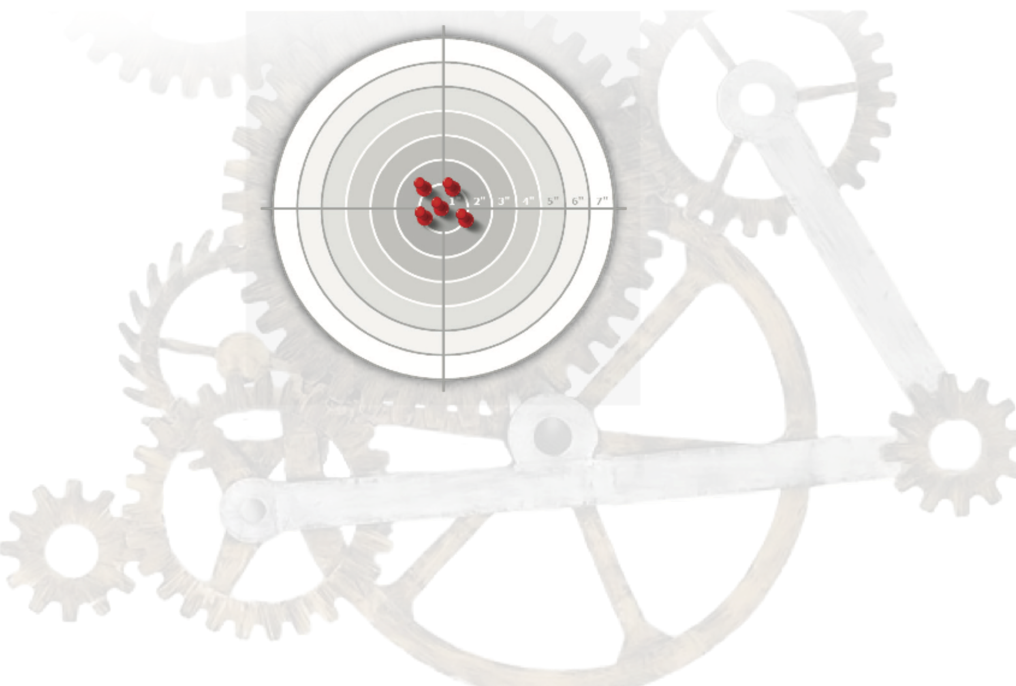
AARST CONSORTIUM On National Radon Standards

ANSI/AARST **MS-PC 202x**

PROPOSED REVISIONS

Performance Specifications for Instrumentation Systems Designed to Measure Radon Gas in Air

Measurement Systems - Performance Criteria



AARST CONSORTIUM ON NATIONAL RADON STANDARDS

Public Review: MS-PC *04-2020*

Performance Specifications for Instrumentation Systems Designed to Measure Radon Gas in Air

COMMENT DEADLINE: June 1st, 2020

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Title of Public Review Draft: **MS-PC Proposed Revision 04-2020**

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Rev. 05-01-2019

MS-PC Introduction

Performance Specifications for Instrumentation Systems Designed to Measure Radon Gas in Air

Scope Summary

This standard specifies minimum performance criteria and testing procedures for instruments and/or systems designed to quantify the concentration of ^{222}Rn gas in air. These are consistent but general performance criteria applicable to the wide variety of radon measurement devices used for indoor measurements, primarily in residential environments or buildings not associated with the possession or handling of radioactive materials. Also included is a description of documentation necessary for demonstration of compliance with this standard.

This standard addresses performance criteria for radiological and environmental parameters only. This standard does not address the *calibration* or other quality assurance requirements for the use of the instruments and/or systems, or the measurement of other isotopes of radon such as ^{220}Rn and ^{219}Rn or progeny of any radon isotope. This standard does not address interference from isotopes of radon other than ^{222}Rn, grab sampling methods, mechanical and electrical issues related to the devices, or performance criteria for laboratory equipment that might be used to analyze devices, such as a gamma-ray spectroscopy system for analyzing a charcoal canister. Sampling periods of less than 1 hour in duration are explicitly excluded from consideration in this standard. Although the performance criteria could be adopted for use in a certification program, such a program is beyond the scope of this standard.

Overview

In 1992, the U.S. Environmental Protection Agency (*EPA*) published *Indoor Radon and Radon Decay Product Measurement Device Protocols* as guidance for devices that were to be listed in the *EPA*'s National Radon Proficiency Program. This *EPA* program was privatized in 1998. Because there remained a need for consensus standards related to radon measurements in homes, schools and other buildings, radon mitigation, measurement devices, quality assurance, etc., the American Association of Radon Scientists and Technologists (AARST) created under its auspices the AARST Consortium on National Radon Standards to promulgate a series of standards to address these issues. This standard is one in that series. The primary aim of this standard is to identify minimum performance criteria for devices or systems used for measurements of radon in indoor environments for the purpose of determining whether or not the home or building should be mitigated to reduce the radon concentration below an applicable guideline concentration. However, this standard may be useful for devices or systems for measuring radon in other circumstances. Devices that are used to measure radon for the purpose of compliance with federal or State regulations related to the possession or handling of radioactive materials may require additional or more restrictive criteria than set forth in this standard.

Manufacturers and/or laboratories claiming that the device(s) they produce or use meet the requirements of this standard should maintain documentation supporting that claim; Section 8 provides a sample report template. Compliance with this standard does not constitute "certification" or "device approval," such as from a national proficiency program.

Hereafter, the term *radon* is used to mean specifically ^{222}Rn gas and *thoron* to mean specifically ^{220}Rn gas; the term *radon progeny* means the short-lived radioactive decay products of ^{222}Rn gas, and *thoron progeny* means the short-lived radioactive decay products of ^{220}Rn gas. A complementary standard, ANSI N42.50, *Performance Specifications for Systems Designed to Measure Radon Progeny in Air* (ANSI/IEEE N42.50), has been promulgated to address instrumentation for the measurement of radon progeny.

This standard specifies minimum performance requirements for radon measuring devices, as well as testing criteria for demonstrating and documenting compliance. The tests are to be conducted in a *STAR* under various conditions of radon concentration, temperature and humidity. A *manufacturer* or laboratory that makes or uses a device or measurement system that is listed by a national radon proficiency program may already have results of testing on file that could partially or fully suffice to demonstrate compliance with this standard. For example, results of device exposures conducted in a *STAR* for device evaluation, *quality control* (spiking), *performance testing*, or in some cases *calibrations*, may be used to demonstrate compliance with this standard. Such exposures might not be conducted as *blind* tests, yet may be used to demonstrate compliance with this standard. *Providers* with multiple device types, or multiple models of the same device type, may test more than one type and/or model simultaneously. Once a *manufacturer* and/or laboratory has demonstrated that a device or measurement system complies with this standard, the testing procedure would only be required again if a significant change, as defined in Section 4, was made to the instrument or measurement system.

