	0	N/A	2	Screening	FORMER FLEBALMISUBTRACEN CHARLESTON SC
Southeast	N63425	NCTS JACKSONVILLE DET K WEST	0	0	N/A	2	Screening	FORMER NAVCOMMU KEY WEST FL
Southeast	N63482	NAVOPSPTCEN TALLAHASSEE FL	10	0	0.7	2	Screening	FORMER NAVMARCORESCEN TALLAHASSEE FL
Southeast	N63821	NAVUNSEAWARCENDET AUTEC ANDROS	149	0	1.8	3	Monitoring	FORMER NUSCDETAUTEC ANFROS ISL BF
Southeast	N65114	PWC JACKSONVILLE DET PENSACOLA	190	0	1.0	3	Monitoring	FORMER PWC PENSACOLA FL
Southeast	N65236	SPAWARSYSCEN ATLANTIC	59	1	5.1	1	Assessment	FORMER NAVELEXCEN CHARLESTON SC
Southeast	N65492	NAVHOSP ORLANDO FL	5	0	1.0	2	Screening	
Southeast	N65928	NTC ORLANDO FL	908	0	2.9	3	Monitoring	
Southeast	N65980	FORMER NISEEAST DET	116	0	2.1	N/A	Does not apply	DIS-ESTABLISHED
Southeast	N66754	FORMER NAVSECGRUACT SABANA SECA PR	88	0	1.4	N/A	Does not apply	DIS-ESTABLISHED
Southeast	N66833	NAVSTA PANAMA CANAL RODMAN PN	90	0	0.8	3	Monitoring	

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N/A: Not applicable
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Navy Initial Radon Potential Categories

Navy Region	UIC	UIC Name	Total Number Radon Measurements	Number of Measurements at UIC ≥ 4 pCi/L	Highest Radon Result at UIC	Radon Potential Category	Radon Testing Phase	Comments
Southeast	N66863	NAVBIODYNLAB NEW ORLEANS LA	0	0	N/A	2	Screening	
Southeast	N66898	NAVAMBCARECEN NEW ORLEANS LA	0	0	N/A	2	Screening	FORMER NAVMEDCLINIC NEW ORLEANS LA
Southeast	N68084	NAVHEALTHCLINIC CHARLESTON SC	6	0	1.0	2	Screening	FORMER NAVHOSP CHARLESTON SC
Southeast	N68305	PUBLIC WORKS DEPT ORLANDO	0	0	N/A	N/A	Does not apply	DATA MOVED TO NEW UIC NCELPH
Southeast	N68322	NETPDTC PENSACOLA FL	1	0	0.9	2	Screening	FORMER NAVEDTRANCEN PENSACOLA FL
Southeast	N68378 (HIST-ORICAL)	FORMER PWC SAN FRANCISCO	192	0	3.7	3	Monitoring	NAVFAC MIDLANT DET MECH PA HAS ADMIN CONTROL OF THIS FORMER INSTALLATION
Southeast	N68449	NAVOPSPTCEN ORANGE TX	9	0	0.3	2	Screening	FORMER NAVMARCORESCEN ORANGE TX
Southeast	N68462	FORMER NRL DET STENNIS SPACE CTR MS	0	0	N/A	N/A	Does not apply	DATA IN NEW UIC N40282 CNI NAVAL METOC
Southeast	N68701	TRITRAFAC KINGS BAY GEORGIA	0	0	N/A	2	Screening	
Southeast	N68702	FORMER NAVRESCEN CALL BOX SAN JUAN PR	10	0	0.1	2	Screening	
Southeast	N68709	NAS MAYPORT FL	116	0	1.4	3	Monitoring	

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N/A: Not applicable
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Navy Initial Radon Potential Categories

Navy Region	UIC	UIC Name	Total Number Radon Measurements	Number of Measurements at UIC ≥ 4 pCi/L	Highest Radon Result at UIC	Radon Potential Category	Radon Testing Phase	Comments
Southeast	N68733	SWFLANT KINGS BAY GA	21	4	5.5	1	Assessment	
Southeast	N68836	FISC JACKSONVILLE FL (NWCF)	0	0	N/A	2	Screening	FORMER NSC JACKSONVILLE FL
Southeast	N68889	FORMER NAVSTA MOBILE AL	59	0	0.6	3	Monitoring	
Southeast	N68890	FORMER NS PASCAGOULA MS	140	0	1.4	N/A	Does not apply	DIS-ESTABLISHED
Southeast	N68891	NAVSTA INGLESIDE TX	0	0	N/A	2	Screening	
Southeast	N69175	ORLANDO FL NTC CSO	0	0	N/A	N/A	Does not apply	CLOSED
Southeast	N69177	CECIL FIELD FL NAS CSO	0	0	N/A	N/A	Does not apply	CLOSED
Southeast	N69214	NAVAL WEAPONS STATION CHASN	0	0	N/A	2	Screening	
Southeast	N70283	NAVSECGRUACT GALETA IS PN	14	0	0.3	3	Monitoring	
Southeast	N83447	NAS JRB FT WORTH TX	902	50	75.3	1	Assessment	
Southeast	N91662	APPLIED RESEARCH LAB AUSTIN TX	0	0	N/A	2	Screening	
Southeast	N94307	FORMER NWIRP BRISTOL TN	59	0	1.2	N/A	Does not apply	DIS-ESTABLISHED
Southeast	N95918	NWIRP MCGREGOR TX	0	0	N/A	2	Screening	
Southeast	UNKNOWN	FORMER FLEMINEWARTRACEN CHARLESTON SC	0	0	N/A	2	Screening	FORMER MINEWARTRACEN SAN DIEGO UIC N62603

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N/A: Not applicable
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Navy Initial Radon Potential Categories

Navy Region	UIC	UIC Name	Total Number Radon Measurements	Number of Measurements at UIC ≥ 4 pCi/L	Highest Radon Result at UIC	Radon Potential Category	Radon Testing Phase	Comments
Southwest	N00221	FORMER NSY MARE ISLAND VALLEJO CA	2252	3	7.7	N/A	Does not apply	BRAC
Southwest	N00228	FORMER FISC OAKLAND CA	135	0	1.0	N/A	Does not apply	BRAC
Southwest	N00236	FORMER NAS ALAMEDA	0	0	N/A	N/A	Does not apply	BRAC
Southwest	N00244	FISC SAN DIEGO CA	0	0	N/A	2	Screening	FORMER NSC SAN DIEGO CA
Southwest	N00245	NAVBASE SAN DIEGO	7	0	2.0	2	Screening	
Southwest	N00246	NAVBASE CORONADO	0	0	N/A	2	Screening	FORMER NAS NORTH ISLAND SAN DIEGO CA
Southwest	N00247	FORMER NTC SAN DIEGO CA	3	0	1.3	N/A	Does not apply	BRAC
Southwest	N00259	NAVMEDCEN SAN DIEGO CA	543	0	3.0	3	Monitoring	FORMER NAVHOSP SAN DIEGO CA
Southwest	N00296	FORMER NAS MOFFETT FIELD CA	747	7	6.1	N/A	Does not apply	BRAC
Southwest	N00619	FORMER NAVHOSP OAKLAND CA	151	0	1.5	N/A	Does not apply	
Southwest	N00849	FORMER NAVSECGRUACT SKAGGS IS CA	0	0	N/A	N/A	Does not apply	BRAC
Southwest	N00886	NAVCOMTELSTA DIXON	78	1	4.1	1	Assessment	NOW GOES BY DIXON RATHER THAN STOCKTON
Southwest	N00948	FLEASWTRACENPAC SAN DIEGO	0	0	N/A	2	Screening	

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N/A: Not applicable
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Navy Initial Radon Potential Categories

Navy Region	UIC	UIC Name	Total Number Radon Measurements	Number of Measurements at UIC ≥ 4 pCi/L	Highest Radon Result at UIC	Radon Potential Category	Radon Testing Phase	Comments
Southwest	N08915	FORMER NMCB 16 LOS ALAMITOS CA	0	0	N/A	N/A	Does not apply	NO LONGER NAVY OWNED
Southwest	N47609	NAWS CHINA LAKE	0	0	N/A	2	Screening	
Southwest	N47615	NMC CWD UNIT SEAL BEACH CA	112	0	2.5	3	Monitoring	FORMER WEAPONS SUPPORT FACILITY SB - UIC N60701
Southwest	N47822	FORMER NAVMEDCOM OAKLAND CA	23	0	0.2	3	Monitoring	
Southwest	N55262	SWRMC SAN DIEGO CA	307	0	1.6	3	Monitoring	FORMER SUPSHIP SAN DIEGO CA - UIC N62791 AND FORMER SIMA SAN DIEGO CA - UIC N65918
Southwest	N57053	NAVSUPPACT MONTEREY CA	20	0	1.6	N/A	Does not apply	FORMER NAVFAC CENTERVILLE BEACH CA - DECOMMISSIONED 1993
Southwest	N60028	NAVSTA TREASURE ISLAND CA	6	0	0.6	N/A	Does not apply	BRAC
Southwest	N60036	FORMER NAVWPNSTA SEAL BCH DET CONCORD	35	0	1.5	N/A	Does not apply	NOW RUN BY ARMY
Southwest	N60042	NAF EL CENTRO CA	753	0	1.8	3	Monitoring	
Southwest	N60258	FORMER NSY LONG BEACH CA	116	0	0.9	N/A	Does not apply	BRAC
Southwest	N60259	MCAS MIRAMAR CA	305	0	2.2	3	Monitoring	FORMER NAS MIRAMAR
Southwest	N60285	NAVHOSP CAMP PENDLETON CA	231	0	1.1	3	Monitoring	

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Navy Initial Radon Potential Categories

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Southwest	N60495	NAS FALLON NV	315	1	4.3	1	Assessment	
Southwest	N60530	FORMER NAVAIRWARCENWPNDIV CHINA LAKE	0	0	N/A	N/A	Does not apply	DATA MOVED TO NEW UIC N68937 NAWS CHINA LAKE
Southwest	N60701	FORMER WEAPONS SUPPORT FACILITY SB	0	0	N/A	N/A	Does not apply	DATA LOCATED IN UIC N47615 NAVWPNSTA SEAL BEACH
Southwest	N61014	NAVSUPPACT MONTEREY CA	1844	328	9.9	1	Assessment	
Southwest	N61065	NAVWPNSTA SEAL BEACH	0	0	N/A	2	Screening	
Southwest	N61665	FLEET COMBAT TRAINING CENTER SAN DIEGO	123	0	3.2	3	Monitoring	FORMER NPDC TRNG SUPP SITE SAN DIEGO - PART OF NAVBASE POINT LOMA AND PHYSICALLY ADJOINING MAIN BASE, SEPARATED BY PUBLIC ROAD
Southwest	N61762	NAVSURFWARCEN DET WHITE SANDS	4	1	5.5	1	Assessment	FORMER NAVORDMISTESTSTA WHITESANDS NM
Southwest	N62021	NAVPHIBASE CORONADO SDIEGO CA	4	0	0.6	2	Screening	
Southwest	N62102	NAVOPSPTCEN LOS ANGELES CA	55	0	0.5	3	Monitoring	FORMER NAVMARCORESCEN LONG BEACH CA

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Navy Initial Radon Potential Categories

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Southwest	N62103	NAVMARCORESCEN LOS ANGELES CA	0	0	N/A	2	Screening	
Southwest	N62105	NAVOPSPTCEN PORT HUENEME CA	26	0	0.4	3	Monitoring	FORMER NAVRESCENDET PT HUENME CA
Southwest	N62106	NAVOPSPTCEN SAN DIEGO	43	0	0.6	3	Monitoring	FORMER NAVMARESCEN SAN DIEGO CA
Southwest	N62107	NAVOPSPTCEN TUCSON AZ	49	0	1.2	3	Monitoring	FORMER NAVMARCORESCEN TUCSON AZ
Southwest	N62109	NAVOPSPTCEN PHOENIX AZ	45	0	2.7	3	Monitoring	FORMER NAVMARCORESCEN PHOENIX AZ
Southwest	N62111	NAVMARCORESCEN BAKERSFIELD CA	54	0	1.8	3	Monitoring	
Southwest	N62114	NAVOPSPTCEN MORENO VALLEY	55	0	0.9	3	Monitoring	FORMER NAVMARCORESCEN MORENO VALLEY CA
Southwest	N62115	FORMER NAVRESCEN SAN FRANCISCO CA	10	0	0.3	2	Screening	
Southwest	N62116	NAVOPSPTCEN ALAMEDA, CA	85	0	1.5	3	Monitoring	FORMER NMCRC ALAMEDA CA
Southwest	N62117	NAVRESCEN STOCKTON CA	0	0	N/A	2	Screening	
Southwest	N62118	FORMER NAVRESCEN VALLEJO CA	10	0	1.3	2	Screening	

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N/A: Not applicable
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Navy Initial Radon Potential Categories

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Southwest	N62119	NAVOPSPTCEN SACRAMENTO CA	56	0	0.8	3	Monitoring	FORMER NMCRC SACRAMENTO CA
Southwest	N62121	NAVOPSPTCEN LEMOORE CA	52	0	3.1	3	Monitoring	FORMER NAVRESCENAFRC FRESNO CA
Southwest	N62123	NAVRESCEN COLORADO SPRINGS CO	0	0	N/A	2	Screening	
Southwest	N62124	NAVRESCEN OGDEN UT	11	0	1.4	3	Monitoring	FORMER NRC OGDEN UT
Southwest	N62125	NAVRESCEN PUEBLO CO	0	0	N/A	2	Screening	
Southwest	N62126	NAVOPSPTCEN SALT LAKE CT UT	36	0	1.6	3	Monitoring	FORMER NAVMARCORESCEN SALT LAKE CT UT
Southwest	N62127	NAVOPSPTCEN RENO NV	25	0	2.8	3	Monitoring	FORMER NMCRC RENO NV
Southwest	N62128	NAVOPSPTCEN SAN JOSE CA	66	0	2.7	3	Monitoring	FORMER NMCRC SAN JOSE CA
Southwest	N62130	NAVOPSPTCEN DENVER CO	9	0	0.6	2	Screening	FORMER NAVMARCORESCEN DENVER CO
Southwest	N62180	NAVRESCEN SANTA ANA CA	0	0	N/A	2	Screening	
Southwest	N62241	NAVOPSPTCEN LAS VEGAS NV	0	0	N/A	2	Screening	FORMER NAVMARCORESCEN AFRC LAS VEGAS NV
Southwest	N62267	NAVRESCEN PACIFIC GROVE CA	10	0	1.0	2	Screening	

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N/A: Not applicable
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Navy Initial Radon Potential Categories

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Southwest	N62271	FORMER NAVAL POST GRADUATE SCHOOL	0	0	N/A	N/A	Does not apply	DATA MOVED TO UIC N61014 NAVSUPPACT MONTEREY CA
Southwest	N62474	FORMER NAVFAC EFA W DALY CITY CA	109	0	0.8	N/A	Does not apply	BRAC
Southwest	N62583	FORMER NFELC PORT HUENEME CA	119	0	2.1	3	Monitoring	FORMER NFELC PORT HUENEME CA IS NOW PART OF NAVBASE VENTURA CITY PT MUGU CA UIC N69232
Southwest	N62603	MINEWARTRACEN SAN DIEGO CA	68	0	1.0	3	Monitoring	
Southwest	N62654	NAVAIRWARCENWPNDIV ALBUQUERQUE	0	0	N/A	2	Screening	FORMER NAVWPNEVALFAC ALBUQUERQUE NM
Southwest	N62738	NAWPNCENCORONA DET NORCO CA	0	0	N/A	2	Screening	
Southwest	N62791	SUPSHIP SAN DIEGO CA	0	0	N/A	N/A	Does not apply	SUPSHIP SAN DIEGO CHANGED NAME TO SWRMC SAN DIEGO (UIC N55262; DATA LOCATED IN THIS UIC) BUT IS PHYSICALLY LOCATED ON NAVBASE SAN DIEGO UIC N00245
Southwest	N62818	NAVRESCEN POMONA CA	10	0	1.5	2	Screening	

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Southwest	N62887	ONRDET MONTEREY CA	0	0	N/A	2	Screening	CONTACT AT NAVSUPPACT MONTEREY HAD NO KNOWLEDGE OF THIS ORGANIZATINO OR UIC
Southwest	N63042	NAS LEMOORE CA	9	0	2.9	2	Screening	
Southwest	N63126	FORMER NAVAIRWARCENWPNDIV PT MUGU CA	792	2	10.2	1	Assessment	NAS PT MUGU IS NOW PART OF NAVBASE VENTURA CTY PT MUGU CA N69232
Southwest	N63243	NAVRESFAC CARLSBAD NM	0	0	N/A	2	Screening	
Southwest	N63387	NAVFAC SOUTHWEST SAN DIEGO CA PWC DEPARTMENT	372	0	2.8	3	Monitoring	FORMER PWC SAN DIEGO CA
Southwest	N63394	FORMER NAVSURFWARCENDIV PORT HUENEME	0	0	N/A	2	Screening	NOW NAVBASE VENTURA CTY PT MUGU CA N62583; NAVSURFWARCENDIV IS LOCATED ON PORT HUENEME
Southwest	N63406	NAVBASE POINT LOMA	497	9	14.5	1	Assessment	FORMER SUBASE SAN DIEGO CA
Southwest	N65584	NISE-WEST SAN DIEGO CA	34	0	0.5	3	Monitoring	FORMER NAVELEXSYSENGCEN SAN DIEGO CA
Southwest	N65913	NAVSEACENPAC SAN DIEGO CA	0	0	N/A	N/A	Does not apply	

RPC 1: Elevated radon potential exists
RPC 2: Radon potential is unknown
RPC 3: Low radon potential
If UIC is not listed, assume RPC 2 (Screening).
N/A: Not applicable
Radon data summary includes residential and nonresidential data collected from 1989 through 2015

Navy Initial Radon Potential Categories

Navy Region	UIC	UIC Name	Total Number Radon Measurements	Number of Measurements at UIC ≥ 4 pCi/L	Highest Radon Result at UIC	Radon Potential Category	Radon Testing Phase	Comments
Southwest	N65918	SIMA SAN DIEGO CA	0	0	N/A	N/A	Does not apply	NOW SWRMC SAN DIEGO UIC N55262 AND THE DATA IS LOCTED IN THIS UIC. IT IS PHYSICALLY LOCATED ON NAVBASE SAN DIEGO.
Southwest	N66001	SPAWARSYSCEN PACIFIC SAN DIEGO	245	3	9.6	1	Assessment	
Southwest	N66890	FORMER NAVSTA MARE ISLAND CA	4	0	1.4	N/A	Does not apply	BRAC
Southwest	N68090	FORMER NAVHOSP LONG BEACH CA	7	0	1.2	N/A	Does not apply	BRAC
Southwest	N68174	NAVOPSPTCEN ENCINO CA	67	0	3.1	3	Monitoring	FORMER NAVMARCORESCEN ENCINO CA
Southwest	N68311	FORMER NAVSTA LONG BEACH CA	7	0	1.1	N/A	Does not apply	BRAC
Southwest	N68318	NAVMARCORESCEN SAN BRUNO CA	56	0	1.5	3	Monitoring	
Southwest	N68937	NAWS CHINA LAKE	81	0	3.2	3	Monitoring	DATA MOVED TO HERE FROM OLD UIC N60530
Southwest	N69127	CSO HUNTERS POINT ANNEX	0	0	N/A	N/A	Does not apply	CLOSED
Southwest	N69141	CSO NS LONG BEACH CA	0	0	N/A	N/A	Does not apply	CLOSED

RPC 1: Elevated radon potential exists
RPC 2: Radon potential is unknown
RPC 3: Low radon potential
If UIC is not listed, assume RPC 2 (Screening).
N/A: Not applicable
Radon data summary includes residential and nonresidential data collected from 1989 through 2015

Navy Initial Radon Potential Categories

Navy Region	UIC	UIC Name	Total Number Radon Measurements	Number of Measurements at UIC ≥ 4 pCi/L	Highest Radon Result at UIC	Radon Potential Category	Radon Testing Phase	Comments
Southwest	N69152	CSO NSY MARE ISLAND CA	0	0	N/A	N/A	Does not apply	CLOSED
Southwest	N69161	CSO NAS ALAMEDA CA	0	0	N/A	N/A	Does not apply	CLOSED
Southwest	N69162	CSO NTC SAN DIEGO CA	0	0	N/A	N/A	Does not apply	CLOSED
Southwest	N69165	CSO NSY LONG BEACH CA	0	0	N/A	N/A	Does not apply	CLOSED
Southwest	N69168	CSO NS TREASURE ISLAND CA	0	0	N/A	N/A	Does not apply	CLOSED
Southwest	N69174	CSO PWC SAN FRANCISCO CA	0	0	N/A	N/A	Does not apply	CLOSED
Southwest	N69232	NAVBASE VENTURA CTY PT MUGU CA	0	0	N/A	2	Screening	
Southwest	N70240	NAVCOMTELSTA SAN DIEGO, CA	0	0	N/A	2	Screening	FORMER NAVCOMMSTA SAN DIEGO CA
Southwest	N91285	NIROP SUNNYVALE CA	149	0	3.0	3	Monitoring	
Southwest	N91726	CAL INST OF TECH PASADENA CA	0	0	N/A	2	Screening	NAVY OWNS BLDGS AT THE UNIVERSITY
Southwest	N91947	INST OF MINING/TECH SOCORRO NM	0	0	N/A	2	Screening	NAVY OWNS BLDGS AT THE UNIVERSITY
Southwest	N91961	NWIRP DALLAS TX	0	0	N/A	2	Screening	
Southwest	N92625	U OF CAL SAN DIEGO LA JOLLA CA	0	0	N/A	2	Screening	NAVY OWNS BLDGS AT THE UNIVERSITY
Southwest	N93055	NIROP POMONA CA	0	0	N/A	2	Screening	

RPC 1: Elevated radon potential exists
RPC 2: Radon potential is unknown
RPC 3: Low radon potential
If UIC is not listed, assume RPC 2 (Screening).
N/A: Not applicable
Radon data summary includes residential and nonresidential data collected from 1989 through 2015

Navy Initial Radon Potential Categories

Navy Region	UIC	UIC Name	Total Number Radon Measurements	Number of Measurements at UIC ≥ 4 pCi/L	Highest Radon Result at UIC	Radon Potential Category	Radon Testing Phase	Comments
Southwest	N94750	NIROP MAGNA UT	0	0	N/A	2	Screening	
Southwest	N95137	NIROP SACRAMENTO CA	0	0	N/A	2	Screening	
Southwest	NCELPH	FORMER NAVCIVENGRLAB PORT HUENEME CA	160	0	2.4	3	Monitoring	FORMER UIC N68305

RPC 1: Elevated radon potential exists
RPC 2: Radon potential is unknown
RPC 3: Low radon potential
If UIC is not listed, assume RPC 2 (Screening).
N/A: Not applicable
Radon data summary includes residential and nonresidential data collected from 1989 through 2015

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MARINE CORPS INITIAL RPCs

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Marine Corps Initial Radon Potential Categories

UIC	UIC Name	Total Number Radon Measurements	Number of Measurements at UIC ≥ 4 pCi/L	Highest Radon Result at UIC	Radon Potential Category	Radon Testing Phase	Comments
M00146	MCAS CHERRY POINT NC	279	0	3.9	3	Monitoring	
M00243	MARCORPRCUITDEP SAN DIEGO CA	10	0	1.2	3	Screening	
M00262	MCAF QUANTICO VA	0	0	N/A	2	Screening	
M00263	MCRD/BEAUFORT PI SC	197	0	1.9	3	Monitoring	
M00264	MARINE CORPS BASE QUANITCO VA	3482	39	8.9	1	Assessment	
M00318	MCB HAWAII KANEOHE	1255	1	5.6	1	Assessment	DATA INCLUDES MAIN BASE, CAMP SMITH, AND MANANA AREAS
M00526	FORMER USMCRC WYOMING PA	0	0	N/A	N/A	Does not apply	DATA MOVED TO NEW UIC M03035
M00540	FORMER NAS SOUTH WEYMOUTH MA	0	0	N/A	N/A	Does not apply	DATA LOCATED IN UIC N00101 NAS SOUTH WEYMOUTH MA
M00681	MCB CAMP PENDLETON CA	3565	2	10.8	1	Assessment	
M01139	SITE SUPPORT - FRESNO CA (FORMER USMCRC FRESNO CA)	0	0	N/A	N/A	Does not apply	DATA MOVED TO UIC M03040 SITE SUPPORT FRESNO CA
M01199	FORMER MSMCRC JOHNSTOWN PA	0	0	N/A	N/A	Does not apply	DATA MOVED TO NEW UIC M03045
M03029	4TH LAAD MAW	0	0	N/A	N/A	Does not apply	UIC was formerly assigned to USMCRC Pasadena CA
M03035	SITE SUPPORT WYOMING PA	49	1	9.0	1	Monitoring	FORMER USMCRC WYOMING PA UIC M00526

RPC 1: Elevated radon potential exists
RPC 2: Radon potential is unknown
RPC 3: Low radon potential
If UIC is not listed, assume RPC 2 (Screening).
N/A: Not applicable
Radon data summary includes residential and nonresidential data collected from 1989 through 2015.

Marine Corps Initial Radon Potential Categories

UIC	UIC Name	Total Number Radon Measurements	Number of Measurements at UIC ≥ 4 pCi/L	Highest Radon Result at UIC	Radon Potential Category	Radon Testing Phase	Comments
M03040	SITE SUPPORT - FRESNO CA	98	0	2.6	3	Monitoring	FORMER USMCRC FRESNO CA UIC M01139
M03045	SITE SUPPORT JOHNSTOWN PA	36	0	1.5	3	Monitoring	FORMER MSMCRC JOHNSTOWN PA UIC M01199
M14069	FORMER USMCRC LAFAYETTE LA	0	0	N/A	N/A	Does not apply	DATA MOVED TO NEW UIC M84286
M14120	USMCRC PASADENA CA	128	0	1.9	3	Monitoring	Former UICs sampled at this installation include M03029 and M14121
M14167	FORMER USMCRC PERRYSBURG OH	60	0	3.3	3	Monitoring	
M14170	FORMER USMCRC CHICAGO IL	0	0	N/A	N/A	Does not apply	DATA MOVED TO NEW UIC M85225 SITE SUPPORT CHICAGO IL
M14231	FORMER USMSRC BROOKPARK OH	0	0	N/A	N/A	Does not apply	DATA MOVED TO NEW UIC M81225 SITE SUPPORT BROOK PARK OH
M14314	FORMER USMCRC PICO RIVERA CA	25	0	0.3	3	Monitoring	
M14333	USMCRC WEST TRENTON, NJ	0	0	N/A	2	Screening	
M14633	USMCRC HUNTSVILLE, AL	0	0	N/A	2	Screening	DATA LOCATED IN UIC M83185
M14703	USMCRC WINDY HILL GA	50	0	1.1	3	Monitoring	
M20810	CAMP MUJUK REPUBLIC OF KOREA	174	1	9.7	1	Monitoring	

RPC 1: Elevated radon potential exists
RPC 2: Radon potential is unknown
RPC 3: Low radon potential
If UIC is not listed, assume RPC 2 (Screening).
N/A: Not applicable
Radon data summary includes residential and nonresidential data collected from 1989 through 2015.

