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How Do We Ensure Our Measurements Are Accurate?

By following our Quality Assurance Plan and conducting Quality Control measurements

Quality Assurance (QA) and Quality Control (QC)

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- QA
- A complete program designed to produce results that are valid; scientifically defensible; and of known precision, bias, and accuracy, including planning, documentation, and quality control activities.

- QC
- The system of activities to ensure a quality product, including measurements made to ensure and monitor data quality.
- This includes calibrations and background, duplicate, blank and spiked measurements; inter-laboratory comparisons; audits; and other control activities.

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QA/QC Elements

Live it. Breathe it…

Who Needs QA Plans? Everyone!!!

- Residential Measurement Professionals (aka testers)
  - Individuals who place devices in homes, schools and other buildings and interpret results obtained from an Analytical Laboratory
  - Organizations conducting large surveys
- Analytical Laboratory
  - Anyone who analyses the device to obtain a radon or WL value
  - It is possible to be both:
    - 1) Analytical and
    - 2) Measurement Service Providers
- If an analytical lab performs QA/QC, why does an individual who only places passive devices need to do QA/QC?
  - Because you are testing your storage and handling
  - Because you are testing the lab

Who Should Perform QA/QC? Everyone!!!

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- Quite simply, ANYONE performing any radon measurement services including
  - Any state, province, or public agency which:
    - Performs radon measurements or
    - Offers radon test devices to the public or others
  - Any private party including non-profit organizations who:
    - Performs radon measurements or
    - Offers radon test devices to the public or others
  - Anyone offering analytic services

Why Do We Have to Do This?

- Because it is necessary based on the history of radon measurements and lessons learned, what affects measurements, and represents the best practices to provide results that are reliable, valid and representative of the radon concentration so that clients can rely on the information for their purposes.

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Quality Assurance Plans

A written plan of your operations

- That you implement according to its guidance and procedures
- Which involves evaluating your results and the quality control measurements you make to assess the measurements validity and reliability which,
- Provides confidence in results as a basis for risk reduction decisions by clients and,
- Demonstrates you know what you are doing and do it consistently

Sources for QA Plans

MSQA

- Has a template in the Companion Guidance
- https://drive.google.com/file/d/1DgOFTOt2qhLm7H20U6pcc8oiz7RSZITS/view
- AARST Templates are available on the AARST website for free in Members Only and for purchase for all others to assist in creation of a QA/QC plan.
- Contact device manufacturers and laboratories for boiler plate sections.

Check your state radon program web site for guidance and example forms

Quality Management will include….

All six elements are to be documented in a QAP and associated standard operating procedures

(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 (internal audits) and corrective action; and

(6) QA reporting that is reviewed at regular intervals to improve quality over time.

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Precision, Accuracy & Background Contamination

Too. Many. Words…

Precision, Accuracy & Background Contamination

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- Definitions
  - Accuracy
    - Degree of agreement of a measurement (x) with a 'true' value (T)
  - Bias
    - Systematic (or consistent) error in test results
    - Absolute bias
      - Bias between field measurements and the 'true' value
    - Relative bias
      - Bias between results from different sources

Precision, Accuracy & Background Contamination

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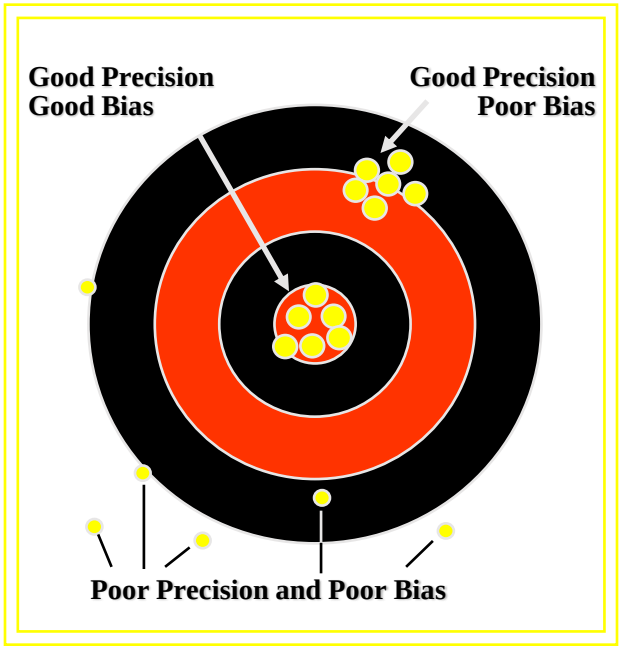
- Definitions- cont
  - Precision
    - Measure of mutual agreement among individual measurements of the same property under prescribed conditions
  - Uncertainty
    - Estimated bounds of the deviation from the mean value
      - Expressed generally as a percentage of the mean value

Precision, Accuracy & Background Contamination

- Concept of Precision & Bias
  - Good precision is like having a good "group" of shots. That is, you do everything very "precisely" each time.
  - Good "bias" is when the average of group is close to bulls eye.



