**Section 422.140 Device Protocol**

a) Quality Assurance

1) Professional licensees providing measurement services using radon and radon product measurement devices shall establish and maintain a Quality Assurance Program (QAP). These programs shall include written procedures for attaining quality assurance objectives and a system for recording and monitoring the results of the quality assurance measurements for each device used. The QAP shall include the maintenance of control charts and related statistical data.

2) The objective of quality assurance is to ensure that data are scientifically sound and of known precision and accuracy. This subsection (a)(2) discusses the 6 general categories of quality control measurements. Specific guidance is provided for each method in the relevant protocol.

A) Calibration Measurements. Calibration measurements are samples collected or measurements made in a known radon environment, such as a radon chamber. Instruments providing immediate results, such as continuous working level and radon monitors, shall be operated in a radon chamber to establish individual instrument calibration factors.

i) Calibration measurements must be conducted to determine and verify the conversion factors used to derive the concentration results. These factors are determined normally for a range of concentrations and exposure times, and for a range of other exposure and/or analysis conditions pertinent to the particular device.

ii) Determination of these calibration factors is a necessary part of the laboratory analysis and is the responsibility of the laboratory. These calibration measurement procedures, including the frequency of tests and the number of devices to be tested, shall be specified in the QAP maintained by manufacturers and analysis laboratories.

iii) Licensees providing measurements with active devices are required to recalibrate their instruments at least once every 12 months.

B) Known Exposure Measurements (Spikes). Known exposure measurements or spiked samples consist of detectors that have been exposed to known concentrations in a radon chamber. These detectors, such as charcoal canisters, alpha track detectors and electret ion chambers, are labeled and submitted to the laboratory in the same manner as ordinary samples to preclude special processing.

i) Suppliers and analysis laboratories shall provide for the blind introduction of spiked samples into their measurement processes and the monitoring of the results in their QAP.

ii) Licensees using passive monitors shall conduct spiked measurements (i.e., exposure in a radon chamber where the environmental radon level is controlled) to aid the Agency in verifying the accuracy of the entire measurement system. The licensee shall conduct 3 spiked measurements per 100 measurements, with a minimum of 3 spiked measurements per year. For example, a licensee conducting only 70 measurements in a year must conduct at least 3 spiked measurements. A licensee conducting 500 measurements during a one-year period must conduct at least 15 spiked measurements (3 per each 100). No more than 6 spiked measurements will be required to be taken within any single month. For example, a licensee performing more than 200 measurements in one month is not required to perform more than 6 spiked measurements that month. Licensees are encouraged to take their spiked measurements from multiple batches when possible and to take more than the minimally required spiked measurements at their discretion. Devices shall be exposed in a radon chamber at a minimum of 3 different radon concentrations, such as approximately 4.0, 10-30 and 30-100 pCi/L.

iii) Spikes shall be labeled in the same manner as field detectors to ensure identical processing. The results of analyses of detectors exposed to known radon concentrations shall be monitored and recorded. Any significant deviation from the known concentration to which they were exposed shall be investigated and corrective action taken.

C) Background Measurements. Background measurements are required both for continuous monitors and for passive detectors requiring laboratory analysis.

i) Licensees using continuous monitors shall perform sufficient instrument background measurements to establish a reliable instrument background and to act as a check on instrument operation.

AGENCY NOTE: Calibration laboratories routinely perform background measurements of continuous monitors during the calibration of instruments.

ii) Passive detectors requiring laboratory analysis require one type of background measurement made in the laboratory and another in the field.

iii) Laboratories shall measure the background of a statistically significant number of unexposed detectors from each batch or lot to establish the laboratory background for the batch and the entire measurement system. This laboratory blank value is subtracted (by the laboratory) from the field sample results reported to the user, and shall be made available to the users for quality assurance purposes.

iv) Laboratories performing these measurements shall calculate the lower limit of detection (LLD) for their measurement systems. This LLD is based on the detector and analysis system's background and can restrict the ability of some measurement systems to measure low concentrations.

v) Licensees using passive detectors shall employ field controls (called blanks) equal to approximately 5 percent of the detectors that are deployed, or 25 each month, whichever is smaller.

vi) These controls shall be set aside from each detector shipment, kept sealed and in a low radon environment, labeled in the same manner as the field samples to preclude special processing, and returned to the analysis laboratory along with each shipment. These field blanks measure the background exposure that may accumulate during shipment and storage. The results shall be monitored and recorded.

vii) The recommended action to be taken if the concentrations measured by one or more of the field blanks is significantly greater than the LLD is dependent upon the type of detector and is discussed in the protocol for each method.

