Quality Assurance Plan

For Conducting Radon Measurements

Date of original QA Plan
8/1/2020

Date of Last Revision
--/--/-----

1. Introduction

Policy and Commitment

In order to protect health and financial interests of building owners and occupants, it is the policy of our organization to provide accurate, reproducible, and valid measurements of indoor radon concentrations. Each measurement employee is individually and collectively committed to the highest quality work in accordance with this plan.

Quality Assurance Plan Purpose

The purpose of this Quality Assurance (QA) Plan is to: set policies, performance goals, and objectives; identify responsibilities; establish procedures for assessing performance relative to quality; and to define corrective actions when needed.

It is important to recognize that usually quality assurance (QA) practices result not in the identification of out-of-control processes, but in the continued documentation of stable, within limits operations. Only with such documentation can the validity of measurement results be defended.

This QA plan will be revised with any adjustments involving changes of personnel and measurement devices as well as regulatory requirements or professional association recommendations. If there are no revisions triggering changes, this plan will be reviewed a minimum of annually.

Quality Assurance Goal and Objectives

Our staff are committed to providing customers with accurate, valid, reproducible, and defensible radon measurements which may be used to make critical decisions about radiation-related environmental health.

The objectives of the QA plan are to maintain a quality measurement program and to document relative quality. In addition, a QA program adds greatly to an operator's understanding of the methods they use and provides early detection of problems so that they can be rectified quickly and completely.

We collect evidence of the relative quality of our performance and evaluate that evidence through Quality Control (Section 6), take Corrective Action as needed (Section 7), and conduct Quality Assurance Audits (Section 9). A record of this evidence and resulting actions are maintained with those of this QA Plan.

2. Organization

Licensed radon professionals are responsible for our organization's field radon measurements. Quality Assurance Officer is responsible to the Superintendent for all QA as related to field operations and for field measurements and data analysis.

This QA Plan was reviewed by all personnel involved with radon work and will continue to be made available for future reference.

3. Description of Operations

Duties of the Quality Assurance Officer

The Quality Assurance Officer's responsibilities are to:

- ensure proper storage of radon measurement devices;
- design and present training to new employees and, on an annual basis, to all employees;
- oversee measurement device use including placement and retrieval;
- create and maintain QA records;
- prepare or oversee client test reports and to specify how they are distributed to clients;
- manage and oversee quality control (QC) measures;
- initiate QA audits;
- make recommendations on corrective action and to insure corrective action is carried out;
- initiate QA audit reporting to management; and
- participate in all meetings regarding staffing, training, equipment, record keeping, and changes in practices and procedures.

Personnel and Subcontractor Qualifications

Staff members and/or contractors conducting radon measurement services are individually licensed as radon measurement professionals by National Radon Proficiency Program. This includes anyone placing and/or retrieving testing devices.

Documents and Records

All records and documents are maintained so they are legible, retrievable, and protected from fire, water, theft, and deterioration for a minimum period of 5 years. Computer software and records for our radon measurements are routinely backed up to the cloud or a remote server.

4. Measurement Procedures

We perform radon measurements in accordance with Oregon Health Authority guidelines, rules, adopted measurement standards of practice, and the instructions of the measurement device manufacture(s).

Measurement Devices

The measurement devices used shall be listed for meeting the requirements of Oregon Health Authority rules and be approved for use by the state and NRPP.

The manufacturer's operating instructions are attached to the QA Plan.

Until use, radon measurement devices shall be stored in dry, low radon environments, and per manufacturer instructions.

Measurement Standards of Practice

Our company will follow the protocols and standards listed below:

- ANSI/AARST Protocol for Conducting Measurements of Radon and Radon Decay Products in Homes (ANSI/AARST MAH-2019) or successor ANSI/AARST standards, and test each unique foundation type;
- ANSI/AARST Standard: Protocol for Conducting Radon and Radon Decay Product Measurements in Multifamily Buildings (ANSI/AARST MAMF-2017) or successor ANSI/AARST standards;
- ANSI/AARST Protocol for Conducting Measurements of Radon and Radon Decay Products in Schools and Large Buildings (ANSI/AARST MALB-2014) or successor ANSI/AARST standards.

Inform Client about Required Test Conditions

We will make reasonable efforts to inform the person responsible for the school building of required and recommended test conditions a minimum of 5 days prior to the test as well as during the test.

The person responsible for closed-building conditions will be oriented on testing requirements prior to test administration.

Safety

The licensed radon professional shall not enter any area or perform any test that would damage property or risk the professional's own or another's safety. If it is known that closed-house conditions are detrimental to the health of the occupants, then the radon survey using a short-term test shall not be done.

Measurement Placement and Assessment of Test Conditions

We will place radon measurement devices in testing sites and under conditions in accordance with the Oregon Health Authority Rules and according to the protocols and standards listed above in Measurement Standards of Practice (as shown in Table 3.3 of ANSI/AARST MAH 2019).

The radon professional will visually assess test conditions when deploying and retrieving device(s). Included in this assessment, to ensure essential closed-building protocol requirements are met, the items in table 4-A, table 4-B (if applicable), and Exhibit 1 from ANSI/AARST MAH 2019 will be visually inspected.