The environmental conditions specified for the tests in a *STAR* are those likely to be found in an indoor environment where people may live or work. The standard does not consider outdoor or harsh environmental conditions. In this standard, the devices are categorized in the following way: "continuous," "integrating" or "equilibrating." These terms are defined in Section 4.

This standard makes use of three different verbs, *shall*, *should* and *may*, to indicate the level of rigor with which a particular criterion is applied. For the purposes of this standard, these terms are defined in Section 4.

Designation of this standard: MS-PC

As used for catalogue identification, "MS-PC" stands for Measurement System Performance Criteria.

The Consensus Process and Continuous Maintenance

The consensus process developed for the AARST Consortium on National Radon Standards and as accredited to meet essential requirements for American National Standards by the American National Standards Institute (ANSI) has been applied throughout the process of approving this document.

This standard is under continuous maintenance by the AARST Consortium on National Radon Standards a program has been established for regular publication of addenda or revisions, including procedures for timely consensus action on requests for change to any part of the standard.

User Tools: User tools are posted online (https://standards.aarst.org/public-review/) as they become available such as interpretations and approved addenda updates across time.

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Notice of right to appeal: Bylaws and procedures for the AARST Consortium on National Radon Standards available online (https://standards.aarst.org/public-review/). Section 2.1 of Appendix B (Operating Procedures for Appeals) states, "Persons or representatives who have materially affected interests and who have been or will be adversely affected by any substantive or procedural action or inaction by AARST Consortium on National Radon Standards committee(s), committee participant(s), or AARST have the right to appeal; (3.1) Appeals shall first be directed to the committee responsible for the action or inaction."

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MS-PC

Performance Specifications for Instrumentation Systems Designed to Measure Radon Gas in Air

1. SCOPE

This standard specifies minimum performance criteria and testing procedures for instruments and/or systems designed to quantify the concentration of ^{222}Rn gas in air. These are consistent ~~but~~ with general performance criteria applicable to the wide variety of *radon* measurement devices used for indoor measurements, primarily in residential environments or buildings not associated with the possession or handling of radioactive materials. Also included is a description of documentation necessary for demonstration of compliance with this standard.

Limitations: This ~~initial edition of the~~ standard addresses performance criteria for radiological and environmental parameters only. This standard does not address the *calibration* or other quality assurance requirements for the use of the instruments and/or systems, or the measurement of other isotopes of *radon* such as ^{220}Rn and ^{219}Rn or *progeny* of any *radon* isotope. This initial edition of the standard does not address interference from isotopes of *radon* other than ^{222}Rn, grab sampling methods, mechanical and electrical issues related to the devices, or performance criteria for laboratory equipment that might be used to analyze devices, such as a gamma-ray spectroscopy system for analyzing a charcoal canister. Sampling periods of less than 1 hour in duration are explicitly excluded from ~~consideration~~ performance testing procedures in this standard. Although the performance criteria could be adopted for use in a certification program, the decisions of such a program are beyond the scope of this standard.

2. ~~PURPOSE~~ SIGNIFICANCE OF USE

This standard provides guidance to *manufacturers* and/or laboratories regarding minimum performance criteria for their instruments or measurement systems with the associated tests that they should perform, or have performed by a third party, to demonstrate compliance with the standard. Such tests ~~shall be~~ are conducted in a *Standard Test Atmosphere for Radon (STAR)* as defined in Section 4. Tests conducted under conditions other than the controlled conditions of a *STAR* are insufficient to determine whether the requirements of this standard have been met.

3. APPLICATION

The terms "shall" and "required" indicate provisions herein that are mandatory for compliance with this standard. The terms "note-", "informative", "should" and "recommended" indicate provisions that are considered to be helpful or good practice but that do not contain a mandatory requirement.

~~**May.** Signifies an acceptable method or good practice.~~

~~**Shall** – signifies a mandatory requirement. Note: An appropriate qualifying statement may be included in this standard to indicate if conditional exceptions are allowed. As an example, if a specification is stated as being a "should" or a "may" and is later followed by a subsequent "shall" in the same subsection, the "shall" applies only if the "should" or "may" is implemented.~~

~~**Should** – signifies a recommended specification or method. It is understood that if something this standard states should be done is not done, the *manufacturer* or user shall have included in a technical basis document the justification for not doing so.~~

4 DEFINITIONS & ABBREVIATIONS

Terms not defined herein shall have their ordinary meaning within the context of their use. Ordinary meaning shall be defined in "Webster's Eleventh New Collegiate Dictionary."

Accuracy. The degree of agreement between the observed value (X) and the *conventionally true value* (T) of the quantity being measured. The degree of agreement is often expressed as the difference between X and T: ($X - T$), or as a percentage relative to T: (100 [$X - T$] / T).

Aged Air. Air that has been stored and isolated for at least 30 days before use to allow the *radon* in it to decay to an insignificant concentration.

As Constant as Practicable. This term is defined by agreement between the provider of the device(s) and the operator of the *STAR*, taking into consideration the inherent function of the device(s) and the design limitations and operational requirements of the *STAR*.

Atmosphere. Gas intended to be monitored or sampled for *radon*.

Batch. The set of material that is considered to be homogenous regarding characteristics that determine the *calibration* relationship. For example, activated carbon is prepared and sold in batches, which are then used by laboratories to construct devices with that carbon; a single plastic melt is sold to laboratories who manufacture many ATDs from that batch.

Bias. Systematic or persistent distortion of a measurement process that causes errors in one direction. Bias is determined by measuring the positive or negative difference from the *conventionally true value*, often as a percentage of the *conventionally true value*.

Blanks. A type of *quality control (QC)* check that quantifies detector response due to factors other than the measurement itself. Blanks are devices deployed to measure effects on the measurement result from anything other than the environment tested, i.e., effects caused during storage, shipping, handling and transport. The purpose of blanks for in-control operations is to verify and document the lack of influence of factors encountered outside the measured environment; their records are necessary to support data validity.

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. To adjust or determine or both, the response or reading of an instrument or device relative to a series of *conventionally true values* (U.S. DOE 2011).

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 method 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*).

Continuous Radon Monitor (CRM). An electronic device that is capable of automatically recording a retrievable time series of 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 148 Bq/m^3 (4 pCi/L) for a 1-hour measurement, and (3) has a *calibration factor* of at least 2 counts per hour per 37 Bq/m^3 (0.054 counts per hour [cph] per Bq/m^3 or 2 cph per pCi/L).

