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1 SCOPE

This standard specifies minimum performance requirements and performance testing requirements for instruments designed to measure radon progeny in atmospheres. This standard addresses the needs of users, manufacturers, and regulators concerned with radon progeny measurements.

2 OVERVIEW

The objectives of this standard are to provide performance and testing criteria for instruments and instrument systems that have application in 1) radiation dose and/or risk assessment from exposure to radon progeny in air, and 2) corrections and supporting measurements of radon progeny that interfere with measurements of other radionuclides. The standard includes performance testing or generic (type) testing of new instrument models. This standard does not specify acceptance or routine testing or calibration, except in so far as the basis for periodic calibration must be established during type testing. Instrument users and manufacturers may, however, select mutually agreeable portions of the testing criteria contained herein as acceptance or routine testing requirements.

Hereafter the term *radon* is used to include Rn-222 and Rn-220; the term *radon progeny* is used to include the radioactive progeny of Rn-222 and Rn-220 (Rn-219 is not included in this standard) (see definitions). Excluded from this standard are instruments and instrumentation systems designed to measure radon gas. A complementary standard ANSI N42.51 (*Standard Title*) addresses this class of instrumentation.

The instrumentation addressed by this standard covers a broad range of instrument types that vary in their sampling, detection, and analysis methodologies. This results in a wide range of performance characteristics within this instrument population. A classification system in Section 6 is, therefore, used to group instruments that share similar performance characteristics.

If a system can be determined to fall into multiple instrumentation classes, then those aspects which fall into one class would be governed by those portions of this standard that address that same class. Likewise, those aspects of a system that fall into a separate class would be governed by those portions of this standard that address that same separate class.

This standard specifies requirements and test procedures in the following areas: radiation, response, air sampling, electrical/electronic, environmental and mechanical. 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 verbs are defined in section 4, definitions.

3 NORMATIVE REFERENCES

This standard shall be used in conjunction with the following publications.

- ANSI N42.17B-1989: Radiation protection instrumentation-Performance specifications for Health Physics Instrumentation-Occupational Airborne Radioactivity Monitoring instrumentation.
- ANSI N323C-2007: Radiation protection instrumentation-Test and calibration-Air monitoring instruments. Draft 16 is in the hands of ANSI N42 for balloting.

- IEC 61577 -1 Ed 2: Radiation protection instrumentation. General requirements. The terminology and units of specific field of radon and radon decay products (RnDP) measurement techniques and the concept of the System for Test Atmospheres with Radon (STAR) used for test and calibration of radon and RnDP measuring instruments. Note: We use radon progeny instead of Decay Products.

- IEC 61577-2-1: Radiation protection instrumentation. Specific test requirements for ^{222}Rn measuring instruments. (Shouldn't this be in the companion standard ?)

- IEC 61577-2-2: Radiation protection instrumentation. Specific test requirements for ^{220}Rn measuring instruments. (shouldn't this be in the companion standard ?)

- IEC 61577-3-1: Radiation protection instrumentation. Specific test requirements for ^{222} RnDP measuring instruments.

- IEC 61577-3-2: Radiation protection instrumentation. Specific test requirements for ^{220} RnDP measuring instruments.

- IEC 61577-4: Radiation protection instrumentation. Equipment for the production of reference atmospheres containing radon isotopes and their decay products (STAR).

- IEC 61577-5: Informative: Technical guide to radon and radon decay product measuring instruments.
- Please note that all of the IEC 61577 documents have no publication dates as these documents are continuously updated and refined.

- IEC 61578 (1997): Airborne radioactivity detection- Calibration and verification of the effectiveness of radon compensation for alpha and/or beta measuring instruments. Note: This document applies to alpha continuous air monitors.

- IEC 62302 (2007): Radiation protection instrumentation- Equipment for measuring noble gases in the workplace, in effluents and in the environment and not during and following a reactor accident.

- IEC 62303 (2008): Radiation protection instrumentation- Equipment for measuring tritium in the workplace, in effluents, in the environment and during and following a reactor accident.

- .
- IEC 60050-393 (2003) International Electrotechnical Vocabulary Part 393: Nuclear Instrumentation-Physical Phenomena and Basic Concepts.
- IEC 60050-394 Ed2 (2006) International Electrotechnical Vocabulary Part 394: Instrumentation, Control Systems and Equipment.
- NCRP Report No. 97 (1988) Measurement of radon and radon daughters in air.
- ASTM D6327-2001, Test Method for Determination of Radon Decay Product Concentration and Working Level in Indoor Atmospheres by Active Sampling on Filter

4 DEFINITIONS & ACRONYMS

Comment [DTK1]: The items highlighted in gray were provided by John Rodgers.

Accuracy - The degree of agreement between the observed value and the known value of the quantity being measured. . The degree of agreement is usually expressed as the difference between a measured value (X) and the accepted value (T) : (X-T), or the difference as a percentage of the reference or known value: (100[X – T]/T).

Aerosols – Solid or liquid particles in suspension in a gaseous medium. Note: Radon progeny may adhere to aerosols through electrostatic, condensation and coagulation effects.

Atmospheres – Air intended to be monitored or sampled for radon progeny

Continuous monitoring- The determination of airborne radioactive components based on collection and simultaneous (on-line) detection and analysis of measurands in volumes of air continuously extracted from the environment being monitored. Note: The resultant product of continuous monitoring may be the report of concentrations (DAC) of airborne measurands at regular time intervals or integrated measurements such as exposure, or both.

Decision Level - That net count rate from a measurement which must be exceeded before the sample is to be said to contain measurable radioactive material above background. In statistical terms, the Decision Level (DL) is expressed as
$DL = k\sigma_0$, where k is the one-sided confidence factor (k = 1.65 when there is only a 5% chance that a true mean count rate of zero will be falsely accepted as a positive value), and σ_0 is the standard deviation of repeated measures of a blank (zero activity) sample.

Derived Air Concentration (DAC) - The derived air concentration (DAC) values are derived limits intended to control chronic occupational exposures. The value is based on Annual Limits on Intake (ALI) computed for specific radionuclides that will limit workers annual dose. The relationship between the DAC and the ALI is given by:

DAC=ALI(in µCi)/(2000 hours per working year x 60 minutes/hour x 2 x 10^4 ml per minute)=[ALI/2.4x10^9] µCi/ml, where 2x10^4 ml is the volume of air breathed per minute at work by "Reference Man" under working conditions of "light work."

Grab sampling sample monitoring – The determination of airborne radioactive components based on extraction of a single volume of air that is intended to be representative of the air being monitored and its constituents, over the discrete time of sample acquisition, and analyzed off-line.

Instrument – Equipment used to make radon progeny measurements in this standard.

Instrumentation systems – A complete set of instruments and peripherals utilized in making radon progeny measurements. Note: This includes any custom software.

Integrating sampling – The use of a calculated cumulative or summed gas volume measurement(s) as the primary output.

Manufacturers – The individuals or organizations engaged in the design, manufacturing, servicing and sales of commercial instrumentation.

May – Signifies an acceptable method or an example of good practice.

Measurement method – The combination of air sample collection system design, detector technology, and measurand determination procedure, including software, used in the instrumentation to make radon progeny measurements.

Measurand - A physical parameter being quantified by measurement.

Minimum Detectable Activity/Minimum Detectable Concentration - (MDA or MDC) That level of net activity measured in a sample such that there is both less than a 5% chance of wrongly concluding activity is present when it is not, and less than a 5% chance of falsely concluding that activity is not present when it is. This level is approximately twice the Decision Level.

Precision- Degree of agreement of repeated measurements of the same parameter.

Pulse shape analysis – A detector signal analysis technique utilizing information about the shape of electrical pulses generated during the detection process as a means of inferring the type of radiation (alpha, beta, gamma, x-ray, etc.) being detected.