D) Duplicate Measurements. Duplicate measurements provide a check on the precision of the measurement result and allow the user to make an estimate of the relative precision. Large precision errors may be caused by detector manufacture or improper data transcription or handling by suppliers, laboratories, or technicians performing placements. Precision error can be an important component of the overall error; therefore, licensees performing measurements shall monitor precision.

i) Duplicate measurements shall be side-by-side measurements made in at least 10 percent of the total number of measurement locations, or 50 each month, whichever is smaller. The locations selected for duplicate measurement shall be distributed systematically throughout the entire population of samples.

ii) The precision of duplicate measurements shall be monitored and recorded in the quality assurance records. The analysis of data from duplicates shall be plotted on range control charts. If the precision estimated by the user is not within the precision expected of the measurement method, the cause of the problem shall be investigated.

iii) Detectors shall be treated identically in every respect. They shall be shipped, stored, opened, installed, removed and processed together, and not identified as duplicates to the processing laboratory.

E) Routine Instrument Performance Checks. Proper functioning of analysis equipment and operator usage require that the equipment and measurement system be subject to routine checks. Regular monitoring of equipment and operators is vital to ensure consistently accurate results. Performance checks include the frequent use of an instrument check source. Components of the device (such as a pump, battery or electronics) shall be checked regularly and the results noted in a record. Each user shall develop methods for regularly monitoring (preferably daily with use) their measurement system and for recording and reviewing results.

F) Cross-checks. Professional licensees using active monitors shall check their monitors for bias on a regular basis. Ideally, such measurements are made in a radon chamber. Exposure in a radon chamber is required during calibration. It can be difficult to expose active monitors more often than once every 12 months. It is important to more frequently assess the continued satisfactory operation of the instrument response and to ensure damage from shipping has not occurred prior to an instrument being placed into service after calibration. Cross-checks shall be performed prior to placing an instrument being returned to service after calibration and at 6 months (plus or minus a month) after calibration. The following conditions shall be met:

i) Where feasible, a cross-check shall begin with an instrument background measurement.

ii) The cross-check measurement shall be made in an environment that has been chosen for its stability and radon concentration that is above the lower limit of detection.

iii) Cross-checks shall be side-by-side measurements.

iv) One of the instruments shall have been calibrated within the last 45 days.

v) A measurement of at least 48 hours duration shall be conducted.

vi) The bias of cross-check measurements shall be monitored and recorded in the quality assurance records. If the bias estimated by the user is not within the bias expected of the measurement, the cause of the problem shall be investigated and corrective action taken in accordance with the licensee's Agency-approved QAP.

b) Protocol for using continuous radon monitors (CRs) to measure indoor radon concentrations

1) Refer to Section 422.130 for a list of general conditions that shall be met and standard information that shall be documented.

2) When performing a radon measurement, the CR shall be programmed to run continuously, recording periodically (hourly or more frequently) the radon concentration for at least 48 hours. Longer measurements may be required per the continuous monitor type and the radon level being measured.

3) If the first 4 hours of data from a 48-hour measurement are discarded because data are produced prior to the establishment of equilibrium conditions in the test device, the remaining hours of data shall be averaged and shall be sufficient to represent a 2-day measurement.

4) Every CR shall be calibrated in a radon chamber, approved by the Agency, before being placed into service, and after any repairs or modifications that could affect the calibration. Subsequent recalibrations and background checks shall be performed at least once every 12 months. Each scintillation cell requires an individual calibration factor.

5) Background measurements shall be performed after every 1,000 hours of operation of scintillation cell-type CRs and whenever any type of CR is calibrated. The background shall be checked by purging the monitor with clean, aged air or nitrogen in accordance with the manufacturer's instructions. In addition, the background count rate shall be monitored in accordance with the manufacturer's instruction.