See example placement/retrieval checklist at the end of this QA plan.

If the radon measurement is a long-term measurement of 90- days or more in duration, closed-building conditions need not be maintained prior to, nor during the radon test. For long-term tests, it is recommended that at least half the test period should be during the season that the building is most likely to be operated with closed-house conditions so that the results of the test are more accurate indicators of the yearly average.

Short term test periods should optimally collect at least 48 hours of valid sampling time. Deployment periods shall not be less than 46 hours. In addition, if a short-term test is longer than 2 days, whenever practical it is recommended, but not required, to terminate the test nominally at 24-hour increments to reflect day to night fluctuations in radon concentrations within a building.

For continuous radon monitors, care should be taken to account for data that are produced before equilibrium conditions have been established in a flow-through cell. Generally, conditions stabilize after the first four hours. Measurements made prior to this time are probably low, and the first four hours of data may be discarded or incorporated into the result using system correction factors. If the first four hours of data are discarded, the remaining hours of data can be averaged and are sufficient to represent a two day measurement.

New Construction Test Conditions

Newly built schools are tested in accordance with this QA Plan. If the following items are part of the completed building, they must be installed and completed before the radon test is initiated: all exterior doors, all windows, all heating appliances, all fireplaces and fireplace dampers, all insulation and exterior siding, all wall and ceiling coverings to be completed including interior drywall or paneling (does not include decorative finishing of walls, floors or ceilings). If testing personnel know construction work, which will likely affect the test results, is to be done inside the building during the test period, the test must be scheduled during a time when such interference is less likely to take place.

Post-Mitigation Measurements

A post-mitigation measurement is conducted to confirm the relative impact of mitigation. The post-mitigation measurement is a short-term test made in the same location(s) as the pre-mitigation test(s). The test must not be started sooner than 24-hours after the start-up of the radon mitigation system and within 30 days after the installation of the system. The test must have 12-hours of closed building conditions before the start of the test and closed building conditions during the test. In addition to the post-mitigation test, it must be recommended to the client that they test every two-years thereafter.

5. Data Collection, Validation, Reporting, Entry and Retention

Data Collection

If the hourly printout from the CRM is not given in the customer report, it will be available to customer for at least three years following the test.

Data Validation

Valid data is produced when a measurement system, including storage, field deployment, transport, analysis, and reporting are operating "in control" and within QC limits and when in-control QC checks have been made both before and after a set of validated data. It is the responsibility of the qualified measurement professional to conduct, record, and make available the results of QC checks relevant to each reported result.

The Quality Assurance Officer will review some radon reports to ensure the QA Plan is being followed. Validation factors include proofreading files to see that information entered into the computer from the test placement/retrieval checklist is correct. Any errors found during validation checks are documented including who made the errors, the dates of the errors, and how these errors were resolved.

Data Reporting

The measurement report shall include:

- The complete address of the test, including zip code;
- Company name, contact information and identification of the measurement professional (including MDH licensing number) placing and retrieving the test device;
- Exact location(s) of the detector(s) including level of building and exact room and location within that room tested;
- The start and stop, date and times for each measurement device;
- The detector model or type and identification numbers;
- The calibration date if using a CRM;
- Hourly data from the CRM must either be included in the report or provided to the client upon request;
- Removal of or backing out portions of hourly data imbedded within the contiguous sampling period reported shall invalidate the measurement except for removing the 1st 4 hours for correction factors, 1st 12 hours for closed-house conditions, or 1st 24 hours for newly installed mitigation system;
- Identification of organization used to analyze detectors;
- Radon Information Sources including state radon office and how to obtain federal or state guidance documents;
- The individual and average results of duplicate measurements;
- Description of observed building conditions and other factors that are temporary in nature and may affect the measurement results;
- Deviation(s) from protocol;
- If a mitigation system was present;
- Recommendations; and
- If applicable, whether the occupant or responsible party has agreed in writing to abide by the closed building conditions twelve hours before the test and throughout the test period.

The measurement report should describe the general limitations of the test such as the following statement:

- There can be uncertainty with any radon measurement due to statistical variations and other factors such as: daily and seasonal variations in radon concentrations; due to changes in the weather and operation of the building; as well as possible interference with the necessary test conditions that could influence the results.

All test results include a statement, which recommends that the building be re-tested in each of the following cases whether or not the building has been mitigated:

- If a new addition is added or significant renovation occurs;
- If a ground contact area was not previously tested is occupied or is newly occupied;
- If the building was unoccupied during the test, the building should be retested after occupancy;
- Heating or cooling systems are significantly altered resulting in changes to air pressures or distribution;
- If ventilation is significantly altered by extensive weatherization, changes to mechanical system or comparable procedures;
- If significant openings to the soil occur due to:
    - Groundwater or slab surface water control systems (e.g. sumps, perimeter drain tile, shower/tub retrofits, etc.) or,
    - Natural settlement causing major cracks or penetrations occur in the building's foundation walls or slab;
- If significant nearby construction blasting, earthquakes or formation of sink holes nearby;
- If a mitigation system is altered, modified or repaired.

6. Internal Quality Control

Quality control refers to the technical activities that measure the attributes and performance of a process, item, or service against defined standards in order to verify that they meet established specifications, including documentation.