Pulse height analysis – A detector signal analysis technique utilizing information about the electrical pulse height generated during the detection process as a means of inferring the energy of the particular type of radiation (alpha, beta, gamma, x-ray, etc) being detected.

Radon – Naturally occurring isotopes of the element with Z=86 (Rn) with emphasis only on Rn-222 (“radon”) and Rn-220 (“thoron”).

Progeny – Any radionuclide that occurs anywhere in the decay chain of a specified parent radionuclide .

Regulators – Government employees (state and federal) tasked with oversight, evaluation and adjudication of those laws enacted via written regulations.

Semi-conductor detector – A type of radiation detector based on crystalline material whose electrical conductivity is intermediate between a metal and an insulator, doped with other elements to form a diode structure, and reverse-biased to create a well-defined sensitive volume.

Scintillation detector - One of many types of materials and compounds that have the property of the emission of light at a certain wavelength following the transit of a particular type of radiation through the material. Note: Scintillation detectors require an optical detector (photomultiplier, photo-diode, etc) coupled to the scintillator medium to complete the detection process.

Shall – Signifies a mandatory requirement. Note: An appropriate qualifying statement may be included to indicate that exceptions may be allowed.

Should – Signifies a recommended specification or method.

Unattached Fraction – The fraction of radon progeny in air that is not attached to an ambient aerosol.

Users – Individuals who operate the instrumentation systems.

5 UNITS & CONVERSIONS

This standard uses the International System of units (SI). However, the following traditional units are used within this standard:

Table 5.1 Common unit definitions.

Traditional Units Used	Conversion
Curie (Ci) – a unit of activity	1 Ci = 3.7×10^{10} Bq
roentgen (R) – a measure of ionizing radiation	1 R = 2.58×10^{-4} C/kg
radiation absorbed dose (rad)	1 rad = 1 cGy = 10^{-2} Gy
roentgen equivalent in man (rem)	1 rem = 1 cSv = 10^{-2} Sv

electronvolt (eV) - The electronvolt is the kinetic energy acquired by an electron in passing through a potential difference of 1 V in vacuum (Cohen and Taylor, 1986)	1 eV ≈ 1.602 × $10-^{19}$ J
hour (h) – a unit of time	1 h = 60 min = 3600 s
Working Level (WL) – Any combination of short-lived radon progeny in 1.0 liter of air that will result in the ultimate emission of 1.3 x 10^5 MeV of potential alpha energy. A unit of PAEC	1 MeV. L^{-1} = 1.6 x 10^{-4} μJ.m^{-3} 1 WL = 20.8 μJ . m^{-3}
Working Level Month (WLM) - A quantity of exposure to radon progeny in air, equal to : WL times hours of exposure / 170 hours/working month.	1 WLM = 3.6 mJ.h.m^{-3} 1 WLM = 6x10^{-5} Bq.h.m^{-3}
pCi/l – Activity of radon or radon progeny per unit volume of air	1 pCi.l^{-1} = 0.037 Bq. l^{-1}
PAEC - Potential Alpha Energy Concentration: amount of alpha energy potentially emitted by any mixture of radon or thoron progeny per unit volume of air	J.m^{-3}
F – Equilibrium factor (WL): Fraction of possible PAEC (in WL) present given the amount of radon or thoron present. Hence, F = (PAEC x 100) / radon concentration F = (PAEC x 7.3) / thoron concentration	(dimensionless)
EEC (C_{eq}) – Equilibrium Equivalent Concentration: Activity concentration of radon in equilibrium with its progeny that has the same PAEC as the non-equilibrium mixture to which C_{eq} refers. Hence, EEC = F x radon or thoron concentration	Bq. M^{-3}

6 CLASSIFICATION OF INSTRUMENTS AND INSTRUMENT SYSTEMS

The purpose of the classification scheme developed for inclusion in this standard is to group instruments that share similar performance characteristics, and may be used in similar environments, in order that appropriate minimum performance specifications may be applied to the group. While there are many possible approaches to developing a classification scheme for radon progeny instrumentation, the approach taken here is based at the top level on the sampling methodology, (grab, continuous, or integrating), followed by the detection methodology employed (gas ionization, scintillation, semiconductor ionization, thermoluminescence, and other). A finer level of detail in the classification scheme is provided by considering the measurement methods (current measurement, event counting, and pulse shape analysis) and the analysis schemes utilized. However, only the first two levels (sampling methodology and detection methodology) are required to group the instruments for the purposes of this standard.

~~**7A.** GENERAL CONSIDERATIONS FOR PERFORMANCE TESTING OF INSTRUMENTS DESIGNED TO MEASURE RADON PROGENY CONCENTRATION AND RADON PROGENY INTERFERENCE EFFECTS~~

~~In natural environments Radon Progeny Atmospheres (RnPA) are formed in air containing both radon and atmospheric aerosols the which the radon progeny attach. Test RnPA atmospheres must similarly be formed by controlled mixtures of radon from a radon source and an aerosol source. After radon decay, radon progeny will form hydration clusters (< 5 nm diameter), of which part will attach to available aerosols in the atmosphere, and a part will remain free. The two parts are thus the unattached fraction and the attached fraction.~~
~~In order to set up a test concentration or the PAEC (WL) value to a defined state, stable radon and aerosol generating systems must be used. Adjusting the RnPA and the value of the unattached fraction requires modification of the aerosol characteristics (particle size distribution, concentration) and adjustments using filtration and other means. In general the lower the volume number of particles, the higher the unattached fraction.~~

~~Based on these considerations, in outline, the fundamental equipment needed for performance testing of radon progeny PAEC (WL) measurement instruments will include:~~

- ~~A device for measuring radon continuously~~
- ~~A device for measuring the aerosol particle number per unit volume~~
- ~~A device for measuring size distribution of aerosol particles~~
- ~~A device for measuring the attached and unattached fractions~~
- ~~A device for measuring the sample flow through the test instrument~~
- ~~A device for identifying and counting the activity of individual radon progeny on a test filter which could include a method for deconvoluting alpha spectra alpha spectra~~
- ~~Since no radon progeny standard exists, the conventionally true value of PAEC (WL) of the test atmosphere will typically be obtained by using a reference using a reference instrument~~

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~~Other instrumentation may be required such as devices to measure temperature and atmospheric pressure, and necessary electronic equipment needed to communicate with the test instrument, log data, and control support equipment. The operating conditions~~

~~inside the test chamber should be adjustable to meet the requirements of the instruments used for PAEC monitoring and analysis.~~

~~Different test atmosphere conditions might be required in the case that the instrument under test is designed to measure a specific radionuclide other than the radon progeny, and hence the radon progeny are introduced under controlled conditions as an interference to the design measurement analyte. The equipment requirements and exposure conditions could be very different if, for example, the target radionuclide aerosol is highly radiotoxic (e.g., Pu-239), and thus must be carefully mixed with the RnPA and delivered to the instrument under fully contained and controlled conditions. The specific requirements and designs for such tests shall be established by agreement between the manufacturer, the performance testing laboratory, and cognizant regulatory agencies for the particular target radionuclide involved.~~

7 PERFORMANCE AND TESTING CRITERIA

The following criteria are of a general nature and therefore are applicable to all classes of radon progeny instruments covered within the scope of this standard. Criteria that are specific to a particular instrument class are addressed in the ~~following~~ Ssection 8. The following requirements~~characteristics~~ shall be considered in the design of the instrument and shall be agreed upon between the instrument manufacturer and user.

