C-NRPP Quality Control and Quality Assurance Manual for Radon Sampling and Analysis conducted by Radon Measurement Professionals and Laboratories

October 2018

C-NRPP Quality Control and Quality Assurance Manual for Radon Sampling and Analysis conducted by Radon Measurement Professionals and Laboratories

Table of Contents:

1. Introduction

1.1 Scope

This document specifies requirements for conducting radon measurement activities in Canada. These requirements apply specifically to radon professionals who are certified by the Canadian National Radon Proficiency Program (C-NRPP) and are conducting indoor radon tests in Canada. This document also applies to radon measurement support services including laboratories, manufacturers, suppliers and retailers.

1.2 Purpose

The purpose of this document is to specify quality assurance and quality control requirements that will enable radon professionals to ensure that testing is consistently reliable and that any errors are identified quickly. It is of critical importance that radon measurement professionals provide clients with reliable and repeatable radon measurements, thus allowing clients to feel confident when making the decision to mitigate or when receiving confirmation of the effectiveness of a radon mitigation system installed in a building.

Quality controls must be in place to ensure that radon testing devices are functioning correctly. These controls will help to increase the public's confidence in the radon measurement process, and ensure that public health is protected.

1.3 Application

The requirements of this document apply to all individuals and organizations providing radon measurements, regardless of the type or size of the organization. Radon device manufacturers and analytical laboratories are also encouraged to seek other laboratory certifications such as ISO 9001 and 17025.

The requirements in this document should be interpreted as minimums. The certified radon professional is responsible for ensuring that quality objectives are met, and shall take measures and corrective action where appropriate to maintain quality control. Specific tasks associated with quality assurance and quality control may be delegated to other trained individuals within an organization, but the certified radon professional is ultimately responsible for ensuring that all the requirements of this document are met.

2. Definitions

Acceptable RPD – An acceptable Relative Percent Difference (RPD) as defined in the chart in Appendix 4.

Accuracy - the closeness of a measured value to a standard or known value.

Voltage Drift –the change in an electret's voltage between measurements while the electret has been in storage.

Background – the portion of a radon measurement that is caused by sources other than the radon being measured. This background measurement arises from radiation sources other than radon, such as cosmic rays and the presence of other radioactive materials, and may also be caused by contamination at various stages of media preparation, sample collection, transport and analysis.

Biennial – occurring once every two years.

Blanks – A blank is a device that is deployed to determine the background measurement.

Calibration – correction and maintenance of a measuring instrument by performing routine tasks including the comparison of reported values against known true values.

Change Control – actions that need to be taken after an error in a process is discovered.

Change Control Report – the report which documents the actions taken as part of Change Control.
Control Level – a pre-determined range of quality control factors that indicate a need for immediate action.

Continuous Radon Monitor (CRM) – an electronic device that detects and "counts" alpha particles produced during the decay of radon (Rn-222) and/or its progeny polonium (Po-218, Po-212) within an internal ionization chamber or scintillation cell. Only C-NRPP-approved devices may be used by C-NRPP professionals.

Duplicate – a control measurement conducted using two side by side measurement devices, used to measure precision.

In-Control Level – a pre-determined range of quality control measurements defined as being within an acceptable level.

Independent Accredited Chamber – a facility which provides a known radon reference to which other devices can be compared.

Lower Limit of Detection (LLD) or Minimum Measurable Concentration (MMC) –the lowest radon concentration that may be detected by a given device

Manufacturer – an organization or company that makes and distributes radon measurement devices for sale and use by others

Measured Value (MV) –radon level measured by a measurement device

Minimum Detectable Concentration (MDC) or Minimum Measurable Concentration (MMC) – the lowest radon concentration that may be detected by a given device

Out-of-Control Level - measurements that fall outside the "in-control level" as defined in Appendix 4

Passive Device Laboratory – an organization that provides analysis and reports on the radon levels measured by those passive radon measurement devices.

Passive Device User – a radon measurement professional who places passive radon measurement devices or provides them to homeowners.

Precision –refers to the closeness of two or more measurements to one another.

QA/QC Coordinator - the individual in an organization who is responsible for ensuring C-NRPP Quality Assurance measures are followed by all radon measurement professionals in the organization and for all the devices used in an organization, and who ensures any change control measures required are identified and carried out.

Quality Assurance Plan – the planned and systematic activities documented in a quality system to ensure that quality requirements are met.

Quality Control –the process of measuring the ongoing performance of devices to ensure continued conformance to established performance standards.

Quality Control Measurements – the radon measurements used as part of a quality control process, for example: spikes, duplicates and blanks

Radon professional - An individual who is certified by C-NRPP.

Relative percent differences (RPD) – the difference between two measured values expressed as a percentage of the average of the two values.

Relative Percentage Error (RPE) – the difference between a measured value and a known reference value expressed as a percentage of the known reference value.

Reference value (RV) – the fixed or known value of either the exposed radon level or voltage on an electret.

Shall/Must – means that this is required action.

Should/May – means that this is a recommended action**.**

Spiking – the process of exposing radon detectors to a known radon level and comparing the analyzed value with the known exposed value; used to verify the overall accuracy of a radon measurement device and method of analysis.