Commitment to Quality and Objective

Our staff is committed to providing customers with accurate, valid, reproducible, and defensible radon measurements which may be used to make critical decisions about radiation-related environmental health. The due diligence of each employee and contractor involved with radon measurement is critical for achieving this goal.

A critical step to insure radon measurements meet nationally accepted quality standards is to conduct quality control (QC) measurements at prescribed rates and systematically over time. QC measurements shall be recorded electronically or in a logbook as soon as practicable, and shall be maintained for a minimum of three years. Failed QC measurements should be repeated prior to investigation and corrective action.

A measurement system must operate in such a way as to produce repeatable and stable quality control results. This is accomplished by performing calibration with background checks, crosschecks and duplicates for CRMs, and duplicates, spikes, and blanks for passive methods, as well as other method-specific checks.

Continuous Radon Monitors

Calibration

Calibration refers to the process of determining the response of a measurement device to a series of known radon concentrations and making necessary adjustments to the device. Calibration is made every 12 months or after repair for each CRM by either, the monitor manufacturer or a national radon proficiency program approved calibration laboratory approved by the device manufacturer.

Any monitor that does not have a calibration certification, dated within 12 months, must be removed from service.

In addition to calibration, an annual **background check** is performed by purging with clean aged air or nitrogen. The manufacturer or calibration laboratory completes this process at the time of calibration.

Routine Instrument Checks

Instrument checks involve using the manufacturer's instructions for checking for proper working condition including checking battery voltage levels, cleaning screen inlet ports, and verifying that calibration is up-to-date. Performance checks will be made before every measurement.

Duplicates

Radon measurements, like all measurements, usually do not produce exactly the same results, even for simultaneous, co-located measurements. Duplicate are two side-by-side measurement devices placed 4 to 8 inches apart, or as specified by the manufacturer, that simultaneously measure radon.

The objective of duplicate tests is to assess the precision error of the measurement method or, in other words, how well two side-by-side measurements agree or disagree.

Duplicates shall be made at a rate of 10% of all measurement locations or 50 per month, whichever is less. Tests should be randomly distributed and deployed in the normal course of business across a variety of projects, operators, and environments.

When duplicate measurements are made, the results are reported as such to the customer who receives the primary test. The individual results and the average of the two will be reported. In addition, results of duplicates are recorded on Duplicate Control Charts.

Precision involving duplicates is calculated by using Relative Percent Difference (RPD). RPD is equal to the difference between the higher test result minus the lower test result divided by the average of the two duplicate test results, which is then multiplied by 100. The RPD result is then compared to warning levels and control limits. The Warning Level is set at the deviation from ideal performance that would be expected to occur by chance only 5% of the time, and Control Limits are set at that deviation from ideal performance that would be expected to occur by chance only 1% of the time. The Warning Level indicates a potential problem, which should be investigated. The Control Level indicates that the measurement system should be subject to corrective action and probable recalibration.

The control and warning limits for duplicates are:

- at concentrations averaging less than 2 pCi/L, the control limit is 1 pCi/L,
- between 2 and 3.9 pCi/L,
  - the warning level is 50% RPD;
  - the control limit is 67% RPD;
- 4 or more pCi/L,
  - the warning level is 28% RPD;
  - the control limit is 36% RPD.

If within any 30-day period, precision errors are found that exceed control limits or if any two exceed warning levels within a month, an investigation will be launched, if applicable, in consultation with the analytical laboratory and state authorities.

Crosschecks

Crosschecks are conducted to determine bias and are made every 5 to 7 months after a CRM has been calibrated. For at least 48 hours, the CRM past calibration by 5 to 7 months (designated as CRM-1) is cross-checked with any CRM that has been calibrated within the past 12 months but not at the same time as CRM-1 (designated as CRM-2). This procedure is most effective when CRM 2 has been recently calibrated. When possible, a crosscheck is performed in an environment with a radon concentration that is about 4 pCi/L or greater.

When crosscheck measurements are made, the results are reported as such to the customer who receives the primary test. The individual results and the average of the two will be reported. In addition, the results of crosscheck measurements are recorded on a Crosscheck Control Log and Chart.

The crosscheck is also counted as a duplicate and RPD is calculated the same as a duplicate.

Passive Devices

Routine Instrument Checks

Checks include examining packaging upon both receipt and disbursement of the devices.

Duplicates

Radon measurements, like all measurements, usually do not produce exactly the same results, even for simultaneous, co-located measurements. Duplicates are two side-by-side measurement devices placed 4 to 8 inches apart, or as specified by the manufacturer, that simultaneously measure radon.

The objective of duplicate tests is to assess the precision error of the measurement method or, in other words, how well two side-by-side measurements agree or disagree.

Duplicates shall be made at a rate of 10% of all measurement locations or 50 per month, whichever is less. Tests should be randomly distributed and deployed in the normal course of business across a variety of projects, operators, and environments.

When duplicate measurements are made, the results are reported as such to the customer who receives the primary test. The individual results and the average of the two will be reported. In addition, results of duplicates are recorded on Duplicate Control Charts.

