

# RADON ACTION PLAN

for

Des Moines Public Schools  
1917 Dean Avenue  
Des Moines, Iowa 50316  
(515) 242-7889

Prepared by

Tyler Puls

Signatures and Dates:



Signature

3/30/16

Date

Principal Investigator/Test Technician/Quality Assurance Officer  
Tyler Puls

The signature represents the awareness of, approval of, and responsibility for this plan for ensuring that the provisions of this plan are implemented.

Last updated: 3/28/16

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## **1.0 INTRODUCTION**

The purpose of the Radon Action Plan (RAP) is to identify the objectives and control measures implemented by the district to control radon exposures throughout Des Moines Public Schools (DMPS) facilities. Due to the lack of regulatory requirements for testing and mitigation, the RAP uses guidance documents issued by the U.S. Environmental Protection Agency (EPA) and the American Association of Radon Scientists and Technologists (AARST) to make educated decisions. In 2015, AARST and the American National Standards Institute (ANSI) published protocols for conducting measurements of radon and radon decay products in schools and large buildings. DMPS is using these guidelines as a framework to thoroughly test, evaluate, and control radon concentrations throughout District facilities.

## **2.0 DESCRIPTION OF OBJECTIVES & RESPONSIBILITIES**

### **2.1 Program Objectives**

DMPS believes it has a responsibility to proactively perform measurements of radon and radon decay product concentrations to provide a safe environment for students and staff. The main objectives of the plan include:

- Provide a safe and suitable environment for students and staff to learn and work which is not impacted by the presence of radon gas.
- Identify facilities which have high indoor radon concentrations.
- Implement approved strategies to decrease the amount of radon gas within facilities.
- Utilize radon-resistant building techniques in new construction and renovations of facilities.

### **2.2 Program Responsibilities**

The implementation of the RAP is the responsibility of the Facility Management Department. Facilities Management will test buildings to determine which facilities have high concentrations of indoor radon gas. Test results and pertinent radon information is to be regularly updated to the districts website.

## **3.0 PLAN IMPLEMENTATION**

### **3.1 Testing**

Due to the large number of District-operated facilities and budgetary considerations, facilities will be tested on a revolving five year schedule. The most up to date testing schedule can be found on the district website. Pre-school and childcare facilities throughout the district shall continue to be tested every two years.

Radon identification techniques are to be completed by following established practices and guidance established by the EPA and ANSI/AARST. Testing will be completed throughout DMPS facilities by trained and licensed Radon Measurement Specialists. Radon levels may vary room to room throughout a school so current guidance recommends testing within all occupied classrooms/offices where floors are in contact with the ground. The testing is completed in accordance with established quality control standards to ensure accurate testing results.



Many types of radon tests are available and multiple types are implemented in the plan, including: short-term; long-term; and evaluation with a continuous radon monitor. These types of radon testing will provide the Facility Management department with accurate data to determine the need and value of additional measures including but not limited to an active radon mitigation system. Analysis of testing kits shall be provided by an Iowa-licensed laboratory. A flowchart of the districts sampling plan and how decisions are made can be found in **Attachment A**.

In accordance with guidelines and the Des Moines climate zone, short-term testing to establish a baseline is to be completed between November 1 and March 31 while the buildings are occupied. These dates are optimal for testing because of the higher likelihood for elevated radon levels during the heating season. Short-term tests are typically completed within two to seven days. Weekday testing will be preferred versus weekend tests. The District's Quality Assurance Plan (QAP) for short-term radon testing utilizing the charcoal absorption method is included in **Attachment B**.

If elevated levels are detected during the baseline testing, a long-term test will be completed. Long-term tests will be conducted for a minimum of three months. The District's Quality Assurance Plan (QAP) for long-term radon testing is included in **Attachment C**.

The District may utilize a continuous radon monitor (CRM) in facilities where elevated radon concentrations are detected to identify radon concentrations during occupied hours versus unoccupied hours. The District's Quality Assurance Plan (QAP) for CRM measurements is included in **Attachment D**.

### **3.2 Mitigation**

Radon mitigation techniques are to be completed by following established practices and guidance established by the EPA and ANSI/AARST. Due to the complexity of large buildings with varying heating, ventilation, and air conditioning (HVAC) equipment, the guidance encourages multiple testing events prior to making a decision to install an active radon mitigation system.

Ventilation is one of the key variables when dealing with radon concentrations. The HVAC system will be evaluated within buildings where high radon concentrations are identified to ensure proper operation. Ground-level building penetrations will also be sealed to reduce the potential for radon gas from entering the building. Following HVAC evaluation and sealing, the areas will be retested to determine radon levels and if the follow-up tests are greater than the recommended action level of 4.0 picocuries per liter (pCi/L), an active mitigation strategy will be implemented.

After it is concluded that an active mitigation system is required within a facility, the Facility Management Department will design and implement a system to reduce the radon levels below 4.0 pCi/L. An active mitigation system typically involves the use of a fan to remove radon gas from below the foundation of the building and exhaust the gas outside the facility where it is diluted with ambient air.

### **3.3 Future Construction and Renovation**

In order to control radon exposure in the future radon resistant building techniques will be incorporated into the development of new construction and renovation projects throughout the district. The District will communicate with its engineering, architectural, and contracting partners throughout the entire process to identify and plan for potential radon issues.



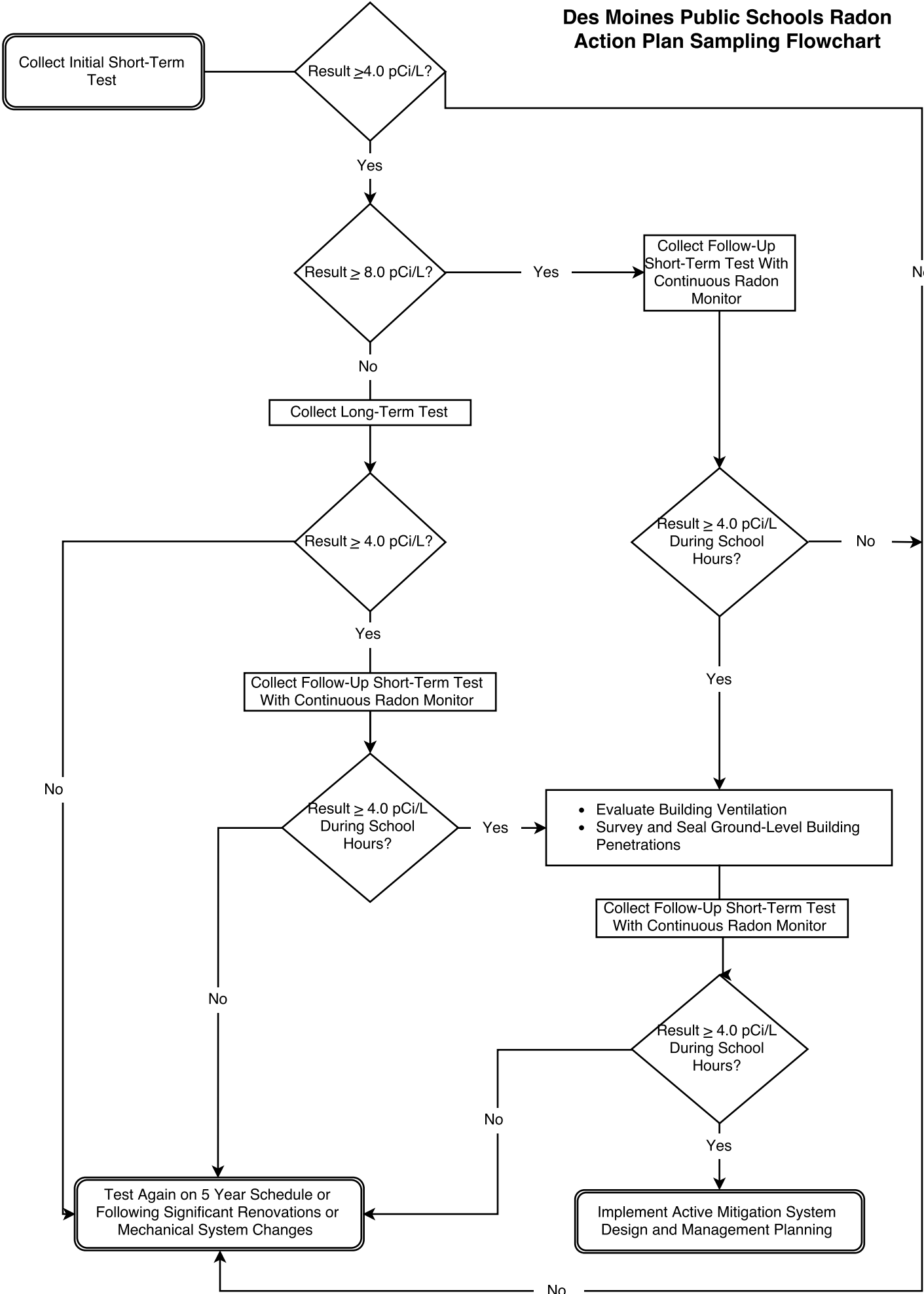
#### **4.0 PLAN UPDATES**

This RAP has the ability to be changed as new regulations or guidance are put in place and experience is gained. Any questions regarding the RAP should be addressed to Tyler Puls in Facilities Management at [tyler.puls@dmschools.org](mailto:tyler.puls@dmschools.org) or 515-242-7889.

# **APPENDIX A**

## **Radon Action Plan Sampling Flowchart**

# Des Moines Public Schools Radon Action Plan Sampling Flowchart



Sampling and Response Approach Based on:

- 1) ANSI/AARST Consortium on National Radon Standards, Protocols for Conducting Measurements of Radon and Radon Decay Products in Schools and Large Buildings (2015)
- 2) United States Environmental Protection Agency, Radon Measurement in Schools: Revised Edition (1993)
- 3) Iowa Department of Public Health, Radon Testing Protocols for Iowa Child Care Centers
- 4) United States Environmental Protection Agency, Managing Radon in Schools (2010)

## **APPENDIX B**

### **Short-Term Radon Testing Quality Assurance Plan**



# RADON MEASUREMENT

## ACTIVATED CHARCOAL QUALITY ASSURANCE PLAN

for

Des Moines Public Schools  
1917 Dean Avenue  
Des Moines, Iowa 50316  
(515) 242-7889

Prepared by

Tyler Puls

Signatures and Dates:

  
\_\_\_\_\_  
Signature

12/10/15  
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Date

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Last updated: 12/10/15

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**Exhibit 2:** Radon Measurement Log Forms

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**Exhibit 4:** Duplicate Control Charts

## **1.0 INTRODUCTION**

### **1.1 Introduction**

This Quality Assurance Plan (QAP) is consistent with the guidance issued by the American Association of Radon Scientists and Technologists and the U.S. Environmental Protection Agency (Protocol for Measurements of Radon and Radon Decay Products in Schools and Large Buildings [ANSI/AARST 2015]; EPA Interim Guidelines for Preparing QA Plans [EPA 1980]; EPA Requirements for QA Project Plans [EPA 1992a]). This Plan is formatted in a way that allows Des Moines Public Schools (DMPS) staff to reference easily pertinent portions of this document. The nomenclature used in this QAP is appropriate for the operations of DMPS and every effort has been made to maintain consistency with the latest guidance documents.

This report reflects current operations, and therefore is often updated and revised. The QA Officer has responsibility for incorporating changes, and ensuring that the changes are reviewed and approved by the management.

## **2.0 DESCRIPTION OF OPERATIONS & EQUIPMENT**

### **2.1 Operation Description**

DMPS performs measurements of radon and/or radon decay product concentrations in facilities operated by the School District. Radon measurements will not be completed for residential or commercial properties. The DMPS Facility Department is responsible for over 70 facilities throughout the District. It is anticipated that the number of measurements performed will exceed 700 per year. Tyler Puls is the Principal Investigator and the Quality Assurance Officer.

### **2.2 Description of Equipment Used**

DMPS measures radon and/or radon decay products (RDP) using the activated charcoal adsorption method for short-term tests. For this method, activated charcoal packaged inside a sealed bag is opened in the area to be sampled and radon, if present, adsorbs onto the charcoal granules inside the bag. At the end of the sampling period, the container is sealed and sent into the laboratory for analysis. Activated charcoal test kits will be sent under proper chain-of-custody (COC) to Air Chek, Inc. (Air Chek) located at 1936 Butler Bridge Road, Mills River, North Carolina 28759.

Activated charcoal kits will be obtained from:

Air Chek, Inc.  
1936 Butler Bridge Road  
Mills River, North Carolina 28759



Example of an activated charcoal kit

Activated charcoal kits will be stored at room temperature at the DMPS Operations Facility located at 1917 Dean Avenue, Des Moines, Iowa, 50316 prior to use. The person in charge of the location of the activated charcoal kits is Tyler Puls.

The devices will be stored in their pre-packaged containers, inside of the temperature controlled storage area at DMPS until they are deployed in the field. We have provided instructions for the deployment for their radon activated charcoal kits that will be used. DMPS employees that are certified licensed radon professionals will be knowledgeable of the deployment instructions.

The following are instructions on how to use the activated charcoal device:

Squeeze the sides of the packet. Look into the opening and the cardboard insert should begin to fold down into the opening. Gently push the insert down about an inch into the opening. Now hang the packet, from the hook provided, at your normal breathing level. Test for a minimum of 48 hours (two days) and no longer than seven days.

At the conclusion of the test:

Look into the open end of the test kit packet and locate the pull tab on the insert. Pull the tab to completely remove the insert from the test kit packet. Flatten and fold back the envelope flap to reveal the white strip. Peel back and discard the white strip. Press flaps together to seal. **DO NOT REMOVE** from the test area until the packet is sealed. Make certain the packet is sealed *air-tight*. Repair any tears with a small piece of plastic tape.

### **3.0 ORGANIZATION & RESPONSIBILITIES**

The following DMPS employee has key responsibilities in the production of radon and/or decay product measurement operations.

- Tyler Puls is the Principal Investigator and Test Technician. The Principal Investigator is responsible for completing reporting activities. Test Technicians are responsible for completing radon and/or RDP measurement.
- Tyler Puls is the Quality Assurance (QA) Officer. The QA Officer is responsible for performing quality control/quality assurance procedures as well as implementing changes for quality control procedures.

- Certified Test Technicians may be added in the future. Test Technicians are responsible for completing radon and/or RDP measurement.

## 4.0 MEASUREMENT PROCEDURES

This section covers the procedures that are followed to ensure that the measurements are made in appropriate locations and test conditions consistent with current guidelines and the District's needs.

### 4.1 Measurement Definitions

**Action Level** – A threshold for when mitigation of exposure to harmful elements is recommended or required.

**Blank Measurements** – Blanks are devices not intentionally exposed to radon gas. Blanks help evaluate any detector response from sources other than radon exposure at a testing location such as in the manufacturing process or during shipping, storage, analysis, and handling.

**Continuous Radon Monitor (CRM)** – Test devices that are capable of, and set to, integrate, record, and produce reviewable readings in time increments of one hour.

**Duplicate Measurements** – Duplicates are pairs of devices deployed in the same location, side-by-side for the same measurement period. The purpose of duplicates is to evaluate precision or agreement between detectors.

**Long-Term Measurement** – Any radon or radon decay product measurement that is acknowledged as appropriate and acceptable in the EPA Measurement Protocols and has a sampling period of at least 91 days to up to one year. Long term measurements are made using alpha track detectors exposed continuously over the exposure period.

**Occupied Area** – Any area of the facility that is occupied on a regular basis for more than four hours per day.

**Passive Integrating Devices** – Measurement devices that do not require electrical power to complete measurement collection activities. Examples include activated charcoal and alpha track detectors.

**Primary Measurement** – A radon or radon decay product measurement that provides an averaged concentration over the exposure period. The detector is to be located as specified in the guidance documents. The detector is to be operated in accordance with the recommendations of the detector manufacturer or supplier. The detector exposure time is not less than the recommended time as specified by the manufacturer. The detector is not exposed for fewer than 48 continuous hours.

**Radon Survey** – The process of following the guidelines of this QAP, making one or more primary measurements to sample and analyze the air in a building, either passively or actively, so as to measure the radon or radon decay product concentration during the test period in the areas being sampled.

**Responsible Individual** – This refers to the person or persons responsible for assuring that the test conditions required by this QAP are being followed during a radon survey.

**Short-Term Testing** – Any radon or radon decay product measurement that is a primary measurement and has a duration of from two to ninety days.

**Spiked Measurements** – Spikes are devices that have been exposed in an approved chamber to a known concentration of radon. Spikes are used to help evaluate the accuracy of a laboratory analysis and/or how accurately detectors supplied by a laboratory measure radon.

**Test Technician** – The person responsible for placing and retrieving the radon or radon decay product detector. This person must be either an employee or subcontractor of the District. The Test Technician abides by the requirements of the State of Iowa.

## 4.2 Measurement Types

DMPS has identified three types of radon gas measurements; initial measurement, follow-up measurement and post-response measurement.

An **initial measurement** is of a relatively short-term duration (usually 2 to 7 days) to detect a radon problem in a facility. Short term tests must be carried out under closed-building conditions and in frequently-occupied rooms in contact with the ground. If the result of the initial measurement done under closed-building conditions is below 4 pCi/L, a follow-up test is not necessary.

A **follow-up measurement** is a measurement made to verify and characterize a radon problem as indicated by a previously made short term measurement value at or above 4 pCi/L. In general, the higher the initial measurement, the sooner the follow-up measurement is made and the shorter the exposure period in order to minimize the health risk to building occupants. In accordance with the DMPS Radon Action Plan (RAP), if the initial test result is found to be between 4 and 7.9 pCi/L, a long term measurement lasting up to a full 12 months is recommended, if the initial measurement was greater or equal to 8 pCi/L, a short term measurement is to be completed with a CRM to evaluate occupied versus unoccupied concentrations.

A **post-response measurement** is a short term measurement made after a response action has been completed within a facility. The test must not be started sooner than 24 hours after completion of the response action. The test must have 24 hours of closed-building conditions before the start of the test and closed-building conditions during the test.

## 4.3 Guidelines, State Regulations, and Federal Protocols

Applicable existing laws, including but not limited to statutes, ordinances and regulations, are complied with by DMPS and DMPS Test Technicians while completed radon sampling or mitigation activities.

#### **4.4 Radon Survey by Test Technician**

During a radon survey of a facility, the primary measurement placement and retrieval of the detector(s) is only performed by a Test Technician as defined in 4.1. The Test Technician ensures that the District has obtained the Test Technician's state certification number.

#### **4.5 Measurement Location**

Measurement locations are chosen according to the following criteria.

- The locations are consistent with the guidelines set forth by the EPA (EPA Device Protocols [EPA 1992], Section 1.2.3, page 1-3).
- The purpose of the measurement and type of building dictates the measurement strategy and location; guidance from ANSI/AARST is used for measurements in school facilities.
- Specific needs or requests are considered when placing devices.

The following general criteria are to be used in selecting the location of a measurement device within a room.

- A location must be selected where the measurement device will not be disturbed during the measurement period.
- The device must not be placed near drafts caused by HVAC vents, windows, and doors. Avoid locations near excessive heat, such as kilns or in direct sunlight.
- The device can be suspended from the ceiling if it is within the breathing zone (6' to 8' high).
- The device must not be placed within 30 centimeters (12") of the outside walls of the building or within 90 centimeters (36") of any opening in the outside walls such as windows.
- Nothing must impede air flow around the device.
- In general, kitchens, bathrooms, boiler rooms, laundry areas, garages, crawl spaces, or sumps are not suitable measurement locations.

#### **4.6 Number of Measurements**

In order to comprehensively determine a facilities potential to have elevated radon levels, a radon survey will include measurements in frequently-occupied rooms in contact with the ground. The measurement placement conforms to the current ANSI/AARST guidelines for radon measurements.

#### **4.7 Measurement Exposure Time**

The measurement exposure time is a minimum of 48 hours. Short-term measurement exposure time should be in increments of 24 hours plus or minus 1 hour for each day of exposure in order to minimize the effect of diurnal variations. This means that a three-day test should be exposed from 69 to 75 hours. The exposure time is not to be less than the manufacturer's or supplier's recommendations.



#### **4.8 Detector Non-Interference**

The testing devices are not to be moved, covered or have its performance altered during the radon survey by anyone. Examples of performance alteration would be covering the detector, moving it to another location during the test period, or opening windows during a short-term test.

Radon tests should not be initiated throughout the facility if there are planned renovations, scheduled changes in the heating, ventilating and air conditioning (HVAC) system, or other modifications that may influence the radon concentration during the measurement period.

#### **4.9 Closed-Building Conditions**

The weather and building ventilation conditions prior to and during the measurement are in accordance with the guidelines set forth by the EPA (Device Protocols [EPA 1992], Section 1.2.2, page 1-2). Closed-building conditions require that the windows are kept closed. External and any basement to first floor doors are closed except for normal momentary entering and exiting. Structural openings due to disrepair or structural defects that allow a significant amount of ventilation are repaired to correct their condition before initiation of closed-building condition sampling. Exterior windows and doors are inspected by the Test Technician at the times of placement and retrieval of the detector. The Test Technician walks around the outside of the building to inspect for closed-building condition.

HVAC systems shall be operated normally. Operation of dryers, range hoods, and bathroom fans should be kept to a minimum. The responsible individual, however, should be informed that overuse of an appliance that exhausts air may influence the final readings. Window air conditioning units are only operated in a recirculating mode.

Ceiling fans, portable dehumidifiers, portable humidifiers, portable air filters and window air conditioners are not operated within twenty feet of the detector. Closed-building conditions should be maintained for twelve hours prior to the start of the radon survey. DMPS inquires with the room occupant to determine if closed-building conditions have been maintained for the twelve hours prior to the start of the test.

The Test Technician takes due and proper care in obtaining closed-building conditions during short-term testing in order to increase measurement reproducibility. If at the initiation of the test, the Test Technician discovers or visually observes that closed-building conditions were not maintained, then the radon survey is not initiated until twelve hours of prior closed-building conditions have been maintained or the radon test period is extended to four days or more with an appropriate detector after closed-building conditions are initiated.

#### **4.10 Informing Building Occupants about Test Conditions**

DMPS will establish a responsible individual for the building during the test period. Before any primary measurements are initiated, the responsible individual is informed, or attempted to be informed, about the requirements of and the need for closed-building conditions as well as other conditions for which they are responsible.

In order to inform occupants of the facility about the test and the conditions of the test, a "*Radon Survey in Progress*" notification form with the conditions of the test stated on the notification, is posted upon initiation of a short-term test in a conspicuous location of the facility. **Exhibit 1** is an example of a *Radon Survey in Progress* notification form used by DMPS.

#### **4.11 Safety**

The Test Technician should not enter any area or perform any test that would damage property or risk the Test Technician's own or another's safety. If it is known that closed-building conditions are detrimental to the health of the occupants, then the radon survey is not completed.

#### **4.12 Minimum Test Condition Verification**

DMPS' minimum requirements for verifying test conditions is fulfilled by the following: informing the responsible individual of the test conditions; interviewing the responsible individual or building occupants regarding device interference; conducting a visual inspection of the building upon placement and retrieval of the device; and posting a *Radon Survey in Progress* notification form. The Test Technician is not responsible for inspecting for closed-building conditions 12 hours before the start of the test or between placement and retrieval of the detectors.

#### **4.13 New Construction Test Conditions**

Newly constructed buildings are tested in accordance with this QAP. The following items, if such items are part of the completed building, are installed and completed before the radon survey is initiated: insulation; exterior doors; windows; heating appliances; ceiling coverings; interior trim and coverings for the exterior walls; exterior siding; weatherproofing and caulking. If DMPS knows construction work, which will likely affect the test results, is to be done inside the building during the test period, then DMPS will reschedule the test when such interference is less likely to take place.

### **5.0 CHAIN OF CUSTODY AND DOCUMENTATION**

Chain of custody for each detector and device used includes documenting the exposure location, times and dates in/out, and persons responsible for the detectors prior to, during and after their exposure, up to their analysis or shipment to the analytical laboratory. The Test Technician is responsible for ensuring that this information is properly recorded for each measurement.

It is important that enough sufficient data about each measurement be recorded on the proper forms by the Test Technician who deploys the test device in the permanent "Field Log." This data is important in the event that further interpretations and measurements are required at a later date.

The information called for on the data form included with the device must be accurately completed by the Test Technician when the device is placed and/or retrieved. The detector serial number is recorded by the analytical laboratory on a separate log sheet and the Test Technician records a description of the location in the building where it was placed. The device is not to be relocated during the measurement period;

however, if it is necessary to do so, the Test Technician should note the new location on relevant log sheets. An example of a chain of custody used to record radon test information is attached in **Exhibit 2**. It should be noted that Air Chek has provided DMPS a portable tablet and scanner to log testing data for accurate and timely test reports. Laboratory equipment will be utilized by DMPS.

The information to be logged must include:

- Address and name of facility surveyed.
- The start and stop, date and times of each measurement.
- The detector type and identification numbers.
- Whether the room occupant has agreed to abide by the closed-building conditions (if applicable) throughout the test period and twelve hours before the test.
- Exact locations of the detector.
- Other easily gathered information that may be useful, such as the type of building, type of heating system, condition of crawl space, etc.