Conventionally True Value. The best estimate of the value of a quantity determined by a primary or secondary standard, or by a reference instrument that has been calibrated against a primary or secondary standard. For the purpose of this standard, the average *radon* concentration value reported by the facility that exposes a device in a *STAR* is considered to be the *conventionally true value*.

Conversion Convention. Conversions are rounded to no more than three significant figures. For example, 4.0 pCi/L is converted to 148 Bq/m^3 and not rounded to 150 Bq/m^3. However, if a conversion results in more than three significant figures, only three significant figures are used. For example, 1500 pCi-d/L is converted to 1.33×10^6 $Bq\text{-}h/m^3$.

Electronic Integrating Device (EID). An electronic *radon* measuring device that (1) does not meet the specifications of the definition of a *CRM* in this standard, and (2) displays or otherwise provides results only for time periods at least as long as those for which it has demonstrated compliance with the performance requirements of this standard.

EPA. The U.S. Environmental Protection Agency.

Individual Percent Error (IPE). The degree from which a single measured value (*X*) deviates from the *conventionally true value* (*T*). The *IPE* is calculated using the following equation:

$$IPE = [100\,(X - T) / T] \qquad (1)$$

X = Measured value (Bq/m^3, pCi/L, $Bq\text{-}h/m^3$, or pCi-d/L)

T = *Conventionally true value* (in the same unit as X)

Integrating Device. A device that records or registers information that is directly related to the integral of *radon* concentration over time within the operating range of the device.

Lower Limit of Detection (LLD_{CT}), Counting Technology Methods. The smallest net count rate at which there is 95% confidence that a signal above background is detected (true positive). The *blank* count rate and *blank* counting time are determined by counting a *blank* sample in the laboratory. For this standard, and for devices that rely on independent event counting technology, this equation by Currie (1968) is used.

$$LLD_{CT} = 2.71/t_s + 3.29(R_b/t_b + R_b/t_s)^{1/2} \qquad (2)$$

where LLD_{CT} = *Lower Limit of Detection* (cpm) for counting technology methods

t_s = Sample counting time (min), or for ATDs, the area of sample scanned (mm^2)

R_b = Background or *blank* count rate (cpm), or for ATDs, the *blank* sample track density ($tracks/mm^2$)

t_b = Background or *blank* counting time (min), or for ATDs, the area of *blank* sample scanned (mm^2)

Note—The *LLD* for ATD counting systems can use the same formula by using the areas of the plastic counted for *blanks* and field exposed detectors as surrogates for the background and sample counting times**.** For *CRMs*, the sample counting time is the time spent making a *radon* measurement; the background count rate and counting time are determined when measuring an atmosphere free of *radon*, such as nitrogen or *aged air*. For CADs, the sample counting time is the time spent counting the sample in the laboratory.

Lower Limit of Detection, Noncounting Technology Methods (LLD_{NCT}). The EIC method does not count detected radioactive decay events, but the *LLD* for such methods is calculated to provide the same assurance: the smallest signal at which there is 95% confidence that a signal above background is detected (true positive). EIC methods use the difference between the two voltage measurements (final subtracted from initial with the uncertainty in each voltage determination being independent of both the concentration and one another). Therefore, the combined variance is given by the sum of the variances in both the initial and final voltage, which follows the traditional root-sum-of-the-squares of *sample standard deviations* of both measurements. Assuming that both voltage determinations have equal variances, and using the square of *sample standard deviation* as the variance, results in the combined standard uncertainty in the net voltage of:

Uncertainty in net voltage loss = $\sqrt{s_{vi}^2 + s_{vf}^2}$ (3)

If both voltage determinations are assumed to have equal variances (s_v^2), then the uncertainty in net voltage loss given by the combined uncertainty of the two analyses is given by $\sqrt{2} * s_v^2$

If the mean background voltage loss m_b is zero, as there should be zero voltage loss in EICs stored with the sensitive plastic prevented from discharge using a "keeper cap," this reduces to:

LLD_{NCT}= 3.29*$\sqrt{2} * s_v^2$ or the familiar (4)

LLD_{NCT}= 4.65$* s_v^2$ (5)

Manufacturer. Individual or organization engaged in the design, manufacture or sale of commercial instrumentation.

Measurement Method. The combination of air sample collection system design, detector technology and analysis procedure, including software, used in the instrumentation to make *radon* measurements.

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.

NIST. National Institute of Standards and Technology.

Performance Test. A Performance Test, or *blind* performance test, is a *blind* spike in which the *radon* concentration reported by the device user or laboratory is compared by an independent party, such as a chamber or proficiency program, to the established chamber concentration in which the device was exposed. Performance Test criteria historically includes an absolute IRE of no more than 25%. Independent verification is a demonstration of quality that is valuable to third parties such as certification bodies (State or private) and consumers.

Precision. A measure of mutual agreement among individual measurements of the same property, under prescribed and similar conditions. Precision may be expressed as variance, relative percent difference, coefficient of variation, or a similar statistic that expresses the spread of the measurements from one another.

Progeny. One or more radionuclides that occur in the decay chain from a specified parent radionuclide.

Provider. *Manufacturer*, laboratory or other entity that submits devices for exposure in a *STAR* for the purpose of demonstrating compliance with the performance requirements of this standard.

QA (Quality Assurance). A corporate or management program which has been established to monitor, evaluate/audit, support and improve activities, including: the establishment and adherence to Quality Control and associated inspection and test procedures, use of proper documentation, and implementation of a Quality Improvement Program, as required to ensure high standards of service and product quality have been met.

QAP (Quality Assurance Plan). A formal document describing in comprehensive detail the *quality system*, including responsibility for data validity, QA policies, QC procedures and other technical activities that need to be implemented to ensure that the results of the work conducted will satisfy the stated performance criteria. The QAP must define objectives (e.g., QC limits at various stages of the operations) and the responsibilities and authorities of personnel, especially regarding data quality and *corrective action*, including an individual responsible for the implementation of the quality policies, who is usually known as a QA Manager or Officer. A QAP will include at least the following elements: (1) organization and responsibilities, including accountability for sufficient training of personnel and QC measurements and their documentation; (2) measurement, data review and reporting procedures; (3) systems for ensuring measurement device and data custody tracking; (4) analytical procedures; (5) assessments (audits) and *corrective action*; and (6) QA reporting that is used to improve quality over time. All six elements are to be documented in a QAP and associated standard operating procedures.