Uncertainty - is the total error generated by background, precision and accuracy errors.

Warning Level – this is a measure of a quality control measurement which indicates the need for investigation.

3. Developing Standard Operation Procedures

3.1 Choosing Device(s)

An important step in the radon measurement process is choosing devices which will best meet the needs of a radon measurement business and its clients. C-NRPP has a list of devices which have been reviewed to meet quality requirements and a list of Analytical Laboratories that are required to fulfill their part in the quality assurance process and report to C-NRPP biennially. Radon Professionals shall use only C-NRPP listed devices analyzed by a C-NRPP certified analytical laboratory. Radon Professionals may select measurement devices by comparing them according to various criteria, as discussed below.

Find a C-NRPP Listed Device at: www.c-nrpp.ca/approved-radon-measurement-devices/

3.2 Communicating with the Device Manufacturer

Radon Measurement Professionals should communicate with the device manufacturer/laboratory when developing Standard Operation Procedures and Quality Assurance processes.

The measurement professional should obtain the following information from the device laboratory/manufacturer when deciding which devices to use and developing proper Standard Operating Procedures:

Research the different devices available to determine the best device for your purposes.

- Optimal duration of device (shortest to longest test duration)
- Maximum time delay for device to be returned to the laboratory
- Optimal method/process of returning the device to the laboratory
- Sample radon test report
- Lower Level of Detection of device
- Upper Level of Detection
- Average Coefficient of Variation on their batches
- Processes of communicating with Measurement Professional and/or homeowners regarding Control Issues with the devices
- Confirmation of equipment calibration
- Other types/standards of lab certifications
- *Storage conditions required*

If a Radon Measurement Professional is using short term devices, there must be clear direction from the laboratory as to the delay within which the devices should be returned to the lab once the test period is completed.

3.3 Storage of Devices

For devices that are received from an analytical laboratory or supplier, the radon professional must take care to store the radon devices in an appropriate environment to ensure that they are not affected by storage conditions. The radon professional should consult with the manufacturer to determine the acceptable range of humidity and temperature of the storage environment. Devices shall be stored in a low radon environment in an area protected from dust. If the devices are re-located to different storage locations this must be tracked as part of the documentation. ***(see more info on Blanks in 5.4)***

Store devices in a low radon environment.

3.4 Placement Protocols

All measurement professionals shall use proper placement procedures when placing radon measurement devices. Placement must be based on Health Canada's ***Guide for Radon Measurements in Residential Dwellings (Homes)*** and Health Canada's ***Guide for Radon Measurements in Public Buildings (Schools, Hospitals, Care Facilities, Detention Centers)*** along with the device manufacturer's recommendations.

Use proper placement protocols and develop standard procedures for handling the devices.

3.5 Development of Standard Operating Procedures(SOP)

Good Standard Operating Procedures and work-flow instructions provide a way to communicate and apply consistent standards and practices within an organization. These procedures also assist in determining change control procedures, if issues arise and errors need to be identified. When an organization develops Standard Operating Procedures, the best practices for use of the devices must be taken into account, including information obtained from the device manufacturer/laboratory, proper storage location and placement protocols, and Quality Control measurements as detailed in this document.

When using short term devices, there must be clear direction from the laboratory on the optimal delay within which the devices should be returned to the lab once the test period is complete.

3.6 Suppliers to Retailers and Radon Measurement Devices

Suppliers to retailers stocking C-NRPP Listed Devices should follow quality assurance practices with radon measurement devices. Arrangements should be made to include blanks and duplicates for quality assurance purposes when stocking radon devices, along with stocking instructions for retailers.

4. Quality Assurance Plan

A Quality Assurance Plan shall be in place when an organization begins offering radon measurement services. The Quality Assurance Plan shall take into account all employees who will be interacting with the measurement process, and shall be appropriate for the number of employees in the organization. While the Quality Assurance Plan should be familiar to all employees, at least one individual in the organization should be responsible as the QA/QC Coordinator and ensure that the Quality Assurance Plan is accurate to current practices within the organization. The QA/QC Coordinator should be informed of any errors and ensure that corrective action is taken as required.

4.1 Elements of a Quality Assurance Plan

I. Background information on the organization
II. Name of Organization's Radon QA/QC Coordinator
III. Radon Services Offered by the Organization
IV. Radon Devices and Equipment Used and Source
V. Employees Using Radon Measurement Devices and their Qualifications
VI. Standard Operating Procedures
    - Including: Work Flow Control, Storage of Device, and Radon Test Procedures (Measurement Protocols)
VII. Documentation and Record Control
    - Ensure to include how, where and who is in charge of ensuring proper documentation and length that you maintain your records
VIII. Change Control - Non-Conformances and Corrective Action
IX. Calibration and Maintenance Plans
X. Signatures of all Radon Measurement Professionals

5. Quality Control Measurements

5.1 Calibration

Measurement device calibration shall be conducted in accordance with the manufacturer's recommended calibration schedule. The calibration is to be conducted by the manufacturer or an authorized representative of the manufacturer. Calibration ensures that the machine is operating properly and measuring accurately. Typically, measurement devices require calibration once per year, but the manufacturer's recommendations should be verified and followed.