Precision, Accuracy & Background Contamination

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- Definitions- cont
  - Background contamination
    - Some source of radiation in the environment that
      - May lead to inaccuracy of our measurements
      - May bias our measurements away from the ‘true’ value

Precision, Accuracy & Background Contamination

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- Definitions- cont
  - In-Control
    - A measurement system that produces repeatable and stable QC results
      - CRM's: background, instrument stability tests, and comparison checks
      - Other methods: duplicates, blanks, and spikes
  - Corrective Action
    - Actions taken to identify and eliminate root causes of a problem thus preventing their recurrence

Precision, Accuracy & Background Contamination

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- Interpretation of QC outputs
  - "In Control" – expect to see duplicate results routinely produce this RPD
  - "Warning Level" – expect to see duplicate results produce this RPD only 5% of the time
  - "Control Limit" – expect to see duplicate results produce this RPD only 1% of the time

Precision, Accuracy & Background Contamination

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- Which QC Measurements Evaluate Which Issues?
  - Duplicates
    - Used to measure precision
  - Blanks
    - Used to measure background contaminations
  - Spikes
    - Used to measure accuracy

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Duplicates

Why aren't they the same number?!

Duplicates

- Duplicate measurements
  - **Collocated**, simultaneous measurements conducted with instruments/devices that are identical (same make/model)
  - The purpose of duplicate measurements
    - Is the assessment and monitoring of the measurement system's ***imprecision***
- By standard,
  - **10%** of all deployed measurements should be duplicate measurements

Duplicates

- 5.4.1 Field Operation Duplicates- Freq & Procedures
  - *Field operation duplicates ARE to be deployed in approximately one in 10 measurements (10% of the time)*
  - Conducting duplicates IS to include
    - Exposing identical, collocated devices simultaneously for at least 48 hours
    - Submitting them for analysis without identification as duplicates (blind), and then
    - Comparing the results
  - Field operation duplicates ARE to be distributed among different environments, operators and projects
    - So the duplicate data reflects the range of environments tested

Why Would Measurements Not Be the Same?

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- What leads to differences of measured outcomes?
  - Error caused by the random nature of counting radioactive decay
  - Slight differences in detector construction or amount of carbon
  - Differences in handling of detectors – weighing process, analysis process
  - Tampering or other site events

Metric of Precision: The RPD

- Relative Percent Difference (RPD)
  - Statistic used to evaluate the difference between two measurements when there is no evidence to support one being more accurate than the other

$$\text{Average} = \frac{\text{Result 1} + \text{Result 2}}{2}$$

$$\text{RPD} = \frac{(\text{Result 1} - \text{Result 2})}{\text{Average of both results}} \times 100$$

- * Should be within expected limits for device*

Relative Percent Difference (RPD) Sample

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- Duplicate long-term tests exposed for the same period are 4.1 pCi/L and 4.6 pCi/L.

What is the RPD?

Average = (4.1 + 4.6) / 2 = 4.4 pCi/L

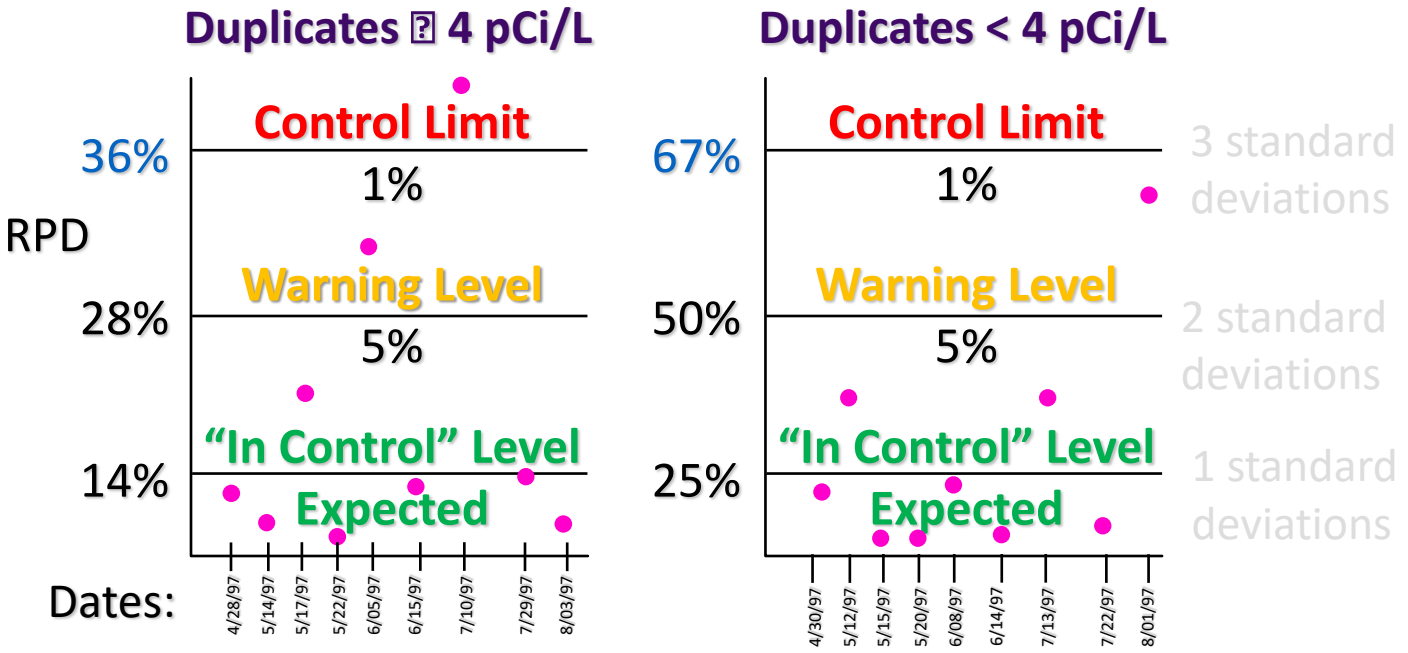
$$RPD = \frac{(4.6 - 4.1)}{4.4} \times 100 = \textbf{\textit{11.5\%}}$$