## **6.0 ANALYTICAL PROCEDURES**

Activated Charcoal devices are sent to Air Chek located at 1936 Butler Bridge Road, Mills River, North Carolina 28759 for analysis

The measurement procedures recommended by EPA (Device Protocols [EPA 1992]) and Air Chek are followed.

## **7.0 DATA CALCULATION, VALIDATION, AND REPORTING**

### **7.1 Data Calculation**

Short-term radon test results are produced by Air Chek and will be reported via email, fax or mailed to the principal investigator at DMPS in Des Moines, Iowa.

### **7.2 Data Validation**

Periodic checks will be made to spot-check reports to clients for accuracy. Periodic checks will search for hand-calculating entry errors, transcription errors, or errors in the computer database and will be conducted at least semi-annually, and after any change in procedure, personnel, or equipment. A transcription error rate greater than 5 significant errors in 100 fields is cause for notification of the QA Officer, who investigates and recommends re-entry of data if necessary.

### **7.3 Data Reporting**

Final results are reported in units of pCi/L. Values are reported to one figure after the decimal for radon concentrations, and to three figures after the decimal for radon decay product concentrations. The QA Officer is responsible for checking the accuracy and completeness of the test reports.

The laboratory reports and testing data will be compiled electronically for upload to the DMPS website. The uploaded report contains the following:

- Address and name of facility surveyed.
- The start and stop, date and times of each measurement.
- The device type and identification numbers.
- Whether closed-building conditions (if applicable) were maintained throughout the test period and twelve hours before the test.
- Location of the device.
- Iowa Radon Measurement Specialist Certification Number.
- Any observed deviations from required test conditions.

The measurements are reported in units that are appropriate to the measurement method. Any test report that converts measurement results to the unit of another product discloses, as a minimum, the limitations and the possibility for variations of such conversion as well as the equilibrium ratio used to make that conversion.

The posted results will describe the general limitations of the test such as the following statement:

There is an uncertainty with any measurement result due to statistical variations and other factors such as daily and seasonal variations in radon concentrations due to changes in the weather and operation of the facility as well as possible interference with the necessary test conditions that may or may not influence the results.

Posted results include a statement which recommends that the facility be retested in each of the following cases whether or not the dwelling has been mitigated:

- Five years since the previous test
- An alteration is made that could change the ventilation pattern
- Major cracks or penetrations occur in the foundation walls or slab
- Changes are made or happen to an installed mitigation system
- Occupation of a ground contact area that was not previously tested

## **7.4 Maintaining Records**

Radon and radon decay product measurement data shall be maintained at DMPS in Des Moines, Iowa for a minimum of 5 years after the radon test is completed.

## **8.0 INTERNAL QUALITY CONTROL (QC)**

This section describes specific procedures for four types of internal quality control (QC) checks, measurements and procedures:

- Routine instrument performance checks

- Analysis of measurements made to assess relative bias
- Analysis of duplicate measurements made to assess precision.
- Laboratory analysis of blank field detectors.

## **8.1 Routine Instrument Performance Checks**

It is important for instruments and devices are to be inspected for damage and performance prior to deployment for accurate measurement results.

### **8.1.1 Passive Integrating Devices**

Devices will be inspected prior to deployment to identify potential issues that may impact the measurement data. Inspection is intended to identify broken/tampered seals or parts. In the event damage is reported the device will be discarded and not used to collect a measurement.

At the completion of deployment the devices will also be inspected to identify damage. Any notable damage will be reported.

## **8.2 Spiked Measurements Made to Assess Bias**

Any consistent bias of passive integrating devices are evaluated by exposing the devices to a known concentration (spiked). Spiked measurements made to assess bias are made at a frequency of at least 3 per 100 measurements (e.g., if approximately 300 measurements are estimated for the next 6 months, then at least nine spiked measurements are made at a radon calibration chamber). Spiked samples will be obtained from Bowser-Morner Radon Reference Laboratory located at 4514 Taylorsville Road, Dayton, Ohio. Bowser-Morner is accredited by the National Radon Safety Board (NRSB) and the National Radon Proficiency Program (NRPP) for the operation of a radon calibration chamber. The QA officer is responsible for ensuring that Bowser-Morner provides documentation of its accreditations from NRSB and NRPP. A copy of the most recent accreditation records of Bowser-Morner are on file.

Devices to be exposed in the calibration chamber are selected from the stock of detectors stored at room temperature inside the Operations Facility by the QA Officer. Specifications for spiking the exposure of the detectors is made by the QA Officer, in written form, directly to the calibration facility.

Results of the analysis of spiked samples are evaluated by the QA Officer following the procedures described in Section 10.1 and recorded on a control chart as shown in **Exhibit 3** to determine any consistent bias in the results and to identify the need to contact the detector manufacturer about making corrections.

## **8.3 Duplicate Measurements Made to Assess Precision**

The precision of the measurement method is evaluated on an ongoing basis through the use of duplicate measurements.

Duplicates are pairs of devices or monitors deployed in the same location, side-by-side for the same measurement period. Duplicates are recommended to be deployed at a rate of 10% of the total

measurement locations. Every tenth measurement receives two devices instead of one, until at least 25 pairs (50 total devices) are placed each month. Duplicate results are logged in the duplicate file as Result A and Result B. Duplicates will be recorded on the Duplicate Log provided in **Exhibit 2**.

The results of duplicates are analyzed following the procedures described in Section 10.2.1 and recorded on a control chart as shown in **Exhibit 4**. The QA Officer is responsible for checking the results of these duplicates and determining upper bounds for agreement between devices.

## 8.4 Exposure of Field Blanks for Passive Integrating Devices

It is recommended that field blanks for passive integrating devices are approximately five percent of the detectors deployed. At least 5 per 100 measurements are set aside as blanks and not exposed. The location and length of storage of blanks is determined by the QA Officer. Blanks are, if possible, shipped and handled as other exposed detectors. The results of these blanks are assessed by the QA Officer. If any blank result is significantly above the lower limit of detection (LLD), the QA Officer assesses the cause for the elevated reading and/or contacts the analysis laboratory. If appropriate, as determined by the QA Officer in consultation with the analysis laboratory, the results of the blanks are subtracted from the results of the exposed detectors. Blanks will be recorded on the Blank Log provided in **Exhibit 1**.

## 9.0 QUALITY ASSURANCE OBJECTIVES FOR ASSESSING PRECISION AND BIAS

The objectives for precision and bias are consistent with U.S. Environmental Protection Agency precedents (Device Protocols [EPA 1992]), and are sufficient to meet the needs of the District.

### 9.1 Monitoring Bias

The objective for relative bias for activated charcoal devices are a relative percent error (RPE) of + or - 10%. This relative bias is calculated as the difference between the measured and the reference value divided by the reference value.

Note: Different values may be set at the QA Officer's discretion.

$$RPE = \frac{\text{Measured Value} - \text{Reference Value}}{\text{Reference Value}} \times 100$$

To assess the results of spiked measurements over time, the results are plotted on a means control chart (see **Exhibit 3**).

#### 9.1.1 Means Control Chart to Evaluate Relative Bias from the Results of Spikes

The results of spikes are plotted on a means control chart (see **Exhibit 3**). The mean line is set at zero, and in general, the range of RPE values between -20% to 20% are considered acceptable.



The QA Officer plots the results from the spikes on the appropriate control chart as results are available, and checks the results as soon as they are plotted.

### 9.1.2 Corrective Action Based on the Determination of High Bias

The following guidelines, are used to determine whether the measurement system exhibits a bias high enough to warrant corrective action.

As the data is plotted, indicators that the measurement system may be "out-of-control" include:

- Two successive points outside the acceptable range of -20% to 20%
- Four successive points outside the expected range of -10% to 10%
- A systematic trend high or low

A systematic trend includes a series of points in the same direction or successive points all on the same side of the mean, even if the points are within the control limits. If the data exhibit any of these indicators, the measurement system should be checked and additional QC measurements made as per the QA officer's recommendations.

## 9.2 Monitoring Precision

Some variation is expected between the results of each detector when completing duplicate measurements. However, if the variation is unusually large, it may indicate problems within the measurement protocols. The percentage of difference between the duplicate results is calculated and reported as relative percent difference (RPD). The following table is used to evaluate the RPD:

If results are:	Expected Precision	Within Control	Warning	Limit
≥4 pCi/L	0-14%	0-27%	28-36%	>36%
2.0-3.9 pCi/L	0-25%	0-49%	50-67%	>67%

RPD is defined as the absolute difference between duplicates divided by their mean times 100, as shown below.

$$RPD = \frac{\text{Larger Result} - \text{Smaller Result}}{\text{Average of Both Results}} \times 100$$

To assess the range of differences between duplicates over time, the results of duplicates are plotted on a control chart (see **Exhibit 4**). The results from duplicates are plotted on the duplicate control chart as they are available, and the QA officer checks the results as soon as they are plotted.

## 10.0 QUALITY ASSURANCE AUDITS AND REPORTS TO MANAGEMENT

The QA Officer conducts an audit of QA operations at least annually. Specific focus of the audit is on:

- Recordkeeping, including results of routine instrument checks
- An adequate number and type of QC measurements
- Maintenance and revisions of SOP
- Adequate training and retraining of staff

The QA Officer is responsible for identifying completes an audit report following the audit. The audit report includes an assessment of bias and precision, and includes recommendations as appropriate.

## **11.0 CORRECTIVE ACTION**

Failure of quality control measurements to be within the defined limits of this QA plan results in immediate action to identify, correct, and document the problem. The QA officer is responsible for ensuring timely solutions to identified problems.

## **12.0 QUALITY ASSURANCE TRAINING**

The QA Officer has responsibility for reviewing the training plans for new staff and the plans for retraining when procedures change. Adequate training is given high priority, since the implementation of this QA plan is dependent upon the staff's understanding of its requirements.

### **12.1 Personnel Training**

Certified DMPS personnel are responsible for knowing the content this QA Plan which falls within their particular area of responsibility as defined under Section 3.1 of this plan and/or their particular Job Description. This QA Plan is the principle source document for the QA procedures and protocols which must be known and practiced by responsible company personnel.

The QA Officer provides each certified employee with a copy of this QA Plan in which the specific QA activities and responsibilities for that particular employee are clearly marked and indexed. At the end of the first month of employment and at least annually thereafter, the QA Officer checks each involved employee's knowledge and understanding of their QA duties and responsibilities as defined in this Plan. If, in the judgment of the QA Officer, an employee does not adequately understand his/her responsibilities, follow-up instructions and checks are carried out until adequate understanding is demonstrated. The QA Officer notifies the employee's supervisor of each check result and these results are given prominent consideration in compensation and job advancement reviews.

## **13.0 REFERENCES**

- |                 |  |
|-----------------|--|
| ANSI/AARST 2015 | American National Standards Institute/American Association of Radon Scientists and Technologists, 2015, "Protocol for Conducting Measurements of Radon and Radon Decay Products in Schools and Large Buildings." |
| EPA 1980        | U.S. Environmental Protection Agency, 1980, "Interim Guidelines and Specifications for Preparing Quality Assurance Project Plans," QAMS-005/80,  |



**Radon Testing Quality Assurance Plan**  
**Activated Charcoal Adsorption**  
Des Moines Public Schools



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- EPA 1992 U.S. Environmental Protection Agency, 1992, "Indoor Radon and Radon Decay Product Measurement Device Protocols," EPA 402-R-92-004, Office of Radiation and Indoor Air, Washington, DC 20460.
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- EPA 1993 U.S. Environmental Protection Agency, 1993, "Protocols for Radon and Radon Decay Product Measurements in Homes," EPA 402-R-92-003, Office of Radiation and Indoor Air, Washington, DC 20460.
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- EPA 1993 draft U.S. Environmental Protection Agency, June 1993 draft, "Radon Measurement Proficiency Program: Guidance on Quality Assurance," Office of Radiation and Indoor Air, Washington, DC 20460.
- NRC 1986 U.S. Nuclear Regulatory Commission, 1986, "Accuracy and Detection Limits for Bio Assay Measurements in Radiation Protection", NUREG-1156, Office of Nuclear Regulatory Research, Washington, DC

**EXHIBIT 1**

**Radon Survey in Progress Notification Form**

# **RADON SURVEY IN PROGRESS**

## **DO NOT REMOVE THIS NOTIFICATION**

The following conditions must be maintained to provide accurate measurement results:

- Do not open any windows. Do not open any doors except for normal momentary entering and exiting.
- Do not touch, cover, move or alter the performance of any radon detectors or non-interference controls.
- The heating and air conditioning system will remain operating normally. Turn off and keep off any equipment that supplies fresh air to the building unless it is make up air to a combustion appliance.

### **NOTE:**

Windows and doors must be kept closed because they can create pressure differences throughout the building, which can raise or lower the radon levels. Please contact Tyler Puls in the facilities department at 515-242-7889 if there are any questions or concerns.

Test Period From: \_\_\_\_\_ To: \_\_\_\_\_

Responsible Individual: Tyler Puls 515-242-7889

Date: \_\_\_\_\_

**EXHIBIT 2**

**Radon Measurement Log Forms**







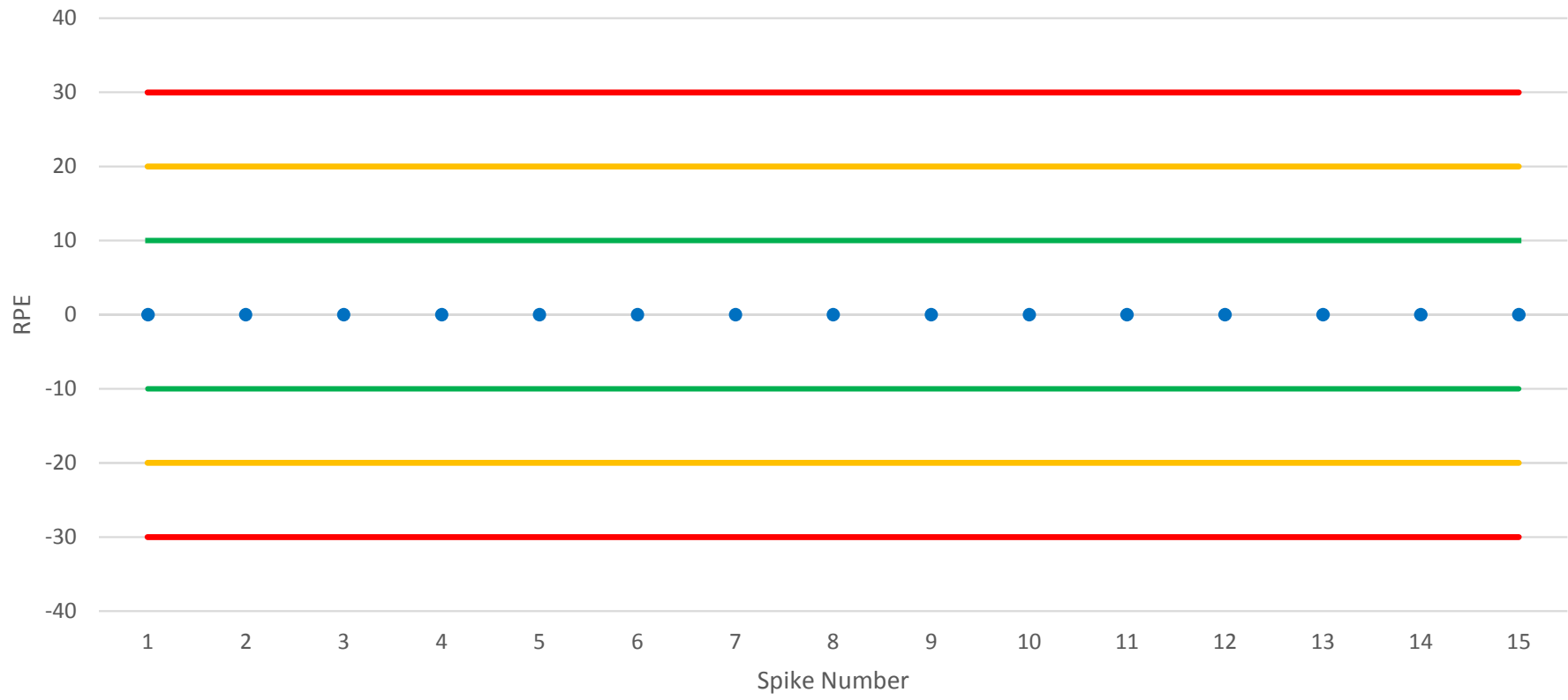




**EXHIBIT 3**

**Spike Control Chart**

### DMPS - Spike Control Chart Activated Charcoal Method

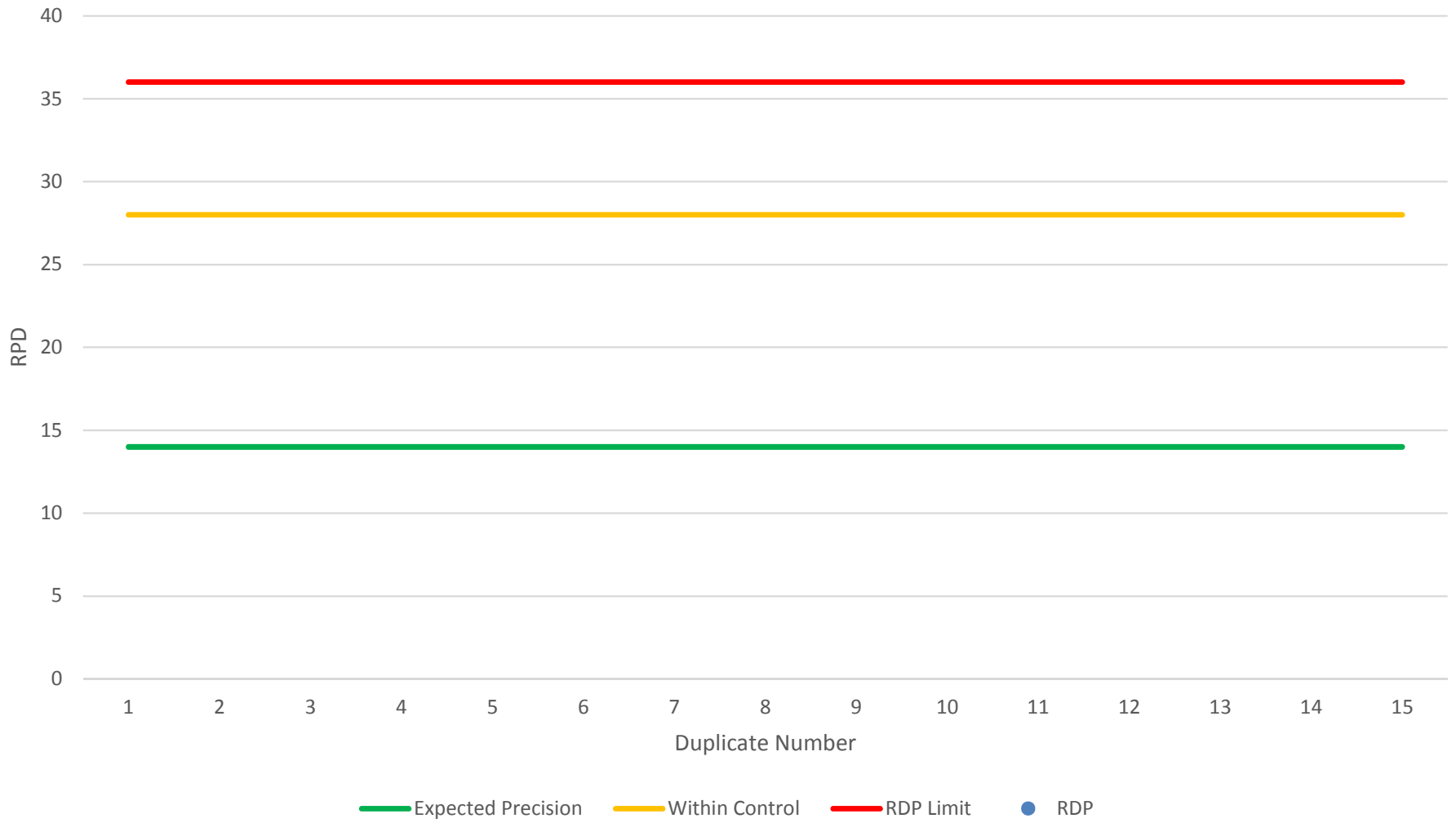


— RPE Limit    — Within Control    — Expected Precision    ● RPE

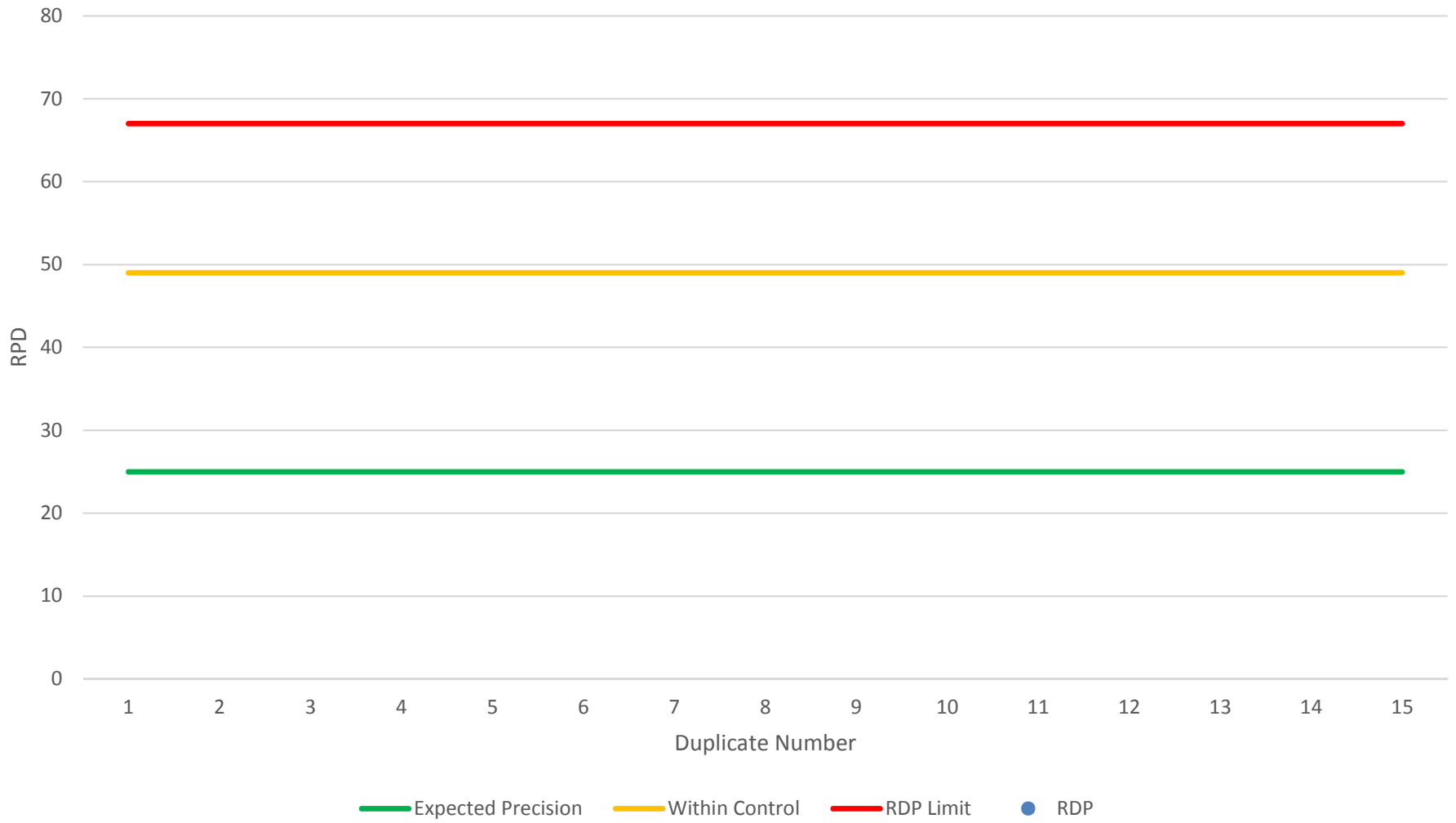
**EXHIBIT 4**

**Duplicate Control Charts**

DMPS - Duplicate Control Chart  
Activated Charcoal Method - Results > 4.0 pCi/L



DMPS - Duplicate Control Chart  
Activated Charcoal Method - Results < 4.0 pCi/L



# **APPENDIX C**

## **Long-Term Radon Testing Quality Assurance Plan**

# RADON MEASUREMENT

## ALPHA TRACK QUALITY ASSURANCE PLAN

for

Des Moines Public Schools  
1917 Dean Avenue  
Des Moines, Iowa 50316  
(515) 242-7889

Prepared by

Tyler Puls

Signatures and Dates:

  
\_\_\_\_\_  
Signature

12/10/15  
\_\_\_\_\_  
Date

Principal Investigator/Test Technician/Quality Assurance Officer  
Tyler Puls

The signature represents the awareness of, approval of, and responsibility for this plan for ensuring that the provisions of this plan are implemented.

