KDHE Quality Assurance Plan for Conducting Radon Measurements

A.1 Approval Sheet

1. This Quality Assurance plan shall be utilized by radon measurement technicians employed by the Kansas Department of Health and Environment (KDHE) Bureau of Environmental Health (BEH) for the conduct of radon measurements. The following Radon Measurement technicians are currently employed by KDHE:

Kimberly Steves (Program Supervisor)
D. Shay Hannah
David Hart
Jessica Snook
Stewart Steen (Quality Assurance Officer)

2. This quality assurance plan shall be reviewed and reissued annually.

Submitted by: Signature Stewart E Steen _____ Date May 14, 2013 _____
Quality Assurance Officer

Approved By: Signature Kimberly Steves _____ Date May 14, 2013 _____
Program Supervisor

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A.3 Distribution List

1. This plan shall be distributed to all certified radon measurement technicians, the Radiation, Asbestos and Right-to-Know section chief and the Director, Bureau of Environmental Health. Distribution may be accomplished by interoffice mail or electronic mail. The current revision of this procedure will be maintained on the BEH shared drive at T:\Radiation\radon\Radon Measurement Quality Assurance.

2. This plan shall be reissued after approval of any revision. Certified radon technicians listed in this document shall submit recommended changes to the Program Supervisor or Quality Assurance Officer. Copies of this document shall be distributed to all parties identified above upon completion of such changes.

A.4 Description of Kansas Radon Program

1. The primary purpose of this program is to provide radon measurement and mitigation technical assistance to the citizens of the State of Kansas.
2. The program shall provide radon measurement utilizing electret ion chambers, continuous radon monitors, and activated charcoal devices.
3. The program oversees the activities of and provides certification for measurement and mitigation professionals in the State and for radon laboratories.

A.5 Work to be Accomplished

1. The program provides measurement services to homeowners pursuant to the *Safe at Home Wichita* project funded by a grant from the United States Department of Housing and Urban Development.
2. The program provides radon measurements as requested and as staffing and equipment permits for State and Local Government buildings and public schools, and may assist with confirmatory measurements for homeowners with measured radon levels greater than 40 pCi/L.
3. The program shall provide other radon measurements in service to the citizens of Kansas as appropriate.

A.6 Quality Objectives for Radon Measurement Activities

1. The quality objective for radon measurements by the Kansas Radon Program is to produce radon measurements which are accurate, consistent and reproducible.

A.7 Personnel

1. Kimberly S. Steves is the Program Supervisor, and will direct and oversee all radon measurement activities.
2. Stewart E. Steen is designated as the Quality Assurance Officer, and as such shall monitor all aspects of the QA/QC program for completeness and provide assistance as required. The Quality Assurance Officer will make quarterly reports to the Program Supervisor as to compliance with the program. He shall perform radon measurement activities as directed, primarily in schools and government buildings.
3. David Hart will be the primary radon measurement technician for activities performed under the Wichita HUD grant. He will control the use of E-Perm electret devices to this end, and will be the primary performer of E-Perm QA activities.
4. Shay Hannah will perform radon measurement activities as directed, primarily in schools and government buildings. He will be the primary user of Continuous Radon Monitors.
5. Jessica Snook will perform radon measurement activities as directed, primarily in schools and government buildings.

A.8 Documents and Records

1. Client measurement reports for the Wichita *Safe at Home* project will be kept on file in the Wichita office.

2. Client measurement reports for measurements performed by Topeka staff will be kept on file in the Topeka office in hardcopy. Reports may be stored on KDHE BEH shared drive T:\Radiation\radon\Radon Measurement Quality Assurance.
3. Quality assurance measurement control charts will be maintained electronically on the KDHE BEH shared drive at T:\Radiation'\radon\Radon Measurement Quality Assurance. Working hardcopies may be maintained by the radon measurement technician performing quality assurance measurements and shall be recorded electronically as soon as practicable, but no later than five working days after completion of measurements.
4. Records above will be maintained for a minimum of three years.
5. Measurement data will be reported to the KDHE quarterly using the spreadsheet provided on the KDHE Radon Program website at: www.kdheks.gov/radiation/radon.htm .

B.1 Measurement Generation

1. Radon will be measured using continuous radon monitors, passive activated charcoal devices and electret chambers.

    a. Continuous radon monitors will be operated according to the applicable manufacturer's operating manual. Continuous radon monitors employed by KDHE are as follows:

- Sun Nuclear Model 1027, serial number 47810011.
- RadonAway RadStar RS800, serial number 1727
- Durridge RAD-7, serial number 433
- FemtoTECH Model # CRM-510, serial number 6149

    b. Electret chambers manufactured by RadElec will utilized according to the RadElect operating manual. Radon levels will be calculated using RadElec Winsper or Winperm software. Electret placement shall be accomplished using Appendix A.

    c. Activated Charcoal devices manufactured by AirChek, inc. will be utilized according the instructions enclosed with each test kit.

Appendix K contains Standard Operating Procedures for each device.

B.2 Sampling Methods

1. Radon measurement/sampling will be performed in accordance with EPA Publications "Indoor Radon and Radon Decay Product Measurement Device Protocols" and "Protocols for Radon and Radon Decay Product Measurement in Homes".
2. The radon measurement technician shall advise the client of the necessity for closed house conditions. A sign or label stating the need for maintenance of closed house conditions and advising against tampering with the measurement device shall be placed at the measurement site.

B.3 Analytical Methods

1. Activated Charcoal devices will be analyzed by AirChek, Inc. , which is certified as a Radon Laboratory by the State of Kansas.

B.4 Instrument Calibration

1. Instruments requiring calibration shall be returned to the manufacturer or a facility approved by the manufacturer for calibration.
2. Calibrations will be performed on an annual basis.
3. Any instrument whose calibration date is greater than one year will be removed from service until calibration is performed.

B.5 Quality Control

1. Quality control measurements will be taken in accordance with EPA National Radon Proficiency Program Guidance on Quality Assurance, EPA 402-R-95-012, Oct. 1997.
    a. Statistical comparison of measured versus expected results will be performed for duplicate and spiked samples. The following statistical method shall be used:
        i. A warning limit of two standard deviations from the mean or expected value (2 sigma) will be observed to check for bias. Two consecutive QC measurements which vary from expected result by 2 sigma, or two consecutive QC measurements which vary from expected by -2 sigma shall be investigated by the QA officer. This investigation should consider instrument performance (as applicable), radon measurement technician procedures and environmental factors at a minimum.
        ii. A control limit of three standard deviations (3 sigma) will be observed. Any measurement which varies from expected by 3 sigma or -3 sigma shall be repeated. If the repeated measurement also falls outside the control limit, all measurement activities shall cease and the QA officer shall investigate as described in paragraph B.5.a.i.
        iii. If five consecutive QA measurements fall above expected value or if five consecutive measurements fall below the expected value (regardless of magnitude) the QA officer shall investigate as described in paragraph B.5.a.i.
    b. Upon initiation of QA measurements, the following warning and control limits shall be utilized:
        i. For spiked samples, warning limit relative percent error of 20%, control limit relative percent error of 30%.
            1. Relative percent error is determined as follows:
                a. Perform the measurement of the spiked sample (this is the measured value).
                b. Obtain the expected result provided by the agency which supplied the spiked sample (this is the reference value).
                c. Relative percent error is calculated by dividing the measured value by the reference value and multiplying by 100.
        ii. For duplicate samples, warning limit of range ratio of 2.2, control limit of range ratio of 3.3
            1. Range ratios are based initially on 14 percent relative percent difference.
                a. The smaller result of two measurements is subtracted from the larger result. (This is the observed relative percent difference)
                b. The expected relative percent difference is determined by multiplying the average of the two results by 14 percent (0.14) (This is the expected relative percent difference)
                c. The range ratio is determined by dividing the observed relative percent difference by the expected relative percent difference.
        iii. For electret blank samples, acceptability is based on a voltage drop of 1 volt per week.

1. Since instrument readings may vary by ± 1 volt, a voltage drop of 2 volts per week will be adjudged acceptable. A voltage drop of greater than 2 volts will require investigation.

iv. For activated charcoal device blank measurements, result is expected to be less than the lower limit of detection of 0.3 pCi/L.

1. Control charts will be maintained with warning limit of 0.6 and control limit of 0.9 pCi/L.
2. Background readings above the control limit will be investigated by the QA officer. The investigation should include attempting to determine sources of radon ingress during transport and storage.

c. Upon completion of 20 measurements, new warning and control limits shall be determined.

i. For duplicates, the mean, and standard deviation (1 sigma) of the relative percent error of the 20 measurements will be calculated. The range ratios shall be recalculated and new 2 sigma warning and 3 sigma control limits established. A new means control chart shall be placed in service using the new limits.

ii. For spiked samples, the average of the relative percent difference shall be calculated for 20 measurements. This is the average of the absolute values of the relative percent error. The control limit shall be set at three times the average relative percent difference, the warning limit at two times the average relative percent difference.

iii. For activated charcoal devices, the average background will be determined after 20 measurements, and the 2 sigma warning limit and 3 sigma control limit determined by two and three times the standard deviation, respectively.