Interpretation for My Clients?

- Regardless of the difference…….
  - If the average of results are below 4 no mitigation would be recommended
  - If the average of results are above 4 mitigation is recommended
  - If one is above and one below 4, look at the difference between them. If twice the lower result is still less than the higher result – retest. Otherwise use the average to recommend action. 4.0 or more=recommend mitigation

Control Charts

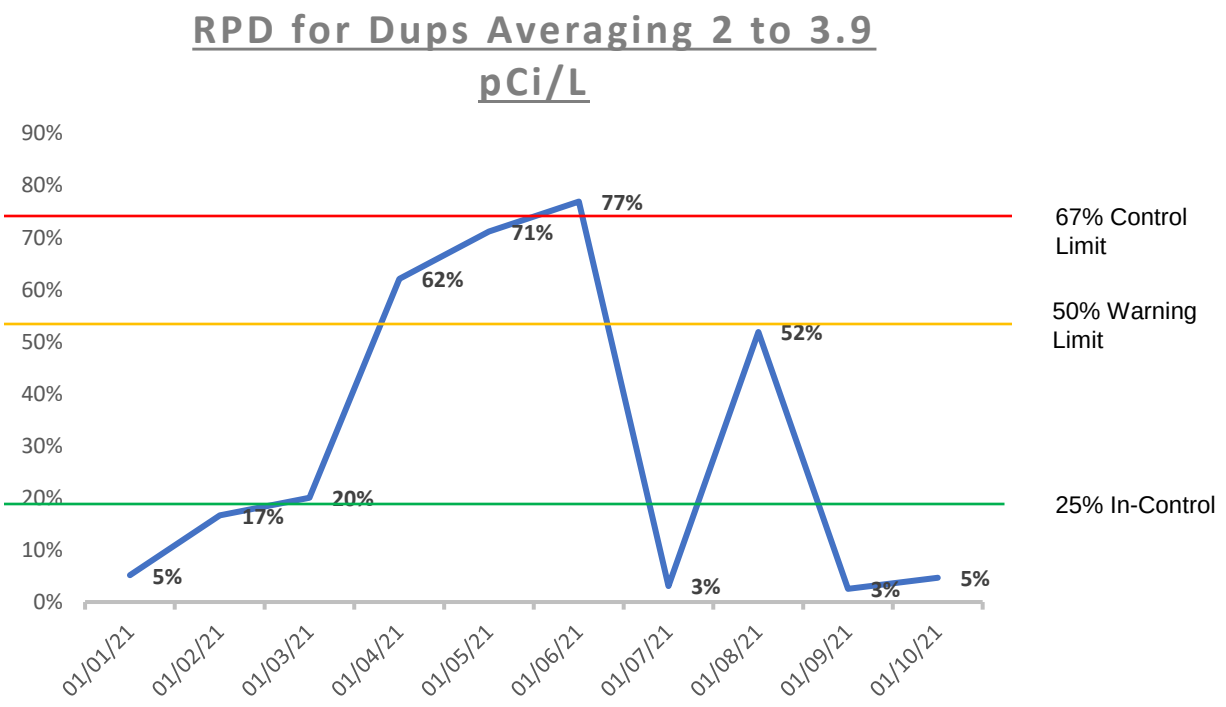
- Control charts are used to track duplicate results



Duplicate QC Set, <4 pCi/L

Start Date	End Date	Higher Test Result - Device Serial Number	Lower Test Result - Device Serial Number	Higher Test Result - Radon Concentration (pCi/L)	Lower Test Result - Radon Concentration (pCi/L)	<Do Not Enter Data in these Columns. The information is calculated by the formulas already in the template> Difference	Average	RPD
01/01/21	01/03/21	100	200	4	3.8	0.2	3.9	5%
01/02/21	01/04/21	101	201	3.9	3.3	0.6	3.6	17%
01/03/21	01/05/21	102	202	2.2	1.8	0.4	2.0	20%
01/04/21	01/06/21	103	203	3.8	2	1.8	2.9	62%
01/05/21	01/07/21	104	204	4	1.9	2.1	3.0	71%
01/06/21	01/08/21	105	205	4.5	2	2.5	3.3	77%
01/07/21	01/09/21	106	206	3.3	3.2	0.1	3.3	3%
01/08/21	01/10/21	107	207	3.4	2	1.4	2.7	52%
01/09/21	01/11/21	108	208	4	3.9	0.1	4.0	3%
01/10/21	01/12/21	109	209	2.2	2.1	0.1	2.2	5%