6) Licensees providing measurement services with CR devices shall perform duplicate measurements. The performance and analysis of duplicates shall be completed in accordance with subsection (a)(2)(D).

7) Pumps and flow meters shall be checked before and after each measurement in accordance with the manufacturer's instruction.

8) Licensees providing measurement services with CR devices shall perform cross-checks. The performance and analysis of cross-checks shall be completed in accordance with subsection (a)(2)(F).

c) Protocol for using alpha track (AT) detectors to measure indoor radon concentrations

1) Refer to Section 422.130 for a list of general conditions that shall be met and standard information that shall be documented.

2) The laboratory background level for each batch of ATs shall be established by each laboratory licensed by the Agency. Laboratories shall measure the background of a statistically significant number of unexposed ATs that have been processed according to the licensee's Quality Assurance Program implementing/operating procedures.

3) Every AT laboratory system shall be calibrated in a radon chamber at least once every 12 months. Determination of a calibration factor requires exposures of ATs to a known radon concentration in a radon chamber. These calibration exposures shall be used to obtain or verify the conversion factor between net tracks per unit area and radon concentration.

A) ATs shall be exposed in a radon chamber at a minimum of 3 different radon concentrations such as approximately 4.0, 10-30 and 30-100 pCi/L or exposure levels similar to those found in the tested buildings.

B) Expose a minimum of 10 detectors at each radon concentration of the chamber.

C) A calibration factor shall be determined for each batch or sheet of detector material received from the supplier. Alternatively, calibration factors may be established for several sheets, and these factors extended to detectors from sheets exhibiting similar sensitivities (within pre-established tolerance limits).

D) Analysis instruments shall be checked at least daily for operability prior to operation. Analysis instruments do not need to be checked on days not used.

4) Licensees providing measurement services with AT devices shall perform known exposure measurements (spikes). The performance and analysis of spikes shall be completed in accordance with subsection (a)(2)(B).

5) Licensees providing measurement services with AT devices shall perform duplicate measurements. The performance and analysis of duplicates shall be completed in accordance with subsection (a)(2)(D).

6) Licensees providing measurement services with AT devices shall perform background measurements. The performance of background measurements shall be completed in accordance with subsection (a)(2)(C).

A) The results shall be monitored and recorded. If one or a few field blanks have concentrations significantly greater than the LLD established by the supplier, it may indicate defective packaging or handling and the licensee shall investigate the cause. If the average value from the field control devices (field blanks) is significantly greater than the LLD established by the supplier, this average value shall be subtracted from the individual values reported for the other devices in the exposure group.

B) It may be advisable to use 3 sets of detectors (pre-exposure, field and post-exposure background) in order to allow the most thorough and complete evaluation of radon levels. For example, one group of detectors (pre-exposure detectors) may be earmarked for background measurement and returned for processing immediately after the other detectors are deployed. The results from these detectors determine if the number of tracks acquired before deployment is significant and should be subtracted from the gross result. The second set of background detectors (post-exposure background detectors) are obtained just before the field monitors are to be collected and are opened and kept in the same location as the returning field monitors for the same duration, and returned with them. Finally, this "post-exposure background" is subtracted from the field results, if found to be significant. In general, a value of 1 pCi/L or greater for any blank AT indicates a significant level that should be investigated and potentially subtracted from the field AT results.

d) Protocol for using electret ion chamber radon (ES or EL) detectors to measure indoor radon concentration.

1) Refer to Section 422.130 for a list of general conditions that shall be met and standard information that shall be documented.

2) Every short-term and long-term electret system and the electret reader(s) shall be calibrated in a radon chamber, approved by the Agency. Initial calibration for the system is provided by the manufacturer. Subsequent recalibrations shall be performed at least once every 12 months. Determination of calibration factors for short-term or long-term detectors requires exposure of detectors to known concentrations of radon-222 in a radon exposure chamber. Since short-term and long-term electret detector systems are also sensitive to gamma radiation, a gamma exposure rate measurement in the test chamber is also required annually.

3) The following is provided to manufacturers and suppliers of ES or EL services as minimum requirements in determining the calibration factor:

A) Detectors shall be exposed in a radon chamber at a minimum of 3 different radon concentrations, such as approximately 4.0, 10-30 and 30-100 pCi/L, or exposure levels similar to those found in the tested buildings.