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7.1 General Considerations for Performance Testing Utilizing A Radon Progeny Test Atmosphere

This standard requires the use of a well characterized radon progeny test atmosphere to challenge an instrument's ability to either quantify radon progeny concentrations in air, or to correct for the interference from radon progeny in the course of conducting measurements of other airborne radionuclides. This section addresses the general requirements for developing and characterizing a radon progeny test atmosphere.

In natural environments Radon Progeny Atmospheres are formed in air containing both radon and atmospheric aerosols to which the radon progeny attach. Radon Progeny Test Atmospheres (RnPTA) must similarly be formed by controlled mixtures of radon from a radon source and an aerosol source. After radon decay, radon progeny will form hydration clusters (< 5 nm diameter), of which part will attach to available aerosols in the atmosphere, and a part will remain free. The two parts are thus the unattached fraction and the attached fraction.

In order to set up a test concentration or the PAEC (WL) value to a defined state, stable radon and aerosol generating systems must be used. Adjusting the RnPTA and the value of the unattached fraction requires modification of the aerosol characteristics (particle size distribution, concentration) and adjustments using filtration and other means. In general the lower the volume number of particles, the higher the unattached fraction.

Based on these considerations, in outline, the fundamental equipment needed for performance testing of radon progeny PAEC (WL) measurement instruments will include:

- A device for measuring radon continuously
- A device for measuring the aerosol particle number per unit volume
- A device for measuring size distribution of aerosol particles
- A device for measuring the attached and unattached fractions
- A device for measuring the sample flow through the test instrument
- A device for identifying and counting the activity of individual radon progeny on a test filter which could include a method for deconvoluting alpha spectra
- Since no radon progeny standard exists, the conventionally true value of PAEC (WL) of the test atmosphere will typically be obtained by using a reference instrument, or a reference grab sampling method.

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Other instrumentation may be required such as devices to measure temperature, relative humidity and atmospheric pressure, and necessary electronic equipment needed to communicate with the test instrument, log data, and control support equipment. The operating conditions inside the test chamber should be adjustable to meet the requirements of the instruments used for PAEC monitoring and analysis.

Different test atmosphere conditions might be required in the case that the instrument under test is designed to measure a specific radionuclide other than the radon progeny, and hence the radon progeny are introduced under controlled conditions as an interference to the design measurement analyte. The equipment requirements and exposure conditions could be very different if, for example, the target radionuclide aerosol is highly radiotoxic (e.g., Pu-239), and thus must be carefully mixed with the RnPA and delivered to the instrument under fully contained and controlled conditions. The specific requirements and designs for such tests shall be established by agreement between the manufacturer, the performance testing laboratory, and cognizant regulatory agencies for the particular target radionuclide involved.

A test report should be prepared and retained as a quality record by the instrument manufacturer and/or user that provides the technical basis for the calibration and operation of all aspects of generation and characterization of the RnPTA. This report should include:

- A listing, that should include the manufacturer and model number, of all instrumentation utilized in the generation and characterization of the RnPTA.
- Documentation of the traceability to recognized national standards for all reference or transfer standards for all measurements required to characterize the RnPTA.
- Computational form of all formula used to manipulate individual measured values resulting in a derived value.
- Written procedures for sampling and/or measurements carried out to characterize the RnPTA.

~~7.1~~7.2 Unattached fraction

The issues and concerns associated with quantifying attached and unattached radon progeny fractions (or uncombined fraction) raised by NCRP 78 [this should be spelled out here ???] should be considered. The extent to which this has been evaluated should be documented in a technical basis document. The technical basis document may be produced by the manufacturer, the user, or by combined effort of both.

~~7.2~~7.3 Radiation Response – Radon Progeny as Target Measurands (Rob Hayes, Paul Kotrappa)

~~7.2.1~~7.3.1 Radiation Type and Energy

Depending on the air filtering mechanisms, time dependence of air filtering, emanation source terms and purpose of the measurements, basic radiation specific variables shall be considered. This includes the gamma, beta, alpha, radiation energies or any combination of these may be integral to or peripheral to the actual measurements. Careful attention shall be paid to insuring the purpose of the measurements is met in consideration of the credible variables that can ~~a~~effect the measurement to insure the expected utility would not be unacceptably compromised such as meteorological changes in activity concentration levels or source term distributions. This should be documented in a technical basis document describing pertinent analysis, testing and evaluation.

Comment [DTK2]: This section will need to be modified to include radon progeny test atmosphere. Here is where we should also put the listing of parameters required to characterize a radon progeny test atmosphere. Either in this section, or in a new section immediately following, we should list the criteria for an acceptable test result against the radon progeny test atmosphere.

~~7.2.2~~7.3.2 Minimum Detectable Activity and Decision Level

The Minimum Detectable Activity (MDA) of a given radioactive material measurement procedure (sample extraction process, detector, sample analysis, etc.) is an a-priori quantification of that level of sample activity that can be detected with a stated level of confidence (typically 95% confidence) that both false positive errors (claiming target activity is present when it is not), and false negative errors (claiming target activity is absent when it is) will not occur. The MDA level is not the same as the detection or decision level (DL) of sample activity. The DL is determined a-posteriori from the standard deviation of the blank count for the given procedure. The DL establishes that level of activity in the sample which can be stated with 95% confidence (typically) to be greater than the blank (or "zero") level, and hence detected. The DL should be used in instrument firmware to report "detected" radiological measurements of the target measurand.

~~7.2.3~~7.3.3 Precision and Accuracy

Precision in a measurement process is a measure of the spread in reported activity outcomes in a population of measurements about the mean for that population. The accuracy of a set of measurements is the degree of agreement between the mean of these measurements and the conventional true value of the activity in the sample. The instrument shall be manufactured to meet the more restrictive precision and accuracy requirement set forth by either the applicable regulations or user requirements. Precision and accuracy determinations should take into consideration all credible variable dependencies including environmental effects (e.g., source term variations in isotopic distributions, concentration levels, humidity, pressure, temperature, air particulate etc.)

and expected anthropogenic conditions (ambient electromagnetic effects, grounding circuit voltage spikes, vibration, shock, etc).
These performance requirements shall be included in the type testing of the system. The full range of test measurements shall be agreed upon by the user and manufacturer. If additional testing is warranted for a commercial off the shelf system (COTS), then the user shall be required to insure that the additional testing takes place. This may be done by the manufacturer if agreed.

Precision shall be determined utilizing a minimum of 30 replicate independent evaluations to approximate a normal distribution. The normalcy should be determined utilizing a chi-squared test on data reformatted for a histogram or an equivalent method. The accuracy should not be determined only at the origin if an algorithm is utilized to quantify the measurand. The algorithm should be evaluated at least over a range including two distinctly separate points, one of which may be zero. If the instrument utilizes multiple scales (such as decade ranges), then each scale shall be tested utilizing at least one point in that scale.

~~7.2.4~~7.3.4 *Interference from Other Radionuclides*

Consideration shall be given to conditions leading to poor performance (especially false positive determinations) which may arise from interfering radionuclides which are not the measurand of interest. Radon progeny concentrations are typically diurnally dependent having seasonal variations in maxima and minima and rates of change. The extent to which this can effect the performance shall be considered and should be documented in a technical basis document. This applies even if the only interference is that of external gamma dose rate.

~~7.3~~7.4 Radiation Response – Radon Progeny as Interfering Radionuclides (David Baltz & Tom Voss)

~~7.3.1~~7.4.1 *General Considerations Regarding Background Compensation (possibly move to an Annex)*

Instruments that are designed to measure anthropogenic activity and other radionuclides not in the ^{220}Rn and ^{222}Rn decay chains shall compensate for the interference from radon progeny. Historically, several compensation methods have been employed by manufacturers. Because target measurands may have a broad range of ALI (DAC) values, resulting in wide variances in acceptable instrument performance, this standard shall not restrict the manufacturer's or user's choice of background subtraction method. However, the system description shall be provided with adequate specificity to allow the user or regulator the ability to assess an individual instrument with regard to the performance and response over a range of measurand energies.