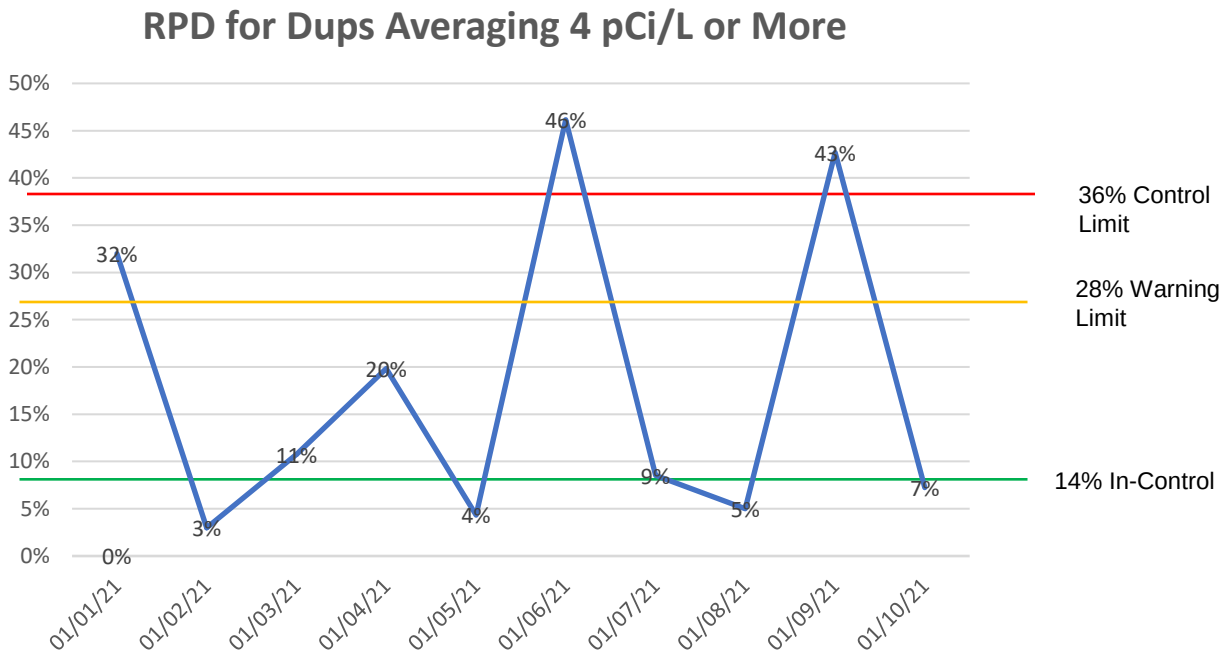
Duplicate QC Set, <4 pCi/L



Duplicate QC Set, >= 4 pCi/L

Start Date	End Date	Higher Test Result - Device Serial Number	Lower Test Result - Device Serial Number	Higher Test Result - Radon Concentration (pCi/L)	Lower Test Result - Radon Concentration (pCi/L)	<Do Not Enter Data in these Columns. The information is calculated by the formulas already in the template>		
						Difference	Average	RPD
01/01/21	01/03/21	300	400	8.7	6.3	2.4	7.5	32%
01/02/21	01/04/21	301	401	6.8	6.6	0.2	6.7	3%
01/03/21	01/05/21	302	402	4.9	4.4	0.5	4.7	11%
01/04/21	01/06/21	303	403	7.2	5.9	1.3	6.6	20%
01/05/21	01/07/21	304	404	7.1	6.8	0.3	7.0	4%
01/06/21	01/08/21	305	405	24	15	9	19.5	46%
01/07/21	01/09/21	306	406	49	45	4	47.0	9%
01/08/21	01/10/21	307	407	4.1	3.9	0.2	4.0	5%
01/09/21	01/11/21	308	408	5.4	3.5	1.9	4.5	43%
01/10/21	01/12/21	309	409	4.3	4	0.3	4.2	7%

Duplicate QC Set, >= 4 pCi/L



Investigative Actions: Duplicates

- Excessive control limit violations could
  - Be a result of handling procedures
    - Action: Review all portions of deployment and chain of custody standard operating procedures (SOP)
  - Be an issue with transport back to the lab
    - Action: Review shipping transit times and adjust shipping speed appropriately
  - Be an issue with laboratory analysis
    - Action: Communicate issues with the laboratory and jointly investigate all procedures for all device handlers

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Blanks

What do you mean there is more than one type of blank?