Calibration records for all devices should be maintained and labels should be provided on calibrated devices to identify upcoming calibration dates.

Ensure devices are labeled with upcoming calibration dates.

Calibration should include a number of steps completed by the manufacturer, or an authorized representative of the manufacturer, including the following: check of voltage, current and/or wave patterns at critical points in the circuitry, check of batteries and recharging, determination of the background by exposure to a radon-free environment of nitrogen or aged air, and checks of the calibration factor by exposure in a reference chamber.

A certificate of calibration must be given by the manufacturer and should include information such as:

- name and address where the calibration was carried out
- condition of the monitor including any physical damage, and settings of discriminator, voltage, background and calibration factor
- measured background
- measured response to the reference atmosphere
- date of calibration
- statement regarding the method of calibration
- name and signature of person responsible for calibration

Devices requiring Calibration: *Electret Ion Chamber Voltage Readers and Continuous Radon Monitors (CRMs)*

5.2 Spikes/Performance Tests

Spikes/Performance tests are designed to monitor and verify the accuracy of the radon measurement systems for each device.

Spikes/Performance tests or inter-comparisons (blind proficiency test) is a technique for exposing radon detectors to a known radon level and then analyzing the detectors as if they were routine field measurements. Spiking tests monitor the accuracy of the overall radon measurement system, including the performance of the device and the analysis process. These tests are to be conducted according to the C-NRPP recommended schedule (see *Appendix 1: Chart of Quality Control Minimum Requirements*), and they must meet requirements of an acceptance range. The acceptance range may be calculated using the formula for Relative Percentage Error (RPE) (see *Appendix 4: Quality Control Targets* for calculation and acceptable values).

Spikes are a requirement for passive device laboratories conducting analysis of alpha track or electret ion detectors; spikes are not a requirement for passive device users. However, if a passive device user is conducting large building measurements and wants to ensure a high level of accuracy for the project, spikes can be included.

Keep track of Spikes to ensure they are completed regularly according to the required schedule.

Spikes are carried out by randomly selecting detectors from the inventory of each type or batch of detectors and sending them to an independent accredited radon chamber where they will be exposed to a known radon concentration. Upon receipt of the exposed devices from the chamber, the measurement professional will analyze each device and determine the radon exposure, or the radon concentration and report the radon level (in kBq/m^3*h or Bq/m^3) to the independent accredited radon chamber. The measurement results should agree with the known level in the radon chamber, within an acceptable range (see Appendix 4). The organization conducting the inter-comparison must provide the radon professional with an interpretation of the results and a certificate confirming that the process was completed and that the requirements of the spiking exercise were met.

A minimum of 3 of each detector type should be sent together for a spike test to help in interpreting the results and to aid in identifying the source of any errors as being bias or precision. In addition, each batch of spikes sent to the independent accredited chamber should include at least one transit blank (see section 5.4 Transit Blanks below) to verify any contamination of the detectors during shipping. The transit blank must be labeled as such so that the radon chamber recognizes it.

A list of currently approved independent organizations with accredited radon chambers may be found at: www.c-nrpp.ca/radonchambers.

Spiking of electret ion devices should focus on measuring the accuracy of the configuration of the chamber and the electrets. A professional using electret ions should consider each configuration as a separate device.

Each electret type should be considered as a separate device.

Spikes are a method of determining the accuracy and the lowest and highest level of detection of a device. An analytical laboratory or a measurement professional who is conducting a small number of tests should ensure that the focus of the spiking is within the action level; therefore, chamber levels and exposure times should be determined to provide an exposure equivalent to between 150 and 500 Bq/m^3 in the field. An analytical laboratory or a measurement professional using a large number of tests, (more than 800 tests per year), may want to arrange that the chamber perform spikes at different exposure levels for each batch of spikes that are sent out; for example the first batch could be near the action guideline, the subsequent batch of spikes could be lower, and the following could be higher.

5.3 Field Duplicates

Field duplicate tests (or duplicates) are quality control measurements designed to assess the precision of radon measurement devices. By actively monitoring duplicates, the radon professional can monitor the precision of the measurement devices and be alerted to random errors. When measurement variability occurs outside of the In-Control level, caution and extra steps should be taken in conjunction with the manufacturer to identify potential errors and improve precision. When a measurement is outside of the In-Control Level, the measurement is not valid and should be repeated. Specific corrective action must be taken.

Duplicates should be randomly distributed throughout the devices deployed to ensure required numbers are met.

Duplicates can also be used to provide a higher level of confidence in the measured results. In addition to the duplicates for Quality Assurance, a professional may want to use duplicate tests in conducting measurements such as real estate transactions, new-home warranty tests, measurements which cannot be repeated or measurements which require a greater degree of certainty.

Duplicate tests are required for 10% of tests deployed to a maximum of 25 duplicates per month (see *Appendix 1: Chart of Quality Control Requirements*). The first detector deployed by the measurement professional should be a duplicate. Subsequent duplicates should be randomly distributed throughout the devices deployed. The organization must record the duplicate measurements and the relative percent difference (RPD) in their Quality Control records.