2. The following device specific QC measurements will be performed:

a. <u>Electret Chambers:</u>

i. Calibration of the voltage reader will be performed annually.

ii. Weekly checks of electret reader zero and reference electret readings will be performed according to the manufacturer's instruction manual. Results are recorded on the control chart which is illustrated in Appendix B.

iii. Spiked sample measurement of samples obtained from the manufacturer will be performed at the rate of three per 100 measurements taken, with a minimum of three per year and a maximum of six per month. Spiked samples will be recorded and evaluated on the control chart which is illustrated in Appendix C.

iv. Duplicates will be performed at the rate of 10 percent of measurements, with a maximum of 50 per month. A control chart for documenting duplicate measurements and tracking precision is illustrated in Appendix D.

v. Blank samples for background measurement will be performed at the rate of 5 percent of measurements or ten per month, whichever is smaller. A measurement log for documenting blank samples is illustrated in Appendix E.

b. <u>Continuous Radon Monitors:</u>

i. Each continuous radon monitor will be calibrated annually.

ii. Each continuous radon monitor in service shall have a label affixed which lists the calibration facility, the date of calibration and the date the next calibration is due.
iii. Instruments which have passed the required calibration date will be removed from service until calibration is performed.
iv. Current calibration certificates will be maintained on hand in the Radiation Shop for each instrument in use.
v. Background measurements shall be performed for each continuous radon monitor during calibration.
vi. Crosscheck measurements (side by side radon comparison measurement using two different types of measurement devices) shall be performed at the rate of ten percent of measurements. A log for documenting crosscheck measurements for continuous radon monitors is illustrated in Appendix F.
vii. Routine instrument checks are performed by the instrument software upon startup.
viii. Radon measurements shall be reported using the "Radon Protocol" result from the instrument printout, which corrects the readings for the measured instrument background.

c. Activated Charcoal devices:
i. Charcoal devices will be stored in a low radon environment when not in use.
ii. Appendix G will be used for device placement.
iii. Duplicate (side by side) measurements shall be made in at least ten percent of measurements, with a maximum of 50 per month. A control chart for documenting activated charcoal duplicates and tracking precision is illustrated in Appendix H.
iv. Field Blanks shall be employed equal to at least 5 percent of measurements, with a maximum of 25 per month. A control chart for documenting activated charcoal blank measurements is illustrated in Appendix I.
v. Three spiked samples shall be performed for every 100 measurements, with a minimum of three per year and a maximum of six per month. Devices shall be sent to Bowser-Morner for spiking per the device manufacturer (Air Chek Inc.) recommendation. A control chart for documenting spiked samples and calculating the mean and standard deviation is illustrated in Attachment J.

3. Chain of custody will be maintained as follows:
   a. For electret ion chambers, Appendix A shall be utilized for documentation of chain of custody and maintained with the client record.
   b. Continuous radon monitor printouts shall be initialed by the radon measurement technician at the time/date for placement and retrieval as applicable. These printouts shall be maintained with the client record.
   c. Activated charcoal device custody shall be monitored using Appendix G, which shall be maintained with the client record. Activated charcoal devices shall be stored in the Bureau of Environmental Health offices on the 3rd floor of the Curtis State Office building, which is a low radon environment.
4. A background radiation measurement shall be accomplished during continuous radon monitor calibration and through routine electret background measurement. The latter shall be recorded

using Appendix E. Background for activated charcoal devices shall be determined using field blanks.

C.1 Assessment and Oversight

1. Measurements performed by KDHE Radon Measurement Technicians shall be submitted to the Program Supervisor for review.
2. Complaints and suggestions regarding programmatic issues shall be reviewed as directed by the Program Supervisor. Upon resolution of issues, programmatic changes required will be documented and this Quality Assurance plan shall be amended as necessary.

D.1 Data Validation and Usability

1. Continuous radon data shall be reported using the "Radon Protocol" result on the printout, which is corrected for instrument background.
2. The radon measurement technician performing the measurement shall adhere to all applicable protocols and standard operating procedures to ensure that measurements are properly conducted. The Program Supervisor or designee shall review all results prior to them being reported to the client.

Appendices

Appendix A, Checklist for Radon Electret Detector Placement and Retrieval

☐ Obtain two prepared Electret chambers for each home to be tested

☐ Ensure closed house conditions are established and discuss with occupant need to maintain it during the testing period

☐ Open the top of the Electret chamber prior to placement. Record the date and time electret is opened.

Date_____ Time_____ Initials_____

OPEN FOR TESTING

☐ Place the Electret chambers side by side on the placement sheet or at least four inches apart.

- Place on lowest *occupied* level of the home
- Do not place in drafts from heating or air conditioning vents
- Do not place in closets, kitchen, bathroom, laundry room or other closed or high humidity areas (bedrooms are good spot)
- Place at least 30 inches above the floor
- Place at least 10 inches from other objects
- Place at least 30 inches from windows and 10 inches from exterior wall

Retrieval

CLOSED AT END OF TEST

☐ Close the tops of the Electret chambers. Record date and time:

Date_____ Time_____ Initials_____

☐ Return Electret chambers and this checklist to KDHE for voltage reading.

☐ Acknowledge Receipt of Electret chambers at KDHE.

Date_____ Time_____ Initials_____

RADON TESTING DEVICES, DO NOT DISTURB

Call 785-296-1560
Kansas Department of Health and Environment
Bureau of Environmental Health
Radiation and Asbestos Control Section

Appendix B Certified Readings of Reference Electrets

Read reference electrets weekly prior to commencement of measurement activities. The observed reading should be within one volt of the value recorded on the certified electret certificate. If they do not agree, the electret reader and reference electrets should be returned to the manufacturer for repair/service.

Electret #	Date	Reading (Volts)	Voltage Reader #	Reference Electrets Read and Certified By

Appendix C Electret Spiked Sample Control Charts

Spiked Sample Results

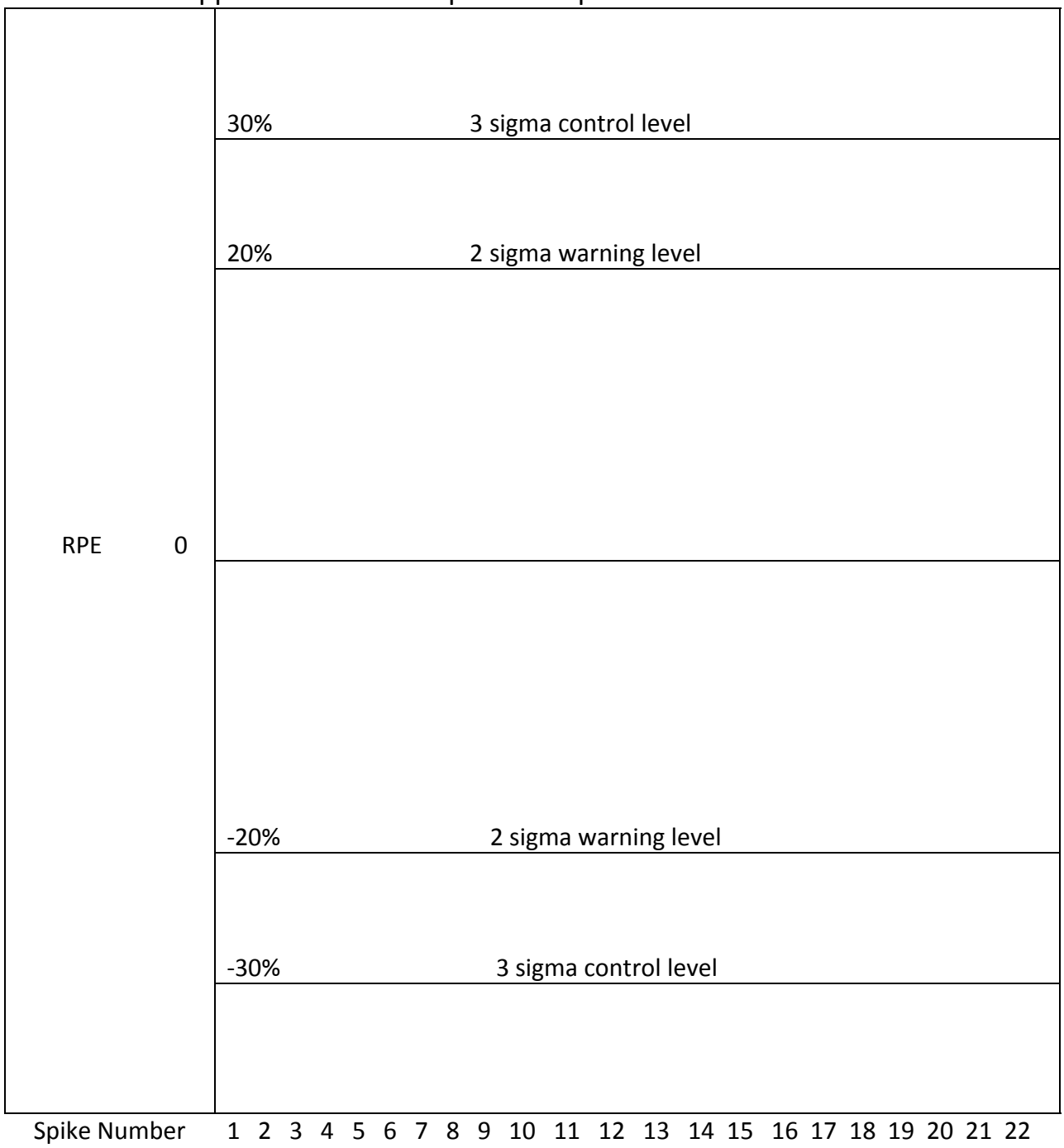
Date	Spike Number	Reference Value	Measured Value (pCi/L)	Relative Percent Error (RPE)