Last updated: 12/10/15

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**Exhibit 1:** Radon Survey in Progress Notification Form

**Exhibit 2:** Radon Measurement Log Forms



**Exhibit 3:** Spike Control Chart

**Exhibit 4:** Duplicate Control Charts



## **1.0 INTRODUCTION**

### **1.1 Introduction**

This Quality Assurance Plan (QAP) is consistent with the guidance issued by the American Association of Radon Scientists and Technologists and the U.S. Environmental Protection Agency (Protocol for Measurements of Radon and Radon Decay Products in Schools and Large Buildings [ANSI/AARST 2015]; EPA Interim Guidelines for Preparing QA Plans [EPA 1980]; EPA Requirements for QA Project Plans [EPA 1992a]). This Plan is formatted in a way that allows Des Moines Public Schools (DMPS) staff to reference easily pertinent portions of this document. The nomenclature used in this QAP is appropriate for the operations of DMPS and every effort has been made to maintain consistency with the latest guidance documents.

This report reflects current operations, and therefore is often updated and revised. The QA Officer has responsibility for incorporating changes, and ensuring that the changes are reviewed and approved by the management.

## **2.0 DESCRIPTION OF OPERATIONS & EQUIPMENT**

### **2.1 Operation Description**

DMPS performs measurements of radon and/or radon decay product concentrations in facilities operated by the School District. Radon measurements will not be completed for residential or commercial properties. The DMPS Facility Department is responsible for over 70 facilities throughout the District. It is anticipated that the number of measurements performed will exceed 700 per year. Tyler Puls is the Principal Investigator and the Quality Assurance Officer.

### **2.2 Description of Equipment Used**

DMPS measures radon and/or RDP using alpha track detectors for long-term testing. For this method, a detector enclosed in a cylindrical housing with filtered openings aligned perpendicular to the detector's chip's surface allows only radon gas into the container. Alpha particles from radon strike the chip causing submicroscopic damage called alpha tracks. At the end of the sampling period, the detector is sealed and sent into the laboratory for analysis. Alpha track detectors will be sent under proper chain-of-custody (COC) to Radon Safety Services, Inc. (RSSI) located at 6312 Oakton Street, Morton Grove, Illinois 60053.

Alpha track detectors will be obtained from:

RSSI  
6312 Oakton Street  
Morton Grove, Illinois 60053



Example of an alpha track detector

Alpha track detectors will be stored at room temperature at the DMPS Operations Facility located at 1917 Dean Avenue, Des Moines, Iowa, 50316 prior to use. The person in charge of the location of the activated charcoal kits is Tyler Puls.

The devices will be stored in their pre-packaged containers, inside of the temperature controlled storage area at DMPS until they are deployed in the field. We have provided the RSSI instructions for the deployment for their alpha track detectors that will be used. DMPS employees that are certified licensed radon professionals will be knowledgeable of the deployment instructions.

The following are instructions provided by RSSI on how to use the alpha track device:

1. Open the protective pouch and remove the radon detector. Discard the pouch. If the detector rattles or if the top or bottom label is torn, call the RSSI radon laboratory at 800-762-7774.
2. Write the start date on the top of the detector.
3. If the detector is hung, firmly slide the hook into the groove on the bottom of the detector.
4. Instructed building occupants to not disturb detectors during the test period.

At the conclusion of the test:

1. Write the end date on the top of the detector.
2. Copy the bulk spread sheet, <http://rssi.us/radon-download.htm> and complete.
3. Do not attempt to reseal the detector or place anything over the filter opening.
4. Pack detectors snugly in a cardboard carton or padded envelope and ship to RSSI.

### **3.0 ORGANIZATION & RESPONSIBILITIES**

The following DMPS employee has key responsibilities in the production of radon and/or decay product measurement operations.

- Tyler Puls is the Principal Investigator and Test Technician. The Principal Investigator is responsible for completing reporting activities. Test Technicians are responsible for completing radon and/or RDP measurement.
- Tyler Puls is the Quality Assurance (QA) Officer. The QA Officer is responsible for performing quality control/quality assurance procedures as well as implementing changes for quality control procedures.
- Certified Test Technicians may be added in the future. Test Technicians are responsible for completing radon and/or RDP measurement.

## 4.0 MEASUREMENT PROCEDURES

This section covers the procedures that are followed to ensure that the measurements are made in appropriate locations and test conditions consistent with current guidelines and the District's needs.

### 4.1 Measurement Definitions

**Action Level** – A threshold for when mitigation of exposure to harmful elements is recommended or required.

**Blank Measurements** – Blanks are devices not intentionally exposed to radon gas. Blanks help evaluate any detector response from sources other than radon exposure at a testing location such as in the manufacturing process or during shipping, storage, analysis, and handling.

**Continuous Radon Monitor (CRM)** – Test devices that are capable of, and set to, integrate, record, and produce reviewable readings in time increments of one hour.

**Duplicate Measurements** – Duplicates are pairs of devices deployed in the same location, side-by-side for the same measurement period. The purpose of duplicates is to evaluate precision or agreement between detectors.

**Long-Term Measurement** – Any radon or radon decay product measurement that is acknowledged as appropriate and acceptable in the EPA Measurement Protocols and has a sampling period of at least 91 days to up to one year. Long term measurements are made using alpha track detectors exposed continuously over the exposure period.

**Occupied Area** – Any area of the facility that is occupied on a regular basis for more than four hours per day.

**Passive Integrating Devices** – Measurement devices that do not require electrical power to complete measurement collection activities. Examples include activated charcoal and alpha track detectors.

**Primary Measurement** – A radon or radon decay product measurement that provides an averaged concentration over the exposure period. The detector is to be located as specified in the guidance documents. The detector is to be operated in accordance with the recommendations of the detector manufacturer or supplier. The detector exposure time is not less than the recommended time as specified by the manufacturer. The detector is not exposed for fewer than 48 continuous hours.

**Radon Survey** – The process of following the guidelines of this QAP, making one or more primary measurements to sample and analyze the air in a building, either passively or actively, so as to measure the radon or radon decay product concentration during the test period in the areas being sampled.

**Responsible Individual** – This refers to the person or persons responsible for assuring that the test conditions required by this QAP are being followed during a radon survey.

**Short-Term Testing** – Any radon or radon decay product measurement that is a primary measurement and has a duration of from two to ninety days.

**Spiked Measurements** – Spikes are devices that have been exposed in an approved chamber to a known concentration of radon. Spikes are used to help evaluate the accuracy of a laboratory analysis and/or how accurately detectors supplied by a laboratory measure radon.

**Test Technician** – The person responsible for placing and retrieving the radon or radon decay product detector. This person must be either an employee or subcontractor of the District. The Test Technician abides by the requirements of the State of Iowa.

## **4.2 Measurement Types**

DMPS has identified three types of radon gas measurements; initial measurement, follow-up measurement and post-response measurement.

An **initial measurement** is of a relatively short-term duration (usually 2 to 7 days) to detect a radon problem in a facility. Short term tests must be carried out under closed-building conditions and in frequently-occupied rooms in contact with the ground. If the result of the initial measurement done under closed-building conditions is below 4 pCi/L, a follow-up test is not necessary.

A **follow-up measurement** is a measurement made to verify and characterize a radon problem as indicated by a previously made short term measurement value at or above 4 pCi/L. In general, the higher the initial measurement, the sooner the follow-up measurement is made and the shorter the exposure period in order to minimize the health risk to building occupants. In accordance with the DMPS Radon Action Plan (RAP), if the initial test result is found to be between 4 and 7.9 pCi/L, a long term measurement lasting up to a full 12 months is recommended, if the initial measurement was greater or equal to 8 pCi/L, a short term measurement is to be completed with a CRM to evaluate occupied versus unoccupied concentrations.

A **post-response measurement** is a short term measurement made after a response action has been completed within a facility. The test must not be started sooner than 24 hours after completion of the response action. The test must have 24 hours of closed-building conditions before the start of the test and closed-building conditions during the test.

## **4.3 Guidelines, State Regulations, and Federal Protocols**

Applicable existing laws, including but not limited to statutes, ordinances and regulations, are complied with by DMPS and DMPS Test Technicians while completed radon sampling or mitigation activities.

## **4.4 Radon Survey by Test Technician**

During a radon survey of a facility, the primary measurement placement and retrieval of the detector(s) is only performed by a Test Technician as defined in 4.1. The Test Technician ensures that the District has obtained the Test Technician's state certification number.

#### **4.5 Measurement Location**

Measurement locations are chosen according to the following criteria.

- The locations are consistent with the guidelines set forth by the EPA (EPA Device Protocols [EPA 1992], Section 1.2.3, page 1-3).
- The purpose of the measurement and type of building dictates the measurement strategy and location; guidance from ANSI/AARST is used for measurements in school facilities.
- Specific needs or requests are considered when placing devices.

The following general criteria are to be used in selecting the location of a measurement device within a room.

- A location must be selected where the measurement device will not be disturbed during the measurement period.
- The device must not be placed near drafts caused by HVAC vents, windows, and doors. Avoid locations near excessive heat, such as kilns or in direct sunlight.
- The device can be suspended from the ceiling if it is within the breathing zone (6' to 8' high) or placed on a shelf or table at least 50 centimeters (20 inches) above floor level and with its top face at least 10 centimeters (4 inches) from other objects.
- The device must not be placed within 30 centimeters (12") of the outside walls of the building or within 90 centimeters (36") of any opening in the outside walls such as windows.
- Nothing must impede air flow around the device.
- In general, kitchens, bathrooms, boiler rooms, laundry areas, garages, crawl spaces, or sumps are not suitable measurement locations.

#### **4.6 Number of Measurements**

The number of measurements is dependent on the number of elevated short-term tests as outlined in the DMPS RAP. The measurement placement conforms to the current ANSI/AARST guidelines for radon measurements.

#### **4.7 Measurement Exposure Time**

If the radon survey is a long-term measurement, closed-building conditions need not be maintained. At least half the test period should be during the season that the building is most likely operated with closed-building conditions and that reasonable closed-building conditions should be maintained during the test period so that the results of the test are more accurate indicators of the yearly average.

#### **4.8 Detector Non-Interference**

The testing devices are not to be moved, covered or have its performance altered during the radon survey by anyone. Examples of performance alteration would be covering the detector, moving it to another location during the test period, or opening windows during a short-term test.

Radon tests should not be initiated throughout the facility if there are planned renovations, scheduled changes in the heating, ventilating and air conditioning (HVAC) system, or other modifications that may influence the radon concentration during the measurement period.

#### **4.9 Informing Building Occupants about Test Conditions**

DMPS will establish a responsible individual for the building during the test period. Before any measurements are initiated, the responsible individual is informed, or attempted to be informed, about the requirements of the tests as well as other conditions for which they are responsible. Closed-building conditions do not need to be maintained during long-term tests.

In order to inform occupants of the facility about the test and the conditions of the test, a "*Radon Survey in Progress*" notification form with the conditions of the test stated on the notification, is posted upon initiation of a long-term test in the portion of the facility being evaluated. **Exhibit 1** is an example of a *Radon Survey in Progress* notification form used by DMPS.

#### **4.10 Safety**

The Test Technician should not enter any area or perform any test that would damage property or risk the Test Technician's own or another's safety.

#### **4.11 Minimum Test Condition Verification**

DMPS' minimum requirements for verifying test conditions is fulfilled by the following: informing the responsible individual of the test conditions; interviewing the responsible individual or building occupants regarding device interference; conducting a visual inspection of the room upon placement and retrieval of the device; and posting a *Radon Survey in Progress* notification form.

### **5.0 CHAIN OF CUSTODY AND DOCUMENTATION**

Chain of custody for each detector and device used includes documenting the exposure location, times and dates in/out, and persons responsible for the detectors prior to, during and after their exposure, up to their analysis or shipment to the analytical laboratory. The Test Technician is responsible for ensuring that this information is properly recorded for each measurement.

It is important that enough sufficient data about each measurement be recorded on the proper forms by the Test Technician who deploys the test device in the permanent "Field Log." This data is important in the event that further interpretations and measurements are required at a later date.

The information called for on the data form included with the device must be accurately completed by the Test Technician when the device is placed and/or retrieved. The detector serial number is recorded by the analytical laboratory on a separate log sheet and the Test Technician records a description of the location in the building where it was placed. The device is not to be relocated during the measurement period; however, if it is necessary to do so, the Test Technician should note the new location on relevant log sheets.

An example of a chain of custody used to record radon test information is attached in **Exhibit 2**. It should be noted that RSSI has provided DMPS a Microsoft Excel spreadsheet to record testing information to log testing data for accurate and timely test reports. Laboratory spreadsheets will be utilized by DMPS.

The information to be logged must include:

- Address and name of facility surveyed.
- The start and stop, date and times of each measurement.
- The detector type and identification numbers.
- Whether the room occupant has agreed to abide by the closed-building conditions (if applicable) throughout the test period and twelve hours before the test.
- Exact locations of the detector.
- Other easily gathered information that may be useful, such as the type of building, type of heating system, condition of crawl space, etc.

## **6.0 ANALYTICAL PROCEDURES**

Alpha Track devices are sent to RSSI at 6312 Oakton Street, Morton Grove, Illinois 60053 for analysis.

The measurement procedures recommended by EPA (Device Protocols [EPA 1992]) and RSSI are followed.

## **7.0 DATA CALCULATION, VALIDATION, AND REPORTING**

### **7.1 Data Calculation**

Long-term radon test results are produced by RSSI and will be reported via email, fax or mailed to the principal investigator at DMPS in Des Moines, Iowa.

### **7.2 Data Validation**

Periodic checks will be made to spot-check reports to clients for accuracy. Periodic checks will search for hand-calculating entry errors, transcription errors, or errors in the computer database and will be conducted at least semi-annually, and after any change in procedure, personnel, or equipment. A transcription error rate greater than 5 significant errors in 100 fields is cause for notification of the QA Officer, who investigates and recommends re-entry of data if necessary.

### **7.3 Data Reporting**

Final results are reported in units of pCi/L. Values are reported to one figure after the decimal for radon concentrations, and to three figures after the decimal for radon decay product concentrations. The QA Officer is responsible for checking the accuracy and completeness of the test reports.



The laboratory reports and testing data will be compiled electronically for upload to the DMPS website. The uploaded report contains the following:

- Address and name of facility surveyed.
- The start and stop, date and times of each measurement.
- The device type and identification numbers.
- Whether closed-building conditions (if applicable) were maintained throughout the test period and twelve hours before the test.
- Location of the device.
- Iowa Radon Measurement Specialist Certification Number.
- Any observed deviations from required test conditions.

The measurements are reported in units that are appropriate to the measurement method. Any test report that converts measurement results to the unit of another product discloses, as a minimum, the limitations and the possibility for variations of such conversion as well as the equilibrium ratio used to make that conversion.

The posted results will describe the general limitations of the test such as the following statement:

There is an uncertainty with any measurement result due to statistical variations and other factors such as daily and seasonal variations in radon concentrations due to changes in the weather and operation of the facility as well as possible interference with the necessary test conditions that may or may not influence the results.

Posted results include a statement which recommends that the facility be retested in each of the following cases whether or not the building has been mitigated:

- Five years since the previous test
- An alteration is made that could change the ventilation pattern
- Major cracks or penetrations occur in the foundation walls or slab
- Changes are made or happen to an installed mitigation system
- Occupation of a ground contact area that was not previously tested

## **7.4 Maintaining Records**

Radon and radon decay product measurement data shall be maintained at DMPS in Des Moines, Iowa for a minimum of 5 years after the radon test is completed.

## **8.0 INTERNAL QUALITY CONTROL (QC)**

This section describes specific procedures for four types of internal quality control (QC) checks, measurements and procedures:

- Routine instrument performance checks
- Analysis of measurements made to assess relative bias

- Analysis of duplicate measurements made to assess precision.
- Laboratory analysis of blank field detectors.

## **8.1 Routine Instrument Performance Checks**

It is important for instruments and devices are to be inspected for damage and performance prior to deployment for accurate measurement results.

### **8.1.1 Passive Integrating Devices**

Devices will be inspected prior to deployment to identify potential issues that may impact the measurement data. Inspection is intended to identify broken/tampered seals or parts. In the event damage is reported the device will be discarded and not used to collect a measurement.

At the completion of deployment the devices will also be inspected to identify damage. Any notable damage will be reported.

## **8.2 Spiked Measurements Made to Assess Bias**

Any consistent bias of passive integrating devices are evaluated by exposing the devices to a known concentration (spiked). Spiked measurements made to assess bias are made at a frequency of at least 3 per 100 measurements (e.g., if approximately 300 measurements are estimated for the next 6 months, then at least nine spiked measurements are made at a radon calibration chamber). Spiked samples will be obtained from Bowser-Morner Radon Reference Laboratory located at 4514 Taylorsville Road, Dayton, Ohio. Bowser-Morner is accredited by the National Radon Safety Board (NRSB) and the National Radon Proficiency Program (NRPP) for the operation of a radon calibration chamber. The QA officer is responsible for ensuring that Bowser-Morner provides documentation of its accreditations from NRSB and NRPP. A copy of the most recent accreditation records of Bowser-Morner are on file.

Devices to be exposed in the calibration chamber are selected from the stock of detectors stored at room temperature inside the Operations Facility by the QA Officer. Specifications for spiking the exposure of the detectors is made by the QA Officer, in written form, directly to the calibration facility.

Results of the analysis of spiked samples are evaluated by the QA Officer following the procedures described in Section 10.1 and recorded on a control chart as shown in **Exhibit 3** to determine any consistent bias in the results and to identify the need to contact the detector manufacturer about making corrections.

## **8.3 Duplicate Measurements Made to Assess Precision**

The precision of the measurement method is evaluated on an ongoing basis through the use of duplicate measurements.

Duplicates are pairs of devices or monitors deployed in the same location, side-by-side for the same measurement period. Duplicates are recommended to be deployed at a rate of 10% of the total measurement locations. Every tenth measurement receives two devices instead of one, until at least 25

pairs (50 total devices) are placed each month. Duplicate results are logged in the duplicate file as Result A and Result B. Duplicates will be recorded on the Duplicate Log provided in **Exhibit 2**.

The results of duplicates are analyzed following the procedures described in Section 10.2.1 and recorded on a control chart as shown in **Exhibit 4**. The QA Officer is responsible for checking the results of these duplicates and determining upper bounds for agreement between devices.

#### **8.4 Exposure of Field Blanks for Passive Integrating Devices**

It is recommended that field blanks for passive integrating devices are approximately five percent of the detectors deployed. At least 5 per 100 measurements are set aside as blanks and not exposed. The location and length of storage of blanks is determined by the QA Officer. Blanks are, if possible, shipped and handled as other exposed detectors. The results of these blanks are assessed by the QA Officer. If any blank result is significantly above the lower limit of detection (LLD), the QA Officer assesses the cause for the elevated reading and/or contacts the analysis laboratory. If appropriate, as determined by the QA Officer in consultation with the analysis laboratory, the results of the blanks are subtracted from the results of the exposed detectors. Blanks will be recorded on the Blank Log provided in **Exhibit 2**.

### **9.0 QUALITY ASSURANCE OBJECTIVES FOR ASSESSING PRECISION AND BIAS**

The objectives for precision and bias are consistent with U.S. Environmental Protection Agency precedents (Device Protocols [EPA 1992]), and are sufficient to meet the needs of the District.

#### **9.1 Monitoring Bias**

The objective for relative bias for alpha track devices are a relative percent error (RPE) of + or - 10%. This relative bias is calculated as the difference between the measured and the reference value divided by the reference value.

Note: Different values may be set at the QA Officer's discretion.

$$\text{RPE} = \frac{\text{Measured Value} - \text{Reference Value}}{\text{Reference Value}} \times 100$$

To assess the results of spiked measurements over time, the results are plotted on a means control chart (see **Exhibit 3**).

##### **9.1.1 Means Control Chart to Evaluate Relative Bias from the Results of Spikes**

The results of spikes are plotted on a means control chart (see **Exhibit 3**). The mean line is set at zero, and in general, the range of RPE values between -20% to 20% are considered acceptable.



The QA Officer plots the results from the spikes on the appropriate control chart as results are available, and checks the results as soon as they are plotted.

### 9.1.2 Corrective Action Based on the Determination of High Bias

The following guidelines, are used to determine whether the measurement system exhibits a bias high enough to warrant corrective action.

As the data is plotted, indicators that the measurement system may be "out-of-control" include:

- Two successive points outside the acceptable range of -20% to 20%
- Four successive points outside the expected range of -10% to 10%
- A systematic trend high or low

A systematic trend includes a series of points in the same direction or successive points all on the same side of the mean, even if the points are within the control limits. If the data exhibit any of these indicators, the measurement system should be checked and additional QC measurements made as per the QA officer's recommendations.

## 9.2 Monitoring Precision

Some variation is expected between the results of each detector when completing duplicate measurements. However, if the variation is unusually large, it may indicate problems within the measurement protocols. The percentage of difference between the duplicate results is calculated and reported as relative percent difference (RPD). The following table is used to evaluate the RPD:

If results are:	Expected Precision	Within Control	Warning	Limit
≥4 pCi/L	0-14%	0-27%	28-36%	>36%
2.0-3.9 pCi/L	0-25%	0-49%	50-67%	>67%

RPD is defined as the absolute difference between duplicates divided by their mean times 100, as shown below.

$$RPD = \frac{\text{Larger Result} - \text{Smaller Result}}{\text{Average of Both Results}} \times 100$$

To assess the range of differences between duplicates over time, the results of duplicates are plotted on a control chart (see **Exhibit 4**). The results from duplicates are plotted on the duplicate control chart as they are available, and the QA officer checks the results as soon as they are plotted.

## 10.0 QUALITY ASSURANCE AUDITS AND REPORTS TO MANAGEMENT

The QA Officer conducts an audit of QA operations at least annually. Specific focus of the audit is on:

- Recordkeeping, including results of routine instrument checks

- An adequate number and type of QC measurements
- Maintenance and revisions of SOP
- Adequate training and retraining of staff

The QA Officer is responsible for identifying completes an audit report following the audit. The audit report includes an assessment of bias and precision, and includes recommendations as appropriate.

## **11.0 CORRECTIVE ACTION**

Failure of quality control measurements to be within the defined limits of this QA plan results in immediate action to identify, correct, and document the problem. The QA officer is responsible for ensuring timely solutions to identified problems.

## **12.0 QUALITY ASSURANCE TRAINING**

The QA Officer has responsibility for reviewing the training plans for new staff and the plans for retraining when procedures change. Adequate training is given high priority, since the implementation of this QA plan is dependent upon the staff's understanding of its requirements.

### **12.1 Personnel Training**

Certified DMPS personnel are responsible for knowing the content of this QA Plan which falls within their particular area of responsibility as defined under Section 3.1 of this plan and/or their particular Job Description. This QA Plan is the principle source document for the QA procedures and protocols which must be known and practiced by responsible company personnel.

The QA Officer provides each certified employee with a copy of this QA Plan in which the specific QA activities and responsibilities for that particular employee are clearly marked and indexed. At the end of the first month of employment and at least annually thereafter, the QA Officer checks each involved employee's knowledge and understanding of their QA duties and responsibilities as defined in this Plan. If, in the judgment of the QA Officer, an employee does not adequately understand his/her responsibilities, follow-up instructions and checks are carried out until adequate understanding is demonstrated. The QA Officer notifies the employee's supervisor of each check result and these results are given prominent consideration in compensation and job advancement reviews.

## **13.0 REFERENCES**

- |                 |  |
|-----------------|--|
| ANSI/AARST 2015 | American National Standards Institute/American Association of Radon Scientists and Technologists, 2015, "Protocol for Conducting Measurements of Radon and Radon Decay Products in Schools and Large Buildings." |
| EPA 1980        | U.S. Environmental Protection Agency, 1980, "Interim Guidelines and Specifications for Preparing Quality Assurance Project Plans," QAMS-005/80,  |

## Radon Testing Quality Assurance Plan

### Alpha Track Method

Des Moines Public Schools



Office of Monitoring Systems and Quality Assurance, Office of Radiation Programs, Washington, D.C. 20460.

- EPA 1991 U.S. Environmental Protection Agency, 1991, "Radon Measurement Proficiency Program Handbook," EPA 520/1-91-006, Office of Radiation and Indoor Air, Washington, DC 20460.
- EPA 1992 U.S. Environmental Protection Agency, 1992, "Indoor Radon and Radon Decay Product Measurement Device Protocols," EPA 402-R-92-004, Office of Radiation and Indoor Air, Washington, DC 20460.
- EPA 1992a U.S. Environmental Protection Agency, 1992, "EPA Requirements for Quality Assurance Project Plans," EPA QA/R-5, Quality Assurance Management Staff, Washington, DC 20460.
- EPA 1993 U.S. Environmental Protection Agency, 1993, "Protocols for Radon and Radon Decay Product Measurements in Homes," EPA 402-R-92-003, Office of Radiation and Indoor Air, Washington, DC 20460.
- EPA 1993a U.S. Environmental Protection Agency, 1993, "Home Buyer's and Seller's Guide to Radon," EPA 402-R-93-003, Office of Radiation and Indoor Air, Washington, DC 20460.
- EPA 1993b U.S. Environmental Protection Agency, 1993, "Radon Measurement in Schools -- Revised Edition," EPA 402-R-92-014, Office of Radiation and Indoor Air, Washington, DC 20460.
- EPA 1993 draft U.S. Environmental Protection Agency, June 1993 draft, "Radon Measurement Proficiency Program: Guidance on Quality Assurance," Office of Radiation and Indoor Air, Washington, DC 20460.
- NRC 1986 U.S. Nuclear Regulatory Commission, 1986, "Accuracy and Detection Limits for Bio Assay Measurements in Radiation Protection", NUREG-1156, Office of Nuclear Regulatory Research, Washington, DC

**EXHIBIT 1**

**Radon Survey in Progress Notification Form**

# **RADON SURVEY IN PROGRESS**

## **DO NOT REMOVE THIS NOTIFICATION**

Do not touch, cover, move or alter the performance of any radon detectors or non-interference controls.