Precision involving duplicates is calculated by using Relative Percent Difference (RPD). RPD is equal to the difference between the higher test result minus the lower test result divided by the average of the two duplicate test results, which is then multiplied by 100. The RPD result is then compared to warning levels and control limits. The Warning Level is set at the deviation from ideal performance that would be expected to occur by chance only 5% of the time, and Control Limits are set at that deviation from ideal performance that would be expected to occur by chance only 1% of the time. The Warning Level indicates a potential problem, which should be investigated. The Control Level indicates that the measurement system should be subject to corrective action.

The control and warning limits for duplicates are:

- at concentrations averaging less than 2 pCi/L, the control limit is 1 pCi/L,
- between 2 and 3.9 pCi/L,
  - the warning level is 50% RPD;
  - the control limit is 67% RPD;
- 4 or more pCi/L,
  - the warning level is 28% RPD;
  - the control limit is 36% RPD.

If within any 30-day period, precision errors are found that exceed control limits or if any two exceed warning levels within a month, an investigation will be launched, if applicable, in consultation with the analytical laboratory and state authorities.

Blanks

Blanks are measurements performed to determine if the measurement device may have unintended exposure (background) during storage, handling and shipping. A blank is an unexposed measurement device that is opened, immediately closed and sealed, and, like an exposed measurement device, labelled with plausible start and stop dates and times, and then

returned to the analytical laboratory. Blanks must be the same type, configuration, and from the same analytical laboratory as the other devices used by the provider. To facilitate problem investigations, it is important to track the environments that the measurement devices are stored, transported, and used.

Blanks are placed at a rate of 5% of measurements or 25 per month, whichever is less. The results of blank measurements are recorded on a Blank Control Chart.

Blank test results should be less than the minimum detectable concentration of the passive measurement device. If background is detected with any blank, investigation shall be made into the cause which could include contacting the analytical laboratory. Corrective action shall be made as necessary to remedy any discovered issues.

Spikes

Spikes are also called known exposure measurements and are made to determine accuracy at a rate of 3 per 100 measurements per device type, minimum of 3 per year, and a maximum of 6/month. Spike measurements are obtained from a spiking chamber that is certified by NRPP or NRSB. The process involves: 1) sending an unused passive measurement device(s) to the approved chamber; and 2) then, after it is returned, sending the device to the device's analytical laboratory.

Spiked devices must be the same type and configuration as those used by the measurement provider. In the event of an order of more than 50 passive measurement devices, at least one spiked measurement should be made before using the remaining devices as well as periodically over the course of the year.

The results of spiked measurements are recorded on a Spike Control Log and Chart. Relative Percent Error (RPE) is calculated by subtracting the spiking chamber's value from the value obtained from the analytical laboratory, and that difference is divided by the spiking chamber's value. The expectation is that the values of RPE fall between +10% and -10%, but the entire range of +20% to -20% is considered "in control." Outside of +/- 20% but inside of +/- 30% is the warning level and outside of +/- 30% is the control limit. Any RPE outside of 20% will be investigated and documented.

7. Corrective Action

This section specifies procedures and corrective action taken when problems have been revealed by QC measures or internal QA audits; deviations from routine circumstances are found; and complaints or suggestions are received from customers or licensed radon professionals.

The QA Officer is responsible for assessing the potential impact or effects of problems on radon testing and initiating corrective action. To avoid problem recurrence, corrective action includes initiation of preventive actions. Documentation of your investigation and corrective action is an essential part of the QA plan. Having an unusual QC measurement is possibly acceptable, however, not investigating the issue defeats the whole purpose of the doing the test.

If there is a pattern of quality control measurements that is not within the expected range of results, then the system may be out of control and all results are questionable. When a QC measurement is in the warning level, there may be a potential problem and investigation is required. When a QC measurement is outside the control limit, the measurement system shall be subject to corrective action and possibly recalibration.

Investigation includes communicating with instrument providers, the analysis laboratory and shippers (as relevant) to find and fix the cause of poor measurement performance, as well as thorough documentation of the problem, the solution and preventive action. Failed QC checks may indicate a problem with already-completed measurements, and corrective action in that case may include retesting environments where previous measurements are not defensible. Investigation records document how the results of QC checks were used to validate or invalidate measurements already conducted with that measurement system.

It is important to note that some failed QC results, especially those near the limits, may occur solely by chance and not be due to a correctible problem. This can be the case if the QC check is repeated and is within limits. In such cases, no corrective action is needed, but it shall be documented.

Important Duplicate Requirement: If one measurement is equal to or greater than 4 pCi/L and the other below, the higher result may not be twice or more than the other. Such measurements **MUST** be repeated. Examples are 2.0 and 4.1 or 1.9 and 4.0.

If blanks exceed the lower limit of detection, investigation will be performed to identify the cause of the problem. The remainder of the test kits will not be used until the problem is identified to determine if all of the kits have been contaminated. Necessary corrective actions will be taken as advised by the analysis laboratory.

If problems are found during internal audits or inspections, the QA Plan will be reviewed and staff will be trained on proper procedures. Potential problems with proper procedures could include detectors not returned within the time limit, closed house conditions not being maintained, improperly returned devices, device tampering, etc.