Upon completion of spiked sample reading, record the date, spike number and reference value above. Upon receipt of reference value from spike provider, determine relative percent error by performing the following calculation:

RPE= (Reference Value-Measured Value)/Reference Value*100

Record the relative percent error. Record the value on the control chart. An excel spreadsheet provided by the QA officer shall be utilized for recording data.

Appendix C Electret Spiked Sample Means Control Chart



After 20 measurements have been performed the actual mean and standard deviation shall be calculated and a new means control chart produced and placed in service. 2 consecutive measurements outside the same 2 sigma warning level should be investigated to determine cause of bias. Any measurement outside the 3 sigma control level should be investigated. See See KDHE Quality Assurance Plan for Conducting Radon Measurements, section B.5.1

Appendix D, Electret Duplicate Control Chart (Results greater than 4.0 pCi/L)

Date	Dup. No.	A (pCI/L)	B(pCi/L)	R_0 (A/B)	R_e	R= R_0 / R_e

R_0=Higher result-lower result

R_e=[(A+B)/2]*0.14 (Initially based on 14 percent Relative Percent Difference, should recalculate after 20 measurements and amend control chart accordingly). See KDHE Quality Assurance Plan for Conducting Radon Measurements, section B.5.1

Appendix D Ratio Control Chart for Tracking Precision of Electret Duplicate Measurements

3.4																				
3.2																				
3.0																				
2.8																				
2.6																				
2.4																				
2.2	Control Level																			
2.0																				
1.8																				
1.6																				
1.4																				
1.2																				
1.0	Warning Level																			
0.8																				
0.6																				
0.4																				
0.2																				
0.0																				
Duplicate No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20

Appendix E Electret Blank Measurement Log

Date	Initial Voltage	Date	Final Voltage	Difference	Electret Serial Number

Perform blank measurement for 5 percent of all radon measurements. Read initial voltage, transport device with devices being placed for measurement, return blank device to office. Read voltage upon return of measurement devices. Voltage drop should not exceed 2 volts per week. Notify QA officer for investigation if reading drops by more than 2 volts.

Appendix F Continuous Radon Monitor Crosscheck Log

Date	Duplicate Number	A (pCi/L)	B (pCi/L)	Mean ((A+B)/2)	R_O (Observed Range) (Absolute value of A-B)	R_E (Expected Range)	CRM Serial Nos.
							A B
							A B
							A B
							A B
							A B
							A B
							A B
							A B
							A B
							A B
							A B

R_0=Higher result-lower result

R_e=[(A+B)/2]*0.14 (Initially based on 14 percent Relative Percent Difference, should recalculate after 20 measurements and amend control chart accordingly). See KDHE Quality Assurance Plan for Conducting Radon Measurements, section B.5.1

Appendix G Activated Charcoal Device Placement Checklist

☐ Obtain activated charcoal device(s) for site to be tested.
Record test kit number(s) _____

☐ Open the packet being careful not to tear the brown paper inside. Insert the foam block into the opening per the kit instructions.

☐ Record start time and date on packet and below.
Date_____ Time_____ Initials_____

☐ Hang the packet(s) at normal breathing level. Attach information sign (example is illustrated on the following page) where clearly visible.

- Place on lowest *occupied* level of the home
- Do not place in drafts from heating or air conditioning vents
- Do not place in closets, kitchen, bathroom, laundry room or other closed or high humidity areas (bedrooms are good spot)
- Place at least 30 inches above the floor
- Place at least 10 inches from other objects
- Place at least 30 inches from windows and 10 inches from exterior wall

Retrieval

☐ Retrieve the device, remove foam block and seal the packet. Record stop time and date on packet and below. Initial below to verify the time the test kit was sealed.

Date_____ Time_____ Initials_____

☐ Place the devices in mail as soon as practical.

RADON TESTING DEVICE, DO NOT DISTURB

Call 785-296-1560
Kansas Department of Health and Environment
Bureau of Environmental Health
Radiation and Asbestos Control Section

Appendix H, Activated Charcoal Duplicate Control Chart (Results greater than 4.0 pCi/L)

Date	Dup. No.	A (pCI/L)	B(pCi/L)	R_0 (A/B)	R_e	R= R_0 / R_e

Appendix H Ratio Control Chart for Tracking Precision of Activated Charcoal Duplicate Measurements

3.4																				
3.2																				
3.0																				
2.8																				
2.6																				
2.4																				
2.2	Control Level																			
2.0																				
1.8																				
1.6																				
1.4																				
1.2																				
1.0	Warning Level																			
0.8																				
0.6																				
0.4																				
0.2																				
0.0																				
Duplicate No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20

Appendix I Activated Charcoal Device Blank Measurement Log/Means Control Chart

Date	Radon Concentration (pCi/L)	Means Control Chart		
		<0.3 LLD	0.3-<0.6 Warning	>/=0.6 Control Limit

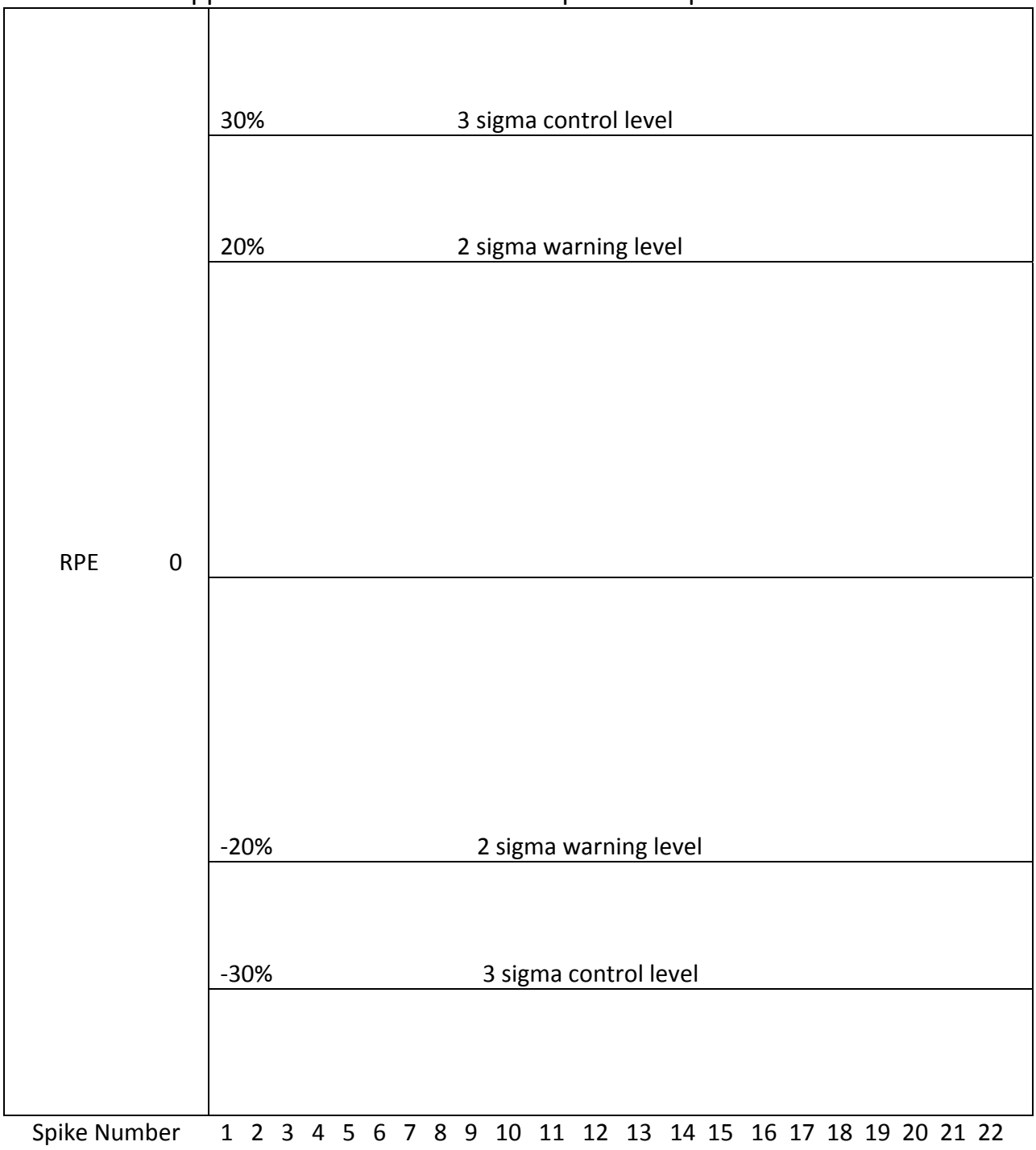
LLD is 0.3 pCi/L, per manufacturer. Warning Limit 0.6 pCi/L, Control Limit 0.9 pCi/L. Investigate two consecutive results above warning limit or one result above After 20 measurements determine standard deviation, mean, and 2 and 3 sigma warning and control limits. See KDHE Quality Assurance Plan for Conducting Radon Measurements, section B.5.1