Duplicate tests are conducted by placing two radon devices side-by-side, no further than 10 cm (4”) apart, or as otherwise recommended by the manufacturer. The test duration for the two devices must be identical, meaning that the start and stop times must be the same. Duplicate measurements are compared by calculating their relative percent difference (RPD). When providing a report to a client when a duplicate measurement is used, the two values must be averaged and provided as one number on the report.

Duplicate detectors could be connected by zip-tie or some other form and placed by the manufacturer in the same package to ensure they are being placed properly. *Appendix 4: Quality Control Targets*

Duplicate measurements must be recorded and tracked on a Quality Control Chart (eg. Spreadsheet) and analyzed for changes or trends.

5.4 Blanks

Blank tests are designed to measure the limit of detection of the radon measurement device by assessing any background exposure which may interfere with the measurement and thus increase the Lower Limit of Detection (LLD) from the manufacturer's stated levels. The detection limit is defined to be the lowest concentration of radon that can be measured within a 95 % confidence. LLD, which can also be referred to as the Minimum Measurable Concentration (MMC), is calculated by the manufacturer of a given measurement device. However, the LLD may be elevated by background exposure which produces a measurement bias in the field radon test. If a professional identifies bias during a blank test measurement, it should be discussed with the manufacturer, so that the LLD for the affected devices can be adjusted.

Blank test requirements are detailed in *Appendix 1: Chart of Quality Control Requirements.* Blank tests should also be conducted when a device is stored in a new location, or if any concerns of exposure are suspected.

For all devices (except electret ion detectors) the lowest level of detection must be supplied to the Measurement Professional by the lab as this is a value calculated for each batch and taken into consideration when the radon level is reported. The radon test report should report radon levels below the limit of detection as "below the limit of detection".

For electret ion chambers, the MMC is given by the manufacturer for each configuration type.

There are various types of blank tests.

Lab Blanks – Field blanks are analyzed by the analytical laboratory after manufacturing to assess original LLD and to assess additional background exposure that a device will accrue while waiting to be deployed by a measurement professional. A lab must retain 5 % of its devices to analyze at least one device each time a batch is sent to a purchaser.

Field Blanks – Field blanks are sent to the lab as blind tests to verify that the devices are not being exposed to background exposure which would interfere with regular radon tests during placement. Field Blanks should be conducted using the same procedure as for duplicates, however the blank detector or device will not be opened or activated until the end of the test, where it would be opened and sent to the lab to be treated the same as the exposed devices regarding analysis.

Transit Blanks, Storage Blanks and Field Blanks are all deployed differently to ensure detectors aren't exposed to background levels which will affect their accuracy.

A Field Blank measurement is conducted by placing a device in the same location, no further than 10 cm (4") apart from an activated device. The activated device is opened while the Field Blank remains closed, sealed or not activated. The Field Blank should be opened and returned to the lab using the same method as exposed detectors will be returned to the analysis lab. This is a blind test to the laboratory; the passive measurement user should send the field blank in with a report as if it were an active test. Both tests are then analyzed at the same time as if they were both active tests. It is important that the Field Blank follow the same path and be stored together with those devices that will be activated.

For electret ion detectors a field blank would be opened and immediately closed and then returned to the analysis lab.

The following types of blank tests should be used for investigative measures.

Transit Blanks – A transit blank is a device that is used to ensure that there was no uncertainty (or bias) to the shipment of radon tests during transit. This quality control can be used to determine if background exposure is added to the device prior to the passive device user obtaining the devices. A blank test should be opened and returned to the lab using the same method as exposed detectors, and can be used at any other time when devices are shipped.

Storage Blanks – Storage blanks are devices which are sent to the lab to verify the devices are not being exposed to background exposures while being stored, which would interfere with radon measurement. Since electret ion chambers are checked before each use, a storage blank is not necessary with this device.

All blank measurements should be recorded and tracked on a spreadsheet by the organization and analyzed for changes or trends.

Blank tests are acceptable if they are within Control Limits listed in *Appendix 4: Quality Control Targets*.

If a Blank test measured above the acceptable range, and there is no evidence of tampering, then a retest should be conducted. A second blank test should be deployed in the same manner as the previous blank test. If the second test is above the acceptable level then corrective action should be taken in order to determine the root cause of the failure.

5.5 Cross-Checks (for CRMs only)

Cross-checks are similar to duplicate tests, but applicable to Continuous Radon Monitors (CRMs). Professionals who use CRMs must perform a cross check at the six-month point between annual calibrations to identify any anomalies with the testing equipment. If a standard check source (such as a built-in source) is available for the device, it can be used for the cross–check purpose. Otherwise either a separate calibrated C-NRPP approved CRM or a duplicate Electret Ion Chamber shall be used.

A cross-check must be conducted for at least 48 hours and can be conducted using a second calibrated device (with a valid certificate) set up side by side (within 10 cm to 20 cm apart). The devices must be within allowable limits as specified in *Appendix 4.*

5.6 Electret Reader Reference Checks (for electret ion chambers only)

The electret voltage reader must be monitored weekly while in active use by measuring a minimum of two reference electrets with set voltages and a reference “zero” electret. The voltage of each reference electret must be recorded weekly in a logbook, spreadsheet or database.