QC (Quality Control). An ongoing system of activities designed to measure and control the quality of a product or service to ensure it meets pre-established performance standards and the needs of users.

~~**Quality Control.** The overall system of technical activities whose purpose is to measure and control the quality of a product or service so that it meets the needs of users.~~

Quality Improvement Program. A dynamic process practiced by the person(s) responsible for quality control within an organization to ensure its Quality Control procedures comply with the evolving requirements of normative standards and industry guidelines.

Radon. The specific isotope radon-222 (^{222}Rn).

Representative. Devices that are from the same lot, *batch*, model number or other identifying characteristics and are identical in operation and configuration to such devices made available to consumers.

Sample Standard Deviation. The estimate of the standard deviation of a distribution, given by s, calculated by the square root of the sum of the squares of the deviations about the mean divided by one less than the sample size.

Short-Lived Radon Progeny . The following specific radionuclides in the ^{222}Rn decay chain: ^{218}Po, ^{214}Pb, ^{214}Bi and ^{214}Po.

Short-Lived Thoron Progeny. The following specific radionuclides in the ^{220}Rn decay chain: ^{216}Po, ^{212}Pb, ^{212}Bi, ^{212}Po and ^{208}Tl.

Significant change. A measurement system change requiring retesting for conformance to this standard includes:

1. A change in the detection mechanism and/or geometry that results in a change in the operating characteristics of the instrument in the field or the laboratory analysis of the device;
2. Changes in recommended measurement durations;
3. Expansion of the *manufacturers'* recommended range of temperature, pressure, relative humidity or *radon* concentration within which it should be used.

Note: *Manufacturers* periodically change device user interfaces, software, internal electrical components and instrument housings; such changes do not generally change the method's response characteristics and are not considered a significant change.

Spike. Spikes are devices or materials that are exposed in a STAR to known radon concentrations for duration or integrated exposures normally encountered in field measurements. Results of spikes are assessed using the RPE statistic (also known by IPE, see definition), which is the degree from which each single measured value (spike) deviates from the chamber's average concentration during the exposure period.

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:

1. 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*;
2. the performance of the devices being tested is their function for measuring *radon* concentration;
3. temperature, relative humidity and *radon* concentration are recorded hourly or more frequently by devices with annual *NIST*-traceable *calibrations* (or *traceable* as defined below) and documented uncertainty estimates;
4. barometric pressure in the STAR at local conditions is recorded or otherwise available and included in exposure reports;
5. temperature and relative humidity are controlled to within the limits of this standard for the particular test being conducted;
6. 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;
7. the STAR is operated under a documented quality management system consistent with recognized international standards such as ISO 9001.

Thoron. The specific isotope radon-220.

Traceable. For the purpose of this standard, the response of an instrument or system can be related, or traced, with an unbroken chain of documentation and associated estimates of uncertainty, to a standard maintained by *NIST*. *Radon* concentration traceability requires that the *radon* concentration used as a working standard was derived from a certified *NIST* radium-226 standard. Note: These working standards of *radon* are usually constructed by bubbling nitrogen, *aged air* or other gas through a vessel containing a certified radium solution (Ra-226 in weak acid). By strict definition, any sealed ampoule that was purchased from *NIST* and that is opened is no longer *NIST*-traceable. With careful handling, however, such a solution can be transferred to another vessel while retaining its quality. At present, *NIST* produces Standard Reference Material (SRM) Ra-226 solutions that may be used to produce working laboratory standards for *radon*. There is no SRM for *radon*. General procedures for producing these working standards are described by the National Council on Radiation Protection and Measurements (NCRP; see NCRP 1988) and others (e.g., Sensintaffar 1990). Traceability for *radon* may be achieved through interlaboratory comparisons with a facility using standards as described above.

5 UNIT ABBREVIATIONS & CONVERSIONS

The units used in this standard, abbreviations of those units, and some conversions between traditional units and those of the International System of Units (SI) are listed in Table 5.1.

Table 5.1 Unit abbreviations and conversions

Unit & Abbreviation	Conversion
becquerel (Bq) – a unit of activity	1 Bq = 1 disintegration per second = 27 pCi
becquerel per cubic meter (Bq/m^3) – a unit of activity concentration	1 Bq/m^3 = 0.027 pCi/L
becquerel-hours per cubic meter ($Bq\text{-}h/m^3$) – a unit of integrated concentration	1 $Bq\text{-}h/m^3$ = 0.00113 pCi-d/L
counts per hour (cph) – a unit of rate of observed counts	1 cph = 0.0167 cpm
counts per minute (cpm) – a unit of rate of observed counts	1 cpm = 60 cph
curie (Ci) – a unit of activity	1 Ci = 3.7×10^{10} Bq
hour (h) – a unit of time	1 h = 60 min
liter (L) – a unit of volume	1 L = 1,000 cm^3
minute (min) – a unit of time	1 min = 0.0167 h
picocurie (pCi) – a unit of activity	1 pCi = 0.037 Bq
picocuries per liter (pCi/L) – a unit of activity concentration	1 pCi/L = 37 Bq/m^3
picocurie-days per liter (pCi-d/L) – a unit of integrated concentration	1 pCi-d/L = 888 $Bq\text{-}h/m^3$

6 CLASSIFICATION OF INSTRUMENT SYSTEMS

Informative—The minimum performance criteria and testing requirements specified in this standard are consistent for all methods, with the exception of two additional requirements for *continuous radon monitors* used for measurements over 1-hour intervals. These additional requirements pertain to the *calibration factor* and the *minimum detectable concentration (MDC)*. These requirements are discussed further in Section 6.1. The following brief descriptions of the various types of devices or measurement systems are included here primarily as information supplemental to this standard.

6.1 Continuous Radon Monitors

For the purpose of this standard, a *Continuous Radon Monitor (CRM)* is an electronic instrument that is capable of providing reviewable, numeric values of *radon* concentration in air at intervals of 1 hour or less and can meet the criteria contained in the definition of a *CRM* in **Section 4**.

To comply with this standard, a *Continuous Radon Monitor (CRM)* shall be an electronic device that:

(1) is capable of automatically recording a retrievable time series of 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 148 Bq/m^3 (4 pCi/L) for a 1-hour measurement, and

(3) has a *calibration factor* of at least 2 counts per hour per 37 Bq/m^3 (0.054 counts per hour [cph] per Bq/m^3 or 2 cph per pCi/L).

Note—For results with less uncertainty in the accuracy of hourly data, the *calibration factor* should be larger.

Electronic *radon* measuring devices that do not provide hourly measurements, or otherwise do not meet these requirements shall be classified as *Electronic Integrating Device (EID)* in accordance with Section 6.2.3.