8. Quality Assurance Training

The Quality Assurance (QA) Officer is responsible for reviewing and developing the training plans for all staff and the plans for retraining when procedures change. New staff shall receive QA training prior to conducting radon measurements. Adequate training is given high priority, since the implementation of this QA plan is dependent upon the staff's understanding of its requirements. The training includes an emphasis on each employee's ethical and legal responsibilities for reliable and valid measurement test results as well as reporting of those results.

Personnel are responsible for knowing everything in this QA Plan, which falls within their particular area of responsibility. This QA Plan is the principle source document for the QA procedures and protocols, which must be known and practiced by responsible company personnel.

The QA Officer provides each employee with a copy of this QA Plan in which the specific QA activities and responsibilities for that particular employee are clearly marked and indexed.

Prior to conducting radon measurements and at least annually thereafter, the QA Officer checks each involved employee's knowledge and understanding of their QA duties and responsibilities as defined in this Plan. If, in the judgment of the QA Officer, an employee does not adequately understand his/her responsibilities, follow-up instructions and checks are carried out until acceptable understanding is demonstrated.

9. Quality Assurance Audits and Reports

QA Audits are formal, structured comprehensive and independent reviews to determine whether quality activities comply with planned arrangements and are suitable to achieve objectives.

The QA Officer conducts QA Audits periodically and reports audit results in writing to the Superintendent. QA Audit Reports contain the following information about measurement data quality: record keeping; results of duplicates, blank and spike test results; calibration completions; crosschecks; routine instrument checks; source check results; results of any additional audit steps; and revisions of the QA Plan; and corrective action needed and enacted.

10. Definitions

- **As Constant as Practicable:** This term is defined by agreement between the provider of the device(s) and the operator of the Standard Test Atmosphere for Radon (STAR; also known as a radon chamber), taking into consideration the inherent function of the device(s) and the design limitations and operational requirements of the STAR.
- **Audit:** A systematic and independent examination to determine whether quality activities and related results comply with planned arrangements and whether these arrangements are implemented effectively and are suitable to achieve objectives.
- **Blind:** A type of performance test of the analytical capability of a method in which a sample is not identified as a performance test to the analyst.
- **Calibration Factor:** That factor or function that represents the relationship between the method's response and the concentration to which it is responding. The calibration relationship is the ratio of "rise," or the response (dependent variable represented on the vertical axis), to the "run" of the concentration being analyzed (independent variable represented on the horizontal axis), and therefore, in all cases the calibration factor is based on measurement system response divided by the concentration to which it is responding.
- **Coefficient of Variation (COV):** The sample standard deviation (s) of a set of measurements expressed as a percentage of the arithmetic mean of the measurements; COV = 100 (s/mean).
- **Collocation:** Measurements conducted in which the inlet or diffusion area of every set of two separate devices is not closer than 4 inches (10 cm) and not further than 8 in (20 cm) in both the horizontal and vertical plane, and in the same room. The usual objective of collocation is to simultaneously measure the same radon concentration.

- **Continuous Radon Monitor (CRM):** An electronic device that: (1) is capable of providing reviewable, numeric measurements of radon concentration averaged over time intervals of 1 hour or less; (2) has a minimum detectable concentration (MDC) of no greater than 4 pCi/L (148 Bq/m3) for a 1-hour measurement; and (3) has a calibration factor of at least 2 counts per hour per 37 Bq/m3 (2 cph per pCi/L or 0.054 counts per hour [cph] per Bq/m3).
- **Corrective Action:** Actions taken to identify and eliminate root causes of a problem, thus preventing their recurrence. It is important to note that some failed QC results, especially those near the limits, may occur solely by chance and not be due to a correctible problem. In such cases, a repeat of the QC check will meet the criteria for continued stable operation, and no corrective action may be needed. Investigation includes communicating with MDH, instrument providers, the analysis laboratory and shippers (as relevant) to find and fix the cause of poor measurement performance, as well as thorough documentation of the problem, the solution and preventive action. Failed QC checks may indicate a problem with already-completed measurements, and corrective action in that case may include retesting environments where previous measurements may be suspect. Corrective action records should indicate how the results of QC checks were used to validate or invalidate measurements already conducted with that measurement system.
- **Data Validation:** Valid data are produced when a measurement system, including storage, field deployment, transport, analysis, and reporting are operating “in control” and within (Quality Control (QC) limits and in-control QC checks have been made both before and after a set of validated data. It is the responsibility of the qualified measurement professional to conduct, record, and make available the results of QC checks relevant to each reported result. For example, if approximately 100 measurements are conducted each quarter with a single charcoal device configuration, there must be documented, within-limits QC results for at least five blanks, three spikes, ten duplicate pairs, and a record of exposure conditions during storage, both before and after the approximately 100 measurement results made during that quarter. The record of these satisfactory QC checks should be part of the quality system documentation and available to auditors.
- **Equilibrating Method:** This class of device employs a material such as activated charcoal that adsorbs radon from the air. During exposure to constant radon concentrations, temperatures, and humidity, a state of equilibrium is reached between the quantity of adsorbed radon and the concentration of radon in the surrounding air. Once equilibrium is established, radon may exchange between the charcoal and the air. Some of the adsorbed radon may be replaced by moisture from the air and, thus, the quantity of adsorbed radon may decrease after equilibrium is established. If the radon concentration, temperature, or humidity in the environment changes, the adsorption properties of the charcoal change, and radon may desorb so as to maintain the state of equilibrium.
  Moisture in the air competes with adsorption sites on the charcoal; therefore, less radon is adsorbed when the air contains more moisture (higher relative humidity). In addition, less radon is adsorbed by charcoal at higher temperatures.
  Therefore, devices using adsorption of radon by activated carbon are subject to effects of moisture and temperature. Device providers may need to consider such effects to meet the requirements of the standard.
  This class of device can provide a good representation of the average radon concentration during the exposure period as long as there are no large changes in the radon