B) Expose a minimum of 10 detectors at each radon concentration of the chamber.

C) Ensure a period of exposure sufficient to allow the detector to achieve equilibrium with the radon chamber atmosphere.

4) Licensees providing measurement services with ES or EL devices shall perform known exposure measurements (spikes). The performance and analysis of spikes shall be completed in accordance with subsection (a)(2)(B).

5) Licensees providing measurement services with ES or EL devices shall perform duplicate measurements. The performance and analysis of duplicates shall be completed in accordance with subsection (a)(2)(D).

6) Licensees providing measurement services with short-term or long-term electrets shall set aside a minimum of 5 percent of the electrets or 10, whichever number is smaller, from each shipment and evaluate them for voltage drift. The electrets shall be kept covered with protective caps in a low radon environment and analyzed for voltage drift over a time period similar to the time period used for those deployed in measurements. Any voltage loss found in the control electrets of more than one volt per week over a 3-week test period for short-term electrets, or one volt per month over a 3-month period for long-term electrets, shall be investigated.

7) Proper operation of the surface voltmeter shall be monitored following the manufacturer's procedures for zeroing the voltmeter and analyzing a reference electret. These checks shall be conducted at least once a week while the voltmeter is in use.

8) All Laboratory Analysis licensees providing recharging services of short-term or long-term electrets shall only provide those services for devices they manufacture or for devices for which they have written authorization from the manufacturer.

e) Protocol for using activated charcoal adsorption (AC) devices to measure indoor radon concentrations

1) Refer to Section 422.130 for a list of general conditions that shall be met and standard information that shall be documented.

2) Every activated charcoal adsorption system shall be calibrated in a radon chamber at least once every 12 months. Determination of calibration factors for ACs requires exposure of the detectors to known concentrations of radon-222 in a radon chamber. The calibration factors depend on the exposure time and may also depend on the amount of water adsorbed by the charcoal container during exposure. Calibration factors shall be determined for each AC measurement system (container type, amount of charcoal, gamma detector type, etc.).

3) Licensees providing measurement services with AC devices shall perform known exposure measurements (spikes). The performance and analysis of spikes shall be completed in accordance with subsection (a)(2)(B).

4) Licensees providing measurement services with AC devices shall perform duplicate measurements. The performance and analysis of duplicates shall be completed in accordance with subsection (a)(2)(D).

5) Laboratory Control Detectors. The laboratory background level for each batch of ACs shall be established by each laboratory or supplier. Suppliers shall measure the background of a statistically significant number of unexposed detectors that have been processed according to their standard operating procedures (laboratory blanks). The analysis laboratory or supplier calculates the net readings, that are used to calculate the reported sample radon concentrations, by subtracting the laboratory blank values from the results obtained from the field detectors.

6) Licensees providing measurement services with AC devices shall perform background measurements. The performance of background measurements shall be completed in accordance with subsection (a)(2)(C).

A) One or a few of the field blanks have concentrations significantly greater than LLD established by the supplier may indicate defective devices or poor procedures and the licensee shall investigate the cause.

B) If most of the field blanks have concentrations significantly greater than the LLD, the average value of the field blanks shall be subtracted from the reported field detector concentrations and the supplier notified of a possible problem.

7) Counting equipment shall be subject to daily operability checks by counting an instrument check source and determining whether the reference source is constant to within established limits (2 standard deviations). Daily operability checks do not need to be performed on days the instrument is not used. The characteristics of the check source (geometry, type of radiation emitted, etc.) shall be similar to those of the samples analyzed. The count rate of the check sources shall be high enough to yield good counting statistics in a short time (for example, 1000 to 10,000 counts per minute) to provide a maximum random uncertainty of 5 percent.

f) Protocol for using charcoal liquid scintillation (LS) devices to measure indoor radon concentrations

1) Refer to Section 422.130 for a list of general conditions that shall be met and standard information that shall be documented.

2) Every LS laboratory system shall be calibrated in a radon chamber at least once every 12 months. Determination of calibration factors for LS devices requires exposure of calibration devices to known concentrations of radon-222 in a radon chamber at carefully measured radon concentrations. The calibration factors depend on the exposure time and may also depend on the amount of water adsorbed by the device during exposure. Calibration factors shall be determined for a range of different exposure times and, as appropriate, humidities.