Described below are three types of *CRMs* that differ by the mechanism used to detect radiation from *radon* and/or its *progeny*. This standard does not exclude devices with detection mechanisms that may vary from those described here, provided that the device meets all of the requirements for being classified as a *CRM*.

Informative—Measurements made during short time periods, such as 1 hour, are not independently sufficient for determining if there is need for remedial action, or mitigation, of a residence or building (ANSI/AARST MAMF). Such measurements of short duration may be used to supplement measurements of longer duration by helping to judge whether or not there was some unusual occurrence (for example, a severe weather disturbance, tampering, instrument malfunction, etc.) during the measurement period that would invalidate the overall measurement. CRM requirements herein for *MDC* and *calibration factor* are to ensure that 1-hour measurements provide results that are usable for such tasks. , additional requirements for *CRMs* used to produce hourly measurements are that such devices must have an MDC of no greater than 148 Bq/m^3 (4 pCi/L) for a 1-hour measurement and have a *calibration factor* of no less than 2 cph per 37 Bq/m^3 (0.054 cph per Bq/m^3 or 2 cph per pCi/L). For results with less uncertainty, the *calibration factor* should be larger.

Note—Continuous *radon* monitors may be affected by the temperature and relative humidity of the surrounding air. For example, some devices require that a desiccant be used so that the air coming into the monitor is very dry. If effects of temperature and humidity on the response of the device are significant according to the device manufacturer, then some method must be used to eliminate or compensate for the effects would be needed to meet requirements in Section 7.

6.1.1 Scintillation Cells

_Informative—_This type of *CRM* uses a combination of a scintillation cell and a photomultiplier tube as the detection mechanism. Depending on the design of the scintillation cell, air containing *radon* is continuously pumped through the scintillation cell, or *radon* passively diffuses into the cell. The interior surface of the cell is coated with zinc sulfide (ZnS). Alpha particles emitted by *radon* and its short-lived *progeny*, ^{218}Po and ^{214}Po, strike the ZnS coating and cause it to scintillate; i.e., emit weak flashes of light. The photomultiplier tube detects the flashes of light, converts them to electronic signals, and amplifies those signals so that they can be detected as electrical pulses. The pulses are further processed by an electronics circuit and are counted using a scaler. The number of counts detected over a specific period of time is then converted to an average *radon* concentration through a *calibration factor*. The *calibration* is achieved by exposing the *CRM* to a reference *radon* concentration in a *STAR*.

6.1.2 Ion Chambers

_Informative—_This type of *CRM* uses an ion chamber, as described below, to detect emissions of alpha particles from *radon* and in some cases also from two short-lived *progeny* of *radon*, ^{218}Po and ^{214}Po. The ion chamber typically consists of a metal cage or cylinder defining the sensing volume with an electrode through the center. An electrical potential is applied between the cage or cylinder and the center electrode. When alpha particles travel through the air in the sensing volume, they strip electrons from molecules of gas and thus create negatively charged electrons and positively charged ions. The electrons are collected on the positively charged electrode, and the positively charged ions are collected on the negatively charged electrode. An electronics circuit detects the resulting electrical signals, shapes and amplifies the pulses, and counts them using a scaler. Depending on the design of the monitor, *radon* passively diffuses into the sensing volume, or a pump or blower is used to bring air containing *radon* into the sensing volume. The number of counts detected over a specific period of time is converted to an average *radon* concentration through a *calibration factor* that is determined by exposing the instrument to a reference *radon* concentration in a *STAR*.

6.1.3 Solid-state Detectors

_Informative—_This type of *CRM* uses a solid-state detector to detect alpha particles primarily from ^{218}Po and ^{214}Po, and to a lesser extent from *radon* itself. Alpha particles striking the surface of the detector create electrical pulses. An electronics circuit detects the pulses, shapes them and counts them using a scaler. Depending on the design of the monitor, *radon* passively diffuses into the sensing volume, or a pump or blower is used to bring air containing *radon* into the sensing volume. Depending on the type of detector, it may be possible to perform alpha spectroscopy; i.e., measure the energy of the alpha particle and thus identify the specific nuclide from which the alpha particle was emitted. The number of counts detected over a specific period of time is converted to an average *radon* concentration through a *calibration factor* that is determined by exposing the instrument to a reference *radon* concentration in a *STAR*.

6.2 Integrating Methods

Described below are three types of *integrating device*s that differ by the mechanism used to detect radiation from *radon* and/or its *progeny*. This standard does not exclude devices with detection mechanisms that may vary from those described here.

_Informative—_This class of device stores a signal that continuously updates in such forms as an increasing number of counts or latent tracks, or a decreasing electrical charge, during the exposure period. Some devices are later processed or read out to produce a response that is directly related to the integral of the *radon* concentration over the exposure time, enabling the calculation of the average concentration during the measurement period. Electronic devices in this class may produce measurements in real time or store data to be read out at a later time. Depending on the specific design, an *integrating device* may be used for a measurement duration as short as 2 days or as long as 1 year.

Note—Some devices in this class may be affected by the temperature and relative humidity of the surrounding air. If effects of temperature and humidity on the response of the device are significant, then some method ~~must be used~~ is needed to eliminate or compensate for the effects to meet requirements in Section 7.

6.2.1 Electret Ion Chambers

Informative—This type of device uses an ion chamber made of an electrically conductive plastic with an electret as the detecting mechanism. The surface voltage of the positively charged electret is measured before and after the exposure to *radon*. During the exposure, *radon* passively diffuses into the ion chamber and subsequently decays. The decay of *radon* and its short-lived *progeny* ionizes the air inside the chamber. Negative ions ~~Electrons~~ are attracted to the electret and discharge it. From the surface voltage of the electret measured before and after the exposure, and the length of the exposure, the average *radon* concentration during the exposure can be calculated using *calibration factors* determined through exposures of devices in a *STAR*. Electrets of different sensitivities and chambers of different sizes can be used in combination to measure a range of *radon* concentrations over time periods ranging from 2 days to 1 year.

Note—Ambient gamma rays also ionize air inside the chamber; therefore, the effect of ambient gamma radiation must be taken into account to meet requirements in Section 7.