~~7.3.2~~7.4.2 *Radiation Type and Energy (possibly move to an Annex)*

Interferants from the decay of ^{222}Rn and ^{220}Rn are listed in the tables below. The tables do not include all the products in the decay chain, but have been limited to only short-lived progeny which are the primary interferents. Decay events with a yield of less than 10% have also been omitted.

Table 7.1 Radon decay product information.

^{222}Rn Decay Product Interferents

Radionuclide	Half Life	Alpha (keV)	Beta (keV)	Gamma (keV)	X-Ray (keV)
^{218}Po	3.05 m	6003			
^{214}Pb	26.8 m		672, 729, 1024	242, 295, 352	11, 75, 77
^{214}Bi	19.9 m		1505, 1540, 3270	609, 1120, 1764	
^{214}Po	164 µs	7687			
^{210}Tl	1.3 m		1320, 1870, 2340	298, 800, 1310	11, 73, 75, 85
^{210}Po[1]	138.4 d	5305			

^{220}Rn Decay Product Interferents

Radionuclide	Alpha (keV)	Beta (keV)	Gamma (keV)	X-Ray (keV)
^{212}Pb		334, 573	239	11, 75, 77, 87
^{212}Bi	6050, 6090	1519, 2246	727	10
^{212}Po	8785			
^{208}Tl		1283, 1517, 1794	511, 583, 860, 2614	

~~7.3.3~~7.4.3 Comparison of Some Common Alpha Measurands (possibly move to an Annex)

Figure 1 shows the positions of some common measurands against the background alpha spectrum of radon interferants. The inhalation ALI and DAC factors are listed in Table 7.2.

[1] ^{210}Po may also be considered a target measurand

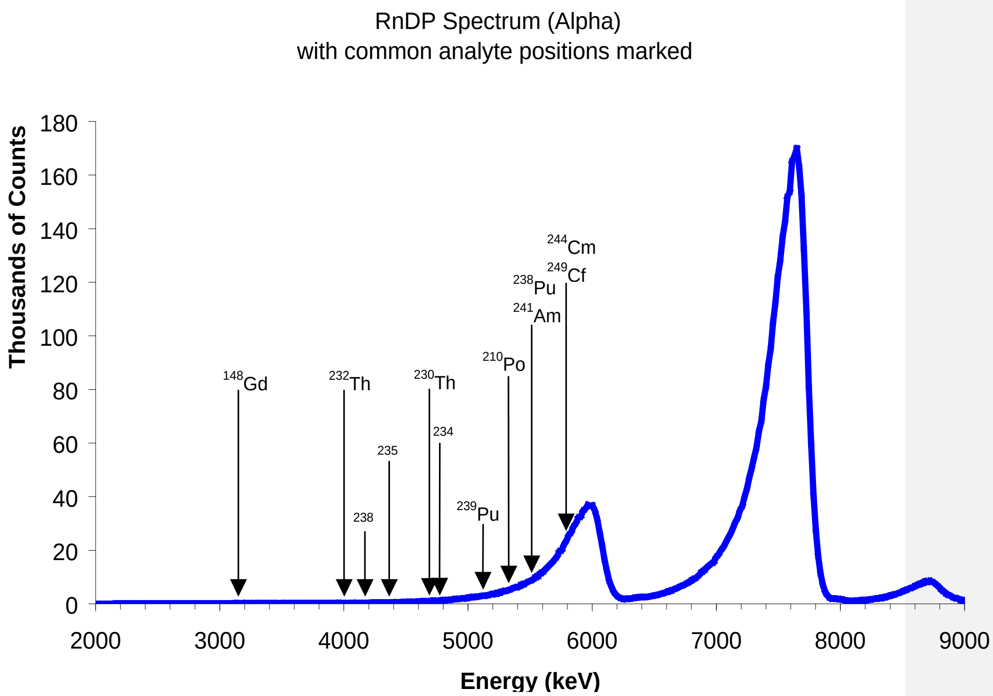

Figure 1. Typical alpha spectrum from radon progeny deposited on an air filter.

Table 7.2: Alpha Measurand Regulatory Limits

Radionuclide	Energy (keV)	ALI (Bq/m³)	DAC (µCi/ml)
^{244}Cm	5805	0.3	9E-12
^{249}Cf	5814	0.1	3E-12
^{238}Pu	5499	0.2	6E-12
^{241}Am	5486	0.1	5E-12
^{210}Po	5305	9	2E-10
^{239}Pu	5155	0.2	5E-12
^{234}U	4776	2	7E-11
^{230}Th	4688	0.1	3E-12
^{235}U	4396	3	8E-11
^{238}U	4196	3	8E-11
^{232}Th	4010	0.1	3E-12
^{148}Gd	3180	0.2	5E-12

From the spectrum in Figure 1 and from Table 7.2, the most restrictive ALI with significant RnDP interference is ^{249}Cf. The most restrictive ALI at a mid-point in the ^{218}Po tail is ^{239}Pu. At the nominal interference region of the tail, ^{232}Th has the most restrictive ALI. Response data on these three radionuclides will provide users and regulators with a very meaningful picture of an instrument capability with regard to compensation for RnDP interference.

7.4.4 Comparison of Some Common Beta ~~Analyte~~Measurands (possibly move to an Annex)

Radionuclide	Energy (keV)	ALI (Bq/m³)	DAC (µCi/ml)
Co-60			
Sr90			
Cs137			
I131			

~~7.3.4~~7.4.5 Radon Decay Product Background Subtraction Requirements

The ability of the instrument to reject unwanted interferants from RnDPs during the measurement of a target measurand shall be stated along with the method used for testing. The manufacturer shall select one measurand subject to moderate interference from RnDP for the testing (e.g. ^{239}Pu). A second measurand subject to significant interference (e.g. ^{241}Am) should be selected, to provide a basis for judging the effectiveness of the subtraction method. A third measurand subject to nominal interference (e.g. ^{230}Th) may be selected to provide information on optimal performance of the instrument. The manufacturer shall document the target measurand MDA, MDC, gross activity, and the ratio of target measurand MDA to gross activity. For instruments capable of alpha spectroscopic analysis, the manufacturer shall also document Radon progeny concentrations, and the ratio of target measurand activity to the ^{218}Po activity and ^{214}Po activity—denoted by the term, Resolution Ratio (RR-A & RR-C, respectively). Other factors that affect the performance metrics above, such as, but not limited to, filter type, window time, air gap, barometric pressure, FWHM, flow rate, moving filter speed (if applicable), and detector type, shall also be documented.

Comment [DTK3]: Do we need a section here that provides a test for the initial claim made in Sec. 7.4.5 above?

~~7.4~~7.5 Sampling System ~~er~~ Design (Murray, Tom K. John R.)

~~7.4.1~~7.5.1 Sampling Inlet Requirements

The instrument manufacturer shall specify the aerosol size range over which the instrument is designed to operate. In the absence of regulatory or user requirements, or a design basis on the part of the manufacturer for a particular aerosol size range, the sampling inlet, including any sample extraction and transport nozzle and line used, should be designed to operate with a minimum collection efficiency of 50% over the aerosol size range of 0.2 μm to 10 μm, mean aerodynamic diameter. Further, the instrument manufacturer shall specify the face velocity range over which the instrument is designed to operate. In the absence of regulatory or user requirements, the ambient wind speed range should be designated to cover the range of wind speeds between 0.5 to 2.0 m /sec.