Marine Corps Initial Radon Potential Categories

UIC	UIC Name	Total Number Radon Measurements	Number of Measurements at UIC ≥ 4 pCi/L	Highest Radon Result at UIC	Radon Potential Category	Radon Testing Phase	Comments
M21443	FORMER USMCRTC YAKIMA WA	53	0	3.6	3	Monitoring	
M21445	USMCRC TWENTY-NINE PALMS CA	56	0	0.8	3	Monitoring	UNIT PHYSICALLY LOCATED ON MCAGCC TWENTY-NINE PALMS
M21833	USMCRC JACKSONVILLE FL	54	0	0.7	3	Monitoring	
M29060	FORMER USMCRTC NEWPORT NEWS, VA	0	0	N/A	N/A	Does not apply	RADON DATA MOVED TO NEW UIC M61896 MCRC NEWPORT NEWS VA
M29062	FORMER EASTOVER, SC	40	0	1.2	3	Monitoring	
M29074	USMCRTC OMAHA NE	62	2	5.1	1	Monitoring	
M33610	FORMER MARMTNTRANCEN BRIDGEPORT, CA	0	0	N/A	2	Screening	
M38450	USMC BICMD JACKSONVILLE FL	43	0	0.5	3	Monitoring	
M45271	SITE SUPPORT FOLSOM PA	24	0	1.3	3	Monitoring	FORMER USMCRC FOLSOM PA UIC M81229
M60050	MCAS EL TORO SANTA ANA CA	185	0	3.4	N/A	Does Not Apply	Decommissioned, No Longer USMC Owned
M60169	MCAS BEAUFORT SC	2690	8	7.7	1	Assessment	
M61896	MCRC NEWPORT NEWS VA	56	0	1.2	3	Monitoring	FORMER USMCRTC NEWPORT NEWS VA UIC M29060
M62204	MCLB BARSTOW CA	1539	1	11.5	1	Monitoring	

RPC 1: Elevated radon potential exists
RPC 2: Radon potential is unknown
RPC 3: Low radon potential
If UIC is not listed, assume RPC 2 (Screening).
N/A: Not applicable
Radon data summary includes residential and nonresidential data collected from 1989 through 2015.

Marine Corps Initial Radon Potential Categories

UIC	UIC Name	Total Number Radon Measurements	Number of Measurements at UIC ≥ 4 pCi/L	Highest Radon Result at UIC	Radon Potential Category	Radon Testing Phase	Comments
M62535	MCAS TUSTIN CA	2	0	1.6	2	Screening	
M62613	MCAS IWAKUNI	521	7	5.9	3	Assessment	
M62974	MCAS YUMA AZ	223	0	3.2	3	Monitoring	
M67001	MCB CAMP LEJEUNE NC	357	0	3.6	3	Monitoring	
M67004	MCLB ALBANY GA	2511	53	5.5	1	Assessment	
M67011	MARCOPS DIST 1 GARDEN CITY NY	0	0	N/A	2	Screening	
M67021	HDQTRS 4TH MAW NEW ORLEANS LA	0	0	N/A	2	Screening	
M67029	MARBKS WASHINGTON DC	7	0	1.6	3	Screening	
M67353	HQBN HQMC ARLINGTON VA	185	2	5.0	1	Assessment	
M67385	MCB HAWAII CAMP HM SMITH	0	0	N/A	N/A	Does not apply	DATA PART OF MCB HAWAII KANEOHE UIC N00318
M67386	MCSPTACT KANSAS CITY MO	0	0	N/A	2	Screening	
M67391	MARFORLANT CAMP ELMORE NORFOLK VA	2	0	1.3	2	Screening	
M67399	MCAGCC TWENTYNINE PALMS CA	563	0	3.4	3	Monitoring	
M67400	MCB CAMP SD BUTLER OKINAWA	10,211	944	79.1	1	Monitoring	DATA INCLUDES VARIOUS CAMPS
M67443	DFAS-KANSAS CITY CTR-PERS ONLY	306	42	8.7	1	Assessment	FORMER MARFINCEN KANSAS CITY MO
M67604	MCAS CAMP PENDLETON CA	0	0	N/A	N/A	Does Not Apply	PART OF MCB CAMP PENDLETON CA
M67695	MCSF BLOUNT ISLAND	18	0	0.5	2	Screening	
M67861	MARCORRESFOR NEW ORLEANS LA	0	0	N/A	2	Screening	
M67865	MCAS MIRAMAR	702	4	6.2	1	Assessment	

RPC 1: Elevated radon potential exists
RPC 2: Radon potential is unknown
RPC 3: Low radon potential
If UIC is not listed, assume RPC 2 (Screening).
N/A: Not applicable
Radon data summary includes residential and nonresidential data collected from 1989 through 2015.

Marine Corps Initial Radon Potential Categories

UIC	UIC Name	Total Number Radon Measurements	Number of Measurements at UIC ≥ 4 pCi/L	Highest Radon Result at UIC	Radon Potential Category	Radon Testing Phase	Comments
M68479	HDQTRS 4TH MARDIV NEW ORLEANS	0	0	N/A	2	Screening	
M71778	FORMER USMCRTC DAYTON OH	0	0	N/A	2	Screening	
M81225	SITE SUPPORT BROOK PARK OH	46	0	1.1	3	Monitoring	FORMER UIC M14231
M81229	FORMER SITE SUPPORT FOLSOM PA	0	0	N/A	N/A	Does not apply	DATA MOVED TO NEW UIC M45271
M81247	SITE SUPPORT (DAYTON OH)	123	8	43.9	1	Monitoring	FORMER USMCRTC DAYTON OH
M82220	SITE SUPPORT BALTIMORE MD	66	0	2.3	3	Monitoring	FORMER USMCRTC BALTIMORE MD
M82221	SITE SUPPORT LYNCHBURG VA	44	0	3.5	3	Monitoring	FORMER USMCRC LYNCHBURG VA
M83185	SITE SUPPORT HUNTSVILLE AL	34	1	5.0	1	Monitoring	
M83227	SITE SUPPORT CHARLESTON, SC	33	0	2.0	3	Monitoring	FORMER USMCRC CHARLESTON SC
M83263	SITE SUPPORT MEMPHIS TN	41	0	0.5	3	Monitoring	FORMER USMCRC MEMPHIS TN
M83304	SITE SUPPORT ROME GA	27	1	5.7	1	Monitoring	FORMER USMCRC ROME GA
M84237	SITE SUPPORT TEXARKANA TX	48	1	4.0	1	Monitoring	FORMER USMCRC TEXARKANA TX
M84267	SITE SUPPORT GALVESTON TX	30	0	0.6	3	Monitoring	FORMER USMCRC GALVESTON TX
M84286	SITE SUPPORT LAFAYETTE LA	127	0	2.2	3	Monitoring	FORMER USMCRC BROUSSARD LA
M85220	SITE SUPPORT SELFRIDGE ANGB	36	1	5.7	1	Assessment	

RPC 1: Elevated radon potential exists
RPC 2: Radon potential is unknown
RPC 3: Low radon potential
If UIC is not listed, assume RPC 2 (Screening).
N/A: Not applicable
Radon data summary includes residential and nonresidential data collected from 1989 through 2015.

Marine Corps Initial Radon Potential Categories

UIC	UIC Name	Total Number Radon Measurements	Number of Measurements at UIC ≥ 4 pCi/L	Highest Radon Result at UIC	Radon Potential Category	Radon Testing Phase	Comments
M85225	SITE SUPPORT CHICAGO IL	42	0	1.5	3	Monitoring	
M95429	CMC HQ MARCORPS ARLINGTON VA	0	0	N/A	2	Screening	

RPC 1: Elevated radon potential exists
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RPC 3: Low radon potential
If UIC is not listed, assume RPC 2 (Screening).
N/A: Not applicable
Radon data summary includes residential and nonresidential data collected from 1989 through 2015.

APPENDIX C: EXAMPLE OF RADON TESTING HANDOUT

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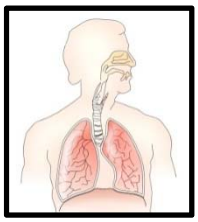
NOTE: This handout is provided as an example and can be used "as is" by simply editing the highlighted areas. However, as circumstances dictate, the handout can be modified in whole or part by the installation to meet their specific needs or replaced entirely with an installation specific handout.

What Is Radon?

Radon is a colorless, odorless, tasteless gas that is produced by the breakdown (radioactive decay) of naturally occurring uranium. Outdoors, radon is harmlessly diluted by the atmosphere. However, in enclosed places like homes and buildings, radon can accumulate to unacceptable levels.

Is There A Health Risk?

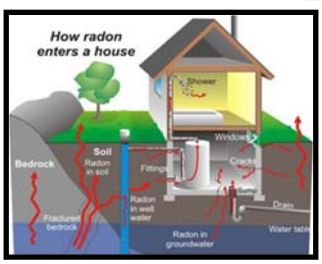


Radon gas decays into radioactive particles that can become trapped in your lungs. As these particles break down further, they release small bursts of energy that can damage lung tissue. Many years of exposure to elevated radon levels can lead to an increased risk of lung cancer.

How Common Is Radon?

The EPA has estimated that 14% of all homes in the United States have elevated levels of radon. Elevated radon has also been found in almost every country in the world as well. No area in the world is considered radon free.

How Does Radon Enter a Building?



Radon gas comes from uranium in the soil and bedrock. Wherever air and moisture seep in through drains, joints, cracks, and pores in the foundation and exterior walls, radon can enter your building. If the building shell is tight, the radon cannot escape.

Am I being Exposed to Radon?

The only way to know if elevated level radon is present is to test.

Why Is the Navy Testing For Radon?

The health of its military personnel, their dependents, and employees is a primary concern of the Navy. When various medical studies showed that radon could be a potential health risk, the Navy developed a program called the Navy Radon Assessment and Mitigation Program (NAVRAMP) to identify and manage radon at all naval installations worldwide.

How Is The Navy Going To Test?

For this radon testing project, the Navy has selected the Alpha Track Radon detector. This detector emits no noise, emits no harmful chemicals, and requires no special attention. It only needs to be left undisturbed. If the detector is moved or falls down during the test period, please return it to its original location.

How Long Will The Test Period Last?

Depending on the local climate, the test could last up to 1 year.

How Soon Will the Navy Fix the Problem?

If a problem is found, the Navy will take corrective action in accordance with NAVRAMP and published US Environmental Protection Agency (EPA) guidelines. Depending on the radon concentration, EPA recommends corrective action be taken within a few months to a few years.

What Can I Do?

Provide the Navy access to your residence or work place for testing. Leave the radon detectors undisturbed. Inform your local Environmental Office if any issues arise.

Whom Do I Call For More Information?

For more information about radon, please contact your local Environmental Office at Phone Number.

APPENDIX D: EXAMPLE OF RADON MITIGATION SYSTEM INSPECTION FORM

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New Subslab Depressurization System Inspection Form (Pg 1 of 2)

Building Number: __________ **Building Name:** _________________________________

Date: __________ **Inspectors:** _____________________________________

General System Description

System Number: Number Suction Points:	Suction Point Locations	Room(s) System Fixes
Fan Make and Model	Fan Location Interior_____ Exterior_____ Attic_____ Roof_____	System Design Ext. (Type 1) ___ Int. w egress (Type 2) ___ Int. w/o egress (Type 3) ___
Performance Indicator Type	Performance Indicator Location	Performance Indicator Reading
Breaker/Panel Number	Switch Location	Electrical Tap Location
Comments		

Drawings/Notes

New Subslab Depressurization System Inspection Form (Pg 2 of 2)

Component	Specification	Findings	Comments
Vent Pipe	4 in, PVC, SCH 40, White	**Pass Fail**	
	Fittings and connections appear to be airtight, properly joined/sealed	**Pass Fail**	
	10 ft above grade, at least 12 in. above eave/roof and at least 10 ft from any opening to conditioned space	**Pass Fail**	
	Vent exhaust cap present	**Pass Fail**	
	Fire collar/damper present if fire rated wall is penetrated	**Pass Fail** **Not Applicable**	
	Sealing around vent pipe penetrations through slab, wall and floor is intact	**Pass Fail**	
	Pipe is strapped at least every 6 ft on horizontal runs and every 8 ft on vertical runs	**Pass Fail**	
	All exterior fasteners are stainless steel, galvanized, or corrosion resistant	**Pass Fail**	
Performance Indicator	A performance indicator is present, visible, operating and accessible.	**Pass Fail**	
	Pressure tubing is sealed and intact	**Pass Fail**	
	Instructions on how to use the indicator are present and a contact phone number is provided	**Pass Fail**	
Mitigation Fan	Mounted in a vertical section of pipe and level	**Pass Fail**	
	Fan is **<u>not</u>** located in or below conditioned space	**True False**	
	Vacuum within manufacturers performance range	**Pass Fail**	
	Fan not vibrating	**Pass Fail**	
Does System Meet EPA/ASTM/FTC Standards	Any negative findings above circle, No	**Yes No**	
Additional Comments			

O&M Subslab Depressurization System Inspection Form

Building Number: __________ **Building Name:** ________________________________

Date: __________ **Inspectors:** ____________________________________

System Number: _______ **Fan Make/Model:** ____________________________

Item	P	F	NA	Comments	Corrected
Fan Cover					
Cover Screws					
Fan Operation				Replacement Fan: _______________	
Fan Boots					
Fan Mounting					
System Decals					
Vacuum Indicator				Reading: _________	
Vacuum Tubing					
Pipe					
Pipe/Wall/Slab Seals					
Pipe Clamps					
Clamp Anchors					
Roof Cap					
Flex					
Flex Connectors					
Switch Operation					
Conduit					
Conduit Clamps					
Electrical Tap Seal					
Roof Seal					

Comments:

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APPENDIX E: REFERENCE DOCUMENTS FOR GUIDEBOOK

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REFERENCE DOCUMENT FOR

NAVY RADON ASSESSMENT AND MITIGATION PROGRAM GUIDEBOOK

FOR

NAVAL SHORE INSTALLATIONS

June 6, 2015

prepared for
NAVAL FACILITIES ENGINEERING COMMAND, PACIFIC
Environmental Compliance Product Line
Pearl Harbor, Hawaii 96860-7300
prepared by
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for the
US DEPARTMENT OF ENERGY
under contract DE-AC05-00OR22725

DISCLAIMER

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ABBREVIATIONS, ACRONYMS, AND INITIALISMS

ACH	air change per hour
ANSI	American National Standards Institute
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
ASTM	American Society for Testing and Materials
ATD	alpha track detector
BEIR	Biological Effects of Ionizing Radiation (Committee on)
CDC	Centers for Disease Control
cfm	cubic foot per minute
cm	centimeter
CRM	continuous radon monitor
DOE	US Department of Energy
EIC	electret ion chamber
EPA	US Environmental Protection Agency
EpCi/L	equivalent picocurie per liter
ER	equilibrium ratio
ERV	energy recovery ventilation
FT	foot
GAC	granular activated carbon
h	hour
h^{-1}	per hour
HEPA	high-efficiency particulate air
HVAC	heating, ventilating, and air-conditioning
IRAA	Indoor Radon Abatement Act
L	liter
LFE	lateral field extension
MPC	Maximum Permissible Concentration
NAVFAC	Naval Facilities Engineering Command
O&M	operation and maintenance
ORNL	Oak Ridge National Laboratory
OSHA	Occupational Safety and Health Administration
pCi	picocurie
pCi/h	picocurie per hour
pCi/L	picocurie per liter
ppm	parts per million
QA/QC	quality assurance/quality control
RDP	radon decay product
RPD	relative percent difference
RRNC	radon-resistant new construction
SAM	supplemental air mitigation
SMD	submembrane depressurization
SP	shell pressurization
SSD	subslab depressurization

TSCA	Toxic Substances Control Act
USGS	US Geological Survey
WHO	World Health Organization
WL	working level

EXECUTIVE SUMMARY

Radon is a known Class 1 human carcinogen, and many studies have shown that radon exposure is the second leading cause of lung cancer deaths in the United States. Although in the early 1980s it was hypothesized that indoor elevated radon would be found only in areas high in uranium or along geological faults, data collected over the last 30 years have shown elevated radon in every state and almost every county in the United States. Although a precursor for the presence of elevated radon is some concentrations of uranium and thorium in the soil or rock formations under a building, structures with low ventilation have been found to have elevated radon in areas where uranium and thorium are at or below the detection limits of most standard radiological assessment methods. Although analytical methods exist to measure the radon surface flux and radon soil gas concentrations at a building site, the uncertainties in estimating the radon infiltration rate through the soil/building interface and its retention within the building shell bring into question the overall reliability of these methods as a prognostication tool. It is for these reasons that the Environmental Protection Agency (EPA) and US Geological Survey recommend that all buildings be tested for radon.

Although EPA protocols allow for radon measurements to be performed in as little as 48 h, it is a well-established fact that the concentration can vary significantly because of the season, episodic weather conditions, and occupant lifestyle. For these reasons, EPA recommends that a single radon test be performed for as long as possible or a multi-test strategy be employed (separate short-term tests during different seasons). If the conclusion of the testing is that elevated radon is present (currently defined as radon ≥4 pCi/L), EPA recommends that the mitigation be performed as soon as possible. EPA recommends retesting after every renovation in which changes have been made in the soil/building interface or to the shell ventilation rate. Also, in light of the fact that radon generation is permanent, and buildings change over time (e.g., use, settling, interior modifications), retesting should be performed in the future as well.

In nonresidential buildings, studies have shown significant variation in the room-to-room radon concentration. The causes for this are varied (e.g., type of forced air system, structural features, pressure imbalances) but are considered too complex and unreliable to model. For these reasons, EPA recommends testing all ground-contact rooms that are routinely occupied.

In selecting a mitigation method, techniques using active soil depressurization have proved to be the most economical and reliable over time. However, other considerations (e.g., structural, ventilation, and aesthetic) may override these considerations. Therefore, mitigation diagnostics (scientific tests that help with the selection of the most appropriate mitigation method) are recommended before selecting a mitigation method. Regardless of the mitigation method installed, periodic inspection of the system components is recommended, and retesting is recommended every 2 years to ensure that the system is still working.

In new construction, in particular at sites with known elevated radon potential (EPA Radon Zone 1, http://www.epa.gov/radon/zonemap.html), EPA recommends that radon-resistant features be incorporated into the building design. Although these features will not guarantee that elevated radon will not be present upon building completion or at some time in the future, they will (if installed properly) ensure that mitigation will be predictable, effective, and lower in cost than installing a system from scratch. However, in marginal radon potential areas (EPA Zones 2 and 3), the potential savings are not as clear.

INTRODUCTION

This document was developed in support of the Naval Facilities Engineering Command Pacific, (NAVFAC Pacific) under US Department of Energy (DOE) Proposal 2172-S515-A1 for the performance of radon technical support. DOE assigned the project to its Oak Ridge National Laboratory (ORNL) Building Technologies Research and Integration Center, managed by UT-Battelle, LLC, to assist with this agreement with NAVFAC Pacific.

This document has been designed to be used as a technical reference document for "*Navy Radon Assessment and Mitigation Program Guidebook for Naval Shore Installations*" March 4, 2015. The information contained within this document is suitable for both internal and public dissemination, and it can be used as a stand-alone document as circumstances dictate.

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1. OVERVIEW OF RADON

1.1 WHAT IS RADON

Radon is a naturally occurring, odorless, colorless, radioactive gas caused by the breakdown of uranium (Fig. 1). Because uranium is a common substituent found in soil and rock matrixes throughout the world (on average about 3 g of natural uranium per ton), detectable quantities of radon can be measured everywhere. However, within certain rock formations (limestone, granite, shale, phosphate, and pitchblende), higher levels of uranium and its decay product radon are present. When radon is generated, it immediately begins diffusing toward the surface. In the outdoors, radon rarely reaches concentrations of concern; however, within enclosed spaces, such as buildings, radon can accumulate to levels in excess of federally mandated exposure limits for radiation workers (CFR 29 1910.1096[b]). Because these geological formations are fairly common within the United States and worldwide, measurable quantities of radon have been detected and reported in all 50 states and in most countries as well. In fact, the US Environmental Protection Agency (EPA) has estimated that 1 in every 15 homes has elevated radon levels (EPA September 1994, *A Citizen's Guide to Radon*, Fourth Edition). Because of the prevalence of indoor elevated radon, radon exposure represents over half of the average annual radiation exposure for the typical US citizen (Fig. 2) and most people worldwide (WHO 2009). Currently the EPA has set an action level of any result ≥4 pCi/L (EPA May 2012, EPA 402-K-12-002).

1.1.1 The Isotopes of Radon

There are 33 known isotopes of radon; however only 2 [radon-220 (^{220}Rn) and radon-222 (^{222}Rn) are typically found indoors. Radon-220, typically called thoron, comes from the thorium-232 (^{232}Th) decay chain and is also a common substituent found in soil and rock matrixes throughout the world. However, because of its short half-life (55.6 seconds) its diffusion potential through soil and rock is limited; and if it is found indoors at any appreciable concentration, it is usually linked to a source inside the building (e.g., water supply or building material). The other isotope, ^{222}Rn which is part of the uranium-238 decay chain (Fig. 1) has a radioactive half-life of 3.82 days, which does allow it sufficient time to diffuse from its matrix and come in contact with building components that contact the soil. For this reason, ^{222}Rn is considered the primary isotope responsible for the radiation dose throughout the world (WHO 2009).

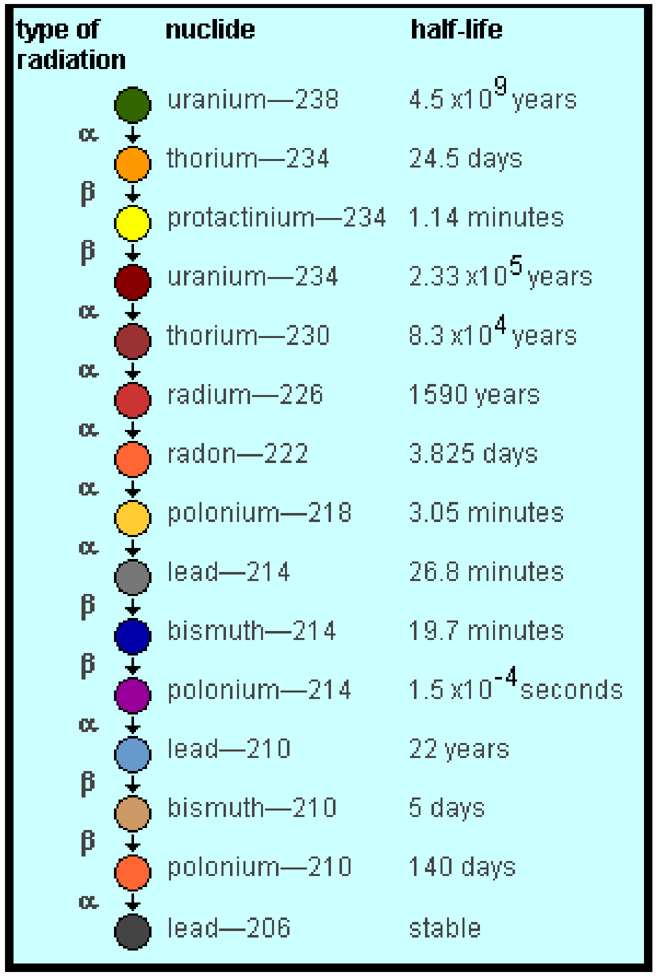


Fig. 1. The uranium decay series.

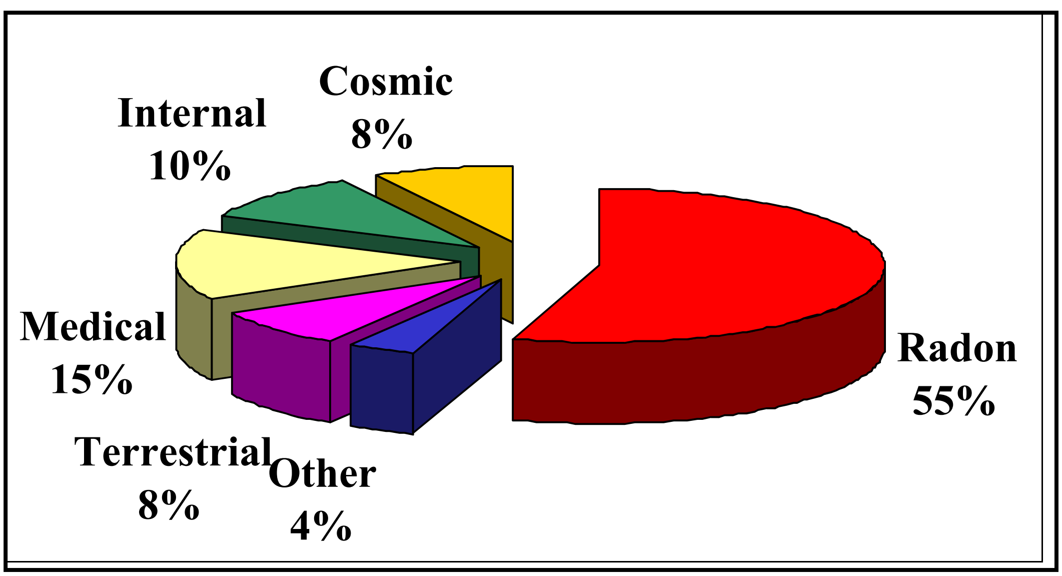


Fig. 2. Sources of radiation exposure for the average US citizen.