Blanks

- Blank measurements
  - Type of QC check quantifying detector response due to factors OTHER THAN the measurement itself
  - Deployed to measure effects on the measurement from anything OTHER THAN the environment being tested
  - UNEXPOSED devices submitted with the device stream to test for confounding measurement factors

Blanks

- Blank measurements cont.
  - Purpose
    - Verify/document the lack of influence of factors encountered outside the measured environment
- By standard
  - 5% of all deployed devices deployed [in the field] should be blanks

Types of Blanks

- Blank type definitions
  - Field blank
    - Blank devices left UNEXPOSED in the measurement environment to measure for *confounding environmental exposures*
    - Submitted in the device stream AS IF exposed (blind)
  - Office blank
    - Blanks submitted to the laboratory to measure for unintentional storage exposure of devices
  - Transit blank
    - Blanks shipped with devices to measure for unintentional transit exposures of devices

Blanks

- 5.2.1 Field Operation Blanks- Distribution
- Field blanks
  - A portion of the required 5% blanks SHALL be field blanks w/additional blanks dedicated to other evaluations
    - As for storage, office or trip blanks

Blanks

- 5.2.1 Field Operation Blanks- Distribution
- Office/storage blanks
  - IF CAD/ATD inventories are stored in a low radon/RH-controlled environment AND these conditions are regularly documented
    - Office blanks need NOT be used if consistent with manufacturer's directions
- Lab-transit blanks
  - Transit blanks verify and document the lack of influence during shipping
    - Practically speaking: most common transit blanks will be EIC plate blanks

Field Blanks Measure Bias

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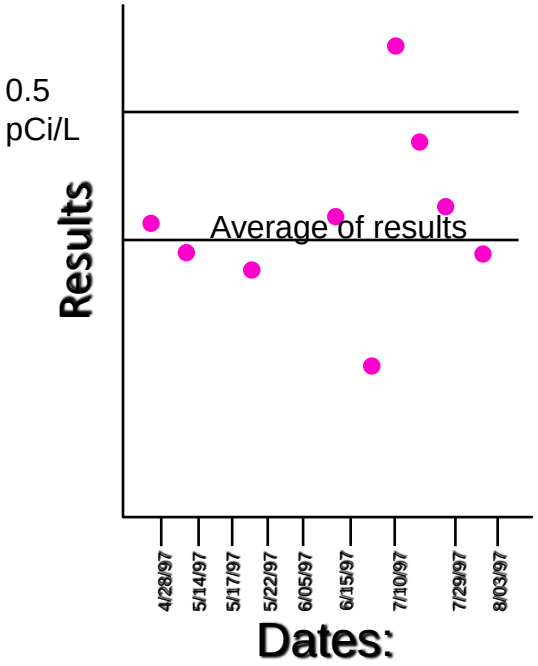
How Far Off of the Bullseye?

- Bias is how far the average of simultaneous results are off from the "target" value
  - It indicates a **systematic** error
- Bias is indicated by blanks, or unexposed measuring devices
  - Results should be within Lower Limit of Detection (LLD) of device

Control Chart for Blanks

Blank results that are **BELOW** the average or LLD are not a concern

- Only when blank results come back high are we concerned.



Blank results should be within Lower Limit of Detection of your device

- Typically 0.5 pCi/L
- Check with manufacturer

Control Chart for Blanks

Start Date	End Date	Device Identification Number	Radon Concentration (pCi/L)	Means Control Chart		
				Less than 0.3 pCi/L	Warning Level 0.3 to 0.6 pCi/L	Control Level Greater than 0.6 pCi/L
01/01/21	01/03/21	500	0.4		X	
01/02/21	01/04/21	501	0.3	X		
01/03/21	01/05/21	502	0.8			X
01/04/21	01/06/21	503	0.5		X	
01/05/21	01/07/21	504	0.2	X		
01/06/21	01/08/21	505	0.3		X	
01/07/21	01/09/21	506	1.2			X
01/08/21	01/10/21	507	0.5		X	
01/09/21	01/11/21	508	0.2	X		
01/10/21	01/12/21	509	0.3		X	

Investigative Actions: Blanks

- Excessive control limit violations could
  - Be a result of deployment procedures
    - Action: Review deployment log and investigate for potential unintentional field exposure, such as devices deployed on stone surfaces
  - Be an issue with transport back to the lab
    - Action: Conduct shipping blank analyses
  - Be an issue with device storage
    - Action: Conduct radon testing in office device storage locations

Spikes

The answer depends on the definition of the word ‘true’…

Spikes

- Spike measurements
  - Devices exposed in a STAR environment to a KNOWN ('true') radon concentration
  - Exposures are to be comparable to field exposure durations
  - Spike devices are to be SUBMITTED BLIND to the laboratory
  - Spike measurements measure accuracy
- By standard
  - 3% of all deployed devices should be spike devices

Spikes

- Standard Test Atmosphere for Radon (STAR)
  - Technical term for a Radon Chamber
  - In relation to the MS-QA 2023
    - Refers to an ACCREDITED radon chamber
      - Sometimes called a Secondary Radon Chamber or Certified Reference Chambers, or
      - Tertiary chambers such as operated by manufacturers or laboratories