~~7.4.2~~7.5.2 Sampling Inlet Testing

Characterization of the collection efficiency of the instrument inlet shall be carried out in an aerosol test facility that meets or exceeds the uniformity requirements of the US Environmental Protection Agency (1995) for air monitor testing. The aerosol collection efficiency of the sampler shall be tested by introducing into the sampler inlet a sample atmosphere containing particles covering a range of particle aerodynamic diameters sufficient to determine the aerosol penetration curve of the instrument over the size range specified in 7.4.1~~of the appropriate aerodynamic diameter~~. The size distribution of the particles should ~~be monodisperse, or polydisperse with a size distribution of TBD~~well characterized. The manufacturer shall specify the instrument sampling flow rate to be used during the collection efficiency tests, and that flow rate shall be within the operational capabilities of the instrument under nominal use conditions. ~~Replicate measurements of collection efficiency should be conducted at a minimum of 3 different particle sizes, and three wind speeds (0.5, 1.0, and 2.0 m·s^{-1}).~~ If an extraction nozzle and transport line or tube is used together with the instrument inlet during monitoring, each component of the air sample train shall be evaluated separately or concurrently if possible, and overall system efficiency determined. Either of two alternate methods is acceptable for the determination of collection efficiency.

7.5.2.1 Method 1

The sampling system under test is operated in the test conditions specified above for a duration sufficient to collect sufficient aerosols to allow a determination of the following parameters with the listed relative standard deviation σ. Following cessation of sampling the following parameters are determined:

C_M – the abundance of aerosol collected on the collection media (σ = ± 15%)

Cu – the abundance of aerosol collected on the sample inlet surfaces up-stream of the collection media (σ = ± 15%)

C_D – the abundance of aerosol collected on the interior surfaces of the air flow circuit down stream of the collection media (σ = ± 50%)

The total aerosol collected (C_T) is obtained by:

$$C_T = C_M + C_U + C_D$$

The measurand for aerosol abundance may be activity, mass, or particle number.

The collection efficiency (E_M) of the inlet, as registered on the media is given by:

$$E_M = \frac{C_M}{C_T} x100$$

7.5.2.2 Method 2

The sampling system under test is operated in the test conditions specified above for a duration appropriate to collect sufficient aerosols to allow a determination of the aerosol abundance on the collection medium with a relative standard deviation of ± 15%. The abundance of aerosols on the collection medium under test is compared to that collected by a minimum of two well characterized reference samplers, such as isokinetic samplers. The measurand may be activity, mass, or fluorescence of the aerosols extracted from the collection media.

The collection efficiency (E_M) of the inlet as registered on the media is given by:

$$E_M = \frac{C_M}{C_R} x100$$

Where:

E_M = the collection efficiency reported as a percentage.

C_M = the abundance measured for the collection medium from the sampler under test.

C_R = the abundance measured for the collection medium from the reference samplers.

A minimum of 3 replicate measurements should be made for each aerosol size and wind speed. The collection efficiency for the particle size and wind speed combination shall be reported as the arithmetic average of the individual measurements.

~~7.4.3~~7.5.3 Materials Requirements for Sampler Inlet and Sample Lines

The materials used in the construction of the sampling inlet and sampling lines shall be such that electrostatic and chemical reactions with the sampled atmospheres are minimized. Materials that are electrically conductive shall be used whenever possible to minimize residual electrostatic charge on the surfaces of the lines. Materials that minimize absorption, adsorption, and permeation of radon shall be used whenever possible to prevent the sampling lines from becoming a localized source of radon progeny. Manufacturers shall provide identification of the materials used in construction of the instrument that come into direct contact with the sample flow prior to, and including the collection medium.

~~7.4.4~~7.5.4 Test for Sampler Inlet and Sample Lines Materials

Verify the requirements by inspection.

~~7.4.5~~7.5.5 Requirements Regarding Flow Obstructions

The number and severity of obstructions to air flow between the inlet and collection medium and/or detector shall be minimized to limit losses of aerosols in the sample flow path to a minimum and to prevent unintentional size fractionation of the sampled aerosols. Flow obstructions are considered to include: bends or elbows, reductions in the cross-sectional area of the flow line and protrusions into the flow path. An exception to these requirements is provided in the event that the sampling flow path has been purposefully designed with flow obstructions to achieve particular aerosol sampling characteristics.

~~7.4.6~~7.5.6 Test for Minimization of Flow Restrictions

Verify the requirements by inspection.

~~7.4.7~~7.5.7 Requirements Regarding Location of the Air Moving Device

The air, or atmosphere moving device (pump) shall be placed down stream of the collection medium and/or detector.

~~7.4.8~~7.5.8 Test for Location of the Air Moving Device

Verify the requirements by inspection.

~~7.4.9~~7.5.9 Requirements for the Collection Medium

The specifications for the collection medium to be used with the instrument shall be stated by the manufacturer.

~~7.4.10~~7.5.10 Test for Collection Medium Requirements

Verify the requirements by inspection of documentation supplied by the manufacturer.

~~7.4.11~~7.5.11 Requirements for Ease of Decontamination of Sampling Apparatus

The sampling inlet, flow lines and/or flow pathways, collection medium, and detector shall be easily removed from the instrument to facilitate decontamination or replacement. The remaining portions of the instrument shall be designed so as to minimize internal contamination.

~~7.4.12~~7.5.12 Test for Ease of Decontamination of Sampling Apparatus

Verify the requirements by inspection.

~~7.4.13~~7.5.13 Requirements for Air or Atmosphere Leakage

The design of the sampling system shall be such that unintentional dilution of the sample flow volume by atmospheres other than that which is the subject of the sampling, is minimized. The system shall be designed to prevent loss of sample through outleakage.

~~7.4.14~~7.5.14 Test for Air or Atmosphere Leakage

Verify the requirements by ?? (who is on this one).…We shall test for inleakage and outleakage.~~MC~~mc

~~7.4.15~~7.5.15 Requirements for Flow Rate Measurement

For instruments that produce a measurement of measurand concentration, or a derived measure based on concentration in air, the volume of air sampled and air sample flow rate shall be determined as actual sample volume (cubic meters or cubic feet), and actual volumetric rate (cubic meters per second, or cubic feet per minute), not as volume or rate reduced to standard temperature and pressure.

For those instruments that measure and/or report air flow rate, the manufacturer shall state whether the flow rate is provided as a volumetric flow rate, or a mass flow rate. The flow rate measurements results shall be within ± 15% of the conventionally true value.

~~7.4.16~~7.5.16 Test for Flow Rate Measurement Type

Verify the requirement for utilization of actual sample volume and/or actual volumetric flow rate by inspection of the system documentation.

7.5.17 Test for Flow Accuracy

Verify the accuracy of the reported flow rate by comparison with a flow rate or flow totalizing instrument (transfer standard) that has a valid calibration traceable to NIST standards. The stated uncertainty of the flow or volume measuring transfer standard shall be less than or equal to the uncertainty stated by the manufacturer for the instrument under test. Follow the procedures provided by the manufacturer of the transfer standard with regards to interconnection with the instrument under test and operation of the transfer standard. Due care should be exercised in the selection of a suitable transfer standard to ensure that its use does not significantly alter the air flow characteristics of the instrument under test.

~~7.5~~7.6 Electronic Criteria (Morgan)

~~7.5.1~~7.6.1 Requirements for Mains Power

For air sampling and/or monitoring equipment using main (or line) power the instrument shall be capable of operating from mains with the supply voltage tolerance of ±10% and supply frequencies of 57 to 61 Hz without the indication varying by more than 10% from the indication under standard test conditions.

~~7.5.2~~7.6.2 Testing for Mains Power

A radioactive source shall be used to give a reading between 10 and 50 times the lowest values of the measuring range. With the supply voltage at the nominal value, the mean value of at least of twelve consecutive reading shall be taken.