Place Device Here

Please contact Tyler Puls in the facilities department at 515-242-7889 if there are any questions or concerns.

Test Period From: \_\_\_\_\_ To: \_\_\_\_\_

Responsible Individual: Tyler Puls 515-242-7889

Date: \_\_\_\_\_



**EXHIBIT 2**

**Radon Measurement Log Forms**

Des Moines Public Schools

Field Log - Alpha Track

DMPS 1917 Dean Avenue Des Moines, IA 50316

Detector Number	Start Date (mm/dd/yyyy)	End Date (mm/dd/yyyy)	Customer Number (may be left blank)	Company or Organization	First Name	Last Name	Mailing Address 1	Mailing Address 2	Mailing City	Mailing State/Province	Mailing Zip
-----------------	----------------------------	--------------------------	--	-------------------------	------------	-----------	-------------------	-------------------	--------------	---------------------------	-------------

Des Moines Public Schools

Field Log - Alpha Track

DMPS 1917 Dean Avenue Des Moines, IA 50316

Mailing Zip + Four	Mailing County	Mailing Country	Phone Number	Fax Number	Email Address	Test Location Address 1	Test Location Address 2	Test Location City	Test Location State/Province	Test Location Zip
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**Des Moines Public Schools**

Field Log - Alpha Track

DMPS 1917 Dean Avenue Des Moines, IA 50316

Test Location County	Test Location Country	Test Location Room Description	Result	Technician	Notes
----------------------	-----------------------	--------------------------------	--------	------------	-------

Des Moines Public Schools

Blank Log - Alpha Track

DMPS 1917 Dean Avenue Des Moines, IA 50316

Detector Number	Start Date (mm/dd/yyyy)	End Date (mm/dd/yyyy)	Customer Number (may be left blank)	Company or Organization	First Name	Last Name	Mailing Address 1	Mailing Address 2	Mailing City	Mailing State/Province	Mailing Zip
-----------------	----------------------------	--------------------------	--	-------------------------	------------	-----------	-------------------	-------------------	--------------	---------------------------	-------------

Des Moines Public Schools

Blank Log - Alpha Track

DMPS 1917 Dean Avenue Des Moines, IA 50316

Mailing Zip + Four	Mailing County	Mailing Country	Phone Number	Fax Number	Email Address	Test Location Address 1	Test Location Address 2	Test Location City	Test Location State/Province	Test Location Zip
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Des Moines Public Schools

Blank Log - Alpha Track

DMPS 1917 Dean Avenue Des Moines, IA 50316

Test Location County	Test Location Country	Test Location Room Description	Result	Technician	Notes
----------------------	-----------------------	--------------------------------	--------	------------	-------

Des Moines Public Schools

Duplicate Log - Alpha Track

DMPS 1917 Dean Avenue Des Moines, IA 50316

Duplicate ID	Building Name	Test Kit #	Room #/ ID	Hours	End Date	Measured Value	RPD	RPD Range	Technician	Notes
Result A							0.0	Good		
Result B										
Result A							0.0	Good		
Result B										
Result A							0.0	Good		
Result B										
Result A							0.0	Good		
Result B										
Result A							0.0	Good		
Result B										
Result A							0.0	Good		
Result B										
Result A							0.0	Good		
Result B										
Result A							0.0	Good		
Result B										
Result A							0.0	Good		
Result B										
Result A							0.0	Good		
Result B										
Result A							0.0	Good		
Result B										
Result A							0.0	Good		
Result B										
Result A							0.0	Good		
Result B										
Result A							0.0	Good		
Result B										
Result A							0.0	Good		
Result B										
Result A							0.0	Good		
Result B										

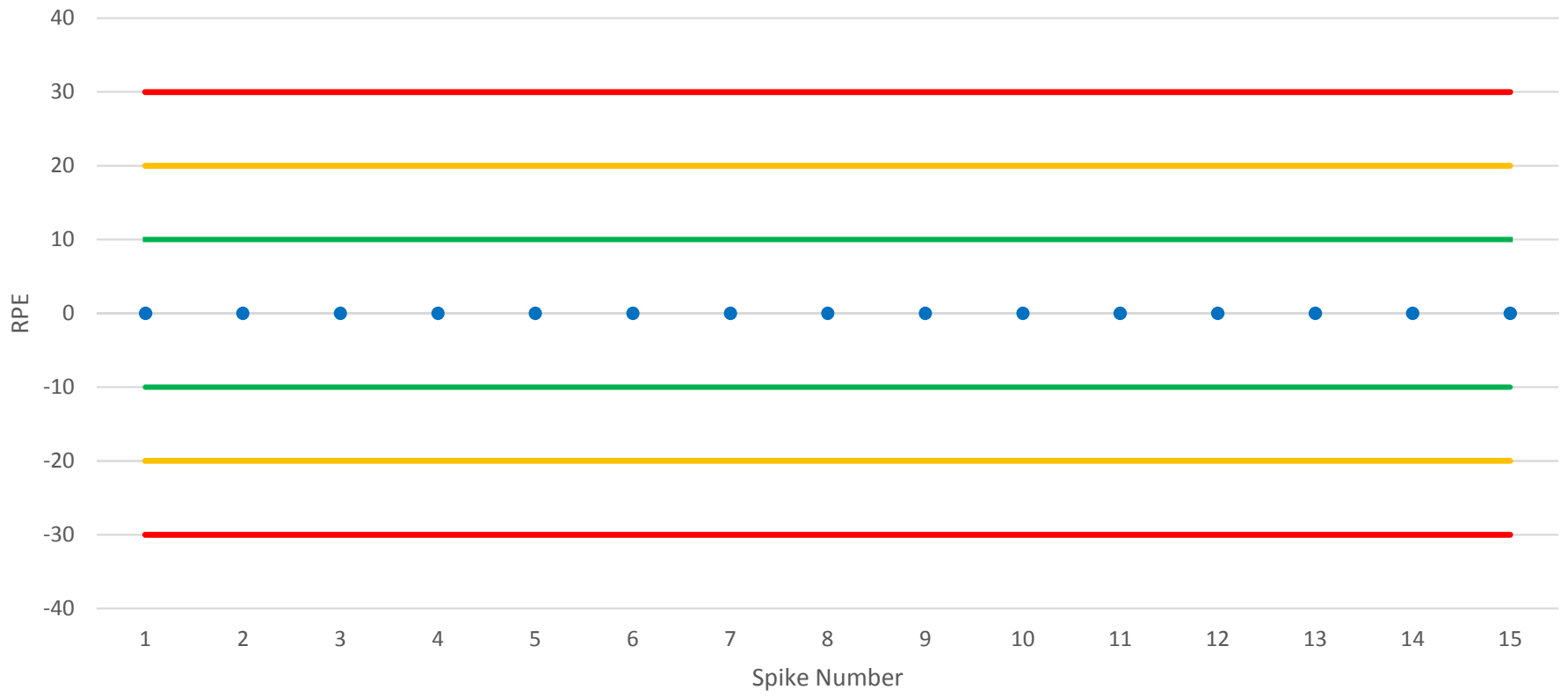




**EXHIBIT 3**

**Spike Control Chart**

# DMPS - Spike Control Chart Alpha Track Method



— RPE Limit    — Within Control    — Expected Precision    ● RPE

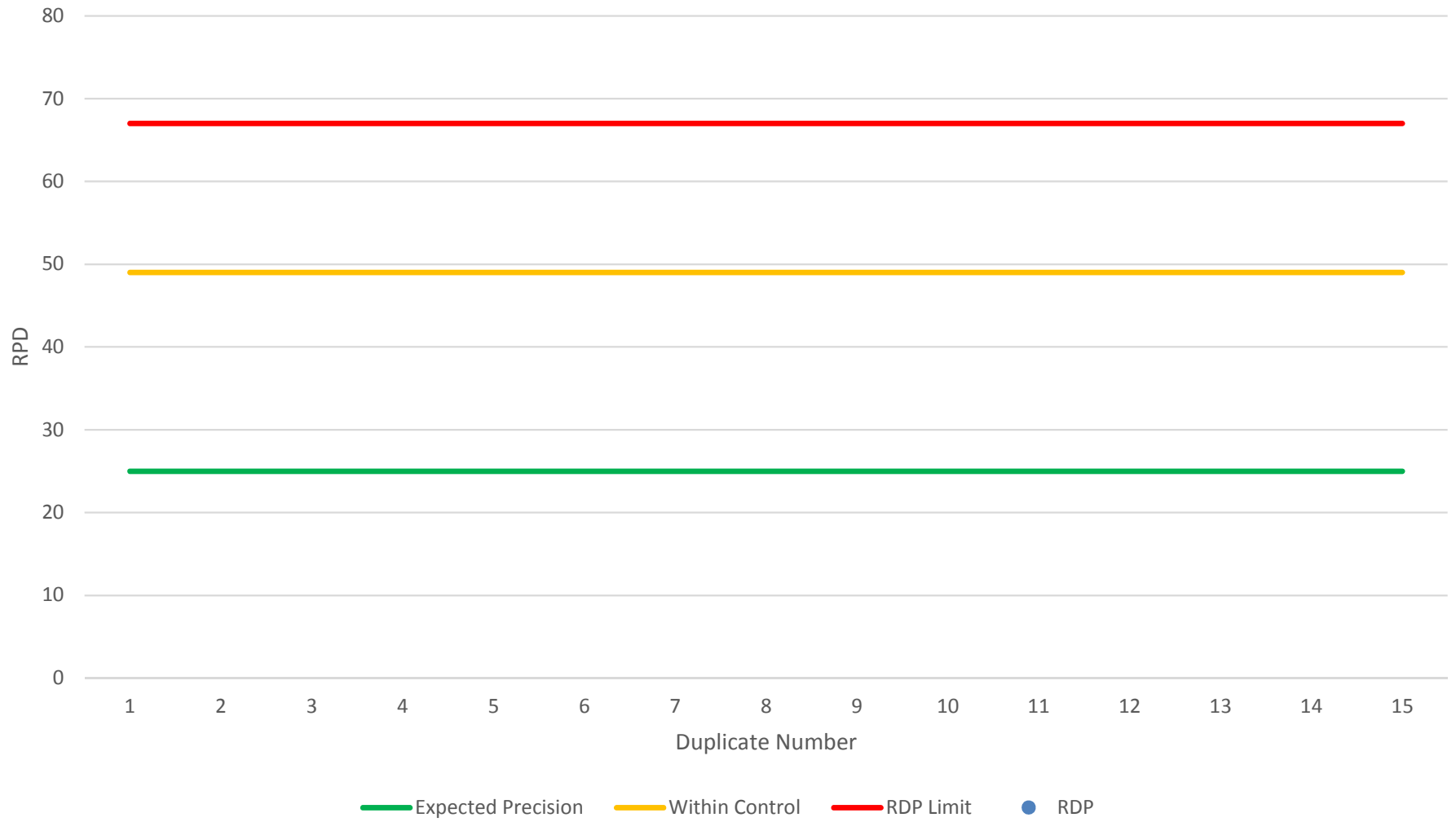
**EXHIBIT 4**

**Duplicate Control Charts**

### DMPS - Duplicate Control Chart Alpha Track Method - Results > 4.0 pCi/L



### DMPS - Duplicate Control Chart Alpha Track Method - Results < 4.0 pCi/L



## **APPENDIX D**

### **Continuous Radon Monitor Quality Assurance Plan**

# RADON MEASUREMENT

## CONTINUOUS RADON MONITOR QUALITY ASSURANCE PLAN

for

Des Moines Public Schools  
1917 Dean Avenue  
Des Moines, Iowa 50316  
(515) 242-7889

Prepared by

Tyler Puls

Signatures and Dates:

  
\_\_\_\_\_  
Signature

3/28/16  
Date

Principal Investigator/Test Technician/Quality Assurance Officer  
Tyler Puls

The signature represents the awareness of, approval of, and responsibility for this plan for ensuring that the provisions of this plan are implemented.

Last updated: 3/28/16



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**Exhibit 1:** Femto-TECH Model CRM510-510LP/CO Manufacturer Specifications and General Description

**Exhibit 2:** Radon Survey in Progress Notification Form

**Exhibit 3:** Radon Measurement Log Forms

**Exhibit 4:** Crosscheck Control Chart

**Exhibit 5:** Duplicate Control Charts



## **1.0 INTRODUCTION**

### **1.1 Introduction**

This Quality Assurance Plan (QAP) is consistent with the guidance issued by the American Association of Radon Scientists and Technologists and the U.S. Environmental Protection Agency (Protocol for Measurements of Radon and Radon Decay Products in Schools and Large Buildings [ANSI/AARST 2015]; EPA Interim Guidelines for Preparing QA Plans [EPA 1980]; EPA Requirements for QA Project Plans [EPA 1992a]). This Plan is formatted in a way that allows Des Moines Public Schools (DMPS) staff to reference easily pertinent portions of this document. The nomenclature used in this QAP is appropriate for the operations of DMPS and every effort has been made to maintain consistency with the latest guidance documents.

This report reflects current operations, and therefore is often updated and revised. The QA Officer has responsibility for incorporating changes, and ensuring that the changes are reviewed and approved by the management.

## **2.0 DESCRIPTION OF OPERATIONS & EQUIPMENT**

### **2.1 Operation Description**

DMPS performs measurements of radon and/or radon decay product concentrations in facilities operated by the School District. Radon measurements will not be completed for residential or commercial properties. The DMPS Facility Department is responsible for over 70 facilities throughout the District. Tyler Puls is the Principal Investigator and the Quality Assurance Officer.

### **2.2 Description of Equipment Used**

DMPS measures radon using a Femto-TECH Model CRM-510LP/CO Continuous Radon Monitor (CRM).

EPA Listing Code 00444 NEHA/NRPP CODE 444 GROUP #3

CRM devices will be rented from:

Femto-TECH, Inc.  
25 Eagle Court  
Carlisle, OH 45005



Example of a Femto-TECH Model CRM-510LP/CO

Currently DMPS rent's and deploys:

Femto-TECH CRM 510LP/CO unit Serial # CRM5105245 last calibrated on January 25, 2016.

Due to the nature of renting equipment the unit serial number may change over time. The serial number of the CRM used for the measurement will be included with the test results.

Please refer to **Exhibit 1** to view the Femto-TECH Model CRM510-510LP/CO Manufacturer Specifications and General Description.

The CRM will be stored at room temperature at the DMPS Operations Facility located at 1917 Dean Avenue, Des Moines, Iowa, 50316 prior to use. The person in charge of the location of the CRM is Tyler Puls.

The device will be stored in a protective case, inside of the temperature controlled storage area at DMPS until deployed in the field. We have provided instructions for the deployment of the device. DMPS employees that are certified licensed radon professionals will be knowledgeable of the deployment instructions.

### 3.0 ORGANIZATION & RESPONSIBILITIES

The following DMPS employee has key responsibilities in the production of radon measurement operations.

- Tyler Puls is the Principal Investigator and Test Technician. The Principal Investigator is responsible for completing reporting activities. Test Technicians are responsible for completing radon and/or RDP measurement.
- Tyler Puls is the Quality Assurance (QA) Officer. The QA Officer is responsible for performing quality control/quality assurance procedures as well as implementing changes for quality control procedures.
- Certified Test Technicians may be added in the future. Test Technicians are responsible for completing radon and/or RDP measurement.

### 4.0 MEASUREMENT PROCEDURES

This section covers the procedures that are followed to ensure that the measurements are made in appropriate locations and test conditions consistent with current guidelines and the District's needs.

## 4.1 Measurement Definitions

**Action Level** – A threshold for when mitigation of exposure to harmful elements is recommended or required.

**Blank Measurements** – Blanks are devices not intentionally exposed to radon gas. Blanks help evaluate any detector response from sources other than radon exposure at a testing location such as in the manufacturing process or during shipping, storage, analysis, and handling.

**Continuous Radon Monitor (CRM)** – Test devices that are capable of, and set to, integrate, record, and produce reviewable readings in time increments of one hour.

**Duplicate Measurements** – Duplicates are pairs of devices deployed in the same location, side-by-side for the same measurement period. The purpose of duplicates is to evaluate precision or agreement between detectors.

**Long-Term Measurement** – Any radon or radon decay product measurement that is acknowledged as appropriate and acceptable in the EPA Measurement Protocols and has a sampling period of at least 91 days to up to one year. Long term measurements are made using alpha track detectors exposed continuously over the exposure period.

**Occupied Area** – Any area of the facility that is occupied on a regular basis for more than four hours per day.

**Passive Integrating Devices** – Measurement devices that do not require electrical power to complete measurement collection activities. Examples include activated charcoal and alpha track detectors.

**Primary Measurement** – A radon or radon decay product measurement that provides an averaged concentration over the exposure period. The detector is to be located as specified in the guidance documents. The detector is to be operated in accordance with the recommendations of the detector manufacturer or supplier. The detector exposure time is not less than the recommended time as specified by the manufacturer. The detector is not exposed for fewer than 48 continuous hours.

**Radon Survey** – The process of following the guidelines of this QAP, making one or more primary measurements to sample and analyze the air in a building, either passively or actively, so as to measure the radon or radon decay product concentration during the test period in the areas being sampled.

**Responsible Individual** – This refers to the person or persons responsible for assuring that the test conditions required by this QAP are being followed during a radon survey.

**Short-Term Testing** – Any radon or radon decay product measurement that is a primary measurement and has a duration of from two to ninety days.

**Spiked Measurements** – Spikes are devices that have been exposed in an approved chamber to a known concentration of radon. Spikes are used to help evaluate the accuracy of a laboratory analysis and/or how accurately detectors supplied by a laboratory measure radon.

**Test Technician** – The person responsible for placing and retrieving the radon or radon decay product detector. This person must be either an employee or subcontractor of the District. The Test Technician abides by the requirements of the State of Iowa.

## **4.2 Measurement Types**

DMPS has identified three types of radon gas measurements; initial measurement, follow-up measurement and post-response measurement.

An **initial measurement** is of a relatively short-term duration (usually 2 to 7 days) to detect a radon problem in a facility. Short term tests must be carried out under closed-building conditions and in frequently-occupied rooms in contact with the ground. If the result of the initial measurement done under closed-building conditions is below 4 pCi/L, a follow-up test is not necessary.

A **follow-up measurement** is a measurement made to verify and characterize a radon problem as indicated by a previously made short term measurement value at or above 4 pCi/L. In general, the higher the initial measurement, the sooner the follow-up measurement is made and the shorter the exposure period in order to minimize the health risk to building occupants. In accordance with the DMPS Radon Action Plan (RAP), if the initial test result is found to be between 4 and 7.9 pCi/L, a long term measurement lasting up to a full 12 months is recommended, if the initial measurement was greater or equal to 8 pCi/L, a short term measurement is to be completed with a CRM to evaluate occupied versus unoccupied concentrations.

A **post-response measurement** is a short term measurement made after a response action has been completed within a facility. The test must not be started sooner than 24 hours after completion of the response action. The test must have 24 hours of closed-building conditions before the start of the test and closed-building conditions during the test.

## **4.3 Guidelines, State Regulations, and Federal Protocols**

Applicable existing laws, including but not limited to statutes, ordinances and regulations, are complied with by DMPS and DMPS Test Technicians while completed radon sampling or mitigation activities.

## **4.4 Radon Survey by Test Technician**

During a radon survey of a facility, the primary measurement placement and retrieval of the detector(s) is only performed by a Test Technician as defined in 4.1. The Test Technician ensures that the District has obtained the Test Technician's state certification number.

#### **4.5 Measurement Location**

Measurement locations are chosen according to the following criteria.

- The locations are consistent with the guidelines set forth by the EPA (EPA Device Protocols [EPA 1992], Section 1.2.3, page 1-3).
- The purpose of the measurement and type of building dictates the measurement strategy and location; guidance from ANSI/AARST is used for measurements in school facilities.
- Specific needs or requests are considered when placing devices.

The following general criteria are to be used in selecting the location of a measurement device within a room.

- A location must be selected where the measurement device will not be disturbed during the measurement period.
- The device must not be placed near drafts caused by HVAC vents, windows, and doors. Avoid locations near excessive heat, such as kilns or in direct sunlight.
- The detector can be suspended from the ceiling if it is within the breathing zone (6' to 8' high) or placed on a shelf or table at least 20 inches above floor level and with its top face at least 4 inches from other objects.
- The device must not be placed within 30 centimeters (12") of the outside walls of the building or within 90 centimeters (36") of any opening in the outside walls such as windows.
- Nothing must impede air flow around the device.
- In general, kitchens, bathrooms, boiler rooms, laundry areas, garages, crawl spaces, or sumps are not suitable measurement locations.

#### **4.6 Number of Measurements**

Measurements will be completed in areas where prior testing deemed necessary. Areas will be evaluated to determine occupied versus unoccupied conditions. The measurement placement conforms to the current ANSI/AARST guidelines for radon measurements.

#### **4.7 Measurement Exposure Time**

The measurement exposure time is a minimum of 48 hours. Short-term measurement exposure time should be in increments of 24 hours plus or minus 1 hour for each day of exposure in order to minimize the effect of diurnal variations. This means that a three-day test should be exposed from 69 to 75 hours. The exposure time is not to be less than the manufacturer's or supplier's recommendations.

#### **4.8 Detector Non-Interference**

The testing devices are not to be moved, covered or have its performance altered during the radon survey by anyone. Examples of performance alteration would be covering the detector, moving it to another location during the test period, or opening windows during a short-term test.

Radon tests should not be initiated throughout the facility if there are planned renovations, scheduled changes in the heating, ventilating and air conditioning (HVAC) system, or other modifications that may influence the radon concentration during the measurement period.

#### **4.9 Closed-Building Conditions**

The weather and building ventilation conditions prior to and during the measurement are in accordance with the guidelines set forth by the EPA (Device Protocols [EPA 1992], Section 1.2.2, page 1-2). Closed-building conditions require that the windows are kept closed. External and any basement to first floor doors are closed except for normal momentary entering and exiting. Structural openings due to disrepair or structural defects that allow a significant amount of ventilation are repaired to correct their condition before initiation of closed-building condition sampling. Exterior windows and doors are inspected by the Test Technician at the times of placement and retrieval of the detector. The Test Technician walks around the outside of the building to inspect for closed-building condition.

HVAC systems shall be operated normally. Operation of dryers, range hoods, and bathroom fans should be kept to a minimum. The responsible individual, however, should be informed that overuse of an appliance that exhausts air may influence the final readings. Window air conditioning units are only operated in a recirculating mode.

Ceiling fans, portable dehumidifiers, portable humidifiers, portable air filters and window air conditioners are not operated within twenty feet of the detector. Closed-building conditions should be maintained for twelve hours prior to the start of the radon survey. DMPS inquires with the room occupant to determine if closed-building conditions have been maintained for the twelve hours prior to the start of the test.

The Test Technician takes due and proper care in obtaining closed-building conditions during short-term testing in order to increase measurement reproducibility. If at the initiation of the test, the Test Technician discovers or visually observes that closed-building conditions were not maintained, then the radon survey is not initiated until twelve hours of prior closed-building conditions have been maintained or the radon test period is extended to four days or more with an appropriate detector after closed-building conditions are initiated.

#### **4.10 Informing Building Occupants about Test Conditions**

DMPS will establish a responsible individual for the building during the test period. Before any measurements are initiated, the responsible individual is informed, or attempted to be informed, about the requirements of and the need for closed-building conditions as well as other conditions for which they are responsible.

In the event the Test Technician is not able to communicate with the responsible individual about the test and the conditions of the test, a "*Radon Survey in Progress*" notification form with the conditions of the test stated on the notification, is posted upon initiation of a short-term test in a conspicuous location of the facility. **Exhibit 2** is an example of a *Radon Survey in Progress* notification form used by DMPS.



#### **4.11 Safety**

The Test Technician should not enter any area or perform any test that would damage property or risk the Test Technician's own or another's safety. If it is known that closed-building conditions are detrimental to the health of the occupants, then the radon survey is not completed.

#### **4.12 Minimum Test Condition Verification**

DMPS' minimum requirements for verifying test conditions is fulfilled by the following: informing the responsible individual of the test conditions; interviewing the responsible individual or building occupants regarding device interference; conducting a visual inspection of the building upon placement and retrieval of the device; and posting a *Radon Survey in Progress* notification form. The Test Technician is not responsible for inspecting for closed-building conditions 12 hours before the start of the test or between placement and retrieval of the detectors.