concentration during the exposure. Depending on the design of the device, its response may be significantly influenced by the radon concentration in the air during the last 12 hours or so of the exposure period. Because of the half-life of radon and the time, it takes for equilibrium to be established between the adsorbed radon and the radon concentration in the air, this class of device is typically limited to exposure durations from 2 to 7 days. Calibration of an equilibrating device is accomplished through exposures of representative sets of devices in a STAR for various time periods and under various controlled and monitored conditions of radon concentration, temperature and humidity.

- **In Control:** A measurement system operating in such a way as to produce repeatable and stable quality control results, including background for CRMs, crosschecks and comparison checks for CRMs, and duplicates, spikes, and blanks for passive methods, as well as other method-specific checks. This standard presents limits on QC results derived from industry statistics applicable to categories of measurement methods. Each measurement system can develop more restrictive limits than those presented here, based on their QC results, which should in all cases be derived using the method described in the EPA National Radon Proficiency Program's Guidance on Quality Assurance and documented. Until such time as a measurement system derives such limits from their own QC results, the limits presented in this standard can be applied to determine data validity.
- **Lower Limit of Detection Counting Technology Methods (LLDCT):** the smallest net count rate at which there is 95% confidence that a signal above background is detected. For the purpose of this standard, and for devices that rely on counting technology, the following equation is used (Currie, 1968):
  - LLDCT = [2.71/ts + 3.29(Rb/tb + Rb/ts)½]
  - Where: LLDCT = Lower Limit of Detection (cpm) for counting technology methods
  - ts = Sample counting time (min)
  - Rb = Background or blank count rate (cpm)
  - tb = Background or blank counting time (min)
- **Measurement System:** All the components that are involved in the measurement of 222Rn concentration and that are part of the quality system, including the trained measurement professional and those assisting in data management, auditors, shippers, the analysis laboratory, and anyone else who is part of the system used routinely to provide valid measurement results. MS-PC: Performance Specifications for Instrumentation Systems Designed to Measure Radon Gas in Air, American National Standards Institute, 2015.
- **Minimum Detectable Concentration (MDC):** The lowest concentration that is detectable above background with 95% confidence. This concentration is derived from the LLD by applying the same factors that are used to convert the sample net count rate to radon concentration or integrated concentration. For a CRM, the LLD is divided by the calibration factor to obtain the MDC. For charcoal devices, the net count rate may be divided by factors that take into account such parameters as the adsorbed moisture, the duration of the exposure, the system counting calibration factor, and radioactive decay.
- **Quality Assurance Plan:** A Quality Assurance Plan is a formal document describing in comprehensive detail the necessary quality assurance policies, quality control procedures, and other technical activities that need to be implemented to ensure that the results of the work performed will satisfy the stated performance or acceptance criteria. The QAP should define objectives to be attained (for example, QC limits at various stages of the operations)

and the responsibilities and authorities of personnel especially in regards to data quality and corrective action.

- **Quality Control (QC):** The technical activities that measures the attributes and performance of a process, item, or service against defined standards to verify that they meet established specifications, including documentation.
- **Quality System:** The overall management of an organization that establishes a quality policy and procedures to implement that policy, including documented policies, objectives, principles, organizational authority, responsibilities, accountability, and implementation plan of an organization for ensuring quality in its work processes and services (International Standards Organization [ISO] 9000:2000, 2.2.3). Quality system documentation will include the following elements: (1) organization and responsibilities, including accountability for the QC measurements and their documentation; (2) measurement, data review and reporting procedures; (3) procedures for ensuring measurement device and data custody tracking; (4) analytical procedures; (5) assessments (audits) and corrective action; and (6) Quality Assurance (QA) reporting. All six elements should be documented in a QA Plan and associated standard operating procedures.
- **Percent Error (RPE):** A statistic used to evaluate the difference between a measurement and the conventionally true value, which may be a more recently calibrated CRM or a chamber concentration. The RPE is the degree from which a single measured value (X) deviates from the conventionally true value (T). The RPE is calculated using the following equation and compared against QC limits. Although the equation uses the absolute value of the difference, it is important to note that if one measurement is consistently greater or less than the other, there may be a calibration difference between the two measurement systems that should be identified.
  - RPE = absolute value [100 (X – T) / T] * 100
  - X = Measured value (Bq/m3, pCi/L, Bq-h/m3, or pCi-d/L)
  - T = Conventionally true value (in the same unit as X)
- **Relative Percent Difference (RPD):** A statistic used to evaluate the difference between two measurements when neither one can be assumed to be more accurate than the other. The RPD compares the difference between two measurements divided by their mean, which in this case is the best estimate of the true concentration. Note that a 14% RPD corresponds to a 10% COV for two measurements. RPD is always positive, as there is no reason to assume that one measurement is more accurate than the other, and RPD is used as an estimate of imprecision.
  - RPD = [(A - B) / mean] * 100, where
  - A = the larger result,
  - B = the smaller result, and mean = the average of the two results.
- **Standard Test Atmosphere for Radon (STAR):** A standard test atmosphere for radon (often called a “radon chamber”), sufficient in size and configuration, radon concentration range, and radon concentration controls such that:
  - at least five simultaneous and independent measurements of radon concentration can be conducted at the high and/or low limits of the ranges of radon concentration (e.g., in pCi/L) or integrated concentration (e.g., in pCi-d/L), during which time the conditions in the STAR are as constant as practicable;