~~7.5.2.1~~7.6.2.1 For either alternating or direct current supplied instruments:

The mean of two additional sets of at least twelve consecutive readings shall be taken with the supply at the nominal frequency for alternating current at a voltage 10% above the nominal value, and the mean of at least twelve consecutive reading shall be taken at a voltage 10% below the nominal value.

The two mean values shall not vary from that obtained with the nominal supply voltage by more that ±10%.

~~7.5.2.2~~7.6.2.2 For alternating current instruments:

The mean of at least twelve consecutive reading shall be taken with the nominal supply voltage and a frequency of 57 Hz, and the mean of at least twelve reading shall be taken at the nominal supply voltage and a frequency of 61 Hz.
The two mean values shall not vary from that obtained at the nominal frequency by more than ±10%.

~~7.5.3~~7.6.3 Battery Requirements

For instruments that may operate on battery supplied power for all or a portion of their operational cycle, the capacity of batteries directly influences the operational time of monitors. Decreasing battery voltage during the measuring period may influence the quality of the measurement. Therefore a test of the capacity of the battery is necessary for the satisfactory functioning of monitors.

The capacity of the battery shall be such that, after 16 hours of intermittent use with maximum periods of 4 hours, separated by intervals of at least 1 hour, or 8 hours of continuous use, the indication of the instrument shall no vary from the initial indication by more than 10%.
When power is supplied by secondary batteries their capacity shall be such that after 8 hours of continuous use the indication of the monitor shall not vary by more than 10% from the initial value.

~~7.5.4~~7.6.4 Test for Primary Battery

The monitor shall be exposed to an appropriate radioactive source to give an indication of approximately two-thirds of full scale on the least sensitive scale. The initial response shall be noted. The monitor shall then be used continuously for 8 hours. The actual response shall be compared with the response at the beginning of the tests. The difference in response shall be less than 10% of the initial value.

~~7.5.5~~7.6.5 Test for Secondary Battery

The charging unit shall be turned off and the same test procedure performed as above for the primary battery. The difference in response shall also be less than 10% of the initial value.

~~7.5.6~~7.6.6 Requirements for Power Supply Transient Effects

The monitor shall meet the requirements of the IEC 61000-4-4 level 3, electrical fast transient/burst, and the IEC 61000-4-11 withstand half period interruption in its power supply. With no radioactive source present the variation from background indication shall not exceed three times the lowest value of the range of measurement. With the source present the response shall not vary by more than 10% of the means response and no alarm shall be actuated during the transient.

~~7.5.7~~7.6.7 Test for Power Supply Transient Effects

Two different test shall be necessary, one without the radioactive source, and on with a source giving a response within the lowest value of the range of measurement. With the source present the mean response shall be at least 20% of the alarm set value.
At least twelve reading shall be taken in order to minimize statistical uncertainties. One set of reading shall be performed without power transients, one with fast transients with the test method from IEC 61000-4-4, and one with short interruption using the test method from IEC 61000-4-11, frequency of interruption: 10 Hz.

~~7.5.8~~7.6.8 Alarm Trip Range Requirement

This requirement excludes the detector. The range of the alarm shall be the entire measurement range of the instrument.

~~7.5.9~~7.6.9 Test for Alarm Trip range

This test shall be performed on each adjustable alarm. Using an appropriate electronic signal generator as specified by the manufacturer, the range of response of the instrument over which the alarm trip operates shall be determined.

For alarms intended to operate on increasing signals the alarm shall be adjusted to its lowest setting and the input signal slowly increased until the alarm is actuated. The indication of the alarm shall be recorded. The alarm shall the then be adjust to the highest setting and the input signal slowly increased until the alarm operates.

The indication of the instrument shall be noted at 50 times the lowest value of the range of measurement.

For alarms intended to operate on decreasing signals, operate as above from the highest setting to the lowest setting and slowly decrease the level of input signal.

~~7.5.10~~7.6.10 Alarm Trip Stability

This test shall be performed using an appropriate electronic signal generator.

~~7.5.11~~7.6.11 Test For Alarm Trip Stability

These requirements exclude the detector. The operating point of any alarm signal shall not vary outside of the range of 95% X to 105% X, where X is the nominal alarm set level for the period of 100 hours of operation.

For any alarm circuit whose nominal trip setting has been determined as X:

1. When a condition equivalent to 95% X is applied to the instrument or assembly electronically NO trip alarm shall occur within 100 hours;

2. When a condition equivalent to 105% X is applied to the instrument or assembly electronically after one hour and 100 hours of operation the alarm shall operate within one minute.

~~7.5.12~~7.6.12 Equipment fault alarm

The detector fault alarm shall be tested.

~~7.5.13~~7.6.13 Switches, Controls, and Graphical User Interfaces

These should be simple, user friendly and intuitive to the extent practical for the intended user competency.

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~~7.5.14~~7.6.14 Testing for Switches, Controls, and Graphical User Interfaces

Test by inspection to include intended operation of all controls and user interfaces.

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~~7.5.15~~7.6.15 Software/Firmware Requirements

Documentation of the initial as built shall be completed prior to delivery of instrumentation to customer. A mechanism to provide software updates to end users should be maintained and described in user documentation.

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7.6.16 Testing for Software/Firmware Requirements

Test by inspection of user documentation.

~~Requirements Regarding Units of Read-Out~~

~~Testing for Units of Readout~~

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~~7.5.16~~7.6.17 Requirements Regarding Susceptibility to Line Noise

Consideration should be given to insuring line noise will not adversely be present in such a way as to unexpectedly cause instrumentation problems. The manufacturer should characterize the change in instrument response to variations in power supply noise to include acute (i.e, voltage spikes) and chronic (i.e. DC drift) characteristics.

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~~7.5.17~~7.6.18 Test for Susceptibility to Line Noise

Testing should by appropriate simulation measurement of expected supply line variations while quantifying changes in instrument output if any. Testing under actual operating conditions is preferable.

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~~7.5.18~~7.6.19 Requirements Regarding Electronic Communications Interfaces

The use of industry standards based interface protocols should be used wherever practical. Use of company proprietary or non-standards based interfaces should be minimized whenever practical. Whatever interface protocols are used, these shall be documented in the user documentation.

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~~7.5.19~~7.6.20 Testing for Communications Interfaces

Verify compliance with requirement by inspection of the system documentation.

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~~7.6~~7.7 Interfering Responses (Morgan / Rob)

The generation of the technical basis document for testing results and instrument assessment shall be done by the manufacturer to characterize instrument performance for the intended end user applications. If an end-user chooses to utilize a particular instrument for a unique purpose (such as using a generic instrument for a specialized application), the generation of the technical basis document intended to validate the unique use of this equipment shall fall on the end-user in this latter case.

~~7.6.1~~7.7.1 Gamma and X-ray Fields

The extent to which external gamma or x-ray fields from natural or man-made sources can cause changes in instrument performance shall be documented if the instrument can credibly be operated in such radiation fields above 5 to 25 uR/h (environmental levels). . The results of all measurements and assessments from this section shall be reported in a technical basis document.

~~7.6.2~~7.7.2 Radio Frequency and Microwave Fields

The extent to which external radiofrequency and microwave fields can cause changes in instrument performance shall be documented for all ranges of frequencies in the geospatial area. Care should be taken to measure the effects over all ranges of legally allowed frequencies to account for future possible changes in those frequencies which could be used in the region.

~~7.6.3~~7.7.3 Electrostatic Fields

Instrument susceptibility to interference from an electrostatic field should be eliminated by use of an appropriate grounded exterior housing. If this is not accomplished, the potential for the instrument or adjacent items to collect or generate an electrostatic charge shall be quantified and documented in a technical basis document.