1.2 RADON AND GEOLOGY

In 1995, the US Geological Survey (USGS) in cooperation with EPA published a series of reports (USGS 1993, Open File Reports 93-292-A through K) that generalized radon potential within specific EPA regions. The evaluation and conclusions were based upon available USGS geological data and soil survey data collected by the Soil Conservation Service and included radon data collected by EPA during the 1986–1987 national residential radon survey. Practically speaking, one would expect that a precursor for elevated radon would be the presence of appreciable amounts of surface uranium concentrations (Fig. 3). Although the correlation was good between high indoor radon levels and significant levels of uranium and thorium in the soil, it was noted that similar levels of radon were also found in areas of the country with only trace levels of these elements. In addition, some areas that were known radiological "hot spots" exhibited a significantly lower than expected percentage of buildings with elevated radon. After further review and study, the conclusion was reached that the geologic radon potential was only part of predicting radon levels in a particular area. Factors such as the type and state of the geological formation (e.g., solid, layered, or fractured); local building codes; soil moisture content, depth, and permeability; and weather all played a contributing role. Therefore, in 1993, the EPA and USGS included with the release of the radon potential map a disclaimer that the map should not be used as an indicator whether to test and recommended that all homes and buildings be tested regardless of geographic location.

1.2.1 National Radon Potential Map

In the early 1980s, little was understood about the mechanisms of radon transport and its retention inside buildings. The key assumption made at that time was that for a building to have an indoor radon problem, a significant uranium source needed to be close at hand. It was therefore postulated that a radiological potential map showing uranium deposits would greatly assist in identifying areas of the United States that would require radon testing. Limited studies conducted in Colorado and Pennsylvania in the mid-1980s tended to support this hypothesis. However, these studies were performed mostly in areas with high levels of uranium covered with moderately to highly permeable soils. Because of this assumed correlation between geology and radon potential, the Indoor Radon Abatement Act (IRAA) of 1988 (Public Law 100-551a and b, Sections 307 and 309) directed the EPA to identify areas of the United States and its territories that have the potential to produce harmful levels of indoor radon. These characterizations were to be based on both geological data and indoor radon levels in homes and other structures. To assist with the geological requirements of the law, EPA entered into an Interagency Agreement with the USGS. From 1989 through 1992, EPA and USGS reviewed existing radiological maps, performed radon and geological surveys, and summarized all available radon data sets. The culmination of this effort was the publication in 1993 of the first EPA Map of Radon Zones (a more recent updated edition of the map is shown in Fig. 4 and can be downloaded at http://www.epa.gov/radon/zonemap.html). On the radon map, each county was placed into one of 3 categories:

- Zone 1 High Potential (red): counties that have a predicted average indoor radon concentration >4 picocuries per liter (pCi/L).
- Zone 2 Moderate Potential (orange): counties that have a predicted average indoor radon concentration between 2 and 4 pCi/L.
- Zone 3 Low Potential (yellow): counties that have a predicted average indoor radon concentration <2 pCi/L.

A common misunderstanding by the public and others in interpreting the map was the use of the word "average," which brought into question the need to test buildings in Zone 2 and 3 counties. Later, EPA clarified the meaning of "average" to mean that if all the homes in this county were tested, the average results of all the homes tested would be expected to fall within those ranges. In addition, EPA stated that some homes in Zone 2 and 3 counties would test >4 pCi/L, and **the only way to know the radon level of a particular building is to test it.**

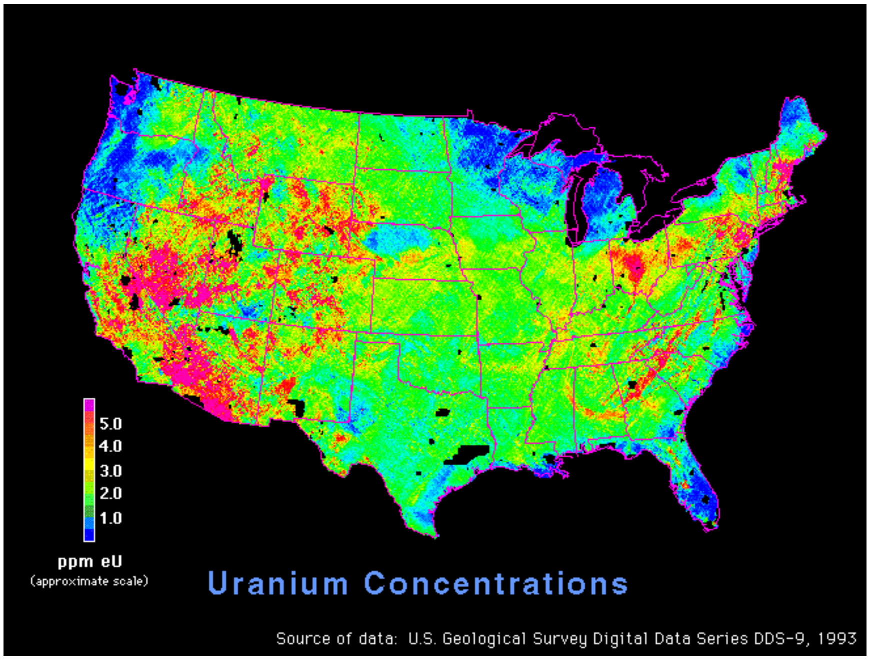


Fig. 3. Uranium concentrations within the United States.

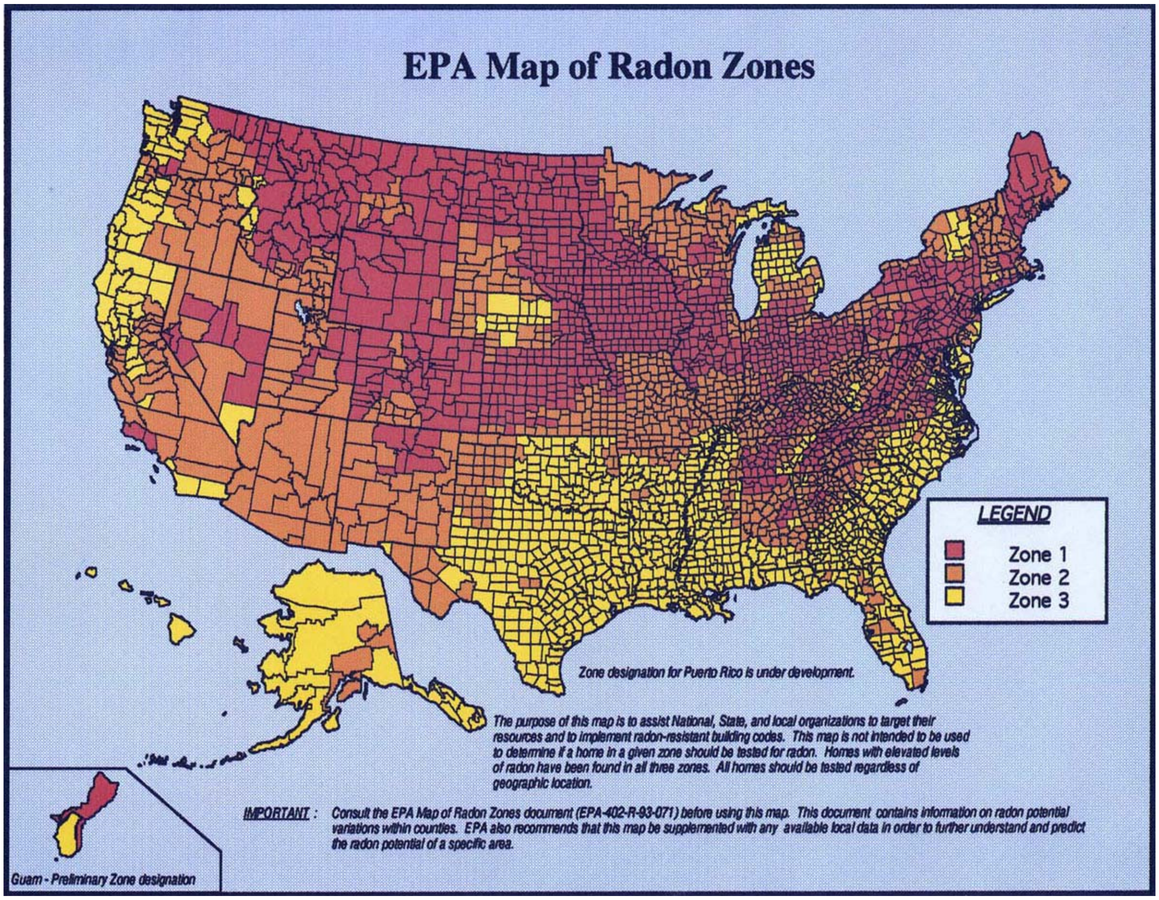


Fig. 4. United States radon potential map.

1.2.2 Radon Emanation within Rock and Soil

Radon is a naturally occurring, odorless, colorless, radioactive gas caused by the breakdown of uranium. In nature, uranium is found in varying amounts throughout the earth's crust, primarily in the mineral form of tyuyamunite [$Ca(UO_2)_2(VO_4)_2 \cdot 6(H_2O)$]. However, certain rock formations—primarily light-colored volcanic rocks, granites, dark shales, sedimentary rocks that contain phosphate, and metamorphic rocks derived from these rocks—contain higher than average uranium content [e.g., >3 parts per million (ppm) of natural uranium per ton]. Because soil is essentially weathered rock mixed with organic matter, tyuyamunite is also found in soil at the same concentration as in the rock from which the soil was derived.

Because radon is a gas, it has much greater mobility than uranium and radium, which are fixed in the solid matrix of rocks and soils. However, for radon to be a concern, it has to migrate (diffuse or flow) from the rock or soil and become entrapped within a building. The term "radon emanation efficiency" refers to the overall ease with which radon moves from its natural matrix into the environment by a diffusion and/or flow mechanism. This efficiency is dependent upon the density of the matrix, the degree of fracture, the size of the pore spaces between the grains, and the moisture content. In addition, the efficiency is time-sensitive, because the most common isotope of indoor radon (^{222}Rn) has a relatively short half-life of 3.8 days. Therefore, in most cases, if radon is going to make a measurable contribution to the indoor levels, it must escape from the matrix and enter the building within fewer than five half-lives (USGS 1988, *Relationships Between Geology, Equivalent Uranium Concentration, and Radon in Soil Gas, Fairfax County, Virginia*). If radon is generated within a dense rock with minimal pore sizes, at most it could migrate only a few centimeters (Tanner 1964). Therefore, in this type of rock, only radon generated within the top few centimeters of the surface could escape and potentially migrate into a building. Conversely, if the rock has a low density and a large pore size and is fractured, the migration of radon can be on the order of hundreds or thousands of feet (Akerblom 1984; Sextro 1987).

Regardless of the primary source of radon (e.g., rock or soil grain), before radon can enter a building, it usually must past through a layer of soil. The method (e.g., flow or diffusion) and speed of radon movement through soils are controlled by the amount of water present in the pore space (the soil moisture content), the percentage of pore space in the soil (the porosity), and the interconnectedness of the pore spaces, which determines the soil's ability to transmit water and air (Otton et al. 1993). The term "soil permeability" refers to the overall air flow characteristics of a particular soil and is an indicator of the relative ease with which radon moves from its natural matrix into the environment by a diffusion and/or flow mechanism. As with radon transport through rock, extremely dense, nonporous soils (e.g., low-permeability soils, <1.5 cm/h) can significantly reduce the amount of radon available for incorporation into a building. Likewise, if radon is able to move easily in the pore space (e.g., high-permeability soils, >15 cm/h), then it can travel a greater distance before it decays, and it is more likely to collect in high concentrations inside a building (Nagada 1994; Otton et al. 1993).

In summary, the presence of high levels of uranium in the soil and/or rock is not the sole precursor of elevated indoor radon potential. Radon must first emanate from the rock or soil grain and find a pathway through the soil to the building. In dense rock and nonporous compacted soils, the reservoir of radon available for transport into a building can be limited to just the first few inches of rock and/or soil under a building. However, in high-emanation-efficiency rock and/or soil matrixes in contact with a permeable soil, even negligible levels of uranium can produce a high soil gas concentration.

1.2.3 Geological Features that Enhance Radon Transport

In addition, certain geological features, such as karst topography, have demonstrated the capacity for seasonal variation (Gammage et al. 1992). "Karst" is a term used to describe a topography in which surface water or groundwater has dissolved sedimentary rock such as limestone. The result of the erosion is a subterranean network of shafts, tunnels, cavities, and caves (Mammoth Cave in Kentucky is a good example). Also, in most cases, the shafts, tunnels, and cavities connect to the surface (Fig. 5). In solid rock, radon can at most diffuse a few centimeters (Tanner 1964). Therefore, for all practical purposes, radon availability is limited to the surface of the rock. However, a karst network greatly increases the surface area of a given formation, resulting in much greater emanation efficiency. The network of caves, tunnels, and shafts then serve as a means to both concentrate the radon and transport it from considerable depths to the surface. Another characteristic of karst networks is that they breathe: whenever the ambient outdoor temperature is different from the ground temperature, the network will exhaust air or draw it in. The driving force is simply that warm air rises and cool air sinks. In flat karst areas, winter levels of indoor radon average 2–3 times those observed in the summer months. However, in cases in which a karst network is inside a hill, ridge, or mountain, the effect is even more enhanced by the stack or chimney effect. For example, a building built on the top of a hill connected to a karst network will see an order-of-magnitude increase in indoor radon concentration in the winter. Those located at the bottom of the hill will have a similar order-of-magnitude increase, but only in the summer months. Other geological types with similar features include lava tubes, layered basalts and volcanic tuff, weathered granite, and coquina.

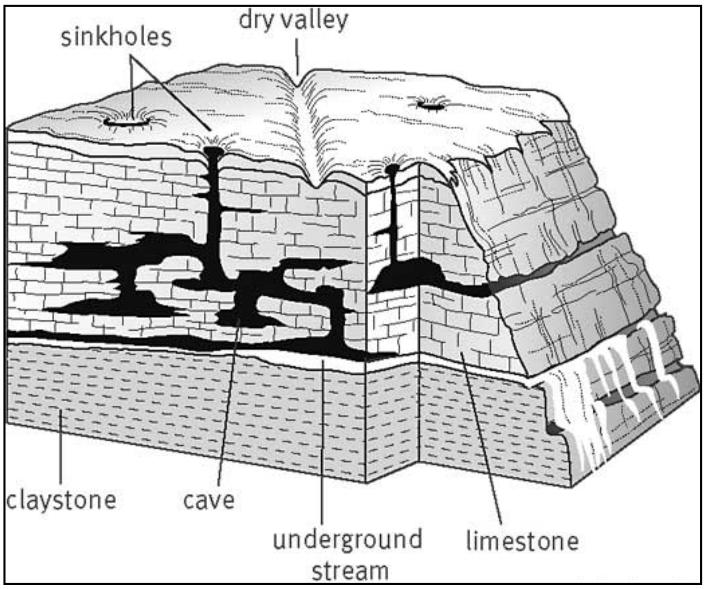


Fig. 5. Typical features found in karst topography.

Another example of a geological feature that causes seasonal variation and higher than expected indoor radon levels is sheared fault zones (common in the Appalachian region of the eastern United States). Like karst, these faults result in higher radon emanation from the uranium-bearing formation (rocks with cracks have more surface area than solid rocks) and allow the radon to migrate from considerable depths (upward of 1,000 ft.) and distances (several miles).

In soils, certain types of glacial deposits also enhance the indoor radon concentrations. Many areas of the United States underlain by soils derived from continental glacial deposits generate elevated indoor radon levels (>4 pCi/L). For example, Iowa (71%), North Dakota (63%), and Minnesota (46%) have some of the highest percentages of homes with elevated indoor radon levels in the State/EPA Residential Radon Survey. Determining the radon potential of glaciated areas is complicated by several problems:

1. Surface radioactivity is generally uncharacteristically low in glaciated areas and does not appear to correlate well with indoor radon values.
2. Because glaciers redistribute the bedrock they override and entrain, the composition and physical properties of till soils do not necessarily reflect those of the underlying bedrock (transport distances were much further for the continental glaciers of the Great Plains and Great Lakes regions than for glaciers in New England or for valley glaciers.
3. Where glacial cover is thin, the radon potential may be a complex product of the glacial cover and the underlying bedrock. Crushing and grinding of rocks by glaciers increases the mobility of uranium and radium in the resulting tills, allowing them to move readily downward through the soil profile with other mobile ions as the soils are leached.

Because of these day-to-day and seasonal variations, the Committee on Biological Effects of Ionizing Radiation (BEIR) VI (BEIR VI 1998) conceded that although all exposure to radon increases the risk of contracting lung cancer, the need for corrective action should be based on an integrated 1 year average, not on short-term excursions.

1.3 HOW RADON ENTERS A BUILDING

Radon, a gas at ambient temperatures and pressures, migrates from the surrounding soil into buildings through cracks in concrete slabs and basement foundation blocks, through pores in concrete masonry units, and through air spaces around pipes (ASHRAE 2010, *Indoor Air Quality Guide*). It can also collect in crawlspaces and then flow into living and work areas. The flow of radon into the living area of a building is caused by both natural diffusion and pressure-assisted flow. However, natural diffusion usually contributes only a small amount of radon within a building; in most cases, radon above ambient levels can be attributed to pressure-assisted flow.

The process of pressure-assisted flow can be either natural or man-made. The rising and exiting of warm air within a building causes natural pressure-assisted flow, or thermal stack effect. As warm air rises, makeup air is pulled into the building through slab and wall imperfections. If the imperfections are in contact with soil, the building radon concentration increases. Man-made enhancement of radon entry is primarily the result of negative pressure created by the operation of a furnace, air-conditioning system, ventilation fan, or air exhaust system.

The physics of radon transport and retention in a building are very complex. The radon source term is the total quantity of radon entering the structure per unit of time (pCi/h). Studies by EPA and DOE have identified more than ten variables that contribute to the source term (e.g., radium content of the soil, emanation efficiency of the soil matrix, soil permeability, soil water content, various temperatures, and shell and subslab pressures). After radon has entered a structure, many other variables either enhance or dilute it. The term relative air change) refers to the rate at which outdoor air infiltrates into the building shell and inside air is exhausted (for both natural and man-made causes). Generally speaking, if the radon source term is greater than the relative air change, then elevated radon will result. Because of these variables, there is no certain way to predict the radon level of a particular building. The only sure way to know if a room/building has elevated indoor radon levels is to test.

1.3.1 Indoor Radon Retention

Although radon diffusing through and, in rare cases, from concrete (e.g., wall, floors, piers, beams) can contribute to the indoor radon level, the main driving force for most buildings is the pressure differential caused by the stack effect (the rising and escape of warm air in a building through the upper floors) and the negative pressures caused by the operation of mechanical exhaust systems within a building (e.g., bathroom exhausts, fume hoods, combustion furnaces). In addition, episodic weather conditions, such as wind and rain, can induce a pressure differential that results in transient increases in the building radon level.

Although the physics of radon transport into and retention in a building are complex (more than ten variables have been identified to date), it can be approximated as a simple dilution ventilation problem using a source term (pCi/h) into a fixed volume (ft^2), with a known ventilation rate (h^{-1}). Because the volume of a structure is fixed, the equation can be further simplified to demonstrate that elevated radon in a building is strongly linked to the overall ventilation rate of the building, meaning that buildings with high ventilation rates have lower elevated radon potential. Conversely, buildings with lower ventilation rates have higher elevated radon potential. However, the relationship between ventilation rate and radon concentration is not 1 to 1; at a constant source term, halving the ventilation rate doubles the radon concentration (EPA 1988a, *Radon Reduction Techniques for Detached Housing*, EPA 1988a, 625/5-87/017). This variable, air-change per hour (ACH), is a function of how tightly the building was constructed and is regulated by the requirements of local building and energy codes. Nationally, the ACH ranges for residential and nonresidential construction are from 0.25 h^{-1} in colder (e.g., Minnesota) or hot and humid (e.g., Florida) climates to over 1.5 h^{-1} in the temperate tropical areas (e.g., Hawaii). The significance of the relationship between indoor radon levels and a building's ACH is as follows. Assume for a source term that you have 500 pCi/L of soil gas (average for most parts of the United States) under a slab that results in a 2 pCi/L radon level (the approximate indoor national average) for a house with an ACH of 1 h^{-1} (typical for homes built in Hawaii). The same home in Tennessee, under identical conditions but with a typical ACH of 0.5 h^{-1}, would have a radon level of 4 pCi/L. However, if the home were located in the upper Midwest, with a typical ACH of 0.25 h^{-1}, the home would have 8 pCi/L. Therefore, when considering elevated indoor radon potential, in addition to the geological variables found in soil and rock, local building practices must be taken into account.

As can be seen in Fig. 6, a rain event that lasted only a few hours resulted in an order-of-magnitude increase in the radon concentration. The time required for the dissipation of such a radon spike depends mostly upon the ventilation rate of the building. For example, if the building has an air change rate of 0.5 h^{-1}, the spike would usually dissipate within 6 h (assume in this example that three air volumes are required to remove a gas pollutant). However, in some cases (e.g., buildings with tight envelopes or buildings with fresh-air makeup greatly reduced), the radon spike may require days or even weeks to fully dissipate. As a result, the integrated concentration in the room over time would vary significantly depending upon the frequency (how often) and quantity (how much) of rainfall within a certain time period.

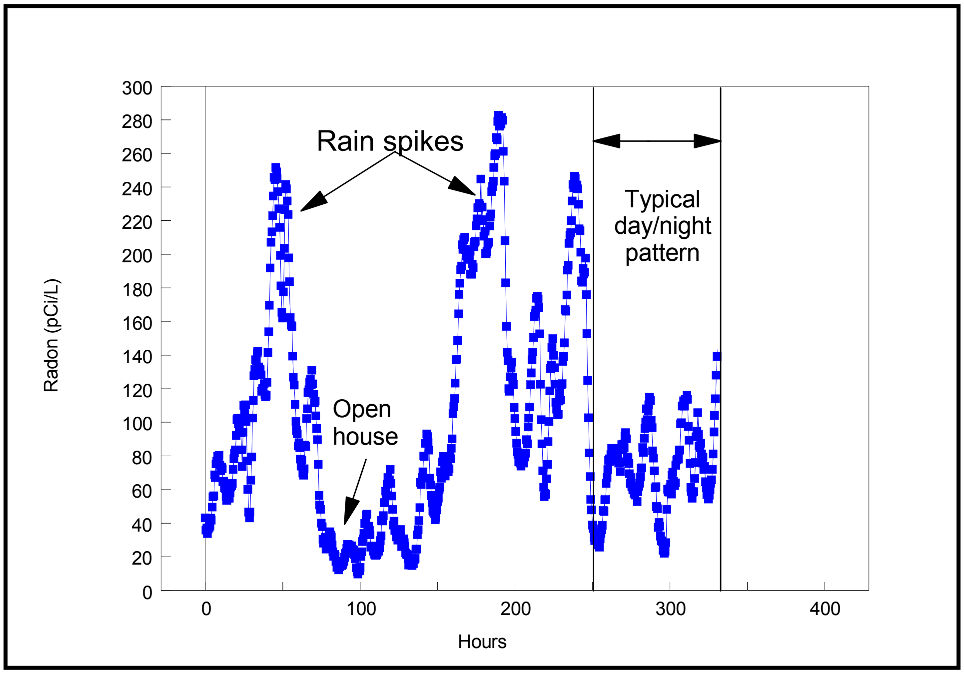


Fig. 6. Example of short-duration events on radon concentration.

1.3.2 Episodic Events that Impact Indoor Radon Levels

Unlike other common indoor environmental concerns (e.g., lead-based paint and asbestos), indoor radon concentration can vary significantly from day to day and from season to season. The day-to-day variation in radon concentration is usually caused by episodic weather events such as rain and wind but can also be caused by actions of the building occupants (e.g., leaving doors or windows open; see Fig. 6). For these reasons, EPA recommends that all short-term testing (testing for <90 days) be performed during normal weather patterns and under closed building conditions (e.g., windows and doors are closed except for routine entrances and exits). With respect to seasonal variation (e.g., heating vs. cooling season), the range observed is dependent upon the geographical region and climate. For example, in the northeastern United States, radon concentrations are typically 50% higher than normal in the winter, vs. 25% higher in the Southeast. Other studies (Lin et al. 1999) have found that a single short-term measurement is typically within a factor of 1.8 of the long-term measurement. Opinions vary as to why this is observed (e.g., increased stack effect in the winter, prolonged periods of closed building conditions, ground freeze, and snow cover), but most experts agree it results from a combination of many things and not just a single cause.

1.3.3 Distribution of Radon within Nonresidential Buildings

Residential studies by EPA have shown that on the same level, the radon concentration does not vary significantly from room to room in most homes. It is for these reasons that, other than recommending that the test be performed on the lowest occupied level, EPA protocols do not specify which rooms to test (EPA May 1993, 402-R-92-003). However, unlike in residential buildings, the distribution of radon within nonresidential buildings does vary significantly from room to room. In fact, studies by DOE have found that for buildings >2000 ft^2 with elevated radon, over 95% of the time, only one in four rooms tested positive (Wilson et al. 1991b). With respect to using statistical means to estimate the extent of elevated radon potential in large buildings, statistical analysis of large nonresidential data sets (Wilson et al. 1991b.) has found that over 70% of the time, the elevated result(s) would not have been predicted at a 95% confidence level. Further modeling of the radon data, the objective of which was to predict the presence of one room with elevated radon in a building, found with 95% confidence that 95% of the rooms needed to be tested. It is for all these reasons that EPA recommends the testing of all occupied ground-contact rooms in its nonresidential testing protocol (EPA July 1993, 402-R-92-014).