Appendix J Activated Charcoal Spiked Sample Control Charts

Spiked Sample Results

Date	Spike Number	Reference Value	Measured Value (pCi/L)	Relative Percent Error (RPE)

Appendix J Activated Charcoal Spiked Sample Means Control Chart



After 20 measurements have been performed the actual mean and standard deviation shall be calculated and a new means control chart produced and placed in service. 2 consecutive measurements outside the same 2 sigma warning level should be investigated to determine cause of bias. Any measurement outside the 3 sigma control level should be investigated. See KDHE Quality Assurance Plan for Conducting Radon Measurements, section B.5.1

Appendix K Standard Operating Procedures for KDHE Radon Measurement Devices

Appendix K contains the following Standard Operating Procedures (SOPs):

- Appendix K, SOP1: Procedure for Durridge RAD-7, Page 29
- Appendix K, SOP2: Procedure for Femto Tech CRM-510F, Page 104
- Appendix K, SOP3: Procedure for RadonAway RadStar RS800, Page 107
- Appendix K, SOP4: Procedure for Sun Nuclear Model 1027, Page 114
- Appendix K, SOP5: Procedure for Rad Elec Electret Chambers, Page 130
- Appendix K, SOP6: Procedure for Air Chek Activated Charcoal Devices, Page 135

SOP1 Procedure for Durridge RAD-7

Durridge RAD-7 in radon measurement mode

Durridge RAD-7 in sniffing mode

RAD7 RADON DETECTOR

User Manual

Owner_____

Serial #_____

SERVICE RECORD

Date	Service

It is recommended that the unit be returned to DURRIDGE Company annually, for recalibration.

DURRIDGE Company Inc.
524 Boston Rd
Billerica, MA 01821
Tel: (978)-667-9556
Fax: (978)-667-9557
service@durridge.com
www.durridge.com

Revision 7.2.0. © 2012 DURRIDGE Company

WARNING

Opening the cover of this instrument is likely to expose dangerous voltages. Disconnect the instrument from all voltage sources while it is being opened. Due to battery power, the instrument may still be dangerous.

Using this instrument in a manner not specified by the manufacturer may impair the protection provided by the instrument.

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INTRODUCTION

The RAD7 is a highly versatile instrument that can form the basis of a comprehensive radon measurement system. It may be used in many different modes for different purposes. This manual adopts a progressive approach, in which there is, first, a simple, step-by-step description of how to get readings for a) real-time monitoring, and b) sniffing. Next comes a more detailed description of the many features of the instrument and how to access them. The rest of the manual covers a whole range of topics, in somewhat arbitrary order. We recommend that, as soon as possible, you read the entire text, just so that you will have an idea of what there is. While you can start to make good measurements on the first day of ownership of the RAD7, it can take years to master the subtleties of radon and thoron behavior, and to appreciate the full capabilities of the instrument.

We have tried to make the manual easy to use, with a useful table of contents. Please let us know how well we have succeeded. If there are some topics inadequately covered, please tell us. We will issue updates from time to time.

Points of special note

The RAD7 is a rugged and long-lasting piece of equipment. There are many units still in daily use that were sold nine years ago or more. However, it is a sophisticated, precision electronic device, and it is not hermetically sealed, so please treat it with respect. Please do not allow water, other liquids or dirt to get into the machine. If using it somewhere where it may get splashed, damaged, or exposed to rain, please protect it. See chapter 4.10.1.

The batteries are lead-acid technology, like a car's. If left in a discharged state they will lose capacity. After running the RAD7 on its batteries please recharge them as soon as possible (by plugging in the unit). With careful use the batteries will last five years or more.

Finally, there is one security feature that is sometimes inadvertently set by an inexperienced, though authorized, user; namely the key pad lockout. If the key pad ceases to function, and all you see is `DURRIDGE RAD7` on the display, just do the following: Hold down the `[ENTER]` and two arrow keys until you hear a beep, release the three keys and immediately push `[MENU]`. You should then be rewarded by `>Test` on the display. If the tone was set to `OFF`, then you will not hear the beep, so hold the three keys down for three to four seconds, before releasing them and pushing `[MENU]`, - try hold-down times a little longer, or shorter, if, at first, you do not succeed.

1. GETTING STARTED: YOUR FIRST DAY WITH THE *RAD7*

1.1 Unpacking

First make sure you have everything you're supposed to have. Take the materials out of the packing boxes and see if you have all the items shown below or on the packing list enclosed with the shipment. If anything is missing, please call DURRIDGE immediately at (978) 667-9556.

1. RAD7
2. Strap and keys, for case
3. Printer and 6 rolls thermal printer paper
4. Rechargeable battery charger
5. 5 lb. Desiccant
6. Gas Drying Unit
7. 4 Drying Tubes
8. Velcro tapes
9. 1 Dust filter
10. 6 Inlet filters
11. 3 x 3ft pieces vinyl tubing, with adapters
12. DURRIDGE Software CD
13. Keyspan Adaptor & null modem cable
14. Manuals (RAD7 & Printer)
15. Accessories Case
16. 12 Volt Power Supply
17. 12 Volt Power Cable
18. Adapter for charger power cord (if applicable)
19. AC Power Cord

1.2 General Safety Instructions

For your own safety and the proper operation of RAD7:

DO NOT spill liquids onto the machine.
DO NOT expose operating panel of machine to rain or any other excess moisture.
DO NOT allow liquid to be sucked into inlet tube.

If you intend to use the instrument in a harsh environment, give it some protection. Even just a transparent plastic bag enclosing the RAD7 (but not the air sampling tube) can protect it from splashing mud and water. Allowing the dry air from the RAD7 outlet to exhaust into the interior of the bag will keep the RAD7 in a clean and dry environment.

If liquid does get into the machine, please disconnect the power cord, turn off the power switch, and return the RAD7 to DURRIDGE for repair.

Do not use your RAD7 if the instrument is damaged or malfunctioning. Please call, or email, the DURRIDGE service department, who will advise what to do about the problem.

Replace a frayed or damaged power cord immediately. Electrical equipment may be hazardous if misused. Keep away from children.

Do not open or attempt to repair the machine. The detector has an internal high voltage supply that can generate more than 2,500V.

The batteries are Gates Monobloc type 0819-0012, 6V 2.5Ah. There are two installed in the instrument. They are not user replaceable.

1.2.1 Air Travel

The RAD7 is safe to take on an airplane either as carry-on or checked baggage. It is probably easiest, and least likely to cause problems, if it is put inside a suitcase, with clothes, and checked in.

Some airlines and some airline staff are concerned about lead-technology batteries, such as those in the RAD7. An MSDS sheet, issued by the battery manufacturer, is enclosed with the manual in the RAD7 documentation. A copy of that should be carried and presented when requested, when traveling with a RAD7 by air.

1.3 Taking a Look

The *RAD7* Professional Electronic Radon Detector

1.4 Starting a Two-day Test

You will need the RAD7 and power cord, the Laboratory Drying Unit (the large tube of desiccant, with a screw cap at one end), an inlet filter (one of the six small filters supplied), the piece of tubing with a 5/16" ID segment at one end and a ⅛" ID segment at the other and the printer.