~~7.6.4~~7.7.4 Magnetic Fields

Instrument susceptibility to interference from magnetic fields should be eliminated by use of an appropriate mu metal exterior housing (ferromagnetic). If this is not accomplished, the potential for the instrument or adjacent items to collect or generate magnetic fields shall be considered and documented in a technical basis document.

~~7.7~~7.8 Mechanical Criteria (Morgan / Rob)

If equipment will only undergo mechanical shock and vibration when not in operation (such as during maintenance or transport) then vibration tests should only be conducted prior to instrument performance verification.

~~7.7.1~~7.8.1 Case Construction

The external housing shall be constructed to withstand designed manual operations including periodic maintenance and calibration. Portable instrumentation (whether on wheels or intended to be transported periodically to remote locations) shall have physical casing designed to reduce or eliminate instrument performance single drop failure. The height for drop evaluation will depend on the expected transport mode. Wheeled equipment shall withstand multiple sequential single stair step falls. Hand carried equipment should withstand a single 1 meter fall.

~~7.7.2~~7.8.2 *Mechanical Shock*

Credible maximum changes in instrument momentum shall be evaluated relevant to the expected configuration of operation.

~~7.7.3~~7.8.3 *Vibration*

Fixed equipment shall be characterized for relevant earthquake vibration conditions under which the instrument will successfully perform. Portable equipment shall be characterized for relevant vibration conditions under which the instrument could be expected to undergo while being transported. If the instrument is not expected to operate in transit, then only verification that post shaking operation of the instrument shall be required.

~~7.8~~7.9 Environmental Criteria (Morgan/Rob)

~~7.8.1~~7.9.1 *Ambient Temperature Requirements*

Over the temperature range from minus 20 degrees to plus 150 degrees F (minus 30 to plus 50 degrees C) the performance of the instrument shall not vary by more than ±15%. The exact operating temperature range shall depend on the user. For example, in a laboratory such as at Los Alamos National Lab, the temperature range would be limited to room temperature or 60 to 80 degrees F (15 to 20 degrees C). In a mine or basement of a home the temperature range would be similar. For outdoor applications the range would be from minus 20 to plus 150 degrees F (minus 30 to plus 50 degrees C).
The mean instrument response shall not vary by more than □15% from a set of reference readings taken at a temperature of 20 C when the instrument is taken from 20 to 50 C and to minus 30 C, in less than 5 minutes.
Conversely the mean instrument response shall not vary more than □15% from a set of reference readings taken at a temperature of 50 C or minus 10 C when the instrument is taken from either one of those temperatures to one of 20 C. These are termed temperature shock tests.

The manufacturer shall test and document the response of the instrument (at least two of that model) during the type test. If unspecified by the customer, the type test shall include testing over the entire temperature range of the instrument, and the temperature shock tests specified above. Or the type test shall only encompass the temperature range and the extreme temperature shock tests specified by the customer.

~~7.8.2~~7.9.2 *Relative Humidity Requirements*

The variation in response of the instrument due to the effect of relative humidity from 10 to 95% shall be within ±10% compared to response at a reference humidity of 65%.

The manufacturer shall test and document the instrument performance (at least two instruments of the same model) over the entire range required above or the humidity range specified by the user.

~~7.8.3~~7.9.3 Ambient Pressure Requirements

The influence of atmospheric pressure is significant with regard to the use of many types of radiation detectors. For, example, with solid state detectors, the distance from the alpha detector to the sample collecting surface and therefore the total mass of air through which the alpha particles travel is important.

The performance of the instrument shall not vary by more than ± 20% over the range of atmospheric pressure from 70 to 101.3 kPa. The reference pressure shall be 101.3 kPa.

The manufacturer shall test and document the performance of the instrument (at least two of the same model) over the entire range of pressures or the range of pressures specified by the user.

~~7.8.4~~7.9.4 Precipitation

This aspect of requirements and testing should already be adequately covered in 8.7.1 and 8.7.2 above.

~~7.8.5~~7.9.5 Ambient Dust and Aerosols

Sampling for radon progeny will almost always involve some ambient dusts and aerosols except for locations where the air to be sampled is HEPA or otherwise heavily filtered. In dusty ambient conditions shorter sampling times should be used to reduce dust burial of the alpha emitting radionuclides.

The testing of radon progeny sampling and measuring instruments with ambient dusts and aerosols shall be done by agreement between the manufacturer and the user. The users' requirements may be widely varying and beyond the scope of this standard.

~~7.9~~7.10 Calibration and Maintenance Rob/Morgan

7.10.1 Calibration for Type Testing

~~7.9.1.1~~7.10.1.1 Detector efficiency

Calibration of the instrumentation shall be appropriate to the measurand of interest. If primary detection of any combination of gamma, beta and/or alpha activity is to be quantified, then commensurate NIST traceable sources shall be used to determine detector efficiency~~. Efficiency calibration should be yearly, as recommended by the manufacturer or from a rigorous technical basis document based on operational history.~~ Measurement technologies which utilize gross counting for assay where mixed radiation types and or energies are measured shall be given additional attention. This should include utilizing standards which approximate the expected operating measurand composition, this could include a quantified radon progeny test atmosphere The detector efficiency shall be documented and examined for degradation.

Comment [DTK4]: IMPORTANT CONSIDERATION Unattached or uncombined fraction
From NCRP Report # 78 on Page 59 and Figure 6.1, "Rarely does the particle concentration in areas of any human activity fall below 10^3 to 10^4 particles per cm^3.
A value of 10^4 particles per cm^3 establishes an upper limit of 0.2 as a reasonable value of the unattached fraction of RaA. ?? is by count or by activity?

~~7.9.1.2~~7.10.1.2 Detector resolution

If specific detector resolution is necessary in quantification or characterization of the measurand, the detector resolution shall be determined prior to use and should be verified adequate for the intended application. To the extent applicable, if resolution degradation is credible, then periodic resolution checks shall be made if corrective actions are warranted.

~~7.9.1.3~~7.10.1.3 Air circuit calibration

If flow rate or differential pressure values in the flow circuit are integral to the quantification process then, flow rate and differential pressure measurements shall be calibrated at installation and upon any mechanical changes in the flow circuit or annually whichever is more frequent.
Periodic

~~7.9.2~~7.10.2 Maintenance and Calibration

~~7.9.2.1~~7.10.2.1 Detector assembly

If degradation of the detector is credible, a maintenance program shall be established. This should program consider the predicted lifetime of all components. The required program may consist of periodic inspection, cleaning and replacement when necessary.

~~7.9.2.2~~7.10.2.2 Air circuit

The flow rate quantification instrumentation (to include thermocouples if standard mass flow rate is reported) and the primary measurement device shall be maintained for either mass flow rate or volumetric flow rate measurement. The maintenance shall consist of inspections and verifications of performance.

~~7.10~~7.11 User Documentation

The following manuals may be combined providing the performance requirements listed below are still met.

~~7.10.1~~7.11.1 Users manual

The manufacturer shall supply the user's manual. The user's manual shall describe all operations and functions that the instrument is capable of performing. This shall include all controls and displays that may be required for operation by the user.

~~7.10.2~~7.11.2 Maintenance manual

The manufacturer shall supply the maintenance manual. The maintenance manual shall include all recommended maintenance for the entire system to prevent any predictable interruptions of proper system operation.

~~7.10.3~~7.11.3 Calibration Manual

The manufacturer shall provide a calibration manual. The calibration shall include the items listed in section 8.9 to include detector efficiency, detector resolution and air circuit parameters.

~~7.10.4~~7.11.4 Instrumentation design specifications

The manufacturer shall provide an instrumentation design specification manual. This manual shall include, all mechanical components, dimensions, electronic schematics and flow circuit diagrams. A description of algorithms shall be provided sufficient to allow prediction of anomalous performance of the system.