If abnormal changes are found in both reference electrets, or in the zero electret, the electret voltage reader should be sent for testing and recalibration. If only one of the reference electrets is affected, both reference electrets should be recertified or the reference electret replaced.

6. Non-Conformances and Corrective Action

Despite the best intentions, problems can occur. The radon professional must take action to identify the cause of nonconformities in order to prevent reoccurrence, to protect public health, and to maintain customer confidence. Nonconformities include unacceptable errors revealed on control charts. Corrective actions should be discussed with the device manufacturer or lab.

The radon professional/organization must have a procedure established to:

- Determine the cause of the problem or error
- Investigate further to determine the root cause
- Develop an action plan
- Carry out the action plan
- Review the results
- Close the activity when complete
- Verify that the actions have been effective.

Control Charts need to be reviewed to ensure errors are caught quickly.

Change Control measures should be documented in a Change Control Report kept in the organization's Quality Assurance files and also submitted with future C-NRPP Certification renewal.

Errors can be identified by comparing Quality Control measures using calculations in *Appendix 4: Quality Control Targets*. For Blanks and Spike measurements that are outside of acceptable levels, the professional should discuss actions with the manufacturer.

The radon professional, together with the manufacturer or supplier, should strive to conduct Duplicate measurements within the In-Control zone. When Duplicate measurements fall within the Warning Level or Out-of-Control Level, as per the chart in *Appendix 4: Quality Control Targets*, then action must be taken to determine why the error occurred and how many past tests may have been affected. The organization must document the investigation, record why the error occurred, how many past tests were reported incorrectly, and what corrective action was taken.

Decisions of how to handle operations once Out-of-Control Levels are found depend on the amount of tests an organization is conducting. Table 1 provides guidance on what type of action to take, and when it should be taken, regarding investigating non-conformance.

Table 1 – Guidance for Action on Control Measurements

Number of Duplicates in the Out of Control Level	Total Number of Duplicates Tested by Radon Measurement Professionals	
	Investigate while Continuing Testing Operations	Stop Testing Operations Until Problem is Identified and Corrected
2	8-19	2-7
3	17-34	8-16
4	29-51	17-28
5	41-67	29-40
6	54-84	41-53
7	67-100	54-66

If during the investigation it is found that past tests may have provided building occupants with a possible false negative result, the potential should be reported to the contact person and retesting should be conducted to protect occupant health.

If duplicates are found to be in the Warning Level, and one or both of the measurements may affect the basis of a decision to not mitigate (for public health protection) or other such decisions (eg. real estate), the quality control measurement should be investigated and that investigation should include discussions with device manufacturer, and may result in a need to retest. If a retest is conducted, the measurement should be repeated at the same location if possible. If circumstances dictate a change of location, the measurement professional may choose to repeat the Quality Control Measurement in an alternate appropriate measurement location. If the measurement continues to be in the Warning Level, the radon measurement professional should investigate the cause of error and a note should be made in the Change Control Report of the subsequent investigation. The measurement professional should also consider increasing the rate at which duplicates are performed as a corrective measure.

If, following quality control measures, radon measurements continue to be found in the Out-of-Control Level, radon measurements should be stopped. An investigation should be conducted until the cause of the error is found.

If duplicate measurements are found to be in the Out-of-Control Level, the measurement is invalid. The radon professional should repeat the measurement and begin an investigation.

When a radon measurement professional is conducting an investigation into control measurements, they should contact the manufacturer/laboratory of the device as part of their investigation.

7. Reporting Requirements

It is the responsibility of each radon measurement professional to ensure that the requirements of this document are followed. These requirements must be verifiable by the C-NRPP. Consequently, all applicable requirements must be documented according to procedures in the organization's Quality Assurance Plan, in the forms used by the organization in the radon measurement processes and in the resulting reports. QA records and reports for spikes, duplicates and blanks must be kept. For electret ion chamber users, these can be reports generated by the Radon Report Manager software. Calibration certificates for CRMs and electret voltage readers must be kept.

All radon professionals must ensure that Quality Assurance requirements are being followed and reports are organized.

QA records can be kept in either hard copy or electronic. If hard copy, data and reports must be kept in an organized filing system. If electronic, the records must be retrievable and protected by a secure backup system.

7.1 C-NRPP Certifications

All QA reports and certificates must be signed, dated, and filed when complete. They must be submitted to C-NRPP with certification renewal every two years as per the chart of requirements in *Appendix 2* and *Appendix 3*.

7.2 C-NRPP's responsibility with QA Data submitted

C-NRPP will review data for Control Measurements outside In-Control, Warning, and Control Levels, and may ask for more details of the investigation regarding the relevant measurements.

C-NRPP will also use the Quality Assurance data submitted to compile information on devices as part of ongoing research efforts, and will share results without any personal or proprietary data with Health Canada.