- the function of the devices being tested is their function for measuring radon concentration; temperature, relative humidity and radon concentration are recorded hourly or more frequently by devices with annual National institute of Standards and Technology (NIST)-traceable calibrations (or traceable as defined below) and documented uncertainty estimates;
- barometric pressure in the STAR at local conditions is recorded or otherwise available and included in exposure reports;
- temperature and relative humidity are controlled to within the limits of this standard for the particular test being conducted; and
- the uncertainty of the average radon concentration during the exposure period is calculated using methods recommended by NIST (NIST TN-1297), published and reported with each exposure.

The STAR is operated under a documented quality management system consistent with recognized international standards such as ISO 9001.

- **Traceability:** Property of the result of a measurement whereby it can be related to stated references, usually national or international standards, through an unbroken chain of comparisons all having stated uncertainties. The concept is often expressed by the adjective traceable. The unbroken chain of comparisons is called a traceability chain [VIM: 1993, 6.10].
- **Warning Levels and Control Limits:** Warning Levels are set at that deviation from ideal performance that would be expected to occur by chance only 5% of the time, and Control Limits are set at that deviation from ideal performance that would be expected to occur by chance only 1% of the time. This standard provides default warning levels based on industry practice that in control operations exhibit a 14% RPD for concentrations greater than or equal to 4 pCi/L, and a 25% RPD for concentrations between 2 and 4 pCi/L.

11. References

AARST/ANSI 2017 Protocols for Conducting Radon and Radon Decay Product Measurements in Multifamily Buildings, Fletcher, NC: American Association of Radon Scientists and Technologists.

AARST/ANSI 2019 Protocols for Conducting Radon and Radon Decay Product Measurements in Homes, Fletcher, NC: American Association of Radon Scientists and Technologists.

AARST/ANSI 2014 Protocols for Conducting Radon and Radon Decay Product Measurements in Schools and Large Buildings, Fletcher, NC: American Association of Radon Scientists and Technologists.

AARST/ANSI 2015 Performance Specifications for Instrumentation Systems Designed to Measure Radon Gas in Air (MS-PC), Fletcher, NC: American Association of Radon Scientists and Technologists.

AARST/ANSI 2018 Quality Assurance for Radon Measurement Systems, Hendersonville, NC: American Association of Radon Scientists and Technologists.

Air Chek 2009a “QA and Quality Control Plan for the Measurement of Indoor Radon Concentrations in Ohio with ProChek Activated Charcoal Test Kits,” Mills River, NC: Air Chek, Inc.

Air Chek 2009b “QA and Quality Control Plan for the Measurement of Indoor Radon Concentrations with ProChek Activated Charcoal Test Kits,” Mills River, NC: Air Chek, Inc.

DEP 2015 Pennsylvania Radon Certification Forms and Information, Harrisburg, PA: Pennsylvania Department of Environmental Protection, Bureau of Radiation Protection.

Femto-Tech 2008 “QA and Quality Control Plan for Measurement of Indoor Radon Concentrations with the Femto-Tech Model CRM-510 or CRM-510LP Continuous Monitor, Dayton, OH: Femto-Tech.

IEMA 2005 Radon QA Program Guidance, Springfield, IL: Illinois Department of Emergency Management.

ISO 2015 Quality Management Systems – Requirements, Geneva, Switzerland: International Standards Organization.

Nebraska Radon Program undated “QA Plan for Conducting Radon Measurements,” Lincoln, NE: Nebraska Health and Human Services.

New Jersey Radon Section 2014 “QA/QC Plan Review Checklist,” Trenton, NJ: Department of environmental Protection, Division of Environmental Safety and Health.

ODH 2012 “Frequently Asked Questions Concerning Radon Licensing,” Columbus, OH: Ohio Department of Health Radon Licensing Program.

Ronca-Battista, M and Brodhead, B (circa 1994) “AARST Model QA Plan,” Fletcher, NC: American Association of Radon Scientists and Technologists.

Steves, K 2013 “QA Plan Checklist for Measurement Technicians/Laboratories,” Topeka, KS: Kansas Department of Health and Environment.

Steves, K, Hannah, DS, Hart, D, Snook, J and Steen, S 2013 KDHE QA Plan for Conducting Radon Measurements, Topeka, KS: Kansas Department of Health and Environment.

US EPA 1992 Indoor Radon and Radon Decay Measurement Protocols (EPA-402-R-92-004), Washington, DC: U.S. Environmental Protection Agency.