There are many accepted reasons for this disparity in room-to-room concentration. For one, slabs in nonresidential buildings are larger, meaning a greater volume of radon can accumulate in the fill area under the slab. In addition because of higher load considerations, large buildings typically have more internal footings and expansion joints per unit area of slab than does residential construction. Also, large buildings tend to have more numerous floor penetrations for water, sanitary, electrical, and communications purposes. Another difference is interior design: to prevent the spread of smoke during a fire, floor-to-ceiling fire walls are typically used throughout a large building. This design feature tends to isolate rooms and areas from one another within the building by reducing the natural flow of air from one zone to another. Finally, large buildings have larger mechanical systems, which move significant volumes of air. If these systems are not balanced, certain areas of the building may become depressurized relative to the soil beneath it. If openings are present within the slab in those rooms, the concentration of radon soil gas entering those rooms will increase significantly. In fact, DOE studies have found that in nonresidential buildings with elevated radon, only about one-third of the higher radon concentration is directly attributed to the elevated radon. Another third was attributed to a combination of mechanical and building design features.

In summary, the distribution of room-to-room radon concentrations in large buildings is different from the distribution in residential buildings simply because the buildings are designed and conditioned differently. For that reason, all occupied, ground-contact rooms need to be tested to determine if the occupant is at risk.

1.3.4 Surface Radon Potential and Indoor Radon Levels

In the late 1980s and 1990s, USGS, EPA, and DOE expended considerable effort in attempting to correlate radon soil gas concentrations and indoor radon levels (Tanner 1986 and 1992). The primary hypothesis of these studies was that if the radon flux at the surface could be measured accurately, the number of homes in a given area with elevated radon could be estimated. If true, this correlation would assist state and local governments in coordinating their respective radon programs and determining if radon-resistant features in new construction were needed. Unfortunately, during these studies, many variables at the surface/building interface were identified which proved difficult to estimate in advance (e.g., estimating the total leakage surface area of the slab for all cracks, joints, and plumbing fixture openings). In addition, order-of-magnitude changes in the radon soil gas concentration were observed at some of the sites because of variations in microgeology. Estimating a building's shell natural ventilation rate and the stack effect of the structure proved difficult as well. In light of all these uncertainties, EPA concluded that radon surface flux or soil gas measurements at a given location did not provide sufficient assurance whether indoor elevated radon would be present. In addition, the costs of such measurements were orders of magnitude higher than simply incorporating radon-resistant features into new construction and testing afterward.

1.3.5 Radon from Building Materials

The precursors for radon—uranium, radium, and thorium—are found naturally in all geological formations. Therefore, in any building where concrete (processed limestone) or decorative stone (e.g., marble, granite, shale) is present, radon is being emitted. In the case of concrete, in the 1970s, homes located in Durango and Grand Junction, Colorado, were found to contain high levels of radon in addition to high radiation levels. The source of the radon and radiation was later determined to be processed uranium mill tail sand that had been used as aggregate in the concrete and cement block in the homes. In response to the health hazards posed by this exposure, Congress enacted the Uranium Mill Tailings Radiation Control Act of 1978. This Act established two programs to protect the public and the environment from uranium mill tailings and prohibited the use of uranium mill tailing sands in building construction. In the 1980s similar problems with radon and elevated radiation were also found in the southeastern United States, where processed phosphate slag had also been used as an aggregate within concrete and cement block manufacturing. A series of environmental regulations were then enacted which prohibited the use of these materials in building construction as well.

For concrete that came from gypsum, fly ash, and limestone, studies by EPA in the late 1980s found minimal contribution to the indoor radon level. With respect to decorative stone, a series of news articles in 2008 indicated that high levels of indoor radon were linked to granite countertops. Studies by the decorative stone and radon industry and by EPA concluded that this claim was false for almost all granites on the commercial market.

More recently, however, the issue of elevated indoor radon linked to building materials has emerged within buildings that have had significant weatherization upgrades or in new construction with high energy-efficiency ratings. The common denominator in all cases observed thus far has been extremely low ventilation rates ($<0.1\ h^{-1}$) within buildings made of concrete (floor, walls, and ceilings). Although the emanation rate of radon from the concrete was found to be low (buildings at the same site made from the same concrete but without weatherization upgrades tested extremely low for radon), the low ventilation rate allowed the radon to concentrate (empirically speaking, if you halve the air change rate, you double the radon concentration). These findings, although rare (>99% of all elevated indoor radon is directly linked to radon soil gas), are predicted to become more common in the future as building codes require tighter buildings to address climate change concerns.

Another example of elevated radon levels from nontraditional sources is cases in which radon is emanating from materials stored within the building. For example, a storage facility containing approximately 1,000 tons of river sand (radon activity 0.07 pCi/g) gave rise to 8.5 pCi/L within the occupied areas of the building. Another facility that warehoused thorium lantern mantels was found to have elevated radon levels as well. Although these cases were extremely rare, the cause—substandard ventilation—was the same.

1.3.6 Radon from Groundwater Sources

The ^{222}Rn concentration in groundwater is due to the decay of ^{226}Ra contained within the rock and soil surrounding the aquifer. As radon gas is generated, it diffuses through the soil and rock and then percolates through the water. Because radon is soluble in water (230 cm^3/kg at 20°C), it can concentrate to levels much higher than that of the dissolved ^{226}Ra. Release of the radon into the indoor environment occurs at point sources wherever the water is used (showers, sinks, clothes washers) and from hot water heaters. According to EPA, approximately 10,000 pCi/L of radon in water is needed to increase the indoor radon level by 1 pCi/L. Because the average waterborne radon level in public groundwater supplies is 353 pCi/L (EPA 1985, 520/5-85-008), radon in water is not considered a major contributor to airborne radon exposure. However, according to the Centers for Disease Control (CDC), 30 to 1,800 deaths per year are attributed to the ingestion of radon in water. Because of these health concerns, Congress included radon in the 1996 Amendments to the Safe Water Drinking Water Act. To address this concern, EPA made available a multimedia mitigation program to address radon risks in indoor air and from drinking water. This option affords states the opportunity to develop enhanced state programs to address the health risks from radon in indoor air, while individual water systems reduce radon levels in drinking water to 4,000 pCi/L or lower. Currently, EPA is encouraging states and sister agencies to adopt this option because it is the most cost-effective way to achieve the greatest radon risk reduction.

1.4 RADON EXPOSURE RISKS

For many years, radon was not considered a health problem in residential buildings; however, in 1984, private homes in the Reading Prong area of Pennsylvania were discovered to have levels of radon in excess of federally mandated exposure limits for radiation workers. Nero et al. (1986) estimated that about one million American homes have radon levels in excess of 8 pCi/L. In 1988, studies by the National Research Council and BEIR found that excessive exposure to radon progeny resulted in a higher-than-predicted number of deaths from lung cancer in mining populations (BEIR VI 1988). Based on this and other information, the EPA estimated that from 5,000 to 20,000 lung cancer deaths per year are attributable to radon exposure (EPA 1986, *A Citizen's Guide To Radon*, OPA-86-004). In 1996 the World Health Organization (WHO) acknowledged that worldwide, radon exposure was the second leading cause of lung cancer, behind smoking (WHO April 1993). More recently, BEIR VI (1999) reinvestigated the health risks associated with radon exposure. Using information from previous studies and supplementing it with information from more recent laboratory studies, the committee estimated that approximately 11,000 lung cancer deaths per year were attributable to exposure to radon (BEIR VI 1998). These mortality estimates make exposure to radon the second-leading cause of lung cancer, behind smoking. However, statistically speaking, an individual's lifetime risk of dying from radon lies between the risks of being killed by a drunk driver and drowning (Fig. 7). Individual relative risk from radon exposure is summarized in Table 1. These findings were borne out by other studies noted by WHO in 2009 (WHO 2009). However, corrective actions (i.e. mitigation, see Chapter 3) greatly reduce these lifetime lung cancer risks (EPA May 2012, EPA 402/K-12/002).

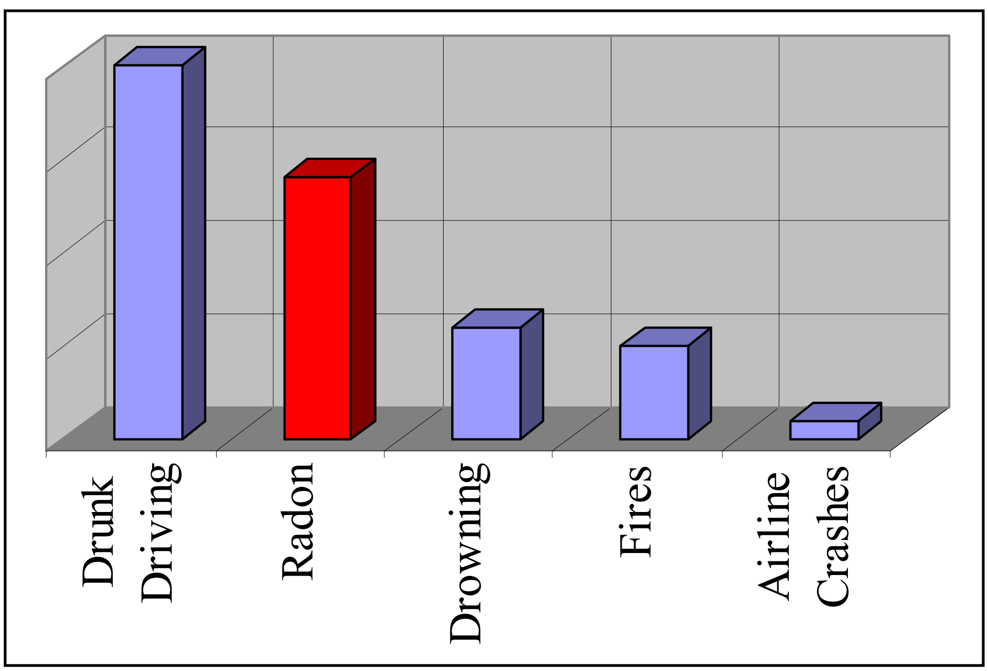


Fig. 7. Lifetime relative risks to radon exposure.

Table 1. Lifetime radon exposure risk

Radon level (pCi/L)	Number of lung cancer deaths per year per 1000 people	Comparable risks
200	440–770	More than 60 times the lung cancer risks of nonsmokers
		Four packs/day smoker
100	270–630	
		20,000 chest x-rays per year
40	120–380	
		Two pack/day smoker
20	60–120	
		One pack/day smoker
10	30–120	
		Five times non-smoker risks
4	13–50	
		200 chest x-rays per year
2	7–30	
		Nonsmoker risk of lung cancer
1	3–13	
0.2	1–3	20 chest x-rays per year

Source: EPA, *A Citizen's Guide to Radon,* OPA-86-004, 1986.

1.4.1 Impact of Radon Exposure on Lung Tissue

The subsequent radioactive decay products of ^{222}Rn, more commonly referred to as radon progeny, consist of four short-lived radon progeny (polonium-218 [^{218}Po], lead-214 [^{214}Pb], bismuth-214 [^{214}Bi], and polonium-214 [^{214}Po]) (Fig. 1)] and three long-lived radon progeny (lead-210 [^{210}Pb], bismuth-210 [^{210}Bi], and polonium-210 [^{210}Po]). Of these seven, typically only the short-lived progeny are considered a health risk. Unlike radon, which is chemically inert, radon progeny are chemically reactive metals that can attach to walls, floors, and airborne particles or combine with water vapor and other gases in the air. The portion of the radon progeny attached to particles in the ambient atmosphere is called the "attached fraction," whereas "unattached fraction" refers to suspended individual atoms or ultrafine particle clusters. Radon progeny that attach to walls or other surfaces are considered to be "plated out" and therefore removed from the air, so they can no longer be inhaled. When the short-lived radon progeny (attached or unattached) are inhaled, a portion of them can attach to the lining on the bronchioles of the lungs. Because of their short half-lives, the lung cannot clear itself of these materials before they undergo radioactive decay. Of particular importance are ^{218}Po and ^{214}Po, which emit highly energetic alpha particles. These alpha particles can strike sensitive cells in the bronchial tissue and cause damage that could lead to lung cancer. It is these two polonium radionuclides that produce the bulk of the radiation dose to the lung and create the greatest source of risk of lung cancer from exposure to radon and radon progeny (EPA May 1992, 400-R-92-011; EPA 1993a, 402-K-93-008). Additional information about the health risk associated with attached and unattached progeny is also provided in Section 2.1.2.

1.4.2 Radon-related Lung Cancer vs. Other Types of Cancer

Compared with other types of cancer, the National Cancer Institute's 2010 Surveillance, Epidemiology, and End Results study identified deaths from lung cancer due to radon as number 3, just behind deaths from leukemia and lymphoma (Fig. 8.). A copy of the study is available at http://seer.cancer.gov/csr/1975_2007/results_single/sect_01_table.01.pdf . Additional information can be obtained at http://www.cancer.gov/.

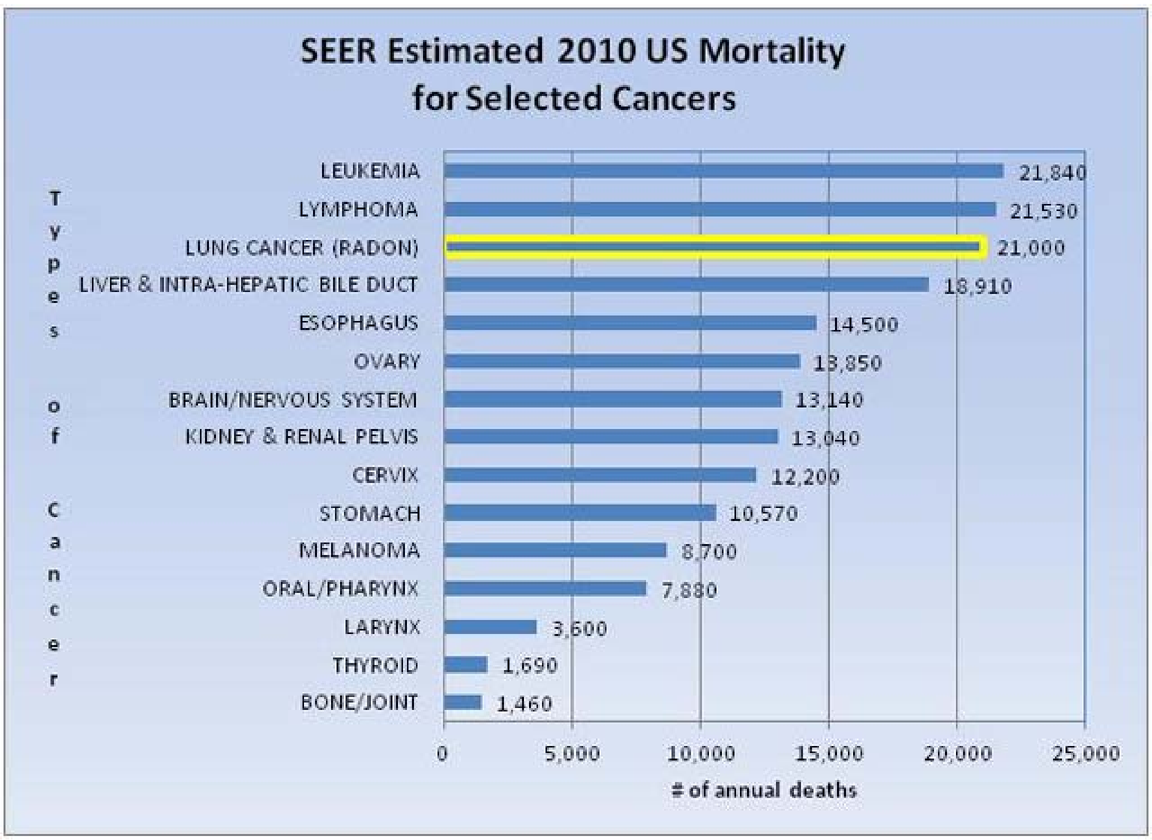


Fig. 8. Surveillance, Epidemiology, and End Results (SEER) 2010 findings.

1.5 EPA CORRECTIVE ACTION GUIDELINES

In 1986 EPA published the first of five subsequent editions of *A Citizen's Guide to Radon* (EPA 1986, 1994, 2007, 2009, 2012). Unlike other EPA publications, the follow-up editions did not supersede or replace previous editions; they only provided additional information and, in the case of subsequent editions (the most recent is EPA May 2012, 402-K-12-002), a more user-friendly format. The key points in these documents are as follows:

1. There are no safe levels of radon. Exposure to the average outdoor level found in the United States is roughly equivalent to 20 chest x-rays per year.
2. Because of the cost of reducing the radon levels in homes, EPA established a guideline of 4 pCi/L as an action level based on reducing the radon risk to the general population at a reasonable cost.
3. In the subsequent editions, the significantly increased risks of radon exposure and smoking were also included.

In the 1986 edition of *A Citizen's Guide to Radon*, EPA provided a recommended timeline for corrective action (Table 2). This timeline, although excluded from later editions, is still a useful guide in determining when to take corrective action. However, EPA currently recommends that corrective action be taken as soon as possible (EPA May 2012, 402-K-12-002).

Table 2. A Citizen's Guide to Radon corrective action schedule

EPA radon action levels (pCi/L)	Recommended actions
0 to <4	No action required
4 to <20	Mitigate within a few years
20 to <200	Mitigate within a few months
≥200	Mitigate within several weeks

Source: US Environmental Protection Agency, *A Citizen's Guide To Radon,* OPA-86-004, 1986.

In comparison, the WHO (WHO 2009) has recommend that the action level for industrialized countries be set at 100 Becquerel per cubic meters (Bq/m^3, 1 pCi/L= 37 Bq/m^3) or 2.7 pCi/L. Note that Bq/m^3 is the international unit of radon measure.

1.6 OCCUPATIONAL SAFETY AND HEALTH ADMINISTRATION AND RADON

In December 2002, the Occupational Safety and Health Administration (OSHA) acknowledged that radon in the workplace within a structure controlled by the employer would fall under CFR 29 1910.1096 (OSHA December 23, 2002). Therefore, occupational exposure to radon would fall under Department of Labor-OSHA standards. Under this standard, a Maximum Permissible Concentration (MPC) of 100 pCi/L for an adult worker during a 40 hour, 7 day period would be allowed. However, if this standard is applied in the workplace, additional measures must also be taken to ensure that the MPC is not being exceeded (e.g., airborne radiation hazard placarding, maintaining individual dose records, rad worker training, etc.). More details can be found at www.osha.gov. In lieu of this requirement, in 2011 OSHA suggested that the EPA 4 pCi/L guideline could be used (OSHA 2011, 3430-04-2011).

2. OVERVIEW OF RADON TESTING

2.1 RADON MEASUREMENT

As defined by EPA, radon measurements are of two distinct types: short term (2 to 90 days) and long term (91 to 365 days). The advantage of short-term measurements is that radon data can be collected quickly. In addition, because detectors are in the field for less time, the potential for field attrition is much lower. With respect to accuracy and cost, both types of measurements are comparable. However, unlike the levels of most pollutants, indoor radon levels are constantly changing. Studies by EPA and DOE have found that indoor radon levels can vary by as much as a factor of 10 from one season to another. Other studies have shown that the indoor concentration of radon can increase by a factor of 2 to 10 during short-duration weather events (e.g., rain, periods of high winds, and cold snaps; see Fig. 6). Because of these variations, EPA bases the health risks of radon exposure on an integrated annual average. When a short-term test is performed, EPA recommends that the measurement be performed under closed building conditions, which means that in a heating climate, the test should be performed ideally at the season midpoint with the building closed (e.g., windows and doors kept closed at all times) and not during periods of abnormal weather conditions. In addition, if the test is <4 days in duration, the house must be closed for at least 12 h before the placement of the testing device.

A long-term measurement offers the advantage of integrating the impact of short-duration weather effects over a longer period of time. Also, a long-term measurement can be performed during normal living conditions, thus minimizing the impact of radon testing on either work or living activities.

Because of these and other considerations, EPA recommends that any radon test be performed for as long as possible to provide the most accurate representation of the annual average. Because corrective action can be expensive, EPA recommends that follow-up measurements be performed in cases where elevated radon was detected and, in particular, in cases when abnormal weather occurred during the test period. Generally speaking, the higher the initial radon result, the more confidence one has that elevated radon is present. For example, if the initial radon result is ≥8 pCi/L, EPA recommends immediate short-term measurements be performed or mitigation performed (EPA January 2009, 402/K-09/001).

2.1.1 Types of Radon Gas Detectors

EPA divides short-term measurement devices into two categories, continuous and integrating. Continuous radon monitors (CRMs) typically measure radon gas or radon decay products in air. These measurements are performed in real time, meaning that the radon concentration can be measured and studied at fixed time intervals. To measure radon, room air is either pumped or diffused into a counting chamber that detects the ion particles generated by the radioactive decay of radon and its progeny. The counts per unit of time measured by the detector are then transmitted to a recording device (electronic or printer), where they are converted into picocuries per liter. Detection methods for CRMs include ion-trap, pulse ion-chamber, scintillation cell, or silicone integrated circuit detector. The typical exposure period for CRMs, as for most short-term devices, is 2 to 7 days. However, the chief advantage of CRMs over passive devices is the ability to "see" what is occurring by recording radon concentration as a function of time. When the instrument is downloaded and the data plotted, the impact of episodic weather events and other nonstandard tests (e.g., doors and windows left open) can be measured and quantified (Fig. 9). If used properly, CRMs are the most accurate of all short-term radon measurement devices. For example, most commercially available instruments are typically within 5% of the true radon concentration (vs. 15 to 25% for integrating devices). However, the disadvantage is the high initial purchase cost, $500 to $25,000 per CRM. Also, CRMs must be maintained and require periodic calibration.

Integrating devices average the radon exposure by absorption, physical damage to a film, or the loss of surface electrical potential. A key difference between integrating devices and continuous devices is that after the measurement has been performed, integrating devices are analyzed in an off-site laboratory. If integrating devices are used in high-priority, short-term measurements (e.g., real estate transactions or confirmation measurements), EPA recommends that the measurement be performed with collocated duplicate detectors (EPA May 1993, 402-R-93-003). Common examples of integrating radon detectors for short-term measurements are charcoal canisters and electrets.

A charcoal canister consists of an airtight container with a known quantity of activated carbon. To sample radon, the carbon is exposed to the area tested (typically, by removing the lid) for a period of 2 to 7 days. During the exposure period, the radon in the air is absorbed into the charcoal granules. At the end of the sampling period, the canister is sealed and returned to the laboratory for gamma spectroscopy analysis. After analysis, the corrected gamma counts per minute divided by the time of exposure are proportional to the radon concentration. The main advantage of using charcoal is its low unit cost. In large quantities, charcoal test kits can be obtained for under $5 per measurement (price includes canister and analysis). However, certain technical and logistical considerations can negate this cost advantage. Because charcoal permits the continual absorption and desorption of radon, this device does not give a true, integrated measurement over the exposure time. This means that the reported result may be significantly biased by either episodic or random events during the last 8 to 12 h of exposure. Another consideration is that all charcoal-based radon detectors have a maximum exposure limit. Because absorption sites within the charcoal granules are not specific, water and certain organic vapors compete with radon. Over time, these active absorption sites become irreversibly saturated with water, preventing further radon absorption. If water saturation occurs, the test must be repeated. Another consideration is holding time. At the laboratory, gamma spectroscopy analysis measures the quantity of radon presently absorbed in the charcoal. Because ^{222}Rn (the most common isotope of radon) has a half-life of 3.8 days, it is imperative that the canister be read within 2 weeks of the conclusion of sampling.

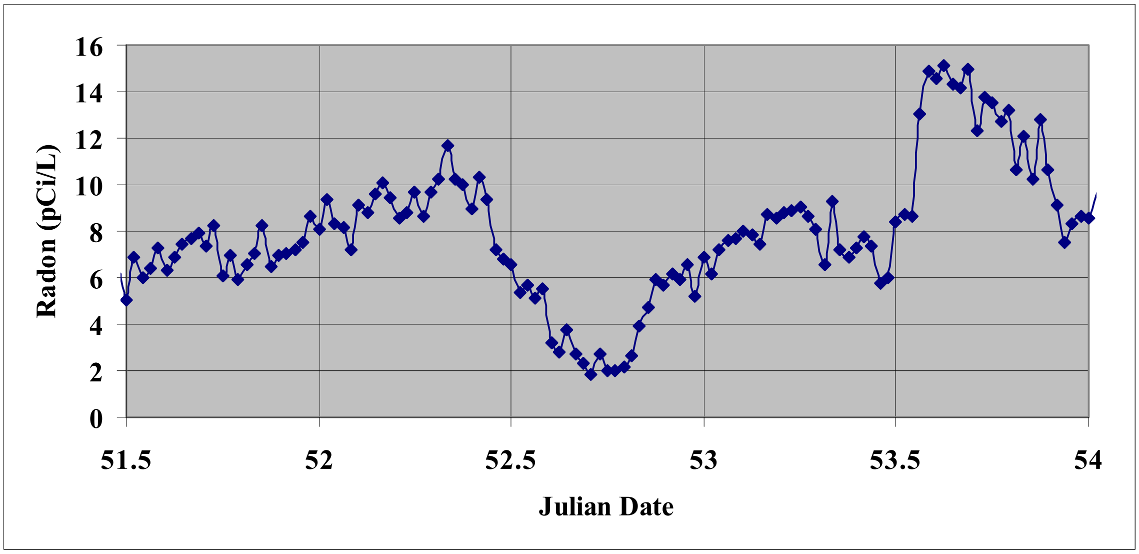


Fig. 9. Example of a continuous radon measurement.

Electret-based radon detectors consist of two distinct parts: the ion chamber and the electret (Fig. 10). The ion chamber is a specially designed holder for the electret, which is made of electrically conducting plastic. This feature permits the uniform discharge of any static energy generated by the decay of radon or radon daughters in the air inside the chamber. An electret consists of an electrically charged wafer of Teflon that has been treated to hold a stable electrostatic potential. This potential attracts oppositely charged ions that collect on the electret surface, thus neutralizing the surface charge and reducing the electrostatic potential. The surface potential is measured before and after exposure, using a specially designed voltage reader. The decrease in surface potential during exposure is proportional to the concentration of radon integrated over time. When new, the voltage of an electret is between 700 and 750 V, and the electret can be reused until the voltage drops below 200 V. The discharge rate, or volts per unit of time per radon concentration, depends on the volume of the ion chamber and on the sensitivity of the electret. High-sensitivity electrets discharge at a rate 11 times that of low-sensitivity electrets. For short-duration tests, such as 90 day tests, a higher discharge rate is needed for better accuracy. For example, a 90 day measurement conducted at 1 pCi/L of radon with a low-sensitivity electret would yield only a 6 V drop, whereas a high-sensitivity electret would yield a 66 V drop. The higher voltage drop results in an accuracy increase of about 50% in this example. Conversely, for longer exposures, such as 240 days, the drop in voltage for the high-sensitivity electret would be 176 V, or 35% of the usable voltage for the electret. The lower-sensitivity electret would drop by only 16 V, losing only 3% of its usable voltage.