Appendix 1: Chart of Quality Control Minimum Requirements

		Passive Devices				Active Devices
		Professionals Measurement		Laboratory		
	Frequency	Alpha Tracks (No Analysis)	Electret Ion (perform analysis)	Alpha Tracks or Electret Ions - Batches less than 20	Alpha tracks or Electret Ions - Batches more than 20	CRM Only User
Develop a Quality Assurance Plan	*On new application and evaluate biennially*	Yes	Yes	Yes	Yes	
Calibrating Equipment	*Annually*		Voltage Reader	Yes	Yes	Yes
Lab and/or Field Blanks Storage and Transit Blanks	*Max 25 per month*	5%	5%	5 %	Yes	
Duplicates	*Max 25 per month*	10%	10%	10%		
Performance Tests/Spikes		No	When purchased; Minimum 3 or 3% of devices purchased and then Minimum 3; maximum 36 Based on 3 % of tests conducted per year	No	3% per batch	
Reference Checks	*Weekly*		Yes	For E-Perm		
Cross Checks	*Annually*					At the 6-month point between annual calibration

Note: if Measurement Professionals are using Electret Ion detectors from an analysis lab, they should determine who will be responsible for the spikes and duplicates.

Appendix 2: Quality Control Calculations and Targets:

Spikes:

$$\text{RPE} = \frac{(\text{MV} - \text{RV}) \times 100\%}{RV}$$

where: RPE = relative percent error;
MV = measured value of spiked measurement; and
RV = reference value.

	Acceptable RPE In-Control Level	**Out of Control RPE Level**
Avg $<$ 150 Bq/m^3	Spike testing should be conducted at levels greater than 150 Bq/m^3	
Avg > 150 Bq/m^3	Less than 20%	20% and above

Duplicates and Cross Checks:

Note: Radon Levels should be rounded up to the nearest 1 Bq/m^3 for each test

$$RPD = \frac{(Test1 - Test2) \times 100\%}{(Test1 + Test2)/2}$$

where: RPD = relative percent difference
Test1 = Larger measured value
Test2 = Smaller measured value

Average Test Measurement (Test 1 + Test 2)/2	**Acceptable RPD In-Control Level**	**Warning Level**	**Out of Control Level**
Avg $<$ 50 Bq/m^3	No limits	No limits	No limits
50 Bq/m^3≤Avg<75 Bq/m^3	Less than 25%	25% up to 50 %	50% and above
75 Bq/m^3 ≤Avg< 150 Bq/m^3	Less than 15%	15% up to 25 %	25% and above
150 Bq/m^3≤Avg	Less than 10%	10% up to 20 %	20% and above

Blanks: (Field or transit) – Lower Limit of Detection (LLD) is to be supplied by manufacturer for each batch.

E-Perm Reference: - Less than 3 volts difference.

E-Perm Voltage Drift Limits:

Type of E-Perm Electret	Allowable Voltage Drift
ST	6 volts per month; minimum drift test duration of 28 days (one month)
LT	4 volts per month; minimum drift test duration of 84 days (three months

Appendix 3: Templates for Quality Control Charts

C-NRPP Control Charts Templates for Electret Ion Devices

- https://c-nrpp.ca/wp-content/uploads/2018/12/CNRPP-Control-Charts-Templates-Electret-Ion-Devices-Dec-2018.xlsx

C-NRPP Control Charts Templates for Passive Devices Users

- https://c-nrpp.ca/wp-content/uploads/2018/12/C-NRPP-Control-Charts-Templates-for-Passive-Device-Users-Dec-2018.xlsx