On first starting up, you will need to set the clock for your time zone (See Setup Clock, Section 2.4.11). Switch on the RAD7, push [MENU], then push [➔] twice. You will see Setup on the display. Push [ENTER], then push [➔] ten times. You will see Setup Clock. Push [ENTER]. Use arrow keys to adjust hours, minutes, seconds, day, month and year, pushing [ENTER] to confirm each setting. Now we are ready to continue.

a) Attach the filter to the tubing (push it into the end with the insert).
b) Carefully remove both plastic caps from the Drying Unit (you will need them later, to reseal the unit). Attach the sleeved end of the tubing to the tube fitting, on the Drying Unit, farthest from the screw cap.
c) Attache the filter to the Inlet port of the RAD7. The air sampling system is now set up for the measurement.
d) Plug in the RAD7 and switch on.
e) Push [MENU], [ENTER], then push [➔] four times. You should see on the LCD display: Test Purge.
f) Push [ENTER]. The pump should start.
g) Set up the printer (insert paper and batteries - see manual).
h) Place printer between green lines on face plate (See photo, Section 1.3).
I) After purging for some time (normally, at least five minutes), push [MENU], and [➔] two times, you will see: Setup on the display.
j) Push [ENTER] twice, then push either arrow key repeatedly until you see:
Protocol: 2-Day on the display. Push [ENTER].
k) With Setup on the display, push [ENTER], then [➔] seven times, to see >Setup Format on the display. Push [ENTER] then use arrow keys to select Format: Short. Push [ENTER].
l) Switch off the RAD7. Switch on the printer, now switch the RAD7 back on. The printer will print out something like the following:

```
DURRIDGE RAD7
Vers 2.5f   991128
Model 711
Serial 00512
Calib 21-MAY-08

Last used
   FRI 21-MAY-08  17:30

Current settings
   FRI 21-MAY-08  19:09

Protocol: 2-Day
Cycle: 01:00
Recycle: 48
Mode: Auto
Thoron: Off
Pump: Auto
Tone: Geiger
Format: Short
Units: pCi/L   C
```

m) Push [MENU], [ENTER], [➔]. You should see on the LCD display: >Test Start
n) Push [ENTER]. The pump will start running. On the LCD display you will see something like:

```
0101        Live        Sniff
00:59:37                00001
```

You are now monitoring the radon level right where you are. Every hour, the printer will print out a reading something like this:

```
0102   2.69  " 0.73  p   Sniff
   FRI  21-MAY-08    19:41
   26.8 C   RH: 7%   B:7.06V
```

Where 0102 are the run (01) and cycle (02) numbers, 2.69 is the measured radon concentration, 0.73 is the STATISTICAL uncertainty, p indicates the units (in this case pCi/L), and Sniff shows that, for this reading, only the Po-218 decays are being counted (after three hours, the mode changes automatically to Normal). The second line is clearly the date and time, while the third shows the temperature and humidity inside the measurement chamber, and the battery voltage. Medium and Long format settings print more information each cycle.

If you allow the RAD7 to complete a run, it will print out a summary of the entire run, including:

1. Date and time

2. Machine serial number
3. Average value for the test
4. Bar chart of the individual readings, and
5. Cumulative alpha energy spectrum.

In the example shown it may be seen that the average level was 3.71 pCi/L, or 137 Bq/m^3.

To terminate the run early, you may switch off the RAD7. The data collected, to the end of the last completed cycle, is automatically stored in the RAD7 memory, and available for later display, printing or download to a PC. If you wish to store the last, incomplete cycle data as well, use Test Save before switching off the RAD7. When you do this, the end-of-run printout does not take place. The summary is stored in memory and may be printed at any time, except that the cumulative spectrum, which would have been printed out at the end of the run, is lost.

End-of-Run Printout

1.5 Starting a Sniff Test

Sniffing lets you make quick, qualitative surveys of radon and thoron levels. It may be used to search for radon entry points. There are some advantages in sniffing for both thoron and radon at the same time, (see Section 3.13.3), so that is the procedure described here.

You will need the same equipment as for the 2-day test, above, except that a small drying tube should be used, instead of the laboratory drying unit. Also, for portability, you may remove the external power from the RAD7, and run both the RAD7 and the printer on their batteries.

If you have not already done so, set the clock, as described above.

a) Attach the filter to the tubing (push it into the end with the ⅛" ID segment).
b) Carefully remove both plastic caps from the small drying tube (you will need them later, to reseal the unit). Attach the 5/16" ID end of the tubing to one end of the tube.
c) Attach the filter to the Inlet port of the RAD7. Make sure it is firmly fit onto the inlet. The air sampling system is now set up for the measurement. While testing, you can use the small drying tube as a wand, to collect your air sample from the location of interest.
d) Plug in the RAD7 and switch on.
e) Push [MENU], [ENTER], then push [→] four times. You should see on the LCD display: Test Purge.
f) Push [ENTER]. The pump should start.
g) Set up the printer.
h) Place printer between green lines on the face plate (See photo, Section 1.3).
i) After purging for a few minutes push [MENU], and [→] two times, you will see: >Setup on the display.
j) Push [ENTER] twice, then push either arrow key repeatedly until you see Protocol: Thoron on the display. Push [ENTER]. (See section 2.4.5 for difference between Thoron and Sniff protocols).
k) With Setup on the display, push [ENTER], then [→] seven times, to see Setup Format on the display. Push [ENTER] then use arrow keys to select Format: Short. Push [ENTER].
l) Switch off the RAD7. Switch on the printer, now switch the RAD7 back on. The printer will print out something like the following:

```
DURRIDGE RAD7
Vers 2.5f   991128
Model 711
Serial 00512
Calib 21-MAY-08

Last used
      WED 23-MAY-08      17:30

Current settings
      FRI 25-MAY-08      19:09

Protocol: Thoron
Cycle: 00:05
Recycle: 00
Mode: Sniff
Thoron: On
Pump: Auto
Tone: Geiger
Format: Short
Units: pCi/L   C
```

m) Push [MENU], [ENTER], [→]. You should see on the LCD display: >Test Start
n) Push [ENTER]. The pump will start running. On the LCD display you will see something like:

```
0201        Live        Sniff
00:04:37                00001
```

You are now sniffing for thoron and radon. Every five minutes, the printer will print out a reading something like this:

```
0203  2.69  " 2.83   p  Sniff
      1.68  " 2.15   p  Thoron
   FRI  21-MAY-99     19:41
   26.8 °C   RH: 7%   B:7.06V
```

Where 0203 are the run (02) and cycle (03) numbers, 2.69 is the measured radon concentration, 2.83 is the STATISTICAL uncertainty, p indicates the units (in this case pCi/L), and Sniff shows that, for this reading, only the Po-218 decays are being counted. The second line is the measured thoron concentration and uncertainty. The third line is now the date and time, while the fourth shows the temperature and humidity inside the measurement chamber, and the battery voltage. Medium and Long format settings print more information each cycle.

Note that the Po-218 has a 3-minute half life. After moving to a new location, it will take about 15 minutes for the count rate to reach equilibrium with the new radon concentration. So not until after the third 5-minute cycle will the reading indicate the new level. However, the thoron daughter, Po-216, has a very short half life (150 ms), so the response of the RAD7 to thoron is virtually instantaneous. For thoron, the first 5-minute cycle is as good as any other.

Thoron will only be found very close to radon entry points. That, together with its fast response, makes thoron sniffing an excellent sleuth for radon entry points.

To terminate the run any time, you may switch off the RAD7. The data collected, of completed cycles, is stored in the RAD7 memory, and available for later display, printing or downloading to a PC.

2. BASICS OF *RAD7* OPERATION

2.1 Introduction

2.1.1 The Key Pad

The RAD7 is operated through a four-key menu-driven interface. These four keys allow you to look at the commands, select one, and then do it.

Menu Key

Press [MENU] and you see the menu prompt (>) and the word Test:

```
>Test
```

Arrow Keys

Press the forward and backward arrow keys to go through the available options. To advance quickly through the options, hold down the key so that it "auto-repeats."

The arrow keys allow you to move right and left through the various commands, looking for the action you want.

Enter Key

When you have decided on a certain menu option, you select it by pressing [ENTER]. The enter key tells the RAD7 that you have made your selection. You are telling it what you want it to do.

The enter key makes it happen.

2.1.2 Command List

The RAD7 command list has four command groups: Test, Data, Setup and Special. The Test group of commands controls the collection of new radon data. The Data group retrieves data from memory, outputs them, and gets rid of old, unwanted data. The Setup group prepares the RAD7 to operate according to your requirements. The Special group is a set of commands that are available when RADLINK, the remote control software, is loaded.