Spikes

- 5.3.1 Field Operations Spikes- Freq & Procedures
- Users of CAD/ATD/EIC methods ARE responsible for setting aside AT LEAST 3% of the devices deployed for field measurements as spikes,
  - Arranging for and interpreting their results,
  - With six (6) per month being the necessary maximum, and
  - No less than three (3) per year

Spikes

- 5.3.1 Field Operations Spikes- Freq & Procedures
- If using detectors of different configurations, the same requirements APPLY for each different configuration
- Any project involving MORE THAN 100 measurements SHALL include at **least three (3) spikes**

Spikes Measure Accuracy

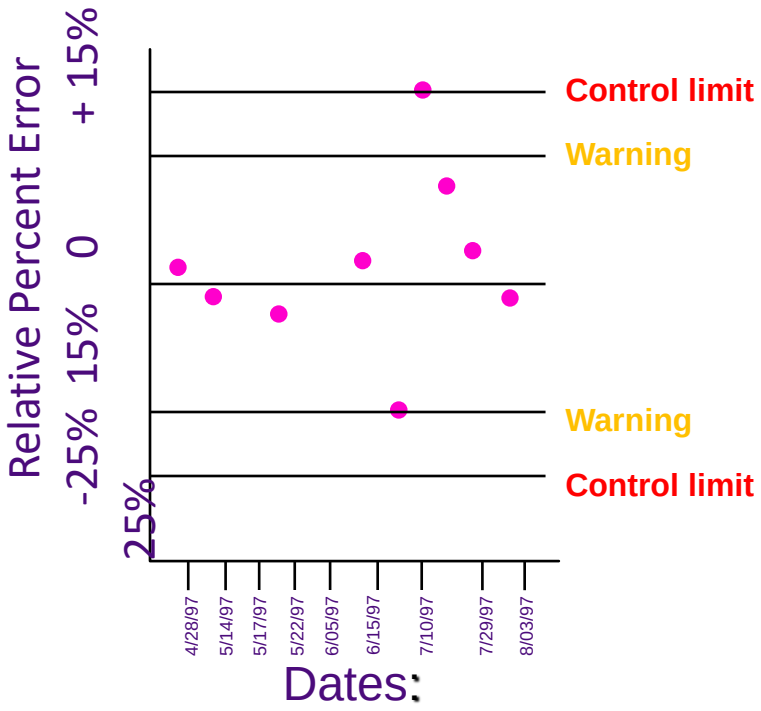
- Accuracy
  - How close the Measured Value is to the Target Value
  - For a single measurement,

- Accuracy = (Measured (your) value – Target (chamber) Value) x 100
- Target (chamber) Value
- EPA's test of laboratories used +/- 25%
  - ANSI/AARST MS-QA 2019 allows +/- 30%
  - (MS-QA 2019 Section 3.5.4, p11)

Metric of Accuracy: The RPE

- Relative Percent Error (RPE)
  - Statistic used to evaluate the difference between a measurement and a known ('true') value
  - Used to estimate total error in radon measurements
    - Where MV= Measured Value
    - Where RV= Reference Value
- RPE = (MV - RV) x 100
- RV
- * Should be within expected limits for device*