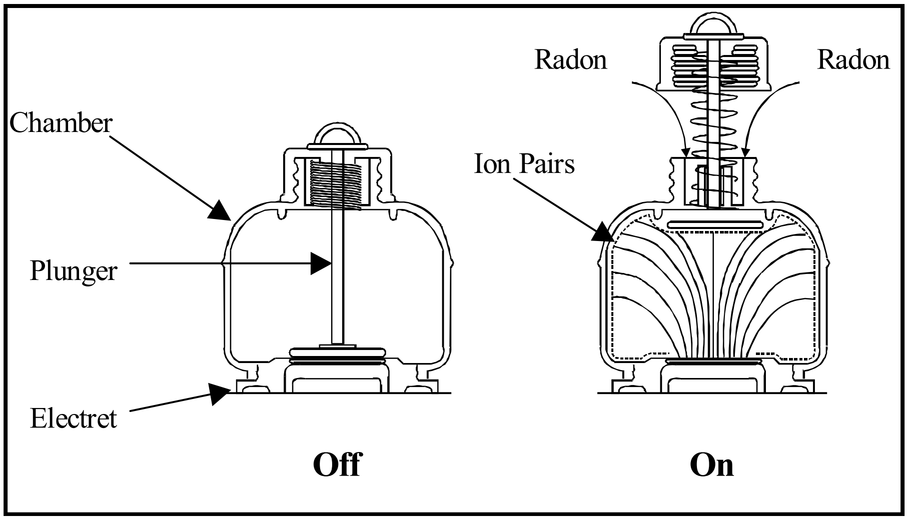
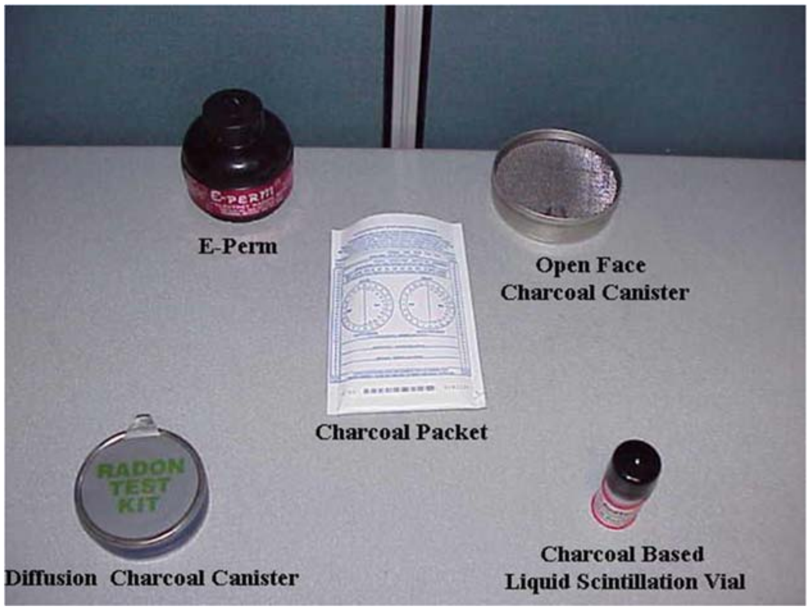


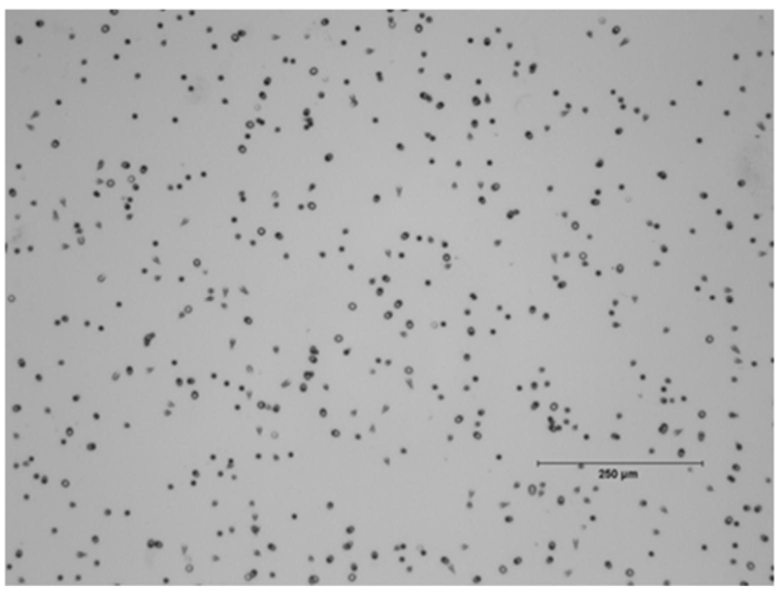
Fig. 10. E-Perm® electret-based radon detector.

As with charcoal, one of the major advantages of electret-based radon measurements is the low cost per measurement. Because electret-based detectors are reusable, electret measurements also can be performed for less than $5 (excluding field labor). Unlike charcoal canisters, electrets can be placed for more than 7 days and are insensitive to water and organic vapors. In addition, electrets are true integrating devices, meaning they are not dependent upon the last 8 to 12 hours of exposure. The total voltage discharge is proportional to the average radon concentration during the exposure period. Most important, electret readers are field portable; that is, detector analysis can be performed at the job location. However, unlike charcoal, an electret does have an upper limit for radon exposure. For new electrets, the maximum usable dose is approximately 250 pCi/L-days (1 pCi/L-day = 1 pCi/L exposure for 1 day). Therefore, each time an electret is used, care must be taken to ensure that sufficient usable voltage remains to perform the measurement. Typical short-term test kits are shown in Picture 1.

For long-term measurements (>90 days), using CRMs is generally not considered cost-effective. Instead, either electrets or alpha track detectors (ATDs) are used. ATDs, the oldest and best understood of long-term measurements, work on the principle of counting physical damage (tracks) to an acrylic chip (CR-39) caused by alpha particles generated during the radioactive decay of radon (Picture 2). During the deployment of an ATD, radon diffuses through a filtered membrane (in the most common type of ATD). If radon undergoes radioactive decay while in the holder, the subsequent radon daughters are attracted to the CR-39. If the daughters deposit on the surface of the CR-39, subsequent alpha decay will leave a submicroscopic track on the surface of the CR-39. After the ATD is retrieved, it is returned to the laboratory for development and analysis. This is performed by disassembling the ATD, removing the CR-39 chip from the holder, and placing the CR-39 chip in a heated caustic solution (potassium or sodium hydroxide) for about 12 to 24 h (depending on the vendor). The caustic development or etching enlarges the alpha tracks so that they can be viewed and counted under a microscope. The tracks per unit of area (track density) as a function of time (days) are proportional to the radon concentration (pCi/L). Picture 3 shows typical ATDs by different manufacturers. Table 3 provides a summary comparison of the most common types of passive detectors.



Picture 1. Typical short-term test kits



Picture 2. Typical tracks (dark spots) on a developed ATD chip

Picture 3. Typical ATD by different manufactures

Table 3. Summary comparison of passive radon detectors

Detector Type	**Passive/ active**	**Typical uncertainty a [%]**	**Typical sampling period**
Alpha-track detector (ATD)	Passive	10 – 25	1 – 12 months
Activated charcoal detector (ACD)	Passive	10 – 30	2 – 7 days
Electret ion chamber (EIC)	Passive	8 – 15	5 days – 1 year
Electronic integrating device (EID)	Active	~ 25	2 days – year(s)
Continuous radon monitor (CRM)	Active	~ 10	1 hour – year(s)
Uncertainty expressed for optimal exposure durations and for exposures 5.4 pCi/L (200 Bq/m ^{3})			
Source: Table 6, WHO Handbook on Indoor Radon (2007)			

2.1.2 Measurement of Radon Decay Products

Although measuring radon gas in air is the most common method used today by radon testing companies within the United States, another method measures the radiological activity of radon progeny that have become attached to particles suspended in air. To perform this measurement, the equilibrium ratio (ER) must either be determined or assumed. Simply speaking, the ER is the percentage of radon daughters attached to particles that are suspended in air. The ER is calculated by dividing the total concentration of radon decay products (RDPs) present by the concentration that would exist if the RDPs were in radioactive equilibrium with the radon gas concentration present. Therefore, at equilibrium (i.e., at an ER of 1.0), one working level (WL) of RDPs would be present when the radon concentration was 100 pCi/L. However, because of ventilation and plate-out (the attachment of RDPs to the walls, floors, or objects within the room), the ratio can never be 1.0. Residential studies performed by EPA found typically an average ER of 50% (the range was from 30 to 70%) for typical residential structures with average air recirculation rates.

In most nonresidential buildings, however, the ERs are consistently lower, ranging from 5 to 30% with an average ER of 25%. The exact reasons for the lower average ER are subject to debate. But most nonresidential buildings are nonsmoking, do not have pets, have more efficient heating and air-conditioning filters, and are usually cleaned more frequently. Therefore, for the most part, the common sources for residential particles in air are absent.

To convert from units of WL to equivalent gas concentration in pCi/L, the WL is multiplied by 100 and then divided by the ER (Eq.[1]). For example, 0.02 WL (RDPs) × 100/0.5 (50% ER assumed) would equal an equivalent gas concentration of 4.0 pCi/L. It is important to note that if the ER is assumed, the gas concentration should be identified as “equivalent gas concentration” to avoid confusion. Table 4 shows equivalent gas concentration in picocuries per liter at various WL concentrations and ER at a 4 pCi/L gas concentration.

$$\textbf{Radon (pCi/L)} = \frac{\textbf{WL} \times \textbf{100}}{\textbf{ER}}$$

Equation 1. Conversion from gas to WL

For many years EPA set the action level for measuring RDP at 0.02 WL (EPA May 1993, 402-R-92-003, and EPA November 2006a, 402-K-06-093), which is equivalent to a 4.0 pCi/L gas concentration at an ER of 0.5 (the default value recommended by EPA if the ER is unknown). But in 2007 EPA lowered the action level from 0.02 to 0.016 WL (the gas concentration action level remained unchanged at 4.0 pCi/L) and decreased the assumed ER to 0.4 (EPA May 2007, 402-K-07-009). However, in the most recent *Citizen’s Guide*, testing options using RDP were not included (EPA January 2009, 402/K-09/001). Instead, only radon gas measurement options were provided.

Table 4. Equivalent gas concentrations at 4 pCi/L for various equilibrium ratios

Equilibrium ratio	Working level	Equivalent gas concentration (EpCi/L)
0.05	0.002	0.4
0.1	0.004	0.8
0.2	0.008	1.6
0.3	0.012	2.4
0.4	0.016	3.2
0.5	0.02	4.0
0.6	0.024	4.8
0.7	0.028	5.6

For many years EPA set the action level for measuring RDP at 0.02 WL (EPA May 1993, 402-R-92-003, and EPA November 2006a, 402-K-06-093), which is equivalent to a 4.0 pCi/L gas concentration at an ER of 0.5 (the default value recommended by EPA if the ER is unknown). But in 2007 EPA lowered the action level from 0.02 to 0.016 WL (the gas concentration action level remained unchanged at 4.0 pCi/L) and decreased the assumed ER to 0.4 (EPA May 2007, 402-K-07-009). However, in the most recent *Citizen's Guide*, testing options using RDP were not included (EPA January 2009, 402/K-09/001). Instead, only radon gas measurement options were provided.

The most common WL measurement devices are CRMs or electrets that consist of a pump, filter paper, and detector. The basic principle of operation is that dust particles with the RDPs attached become trapped on the filter paper. The detector then measures the alpha particles emitted by ^{218}Po and ^{214}Po as a function of time and flow rate. Studies have shown that even common occurrences within buildings can change the ER and, in turn, affect the WL measurement. For example, simple routine occurrences such as smoking, lighting a candle, cooking, dusting, or vacuuming have resulted in doubling the response of the WL meter. Conversely, increasing the amount of air movement within a building by turning on a ceiling fan or the heating and air-conditioning blower can reduce the response of the WL meter by up to 1 order of magnitude.

The generally accepted theory for why routine activities such as cooking or vacuuming affect the measurement is that they generate additional airborne particles, increasing the number of sites suitable for RDP attachment and their subsequent capture on the instrument's filter paper. This results in an increase in measured WL. The reasons why a ceiling fan or heating system blower cause a decrease in instrument response are not as clear. As a result, two divergent but viable theories have been proposed. In the first theory, it is assumed that the RDPs, once adhered to an airborne particle, become irreversibly attached. As these particles (including the attached RDP) collide with a fixed object in the room, they become "stuck" and are removed from the breathing zone. For RDPs that are not attached to particles, the increase in air velocity increases the probability that they will also collide with a fixed object in the room and become irreversibly attached. However, the second theory assumes that some of the RDPs are not irreversibly attached to airborne particles. Increasing the air velocity in the room also increases the frequency and the energy of collisions between air molecules and attached

RDPs. As a result, some of the attached RDPs are dislodged and become unattached once again. Because these unattached RDPs (more accurately visualized as molecules) are small enough to pass through the filter paper on the WL meter and not become trapped, the instrument would not be able to measure the emitted alpha particles.

The importance of what exactly is happening with the unattached RDPs is not academic. It has a direct bearing on the dose and hence the risk of contracting lung cancer. It is generally acknowledged that the respiratory system filters out a significant number of RDPs attached to large particles in the nose and throat. The greater risk comes from the RDPs attached to smaller particles that manage to get past the body's natural defenses and penetrate deeper into the lung. In addition, it is well known and accepted that unattached RDPs have a 20–30 times greater efficiency in delivering a dose to lung tissue. Therefore, any increase in unattached RDP concentration, no matter how small, in the breathing zone would significantly increase the dose to lung tissue.

Because of the higher risk associated with ERs >50% (an ER of 3 pCi/L at 0.65 is equivalent in risk to 4 pCi/L), EPA rationalized that WL measurements should continue to be listed as a viable testing method. However, these measurement uncertainties (in particular when the ER is unknown or highly variable) and the difficulty in interpreting the data were the primary reasons that WL measurements generally fell out of favor with the radon testing industry.

2.1.3 EPA Radon Testing Protocols for Nonresidential Buildings

Although considerable information is available for testing within family housing, the only document published by EPA for radon testing in nonresidential building is for schools (EPA July 1993, 402-R-92-014). In this protocol, EPA states that because of room-to-room variation in radon concentrations, the only way to know if an individual room or area has a high level of radon is to test. As a result, EPA recommends that all frequently occupied rooms in contact with the ground or over a crawlspace be tested for radon. In addition, rooms with walls in ground contact and rooms directly above a basement space that is not frequently occupied should be tested. Large open areas should be tested at an interval of one testing location for every 2,000 ft^2. Areas such as restrooms, hallways, stairwells, elevator shafts, utility closets, and storage closets need not be tested. More recently, the American National Standards Institute (ANSI), in conjunction with the American Association of Radon Scientists and Technologists, has published MALB 2014, an updated set of testing standards for schools and other large buildings (ANSI 2014.). EPA has classified this standard as a "Current Standards of Practice" (see http://www.epa.gov/radon/pubs/index.html) and recommends its application.

2.1.4 EPA Radon Testing Requirements for Federal Agencies

In response to the requirements in the 1988 IRAA, EPA released an updated version of the *Citizen's Guide* (and provided to its sister agencies additional guidance on how to conduct a radon testing program. This guidance also included minimum criteria for quality assurance and quality control (QA/QC) for radon testing within federal buildings (most of these recommendations were eventually incorporated in EPA July 1993, 402-R-92-014). Specifically the document called for each building tested to have

- blanks (5% or 25, whichever was smaller)
- collocated duplicates (10% or 50, whichever was less)
- spikes (no limits were provided, but 3% was recommended in the reference document)

For analysis of the QC data, EPA stated that the procedures presented in *Indoor Radon and Radon Decay Product Measurement Device Protocols* (EPA-520/1-89-009) should be used. However, in 1992, this document was superseded by EPA 402-R-92-004 (EPA July 1992).

For blanks, EPA requires monitoring of the background exposure that may have accumulated during shipment and storage of the testing devices. Because each type of radon testing device (e.g., ATD, charcoal, or electret ion chamber) responds differently to background exposure, the EPA protocol provides device-specific corrective action if a reading is found to be significantly greater than the lower level of detection. For example, for electret ion chambers (EICs), EPA requires that 5% of the EICs or 10, whichever number is smaller, be set aside to track voltage drift. Over a 3 week test period for the EICs, any voltage loss found in the control EICs of more than 1 V per week should be investigated. In addition, because EICs are sensitive to background gamma radiation, a correction must be multiplied by the gamma radiation level at the site (in μR/h) and the product (in equivalent pCi/L) subtracted from the apparent radon concentration. If the gamma radiation at the site is unknown, then a measurement would need to be performed directly using appropriate radiation detection instruments.

The objective of performing simultaneous or duplicate measurements is to assess the precision error of the measurement method, or how well two side-by-side measurements agree. This precision error is the "random" component of error (as opposed to the calibration error, which is systematic). The precision error, or the degree of disagreement between duplicates, can be composed of many factors. These include the error caused by the random nature of counting radioactive decay, slight differences between detector construction (for example, electret chamber volume), and differences in handling of detectors. With respect to collocated duplicates, EPA recommends using the relative percent difference (RPD, Eq. [2]) as the best indicator of overall precision in radon measurements.

$$\textbf{Relative percent difference} = \frac{\textbf{(Highest pCi/L} - \textbf{Lowest pCi/L)} \times \textbf{100\%}}{\textbf{Mean}}$$

Equation 2. Relative percent difference

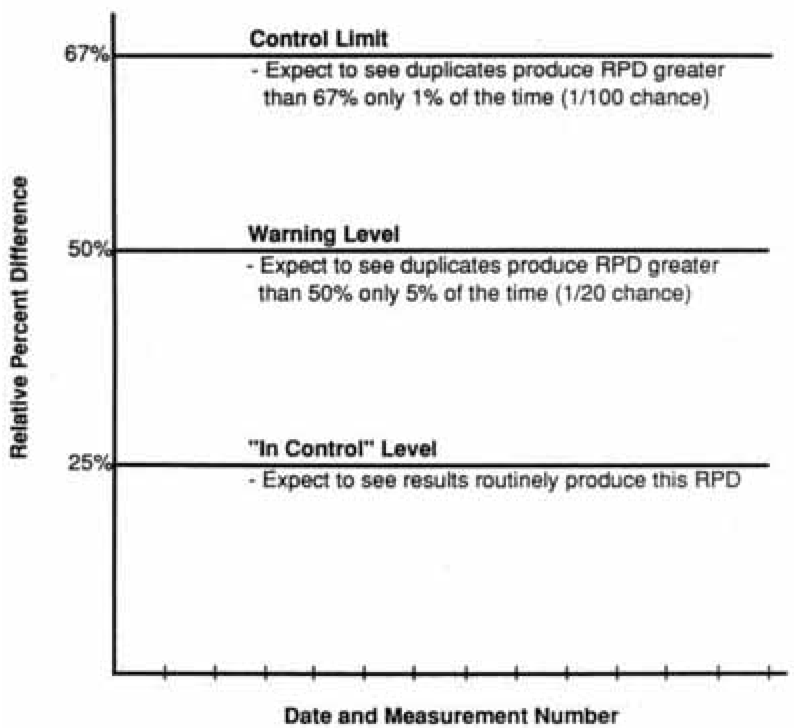
(from *Quality Assurance Handbook for Air Pollution Measurement Systems: Volume I,* EPA 600/9-76-005 [EPA 1984])

Ideally, the results of duplicates should be assessed in a way that allows for determining the level of chance associated with a particular difference between duplicates. This will allow for the predetermination of limits for the allowable differences between duplicates before the cause of large differences is investigated. For example, the warning level, or the level of discrepancy between duplicates that triggers an investigation, may be set at a 5% probability. This level is a difference between duplicates that is so large that, when compared with previous precision errors, should be observed only 5% of the time. A control limit, at which further measurements should cease until the problem is corrected, may be set at 1% probability.

A control chart for duplicates is not as simple as a control chart used to monitor instrument performance, as for a check source. This is because the instrument's response to a check source should be fairly constant with time. Duplicates are performed at various radon concentrations, however, and the total difference between two measurements is expected to increase as radon levels increase. Because of the difficulties in measuring radon at low levels, EPA guidelines recommend that the acceptance criteria be based on the average of the two results relative to 4 pCi/L. After the RPD is calculated, its value is plotted on one of the two applicable control charts by date and average radon concentration (Figs. 11 and 12). Over time, the RPDs are evaluated based on the overall number of results within the respective ranges (i.e., in control, warning level, and control limit). If the number of data points exceeds what would be predicted at the warning level, then investigation into the cause of the problem is warranted. If however, a significant number of data points are at or beyond the control limit, then measurements should cease until the problem has been identified and corrected.

EPA provides a statistical table (Table 5) for determining what constitutes a significant number of RPD warnings and failures. The required action is based upon the number of failures and the total number of data available. For example, if two sets of duplicates had RPDs outside the warning level, and between 2 and 7 sets of data were within the control limit, EPA would recommend that analysis stop until the problem had been identified and corrected. However, if between 8 and 19 sets of acceptable data had been obtained, it would be necessary only to investigate the problem.

Control Chart* for Relative Percent Difference (RPD)
Based on an "In Control" Level of 25% (=COV of 18%)
(For duplicates where average <4 pCi/L or 0.02 WL)



RPD=difference between two measurements divided by their average

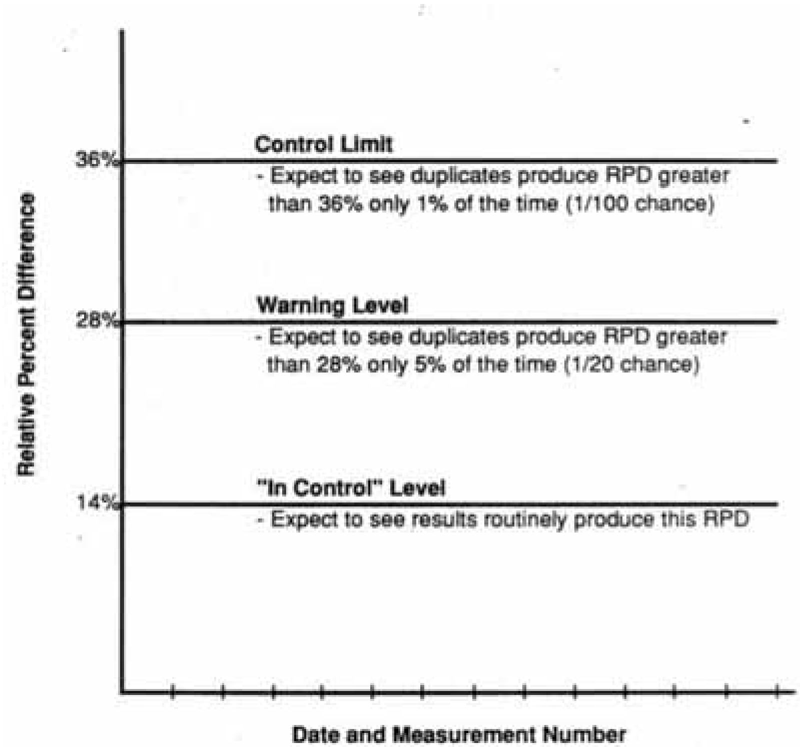
Example: Detector A=2 pCi/L, B=3 pCi/L, RPD=40%

If RPD exceeds the *control limit*—cease measurements until the problem is identified and corrected.

If RPD exceeds the *warning level*—follow guidance in *Section B.3* and see Exhibit B-5 within *Protocols for Radon and Radon Decay Product Measurements in Homes* (EPA 1993, 402-R-93-003)

Fig. 11. Control chart for RPD for average radon results <4 pCi/L.
(*Protocols for Radon and Radon Decay Product Measurements in Homes* [EPA May 1993])

Control Chart* for Relative Percent Difference (RPD)
Based on an "In Control" Level of 14% (=COV of 10%)
(For duplicates where average $\geq$4 pCi/L or 0.02 WL)



RPD=difference between two measurements divided by their average

Example: Detector A=5 pCi/L, B=6 pCi/L, RPD=18%

If RPD exceeds the *control limit*—cease measurements until the problem is identified and corrected.

If RPD exceeds the *warning level*—follow guidance in *Section B.3* and see Exhibit B-5 within *Protocols for Radon and Radon Decay Product Measurements in Homes* (EPA May 1993, 402-R-93-003)

Fig. 12. Control chart for RPD for average radon results >4 pCi/L.
[*Protocols for Radon and Radon Decay Product Measurements in Homes* (EPA May 1993, 402-R-93-003)]

Table 5. Criteria for taking action for measurements outside the warning levela

Number of duplicate results outside the warning level	Total number of duplicates	
	Investigate, but continue operation A	**Stop operation until problem is corrected B**
2	8–19	2–7
3	17–34	8–16
4	29–51	17–28
5	41–67	29–40
6	54–84	41–53
7	67–100	54–66

[a]Modified from Goldin (Goldin 1984) and based upon cumulative probability tables of the binomial distribution.

Protocols for Radon and Radon Decay Product Measurements in Homes (EPA May 1993, 402-R-93-003).

EPA addresses spikes by requiring laboratories (organizations that read electrets are considered laboratories) to maintain a performance ratio (Eq. [3]) between 0.75 and 1.25. If the performance ratio is outside the range, EPA recommends that the measurement cease until the problem has been identified.

$$\text{Performance Ratio} = \frac{\text{(Mean Measured Value)}}{\text{Target Value}}$$

Equation 3. Performance ratio

2.1.5 Radon in Water

EPA has recommended two methods for routine measurement of radon in water. The emanation method, in which radon is degassed from the water and transferred into a Lucas scintillation cell, has a detection limit of approximately 0.05 Bq/L (1 pCi = 0.037 Bq) for a sample volume of 100 mL (Crawford 1989). In the liquid scintillation method, the water is injected directly into a scintillation solution and counted in an automated liquid scintillation device; this method has a detection limit of about 0.4 Bq/L using a sample volume of 10 mL (Prichard and Gesell 1977) and EPA Method 913 (EPA June 1991, Report EMSL/LV). All methods require careful sampling because of the rapid loss of radon from the water when it is agitated and open to the atmosphere. The EPA [EPA 1991, *Fed. Regist.* **56**(138): 33050] estimated a practical quantization limit for radon in water (based on the ability of laboratories to measure radon within reasonable limits of precision and accuracy) at about 10 or 11 Bq/L (1 pCi/L = 37 Bq/m^3).