3) Licensees providing measurement services with LS devices shall perform known exposure measurements (spikes). The performance and analysis of spikes shall be completed in accordance with subsection (a)(2)(B).

4) Licensees providing measurements services with LS devices shall perform duplicate measurements. The performance and analysis of duplicates shall be completed in accordance with subsection (a)(2)(D).

5) Laboratory Control Devices. The laboratory background level for each batch of LS devices shall be established by each laboratory or supplier. Suppliers shall measure the background of a statistically significant number of unexposed LS devices that have been processed according to their standard operating procedures (laboratory blanks). The analysis laboratory or supplier calculates the net readings that are used to calculate the reported sample radon concentrations, by subtracting the laboratory blank values from the results obtained from the field detectors.

6) Licensees providing measurement services with LS devices shall perform background measurements. The performance of background measurements shall be completed in accordance with subsection (a)(2)(C).

A) One or a few of the field blanks have concentrations significantly greater than the LLD established by the supplier may indicate defective devices or poor procedures and the licensee shall investigate the cause.

B) If most of the field blanks have concentrations significantly greater than the LLD, the average value of the field blanks shall be subtracted from the reported field detector concentrations and the supplier notified of a possible problem.

7) Counting equipment shall be subject to daily operability checks by counting an instrument check source and determining whether the reference source is constant to within established limits (2 standard deviations). Daily operability checks do not need to be performed on days the instrument is not used. The characteristics of the check source (geometry, type of radiation emitted, etc.) shall be similar to those of the samples analyzed. The count rate of the check sources shall be high enough to yield good counting statistics in a short time (for example, 1000 to 10,000 counts per minute) to provide a maximum random uncertainty of 5 percent.

g) Protocol for using continuous working level (CW) monitors to measure indoor radon progeny concentrations

1) Radon Decay Product measurements may be appropriate under certain conditions in large buildings, but are not currently routinely performed by licensees or recommended by the American Association of Radon Scientists and Technologists. The Agency does not recommend their use for home environment or residential real estate measurements. Licensees interested in using CWs for measurement purposes shall submit Standard Operating Procedures, consistent with this Part, specific to the model and design of the CW instrument to the Agency for approval.

2) Conditions and information in Section 422.130 shall be met.

3) Any measurement result based on radon progeny shall be reported to no more than 3 decimal places, e.g., 0.033 working level (WL).

4) The integrated average WL over the measurement period shall be reported as the measurement result.

5) When performing a radon measurement, the CW shall be programmed to run continuously, recording the periodic WL and, when possible, the total integrated average WL. The longer the operating time, the smaller the uncertainty associated with using the measurement result to estimate a longer-term average concentration.

6) Working level values shall be converted to pCi/L and both shall be reported to the client. The conversions from WL to pCi/L shall be presented and explained clearly in the report to the client. A statement shall be included in the measurement report that this approximate conversion is based on a 40 percent equilibrium ratio. In addition, the report shall state that this equilibrium ratio is typical, but that any indoor environment may have a different and varying relationship between radon and radon progeny.

7) Every continuous WL monitor shall be calibrated in a radon chamber, approved by the Agency, before being placed into service and after any repairs or modifications that could affect the calibration. Subsequent recalibrations shall be performed at least once every 12 months.

8) Background measurements shall be performed after every 168 hours of operation and whenever the unit is calibrated. The CW shall be purged with clean, aged air or nitrogen in accordance with the manufacturer's instructions. In addition, the background count rate may be monitored more frequently by operating the CW in a low radon concentration.

9) Measurement licensees providing measurement services with CW devices shall perform duplicate measurements. The performance and analysis of duplicates shall be completed in accordance with subsection (a)(2)(D).

10) Pumps and flow meters shall be checked before and after each measurement in accordance with the manufacturer's instruction to ensure accuracy of volume measurements. This may be performed using a dry-gas meter or other flow measurement device of traceable accuracy.

11) Licensees providing measurement services with CW devices shall perform cross-checks. The performance and analysis of cross-checks shall be completed in accordance with subsection (a)(2)(F).

(Source: Amended at 37 Ill. Reg. 20240, effective December 9, 2013)