#### **4.13 New Construction Test Conditions**

Newly constructed buildings are tested in accordance with this QAP. The following items, if such items are part of the completed building, are installed and completed before the radon survey is initiated: insulation; exterior doors; windows; heating appliances; ceiling coverings; interior trim and coverings for the exterior walls; exterior siding; weatherproofing and caulking. If DMPS knows construction work, which will likely affect the test results, is to be done inside the building during the test period, then DMPS will reschedule the test when such interference is less likely to take place.

### **5.0 DETECTOR CUSTODY AND DOCUMENTATION**

Chain of custody for each device used includes documenting the exposure location, times and dates in/out, and persons responsible for the detectors prior to, during and after their exposure. The Test Technician is responsible for ensuring that this information is properly recorded for each measurement.

It is important that enough sufficient data about each measurement be recorded on the proper forms by the Test Technician who deploys the test device in the permanent Field Log. This data is important in the event that further interpretations and measurements are required at a later date.

The information called for on the Field Log must be accurately completed by the Test Technician when the device is placed and/or retrieved. The detector serial number and a description of the location in the building where it was placed is recorded by the Test Technician. The device is not to be relocated during the measurement period; however, if it is necessary to do so, the Test Technician should note the new location on relevant log sheets. An example of a Field Log used to record radon test information is attached in **Exhibit 3**. A site map may be utilized as a field log as long as all required information is reported.

The information to be logged must include:

- Address and name of facility surveyed.
- The start and stop, date and times of each measurement.

- The detector type and identification numbers.
- Whether the room occupant has agreed to abide by the closed-building conditions (if applicable) throughout the test period and twelve hours before the test.
- Exact locations of the detector.
- Other easily gathered information that may be useful, such as the type of building, type of heating system, condition of crawl space, etc.

## **6.0 ANALYTICAL PROCEDURES**

The sampling and analysis procedure is as described in 4.0 through 4.13. The measurement procedures are recommended by EPA (Device Protocols [EPA 1992]), ANSI/AARST, and the SOP provided by Femto-TECH, INC. Results from each of the CRM sampling events are downloaded from the device to a computer and are submitted to the QA/QC Manager for interpretation. A graphic illustration of the hourly measurements, which are computer generated, is completed at the conclusion of the sampling period along with a field report.

## **7.0 CALIBRATION PROCEDURES**

Each CRM-510 unit is calibrated annually per manufactures recommendations or every 6 months if required by states governing guidelines and/or after any repair performed by the manufacturer. The units will be calibrated by the manufacturer.

In addition, a background check is performed annually by purging with clean aged air or nitrogen. The manufacturer completes this process at the time of calibration. Crosschecks to a recently calibrated instrument are done at least semi-annually.

A calibration and crosscheck log is to be maintained with date and the coefficient of variation. Calibration information will be recorded in the calibration log attached as **Exhibit 3**.

Internal quality control is provided by regular battery checks at this time.

## **8.0 DATA CALCULATION, VALIDATION, AND REPORTING**

The QA/QC Manager is responsible for validation of the testing results and the recording of data.

### **8.1 Data Calculation and Validation**

Femto-TECH CRM monitors have a built-in computer which normally performs all the computations and provides the radon concentration data in pCi/L or Bq/m<sup>3</sup>, but it is advisable for the operator to know how to carry out “hand” calculations. A back-up “hand” calculation should be carried out after entering a new calibration factor or background value to verify their correct entry.

To perform a “hand” calculation, record the number of counts accumulated and the elapsed time shown on the LCD display, convert to counts per minute, and apply the conversion factor (C.F.) and background

(BKG) values supplied with the instrument to obtain the radon level in units of pCi/L. The following formula is used for this conversion:

Radon Concentration in pCi/l equals Ending Count minus the Beginning Count divided by Elapsed Time (min.) multiplied by Calibration Factor minus the Background.

The background subtraction is generally only necessary for radon levels below 10 pCi/L.

## **8.2 Data Validation**

Periodic checks will be made to spot-check reports for accuracy. Periodic checks will search for hand-calculating entry errors, transcription errors, or errors in the computer database and will be conducted at least semi-annually, and after any change in procedure, personnel, or equipment. A transcription error rate greater than 5 significant errors in 100 fields is cause for notification of the QA Officer, who investigates and recommends re-entry of data if necessary.

## **8.3 Data Reporting**

Final results are reported in units of pCi/L. Values are reported to one figure after the decimal for radon concentrations. The QA Officer is responsible for checking the accuracy and completeness of the test reports.

The reports and testing data will be compiled electronically for upload to the DMPS website. The uploaded report contains the following:

- Address and name of facility surveyed.
- The start and stop, date and times of each measurement.
- The device type and identification numbers.
- Whether closed-building conditions (if applicable) were maintained throughout the test period and twelve hours before the test.
- Location of the device.
- Iowa Radon Measurement Specialist Certification Number.
- Any observed deviations from required test conditions.

The measurements are reported in units that are appropriate to the measurement method. Any test report that converts measurement results to the unit of another product discloses, as a minimum, the limitations and the possibility for variations of such conversion as well as the equilibrium ratio used to make that conversion.

The posted results will describe the general limitations of the test such as the following statement:

There is an uncertainty with any measurement result due to statistical variations and other factors such as daily and seasonal variations in radon concentrations due to changes in the weather and operation of the facility as well as possible interference with the necessary test conditions that may or may not influence the results.

Posted results include a statement which recommends that the facility be retested in each of the following cases whether or not the dwelling has been mitigated:

- Five years since the previous test
- An alteration is made that could change the ventilation pattern
- Major cracks or penetrations occur in the foundation walls or slab
- Changes are made or happen to an installed mitigation system
- Occupation of a ground contact area that was not previously tested

#### **8.4 Maintaining Records**

Radon and radon decay product measurement data shall be maintained at DMPS in Des Moines, Iowa for a minimum of 5 years after the radon test is completed.

### **9.0 INTERNAL QUALITY CONTROL (QC)**

This section describes specific procedures for four types of internal quality control (QC) checks, measurements and procedures:

- Routine instrument performance checks
- Analysis of measurements made to assess relative bias
- Analysis of duplicate measurements made to assess precision.
- Laboratory analysis of blank field detectors.

#### **9.1 Routine Instrument Performance Checks and Preventative Maintenance**

Devices will be inspected prior to deployment to identify potential issues that may impact the measurement data. Inspection is intended to identify broken/tampered seals or parts. In the event damage is reported the device will not be used to collect a measurement.

The Test Technician will be responsible for checking for proper working condition of all CRM, to include battery voltage levels, screen inlet ports and built-in instrument pump and sub-micron filter sampling system. It is also necessary to verify that calibration is up-to-date.

As stated in section 7.0 Calibration, purging with clean, aged air or nitrogen per the manufacturer's operation manual annually performs a background check. Background checks are to be performed more frequently if the instrument has been exposed to high levels of radon for extended periods of time as described in the operating manual. All information data acquired is logged and those records are kept in the QA/QC Officer's office and reviewed monthly.

At the completion of deployment the devices will also be inspected to identify damage. Any notable damage will be reported.

## 9.2 Measurements Made to Assess Bias

Any consistent bias shown by the instrument(s) is evaluated by performing regular crosschecks with a recently calibrated (see Section 7.0) instrument. These crosschecks are performed during the 12-month interval between calibration, and approximately six months after calibration or a crosscheck. Refer to Section 7.0 for calibration procedures. Crosschecks are conducted with the following procedures.

The monitor is exposed in an environment that averages, if possible, greater than 4 pCi/l for a minimum of 48 hours directly adjacent to a recently calibrated active monitor (not necessarily the same type or model, but one that produces results in the same units and has been calibrated within the last 30 days). The environment where monitors are compared is, if possible, chosen for its radon stability, and in an area where radon levels are considerably greater than each unit's lower limit of detection. Both units measure over the same time interval, although the recently calibrated monitor can have the capability to measure in shorter intervals. The results for each monitor are averaged and analyzed in terms of relative percent error (RPE), as described in Section 10.1.

The results of crosschecks are analyzed following the procedures described in Section 10.1 and recorded on a control chart as shown in **Exhibit 3**. The QA Officer is responsible for checking the results of these crosschecks and determining the maximum amount of disagreement (upper bounds of agreement) between devices.

In the event the CRM is used to evaluate areas which contain greater than 100 pCi/L of radon the device will be checked for background radiation. The pulsed ion counter detector discriminates against all ionizing radiation other than airborne alpha. Therefore, environmental gamma radiation or intrinsic ions are not sources of background as with most other types of detectors. However, progeny plate-out on the detector surfaces can result in a slow build-up of an alpha radiation background from Polonium-210. This background builds at a rate of approximately  $3 \times 10^{-5}$  CPM per day of exposure at 1 pCi/l radon. Thus, background build-up is not significant when the CRM is used in applications where exposures are generally less than 100 pCi/l. However, if the CRM is used extensively in diagnostic applications where relatively high level radon exposures are common (100 pCi/l or more), the instrument background should be checked after every 1000 hours of use.

Background determinations can be carried out using outdoor air or air supplied from a compressed gas cylinder that has been "aged" for at least thirty days. The "aged" air source is preferred because outdoor air can contain detectable quantities of radon. A background determination can be performed by placing the CRM in an air tight enclosure or plastic bag. Flow the background gas through the enclosure or bag for at least six hours. Discard the first three hours of data and calculate the average CPM and/or pCi/l for the remaining hours of the test. If the measured background is greater than 0.3 pCi/l, the amount over 0.3 pCi/l should be subtracted from any measurements taken with this instrument. It is advisable to have the detector assembly replaced in any instrument that has a background over 1 pCi/l.

## 9.3 Duplicate Measurements Made to Assess Precision

The precision of the measurement method is evaluated on an ongoing basis through the use of duplicate measurements.

Active duplicates are defined as measurements made with the same type of instrument over identical time periods with air intakes adjacent. When two monitors are available at the same location, side-by-side-by-side measurements will be completed in approximately 10 percent of the total number of measurements, or up to 25 each month is made. If only one similar active monitor is available, one out of every 10 measurements is checked with a second device. Activated charcoal test kits will be utilized by DMPS for duplicate measurements. Activated charcoal test kits will be sent under proper chain-of-custody to Air Chek, Inc. located at 1936 Butler Bridge Road, Mills River, North Carolina 28759 for analysis. Duplicate results are logged in the Duplicate Log as Result A and Result B. Duplicates will be recorded on the Duplicate Log provided in **Exhibit 3**.

The results of duplicates are analyzed following the procedures described in Section 10.2 and recorded on a control chart as shown in **Exhibit 5**. The QA Officer is responsible for checking the results of these duplicates and determining upper bounds for agreement between devices.

## **10.0 QUALITY ASSURANCE OBJECTIVES FOR ASSESSING PRECISION AND BIAS**

The objectives for precision and bias are consistent with U.S. Environmental Protection Agency precedents (Device Protocols [EPA 1992]), and are sufficient to meet the needs of the District.

### **10.1 Monitoring Bias**

The objective for relative bias for the CRM is a relative percent error (RPE) of  $+ / - 10\%$ . This relative bias is calculated as the difference between the measured and the crosschecked value divided by the crosschecked value.

To assess the results of crosschecked measurements over time, the results are plotted on a means control chart (see **Exhibit 4**).

#### **10.1.1 Evaluate Relative Bias from the Results of Cross-Checks**

The results of crosschecks are plotted on a means control chart (see **Exhibit 4**). The mean line is set at zero, and in general, the range of RPE values between  $-20\%$  to  $20\%$  are considered acceptable.

The QA Officer plots the results from the crosschecks on the appropriate control chart as results are available, and checks the results as soon as they are plotted.

#### **10.1.2 Corrective Action Based on the Determination of High Bias**

The following guidelines, are used to determine whether the measurement system exhibits a bias high enough to warrant corrective action.

As the data is plotted, indicators that the measurement system may be "out-of-control" include:



- Two successive points outside the acceptable range of -20% to 20%
- Four successive points outside the expected range of -10% to 10%
- A systematic trend high or low

A systematic trend includes a series of points in the same direction or successive points all on the same side of the mean, even if the points are within the control limits. If the data exhibit any of these indicators, the measurement system should be checked and additional QC measurements made as per the QA officer's recommendations.

## 10.2 Monitoring Precision

Some variation is expected between the results of each detector when completing duplicate measurements. However, if the variation is unusually large, it may indicate problems within the measurement protocols. The percentage of difference between the duplicate results is calculated and reported as relative percent difference (RPD). The following table is used to evaluate the RPD:

If results are:	Expected Precision	Within Control	Warning	Limit
≥4 pCi/L	0-14%	0-27%	28-36%	>36%
2.0-3.9 pCi/L	0-25%	0-49%	50-67%	>67%

RPD is defined as the absolute difference between duplicates divided by their mean times 100, as shown below.

$$RPD = \frac{\text{Larger Result} - \text{Smaller Result}}{\text{Average of Both Results}} \times 100$$

To assess the range of differences between duplicates over time, the results of duplicates are plotted on a control chart (see **Exhibit 5**). The results from duplicates are plotted on the duplicate control chart as they are available, and the QA officer checks the results as soon as they are plotted.

## 11.0 QUALITY ASSURANCE AUDITS AND REPORTS TO MANAGEMENT

The QA Officer conducts an audit of QA operations at least annually. Specific focus of the audit is on:

- Recordkeeping, including results of routine instrument checks
- An adequate number and type of QC measurements
- Maintenance and revisions of SOP
- Adequate training and retraining of staff

The QA Officer is responsible for identifying and completing an audit report following the audit. The audit report includes an assessment of bias and precision, and includes recommendations as appropriate.

## **12.0 CORRECTIVE ACTION**

Failure of quality control measurements to be within the defined limits of this QA plan results in immediate action to identify, correct, and document the problem. The QA officer is responsible for ensuring timely solutions to identified problems.

## **13.0 QUALITY ASSURANCE TRAINING**

The QA Officer has responsibility for reviewing the training plans for new staff and the plans for retraining when procedures change. Adequate training is given high priority, since the implementation of this QA plan is dependent upon the staff's understanding of its requirements.

### **13.1 Personnel Training**

Certified DMPS personnel are responsible for knowing the content of this QA Plan which falls within their particular area of responsibility as defined under Section 2.1 of this plan and/or their particular Job Description. This QA Plan is the principle source document for the QA procedures and protocols which must be known and practiced by responsible company personnel.

The QA Officer provides each certified employee with a copy of this QA Plan in which the specific QA activities and responsibilities for that particular employee are clearly marked and indexed. At the end of the first month of employment and at least annually thereafter, the QA Officer checks each involved employee's knowledge and understanding of their QA duties and responsibilities as defined in this Plan. If, in the judgment of the QA Officer, an employee does not adequately understand his/her responsibilities, follow-up instructions and checks are carried out until adequate understanding is demonstrated. The QA Officer notifies the employee's supervisor of each check result and these results are given prominent consideration in compensation and job advancement reviews.

## **14.0 REFERENCES**

- |                 |   |
|-----------------|---|
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**Radon Testing Quality Assurance Plan**  
**Continuous Radon Monitor**  
Des Moines Public Schools



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**EXHIBIT 1**

**Femto-TECH Model CRM510-510LP/CO Manufacturer Specifications and General Description**

Underlined text is hyperlinked; hold down the [CTRL] key and click on the test to go directly to that section.

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## 2. Specifications, CRM510LP

RADIATION DETECTED.....	Radon-222 Alpha
DETECTOR .....	Air Ionization Probe
DYNAMIC RANGE.....	0.5 To 2000 pCi/l
UNIT .....	pCi/l or Bq/m <sup>3</sup>
SENSITIVITY .....	0.3 CPM per pCi/l
.....	(0.008 CPM per Bq/m <sup>3</sup> )
LINEARITY .....	0 - 2000 pCi/l (<10% Deviation)
SAMPLING MODE .....	Passive Air Diffusion
OPERATING MODE: DATA STORAGE	
CRM510LP.....	192 one hour data points (8 days)
CRM510LP w/ Carbon Monoxide sensor.....	79 one hour data points (radon), 1185 fifteen minute data points (carbon monoxide)
ENVIRONMENTAL SENSORS:	
TEMPERATURE .....	Range 50-104 °F, 10-40 °C
.....	Sensitivity ±1 °F, ±0.5 °C
BAROMETRIC PRESSURE.....	Range 0-38 "Hg, 0-127 kPa
.....	Sensitivity ± 0.2 "Hg, ±0.5 kPa
RELATIVE HUMIDITY .....	Range 10-90%
.....	Sensitivity ±5%
DISPLAY:	
ALPHANUMERIC CHARACTERS .....	16-Digit One Line LCD
LOW BATTERY INDICATOR.....	LCD Message
PULSE INDICATOR .....	Red LED
CONTROLS:	
KEY SWITCH .....	OFF, I/O & RUN Positions
TWO MOMENTARY PUSH BUTTONS.....	Multifunction Select & Execute
EXTERNAL OUTPUTS (FEMALE DB-25)	
SERIAL.....	RS-232
PARALLEL .....	8 Bit Simplified Centronics®
POWER:	
ELECTROMETER.....	9 volt Battery (1 year typical life)
ION CHAMBER.....	27 volt battery pack (2 year typical life)
COMPUTER/DATA LOGGER .....	7.2 volt lithium battery pack (1 year typical life)
SIZE:	
HEIGHT (w/Handle) .....	5.4" (137 mm)
WIDTH .....	6.6" (160 mm)
DEPTH.....	7.4" (190 mm)
WEIGHT .....	3.9 Pounds (1.8 Kg)
ENVIRONMENTAL OPERATING RANGE .....	50-104 °F (10-40 °C)
.....	10 To 90% RH (noncondensing)

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### 3. General Description

The *femto*-TECH, INC. MODEL CRM-510LP is a precision airborne alpha radiation detection instrument based on the same field proven pulsed ion chamber technology of previous MODELS R210F and RS410F. Due to a unique patented electrometer and open grid probe design, the MODEL CRM-510LP is highly suited for a wide range of radon measurement applications. Because of the low current requirements of the electrometer detector and on-board computer, the MODEL CRM-510LP is truly a portable self-contained continuous radon monitor that can read and store test data for eight days of stand-alone operation. In this "PASSIVE" mode of operation the MODEL CRM-510LP is uniquely suited for screening and follow-up type testing.

The full function computer system incorporated in the MODEL CRM-510LP provides the operator with a highly flexible radon detection instrument and data logger operating system, while still maintaining the simplicity of operation for which *femto*-TECH instruments are noted. In addition to the measurement and storage of radon data, the highly sophisticated on-chip peripheral capabilities of the micro controller (MCU) used in the CRM-510LP provide for the measurement and storage of temperature, barometric pressure, and relative humidity. This multidimensional data acquisition capability provides the tester with a unique data base for evaluating the validity of short term radon measurements. Some of the features offered by this unique combination of computer control and open grid pulsed ion chamber detector are:

REAL TIME RADON MEASUREMENTS  
AUTOMATIC TEST START DATE / TIME STAMP  
TEMPERATURE (°F or °C)  
BAROMETRIC PRESSURE ("Hg or kPa)  
RELATIVE HUMIDITY (%)  
CHOICE OF OPTIONAL PRINTERS  
GRAPHIC PRINTOUTS  
ALPHANUMERIC PRINTOUTS  
PASSIVE SAMPLING (no pump or filters)  
CHOICE OF UNITS (pCi/l or Bq/m<sup>3</sup>)  
BUILT-IN RS-232 INTERFACE PORT  
BUILT-IN PARALLEL PRINTER PORT  
LCD SCREEN DISPLAY  
PERMANENT EPROM BASED OPERATING SYSTEM  
EEPROM DATA STORAGE  
BUILT-IN UPLOAD SOFTWARE  
KEYED SECURITY LOCK  
ANTI-TAMPER MOTION (TILT) DETECTOR  
BUILT IN NUCLEAR PULSE SIMULATOR SELF TEST  
CONCEALED SCREEN TEST MODE

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## 4. Operation

### 4.1 Initial Set Up

Carefully unpack components from shipping package, inspect for damage, and insure that the following are included:

#### STANDARD EQUIPMENT:

<b>Quantity</b>	<b>Item</b>
1	CRM510LP Continuous Radon Monitor, with Certificate of Calibration
1	CRM510LP Instruction Manual
1	Key and Key tag
1	CRM510LP Carrying Case
1	Door Hanger

#### OPTIONAL PRINTER PACKAGE:

<b>Quantity</b>	<b>Item</b>
1	Parallel Printer
1	CRM510LP / Printer Interface Cable
1	Roll of Paper
1	AC Adaptor / Charger (if applicable)
1	Printer Manual or Instructions for Use

#### OPTIONAL PC UPLOAD PACKAGE:

<b>Quantity</b>	<b>Item</b>
1	CRM510LP / PC Interface Cable
1	CRM510LP / PC Upload Program CD

#### OPTIONAL MODEM PACKAGE:

<b>Quantity</b>	<b>Item</b>
1	Portable Modem and AC adaptor (if applicable)
1	CRM510LP / Modem Interface Cable
1	Modem Instructions
1	Telephone Cable—RJ11

Contact your dealer if any discrepancies are found.

Before attempting to operate the instrument, it is recommended that the user read the following CONTROLS and COMPUTER/DATA LOGGER sections of this manual as well as operation sections of the manuals supplied with any optional equipment and accessories that have been purchased. It is further recommended that the user perform practice tests to become familiar with the CRM-510LP, before carrying out actual field tests.

## 4.2. Controls

Operating the CRM-510LP is simplicity itself. The instrument panel consists of a **KEY SWITCH**, a **PRINT** pushbutton, and an **I/O** pushbutton. Because the CRM-510LP operates on only micro-amperes of current, the electrometer detector operates continuously obviating the need for a warm-up period. All other functions are controlled by the internal microcomputer. The functions of all CRM-510LP front panel controls are described below.

### CRM-510LP CONTROLS

#### KEY SWITCH:

<b>POSITION</b>	<b>FUNCTION</b>
OFF	All systems are inactive; software version displayed by pressing either pushbutton.
I/O	Minutes of stored data displayed on LCD screen. <b>[PRINT]</b> and <b>[I/O]</b> pushbuttons are active for data output control.
ON	Measurement units displayed on LCD screen. <b>[PRINT]</b> and <b>[I/O]</b> pushbuttons are active for UNIT SELECTION and START TEST commands.

#### **[PRINT]** Pushbutton (Left):

<b>MODE</b>	<b>FUNCTION</b>
Generic	Serves as ENTER key for executing selection on the LCD screen.
OFF	Ends test; displays software version.
I/O	Executes SUMMARY PRINT of stored data.
Run	Executes test initialization.

#### **[I/O]** Pushbutton (Right):

<b>MODE</b>	<b>FUNCTION</b>
Generic	Serves as SELECTION key for options shown on the LCD screen.
OFF	Displays software version.
I/O	Executes DOWNLOAD (RS-232 Port) of stored data.
Run	Scrolls LCD display (data or selection menus).

The keyswitch serves as a function indicator only. Power to the MCU remains on at all times. To conserve power, the display will be turned off if a pushbutton is not selected in a reasonable time. Pressing either button will wake the MCU to either continue or restart a selection.

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## 4.3. Computer / Data Logger

### 4.3.1. Description

The *femto*-TECH, INC. CRM-510LP Continuous Radon Monitor is a complete data acquisition system based on an internal microcomputer (MCU). All operator interaction is accomplished via easy to follow LCD screen prompted selections and push-button entered commands. Nearly all the features of the data logger program can be used immediately without extensive operator training, because responses are prompted by screen menus. Several types of information are used and/or stored by the MCU. The operating system and fixed parameters are stored in EPROM (Erasable programmable read only memory), whereas instrument settings which seldom need changing (such as units, calibration factor, background value, and serial number) are stored in an EEPROM (Electrically erasable programmable read only memory). Collected data are also saved in EEPROM and the timing/memory device and thus, are retained even when the CRM-510LP is powered down.

### 4.3.2. Run Mode

Description:

The RUN MODE is the data collection mode for the CRM-510LP instrument. In the RUN MODE the MCU reads and stores data from built-in radon and environmental sensors and displays current readings of these parameters on the LCD screen. Elapsed time in minutes; present radon concentration (Rate); average radon concentration, since reset; temperature; barometric pressure; percent relative humidity; and number of "tilts", since reset may be displayed in "real time" on the LCD screen. The MCU also monitors the status of the battery power systems and provides failure responses (See [BATTERY STATUS SECTION 4.3.6](#) for details). The "real time" data are printed in either pCi/l or Bq/m<sup>3</sup>. Selection of units for screen display and printouts can be made at the start of the test program and remain in effect during the total data collection period. However, summary printouts can be obtained in the I/O MODE in either unit set, regardless of the unit set used for the RUN MODE collection period (see [Appendix A](#) for example printouts). The units selected at the start of the test will be retained as the default during output.