US EPA 1993 Protocols for Radon and Radon Decay Product Measurements in Homes (EPA-402-R-92-003), Washington, DC: U.S. Environmental Protection Agency.

US EPA 1997 National Radon Proficiency Program: Guidance on QA, Washington, DC: U.S. Environmental Protection Agency.

Radon Test Placement and Retrieval Checklist

Placement Checklist

☐ Address of test: _____

☐ Contact name and phone number: _____

☐ Has the required written test conditions notification been given?

☐ If the building has multiple foundation types such as basement, crawlspace, and slab-on-grade, it is necessary that a test be conducted in the occupied area above each foundation type (e.g. a occupied basement would have the device placed in the basement, for a crawlspace, the test device would be placed in the occupied space above the crawlspace).

Inspect and document building/testing conditions

☐ Will the building be occupied during the test? Circle: **Yes or No**

☐ Are required test conditions observed when the measurement device is deployed? **Yes / No**

- If no, then:
  □ The radon test is postponed until at least 12 hours of closed-building conditions have been maintained prior to initiating the test; or
  □ The test period is extended to 4 days or more after closed-building conditions are initiated; or
  □ The test period is extended, if testing with a continuous monitor. For this option, device features or other methods are to be employed to obtain an average reading that represents no less than 46 hours of contiguous data collected after 12 hours of closed-building conditions have been maintained.

☐ Are the heating and cooling systems set to normal occupied operating conditons with temperature settings between 65 and 80 degrees F.

☐ Are window air conditioners set to operate in recirculation mode only? **Yes / No**

☐ Is there a forced-air HVAC system? **Yes / No** ☐ Fan setting: **On/Auto/Off**

☐ Are return air ducts from forced air heating and/or cooling systems under concrete floors? **Yes / No** (If so, then conduct at least one test when air handlers are active?

☐ Is a heat recovery ventilator or air-to-air heat exchanger installed in the building? **Yes / No**

☐ Is unit set to the lowest seasonal ventilation condition that occurs during the year? **Yes / No**

☐ Is unit set to operate during the test, and at what setting? **Yes / No** _____

☐ Condition of active or passive air supplies to the building or to combustion appliances. Supplies are: **operating as intended / blocked**

☐ Are fireplaces off, unless used as a primary/normal source of heat for the building? **Yes / No**

(Close dampers or doors if practicable)

☐ Is a radon mitigation system installed in the building? **Yes / No**

☐ Is system on? **Yes / No**

☐ Does system appear to be functional? **Yes / No**

☐ Are there any temporary mitigation strategies observed, including_____?

☐ Are there any unavoidable construction activities being done to the building that could possibly affect radon levels? **Yes / No**

Activities noted:_____

☐ Are there any unusually severe storms or periods of unusually high winds forecasted during the testing period. If so, testing at a different time should be considered.

Conditions noted/forecasted: _____

☐ Are there any permanent vents, such as crawlspace vents to the outside? **Yes / No**

☐ Position of the vents: **Open / Closed**

☐ Do not place the test device in drafts from heating or air conditioning vents or fans.

☐ Do not place the test device in closets, kitchen, bathroom, laundry room or other closed or high humidity areas. Classrooms, conference rooms or gyms are good testing locations.

☐ Either place the measurement device on a stable surface (but not on a stone surface) or, if called for in the device instructions, hang the device(s) at normal breathing level.

☐ Do not place the test device on or near heat sources nor in direct sunlight.

☐ Place the test device at least 20 inches above the floor or, if the device is to be suspended, [6 feet above the floor and a minimum of 12 inches below the ceiling.

☐ Place the test device at least 3 feet from windows or exterior doors or otherwise, a minimum of 12 inches from an exterior wall.

☐ Place the test device at least 4 inches from other objects.

☐ At the test location per device instructions, open the test device or start the CRM.

☐ Record start time and date below and, if appropriate, on the test device.

☐ Leave the testing in progress notice in a conspicuous location.

☐ Initiate any tamper resistant methods if used. Methods used: _____

☐ Note exact test location on map.
(floor/room/location):_____

Retrieval Checklist

☐ When the measurement device was retrieved, were required test conditions observed? **Yes/ No**

☐ If a heat recovery ventilator or air-to-air heat exchanger is present, was it operating? **Yes / No**

☐ If there is a forced-air HVAC system, is the fan setting the same as when the test device was placed? **Yes / No**

☐ If mitigation system present, was it on? **Yes / No**

☐ Note radon testing device location to determine if it had been moved or tampered with during the test.

☐ Any construction activities being done to the building that could possibly affect radon levels? **Yes / No** Activities noted:_____

☐ Were there any unusually severe storms or periods of unusually high winds during the testing period? Conditions noted/forecasted:

_____

☐ Are there any permanent vents, such as crawlspace vents to the outside? **Yes / No**

☐ Position of the vents: **Open / Closed**

☐ Note any deviations from protocol and why it was unavoidable:

_____

_____

_____

☐ End the test by turning off the CRM or reseal the measurement device.

☐ Record stop date and time below and, if appropriate, on the device.

Return the measurement device(s) to the analytical laboratory as soon as practical. Activated charcoal adsorption devices must be returned to the analytical laboratory within 4 days.