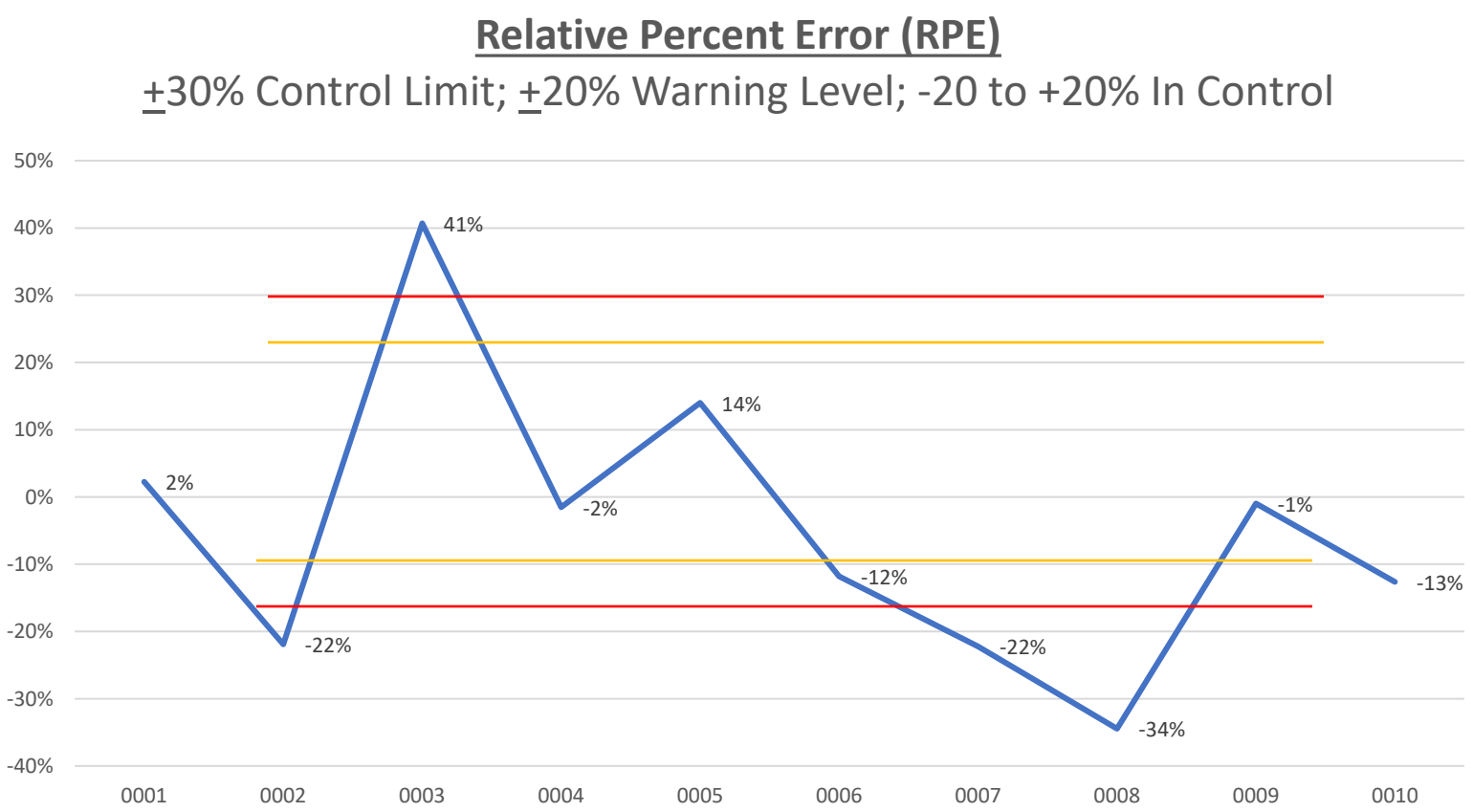
Spikes Control Chart



Spikes Control Chart

Start Date	End Date	Device Identification Number	Spike Number	Measured Value (MV) (pCi/L) (Test Result from the Lab)	Reference Value (RV) (pCi/L) (Stated Radon Level from the Spiking Chamber)	<Do Not Enter Data in these Columns. The information is calculated by the formulas already in the template> Relative Percent Error (RPE)
01/01/21	01/03/21	600	0001	9.1	8.9	2%
01/02/21	01/04/21	601	0002	11.4	14.6	-22%
01/03/21	01/05/21	602	0003	12.1	8.6	41%
01/04/21	01/06/21	603	0004	6.4	6.5	-2%
01/05/21	01/07/21	604	0005	10.6	9.3	14%
01/06/21	01/08/21	605	0006	18.7	21.2	-12%
01/07/21	01/09/21	606	0007	17.5	22.5	-22%
01/08/21	01/10/21	607	0008	9.7	14.8	-34%
01/09/21	01/11/21	608	0009	19.9	20.1	-1%
01/10/21	01/12/21	609	0010	17.3	19.8	-13%

Spikes Control Chart



Investigative Actions: Spikes

- Excessive control limit violations could
  - Be a result of spike submission procedures
    - Action: Review spike procurement and submission procedures for possible issues
  - Be an issue with transport back to the lab
    - Action: Review timing associated with spike procurement and submission to the lab for analysis
      - Shipping delays may impact analysis outcome
  - Be an issue with laboratory practices
    - Action: Conduct a phone audit with the laboratory concerning repeated control limit violations

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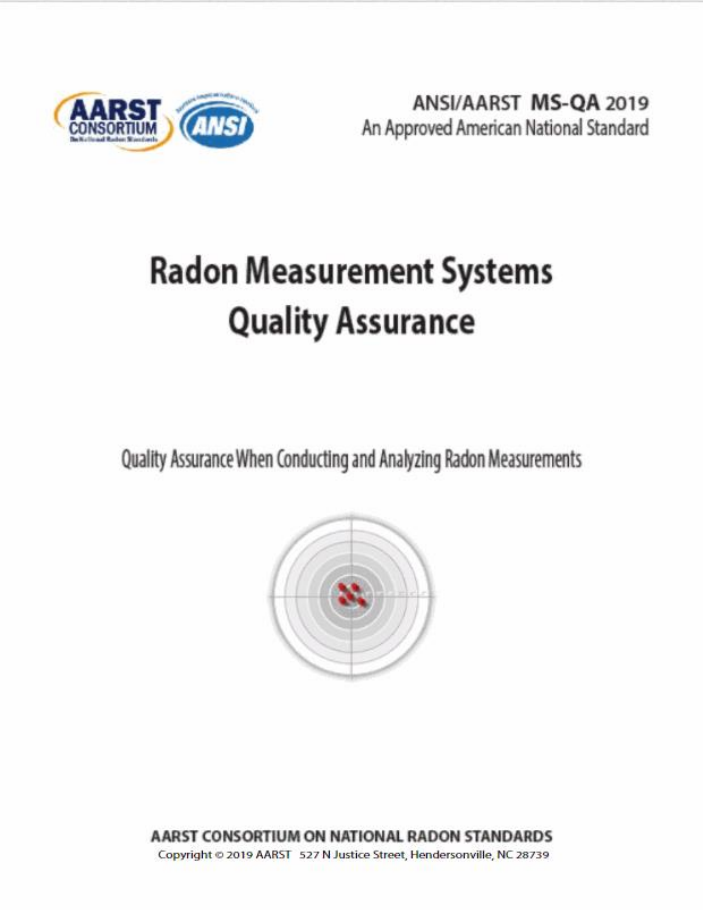
MS-QA Standards Introduction