Up to 8 days (192 hours) of accumulated hourly count interval data are stored. These data are stored in EEPROM and the timing/memory device and thus are retained even on power down of the CRM-510LP. In the event of a system failure for any reason during a test, all data collected prior to the failure point will be retained. Moreover, the CRM-510LP will continue to operate, and recalculate even after the data storage memory is full.

For tamper-proof security during a test, a key lock switch is provided. Screen security is also provided whereby only elapsed time can be viewed without entering a digital unlock code.



## Computation Algorithm:

To fully utilize all the functions of the CRM-510LP an understanding of some of the features of the computational algorithm is helpful. The elapsed time and total accumulated count data are collected, stored, displayed, and printed directly in units of minutes and counts, respectively. However, the present concentration data are computed using an algorithm based on a digital model of a rate meter. To insure statistical integrity of the readings and to dampen large swings in the "real time" display of the data, counts are collected and integrated using a first-in-first-out ten register stack with six a minute collection interval per register. This procedure insures that sufficient counts are collected so that statistical counting errors in the present concentration data do not exceed  $\pm 25\%$  (one sigma confidence level) for radon concentrations as low as 1 pCi/l.

Due to the above features, present concentration data will not reach a stable value for approximately one hour, after initial start-up. However, the accumulated average concentration data are computed and updated at one-tenth minute intervals and are immediately valid (within the counting statistical constraints of the radon level being measured). Thus, for the first hour of a test, the average concentration values are used to represent the "real time" or present concentration.

During the computations for both the present and average radon concentration, a correction of 0.075 CPM (0.3 pCi/l or 11 Bq/m<sup>3</sup>) background is applied to the data. The background value used in this computation is stored in EEPROM and can only be changed by procedures described in [Appendix F](#).

## **Operation:**

1. Turn on the CRM-510LP by turning the key switch to the RUN position. Remove the key, and press the [PRINT] pushbutton once. The screen will temporarily display "RUN;" the units used in the last test will then be displayed on the LCD screen.

(pCi/l, "Hg, °F),

or

(Bq/m<sup>3</sup>, kPa, °C)

If a "LOW BATTERY" message is displayed rather than the unit set, the batteries must be changed before the unit will run a test. Call *femto*-TECH for battery replacement.

2. At this point the user has the option of accepting the unit set being displayed or to change it by pressing the [I/O] pushbutton. The test will be performed in the units displayed on the screen, when step 4 below is executed.

3. Press the [PRINT] pushbutton once. This will display the current date.

4. A test is initiated by pressing both the [PRINT] and [I/O] pushbuttons. It is best to press and hold the [PRINT] pushbutton first, then press the [I/O] pushbutton and release both.

5. At this point the current time will display (in 24-hour format), then the unit will begin a self test of the detector circuitry, using an internal nuclear pulse simulator (N.P.S.). The self test will last approximately 30 seconds, with the LCD displaying:

SELF TEST ACTIVE

6. If successful, the screen will display:

PASSED SELF TEST  
TEST STARTED!  
COUNT        0

After a few seconds, the screen will go “go to sleep,” as a feature to extend battery life.

If, however, the screen displays

FAILED SELF TEST,

then goes blank, repeat the test initiation procedure again. If the unit once again fails, contact *femto*-TECH for technical assistance at (937)746-4427. Typical CAUSES of self test failures include electrometer upset due to rugged handling, high humidity conditions causing condensation (dewpoint), and very high ambient radon levels (over 100 pCi/l).

7. During the first six minutes of a test the security features (tilt and screen lock) are disabled to allow for operator setup. During this period the [I/O] pushbutton can be used to scroll through all seven data displays on the LCD screen. At the end of this six minute period, the screen locks to a blank display and the tilt transducer is activated, and remains active until the end of the test. The tilt transducer is designed for fixed position tests with the CRM-510LP in a level position.

8. After the first six minutes of a test, a digital code must be entered to unlock the screen for viewing the parameters other than elapsed time (See [DIGITAL COMBINATION SCREEN LOCK SECTION 4.3.4](#) for details).

9. The CRM-510LP will continue to collect data until the test is terminated by the exit procedure below. However, only the first 192 hours (8 days) of the test data will be saved in EEPROM.

10. To terminate a test, simply turn the key switch to the OFF position, and press either the [PRINT] or the [I/O] pushbutton. The accumulated data will be retained as long as a new test is not initiated. However, when a new test is initiated, the previous data are cleared. Therefore, a test cannot be resumed once terminated.

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### 4.3.3. Real Time Set Mode

Description:

The current date and time are stored in the computer's "Clock in a Can" (CIC). If, for some reason the time must be changed (i.e. beginning/ending Daylight Savings Time, or change of time zone), the CRM510LP has a feature allowing the user to do so. The unit must have no test (less than 1 hour of data) in its memory. To clear the memory, start a test; after the screen displays "TEST STARTED!" and goes blank, immediately end the test (see previous section).

Turn the keyswitch to the I/O position, and press the [PRINT] pushbutton. The screen will display

TIME 0 MIN.,

then

NO DATA TO PRINT

As soon as either display appears, turn the keyswitch to the RUN position. The screen will then display the time in the MCU's memory. Use the [PRINT] pushbutton to scroll up through the hours (military time), and the [I/O] pushbutton to scroll up through the minutes. After the correct time is displayed, immediately turn the keyswitch off to secure the time.

### 4.3.4. Digital Combination Screen Lock

Description:

A built in screen security feature prevents unauthorized personnel from access to test parameters and results. After the initial operator setup period (6 minutes), the screen display defaults to the "sleep" (blank screen) mode and access to the other data display modes can only be obtained by entering a digital combination code.

Operation:

1. To unlock the screen scroll, press the [I/O] pushbutton once. The following screens should be displayed:

TIME XX MIN.,

then

0123456789

2. Move the blinking cursor to the right by pressing the [I/O] pushbutton until it is on the first digit of the code to be entered (5).

0123456789

3. Enter the first digit (5) by pressing the [PRINT] pushbutton. The cursor will return to the zero digit position upon a successful enter and you can proceed with the second code entry.

0123456789

4. Move the blinking cursor to the right by pressing the [I/O] pushbutton until it is on the digit of the second code to be entered (1).

0123456789

5. Enter the second digit code (1) by pressing the [PRINT] pushbutton. If the correct code has been entered, the count data display will come up on the screen. However, if an incorrect code or if too much time (> 6 seconds) occurs between commands, the screen will return to the locked blank display.

6. Once the screen display is unlocked, the [I/O] key can be used to scroll through all seven data displays on the LCD screen. However, the scroll does not "wrap around" as in the setup period and it locks on the blank at the conclusion of one scroll cycle. The unit will display:

COUNT	X
RATE	.X pCi/l
AVG	.X pCi/l
TEMPERATURE	XX ° F
B/P	XX.X " Hg
TILTS	X

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#### 4.3.5. I/O Mode

Description:

The CRM-510LP Continuous Radon Monitor has two built-in printer driver programs that provide a wide range of options for hard copy of the data collected and stored. Besides supporting the alphanumeric and graphic printers carried as accessories to the CRM-510LP by *femto*-TECH, INC., "generic" printer and graphic dot plotter drivers are included for use with user supplied peripherals.

Operation:

1. With the power off for both the CRM-510LP and the printer, make the interface connections required for the selected printer (consult the appropriate Appendix in this manual and/or the printer instruction manual for connection and cable details).
2. Turn the CRM-510LP key switch to the I/O position and turn the printer on. Press the [PRINT] pushbutton once, and the minutes of stored data are displayed on the LCD screen.

(TIME XXXXX min)

3. To initiate a printout, press the [PRINT] pushbutton once. At this point, the current unit selection is displayed on the LCD screen and the [I/O] pushbutton is used to toggle between the unit selections for the printout.
4. Press the [PRINT] pushbutton again to execute unit selection. At this point the word "TABLE" is displayed on the LCD screen and the [I/O] pushbutton is used to choose from a menu of printout formats and data review options.
5. If the [PRINT] pushbutton is pressed while the "REVIEW DATA" message is displayed on the LCD screen, a summary of the collected test data can be reviewed on the screen using the [I/O] pushbutton to step through the different parameters. Press the [PRINT] pushbutton to exit the data review and return to the selection menu of step 4 above.
6. Press the [PRINT] pushbutton to select the printout format displayed on the LCD screen. At this point, "USE ALL DATA" will be displayed on the screen. Pressing the [PRINT] pushbutton will execute printing. If, however, the test was started under open house conditions, the user may instead press the [I/O] pushbutton. This will display "SKIP 1ST 12 HOURS" on the LCD screen, and the computer will recalculate the test, eliminating the first twelve hours from calculations. Keep in mind that the US EPA protocol test must have a minimum 44 hours of contiguous data. All hours of data will be printed, but the first twelve hours will have three asterisks printed in the hour column to signify that those hours' values were not used in the average radon concentration calculation.

The last test is retained memory until a new test is started. As many tests as desired may be printed, in as many printing formats available, until a new test is begun.

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#### **4.3.6. Battery Status**

The CRM-510LP has two separate built-in battery power sources - the radon detector and electrometer are powered by a 9 volt carbon zinc/ alkaline battery pack, and the microcomputer, display, and I/O interfaces are powered from a lithium battery pack. Test circuitry is built into the CRM-510LP to provide the operator with information on the charge level of both battery systems. The **BATTERY LED** will flash if the remaining charge in the microcomputer battery drops below that needed to sustain a 48 hour test. A test in progress is not jeopardized and may be continued for up to 48 hours. However, the computer will not allow a test to be initiated from the RUN key switch position and displays a **LOW BATTERY** message on the LCD screen, if a test is attempted with less than 48 hours of battery power supply available. If the battery discharges below the minimum voltage for the microprocessor to operate, an under voltage sensor holds the microprocessor in a reset state.

The status of the electrometer battery system is also checked by the microcomputer. If the charge on the electrometer battery drops to a point where the calibration factor of the radon detector could be affected, the computer in the CRM-510LP will not allow a radon test to begin. If a radon test is attempted from the RUN key switch position, a **LOW BATTERY** message is displayed on the LCD screen and test start-up is inhibited. If the computer detects a low

electrometer battery condition during a test, a low battery flag is set in the collected data and the condition indicated in the printed test summary.

The user may check the battery voltages with no test running, and the keyswitch in the “OFF” position, by pressing and releasing the [PRINT] key, waiting for software revision to appear, and pressing and releasing the [PRINT] key again while the message is displaying. The various battery voltages will then briefly display.

The three typical results would be:

LI	batt.	= 72
ELE	batt.	= 93
FLD	batt.	= 27

The numbers would represent the lithium batteries at 7.2 volts, the electrometer battery at 9.3 volts and the field batteries at 27 volts.

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## **4.4. Environmental Sensors**

The CRM-510LP has built-in environmental sensors for measuring temperature, barometric pressure, and relative humidity during a radon test. These sensors have been incorporated in the CRM-510LP to measure environmental parameters that effect the interpretation of short term radon analyses. The variation of these parameters, during a radon analysis, provides information that can be used to judge whether a test has been compromised by environmental conditions. Although the span and scale settings for these sensors are adjusted during manufacturing to agree with precision laboratory instruments, their measurement data should be used as qualitative time varying information only. The MCU reads and processes the information from the environmental sensors every six minutes and saves their hourly averages along with the hourly radon readings

### **4.4.1. Temperature**

Temperature is measured with a thermistor transducer situated inside the CRM-510LP cabinet. The CRM-510LP MCU digitizes and processes the analog signals from the temperature transducer for display and storage in units of °F or °C.

### **4.4.2. Barometric Pressure**

The barometric pressure is measured with a differential pressure transducer referenced to vacuum. The CRM-510LP MCU digitizes and processes the analog signals from the pressure transducer for display and storage in units of "Hg or kPa. The pressure measured by the CRM-510LP is the actual atmospheric pressure at the test location (Station Pressure). This will correspond to the "Barometric Pressure" reported by local weather stations, only if your elevation happens to be mean sea level (MSL). If required, the CRM-510LP MCU can be programmed to apply a MSL adjustment to the pressure measurements (See [APPENDIX F](#)).

### **4.4.3. Relative Humidity**

Relative humidity is measured with a capacitance transducer situated inside the CRM-510LP cabinet. The CRM-510LP MCU digitizes and processes the analog signals from the capacitance transducer for display and storage in units of percent relative humidity.

### **4.5. RS-232 Interface**

The CRM-510LP has a built-in RS-232 serial port for interfacing with computers, modems, and other peripheral devices. The key switch should be in the OFF position when making connections to the RS-232C plug. The serial data output is from pin 22 on the rear 25 pin connector, since this connector also provides a simplified Centronics parallel output. Thus, a standard 25 pin to 9 pin cable available from computer parts stores **WILL NOT WORK**, and a custom cable is required. Contact *femto*-TECH for answers on the use of the RS-232 interface, or see [Appendix F](#) for details.

### **4.6. Parallel Printer Interface**

The CRM-510LP also contains an 8 bit simplified Centronics (Registered trademark of Centronics Corporation) interface on the same DB-25 connector on the back panel. This is useful for connecting to a variety of low cost printers. This may also require a custom cable; see Appendix F for details of the connector. The parallel interface provides data for printers that use the Epson/ Seiko escape sequence printer command set. Other command sets such as for Hewlett-Packard Laserjets and Deskjets or IBM printers will not work. The data printed for the TABLE may not work on some printers since it only contains printable ASCII characters with each line terminated with a carriage return.

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## **5. Radon Monitoring**

### **5.1. Method**

The *femto*-TECH CRM-510LP is a continuous radon monitor (CRM) employing passive diffusion sampling of the ambient air environment in which it is situated. Radon decay products are electrostatically removed and prevented from entering the internal pulsed ion sensing volume. As a radon atom decays within the sensing volume of the chamber, a "burst" of ions is produced and is converted to electrical pulses in an electrometer. These pulses are counted, stored, and converted to pCi/l or Bq/m<sup>3</sup> by the computer/data logger. The CRM must be calibrated in a known radon environment to obtain the conversion factor used to convert to radon concentration.

## **5.2. Measurements**

Reliable and reproducible measurements of indoor radon levels require considerable care and knowledge and this instrument should be used in accord with the measurement protocols described in the United States Environmental Protection Agency document: EPA 520/1-89-009 (Or any revision to this document).

In addition to the general protocol documentation referenced above, *femto*-TECH, INC. provides instrument specific test procedures for use with their various radon detection instruments. A document titled "INSTRUCTIONS FOR PERFORMING SCREENING-TYPE MEASUREMENTS WITH A CRM-510 CONTINUOUS RADON MONITOR" is furnished as a supplement to this instruction manual. Additions and revisions to this document or new documents pertinent to the application of the CRM-510LP RADON MONITOR will be sent to registered owners as they are published.

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## **6. Maintenance**

### **6.1. Calibration**

The factor relating counts per unit time and radon concentration is a consequence of the structural and electronic design of the CRM-510LP and only small variations between different production units have been observed. Never-the-less, each unit is compared against a set of "master" units calibrated in a radon chamber at a U.S. Department of Energy Laboratory and the conversion factor verified before shipping. If a user application demands greater accuracy, direct calibration of the unit at a radon chamber facility is required.

To insure continued confidence in the accuracy of your instrument, it is recommended that a calibration be performed at least once a year. *femto*-TECH, INC. provides a maintenance service which includes replacement of all replaceable batteries, any needed electrometer adjustments, and a radon chamber calibration against a "master" unit (call for current price schedules for maintenance, calibration, and background determination service rates).

### **6.2. Background**

The pulsed ion counter detector in the CRM-510LP discriminates against all ionizing radiation other than airborne alpha. Therefore, environmental gamma radiation or intrinsic ions are not sources of background as with most other types of detectors. However, progeny plate-out on the detector surfaces can result in a slow build-up of an alpha radiation background from Polonium-210. This background builds at a rate of approximately  $3 \times 10^{-5}$  CPM per day of exposure at 1 pCi/l radon. Thus, background build-up is insignificant when the CRM-510LP is used in applications where exposures are generally less than 100 pCi/l. However, if the CRM-510LP is used extensively in diagnostic applications where relatively high level radon exposures



are common (100 pCi/l or more), the instrument background should be checked after every 1000 hours of use.

Background determinations can be carried out using outdoor air or air supplied from a compressed gas cylinder that has been "aged" for at least thirty days. The "aged" air source is preferred because outdoor air can contain detectable quantities of radon. A background determination can be performed by placing the CRM-510LP in an air tight enclosure or plastic bag. Flow the background gas through the enclosure or bag for at least six hours. Discard the first three hours of data and calculate the average CPM and/or pCi/l for the remaining hours of the test. If the measured background is greater than 0.3 pCi/l, the amount over 0.3 pCi/l should be subtracted from any measurements taken with this instrument. It is advisable to have the detector assembly replaced in any instrument that has a background over 1 pCi/l. Call femto-TECH for price schedules on this service.

### **6.3. Battery Replacement**

The battery packs in the CRM510LP unit are custom build and are not meant to be user serviceable. Please contact *femto*-TECH for battery replacement.

## **7. Warranty**

*femto*-TECH, INC. warrants this product to be free of defects in workmanship and materials, and to perform per published specifications for a period of one year from shipping date, providing the unit has been properly stored, handled, and used within the specified environmental limits. This warranty is limited to repair or replacement at *femto*-TECH's option. Buyer assumes responsibility to apply *femto*-TECH, INC. products with due regard to safety where personal injury, death, or property loss is concerned, and *femto*-TECH, INC. and its employees accept no responsibility for these or other consequences. *femto*-TECH, INC. recognizes no other warranty policy than this policy as stated.

## **8. Repair Policy**

If this unit becomes defective due to workmanship or materials at any time within one year of purchase, return this unit to the distributor or dealer from whom the unit was purchased along with proof of purchase (Sales slip, invoice, or receiving slip copy), for repair or replacement.

If the unit becomes defective beyond the one year warranty period, or was damaged due to physical abuse or attempts to operate the unit beyond its environmental specification limits, warranty repair or replacement does not apply. However, *femto*-TECH, INC. maintains a repair service which can repair and return your damaged unit in proper operating condition. For current service charges call (513) 746-4427 between the hours of 9 AM and 4 PM (EST), or send email to [femtotch@aol.com](mailto:femtotch@aol.com) with a subject line as Service Request, and include the company name, your name, unit serial number, telephone number and email address in the message body.

## APPENDIX A

### OPTIONAL DPU-201G THERMAL PRINTER OPERATION

Before using the DPU-201G printer with the *femto*-TECH MODEL CRM-510LP radon monitor, it is recommended that you read pages 1 through 12 of the DPU-201G INSTRUCTION MANUAL. Once you are familiar with the operation of the printer, turn off both the DPU-201G and the CRM-510LP, and connect the two components using the cable supplied with the DPU-201G printer option. The FEMALE DB-25 end of the cable should be connected to the output port on the CRM-510LP and the MALE 14 pin end to the parallel input port on the DPU-201G.

Running DPU-201G Print Software:

1. Make certain the test has ended: turn the keyswitch in the OFF position, and press and release the [PRINT] pushbutton once. The display should read "Software Rev XXX" if the test had previously stopped, or "TEST ENDED!" if had still been running; the unit, in either situation, is now ready to print out.
2. Turn CRM-510LP key switch to the I/O position and press and release the [PRINT] pushbutton once. The number of minutes of stored data is displayed on the LCD screen.
3. Turn printer on.
4. To initiate a printout on the DPU-201G, press the [PRINT] pushbutton once. At this point, the current unit selection is displayed on the LCD screen and the [I/O] key is used to toggle between the unit selections for the printout (pCi/l and Imperial, or Bq/m<sup>3</sup> and metric).
5. Press the [PRINT] pushbutton again to execute unit selection. At this point the word "TABLE" is displayed on the LCD screen and the [I/O] pushbutton is used to choose from a menu of printout formats and data review options (Table, Graph, and Review Data).
5. If the [PRINT] pushbutton is pressed while the "REVIEW DATA" message is displayed on the LCD screen, a summary of the collected test data can be reviewed on the screen using the [I/O] pushbutton to step through the different parameters. Press the [PRINT] pushbutton to exit the data review and return to the selection menu of step 4 above.
6. The screen should now display "Print All Data." Press the [PRINT] pushbutton to print the entire test. If open house conditions were encountered at the start of the test, the user has the option of deleting the first twelve hours of the test. Press and release the [I/O] pushbutton, and the screen will display "Skip First 12 Hours." Press the [PRINT] pushbutton to print out the test. The first twelve hours of the test will be printed, but will be marked by double asterisks instead of hours, and NOT calculated in the final average at the bottom of the printout.
7. At the conclusion of a printout, turn off the power on the printer, and turn the CRM-510LP key switch to the OFF position, before disconnecting the printer.

Examples of both "TABLE" and "GRAPH" format versions of radon test reports from a 42 hour measurement with a CRM-510 are presented in [Figure 1](#) (page 20). In both formats a header is printed with lines for test information to be entered by the operator. The instrument serial number, calibration factor, and background are also printed in the report headers and test summaries of total time, total counts, and average concentration are printed at the end of both report formats. In the "TABLE" format seven columns of hourly data are printed for the radon concentration, the tilt status (/), the low battery warning (LB), the relative humidity, the atmospheric pressure, and the temperature.

The same 42 hour data set printed in "GRAPH" format is shown on the right in Fig. 1. The plot is scaled to provide maximum resolution for each of the plotted parameters. The scale values and a plot key for each of the parameters are printed in the header along the horizontal axis of the graph. Relative humidity and low battery warning are not available in the "GRAPH" format printouts.

[Figure 2](#) (page 21) presents a printout of the "Skip First 12 Hours" option (see step 6); [figure 3](#) (page 23) presents a printout in the Bq/m<sup>3</sup> – metric format (see step 4).

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## **APPENDIX B**

### **OPTIONAL DPU-H245 THERMAL PRINTER OPERATION**

Print operation for the DPU-H245 Printer is the same as the DPU-201G. However, the DPU-H245 has the ability to run on either battery power or AC power, whereas the DPU-201G does not have true AC operation; it simply runs on battery power as it is being charged. Special instructions for DPU-H245 charging, battery and AC operations are:

#### ***Important Notes on Operating Your DPU-H245 Printer***

1. The printer will not operate while in "CHARGE" mode. If the printer battery is low, the AC adaptor may be used as a power supply instead of as a battery charger by simply the adaptor into a wall outlet.
2. To use the adaptor as a battery pack charger, plug the adaptor into a wall outlet. Turn the printer on, and press the "CHARGE" button for about three seconds, then release. The "ERROR" and "POWER" lights will alternate flashing to indicate charging is in process. When the battery pack is completely charged, the "ERROR" light will turn off and the "POWER" light will stay on solid. At this point, turn the power switch off.
3. **DO NOT attempt to remove the adaptor connected to the DPU-H245 printer.** The DPU-H245 printer and its adaptor have a reverse polarity and a different voltage than other *femto*-TECH, INC. instruments. Any attempt to use an adaptor from other *femto*-TECH instruments, printer or data loggers will damage this printer, and its adaptor will damage all other *femto*-TECH instruments and printers.

## Switch and Lamp Functions

Name	Function
Power Switch	Printer power On / Off
Feed Switch	Paper Feed (Paper is fed while this switch is pressed.)
Charge Switch	The internal battery starts charging when this switch is pressed for 3 seconds when using the AC adaptor.
Power Lamp	Lights when the power is ON (green LED) Blinks when the internal battery level becomes low.
Error Lamp	Lights when the paper cover is open Blinks when there is no paper.

1. Test printing.  
Test printing starts when the power switch is set to ON while pressing the FEED switch.
2. HEX dump printing.  
The HEX dump mode is entered by setting the power switch to ON while pressing the CHARGE switch. In the HEX dump mode, the input data is printed in hexadecimal.
3. Selecting function setting mode.  
The function setting mode is entered by setting the power switch to ON while pressing simultaneously the FEED switch and the CHARGE switch.
4. Selecting the charge mode.  
Charging begins when the AC adaptor is connected, the unit power switch is on, and the CHARGE switch is pressed for 3 seconds.
5. Lamp status display.  
The following table shows the various LED display statuses. □ indicates ON of a LED for 0.5 seconds. ■ indicated OFF of a LED for 0.5 seconds.

Example: □■■■□■■■ indicates the blinking status of a LED that alternately lights for 0.5 seconds and goes out for 1.5 seconds.