6.2.2 Alpha-track Detectors

Informative—This type of device utilizes a piece of plastic, typically of either allyl diglycol carbonate or cellulose nitrate, inside a container typically made of electrically conducting plastic. *Radon* diffuses passively into the container, where it subsequently decays. Alpha particles emitted from *radon* and two of its short-lived *progeny*, ^{218}Po and ^{214}Po, strike the plastic detector and create damaged volumes or "latent tracks." The plastic is etched in a caustic solution, which produces tracks that are visible with the use of a microscope, because the latent tracks are more soluble than the surrounding undamaged material in such a solution. The plastic is scanned and the track density is determined in terms of tracks/mm^2. A *calibration factor*, determined through exposures of devices in a *STAR*, is used to convert the track density to a value of integrated concentration in the unit of Bq-h/m^3 or pCi-days/liter. The average *radon* concentration during the exposure is determined by dividing the integrated concentration by the length of time of the exposure.

6.2.3 Electronic Integrating Devices

~~For the purpose of this standard,~~ To comply with this standard:

(1) an electronic *radon* measuring device that does not provide hourly measurements, or otherwise does not meet the requirements in Section 6.1 for being classified as a *CRM*, is an *Electronic Integrating Device (EID),*

(2) such a device shall only begin displaying average *radon* concentration measurements after a time period for which the device has demonstrated compliance with the performance requirements of this standard; and

(3) ~~In particular,~~ *EIDs* in compliance with this standard shall ~~must~~ comply with the requirements for MDC, *precision* and *accuracy* as described in Section 7.

Informative—An *EID* typically utilizes one of the mechanisms described in Subsections 6.1.1 through 6.1.3 to detect alpha particles emitted from *radon* and/or two of its *progeny*, ^{218}Po and ^{214}Po. The detector and associated electronics record the number of alpha particles detected as counts, and the number of counts over a given period of time is converted to a *radon* concentration through a *calibration factor* determined by exposure of the device in a *STAR*.

6.3 Charcoal Adsorption Device (CAD) Methods ~~Equilibrating Methods~~

Described below are two types of charcoal adsorption devices that differ by the mechanism used to detect radiation from *radon* and/or its *progeny*. This standard does not exclude devices with detection mechanisms that may vary from those described here or devices that use an adsorbing material different from activated charcoal.

Informative—This class of device employs a material such as activated charcoal that adsorbs *radon* from the air. The amount of *radon* adsorbed depends on the design of the device, the type of material, the exposure time and the *radon* concentration, temperature and relative humidity in the surrounding air. This class of device can provide an accurate representation of the average *radon* concentration during the exposure period if there are no large changes in *radon* concentration or the environment (e.g., temperature, humidity) during the exposure. Because of the half-life of *radon* and the time it takes for *radon* to adsorb, they are typically limited to exposure durations from 2 to 7 days. *Calibration* of a charcoal adsorption system is accomplished through exposures of *representative* sets of devices in a *STAR* for various time periods and different values of temperature and humidity.

6.3.1 Gamma-ray Spectroscopy

Informative—This type of charcoal adsorption device bases the detection and quantification of the adsorbed radon on gamma-ray spectroscopy, where gamma rays from two short-lived *progeny* of *radon*, ^{214}Pb and ^{214}Bi, are detected. This is often done using a sodium iodide detector and a multichannel analyzer system. Depending on the *manufacturer* or laboratory, the device may be in such forms as metal canisters, paper pouches or trays containing activated charcoal.

Note—Observed counts from ambient gamma radiation in the energy ranges analyzed ~~must, of course,~~ would need to be subtracted from the gross counts to meet requirements in Section 7.

6.3.2 Liquid Scintillation Spectroscopy

Informative—This type of charcoal adsorption device uses liquid scintillation spectroscopy to detect alpha particles emitted by ^{222}Rn, ^{218}Po and ^{214}Po, and possibly also beta particles emitted by ^{214}Pb and ^{214}Bi, to quantify the adsorbed *radon*. The device is typically in the form of a small vial or cartridge containing activated charcoal.

7 PERFORMANCE & TESTING CRITERIA

The following criteria ~~are applicable~~ requirements in Section 7 shall be applicable to all types of *radon* devices or systems within the scope of this standard.

Due to the diversity of technologies addressed within this standard and the natural limitations of each technology, the *provider* shall stipulate limits upon test procedures (e.g., ranges of exposure durations and integrated concentrations) that are consistent with literature published for consumers who will use the device(s).

7.1 Accuracy & Precision (Total Error)

7.1.1 Criteria

Each device shall demonstrate an *Individual Percent Error (IPE)* within 0 ± 25% when tested in a *STAR* (defined in Section 4) for the shortest duration recommended by the *provider* at a *radon* concentration in the range of 222 – 555 Bq/m^3 (6 – 15 pCi/L), a temperature in the range of 18 – 24°C (65 – 75°F), and a relative humidity in the range of 10 – 55%, with *radon* concentration, temperature and relative humidity held *as constant as practicable* (defined in Section 4).

The *precision* of the devices shall be assessed using the COV of the set of five devices, which shall be less than or equal to 15%.

7.1.2 Test for Accuracy & Precision (Total Error)

The test for accuracy & precision (total error) shall be conducted using the following procedure:

(1) A set of at least five *representative* devices is placed in a *STAR* for the minimum period of time recommended for use by the *provider* and under the conditions stated in Subsection 7.1.1, with the *radon* concentration, temperature and relative humidity held *as constant as practicable* in the ranges stated in that subsection during the exposure period.

Note—See the definition of "*as constant as practicable*" in Section 4.

(2) If appropriate, such as for long-term detectors, the devices ~~may~~ are permitted to be exposed to an integrated *radon* concentration in Bq-h/m^3 (or pCi-d/L) equal to the minimum time specified by the *provider* times a *radon* concentration in the range specified in Subsection 7.1.1. The conditions in the *STAR* ~~may~~ are permitted to vary outside of the ranges specified in Subsection 7.1.1 for exposures of durations longer than approximately 1 week.

7.2 Minimum Detectable Concentration

Device *provider*s ~~should~~ shall calculate and report MDCs specific to minimum exposure durations and typical processing. It is incumbent on the *provider* (or *manufacturer*) to provide such statistics in at least the level of detail as described in ~~Section~~ Table 8.1.

7.2.1 Criteria

The device shall have an MDC of no greater than 37 Bq/m^3 (1 pCi/L) for the minimum measurement period recommended by the *provider* and when using the procedures recommended by the *provider*. This criterion ~~applies~~ shall apply to a measurement of at least 2 days in duration.

As discussed in Section 6.1, an additional criterion ~~applies~~ shall apply to 1-hour measurements made with *CRMs*. For 1-hour measurements, the MDC shall be no greater than 148 Bq/m^3 (4 pCi/L).

~~Note—As previously noted, 1-hour measurements are not used in decisions on the need for mitigation.~~

7.2.2 Test for Minimum Detectable Concentration

The basis for the MDC assessment ~~is~~ shall be the count rate of an appropriate set of *blanks*, or the background of a *representative continuous radon monitor* when measuring nitrogen or *aged air* for a time period sufficient to produce a reliable estimate of device response to an atmosphere free of *radon*.