C-NRPP Control Charts Templates for Passive Device Laboratories

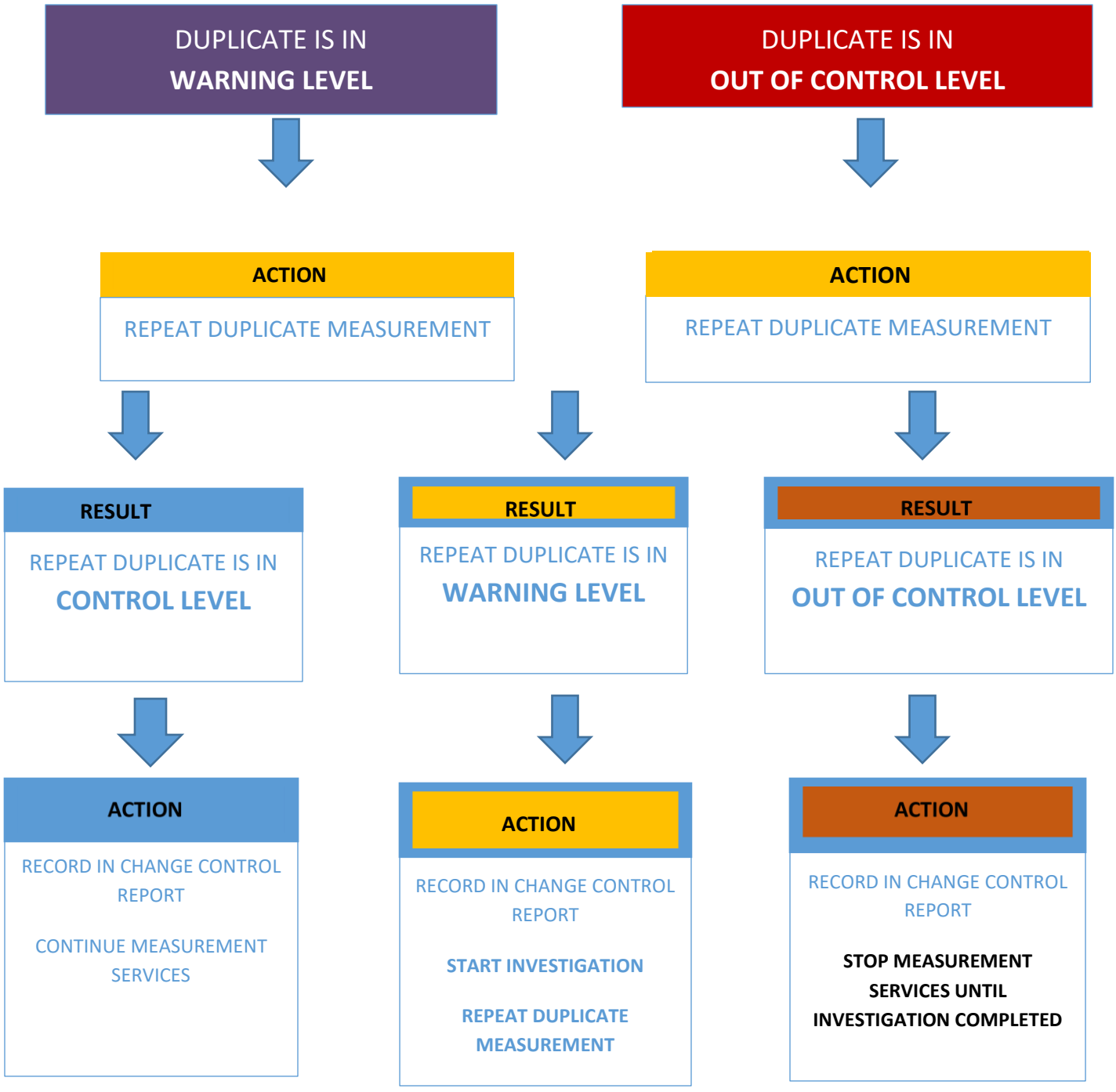
- https://c-nrpp.ca/wp-content/uploads/2018/12/C-NRPP-Control-Charts-Templates-for-Analysis-of-Passive-Devices-Dec-2018.xlsx

C-NRPP Control Charts Templates for CRMs

- https://c-nrpp.ca/wp-content/uploads/2018/12/CNRPP-Control-Charts-Templates-CRMs-Dec-2018.xlsx

Appendix 4: Suggestions of Non-Conformances and Corrective Action Flow Chart for Duplicate Measurements

Below is a simplified chart for example on how to handle non-conformance. Table 1 should also be consulted for guidance.



Appendix 5: Chart of Suggested Procedures including Quality Control and Non-Conformance and Corrective Action

Detector Type	Tasks	Quality Assurance Required	Possible errors and actions required
Passive Devices			
Manufacturer:			
	Batch is finished manufacturing	Devices are sent to an independent certified/recognized chamber for spiking as per quantity in *Appendix 1: Chart of Quality Control Minimum Requirements.*	Error in batch; further testing would be required to identify issue.
		Devices are set aside as blanks; analyzed periodically until all devices have been received back for analysis. Quantity as per *Appendix 1: Chart of Quality Control Minimum Requirements.*	
	Devices are sent to customer in a bulk order	One of the blanks is analyzed after each large order sale	If blank is higher than previous blanks background interference may be present; determine issue to assess course of action to correct errors.
	Devices are sent direct to homeowners or in batches of less than 20 detectors.	Duplicate tests conducted as per quantity in Appendix 1: Chart of Quality Control Minimum Requirements	Possible error in transit. Repeat to determine replication and then determine course of action to correct.
		Blanks analyzed as per quantity in Appendix 1: Chart of Quality Control Requirements	
Measurement Professional:			
	Receives detectors from manufacturer	Ensure serial numbers are accurate and recorded	
		Ensure number of devices ordered are received	

		Store detectors in a low radon environment. Send a storage blank away after 30 days of storage.	
		Send a transit blank back for analysis	Transit blank higher than lab blanks indicate possible contamination in transit. Repeat process and discuss corrective actions with manufacturer.
	Perform test for homeowner	Ensure that test set up follows proper placement guidance.	
		Note in records serial number that has been released to homeowner, with homeowner's contact info for follow up if device is not deployed	
		Perform duplicate test on first test deployed and randomly as per quantity in *Appendix 1: Chart of Quality Control Minimum Requirements.*	Error above allowable levels may indicate a contaminated test. Review past quality control measures to ensure it's the first error and determine possible times and locations of errors to determine corrective actions.
	Perform test for commercial customer with more than 10 devices	Develop a testing protocol with test locations, durations and number of tests required; include additional 10% of tests for duplicates and 5% for blanks	
		Record test serial numbers of devices removed from stock.	
		Record serial numbers and locations of devices; including which devices are used as duplicates and blanks	
		Record anomalies in file	

		Establish agreed-upon procedures for device return with customer	
	Detectors sent to lab for analysis.	When devices are sent to lab, verify serial numbers consistent with those removed from stock	
		When reports are received from lab, record duplicate test results on spreadsheet	
		Verify that duplicate results are within acceptable limits	
		Record blank test result in spreadsheet and verify results are within acceptable limits.	