3. OVERVIEW OF RADON MITIGATION

3.1 EPA RADON MITIGATION SYSTEM CATEGORIES

EPA divides radon mitigation into two basic categories: passive and active. Passive mitigation is defined as a non-mechanical means of radon abatement or control. Examples of passive mitigation include sealing cracks, balancing an existing mechanical system, or increasing the natural ventilation rate of the building substructure (i.e., crawlspace). For the remaining lifetime of the building, passive radon techniques are generally considered the most cost-effective means of radon control. Typically, installation costs for a passive system are less than half those of an active system, and a passive system has no operation and maintenance (O&M) costs (i.e., energy for operation). Unfortunately, successful passive mitigation has proved difficult because all radon entry pathways within the room or building must be identified and negated. However, noted success has been observed in buildings with drainage sumps, French and perimeter drains, and major openings exposed to soil (e.g., wall pipe penetrations and beam pockets). For buildings in which these significant soil gas conduits are not present, the effectiveness of passive mitigation measures is greatly reduced. Another form of passive mitigation is the restoration of a building's mechanical systems (heating, ventilation and air-conditioning [HVAC]) and exhaust to the original design specifications. This would include rebalancing the building's conditioned air supply, return air, fresh-air and exhaust air volumes.

Active mitigation entails the use of mechanical means, such as a fan or blower, to control radon entry into the living area. Generally speaking, all active mitigation methods can be grouped into two categories: pre-entry and post-entry mitigation. Pre-entry mitigation is a technique that retards radon entry into the living area. Common examples of this type are shell pressurization (SP) and active soil depressurization. Post-entry mitigation involves the treatment of the radon-laden air inside the room or building. Examples are energy recovery ventilation (ERV), supplemental air mitigation (SAM), and high-efficiency particulate air (HEPA) filtration (currently not supported by EPA, see Appendix A).

3.1.1 Shell Pressurization Mitigation

SP, the oldest radon mitigation method, retards radon entry by mechanically introducing sufficient outdoor air to the building to induce a positive pressure (typically ≥4 Pa) across the slab and into the soil (Fig. 13). The two basic designs (with minor variations) are

- Type 1 SP: Uses the building's existing mechanical system to condition the required volume of outdoor air (Fig. 13).
- Type 2 SP: Uses an independent mechanical system to condition the outdoor air before its discharge into the structure (Fig. 14).

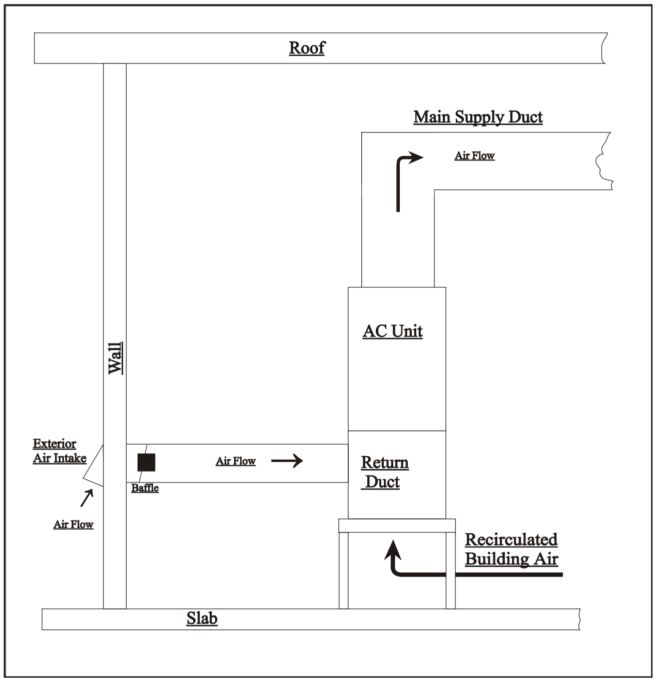


Fig. 13. Example of a Type 1 SP system.

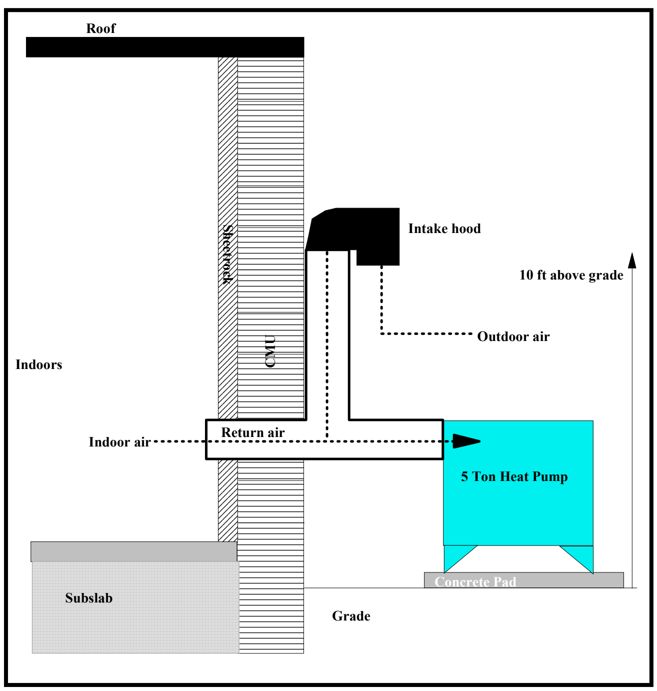


Fig. 14. Example of a Type 2 SP system.

The deciding factor for the selection of a Type 1 or Type 2 SP system is the ability of the existing mechanical system to condition the added volume of outdoor air. Although this information is readily available on the as-built design drawings or the unit itself, with older equipment (e.g., ≥5 years old) performance degradation may be an issue that needs investigation before Type 1 SP mitigation is attempted. Assuming that the HVAC unit has sufficient capacity to condition the additional outdoor volume, the existing fresh-air duct (from the exterior intake to the return air box) is replaced with a larger duct and a higher-capacity damper. A popular cost savings option in this case is the addition of an inline blower fan to the existing air intake duct in lieu of replacement. For buildings without existing intake air ductwork, an appropriately sized duct is run from the exterior to the return box of the unit.

For Type 2 SP mitigation, there are many varieties of commercially available units which can condition the required outdoor air volume. Selection of the most appropriate unit is based mainly on the volume of outdoor air and the year around climate conditions. Common examples are

- single-pass HVAC or heating/air-conditioning units that bring in 100% fresh air (i.e. there is no return air)
- desiccant makeup air units
- split units with a dedicated air makeup
- specially modified heating/air-conditioning units

Although a highly effective radon mitigation technique, SP is extremely vulnerable to occupant interaction. The technique works only as long as the building is under positive pressure. Therefore, all windows must be kept closed year around and doors opened only for normal entrances and exits. In addition, all the pre-filters (bug screens) and system filters must be cleaned or replaced frequently (e.g., weekly or monthly) to ensure that the required volume of fresh air is being supplied. The energy penalty (e.g., the energy cost to condition the outdoor air before it is discharged into the building) is also quite high. For all these reasons, SP mitigation is generally considered the last mitigation alternative.

3.1.2 Active Soil Depressurization Mitigation

Active soil depressurization consists of two main types of mitigation techniques, subslab depressurization (SSD) and submembrane depressurization (SMD). For buildings with slabs or basements, SSD is the most common means of radon control within the United States. This method uses a pipe inserted through the slab and a fan connected to the pipe (Fig. 15). When the fan is activated, the area beneath the slab (subslab) is depressurized. The resulting depressurization prevents radon entry into the living area by redirecting the subslab radon into the pipe for discharge into the atmosphere, where it is harmlessly diluted. However, the overall effectiveness of SSD is limited by pre-existing conditions under the slab that can impede the extension of the vacuum field (e.g., compacted fill, presence of grade beams, enclosed utility vaults, and interior foundations are common conditions that reduce the vacuum field extension). Slab size is another consideration. Under ideal conditions (e.g., noncompacted fill, no grade beams or other structures impeding vacuum) a single SSD system with a 4 in. vent duct (the most common size) can typically depressurize between 2,000 and 5,000 ft^2 of subslab. Systems with vent ducts larger than 4 in. can depressurize up to 10,000 ft^2; however, they typically cost more to install than multiple 4 in. duct systems. Therefore, in larger buildings, the use of two or more independent systems is not uncommon.

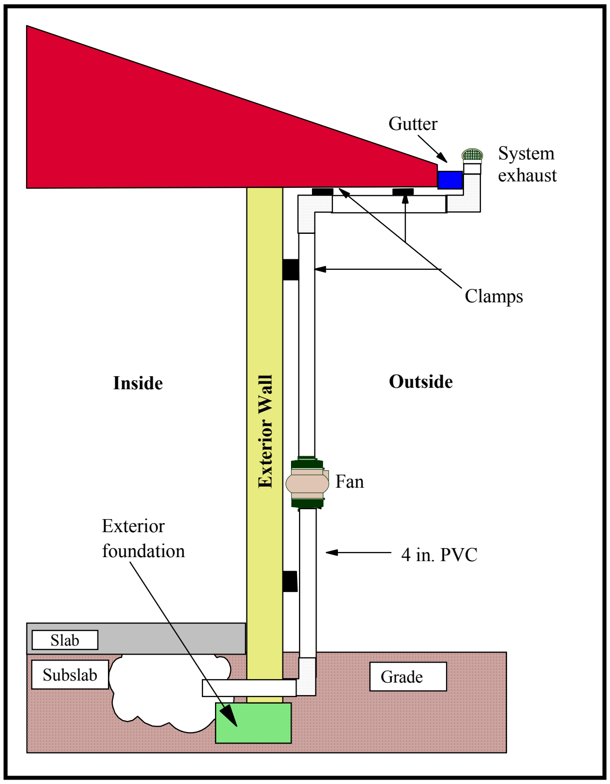


Fig. 15. Type 1 SSD system.

The three basic designs (with minor variations) are

1. Type 1 SSD: an externally mounted pipe/fan system with an exterior penetration (Fig. 15)
2. Type 2 SSD: an externally mounted pipe/fan system with an internal penetration (Fig. 16)
3. Type 3 SSD: an interior pipe penetration with a roof- or attic-mounted fan (Fig. 17)

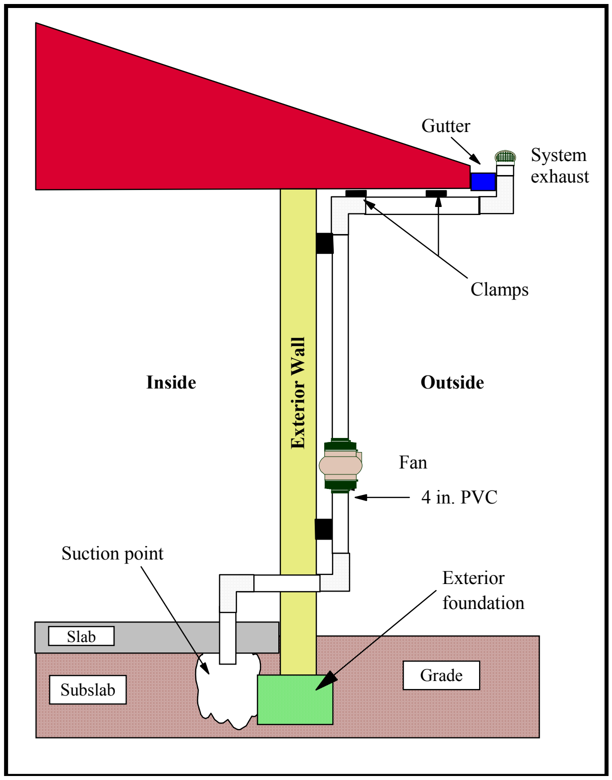


Fig. 16. Type 2 SSD system.

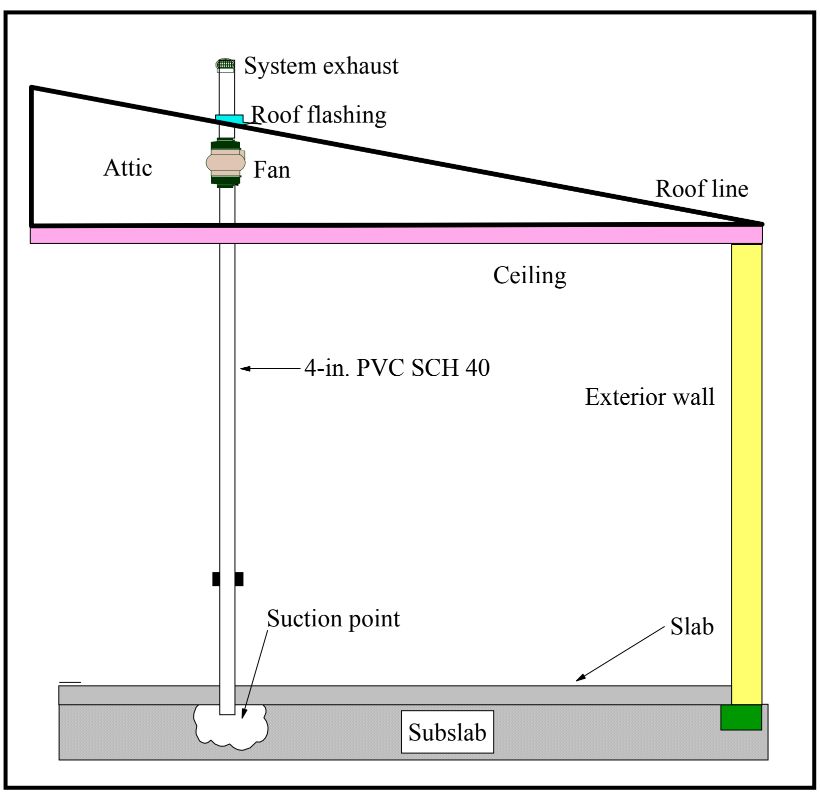


Fig. 17. Type 3 SSD system.

Another consideration in selecting an SSD design is planning for future O&M of the radon system. Although SSD systems do not require any specific routine maintenance, some system components will need to be replaced eventually because of failure or as part of a preventive maintenance schedule. In addition, to verify that the system is working, EPA recommends periodic checks of the system performance indicator in addition to inspecting the system every 2 years.

Although the time required for these checks and repairs is minimal (typically just a few minutes), gaining access to the interior of the building can be a time-consuming process. For example, studies conducted by ORNL within Department of Defense nonresidential buildings have found that one-third to one-half of the time expended for Type 3 SSD repairs and inspections was used arranging for access. Conversely, minimal interaction was required for Type 1 and 2 SSD systems. Another consideration is nonresidential roofing. Commercial buildings usually have complex roofing systems that are warranted or bonded by the contactor for a fixed number of years. Installing a pipe through this roof without the support or permission of the contractor would void the warranty for not only the area where the penetration occurred but also potentially the entire roof.

EPA, the American Society for Testing and Materials (ASTM), and ANSI (EPA 1994, 402-R-93-078; ASTM E2121-13; and ANSI 2014, RMS-LB 2014) require that SSD system performance indicators be simple to read or interpret and be located where they are easily seen or heard by building occupants and protected from damage or destruction. The simplest and most common performance indicator, the manometer, deflects a volume of oil in a U-tube. Others rely on an electrical pressure sensor to trigger either a warning light or audible alarm.

For buildings with crawlspaces, SMD is usually used. Placing a polymeric membrane, such as a plastic sheet (typically ≥ 10 mil in thickness, 1 mil = 0.001 in.), on the floor of the crawlspace and depressurizing underneath the membrane with a fan channels the radon into a vent pipe and discharges it into the atmosphere above the roofline of the building.

3.1.3 Energy Recovery Ventilation Mitigation

ERV mitigation works solely on the principal of indoor volume dilution. This is accomplished by the use of a commercially available unit (Fig. 18) that exchanges a fixed volume of indoor air with an equal volume of outdoor air (units range in capacity from 100 to 100,000 cfm). Selection of the correct size unit is critical and is based on the cubic volume of the room or building being ventilated, the current ventilation rate (measured in ACH), and the initial radon concentration. Empirically speaking, doubling the ACH in the room or building will reduce the radon levels by 50%.

Although ERV is a proven mitigation technique, installation and operational costs (e.g., routine maintenance on filters, drive belts and motors, and desiccant wheel) are significantly higher than for SSD mitigation (Section 1.6.7). Furthermore, because of conditioned air loss during the exchange process (most units typically recover 80%), the energy penalty can be quite high for high-capacity units. This energy deficit may become problematic if the existing HVAC system lacks the capacity to make up for the loss.

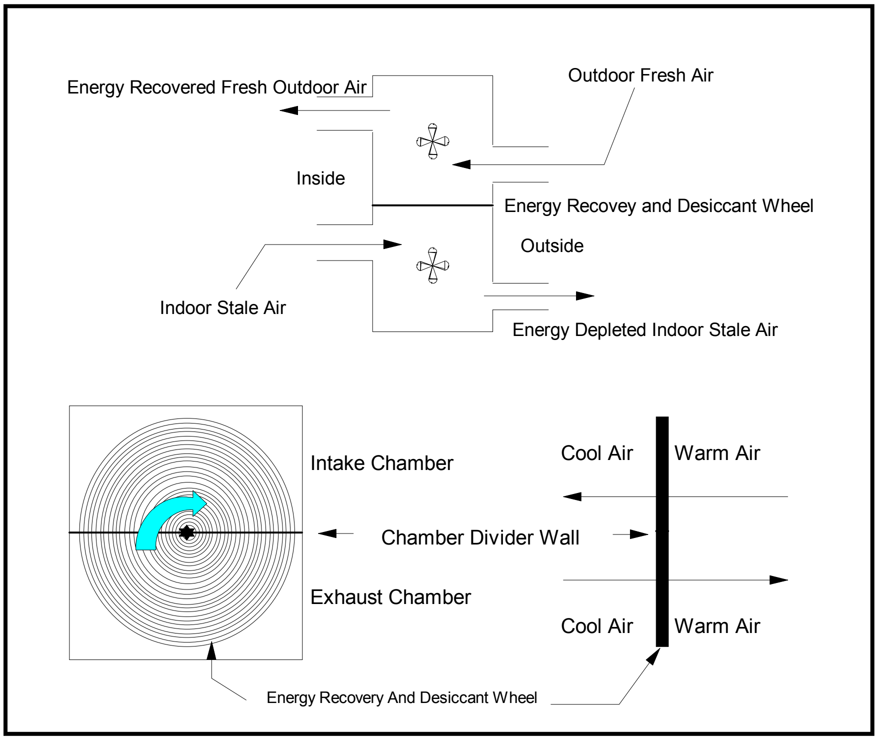


Fig. 18. Energy recovery ventilation overview.

3.1.4 Supplemental Air Mitigation

For individual room mitigation, a SAM system can be installed to control radon by increasing a room's ventilation rate. Typically a SAM system draws 75 to 500 cfm of conditioned air from an adjoining hallway or large room known to have low levels of radon and discharges it into the room (Fig. 19). Unconditioned air from outdoors or from within the building should never be used as the source air for this mitigation technique.

Although a SAM system is the least complex of all active mitigation systems (i.e., typically it only has a fan and two short pieces of ductwork), for it to work properly, significant pre-mitigation planning must be employed. To design a SAM system, one must first estimate or preferably measure the room's ACH rate and then perform a series of calculations that include the room's volume and its current radon level (EPA 1988b, 625/5-87/019). From these calculations, the appropriate duct size and capacity for the in-line ventilator can be ascertained.

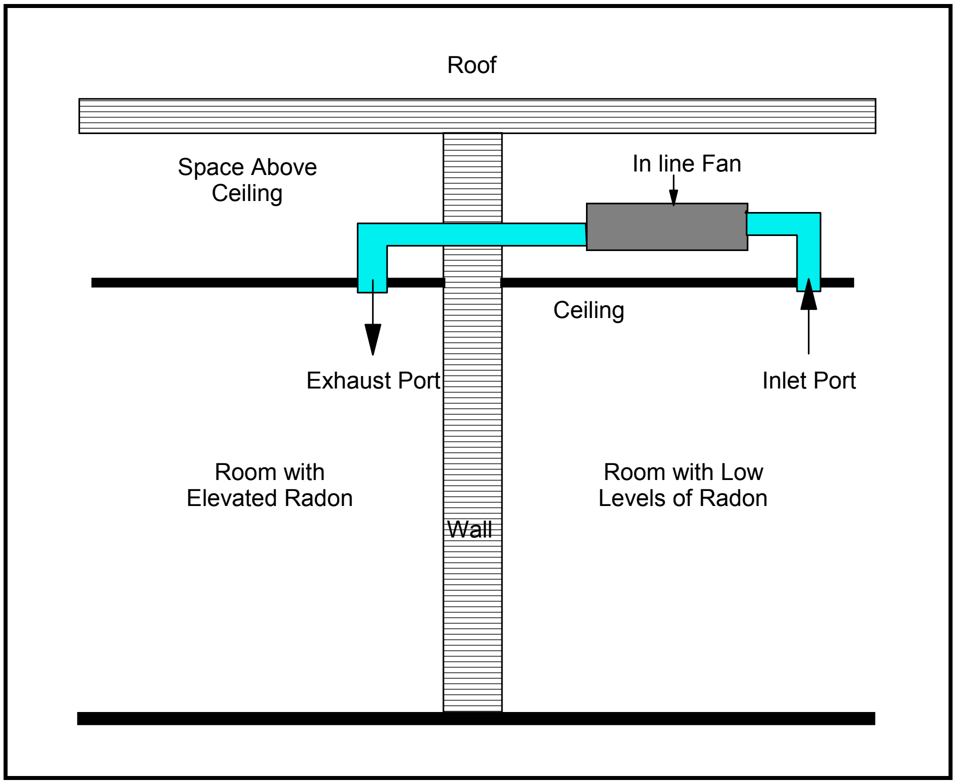


Fig. 19. Supplemental air mitigation system.

A drawback for this mitigation technique is its range of application. Typically, for SAM to be a viable option, the room in question must have radon levels <20 pCi/L, be <3,500 ft^3 in volume, and have a low pre-exiting air-exchange rate (e.g., <0.2 ACH). In addition, the room must be located near a large room or common area from which the required volume of conditioned air containing low radon levels can be withdrawn without a significant risk of depressurization.

In addition to the design parameters, particular attention must be paid to noise and occupant comfort. Because these systems are usually used in single or double offices, the noise generated by the discharge of the supply air may pose an inadvertent distraction to the occupant(s). Therefore, the supply diffuser, in addition to being aesthetically pleasing, must afford the least amount of noise. Another important consideration is the location of the discharge point. The discharge air velocity from a typical SAM system is comparable to that of a forced-air system. So to the best extent possible, the discharge needs to be in a location that would not appreciably increase the air velocity in the primary work areas.

3.1.5 High-Efficiency Particulate Air Mitigation

Another post-entry mitigation method involves the use of high-efficiency air filtration systems that remove particulates from air (similar in design to the portable HEPA filtration units used by asbestos abatement companies). These units are commercially available (air filtration units commonly found in consumer retail stores do not meet

ASHRAE Standard 52.2-2007 [ASHRAE 2007] for this application) and are typically integrated into the existing return air ducting. Like ERVs, these units need to be properly sized (unit and installation costs are comparable to ERV) for the required air volume. The long-term operational cost of HEPA typically exceeds that of ERV because of the need to frequently replace (e.g., weekly or monthly as required) the highly specialized filters (HEPA filters commonly found in consumer retail stores do not meet ASHRAE Standard 52.2-2007 [ASHRAE 2007] for this application).

Although studies have shown that air filtration methods do reduce the concentration of radon daughters in air, there are questions in the scientific community as to whether there is an analogous reduction in risk. The basis for this concern is that filtration of the air changes the distribution of the sizes of the particles in the air to lower sizes. Radon progeny attached to particles of decreased size present in the air may become more effective in delivering dose to the lung; thus the reduction in progeny filtration may not provide equal health risk reduction (Jalbert and Fisher 2008, US EPA correspondence to Douglas County School Board, Minden, Nevada [included in Exhibit 1]). In summary, although HEPA or other high-efficiency filtration can be used to remove particulates and reduce radon progeny in the air, it does not affect the radon gas concentration; therefore, radon progeny will continue to be produced in the ambient air. The resulting shift in particle size distribution in the air will deliver an unknown dose from radon progeny to the lung. Further, radon gas measurements will be unaffected by filtering, and the assessment of the effect of filtration involves multiple measurements of radon progeny concentrations and particle size distributions throughout the building. Therefore, at this time, EPA does not support the use of air filtration as a means of mitigating the health effects of radon (Jalbert and Fisher 2008).

3.1.6 Mechanical Adjustments as a Mitigation Method

Depending on their design and operation, a nonresidential building's mechanical systems can influence radon levels by

- increasing ventilation (diluting indoor radon concentrations with outdoor air)
- decreasing ventilation (allowing radon gas to build up)
- pressurizing a building (keeping radon out)
- depressurizing a building (drawing radon inside)

Consequently, restoring the building's forced air and exhaust systems to their original design specifications may provide the desired reduction in radon levels (EPA April 1994, 402-R-94-008). However, caution should be exercised in making adjustments to the unit's makeup air damper to compensate for a negative shell pressure. Before any adjustments are performed, a review of the building mechanical plans (supply and exhaust) should be performed and an audit of the current mechanicals performed. If the installed mechanical components match the original design specifications, then the fresh-air damper can be adjusted to match the specified flow. However, before the adjustments, it is recommended that temperature and relative humidity measurements (continuous measurement is preferred) be taken in all areas of the building to provide a baseline. These measurements should continue for an extended period of time (days or weeks as needed) to ensure that the forced air system can handle the added heating, cooling, and dehumidification load. If significant changes in the humidity or temperature are observed, then the original fresh-air damper setting should be restored immediately to prevent mold and mildew formation. In cases in which the mechanical audit finds mechanical components other than those specified in the mechanical drawings (e.g., the exhaust blowers have a higher capacity than those specified) or exhaust systems added after the original construction (e.g., fume or exhaust hoods), an HVAC engineer should be consulted before any fresh-air damper adjustments.