~~7.10.5~~7.11.5 Operating Procedures and Instructions

The user shall be responsible for generating final operating procedures and instructions unless agreed upon with the manufacturer. A process should be incorporated to update and improve procedures based on operating experience.

8 CLASS SPECIFIC PERFORMANCE & TESTING CRITERIA

8.1 Grab Sampling Instruments - Ken Courville & Paul Kotrappa

Grab sampling shall/should be done using calibrated flow meters (calibrated or corrected to report actual flow volumes) such that either volumetric or flow rate coupled with total measurement time allows quantitative sample metrics. The sampling shall take place in a location allowing technically sound correlation to the measurand of interest if this is not the measurand in the grab sample itself. Representative sampling should be attempted to the extent practical. Care should be given in the rest of the sampling apparatus to insure pump exhaust is not upstream if the sampling and that the filter media is appropriate for the measurand being sampled. If more than one sample is taken, then care shall be taken to insure each sample is appropriately documented and handled to prevent cross contamination or sample mix up.

8.2 Continuously Sampling Instruments

If a filtering system is used in a continuously sampling instrument, then the instrument shall(?) provide users with error indication if flow is abnormally high or differential pressure is unexpectedly low (as in the case of a torn filter). Similarly, the instrument shall(?) provide users with an error indication if the flow is abnormally low or differential pressure is unexpectedly low (as in the case of a clogged flow line or failed pump). Additionally, some filter media have an optimal collection side (as in membrane-type media) and the instrument design should either prevent insertion of the filter so that collection is on the wrong side, or detect and warn the user of such an occurrence.

These instrumentation systems shall provide a cumulative or time sequence of flow rates or sampled volumes.

The air flow should be designed so as to minimize aerosol loss or any resultant misrepresentation of the correct radon progeny information intended to be measured.

8.2.1 Fixed Filter - Tom Voss, David Baltz, John Rodgers, Linda Frank-Supka

Due to dust buildup, which causes reduced flow and burial of alpha emitters resulting in energy attenuation and degraded spectrums, the filters in a fixed filter system require periodic replacement.

In large instrument systems, the labor required to change out filters can be very costly. Instruments should be designed with simple and accessible filter holder mechanisms to make the operation as efficient as possible.

The instrument should sense and flag a condition when the filter should be changed. This condition could be indicated by a measured out-of-limits (low) flow rate as described in Section 7.2.

The instrument should indicate that a maintenance (e.g. out-of-service, door open) condition is present during filter replacement The condition should appear on the display (if any), the status lights and relay outputs, through any network communication messages, and in any event logging or data archival files.

The instrument should provide the user a method of resetting any spectral or count information (if not done automatically), after a new filter is installed, and before the maintenance condition created during filter change is exited.

If there is a warm-up period following an instrument reset, the special status should be indicated on the display, in the indicator lights and relay outputs, network messages, and in any log files.

Continuous sampling of a fixed filter system introduces the complexity of there being measurand activity due to new accumulations from measurand in sampled air, from the activity due to the decay of a parent isotope already on the filter. Individual radionuclide activity has three components: newly acquired particulates; plus decay products from material already captured; minus material already decayed. At a minimum, the concentration calculation shall take into account the newly acquired material and the decay of material already on the filter. The instrument may take into account of ingrowth due to the decay of a parent already on the filter, if the parent activity can be accurately determined (i.e. alpha/beta CAMs).

8.2.2 Moving Filter

There shall be a means to indicate to the user malfunction of the filters dynamic capability. There shall also be a means to indicate that the last portion of filter is being used. This may be accomplished by giving appropriate indication in advance that the last portion of filter is nearing. If this latter option is utilized, the warning should provide sufficient time to allow filter changing prior to instrumentation system performance degradation occurring due to end of filter type errors.

These malfunction indicators should have the capability to alert users both locally and remotely. This may be accomplished by local visual or audio alarms and signal output ports which can carry the same information to a remote user station or system.

8.2.3 Particle Impaction – Tom Kendrick ~~(include under Fixed Filter???)~~

If particle impaction rather than filtration is used as the methodology for sample collection, the manufacturer shall characterize particle collection efficiency and retention over a range of temperature, relative humidities and fog conditions expected in the operating environment. Care should be given to insure that suspended aerosolized water does not wash the sample off the impaction surfaces. If restrictions on operating conditions are present due to this liability, this shall be described in the user documentation.

8.3 Integrating Sampling Instruments - David Baltz, Paul Kotrappa, Krystyn Clark, John Rodgers, Murray Moore

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9 DOCUMENTATION REQUIREMENTS (MORGAN)

The documentation shall consist of at minimum the following information:

- The name and address of the manufacturer.
- The type of instrument, type (s) of detector and the radiation the instrument is intended to measure.
-
- The range of measurement of the instrument.
- The complete results of the type testing of the instrument, including the radiation, mechanical, electrical/electronic and environmental requirements and requirements-testing.
- The documentation requirements listed in Sections 7.9 and 7.10.

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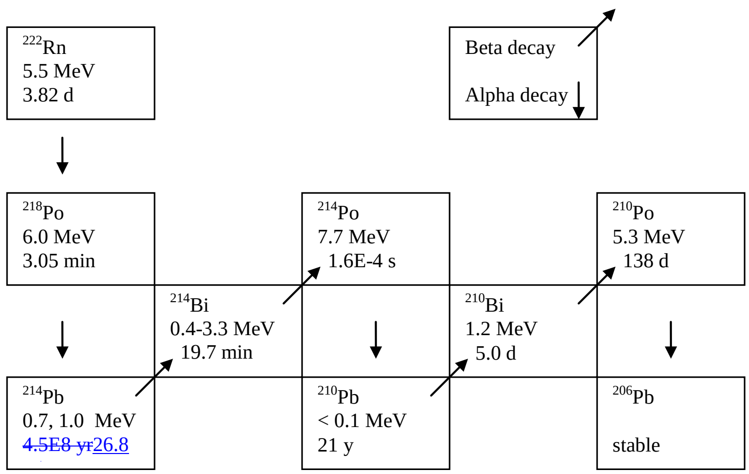
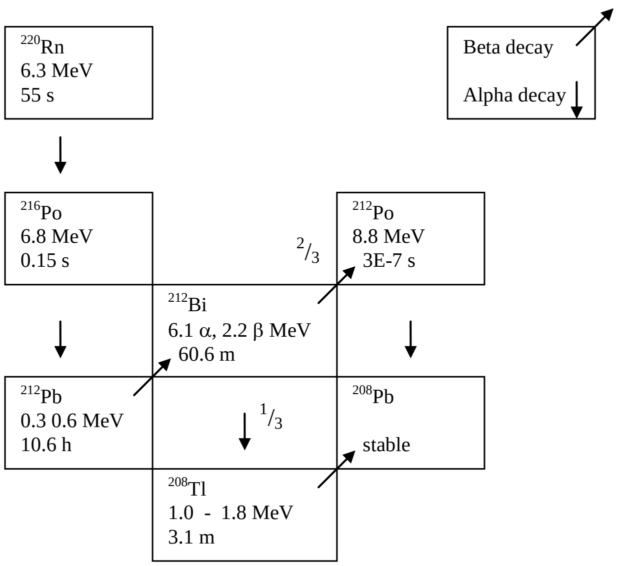
11 ANNEXES

11.1 Radon Decay Chain

Rn222 decay series (from U238)



Rn220 decay series (from Th232)



~~12.2~~11.2 Radon and Radon Progeny Equilibrium

~~12.3~~11.3 Aerosol Sampling Considerations

~~12.4~~11.4 Filter Selection?

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