Electret Ion Chamber Devices			
Manufacturer or Distributor:			
	Batch of Devices sent to customer	Conduct voltage stabilization tests and record results.	
Measurement Professional:			
	Receives electrets from manufacturer	Ensure number of devices ordered are received.	
		Read the electrets to verify that the electrets are approximately in the range of 700 V. Record the serial numbers and voltage measurements.	
		Verify Reference Electrets.	
		Send detectors to the manufacturer or to an independent certified laboratory to conduct performance tests.	Results outside of acceptable levels could be the result of background contamination from transit, error in voltage reader use or error in calculation. Repeat process and discuss corrective actions with manufacturer.
	Perform radon measurement for homeowner	Prepare detector for placement.	
	Check reference electrets	Test reference electrets weekly. Record voltage readings in a log book, spreadsheet or database such as the Radon Report Manager.	Changing reference values beyond allowable limits could mean errors in the voltage meter. Contact manufacturer to discuss.
		Verify voltage loss has not been greater than allowable amounts as per amount in *Appendix 2: Quality Control Calculations and Targets*, since previous reading (while electret has not been in use).	Changing values above allowable levels when not in use could mean errors in the voltage meter, improper use of the voltage meter, electrets are not

			stored in caps properly or background contamination. Review device manual to ensure following proper procedures used for measurement of devices.
		Ensure that measurement placement follows proper placement protocols.	
	Duplicates	Set up duplicate on first radon measurement and randomly as per quantity in *Appendix 1: Chart of Quality Control Minimum Requirements.*. Record data in spreadsheet, database or Radon Report Manager.	Differences in measured values greater than acceptable limits may indicate issues similar to those listed above.
	Blanks	Conduct blanks measurements as per quantity in *Appendix 1: Chart of Quality Control Minimum Requirements.* Record data in proper spreadsheet, database or Radon Report Manager.	Differences in measured values greater than acceptable limits may indicate issues similar to those listed above.
		Conduct Spike measurements as per quantity in *Appendix 1: Chart of Quality Control Minimum Requirements.* Record data in spreadsheet, database or Radon Report Manager.	Differences in measured values greater than acceptable limits may indicate issues similar to those listed above. Plus errors could be a result of background contamination when shipping devices to the chamber. Discuss with chamber contact.

Continuous Radon Monitors (CRM)			
Manufacturer:			
	Device sent to customer	Calibration completed with delivery of device.	
Measurement Professional:			
	Receive CRM from manufacturer	Verify calibration report received. Ensure device labeled with next calibration date.	
	Perform test for homeowner	Prepare device for placement. Ensure battery has sufficient power for test duration or ensure device is plugged into line power for duration of test.	
		Ensure that device set up follows proper placement guidance.	
	Semi-Annual Cross-Checks	Perform cross-check on device as per *Appendix 1: Chart of Quality Control Minimum Requirements.*.	Errors may mean device needs to be re-calibrated. Contact manufacturer.
	Annually	Send device to manufacturer for annual calibration.	

Appendix 6: Reference Documents:

Health Canada, *Guide for Radon Measurements in Public Buildings (Schools, hospitals, Day Care Facilities, Detention Centres),* 2008 http://www.hc-sc.gc.ca/ewh-semt/pubs/radiation/radon_building-edifices/index-eng.php, September 2015

Health Canada, *Guide for Radon Measurements in Residential Dwellings (Homes)*, 2008, http://www.hc-sc.gc.ca/ewh-semt/pubs/radiation/radon_homes-maisons/index-eng.php, September 2015

Illinois Emergency Management Agency, *Radon Quality Assurance Program Guidance*, IEMA 205-700-3/05

ISO – 9001 – *Quality Management Systems*, 2015, ISBN 978-92-67-10650-2,

Kotrappa, P, *Long Term stability of electrets used in electret ion chambers*, 2 June 2008, Journal of Electrostatics, 66(208) 407-409,

The Scientific Consulting Group, Inc. and The Cadmus Group, Inc., 28 July 2014, *Device Performance Check*, https://www.epa.gov/sites/production/files/2015-04/documents/device_performance.pdf

US Environmental Protection Agency, *National Radon Proficiency Program Guidance on Quality Assurance*, October 1997, EPA 402-R-95-012, National Air and Radiation Environmental Laboratory, Montgomery, AL

US Environmental Protection Agency (EPA), *Technical Support Document for the 1992 Citizen's Guide to Radon,* May 1992, Radon Division Office of Radiation Programs, EPC 400-R-92-011

World Health Organization, 2009 *WHO Handbook on Indoor Radon: A Public Health Perspective*, ISBN 978 92 4 154767 3