2.2 Test

The Test group of commands controls the collection of radon data and allows you to manipulate the current test (test-in-progress). You can start and stop data collection, save or clear the current test, or print the current test as it stands. (The Test commands do not allow access to stored data. You have to go to Data for that.)

2.2.1 Test Status

To see the status display, enter the Test Status command. Press [MENU], [ENTER], [ENTER]

On the LCD display, you will see:

```
0501        Idle     Sniff
00:30:00             00000
```

On the upper left, you see the current run number/ cycle number (0501 - run 05, cycle 01.).

The middle shows the detector status (Idle or Live), and the upper right gives the current test mode (Sniff, Normal or Grab). (Note that in AUTO mode, the indication will change from Sniff to Normal after three hours of measurement.

Lower left shows the count-down timer (00:30:00 = 30 minutes) which counts down to zero when the detector is Live (i.e., a test is in progress). The lower right shows the total number of counts since the beginning of the current cycle.

The arrow keys may now be used to access additional status information.

Press [→] once, and you will see something like this:

```
Last reading:
0409  1.80 " 0.74 p
```

The lower left is the run number (2 digits) and cycle number (2 digits) of the last completed cycle stored to memory.

The lower right is the radon reading and statistical uncertainty, followed by "p", indicating

picoCuries/liter, or "b" for Becquerels/cubic meter.

When a cycle ends, the information on this display is updated. If there have been no readings yet, the display will show

```
No readings yet.
```

Press [→] once again, and now you will see something like this:

```
24.8°C        RH:3%
B: 6.36V      P:  00mA
```

Top left is the internal temperature. (To change from Celsius to Fahrenheit, see Setup Units.)

Top right shows the internal Relative Humidity reading. When testing, maintain this value at 10% or less, by using the desiccant.

Bottom left is the battery voltage. This should range from about 6.00V to 7.10V. A discharged battery (less than 6.00) should be recharged as soon as possible. A fully charged battery will rest at 6.40 to 6.50 V. During a recharge, the voltage will eventually rise above 7.00 V. At no time should this read higher than 7.20V. In the lower right is the pump current. This number should vary from 00mA (pump off) to 80mA. When the pump is running with a light load, the current will range from 40-70mA. When the pump is running with a heavy load (clogged filter or blocked hose), the current will go to 90mA or higher. Pump currents above 90mA are considered a sign of trouble. Try changing the filters and check for blockage.

Press [→] again, and you will see something like this:

```
HV:  2218V,  10%
L:   02       S:  0.21V
```

This is a display of diagnostic values. Ordinarily it will be of little interest to you.

The top line is the high voltage reading and duty cycle. The range of normal values is from 2000 to 2500V, and from 8% to 18%.

The lower left corner is the leakage current. At room temperature, this value will normally range from 0 to 10. Higher temperatures ordinarily cause this value to rise. Excessive leakage current will result in "noise" in the lower energy end of the spectrum, and will also cause broadening of the alpha peaks.

The lower right corner is the signal voltage from the analog circuit. This number should be "stable"; that is, fluctuations should be no more than " 0.05V from the average value.

Press [→] yet again, and you will see something like this:

```
w | cpm  | +/-  | %tot
A | 6.0  |  4.3 | 48.8
```

This is the display for the A window data. You may press [→] to advance to B, C, D, etc.

The RAD7 records 8 windows (A - H) every time you make a measurement. They separate counts due to daughters of radon and thoron, and the background. Specific alpha particles end up in specific windows.

W: The window letter.
cpm: The counts per minute observed in the window.
+/-: The statistical uncertainty of the cpm value, also in units of cpm.
%tot: The number of counts in the window as a percentage of the total counts in the spectrum. This tells you quickly where the majority of the counts are: In the 3-minute radon peak (window A), or the long-lived radon peak (window C), etc.

As always, you press the [MENU] key to exit this display and return to the start of the menu.

2.2.1a Quick Save-and-Restart

This function allows the user to end a sniff test, store it to memory, and start up a new sniff test, all using a single key. It operates only from the SNIFF mode.

From the status display (showing the countdown timer), press the [ENTER] key once. The display will show:

```
Save and restart
? Yes
```

Press the [ENTER] key once more to confirm your intention. To escape, push the [MENU] key or push an arrow key to select "No" and push [ENTER].

2.2.2 Test Start and Test Stop

To start testing (or "counting"), after you have chosen the required setup, go to >Test Start by pressing [MENU], [ENTER], [➔], and then [ENTER]. The display will indicate that counting has begun:

```
Start counting.
```

One second later, the Status display will appear with the countdown timer in motion:

```
0501        Live     Sniff
00:29:37             00001
```

When the countdown reaches zero, the RAD7 will automatically calculate the radon concentration, store (or "save") the counts to memory, and clear the counters to begin a new cycle.

To interrupt the measurement, go to >Test Stop by pressing [MENU], [ENTER], [➔], [ENTER].

The display will respond:

```
Stop counting.
```

After one second, the display will go back to the top of the menu >Test.

You may wish to examine the Status display to verify that the status is Idle.

To resume testing from exactly the same point in the cycle where you stopped, select >Test Start as described above.

Note that Stop does not terminate the run, it is a pause. If you do not wish to resume testing from the same point, you should select either >Test Save or >Test Clear before continuing. This will terminate the suspended test, store it to memory (Save) or wipe it out (Clear), and clear the counters to begin a new run.

2.2.3 Test Save

The >Test Save command suspends counting and saves the suspended test (test-in-progress) to memory as if it had reached completion. Test Save completes the current run, so any subsequent test data will be stored as a new run. The display momentarily shows the run and cycle number in the form of 0101 Saved. This command may be accessed whether the status is Live or Idle. It always leaves the status Idle.

You will find this command especially useful when you wish to move the instrument to another location without waiting for the countdown to reach zero, but without losing that last incomplete cycle. The calculated radon concentration from the incomplete cycle is still good.

2.2.4 Test Clear

The >Test Clear command causes counting to be suspended and the current run to be completed without saving the last (suspended) incomplete cycle. Subsequent test data will be stored as a new run. You must answer Yes to the question Are you sure? in order to activate this command.

This command may be accessed whether the status is Live or Idle. It always leaves the status Idle.

2.2.5 Test Purge

The >Test Purge command suspends counting and begins purging the detector. The pump begins running and the high voltage circuit turns off in order to clear the sample chamber of radon gas and daughters as quickly as possible. You must provide clean, desiccated, radon-free air to the inlet in order to push out any radon that was previously sampled. Outdoor air is usually adequate for this purpose.

As always, use the inlet filter and drying tube. Ten minutes is usually sufficient for bringing the background down after exposure to moderate amounts of radon.

In order to dry out the RAD7 without using up much desiccant, connect the hoses from the RAD7 to the drying unit, as a loop. When the pump runs, the same air will circulate repeatedly through the desiccant. This procedure will

efficiently remove residual moisture from the RAD7. This does not introduce any fresh air, and so does not change the radon level in the instrument, but you can make a measurement of the background while it is set up in this configuration.

To end the purge, answer `Yes` to the question `Stop purge?` which appears on the display. Alternatively, you may push `[MENU]` to end the purge.

2.2.6 Test Lock

If you push `[ENTER]` when this is displayed, it will lock the key pad. The LCD display will just show:

```
DURRIDGE RAD7
```

Nobody will be able to unlock the key pad, unless they know the secret.
If the key pad was locked during a measurement, then the readings will continue as normal, with the RAD7 recording all the data, until the end of the run.

Switching the unit off, while locked, will stop the measurement, but the key pad will still be locked when the RAD7 is switched on again.

To unlock the key pad, hold the `[ENTER]` and both arrow keys down, all together, for 3 - 4 seconds, or until the unit beeps, then release the three keys and push `[MENU]` immediately.

2.2.7 Test Sleep

The `>Test Sleep` command allows you to turn off most of the electronic circuits, with the power switch on, in order to conserve battery charge. A fully charged RAD7 should be able to "sleep" for about one week on batteries alone. Press the menu key to "wake up" the RAD7.

The Sleep function was for older models that did not have the Real Time Clock (RTC) and Non-Volatile Memory (NVRAM) options. New and upgraded instruments may be shut down completely, power switch off, without losing any stored data or clock.

2.2.8 Test Print

The `>Test Print` command calculates results for an incomplete or suspended test cycle and prints them according to the print format that is currently set.

Spectrum output is available by selecting `>Setup Format Long` beforehand.

If you wish to abort printing, press the `[MENU]` key. The run number and cycle number that ordinarily appear on printed data are replaced by 0000 to signify that the cycle is not completed.

2.2.9 Test Com

The `>Test Com` command outputs the results for an incomplete test cycle to the serial port.

If you wish to abort output, press the menu key. The run number and cycle number that ordinarily appear with the data are replaced by 0000 to signify that the cycle is not completed.