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, the amount of outdoor air ventilating the indoor environment can be significantly reduced. Less ventilation allows radon to build up indoors. An understanding of the design, operation, and maintenance of a building's HVAC system and how it influences indoor air conditions is essential for understanding and managing a radon problem, as well as managing other indoor air quality concerns in buildings. Although HVAC balancing, repair, and restoration to original design parameters are recognized as passive radon mitigation techniques, it may be advantageous to consult an HVAC engineer before making any modification or changes.

Although HVAC mitigation is effective in the short term, long-term studies conducted by DOE have found problems with sustaining mitigation. For example, in buildings that were mitigated by restoring the fresh air to the original design parameters, 50% of the buildings were found not to be mitigated after 5 years. The primary reasons are reduction in the fresh air makeup as a means of energy conservation, and lack of system maintenance (clogged intake filters). System labeling and education of maintenance staff resulted in only marginal improvements.

3.1.7 Considerations in Mitigation Selection

If passive mitigation techniques are not viable, then the installation of an active mitigation system will be needed. Although initial installation costs and long-term operation and maintenance costs are important considerations, the following issues may have an impact on the selection and system design.

- added energy for conditioning outdoor air
- aesthetics
- noise reduction
- minimal loss of living or working space
- local and state requirements
- proposed and pending renovations
- an understanding of the occupants' concerns about radon exposure

If all active mitigation systems were equivalent in installation and O&M costs, the decisions would be greatly simplified. However, the three most common types of mitigation (SP, ERV, and SSD) differ significantly in installation and O&M costs. For example, using a simple intake grill and duct system, a Type 1 SP mitigation system costs approximately $500 to install. However, the annual operation cost (e.g., energy costs associated with conditioning the air) and the maintenance costs (e.g., cleaning filters and rebalancing the system) are significantly higher than for ERV and SSD. Because O&M of a building's radon mitigation system is permanent for the remaining life cycle of the building, the true cost of mitigation must be looked at over a much longer period. Figure 20 compares the 10 year life-cycle energy consumption cost and the initial installation cost for each of the mitigation systems. For SP and ERV, the higher operation costs reflect the added heating and cooling load for the intake of outside air and maintenance. Because of cost considerations like these, whenever feasible, SSD should be preferred over ERV and SP.

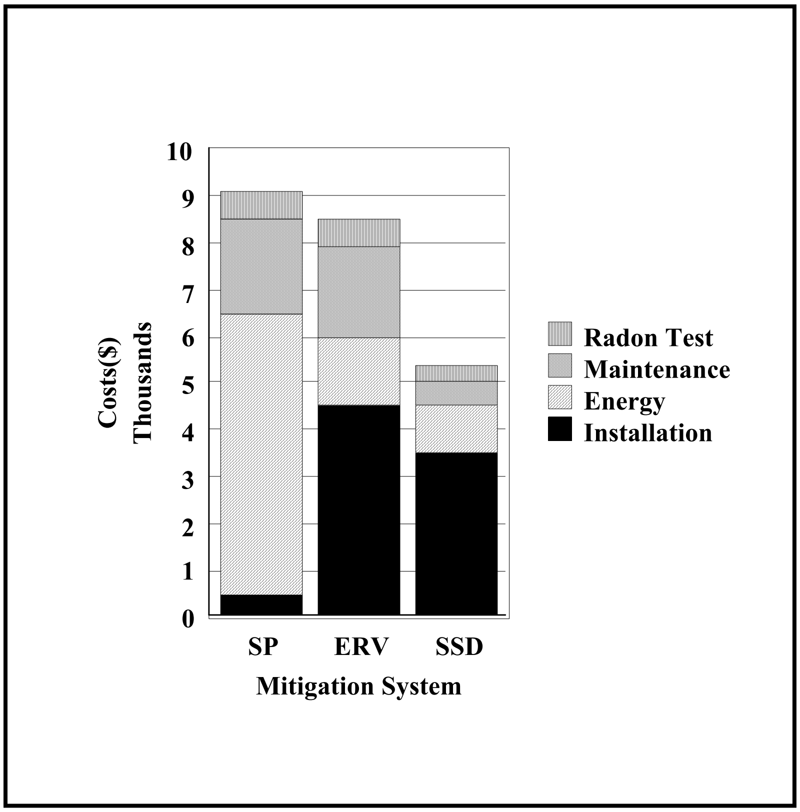


Fig. 20. Comparative 10-year cost for radon mitigation.

3.1.8 Radon Mitigation Diagnostic Measurements

There are many alternatives for passive and active radon mitigation. Selection of the optimal mitigation system for a building is essential for a long-term, cost-effective solution. If a poor selection is made, the radon problem may not be abated, the operational expense (energy penalty) may be higher, the system may fail shortly after installation, and/or the radon level may increase. If any of these problems should occur, then the effort and funds expended for the task would be wasted. It is also important to note that, in some large buildings, a combination of approaches (active and passive) may be needed to successfully mitigate the building (e.g., HVAC adjustment with SSD or ERV with passive sealing). To assist in the selection process, EPA recommends that a series of scientific tests, called mitigation diagnostics, be performed (EPA March 1994, 402-R-94-009). These diagnostics gather technical information on the characteristics of the building, which can then be used to determine the most appropriate mitigation means for the building.

The first diagnostic usually performed (EPA April 1994, 402-R-94-008) is a close examination of the building's radon data vs. the building plans (i.e., floor, foundation, HVAC, and structural plans). Generally speaking, buildings with multiple rooms with elevated radon fall into one of the following categories (Fig. 21):

- random, no discernable pattern
- uniform, all rooms are about the same
- linear, all the elevated rooms are aligned
- clustered, all the elevated rooms are in the same area of the building
- combinations of the four patterns in exceptionally large buildings.

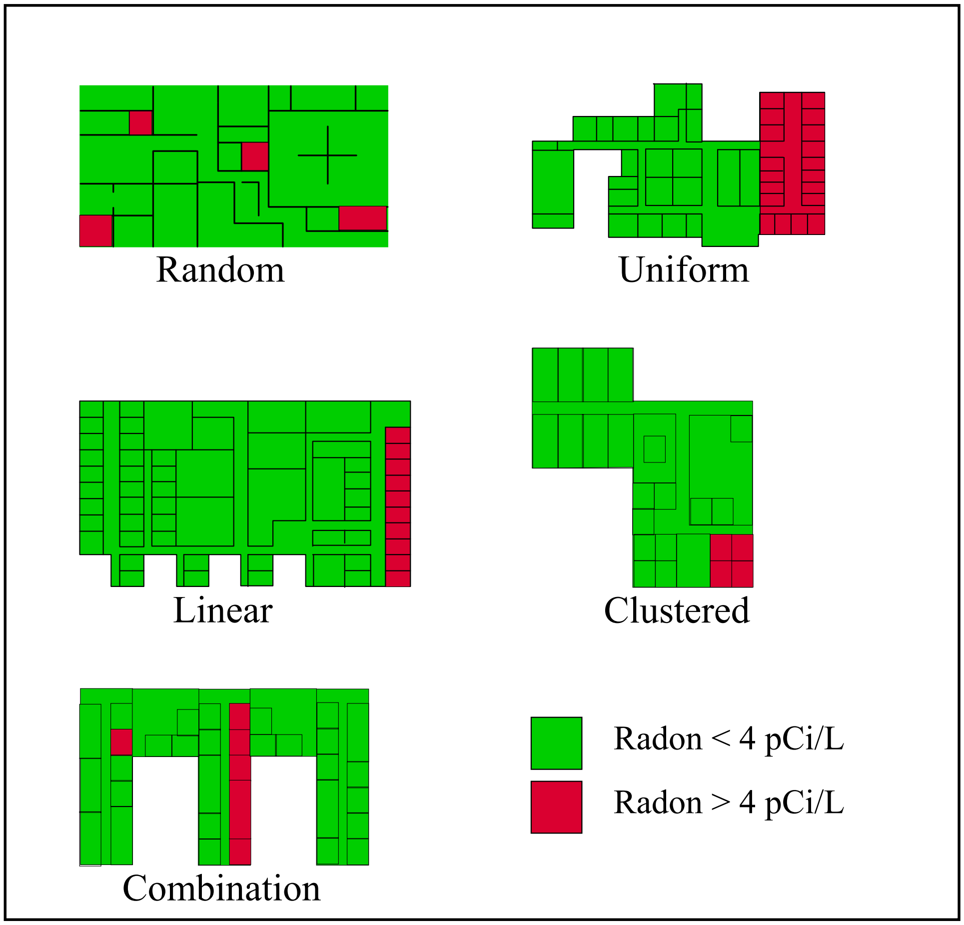


Fig. 21. Distribution patterns of elevated radon in nonresidential buildings.

Analysis of historical data has shown that certain types of patterns may indicate a potential problem in the building. For example, a uniform pattern in which all the rooms in the building are at or near the same concentration indicates that the radon is being mined and distributed by the building's mechanical system. Linear or clustered patterns tend to indicate rooms with localized, substandard ventilation or a possible expansion joint or opening in the slab. Therefore, during the diagnostics phase, all the building's mechanical components (HVAC and exhausts) should be closely examined. The examination should include a detailed review of the building's mechanical drawings followed by a detailed inspection to confirm that the plans are current and accurate (review and inspection should be performed by a qualified HVAC engineer). Concurrent with the plans and mechanical inspection, mechanical diagnostics are usually performed to determine the current system performance. These diagnostics are

- Mechanical balance: A specialized instrument (i.e., flow hood, hot wire anemometer, or pitot tube) is used to measure the supply, return air and exhaust volumes throughout the building.
- Differential pressure: A micomanometer is used to map room-to-room and differential pressure relative to the outdoors or subslab.

If mechanical issues are not suspected or correction has failed to mitigate the building, then additional diagnostics should be performed by a qualified radon mitigator. These diagnostics include but are not limited to the following:

- Radon entry pathway: A specially configured CRM is used to locate entry points in the floor or walls of the building.
- Air change measurement: An instrument is used to monitor the loss rate of an inert tracer gas within a room or building.
- Shell leakage: A blower door is used to generate a plot of shell pressure vs. intake air volume.
- Subslab diagnostic measurements: An artificial vacuum field is induced under the floor to measure the lateral field extension (LFE) through a series of small holes drilled into the floor (see Fig. 22). Concurrent with this measurement, a subslab permeability measurement can also be made which can be used for proper fan selection (Fig. 23).

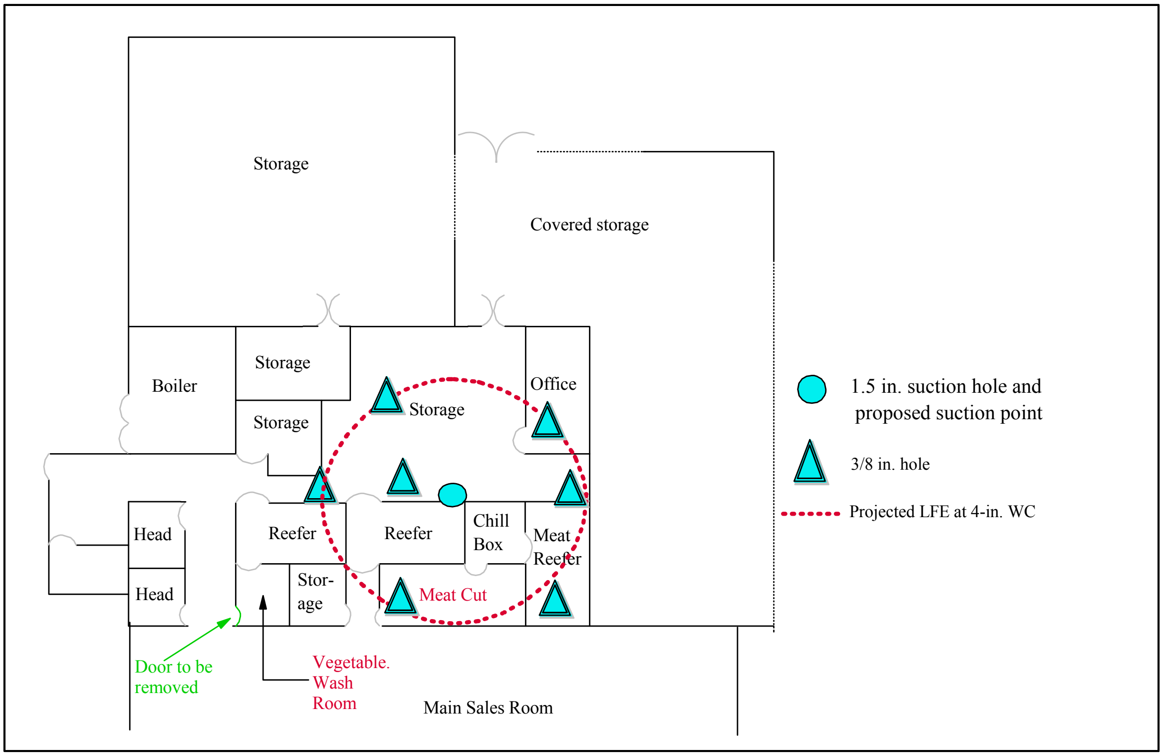


Fig. 22. Example of an SSD LFE diagnostic measurement.

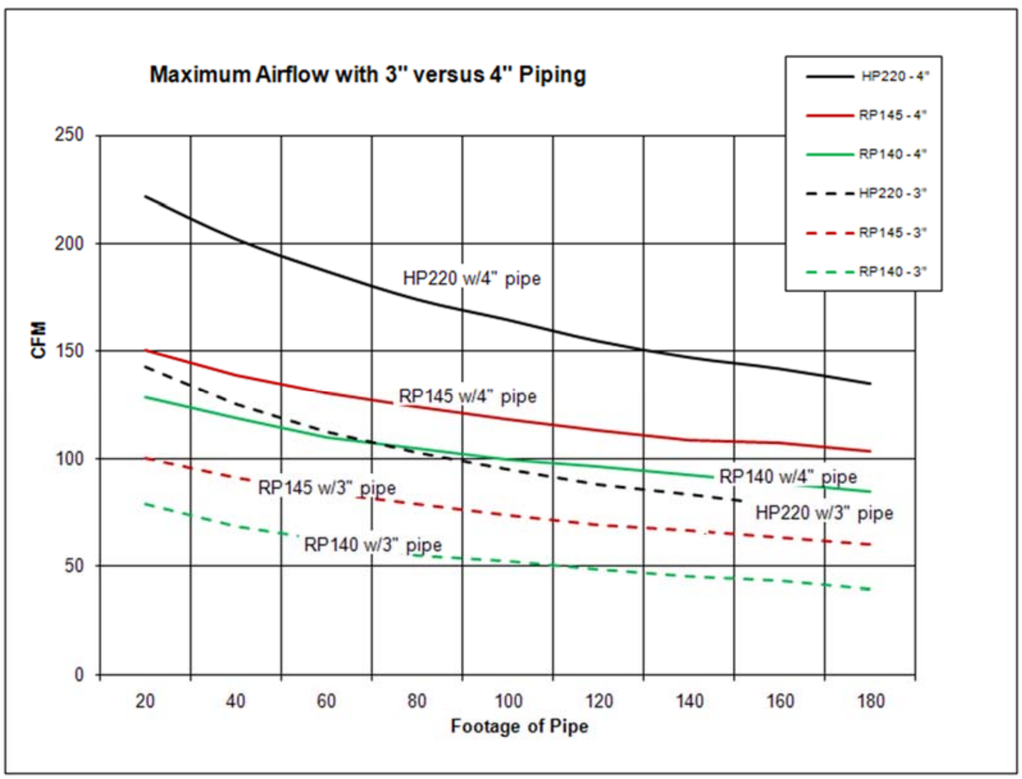


Fig. 23. Typical subslab fan performance curves.

Table 6 summarizes typical mitigation diagnostics performed to determine the best mitigation method in nonresidential buildings. For more detailed information on mitigation diagnostics, see *Reducing Radon in Schools: A Team Approach* (EPA April 1994, 402-R-94-008; available for download at http://www.epa.gov/radon/pubs/index.html).

Table 6. Mitigation diagnostic summary

Diagnostic test	Description	Mitigation method
Radon entry pathway	Performs continuous radon measurements in suspected entry pathways	Passive sealing
Air change	Measures the air turnover rate of the unit	Energy recovery ventilation, supplemental air mitigation
Shell leakage	Determines the quantity of outdoor air required to pressurize the building to 4 Pa	Shell pressurization
Subslab diagnostic and permeability measurements	Quantifies the amount of vacuum required to adequately evacuate the subslab. Assists in the selection of suction point locations and fan size	Subslab depressurization
Differential pressure	Measures the differential pressure across the building shell relative to the outside	Passive mitigation via balancing of existing mechanical systems
Mechanical balance	Quantifies the volume of air being supplied or discharged at a mechanical register	Passive mitigation via balancing of existing mechanical systems

3.2 OPERATION AND MAINTENANCE OF RADON MITIGATION SYSTEMS

Because radon is emanating from the rock and soil beneath a building, it can only be controlled and never removed. For this reason, EPA (EPA 1994, 402-R-93-078) recommends that all mitigation systems be inspected periodically (e.g., performance indicator check) and the impacted building be retested every 2 years to ensure that the radon mitigation system is still working properly. This retesting recommendation also applies to buildings that were mitigated using mechanical balance and HVAC adjustments (EPA April 1994, 402-R-94-008). In these types of buildings, retesting after every mechanical adjustment may be in order. In addition to EPA recommendations, manufacturers and installers may have prescribed additional O&M requirements. For example, ERVs typically require filter replacement every 30 days. SAM and SP mitigation usually require cleaning of the intake duct periodically as well.

3.3 MITIGATION OF RADON IN WATER

Radon can be removed from water using one of two methods:

- aeration treatment—spraying water or mixing it with air and then venting the air from the water before use
- granular activated carbon (GAC) treatment—passing water through a GAC bed

However, if GAC is used, disposal of the carbon may require special handling if it is used at a high radon level or if it has been used for a long time. For either treatment method, it is important to treat the water where it enters the building (point-of-entry device) so that all the water will be treated. Point-of-use devices such as those installed on taps or under sinks will treat only a small portion of the water and are not effective in reducing radon in water. It is also important to maintain the water treatment units properly, because failure to do so can lead to other water contamination problems. In addition, EPA and the CDC recommend that the water be tested at least once a year after installing the treatment system.

4. RADON-RESISTANT NEW CONSTRUCTION

4.1 OVERVIEW OF RADON-RESISTANT NEW CONSTRUCTION

Within the last 15 years, the ASTM, American Association of Radon Scientists and Technologists, the Department of Defense, and EPA have published standards and guidance documents to assist with incorporation of radon-resistant features into new construction. The following are examples of available radon-resistant new construction (RRNC) documents.

Residential

- *Building Radon Out: A Step-by-Step Guide on How to Build Radon-Resistant Homes* (EPA April 2001, 402-K-01-002)
- *Model Standards and Techniques for Control of Radon in New Residential Buildings* (EPA March 1994, 402-R-94-009)
- *Standard Practice for Radon Control Options for the Design and Construction of New Low-Rise Residential Buildings* (ASTM E1465-08a)
- *Standard Practice for Installing Radon Mitigation Systems in Existing Low-Rise Residential Buildings* (ASTM E2121-09, X3.3 and X4)
- *RRNC 2.0 Reducing Radon in New Construction of 1&2 Family Dwellings and Townhouses* (ANSI 2013)

Nonresidential

- *Indoor Radon Prevention and Mitigation* (UFC May 2003, 3-490-04A)
    - Note: This standard has been declared inactive without an active replacement
- *Radon Prevention in the Design and Construction of Schools and Other Large Buildings* (EPA June 1994, 625-R-92-016)
- ASHRAE, *Indoor Air Quality Guide,* Section 3.3 (ASHRAE 2010)

Each document has its own strengths and weakness in selecting the most appropriate standard or guideline to follow. However, in most cases a blended approach (e.g., taking the most applicable parts of each) is best in drafting a nonresidential RRNC design. For example, in deciding the extent of RRNC techniques needed, UFC 3-490-04A (UFC May 2003) recommends taking into account the type of facility, along with the potential for elevated radon based upon the highest radon result collected in close proximity to the new facility. ASTM, on the other hand simply details options that could be incorporated into the design. Another consideration is that certain nonresidential construction techniques go counter to what is needed to incorporate radon-resistant features. For example, when high ground-floor loads are expected or the ground floor is part of a structural support member, compaction of the subslab aggregate is required. Therefore, in this case a “to the best extent possible” approach for RRNC incorporation will have to be employed. The following sections provide an overview of some of the most common options available for RRNC integration.

4.2 PASSIVE SEALING

A common theme in all RRNC approaches is the need to perform sealing in the floor/foundation system to prevent radon entry through openings in the slab (e.g., expansion and foundation joints, pipe penetrations). Presumably, if these are sealed, the radon flux into the building can be greatly reduced. However, more recent additional benefits such as reduction of moisture and insect intrusion into the building have also been identified. Sealing also offers energy savings if SSD mitigation is needed in the future. Studies by DOE and EPA have shown that up to 75% of the exhaust air from an SSD system comes from the living area. Although the energy penalty associated with the loss of this small volume of air is small (typically 50–75 cfm costs about $50/year), the cumulative cost over the lifetime of the building can be significant. Typical estimates for the cost of the sealing range from $0.10 to $0.25 per gross square foot (cost will vary from region to region). Therefore, for a 10,000 ft^2 building, sealing would add an additional $1,000 to $2,500 to the construction cost. It is because of this low cost and the variety of resulting benefits that the authors of the various standards encourage this approach as a minimum for new construction.

4.3 PASSIVE STACK

In addition to sealing, ASTM and EPA recommend what is called a passive stack approach. In addition to passive sealing, they recommend the installation of a 3 or 4 in. PVC vent pipe that runs from the aggregate bed (minimum 4 in. layer of clean coarse gravel [½–¾ in. mesh]) through the building and roof (Fig. 24). The idea is that the pipe would allow some radon to passively vent to the outside above the roof and not diffuse into the building. If this approach is used, they also recommend that an electrical junction box be placed in the attic or outside near the pipe in case a fan is needed later to activate the system. EPA recommends at least one vent pipe for every 2,000 ft^2 of slab area. Cost estimates for this method range from $200 to $400 per vent pipe, which also includes the electrical junction box. For a 10,000 ft^2 building, installing five passive vent pipes would add an additional $1,000 to $2,000 to the construction cost. Unlike sealing, other than the possibility of passive radon control, installing a passive vent pipe offers no other apparent benefits. However, if active mitigation is required, the cost of converting a passive vent pipe to an active SSD system is typically around 10% of the cost of installing a new system. Thus five passive vent stacks could be installed in new construction for approximately the cost of installing one from scratch for an active SSD system.

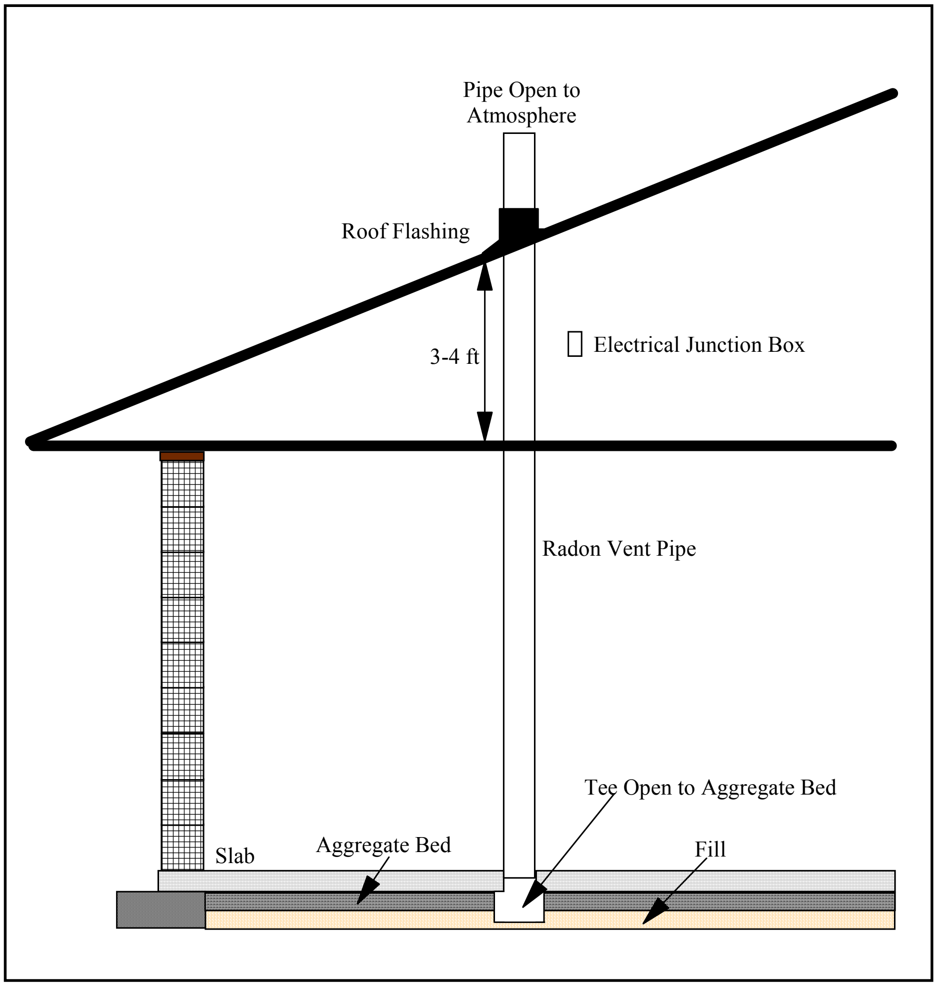


Fig. 24. Basic passive stack design for nonresidential buildings with attics.