For devices that measure counts, the MDC shall be calculated using the LLD_{CT} equation in Section 4, derived specifically for methods that use counting technology. For devices that measure something other than counts, such as a drop in voltage on an electret, the background response and its variability ~~are used in~~ shall be determined using the alternate equation (LLD_{NCT}).

Informative—For example, the *EPA* requires that the MDC for ozone be calculated from the variability (measured by the *sample standard deviation*) of the ozone analyzer's response to ozone-free air (40 CFR 53.23).

7.3 Proportionality

The test for proportionality is the difference between the averages of the *IPEs* from the two exposures in the *STAR*.

7.3.1 Criteria

The difference between the average *IPE* of a set of five devices exposed at a non-zero low concentration (or integrated concentration) and the average *IPE* of a set of five devices exposed at a high concentration (or integrated concentration) shall be in the range of 0 ± 15%.

~~The results of the test performed for the criteria in Section 7.1 may~~ is permitted to ~~be used for the set of devices exposed to a low concentration (or integrated concentration). The requirements for the high concentration (or integrated concentration) are discussed in **Subsection 7.3.2**.~~

As in **Section 7.1** , the *IPE* of each individual measurement shall be in the range of 0 ± 25%, and the COV of each set of measurements shall be no greater than 15%.

7.3.2 Test for Proportionality

A set of at least five devices shall be exposed in a *STAR* under the same conditions as described in **Section 7.1** for the exposure at a low concentration or integrated concentration. The results from the test in **Section 7.1** ~~may~~ is permitted to be used for the set of devices exposed to a low concentration (or integrated concentration). ~~here in lieu of repeating the exposure for this test~~.

For the exposure at a high concentration, a set of at least five devices shall be exposed in a *STAR* under the same conditions, to the extent practicable, of temperature and relative humidity ~~,as far as possible,~~ used for the exposure at low concentration, but with a *radon* concentration in the range of 1110 – 2220 Bq/m^3 (30 – 60 pCi/L), or at least three times the low concentration range, whichever is greater.

Where an integrated exposure is more appropriate, the exposure to a high integrated exposure shall be to a value of approximately 10% less than the upper range recommended by the *provider*, taking into account the limitations of the *STAR*.

Informative example: The average of the *IPE* values from the exposure at a low concentration (or integrated concentration) might be 5%, indicating that the devices exposed to the lower concentrations are *biased* high compared to the *STAR*; and the average of the *IPE* values from the exposure at high concentration (or integrated concentration) might be −5%, indicating that the devices exposed to the higher concentration are *biased* low compared to the *STAR*. The difference between the two values is 10% [i.e., 5% – (– 5%)]; therefore, the proportionality criterion is met in this example.

7.4 Temperature

To ensure that test results adequately represent a device's performance in a range of environments, a relatively tight control on humidity is required in the *STAR* used for testing the effects of temperature.

Informative—Radon measuring devices are typically calibrated at a temperature of approximately 21°C (70°F). If a temperature different from the *calibration* condition but within the range of temperatures generally found in indoor environments causes the *radon* measurement of the device to be substantially *biased*, then some manner of adjusting for this effect should be incorporated into the method.

7.4.1 Criteria for Effect of Temperature

Each individual device shall demonstrate an *IPE* within the range of 0 ± 25% when tested in a *STAR* for a duration of time at least as long as the minimum recommended by the *provider* and in two conditions:

(1) a relative humidity of 10 – 25% and temperature of 16 ± 3°C (60 ± 5°F), and

(2) a relative humidity of 10 – 25% and temperature of 27 ± 3°C (80 ± 5°F).

The COV for each set of five devices shall be less than or equal to 15%.

7.4.2 Test for Effect of Temperature

The test for effect of temperature shall be conducted using the following procedure:

(1) Two sets of at least five devices are exposed in a *STAR* under the conditions specified in Subsection 7.4.1.

(2) The *radon* concentration should be greater than 370 Bq/m^3 (10 pCi/L) so that the measurement uncertainty due to the *radon* concentration itself is not large.

(3) If appropriate, the devices ~~may be~~ are exposed to an integrated exposure of at least 370 Bq/m^3 (10 pCi/L) times the minimum time period recommended by the *provider*. The relative humidity should be kept *as constant as practicable* to a value in the range of 10 – 25%.

(4) As far as practicable, the *radon* concentration and relative humidity shall be the same during the two exposures.

7.5 Humidity

Informative—Many *radon*-measuring devices are affected by the humidity in the surrounding air. If the measurements from a device are affected substantially over the range of relative humidity generally found in indoor environments, then some manner of adjusting for this effect should be incorporated into the method.

7.5.1 Criteria for the Effect of Humidity

Each individual device shall demonstrate an *IPE* value within the range of 0 ± 25% when tested in a *STAR* for a duration of time at least as long as the minimum recommended by the *provider* and at a temperature in the range of 18 – 24°C (65 – 75°F) and values of relative humidity within the ranges of 15 – 25% and 70 – 80%. The COV value for each set of five devices shall be less than or equal to 15%.

7.5.2 Test for Effect of Humidity

The test for effect of humidity shall be conducted using the following procedure:

(1) Two sets of at least five devices are exposed in a *STAR* under the conditions specified in Subsection 7.4.1.

(2) The *radon* concentration should be greater than 370 Bq/m^3 (10 pCi/L) so that the measurement uncertainty due to the *radon* concentration itself is not large.

(3) If appropriate, the devices ~~may be~~ are exposed to an integrated exposure of at least 370 Bq/m^3 (10 pCi/L) times the minimum time period recommended by the *provider*.

(4) As far as practicable, the *radon* concentration and temperature shall be the same during the two exposures.

7.6 Compliance

The ranges of environmental conditions specified in this standard are typical of indoor environments. In order for a device or measurement system to meet this standard's specifications, it must meet the requirements in this Section 7 shall be met, including the requirements for the high and low ranges of temperature and humidity.

7.6.1 Star Chambers

Demonstrations of compliance with performance criteria required in Section 7 shall be conducted in a *STAR* chamber. As described in Section 3, Results of testing in a *STAR* conducted for other purposes other than compliance with this standard could are permitted to partially or fully suffice to demonstrate compliance with this standard.

Tests conducted under conditions other than the controlled conditions of a *STAR* *are* shall be insufficient to determine whether the requirements of this standard have been met.