2.3 Data

The Data group of commands retrieves data from memory, displays it, prints it, reports it graphically, and outputs it to the serial port. The Data group also includes commands for managing memory. The memory will hold the data for 1,000 cycles, in up to 100 runs.

Many commands in the Data group require you to enter a two-digit run number after the command. The "default" run number (the one automatically set if you do nothing) is the run number of the last complete cycle of data stored. The arrow keys allow you to select any other run number.

2.3.1 Data Read

Select `>Data Read` followed by a two-digit run number, to examine radon readings from that particular run. For example, select `>Data Read 01` to examine readings from run number 01, the first test in memory.

You will see something like this:

```
0101  23.3 " 1.54 p
  11:45      19-MAY-99
```

Line 1 is the run/cycle number followed by the radon concentration, uncertainty, and unit indicator. This example shows:

Run 01, Cycle 01, 23.3 " 1.54 pCi/L.

Line 2 is the time (24-hour military time) and date the reading was completed.

Press [→] to advance to the next reading in memory; press the backward arrow to go back to the previous reading.

To quit examining data, press [ENTER] or [MENU].

Note that large numbers are presented in shorthand notation. The symbol "K" stands for 1,000 and "M" stands for 1,000,000. For example, 33K2 stands for 33,200.

2.3.2 Data Print

To print out a run of data from memory, select >Data Print followed by the two-digit run number. For example, to print the data from run number 05, select >Data Print 05.

If the printer format has been set to Short, the following printout will be made for each cycle of the run:

```
0501  2.69  " 2.83   p        Sniff
   FRI  21-MAY-99   19:41
   26.8 EC   RH: 7%   B:7.06V
```

Line 1 is the run/cycle number, the radon concentration, the uncertainty, the units indicator (p=picoCuries per liter, B=Becquerels per cubic meter), and the mode indicator.

Line 2 is the date and time that the cycle was completed and stored to memory.

Line 3 is the temperature (in either "C" Celsius or "F" Fahrenheit), relative humidity (internal), and battery voltage at the time the cycle ended.

If the printer format has been set to Medium or Long, then you will see a printout like this for each cycle:

```
0501  2.69  " 2.83   p        Sniff
   FRI  21-MAY-99   19:41
   26.8 EC   RH: 7%   B:7.06V
Total Counts:     42.
Livetime:   27.8min
A: 0.53"0.08   cpm     47.3%
B: 0.02"0.02   cpm      1.7%
C: 0.52"0.08   cpm     46.4%
D: 0.01"0.02   cpm      0.9%
O: 0.04"0.03   cpm      3.6%
```

Lines 1, 2 and 3 are the same as in Short format, as outlined above. Line 4 is the total number of counts detected during the cycle.

Line 5 is the livetime, the time that the detector was actively collecting data.

Lines 6 through 10 are the windows data for windows A, B, C, D, and O. (O is the consolidated window for "others", or counts that are not included in windows A through D.)

Each line of windows data contains the window letter (A, B, C, etc.) followed by the window's counts per minute (cpm), statistical uncertainty of the counts per minute, and percent of the total counts included within that window.

NOTE: The RAD7 does not store spectra from old cycles, so no spectra will print from memory even if the printer format is Long. If you need a spectrum, be sure you print while the test is still running.

If no data are available to print, the RAD7 will beep and display No tests stored.

To abort a printout, press the menu key, then press the printer paper advance button.

2.3.3 Data Com

The RAD7 has an RS232 port that can transfer data to your computer. Status must be Idle.

To send a run of data to the serial port, select >Data Com followed by the two-digit run number. When ready, push [ENTER].

The following message will appear on the display as the data is sent:

```
Data transfer ...
```

When the data transfer finishes, the RAD7 will beep.

To enable your PC to receive data, appropriate software should be running. A terminal emulation program, or CAPTURE, the data link software provided with the RAD7, may be used. See the chapter on Data Communication, Chapter 5, for more detail.

2.3.4 Data Summary

To print a summary report and time graph of a run's data, select `>Data Summary` followed by the two-digit run number. The following information will be printed:

```
Run 31
Begin 01-Jun-99   12:49
Serial      00500
Cycles = 048
Mean: 0.77 pCi/l
S.D.: 0.27 pCi/l
High: 1.41 pCi/l
Low:  0.20 pCi/l
```

where:
Line 1 is the run number.
Line 2 shows the date and time of the first reading.
Line 3 is the serial number of the instrument.
Line 4 is the number of completed cycles in the run.
Line 5 is the arithmetic mean (or "average") of the radon concentrations recorded.
Line 6 is the standard deviation of the readings taken during the run.
Lines 7 and 8 are the highest and lowest radon concentrations.

Following Line 8 is a bar graph of radon concentration through time. Time-of-day is printed along the left-hand edge of the graph. If there is only one cycle of data, the bar graph will not print.

This printout procedure has been programmed into several protocols. When you choose one of the pre-programmed protocols, this report is printed out automatically at the end of the run, together with a cumulative spectrum.

2.3.5 Data Free

To determine the amount of free memory available for storing new radon readings, select `>Data Free`, and push `[ENTER]`.

For about two seconds, the display will look something like this:

```
910 cycles free.
```

The RAD7 can store up to 999 cycles of data. As the memory fills with data, the Data Free indicator decreases. If the Data Free indicator reaches 000, any subsequent attempt to store data to memory will result in a "memory full" error.

Keep your eye on this indicator to avoid embarrassment! When the amount of free memory gets uncomfortably low (i.e. 200 or less), consider deleting un-needed old data to open up space for new data. See Data Delete and Data Erase.

2.3.6 Data Delete

To delete an entire run of data, select `>Data Delete` followed by the two-digit run number.

The display will prompt you for confirmation:

```
Delete run 31?
No
```

Press `[→]` to find `Yes`, then press `[ENTER]` to delete the run's data from memory and free the space for new data. No other run's data will be affected.

After deletion of a run's data, any attempt to retrieve the data will result in a `No tests stored` message. The main purpose of the Data Delete command is to selectively free up memory space for new tests. Do not confuse Data Delete with Data Erase, which wipes out all runs of data from memory. See also Data Free, Data Renumber, and Data Erase.

2.3.7 Data Renumber

Select >Data Renumber to renumber remaining runs into consecutive order after deleting one or more runs. This allows you to free up run numbers for new runs to be added, which is necessary when the run number approaches 99.

Say you have used all 99 runs and you wish to clear out some space for new runs. Furthermore, you have decided that you no longer need the data from runs 01 to 10. Delete these runs using Data Delete. Now select >Data Renumber to renumber runs. Runs 11 to 99 become runs 01 to 89, leaving 90 to 99 free to take new data.

The Data Renumber command does not free up memory space, only run numbers. The 999 cycle memory limit remains whether or not all 99 runs have been used.

2.3.8 Data Erase

Select >Data Erase only if you wish to completely wipe all data from the entire RAD7 memory. Data Erase deletes all runs and resets the current run/cycle number to 0101.

Select >Data Erase. The RAD7 will ask for confirmation:

Erase all Tests? No

Press [→] to find Yes. Press [ENTER] to complete the erasure. Use with caution!

2.4 *Setup*

The Setup group of commands configures the RAD7 to perform tests according to your needs. The RAD7 remembers all Setup parameters when it is turned off, so access the Setup commands only to change parameters.

Setup includes a 1-step >Setup Protocol command to configure the most frequently used parameters (Cycle time, Recycle number, Mode setting, and Pump setting) according to preset "protocols". These standard preset protocols include (None), Sniff, 1-day, 2-day, Weeks (that is, indefinite), User (which lets you preset your own), Grab, Wat-40 and Wat250 (for use with the RAD H_20), and Thoron.

The special command >Setup SavUser defines the user protocol according to the current parameter settings.

2.4.1 Setup Protocol

Select >Setup Protocol to automatically load in a group of predefined Setup parameters under one of the standardized protocols, or the User protocol. If you do not wish to select a protocol, you may abort the command by pressing the menu key, and no parameters will be changed.

Table 2.4.1 Preset protocols

	Cycle	Recycle	Mode	Thoron	Pump
Sniff	00:05	0	Sniff	Off	Auto
1-day	00:30	48	Auto	Off	Auto
2-day	01:00	48	Auto	Off	Auto
Weeks	02:00	0	Auto	Off	Auto
User	xxx	xxx	xxx	xxx	xxx
Grab	00:05	4	Sniff	Off	Grab
Wat-40	00:05	4	Wat-40	Off	Grab
Wat250	00:05	4	Wat250	Off	Grab
Thoron	00:05	0	Sniff	On	Auto

A Recycle number of 00 indicates indefinite test length. The test ends only if the operator intervenes, or if the RAD7 memory fills.