AARST-NRPP QA Standards



- ANSI/AARST MS-QA 2019
  - Radon Measurement Systems Quality Assurance

ANSI/AARST MS-QA 2019 Sections

- MS-QA Introduction
  - Table of Contents
- Scope
- Definitions
- Requirements (All Methods)
- Continuous Radon Monitors
- Field Operations (EIC, ATD and CAD)
- Analysis of EICs
- Labs (all methods)
- Labs (CAD (Gamma Spectroscopy))
- Labs (CAD (Liquid Scintillation))
- Labs- ATD (Alpha Track)
- Informative References
- MS-QA Consensus Body (committee)
- MS-QA Companion Guidance

MS-QA Sections for Measurement Providers

- Section 3: Requirements (all methods)
  - 3.1 QA REQUIRED
  - 3.2 Approved Devices and Qualified Labs
    - Use of ONLY devices approved by the Device Evaluation Program
  - 3.3 Validation of Performance
    - 3.3.2 Field Operations
      - Blind Blanks
      - Spikes

MS-QA Sections for Measurement Providers

- Section 3: Requirements (all methods)- Cont
  - 3.5 Default Minimum Criteria for Warning & Control Limits- Duplicates & Spikes
    - 3.5.1 Duplicate & Comparison Check
      - In-control Relative Percent Difference (RPD): 14%, >= 4 pCi/L
      - In-control RPD: 25%, <4 pCi/L

MS-QA Sections for Measurement Providers

- Section 3: Requirements (all methods)- Cont
  - 3.5 Default Minimum Criteria for Warning & Control Limits- Duplicates & Spikes
    - 3.5.2 Warning and Control Limits (Duplicates)
      - Radon concentration is >= 4 pCi/L
        - Warning limit RPD: 28%
        - Control limit RPD: 36%
      - Radon concentration <4 pCi/L
        - Warning limit RPD: 50%
        - Control limit RPD: 67%

MS-QA Sections for Measurement Providers

- Section 3: Requirements (all methods)- Cont
  - 3.5 Default Minimum Criteria for Warning & Control Limits- Duplicates & Spikes
    - 3.5.4 Warning & Control Limits (Spikes)
      - Warning limit Individual Percent Error (IPE): +/- 20%
      - Control limit (IPE): +/- 30%

MS-QA Sections for Measurement Providers

- Section 4: Requirements for Continuous Radon Monitors (CRM's)
  - 4.1 CRM instrument checks
  - 4.2 CRM Comparison check requirements
    - Collocated, simultaneous measurements conducted for at least 48 hours
    - 4.2.1 comparison checks are to be made approximately every tenth measurement (i.e. 10% of deployments)
  - 4.3 CRM calibration
    - Each CRM shall be calibrated annually

MS-QA Sections for Measurement Providers

- Section 5: Requirements for Electret Ion Chambers (EIC), Alpha Track Detectors (ATD) & Charcoal Adsorbtion Devices (CAD)
  - 5.2 Required Blanks
  - 5.3 Required Spikes
  - 5.4 Required Duplicates
  - 5.5 EIC additional requirements
    - Log/report test location elevation
    - Log/report potential gamma interference and exact test location
- Section 6: Analysis of EICs

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Global Thoughts on Radon QA/QC

But WHAT does it MEAN?!

Global Thoughts on QC Measurements

- QC measurements and deployment totals
  - 100-room school to be tested
  - Total needed deployments
  - 1 device per RM: 100 devices
  - 10% Duplicates: 10 devices
  - 5% Blanks: 5 devices
  - 3% Spikes: 3 devices
  - Total: 118 devices

Global Thoughts on QC Measurements

- Your QA plan is there to
  - Provide the best quality service possible to your clients
  - Identify problems with your SOP's and help you correct those problems
  - Help you defend yourself when your measurements are called out

"No cause for alarm—we're checking for radon emissions."

Global Thoughts on QC Measurements

- Your QC measurements
  - Provide the data needed to identify issues in your measurements
  - Provide the data to show your measurements are what you say they are

KSU Radon Chamber Services

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- KSU Radon Chamber
  - https://ksuradonchamber.org/
- Device Performance Testing (DPT)
  - Necessary for initial NRPP certification and an option during re-certification
    - Needed for EACH device type used in your business
    - Demonstrates proficiency in your device usage
  - $150 per device test

KSU Radon Chamber Services

- KSU Radon Chamber
  - https://ksuradonchamber.org/
- Spiking Services
  - Necessary QA exposure services
    - Minimum order of three (3) spikes
    - 48-hour exposures: $30 per spike
    - 49-hour to 7 day exposures: $30 per spike
    - >7 day exposures: $40 per spike