Power switch	Status	LED Status
	No Error (printing enabled)	Power <span style="color: green;">□□□□□□□□□□</span> Error <span style="color: black;">■</span>
	Error (no paper)	Power <span style="color: green;">□□□□□□□□□□</span> Error <span style="color: red;">□□■□□■□□■□■</span>
	Error (cover open)	Power <span style="color: green;">□□□□□□□□□□</span> Error <span style="color: red;">□□□□□□□□□□</span>
	Low Battery	Power <span style="color: green;">□□■□□■□□■□■</span> Error <span style="color: red;">□□□□□□□□□□</span>
	Hardware Error	Power <span style="color: green;">□■□■□■□■□■</span> Error <span style="color: red;">□■□■□■□■□■</span>
	Charging (returns to original status when charging is completed.)	Power <span style="color: green;">□■□■□■□■□■</span> Error <span style="color: red;">■□■□■□■□■□■</span>
	Test print	Power <span style="color: green;">□□□□□□□□□□</span> Error <span style="color: red;">□□□□□□□□□□</span>
	HEX dump print	Power <span style="color: green;">□□□□□□□□□□</span> Error <span style="color: black;">■</span>
	Function setting mode	Power <span style="color: green;">□□□□□□□□□□</span> Error <span style="color: red;">□□□□□□□□□□</span>
	OFF	Power OFF

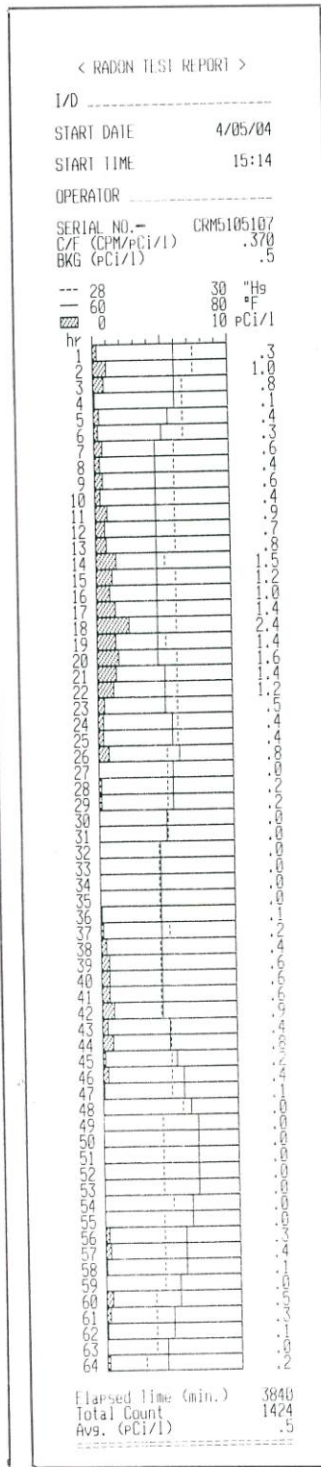
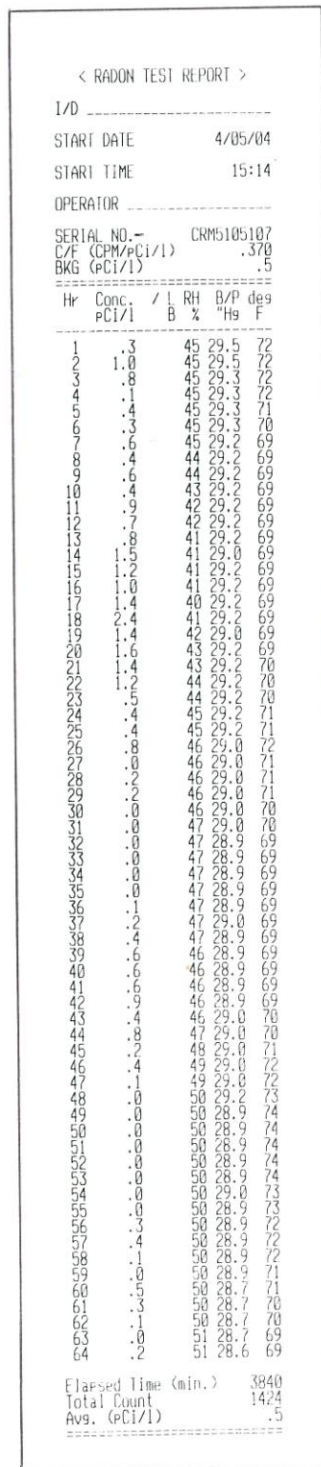


Fig. 1 EXAMPLE CRM510LP RADON TEST REPORTS, pCi/l.

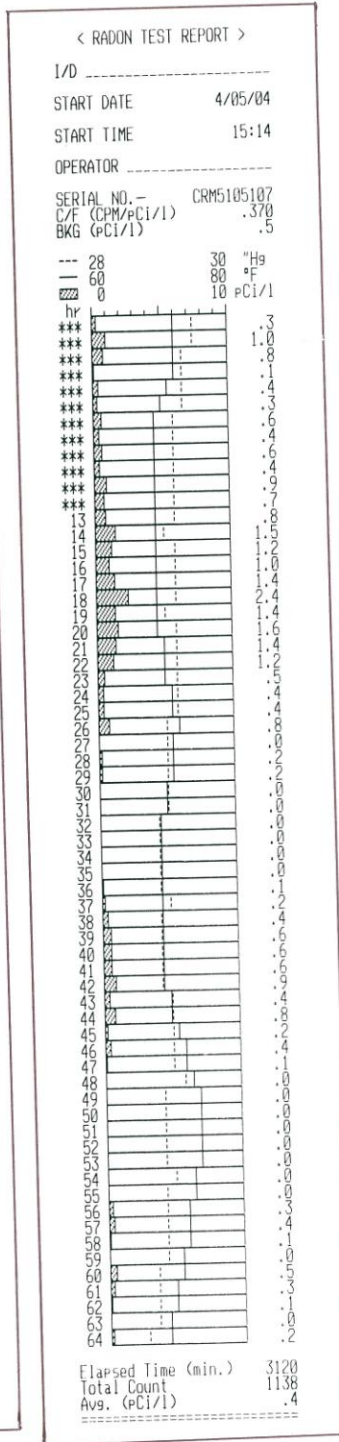
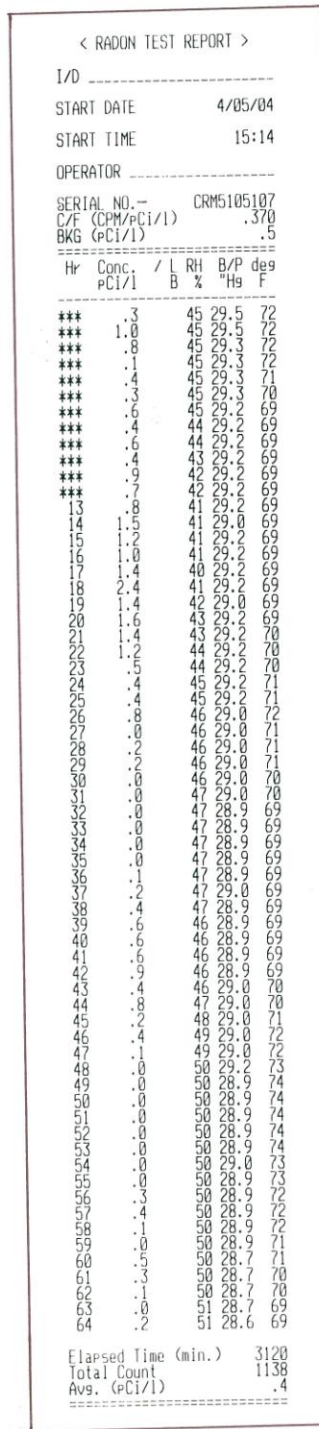


Fig. 2 PRINTOUTS OF "SKIP FIRST 12 HOURS" OPTION

< RADON TEST REPORT >

I/D \_\_\_\_\_

START DATE 4/05/04

START TIME 15:14

OPERATOR \_\_\_\_\_

SERIAL NO. - CRM5105107  
 C/F (CPM/Bq/M3) .00010  
 BKG (Bq/M3) 18

---

Hr	Conc. Bq/M3	L RH B %	B/P kPa	deg C
1	11	45	100	22
2	38	45	100	22
3	33	45	99	22
4	5	45	99	22
5	16	45	99	21
6	11	45	99	21
7	23	45	99	20
8	15	44	99	20
9	23	44	99	20
10	15	43	99	20
11	36	42	99	20
12	26	42	99	20
13	29	41	99	20
14	57	41	98	20
15	44	41	99	20
16	38	41	99	20
17	54	40	99	20
18	90	41	99	20
19	54	42	98	20
20	61	43	99	20
21	52	43	99	21
22	46	44	99	21
23	21	44	99	21
24	15	45	99	21
25	15	45	99	21
26	29	46	98	22
27	0	46	98	21
28	8	46	98	21
29	8	46	98	21
30	3	46	98	21
31	1	47	98	21
32	0	47	98	20
33	0	47	98	20
34	1	47	98	20
35	1	47	98	20
36	6	47	98	20
37	8	47	98	20
38	15	47	98	20
39	23	46	98	20
40	24	46	98	20
41	24	46	98	20
42	36	46	98	20
43	16	47	98	21
44	33	47	98	21
45	10	49	98	21
46	15	49	98	22
47	5	49	98	22
48	1	50	99	22
49	1	50	98	23
50	1	50	98	23
51	0	50	98	23
52	0	50	98	23
53	0	50	98	23
54	0	50	98	22
55	0	50	98	22
56	11	50	98	22
57	16	50	98	22
58	0	50	98	22
59	0	50	98	21
60	21	50	97	21
61	13	50	97	21
62	5	50	97	21
63	0	51	97	20
64	10	51	97	20

Elapsed Time (min.) 3840  
 Total Count 1424  
 Avg. (Bq/M3) 18

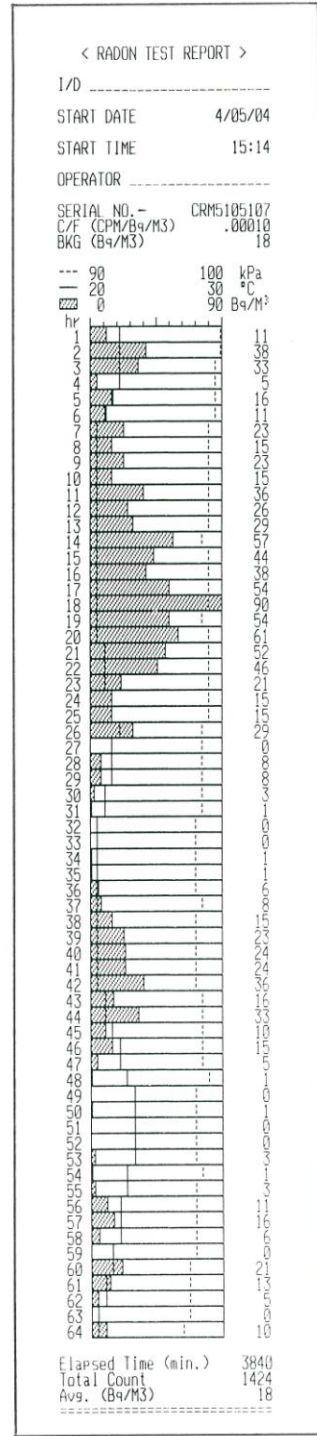


Fig. 3 EXAMPLE CRM510LP RADON TEST REPORTS, Bq/m<sup>3</sup>

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< RADON TEST REPORT >

I/D \_\_\_\_\_

START DATE 4/05/04

START TIME 15:14

OPERATOR \_\_\_\_\_

SERIAL NO. - CRM5105107  
 C/F (CPM/Bq/M3) .00010  
 BKG (Bq/M3) 18

---

Hr	Conc. Bq/M3	/ L B	RH %	B/P kPa	deg C
1	11		45	100	22
2	38		45	100	22
3	33		45	99	22
4	5		45	99	22
5	16		45	99	21
6	11		45	99	21
7	23		45	99	20
8	15		44	99	20
9	23		44	99	20
10	15		43	99	20
11	36		42	99	20
12	26		42	99	20
13	29		41	99	20
14	57		41	98	20
15	44		41	99	20
16	38		41	99	20
17	54		40	99	20
18	90		41	99	20
19	54		42	98	20
20	61		43	99	20
21	52		43	99	21
22	46		44	99	21
23	21		44	99	21
24	15		45	99	21
25	15		45	99	21
26	29		46	98	22
27	0		46	98	21
28	8		46	98	21
29	8		46	98	21
30	3		46	98	21
31	1		47	98	21
32	0		47	98	20
33	0		47	98	20
34	1		47	98	20
35	1		47	98	20
36	6		47	98	20
37	8		47	98	20
38	15		47	98	20
39	23		46	98	20
40	24		46	98	20
41	24		46	98	20
42	36		46	98	20
43	16		46	98	21
44	33		47	98	21
45	10		48	98	22
46	15		49	98	22
47	5		49	98	22
48	1		50	99	22
49	0		50	98	22
50	1		50	98	23
51	0		50	98	23
52	0		50	98	23
53	3		50	98	23
54	1		50	98	22
55	3		50	98	22
56	11		50	98	22
57	16		50	98	22
58	6		50	98	22
59	0		50	98	22
60	21		50	97	21
61	13		50	97	21
62	5		50	97	21
63	0		51	97	20
64	10		51	97	20

Elapsed Time (min.) 3840  
 Total Count 1424  
 Avg. (Bq/M3) 18

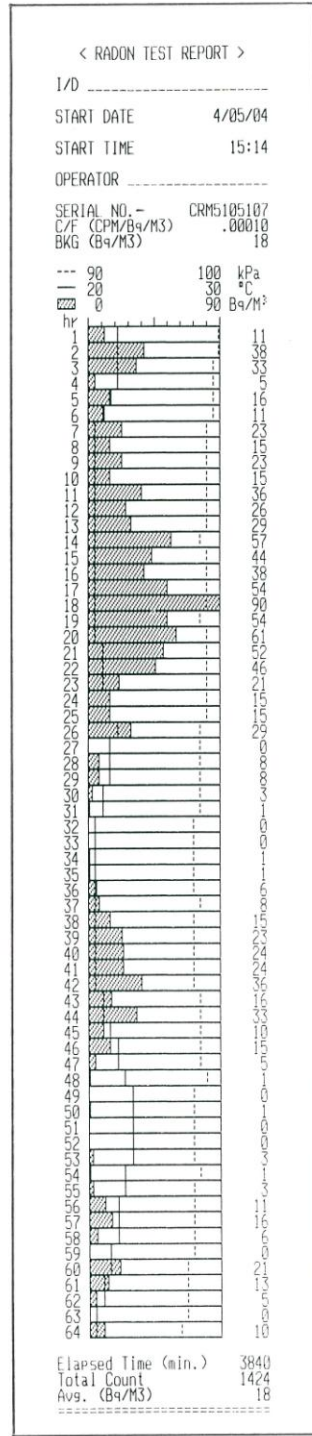


Fig. 4 EXAMPLE CRM510LP CARBON MONOXIDE TEST REPORTS

## APPENDIX C

### *femto*-TECH UPLOAD SOFTWARE

This section provides system requirements, instructions to install this program, a quick description of what it does and quick instructions on how to use the software to retrieve data from a unit. This section can also be found as the ReadMe.txt file on the download software CD.

#### System Requirements:

This program should install to any Win95 computer or greater with at least 10MB of hard drive space. To communicate with a *femto*-TECH radon monitor you will need an available COM port with the port number in the range of 1 to 4 and the serial cable provided with the unit.

#### Directions for Software Installation:

Insert the *femto*-TECH download software CD into your computer CD-ROM drive and the setup program should run automatically. If it does not run automatically, use your file browser and surf to the CD-ROM drive that the *femto*-TECH download software is in and double click the setup.exe file.

The setup.exe installation program will guide you through the rest of the process.

After completing the install process, choose your system settings before trying to retrieve any data from a *femto*-TECH radon monitor. To do this, start the program and click the 'View' menu option and then the 'System Settings' option.

#### Program Operations

The primary purpose of this program is to retrieve data from a *femto*-TECH radon monitor, store the data to your computer, and generate reports for both the technician and the customer. This program also allows the user to regenerate a report using the stored data retrieved from a *femto*-TECH radon monitor.

Each time new data is retrieved from a *femto*-TECH radon monitor, three files are created. The first file is the raw data from the unit stored in a .raw file. The second file is the technician report stored in a .tech file. And the third file is the customer report stored in either a .txt or .doc file depending on which file format you choose in 'System Settings'.

There is an example of each of the files created in the \Reports directory under the directory the application was stored in. All files, except .doc files viewed by Microsoft Word, can be viewed from a simple text editor such as NotePad.exe. The files are designed to be viewed with courier size 10 font.

## Using the Program:

### 1. Start Program:

To start the program, navigate to the program icon in your start menu and click it.

### 2. Change System Settings:

To see or change your system settings, click the 'View' menu option and then click 'System Settings'. Edit the window as needed and click 'Save' to store the data.

### 3. Receive Data:

To retrieve data from a *femto*-TECH radon monitor, click the 'File' menu option and then click 'Receive Data.'

### 4. The program will next ask you to specify a pathname for the report (i.e., street address, customer name, file number).

### 5. A **RECEIVE DATA** window will now appear. Turn the CRM510's keyswitch to the I/O position, and press and release the [I/O] button once. The LCD will display:

**TIME XX MIN.**

Press and release the [I/O] button again, and the LCD will display:

**BEGIN UPLOADING,**

then display:

**USE ALL DATA**

Press release the [PRINT] button once, and the **RECEIVE DATA** screen will begin checking off the STATUS column as items are completed. When "Complete!" is finally checkmarked, click on OK, turn the CRM510's keyswitch off, and disconnect it from your computer.

### 6. Viewing Data.

On the femto-TECH window, click on the 'View' menu option, and click 'Report Directory.' Three files will have been generated for each test: A RAW file (unformatted data), a TECH file (test data in a viewable table format), and a Word or Wordpad file (a sample report document). If you have a Radon/Carbon Monoxide instrument, three additional files will also be generated for the CO test.

## Questions?

If you have any questions, please call *femto*-TECH, INC. at (937) 746-4427 or email to [femtotch@aol.com](mailto:femtotch@aol.com). This information is also listed in the program. To access this information, Click the 'Help' menu option and then click the 'About' option.

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## **APPENDIX D**

### **OPTIONAL CARBON MONOXIDE DETECTION**

The *femto*-TECH, INC. CRM-510LP can include an internal a carbon monoxide sensor. The CRM-510LP reads and stores the hourly average carbon monoxide (CO) levels in addition to the standard radon, barometric pressure, temperature and humidity levels (for up to 192 hours). The data output provides a selection of either the "RADON REPORT" or the "CO REPORT" in either TABLE or GRAPH mode (on a DPU-201G or DPU-H245). Radon and CO levels can be obtained by printing both reports (data for radon and CO are retained until a new test is initiated). The "RADON REPORT" graphs radon, barometric pressure and temperature while the "CO REPORT" graphs CO, barometric pressure and temperature. Humidity results are only available using the "TABLE" output of the reports. A summary of the duration in minutes of the test and the average of the radon or carbon monoxide for the test period is provided at the bottom of the report. [Figure 4](#) (page 23) presents sample CO printouts.

Printing out a CO test on the DPU-201G or DPU-H245 Printer:

1. Follow the first three steps of applying to your specific printer.
2. At this point, the screen will display "RADON REPORT." To print out a radon report, proceed to step 4 of Appendix A.  
To print out a CO report, press the [I/O] button once, and the display will change to "CO REPORT." Proceed to step 4, [Appendix A](#).

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## APPENDIX E

### OPTIONAL MODEM OPERATION

The CRM-510LP can be purchased with software and hardware that provide for uploading data files to a host computer via a telecommunications link. The data transfer link consists of modem driver software and hardware built into the CRM-510LP and a direct connect modem on the upload end of the connection and a "HOST" computer with a modem and communications software on the download end of the connection. All software and hardware required for the upload side of the link is furnished with the *femto*-TECH, INC. CRM-510LP MODEM I/O OPTION. *femto*-TECH, INC. also furnishes "example" download software for use on IBM or IBM compatible personal computers. The user must supply the necessary hardware and communications software to establish a "turnkey" download capability at the "HOST" computer end of the link. However, *femto*-TECH, INC. will furnish source code files for the example programs and technical support to assist users in developing their specific download system.

#### MODEM I/O MODE (CRM-510 DATA FILE UPLOAD)

##### Description:

When the optional MODEM I/O software and hardware are installed, a radon test data set can be transmitted via a telecommunications link with nearly the same ease as performing a local printout of data from the CRM-510LP. The built-in communications software performs all the local modem configuration, dialing, connect verification, password/handshake exchange, file transmission, and transmission verification functions with a minimum of operator input required. The CRM-510LP modem driver routines use standard AT command codes and recognize numerical result codes from the modem. Prompting and response messages are displayed on the CRM-510LP LCD at each stage of the communication. If the modem and connecting cable were purchased from *femto*-TECH, INC., two simple connections to the CRM-510LP and the phone line are all that you will need to perform a file upload. The modem must be connected to a private line and should not be connected to a party, call waiting, or coin-operated telephone line. If a user-furnished modem is being used, a special cable adapter must be prepared using the pin-out configuration for your modem and that given in this manual for the CRM-510LP I/O PORT ([APPENDIX F](#)). Also the MODEM MODE jumpers described in APPENDIX F must be installed on the CRM-510LP side of the cable connector. It is recommended that only individuals with experience in this type of communication hardware attempt to interface a user supplied modem to the CRM-510LP. Moreover, modem manufacturers take certain liberties with the AT and RS-232 conventions which could make it difficult to establish a reliable interface for this application.

## **MODEM UPLOAD PROCEDURE**

With the power off make the interface connections between the CRM-510LP and the modem and insert the modem's telephone cable into a telephone outlet. Once the hardware connections have been made, a file transfer is performed following the procedure described below.

1. Turn the Keyswitch to the I/O position; press and release the [I/O] button once. The LCD will display:

TIME XX MIN.,

2. Press and release the [I/O] button again, and the display will show:

USE ALL DATA

3. Press and release the [PRINT] button to accept this, and

OK

will display, then the preprogrammed phone number will display.

X,XXX-XXX-XXXX

4. Press and release the [I/O] button once, and the modem will dial out. If a connection is made, the LCD will display, in order:

CONNECT 2400  
TRANSMITTING  
FILE RECEIVED.

5. Press and release the [I/O] button one final time, and the LCD will display:

ON HOOK.

6. Turn the keyswitch to the OFF position, then turn off the power to the modem (if applicable).

Note 1. The RESPONSE/ (DISPLAY) sequence shown is for a successful upload session between the CRM-510LP and a HOST computer. If all hardware is operating properly and a successful password/handshake has been accomplished, the HOST computer will verify that it has received the upload file from the CRM-510LP by sending a FILE RECEIVED message.

Note 2. The phone number may be manually changed by the operator. Connect the modem cable to the CRM510LP, and turn the keyswitch to the RUN position. Pressing either button once should wake the unit up. Pressing the [I/O] button will increment a particular digit, and pressing the [PRINT] button will move the cursor to the next digit position.

Note 3. The JOB NO. is incremented each time a new test is started, giving each test a traceable identity.

Note 4. If a successful connection is not accomplished between the CRM-510LP and the modem or the telephone line, a NO DIALTONE or ERROR message will be displayed. Turn off the CRM-510LP, check all hardware connections and restart the upload sequence.

Note 5. The blinking cursor will progress through the digits as the number is dialed. If the HOST computer telephone line is busy, a BUSY message will be displayed. Press the [I/O] key to initiate a redial or press the [PRINT] key to restart an upload sequence from the beginning.

Note 6. An ERROR message indicates a problem in the password/handshake protocol between the CRM-510LP and HOST computer. If a connection can not be successfully made after several tries, check with the host computer operator to determine whether the receive hardware and software are operating properly.

## **MODEM I/O MODE (DATA FILE DOWNLOAD TO HOST COMPUTER)**

### **Description:**

A computer, a 2400 baud rate modem, a direct telephone line, and communication software are required to receive the data files transmitted from a CRM-510LP/MODEM link. Although the user is required to furnish this portion of the telecommunications link, a description of a simple workable system is presented as a guide for the user to develop a custom system. The system described below is based on a commercially available communications software program (ProComm Plus 1.1B by Datastorm Technologies, Inc.) running on an IBM type PC.

The communications software must perform the following tasks:

1. Auto answer on ring,
2. Connect on-line at 2400 baud,
3. Interpret password sent from CRM-510LP,
4. Transmit a ready-to-receive file code to the CRM-510LP,
5. Receive ASCII file transmitted from CRM-510LP,
6. Store received file,
7. Send file-received code to the CRM-510LP, and
8. Go on hook and wait for next call.

A "Script" file is used to command ProComm Plus to perform the above tasks. At the completion of the download sequence, a compiled BASIC program is called to format and save

the data set in an ASCII file that can be easily transported to a data base, a spread sheet, a word processor, or another program specific to the reporting and record keeping needs of the user. The required handshake protocols can best be understood by examining the example programs listed below.

#### MODEMJ.ASP

MODEMJ.ASP is a "script" file for configuring a host computer for unattended and log-on operations with ProComm Plus 1.1B telecommunications software. This program is specifically designed for the password and file transmission protocol required for downloading data from the *femto*-TECH, INC. CRM510LP Radon Monitor. Most of the modem hardware and/or software parameters can be set at their default values. The terminal option settings used for this application are as follows:

```
Terminal emulation..... VT102
Duplex.....FULL
Software flow control (XON/XOFF)..... OFF
Hardware flow control (RTS/CTS)..... OFF
Line wrap ..... OFF
Screen scroll.....ON
CR translation ..... CR/LF
BS translation..... DESTRUCTIVE
Break Length (milliseconds).....350
Enquiry (ENQ)..... OFF
Break Length (milliseconds).....350
```

#### CRMJ.EXE (CRMJ.BAS)

This program translates the compressed and encoded data files transmitted from the CRM-510LP and saved in a temporary CRM.LOG file to an ASCII data file. The ASCII data file is saved with a filespec made up of the date and time the CRM-510LP logged on to the system, e.g., 09240930.LOG. The listable source file, CRMJ.BAS, has been included as a reference to the format and sequence requirements for receiving and translating the data stream sent from a CRM-510LP. The telecommunications data stream sequence sent by the CRM-510LP is nearly identical to that used in the direct link for computer download - the only difference being that the telecommunication transmitted data stream includes an additional JN (JOB NUMBER) variable.