From an RRNC contractual point of view, it would be expedient to install the mitigation fan and go ahead and take the system active as part of the construction project; however, the long-term costs of maintaining a system that is not needed can be significant over the lifetime of the building. For example, over 30 years, a 150 W radon fan would accrue $4,500 in electrical cost (assume $0.08/kwh; cost will vary from region to region). Using industry averages, fan replacements would cost an additional $900 ($300/fan replaced on average every 10 years). Finally, active systems need periodic testing with an inspection (every 2 years) to ensure that the system is operating properly, which would require an additional $7,500 (five rooms/system at $100/room every 2 years). Therefore, over 30 years, the projected cost of operating an active system would be approximately $13,000. Not included in this estimate would be any institutional cost (e.g., periodic inspections and recordkeeping) associated with the active system. However, although the 30 year cost of active mitigation is significant, mitigating circumstances (e.g., location, historical test data, type of building) may be an overriding factor in the decision to go active.

4.4 SOIL GAS COLLECTION SYSTEM

Over the past 10 years, there has been a considerable increase in the number and types of soil gas collections systems available for incorporation in new construction. The oldest and perhaps simplest designs focused primarily on making the aggregate bed as permeable as possible. In this design, 6–8 in. of noncompacted, clean, ½–¾ in. mesh stone was used under the slab, grade beams, and interior footings. If radon mitigation were required later, an SSD system was installed. The key advantage of this approach was the low cost for initial installation and the additional and predictable subslab coverage (typically 2,000 ft^2 for an active system) offered by the added aggregate. In cases where the additional aggregate was not available or not practical, later designs made use of trenches filled with aggregate or proprietary strip mats.

To enhance subslab coverage for both passive and active mitigation systems, later approaches used, in addition to the enhanced aggregate bed, a network of perforated pipe under the slab. This network consists of a perforated 4 in. PVC pipe (commonly called septic field line or slotted PVC well casing) in the aggregate bed which bisects the length of the slab and, as needed, branches to penetrate interior footings or foundations (Fig. 25). In lieu of using PVC pipe, 4 in. polyethylene slotted, flexible, corrugated drain pipe can be used, but care must be taken to ensure that the pipe is not crushed before the slab is poured. In this technique, the flexible pipe is looped around the perimeter of the subslab on top of a layer of aggregate (Fig. 26). At a convenient location, one side of the loop is connected (by solid or flexible pipe) to the other side and a tee is inserted. Inside the tee, a section of solid PVC is installed that will extend at least 6 in. above the top of the slab. To successfully cover the perforated pipe, an additional 3–4 in. (½–¾ in. mesh) of aggregate (8 in. total) is applied, in addition to a vapor barrier on top of the aggregate. In designing the soil gas collection system, it is imperative that the pipe extend into each and every compartment of the subslab. In addition, aggregate depth, size, and degree of compaction have a strong influence on the coverage. For example, if 8 in. of noncompacted, ½–¾ in. mesh stone is used, the vacuum field will extend up to 50 ft from each side of the branch in a non-subdivided subslab compartment. However, if the same aggregate is highly compacted, the coverage can drop to <10 ft. If the system is properly installed and if the correct aggregate is used, field extensions of 5,000 ft^2 or more can be expected for active mitigation systems.

More recently, in 2008, ASTM conducted a review of all available soil gas system methods and consolidated its findings in *Standard Practice for Radon Control Options for the Design and Construction of New Low-Rise Residential Buildings (*ASTM E1465-08a). The ASTM standard has categorized the most common soil gas collection systems into five general designs (Table 2, page 9) each with its own options (Table 4, page 10). Although this document was drafted for residential applications, the decision tree and specifications extrapolate readily to nonresidential applications.

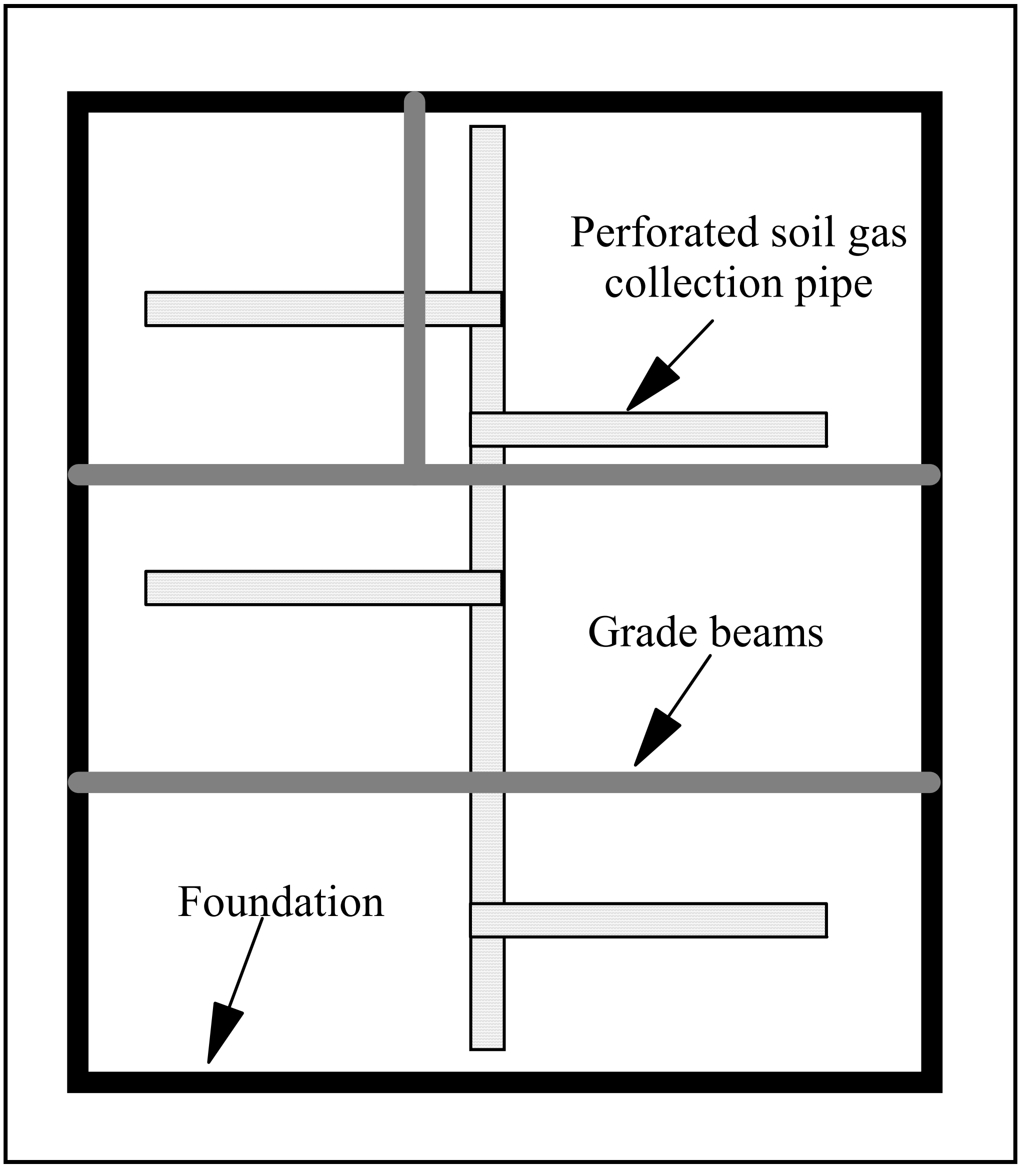


Fig. 25. Example of a simple, rigid, soil gas collection system.

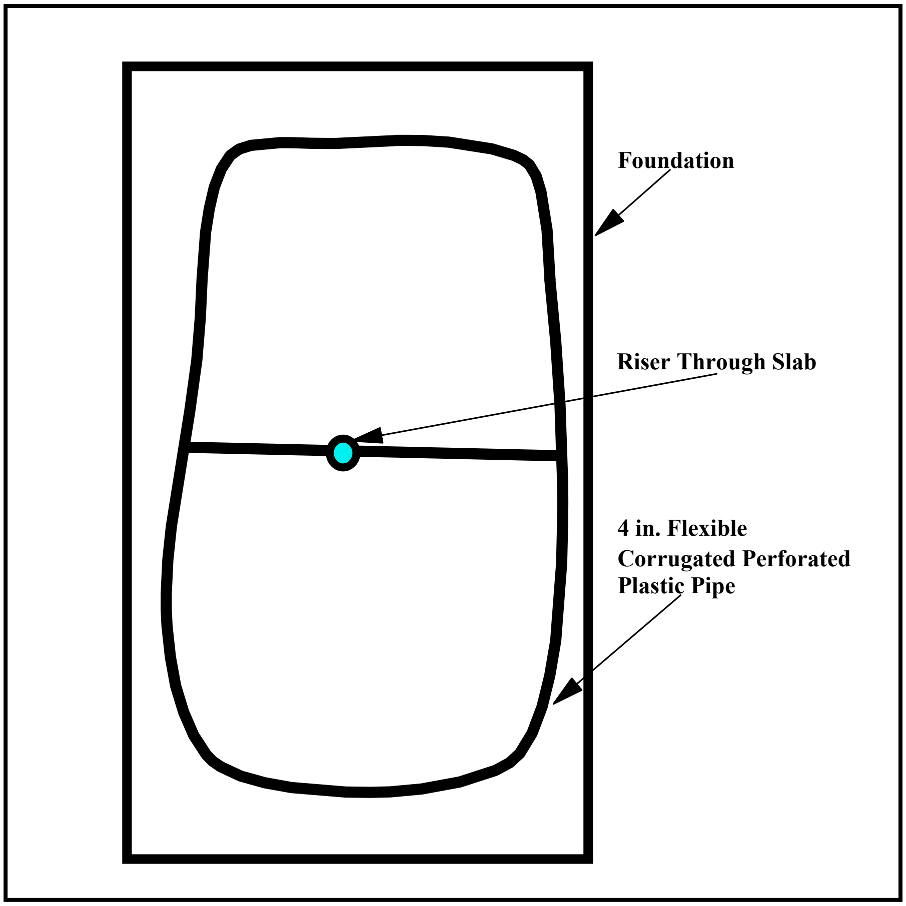


Fig. 26. Example of a simple, flexible, soil gas collection system.

4.4.1 Vent Pipe Options for Soil Gas Collection System

If a soil gas collection system is installed, the pipe network must be connected either to a passive stack vent or to a pipe that is stubbed out and capped either in the living area or attic or on the exterior of the building. The number of vent pipes, commonly referred to as risers, depends upon the aggregate depth, size, and degree of compaction. For example, if 8 in. of noncompacted, ½–¾ in. mesh stone is used, one riser would usually cover 3,000–5,000 ft^2 in a non-subdivided compartment. However, if the same aggregate is highly compacted, the coverage can drop to <1,000 ft^2; in that case, additional stacks would be needed to provide the same coverage. Because of the possibility of passive mitigation in noncompacted aggregate beds, EPA recommends that a passive stack be connected to the soil gas collection system with allowances for the installation of a fan if needed later.

Because not all building designs can accommodate a passive stack, another option is to extend a branch through the outside foundation to the outside of the building and install a capped riser (Fig. 27) with an electrical junction box nearby. If later testing determines that an active system is needed, the vent pipe and fan can be installed at a significant cost savings compared with installing a new mitigation system for an existing building.

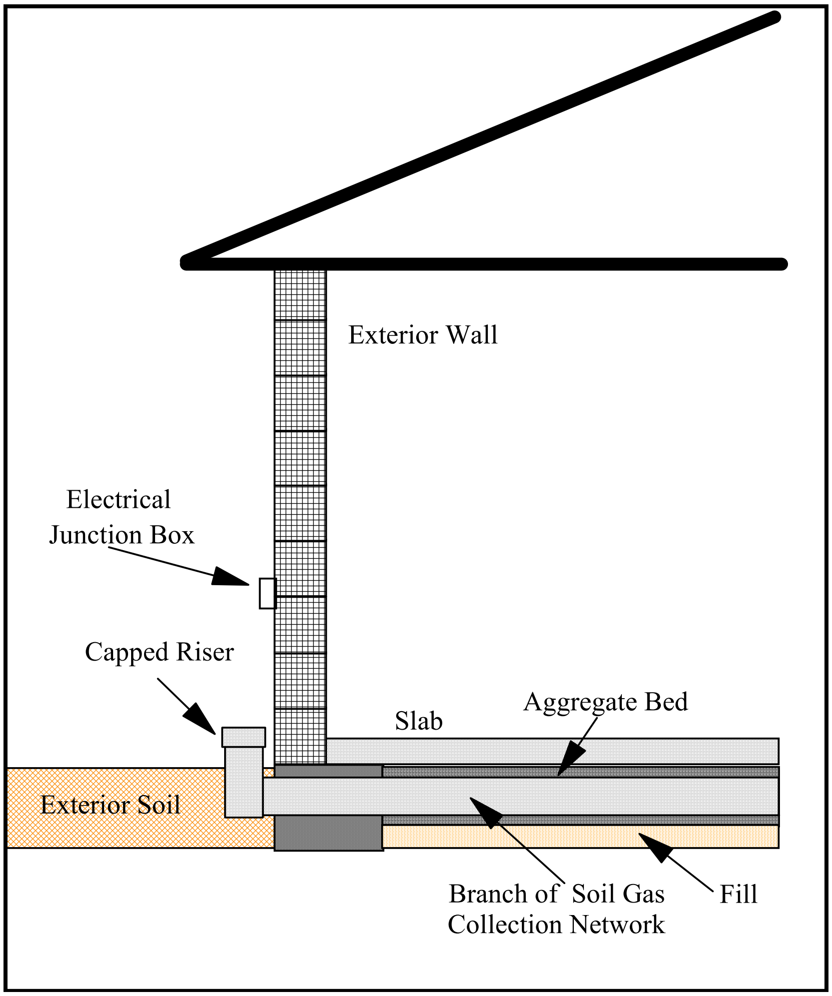


Fig. 27. Exterior riser on a soil gas collection network.

4.5 ROLE OF BUILDING MECHANICAL SYSTEMS IN RRNC

Another RRNC technique in nonresidential construction that supplements the techniques mentioned previously is to design the building mechanical systems so that all the rooms in ground contact are pressurized relative to the subslab (ASHRAE 2010, *Indoor Air Quality Guide*, Section 3.3). Although no standard has been proposed for how much pressure is needed, studies by DOE have found 4 Pa (0.016 WC) sufficient for consistent radon control. Another option is to allow for additional ventilation in the ground-contact rooms in the design. However, the inability to predict in advance what the radon levels might be within those rooms limits the application of this technique.

4.6 CONSIDERATIONS FOR RRNC IN NONRESIDENTIAL BUILDINGS

Although EPA recommends that RRNC techniques be considered for all new construction, this statement is based primarily on successes in residential applications.

For most residential applications, the average cost of an RRNC passive stack connected to a soil gas collection system is around $500. If post-construction testing finds elevated radon, then only a fan is needed to complete installation. If installed properly and with the right aggregate, one riser can typically handle up to 5,000 ft^2 of subslab. In nonresidential buildings, however, subslab construction usually contains grade beams, interior footings and foundations, pier supports, and enclosed utility chases. In addition, aggregate compaction is commonly used to prevent excessive slab settling or to support the slab in areas of high load potential. All of these features will have a significant impact on the efficiency of the soil gas collection network. To compensate, additional branches, multiple soil gas collection networks, and risers may be needed (Fig. 28). This added complexity increases the cost of nonresidential RRNC (additional materials and installation labor plus qualified designers and reviewers) and may bring into question its overall cost benefit. In fact, in some continental United States Department of Defense nonresidential applications following ASTM E 1465-08a, total costs (design through installation) were about $1–2/ft^2 of ground-contact area. In areas of high radon potential (e.g., EPA Zone 1, Fig. 4) population studies have shown that RRNC is cost-effective. However in marginal and low-potential areas (e.g., EPA Zones 2 and 3, respectively), the potential savings is not as clear.

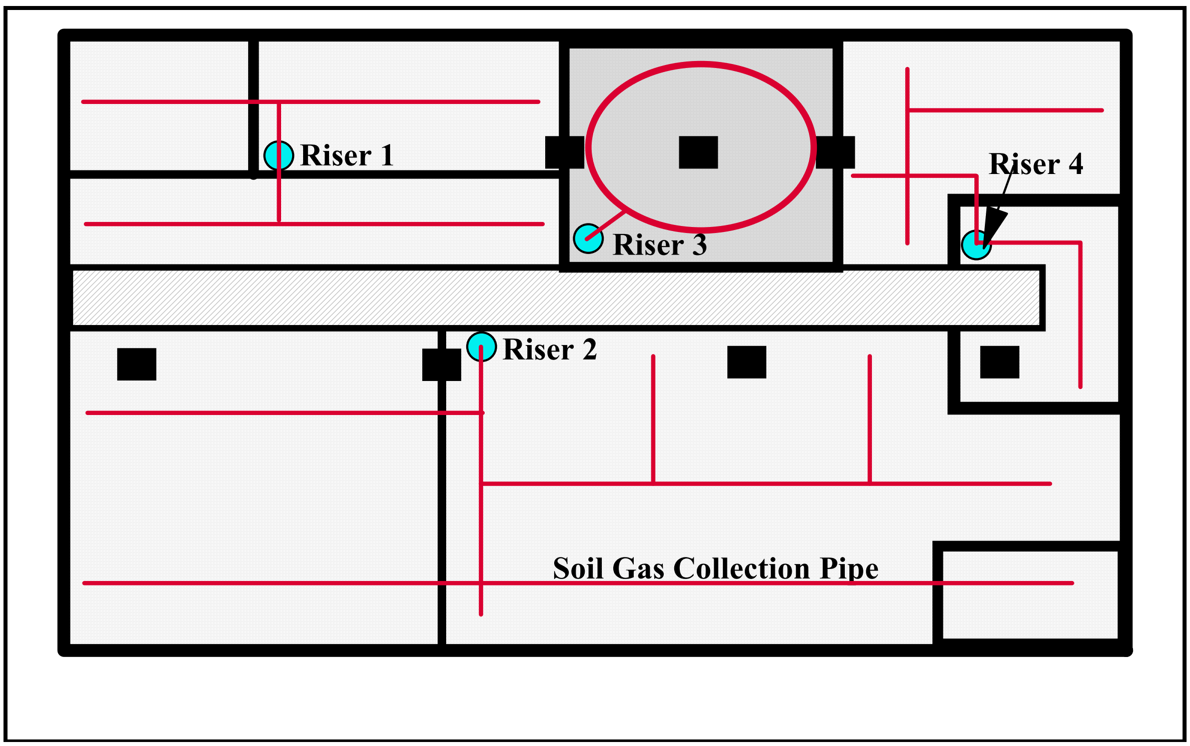


Fig. 28. Example of a nonresidential soil gas collection network.

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DEFINITIONS AND TERMS

Blank: A radon detector that is returned to the laboratory unexposed in order to measure the background of the device.

Closed-building conditions: During the radon test, the building's windows and exterior doors are closed except for routine entrances and exits.

Collocated: Radon test devices that are placed within 12 in. of each other during a simultaneous measurement.

Duplicate: Radon measurements that are performed using two radon testing devices at the same time that are collocated with each other.

Equivalent Picocurie per liter (EpCi/L): The equivalent radon gas concentration assuming 100% plate out of all unattached RDP in air.

Karst: Landscape underlain by limestone that has been eroded by dissolution, producing ridges, towers, fissures, sinkholes, and other characteristic landforms.

Mitigation: The corrective action taken in buildings or rooms that have been found to have radon levels ≥4 pCi/L.

Nonresidential building: Simply put, a building that is not considered family housing.

Picocurie per liter (pCi/L): A common unit of measurement of the concentration of radioactivity in a fluid (liquid or gas). A picocurie per liter corresponds to 0.037 radioactive disintegrations per second in every liter of fluid. For radon testing purposes, pCi/L is the unit of measure of radon gas. EPA has set an action level of 4 pCi/L.

Picocurie per liter per day (pCi/L-day): A measure of the detector dose; 1 pCi/L-day is the dose a detector receives if it is exposed to 1 pCi/L for 1 day.

Spike: A radon detector exposed at a laboratory to a known radon concentration. When used in conjunction with field testing, spikes measure the accuracy of the survey radon results.

Radon: A naturally occurring, odorless, colorless, radioactive gas caused by the breakdown of uranium. Studies have shown that many years of exposure to elevated indoor levels of radon increase the risk of contracting lung cancer.

Radon progeny: Radon particles that can be breathed into the lungs, where they continue to release radiation as they further decay. Also known as radon decay products or radon daughters.

EXHIBIT 1: EPA CORRESPONDENCE

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UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460
Office of Radiation and Indoor Air
Indoor Environments Division

March 6, 2008

Ms. Teri Jamin, President
Douglas County School Board
1638 Mono Avenue
P.O. Box 1888
Minden, Nevada 89423

Dear Ms. Jamin:

Thank you for your letter of February 19, 2008 requesting assistance in answering questions posed by you and Ms. Luna with regard to the Zephyr Cove Elementary School (ZCES). We also received additional information from Mr. Greg Felton. He provided the minutes of the School Board Meeting (February 12, 2008) and a detailed email (March 4, 2008) on his observations and five questions related to radon risk. We normally refer such requests to our Regional offices. However, in this case, the EPA Region 9 office (San Francisco) has asked us to respond directly to your request.

Please be aware that this response is based only on the information we have received. Therefore, in the absence of complete information or a site inspection, we've limited our response to several general observations and recommendations. Our response addresses measurement, risk, mitigation and technical assistance. EPA's policies on radon measurement and mitigation are necessarily conservative and protective, and based on many years of research and experience in a wide variety of buildings, including schools. EPA's guidance on radon is a prudent and cost-effective long-term approach to risk reduction that is protective of students and staff alike.

Radon measurement. EPA's recommended action level has always been primarily defined as a radon gas measurement, i.e., 4 picocuries per liter of air (pCi/L). The Fallon report incorrectly claims that EPA views working level (WL or progeny) measurements as equally acceptable to radon gas (pCi/L) measurements. Radon gas measurements should always be preferred, especially when the measurement result will be used in mitigation decisions.

Since the actual radon gas measurements from the ZCES are available, they should be used in mitigation decisions, provided the measurements were obtained in accordance with the EPA Radon Measurement in Schools Protocol (EPA 420-R-92-014, July 1993). The Schools protocol allows for initial short-term measurements to be conducted in every ground contact room. Measurement results at or above 4 pCi/L (e.g., 4-10 pCi/L) should be verified with follow-up measurements which can be long-term or short-term. Long-term measurements (90-days+) give a more accurate estimate of the average annual radon level.

Making a good working level or progeny measurement is more difficult than making a radon gas measurement. Because of the uncertainties associated with progeny measurements, the state of New Jersey and the American Association of Radon Scientists and Technologists (AARST) do not recommend making mitigation decisions based on working level measurements. Working level (WL) measurements are mentioned very briefly in EPA documents. The main reason for their inclusion is that in the early years of EPA's radon program there were some devices being used in the market to measure working level (progeny). The use of WL devices has declined over time due to the difficulty and expense of making such measurements.

For the reasons above, EPA's recommendation is to base a mitigation decision on a gas measurement, which we consider a conservative and protective, as well as practical way to evaluate potential risk. More simply put, "no radon gas, no risk." Of course, there is rarely, if ever, "no" radon gas. Background concentrations of radon in outdoor air can vary from place to place and time of day. The available data suggest that the outdoor average is about 0.4 pCi/L, or 1/10th EPA's action level.

Radon health risk. To our knowledge, lung cancer is the only health effect from exposure to radon in air. There are no data to suggest that children are at greater risk from exposure to radon in air than are adults. Recent radon risk assessments confirm that the risk at relatively low levels of radon is significant. For this reason, EPA recommends that mitigation be considered at levels even below our action level of 4 pCi/L (and specifically between 2 and 4 pCi/L) for residential structures. As you know, the 2003 EPA risk assessment estimated 20,000 annual radon-related lung cancer deaths. It's important to remember that this estimate is based on exposure to 1.25 pCi/L, which is the average U.S. indoor radon level. It is for these reasons that the International Commission on Radiation Protection (ICRP) recommends that radon be reduced to a level as low as reasonably achievable (ALARA).

Mitigation. EPA's principal recommendation for mitigating radon levels in school buildings is to control the source, i.e., to minimize or prevent radon entry. The technique used most often and successfully is sub-slab or sub-membrane Active Soil Depressurization (ASD). From the Fallon report we reviewed, it appears that the existing ZCES ASD systems have not been adequately evaluated for their effectiveness.

A complete and thorough evaluation of the existing ASD systems should be conducted. The evaluation should identify needed upgrades to, or extensions of, the existing radon mitigation systems. Any upgrades or new systems should conform to EPA's guidance. We recommend that school ASD systems be operated continuously. For the school's slab-on-grade footprint not served by an existing ASD system, if measurement results warrant mitigation, additional diagnostics should be done to determine whether ASD can be employed. These evaluation/diagnostic activities should be conducted by a qualified professional with experience in large, low-rise, slab-on-grade/crawlspace school/commercial buildings. Evaluations and diagnostics can be conducted independent of weather conditions and when convenient.

EPA does not recommend filtration as a radon control measure; the use of High Efficiency Particle Air (HEPA) filtration devices is not recommended as a mitigation technique. While there is evidence that filtration can reduce progeny concentrations, many factors can impinge on the effectiveness of filtration in maintaining reduced progeny concentrations with an attendant reduction in radon dose.

Some of these complicating factors include: a potential increase in ultra fine particles available for progeny attachment and deposition in the lung; a potentially larger percentage of progeny as an unattached fraction available to be deposited in the lung; maintaining a consistent air volume setting; human interference with filtration device operation; uncertainties with filter loading and progeny reductions; and the frequency of radon progeny measurements needed to maintain the target progeny concentration.

Technical assistance. Further technical assistance may be available to assist you in your ZCES deliberations. Radon professionals at EPA and the State of Nevada are available to support you through letters like this, via conference calls, etc. Also, onsite technical assistance may be available through the Conference of Radiation Control Program Directors (CRCPD). For such a request you should contact Adrian Howe with the Nevada State Radon Program (775-687-7531, ahowe@health.nv.gov).

We acknowledge the good offices of the State of Nevada Radon Program in addressing this issue to date. Thank you for the opportunity of joining in the effort to assist the Douglas County School District in resolving this important public health issue.

Sincerely,

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