Exception: When climate conditions local to a STAR render it not practicable to achieve timely verification of meeting criteria associated with the highest or lowest ranges specified for humidity, evidence obtained by other statistically valid means in other chambers shall be an acceptable substitute for demonstration of compliance.

8 DOCUMENTATION

To meet the requirements of this standard, the manufacturer shall have available upon request a report covering the tests performed on the device model demonstrating the attainment of the performance requirements of this standard. The report shall list the requirements and corresponding test results described in this standard, with the STAR information where the tests were performed and a description of how the system used to determine the average radon concentration from the STAR is traceable as defined in Section 4. At a minimum, the provider's (manufacturer's or distributor's) report of tests shall cover, as appropriate, the information listed in Table 8.1, with:

- ranges of radon concentration and measurement duration for which the device meets this standard's requirements;
- effects of other types of radiation;
- suggested method(s) of calibration;
- effects of temperature, pressure and humidity, and shocks inherent to the vibrations associated with the operation of hand-held or hand-carried equipment, including the results of the tests specifically listed in this standard;
- effects of radio frequency, electrostatics, electromagnetic interference forces and microwaves;
- personnel responsible for the test results, and
- summary or reference to the quality assurance/quality control requirements for the chamber.

In addition to these, the manufacturer shall document any other factors that affect the performance metrics.

Not all tests must be conducted in the same STAR. Documentation of results of testing in a STAR shall include the information in the sample report shown in Table 8.1. Formatting and order of information may differ is permitted to be different from that shown in the sample report, but all of the information must shall be included in order to provide the test report that shall be made available to demonstrate compliance with the requirements of this standard..

Table 8.1: MS-PC Test Report This test report template is intended as guidance and will be revised in accordance with the revisions in the standard.

STAR Information, including name, location and elevation:

Conditions during exposure:

Air velocity__________±______ (units)

Approximate ambient gamma radiation exposure rate______________ (units)

Hourly chamber conditions, including radon concentrations, and a report providing the description of the derivation of the uncertainty of average radon concentrations or integrated radon concentrations for the durations used in these exposures are provided as an attachment to this summary report. The derivation of the uncertainty estimates should be consistent with NIST Technical Note 1297 and include the original data used for the derivation.

Device Information:

Manufacturer:_______________________________________ Model Name:______________________________

Provider (sent by):___________________________________ Photos of devices as provided to the STAR facility are attached.

Description of any operations necessary to start/stop exposure :____(photos also attached, if appropriate)

Serial numbers of the devices: ____________________________________

Test Results:

Accuracy (Total Error) and Precision (Sec. 7.1) **Requirements:** Each Individual Percent Error (IPE) = 0 ± 25% and COV ≤ 15% for each set of five devices when exposed for the shortest duration specified for use by the provider.

Temperature _______ range 18 – 24°C (65 – 75°F)

Rn Conc __________ range 222 – 555 Bq/m^3 (6 – 15 pCi/L)

RH______ range 10 – 55%

Serial number	Date-time start	Date-time end	Temp	RH	Device result	STAR conc	IPE	COV

Proportionality (Sec. 7.3) **Requirements:** Each IPE = 0 ± 25% and COV ≤ 15% for each set of five devices, and the difference between the average IPE(low concentration) and the average IPE(high concentration) must be between −15% and +15%. Note that a test in either a high radon concentration or a high *integrated* radon concentration is required (not both).

Low Concentration Exposure:

Temperature _______ range 18 – 24°C (65 – 75°F)

Rn Conc __________ range 222 – 555 Bq/m^3 (6 – 15 pCi/L)

RH______ range 10 – 55%

Serial number	Date-time start	Date-time end	Temp	RH	Device result	STAR conc	IPE	COV

High Concentration Exposure:

Temperature _______ range 18 – 24°C (65 – 75°F)

Rn Conc __________ range 1110 – 2220 Bq/m^3 (30 – 60 pCi/L) or at least 3 times the low concentration, whichever is greater

RH______ range 10 – 55%

Serial number	Date-time start	Date-time end	Temp	RH	Device result	STAR conc	IPE	COV

High Integrated Concentration Exposure:

Temperature _______ range 18 – 24°C (65 – 75°F)

Rn Conc __________ integrated concentration of approximately 10% less than the highest integrated concentration stated by the provider, taking into account the limitations of the STAR

RH______ range 10 – 55%

Serial number	Date-time start	Date-time end	Temp	RH	Device result	STAR conc	IPE	COV

Temperature Group (low) (Sec. 7.4) **Requirements:** Each IPE = 0 ± 25% and COV ≤ 15% for each set of five devices.

Temperature _______ range 16 ± 3°C (60 ± 5°F)

Rn Conc __________ ≥ 370 Bq/m^3 (10 pCi/L)

RH______ range 10 – 25%

Serial number	Date-time start	Date-time end	Temp	RH	Device result	STAR conc	IPE	COV

Temperature Group (high) (Sec. 7.4) **Requirements:** Each IPE = 0 ± 25% and COV ≤ 15% for each set of five devices.

Temperature _______ range 27 ± 3°C (80 ± 5°F)

Rn Conc __________ ≥ 370 Bq/m^3 (10 pCi/L)

RH______ range 10 – 25%

Serial number	Date-time start	Date-time end	Temp	RH	Device result	STAR conc	IPE	COV

Relative Humidity Group (low) (Sec. 7.5) **Requirements:** Each IPE = 0 ± 25% and COV ≤ 15% for each set of five devices.

Temperature _______ range 18 – 24°C (65 – 75°F)

Rn Conc __________ ≥ 370 Bq/m^3 (10 pCi/L)

RH______ range 15 – 25%

Serial number	Date-time start	Date-time end	Temp	RH	Device result	STAR conc	IPE	COV

Relative Humidity Group (high) (Sec. 7.5) **Requirements:** Each IPE = 0 ± 25% and COV ≤ 15% for each set of five devices.

Temperature _______ range 18 – 24°C (65 – 75°F)

Rn Conc __________ ≥ 370 Bq/m^3 (10 pCi/L)

RH______ range 70 – 80%

Serial number	Date-time start	Date-time end	Temp	RH	Device result	STAR conc	IPE	COV

Minimum Detectable Concentration (Sec. 7.2) **Requirement:** ≤ 37 Bq/m^3 (1 pCi/L) for measurements of 2 days or longer; for 1-hour measurements, the MDC shall be no greater than 148 Bq/m^3 (4 pCi/L). Tests to determine MDC are run outside the STAR(s); and the individual device results, including exposure durations and the complete calculations, are provided in this report. Calculations are performed using the algorithms in Section 4. The MDC is: _____________ (units) for the measurement duration of ______________.

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