## BASRUN.EXE And BASRUN.LIB

These programs are IBM BASIC "runtime" programs required to execute the compiled CRMJ.EXE program.

## CRMPTJ.BAS

This is a simple example interpretive BASIC program demonstrating how the ASCII formatted \*.LOG files can be utilized. This program functions similar to the DWNLCR.BAS program for computer download. Note: Line 70 will require modification to conform to the directory where your \*.LOG files are saved.

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## APPENDIX F SPECIAL FEATURES

The CRM-510LP has special features and capabilities that can be utilized by advanced users. Because most of these features are either accessed through or controlled by the DB-25 I/O CONNECTOR PORT, a complete description of this port is presented below.

### CRM-510 I/O PORT (MALE DB-25)

Pin	I/O	Description
1	O	Parallel Port Strobe
2	O	Parallel Data Line D0
3	O	Parallel Data Line D1
4	O	Parallel Data Line D2
5	O	Parallel Data Line D3
6	O	Parallel Data Line D4
7	O	Parallel Data Line D5
8	O	Parallel Data Line D6
9	O	Parallel Data Line D7
10	-	No Connection
11	I	Parallel Port BUSY
12	-	No Connection
13	O	Test*
14	I	Control Code Line (C0)
15	I	Control Code Line (C1)
16	-	No Connection
17	I	Control Code Line (C2)
18	-	No Connection
19	-	No Connection
20	I	RS-232 Receive Data Line
21	I	RS-232 Clear To Send (CS)
22	O	RS-232 Transmit Data Line
23	O	RS-232 Ready To Send (RS)
24	-	No Connection
25	-	No Connection

\*The TEST output, pin 13, is used for electrometer evaluation and no user connection should be made to this pin.

## CONTROL CODE SETTINGS

The three control code lines on pins 14, 15, and 17 are internally pulled up to +5VDC so that an open circuit condition is interpreted by the computer as an ON logic state. An OFF logic state is set by connecting the particular pin to the ground pin (16). The computer reads these control code lines on power up and enters the operating mode designated by the setting. The code settings supported at this time are described below.

### I/O PORT CODE LINE SETTINGS

<b>C2</b>	<b>C1</b>	<b>C0</b>	<b>Function</b>
1	1	1	Parallel Port Strobe
1	1	0	Parallel Data Line D0
1	0	1	Parallel Data Line D1
1	0	0	Parallel Data Line D2
0	1	1	Parallel Data Line D3
0	1	0	Parallel Data Line D4
0	0	1	Parallel Data Line D5
0	0	0	Parallel Data Line D6

- a. In the normal or default operating mode a carriage return is sent after each line of print. If your printer requires both a carriage return and line feed, jumper pin 14(C0) to pin 16(GND) in the printer cable connector that plugs into the CRM-510LP I/O port.
- b. If a jumper plug with pins 14(C0) and 15(C1) connected to pin 16(GND) is connected to the CRM-510LP output port, the CALIBRATION FACTOR, BACKGROUND, and PHONE NUMBER ENTER MODE are entered, when the key switch is turned to the RUN position. The present values that are stored in the CRM-510LP EEPROM memory are displayed on the LCD screen. New values are entered into the display by using the [I/O] key to toggle the digit at the blinking cursor to the desired value. The [PRINT] key is then used to enter the digit selection and advance to the next digit or parameter. When the new values have been entered, turn the key switch to the OFF position and remove the DB-25 jumper plug - the new parameters are now stored in EEPROM and will remain in effect until reset by this procedure.
- c. If a jumper plug with pins 14(C0) and 17(C2) connected to pin 16(GND) is connected to the CRM-510LP output port, a forty-eight hour test data set is generated, when the key switch is turned to the I/O position and the [PRINT] button is pressed and released.. This procedure is useful as a quick means of generating a test data set for evaluating printer and download functions.
- d. If optional modem hardware and software are installed, this jumper configuration instructs the CRM-510LP to enter the MODEM I/O MODE, when the key switch is turned to the I/O position. Contact *femto*-TECH, INC. for description of MODEM I/O MODE.

e. If an interface cable with the appropriate data lines is used to connect the CRM510LP to a personal computer, a communications application may be used to program the unit in the ALL PARAMETER SETUP MODE. This will ordinarily be done by *femto*-TECH and should not be attempted by the user. Contact *femto*-TECH if more information is desired.

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# **INSTRUCTIONS FOR PERFORMING SCREENING-TYPE MEASUREMENTS WITH A CRM-510LP CONTINUOUS RADON MONITOR**

## **STANDARD OPERATING PROCEDURES rev-2.0 (1/97)**

### **1.1 Purpose**

This instruction provides guidance for using the *femto*-TECH, INC. Model CRM-510LP continuous radon monitor to obtain accurate and reproducible measurements of indoor radon concentrations. Short-term measurements (greater than or equal to 48 hours) made in accordance with these procedures will produce measurements of radon concentration representative of standardized, closed-house conditions. Such measurements of closed-house concentrations have a smaller variability and are more reproducible than measurements made when the house conditions are not controlled.

### **1.2 Scope**

This instruction guidance covers, in general terms, the equipment, procedures, and quality control objectives to be used in performing radon gas measurements in accordance with U.S. Environmental Protection Agency screening measurement protocols.

### **1.3 Method**

The *femto*-TECH Model CRM-510LP is a continuous radon monitor (CRM) employing passive diffusion sampling of the ambient air environment in which it is situated. Radon decay products are electrostatically removed and prevented from entering the internal pulsed ion sensing volume. As a radon atom decays within the sensing volume of the chamber, a "burst" of ions is produced and is converted to electrical pulses in an electrometer. These pulses are counted, stored, and converted to pCi/l or Bq/m<sup>3</sup> by a built-in computer/data logger. All new CRM-510LP instruments are calibrated in a known radon environment to obtain the conversion factor used to convert to radon concentration. To assure the continued accuracy of the measurements, scheduled calibration checks should be performed during the service life of the instrument (See Section 1.5 for details).

### **1.4 Equipment and Materials**

The following equipment and materials are required to monitor an indoor environment using the *femto*-TECH Model CRM-510LP radon monitor:

1. A *femto*-TECH Model CRM-510LP continuous radon monitor.
2. An operating instruction sheet.
3. A quality assurance plan.
4. An analysis report form.

The following optional equipment may be employed:

1. A parallel input printer with graphics and/or alphanumeric printout.
2. A PC with an RS-232 input port and data transfer software.
3. Appropriate cables for connecting the above equipment to the CRM-510LP output port.

### **1.5 Pre Deployment Considerations**

The measurement should not be made if the occupant is planning remodeling, changes in the heating, ventilating and air conditioning (HVAC) system, or other modifications that may influence the radon concentration during the measurement period.

The CRM should be carefully checked before and after each measurement to:

1. Verify that the CRM-510LP has not sustained any physical damage, since the last calibration or successful operation.
2. Verify that the screen inlet ports are clean and not obstructed.
3. Verify that the calibration is up-to-date.

Participation in a laboratory intercomparison program should be conducted at least once annually to verify that the conversion factor used by the CRM is accurate. This is done by comparing the unit's response to a known radon concentration. Background count rate determinations should also be performed at least annually or sooner, if the instrument has been exposed to high levels of radon for extended periods of time (see section 1.7.2.1 for details). A calibration and background determination should also be performed after any maintenance or repair work on the instrument.

### **1.6 Measurement Criteria**

Reliable and reproducible measurements of indoor radon levels require considerable care and knowledge and this instrument should be used in accordance with the measurement protocols published by the United States Environmental Protection Agency (EPA 402-R-92-004 and revisions thereof). In accordance with these EPA protocols the following house conditions should exist, prior to and during the measurement.

1. The measurement should be made under closed-house conditions. To the extent reasonable, windows and external doors should be closed (except for normal entrance and exit) for 12 hours prior to and during the measurement period. Normal entrance and exit includes opening and closing of a door, but an external door should not be left open for more than a few minutes. These conditions are expected to exist as normal living conditions during the winter in northern climates. Thus, measurements should be made during winter periods whenever possible.

2. Internal-external air exchange systems (other than a furnace) such as hi-volume attic and window fans should not be operating during the measurement and for at least 12 hours before the measurement is initiated.
3. In southern climates or when the measurements must be made during a warm season, the standardized closed-house conditions are satisfied by meeting the criteria just listed. These criteria can be most conveniently satisfied if the measurement is begun in the morning, after the occupant has been instructed to keep the windows closed during the night and not to open them until the measurement has been completed. Air-conditioning systems that recycle interior air may be operated. The closed-house conditions must be more rigorously verified and maintained, however, when they are not the normal living conditions.
4. The measurement should not be conducted if severe storms with high winds are predicted during the measurement period. Weather predictions available on local news stations will provide sufficient information to determine if this condition is satisfied.

## **1.7 Deployment and Operation**

### **1.7.1 Location Selection**

The following deployment criteria should be applied to select the location of the Model CRM-510LP within a room.

1. Samples should be taken from the lowest livable level in the house -- i.e., a basement, a bedroom or a playroom. Bathrooms, kitchens, laundry rooms, root cellars, garages, crawl spaces or sumps are not suitable.
2. The measurement should not be made near drafts caused by heating, ventilating, and air conditioning (HVAC) vents, doors, windows, and fireplaces.
3. The measurement location should not be close to the outside walls of the house.
4. The unit should be placed on a table or stool so that the air intake is at least 20 inches from the floor (30 inches, where practical).
5. Because the Model CRM-510LP is self contained and not connected to a line power source and is shielded by its metal cabinet, it is generally unaffected by external electromagnetic disturbances. However, since it operates on an ion collection principal and employs an extremely sensitive electrometer, operating near microwave equipment or spark generating equipment, including electric arc welders or fan controllers, should be avoided. Electromagnetic field strength diminishes as the square of the distance from the source and a separation of ten feet or more between the Model CRM-510LP and such a source has been found to be sufficient to eliminate any interference with the radon measurement.
6. Although extreme design measures have been taken to minimize microphonic sensitivity in the Model CRM-510LP, dropping or placing it in a high vibration environment can produce false counts. Thus, data collected during transport of the monitor should not be used.

7. Operating the Model CRM-510LP outside the specified humidity range (10 to 90% RH) is not recommended, due to the possibility of moisture condensation on the surfaces of sensitive electronic components. If a measurement must be performed under very high (>90% RH) humidity conditions, the condensation can be eliminated by heating the Model CRM-510LP cabinet slightly above room temperature. A convenient way to accomplish this is through radiant heating with a small wattage lamp (15 to 25 watt).

## 1.7.2 Operation

Operating the Model CRM-510LP is simplicity itself. The instrument panel consists of a key switch, a PRINT push-button, an I/O push-button, a battery indicator LED, and a sixteen character liquid crystal display. A test is initiated by turning the key switch to the RUN position, pressing and releasing the [PRINT] key twice, then pressing both the [PRINT] and [I/O] keys simultaneously. Before the operator leaves the instrument, proper startup should be verified by noting that the elapsed time clock is operating and that counts are being recorded (See CRM-510LP INSTRUCTION MANUAL for details on displaying parameters on the LCD). The CRM-510LP will collect and store hourly data for up to eight days, operating only on its internal battery power. A test is terminated by turning the key switch to the OFF position, and pressing either the [PRINT] or [I/O] button. As long as a new test is not initiated, the collected data are stored in non-volatile memory and can be read out to a printer or another computer as many times as needed.

### 1.7.2.1 Test Data

Although the built-in computer normally performs all the computations and provides the radon concentration data in pCi/l or Bq/m<sup>3</sup>, it is advisable for the operator to know how to carry out "hand" calculations. A back-up "hand" calculation should be carried out after entering a new calibration factor or background value to verify their correct entry.

To perform a "hand" calculation, record the number of counts accumulated and the elapsed time shown on the LCD display, convert to counts per minute, and apply the conversion factor (C.F.) and background (BKG) values supplied with the instrument to obtain the radon level in units of pCi/l. The following formula is used for this conversion:

$$\text{Radon Conc. in pCi/l} = (\text{Ending Count} - \text{Beginning Count}) / [\text{Elapsed Time (in minutes)} \times \text{C.F.}] - \text{BKG}$$

The background subtraction is generally only necessary for radon levels below 10 pCi/l. Background of the Model CRM-510LP has been determined from aged air measurements to be in the range of 0.075 to 0.30 counts per minute. This corresponds to 0.25 to 1 pCi/l for a unit with a nominal 0.3 CPM/pCi/l calibration factor. The background does not vary significantly with time nor from unit to unit, because the pulsed ion counter detector and open grid chamber in the CRM-510LP discriminates against all ionizing radiation other than airborne alpha. Therefore, environmental gamma radiation or intrinsic ions are not sources of background as with most other types of detectors. However, progeny plate-out on the detector surfaces can result in a slow build-up of an alpha radiation background from Polonium-210. This background builds at a rate of approximately  $3 \times 10^{-5}$  CPM per day of exposure at 1 pCi/l radon. Thus, background build-up is insignificant when the Model CRM-510LP is used in screening and



survey applications where exposures are generally less than 100 pCi/l. However, if the CRM-510LP is used extensively in diagnostic applications where relatively high level radon exposures are common (1000 pCi/l or more), the instrument background should be checked, after every 100 hours of use.

Background determinations can be carried out using outdoor air or air supplied from a compressed gas cylinder that has been "aged" for at least thirty days. The "aged" air source is preferred, because outdoor air can contain detectable quantities of radon. A background determination can be performed by placing the CRM-510LP in an air tight enclosure or heavy plastic bag. Flow the background gas through the enclosure or bag at a rate of at least one volume exchange per hour. Maintain the flow for at least twelve hours. Discard the first three hours of data and calculate the average CPM and/or pCi/l for the remaining hours of the test. The measured background should be entered into the CRM-510LP computer using the procedure given in APPENDIX B of the CRM-510 INSTRUCTION MANUAL. It is advisable to have the detector assembly replaced in any instrument that has a background over 1 pCi/l. Call *femto-TECH* for price schedules on this service.

Because of the high sensitivity and fast response time of the CRM-510LP, counts will be obtained in a matter of minutes -- even at radon levels as low as 1 pCi/l. However, to obtain statistically significant data, collection times must be chosen according to the deviation and confidence level required for the measurements. In general, variations due to counting statistics will only be of significance where the CRM-510LP is being used for relative concentration measurements in short-term tracking or control applications. Thus, when using the CRM-510LP in accord with the U.S. EPA recommended survey protocols for performing indoor radon screening and follow-up measurements, instrument counting statistics will not be limiting on the overall accuracy of the data. However to minimize other sampling errors, it is recommended that an acclimation period in the test environment of at least three hours be used before data collection.

## 1.8 Documentation

It is important that the operator of the CRM-510LP records enough information about the measurement in a permanent log so that data interpretations and comparisons can be made. This information includes:

1. Instrument identification, calibration, and background data.
2. Start and stop times and date of the measurement.
3. Exact location of the instrument, on a diagram of the room and house, if possible.
4. Measured Radon levels
5. Test operator's name.

## Frequently Asked Questions

**EXHIBIT 2**

**Radon Survey in Progress Notification Form**

# **RADON SURVEY IN PROGRESS**

## **DO NOT REMOVE THIS NOTIFICATION**

The following conditions must be maintained to provide accurate measurement results:

- Do not open any windows. Do not open any doors except for normal momentary entering and exiting.
- Do not touch, cover, move or alter the performance of any radon detectors or non-interference controls.
- The heating and air conditioning system will remain operating normally. Turn off and keep off any equipment that supplies fresh air to the building unless it is make up air to a combustion appliance.

### **NOTE:**

Windows and doors must be kept closed because they can create pressure differences throughout the building, which can raise or lower the radon levels. Please contact Tyler Puls in the facilities department at 515-242-7889 if there are any questions or concerns.

Test Period From: \_\_\_\_\_ To: \_\_\_\_\_

Responsible Individual: Tyler Puls 515-242-7889

Date: \_\_\_\_\_

**EXHIBIT 3**

**Radon Measurement Log Forms**





**Des Moines Public Schools**  
Duplicate Log - Continuous Radon Monitor

DMPS 1917 Dean Avenue Des Moines, IA 50316

Duplicate ID	Building Name	Test Kit #	Room #/ ID	Hours	End Date	Measured Value	RPD	RPD Range	Technician	Notes
Result A							0.0	Good		
Result B										
Result A							0.0	Good		
Result B										
Result A							0.0	Good		
Result B										
Result A							0.0	Good		
Result B										
Result A							0.0	Good		
Result B										
Result A							0.0	Good		
Result B										
Result A							0.0	Good		
Result B										
Result A							0.0	Good		
Result B										
Result A							0.0	Good		
Result B										
Result A							0.0	Good		
Result B										
Result A							0.0	Good		
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Result B										
Result A							0.0	Good		
Result B										
Result A							0.0	Good		
Result B										
Result A							0.0	Good		
Result B										
Result A							0.0	Good		
Result B										

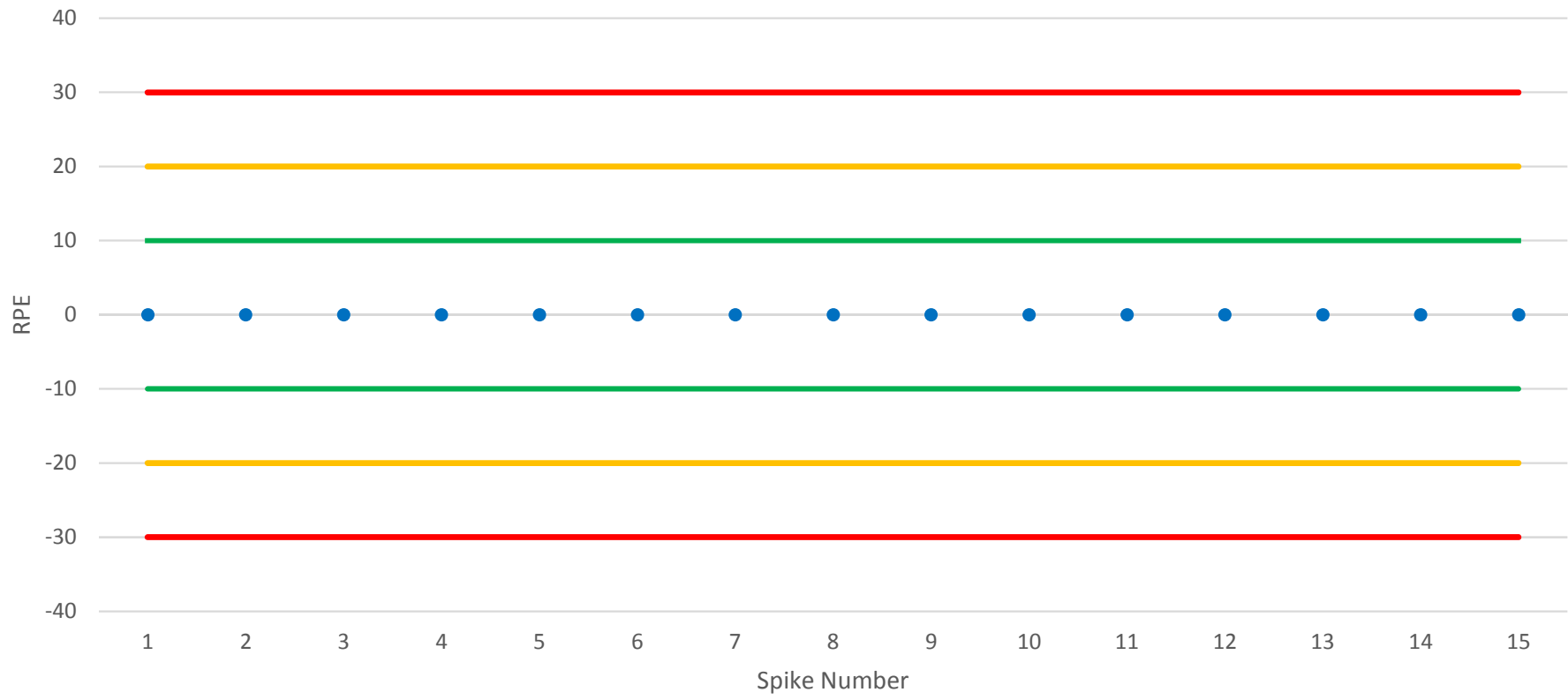




**EXHIBIT 4**

**Crosscheck Control Chart**

### DMPS - Crosscheck Control Chart Continuous Radon Monitor

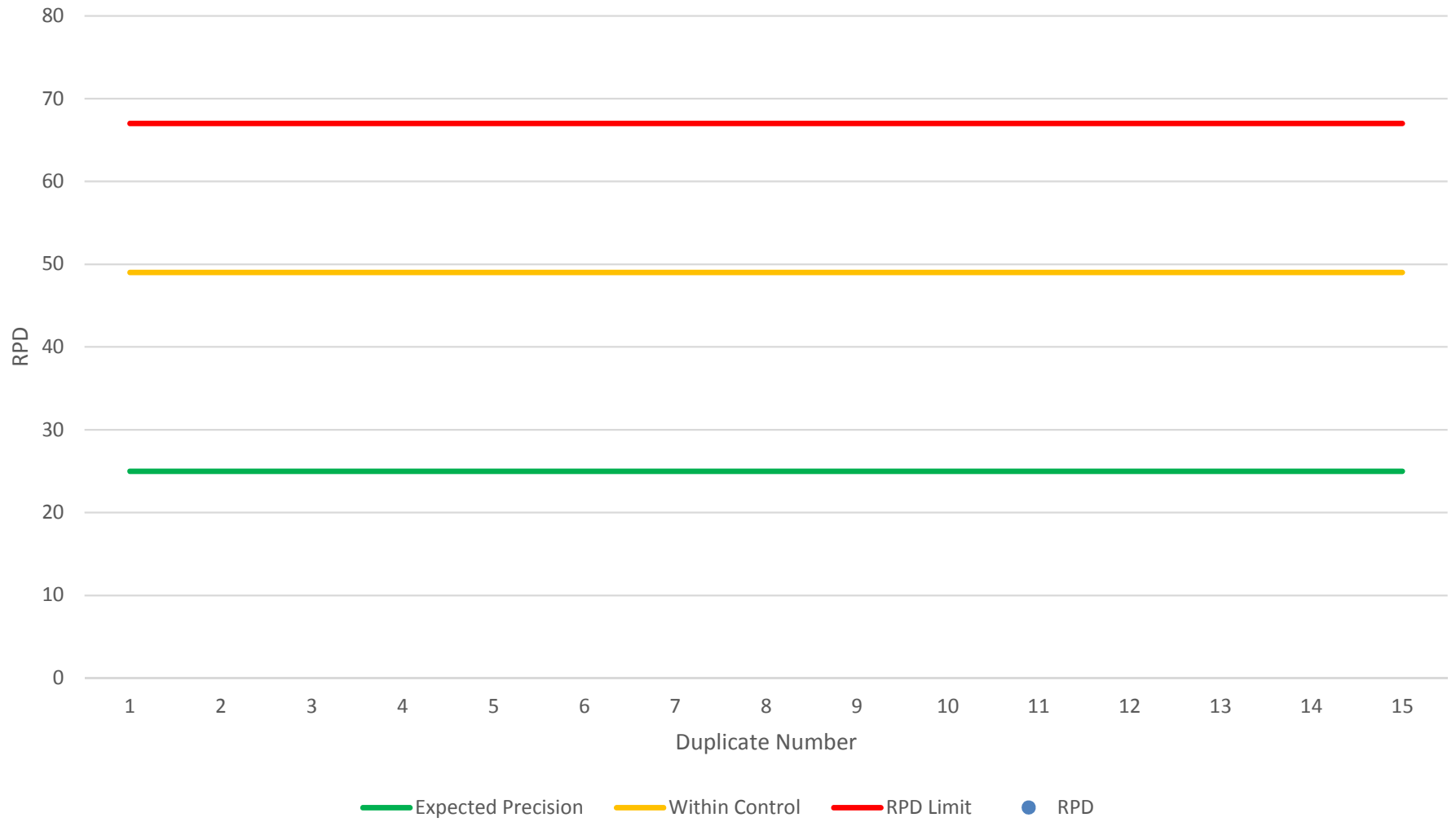


Control Limit    Within Control    Expected Precision    RPE

**EXHIBIT 5**

**Duplicate Control Charts**

### DMPS - Duplicate Control Chart Continuous Radon Monitor - Results < 4.0 pCi/L



### DMPS - Duplicate Control Chart Continuous Radon Monitor - Results > 4.0 pCi/L