2.4.2 Setup Cycle

How long a test do you want, and how often do you want the RAD7 to take a reading (a cycle)? A typical radon test is made up of many cycles.

Select >Setup Cycle to adjust the Cycle time, or integration time, for a single radon reading. The Cycle time can be adjusted anywhere from two minutes to 24 hours. For continuous monitoring, the Cycle time is usually 30 minutes or longer. For radon sniffing, the Cycle time is usually 5 or 10 minutes. For thoron sniffing, the cycle time may be as little as 3 minutes.

Upon selection of `>Setup Cycle`, push `[ENTER]` and you will see something like this:

```
Cycle:    00:30
```

First, select the number of hours (00 to 23), and press `[ENTER]`. Then select the number of minutes (00 to 59) and press `[ENTER]`.

Remember that a run includes many cycles in sequence, and the total duration of the radon test is determined by the Cycle time multiplied by the number of cycles, or Recycle number. To adjust the Recycle number, use the `>Setup Recycle` command.

2.4.3 Setup Recycle

How long a test do you want, and how often do you want the RAD7 to take a reading (a cycle)? You determine the length of your test by choosing both the length and number of cycles. If you make a reading every 30 minutes, you will need 48 cycles to get a 24-hour test. In this case, 48 is the Recycle number.

Use `>Setup Recycle` to set the total number of cycles in a complete run. Multiply Cycle time by Recycle number to determine the total duration of the run.

Select `>Setup Recycle`. Push `[ENTER]` and you will see something like this:

```
Recycle:   48
```

Use the arrow keys to change the Recycle number, and press `[ENTER]` to complete the selection. Recycle number may be set from 00 to 99.

If 00 is selected, then the number of cycles is assumed to be infinite. Select 00 if you want the RAD7 to collect data indefinitely, or to go beyond the 99th cycle. After the 99th cycle, the RAD7 will then simply start a new run, and continue collecting data. Data collection will stop only when the operator intervenes, or when the memory completely fills up.

2.4.4 Setup Mode

Select `>Setup Mode` to change the RAD7 mode of operation. Five modes are available: Sniff, Auto, Wat-40, Wat-250, and Normal.

SNIFF mode is used when you want to follow rapid changes of radon concentration. In SNIFF mode, the RAD7 achieves rapid response to changing radon levels by focusing on the 3-minute polonium-218 alpha peak, calculating the radon concentration on the basis of this peak alone.

In NORMAL mode, the RAD7 achieves higher statistical precision by counting both polonium-218 and polonium-214 alpha peaks.

AUTO mode automatically switches from SNIFF mode to NORMAL mode after three hours of continuous measurement. This allows time for the equilibrium of the longer-lived radon daughter isotopes. The earliest part of the run will have the benefit of the SNIFF mode's quick response, while the latter parts of the run will benefit from the NORMAL mode's superior statistical precision.

We recommend that the AUTO mode be used for all screening tests and any tests to measure the average concentration over a period of time. With the AUTO mode there is no need to throw away the first three hours of data, or to calculate adjustments to correct for disequilibrium. The mean concentration reported in the run summary should accurately reflect the actual mean. SNIFF mode should be used where the goal is to follow, and measure, rapid changes in the radon concentration.

Wat-40 and Wat250 make calculations of the radon concentration in 40 ml and 250 ml water samples, respectively. They require the RAD H_2O water accessory kit to aerate the water under the controlled conditions necessary for these calculations.

2.4.5 Setup Thoron

Select `>Setup Thoron`. Push `[ENTER]` and you will see:

```
Thoron:   Off
```

Use the arrow keys to toggle between On and Off, and press [ENTER] to complete the selection.

With Thoron On, the calculated thoron concentration will be printed during continuous data logging, or in subsequent printing of data. Also, if the pump is in AUTO mode, it will be directed to pump continuously during the thoron measurement.

Note that the thoron calculation assumes a standard setup for the measurement. A small drying tube, three feet of vinyl tubing, and the inlet filter, should be used. Typically, the small drying tube is held in the hand, and used as a wand. If the laboratory drying unit is used instead of the small drying tube, it creates additional sampling delay, which allows more of the thoron to decay before reaching the RAD7, reducing the sensitivity of the measurement to about half that of the standard setup.

The only difference between Sniff protocol and Thoron protocol is that this setting, 'Setup Thoron', is Off in Sniff protocol and On in Thoron protocol (See Setup Protocol, Section 2.4.1).

2.4.6 Setup Pump

Select `>Setup Pump` to change the Pump setting. Four settings are available: Auto, On, Grab, and Off.

Auto means that the RAD7 switches the pump on and off according to a predetermined pattern that allows for sufficient sampling of air while conserving battery charge and pump wear.

In Auto pump setting, the pump always switches on for 4 minutes at the beginning of a new test cycle to ensure a good initial sample. If the humidity in the sample cell remains above 10%, then the pump stays on to allow the cell to dry out. Then the pump runs for just one minute in every five, until the end of the cycle.

On means the pump is always on, whether the RAD7 is counting (Live) or not (Idle).

Grab initiates a standard grab sampling sequence at the beginning of a run. When you start a new run with the pump set to Grab, the pump will run for exactly 5 minutes. This is followed by a five-minute equilibrium delay, after which the counting period begins. The pump does not run at all during the counting period. As usual, you can determine the length of the count period by multiplying the cycle time by the recycle number. The total time to complete a test is the pump sample time (5 minutes) plus the delay period (5 minutes) plus the count period. Note that the Grab, Wat-40 and Wat250 protocols, under `>Setup Protocol`, above, all use this pump setting.

Off means the pump is always off.

Use Auto pump setting for routine radon testing. The RAD7 has been factory calibrated with the pump in this setting.

2.4.7 Setup Tone

Select `>Setup Tone` to choose the audible tone type. Three settings are available: Off, Chime, and Geiger. Off means the beeper remains quiet. Chime means the beeper will sound only at the end of a cycle, and is otherwise silent. Geiger means the beeper will emit a chirp whenever a particle is detected, much like the familiar Geiger counter. But unlike a Geiger counter, the pitch of the chirp depends on the energy of the alpha particle. A trained ear can distinguish "old" radon from "new" radon by the sound of the chirps. The thoron beep is the highest pitch. In the Geiger setting, anyone will recognize a radon "gusher" by the rapid-fire chirping the RAD7 produces.

2.4.8 Setup Format

Select `>Setup Format` to change the way data are printed out. Four settings are available: Short, Medium, Long, and Off.

Short causes the RAD7 to print results in an abbreviated form. Three lines of printed text contain a cycle's most important data: the run/cycle number, radon concentration and uncertainty, units and mode, time and date, temperature, relative humidity (internal), and battery voltage.

Medium and Long printouts include seven additional lines of data: total counts, livetime, and counts per minute for five alpha energy windows. These seven lines are the raw data from which the

radon concentrations shown in the first line of the printout are calculated.

The Long format, when printing from a test in progress (Live) includes a graph of the alpha energy spectrum. Since spectra cannot be saved to long-term memory, the spectrum will not be printed when retrieving past data.

Off means that no data will print out at the end of each cycle, but the summary and cumulative spectrum will print at the end of the run (if the printer is set up, switched on and has external power).

2.4.9 Setup Units

Select `>Setup Units` to change the measurement units with which the RAD7 reports radon concentration and temperature. First, enter the radon concentration unit (pCi/L = picoCuries per liter, Bq/m3 = Becquerels per cubic meter, cpm = counts per minute, #cnts = number of raw counts). Next, enter the temperature unit (_F = degrees Fahrenheit, _C = degrees Celsius or Centigrade).

PicoCurie is the favored unit of radon activity in the U.S., while Becquerel is the favored unit in Europe and Canada. 1 pCi/L equals 37 Bq/m^3. "Counts per minute" is the direct output of the RAD7 while "number of raw counts" is the raw direct output. With livetime, mode, and calibration factor, one can convert from any of these units to any other, but it is usually easier to let the RAD7 do the work.

The choice is retroactive. Change the unit using the `>Setup Units` command, then print out the same data. Everything will print as before, but in the new units.

2.4.10 Setup Savuser

Select `>Setup SavUser` to program the special User protocol according to the present Setup parameters. You must answer Yes, and push `[ENTER]`, to confirm that you wish to change the User protocol. The purpose of this command is to give you an opportunity to customize a protocol according to a set of favorite parameters. Thereafter, it's a cinch to return to the same set of parameters; simply select `>Setup Protocol [→] User`.

The User protocol has many possible applications. One RAD7 owner uses her instrument for 3-day screening tests. To make the setup easy, she programs the User protocol with the parameters for a 72-hour screening test. To do this, she first sets up all the parameters as she wants them. She enters 2 hour for the Cycle time, 36 for the Recycle number, Auto for the Mode setting, Off for thoron, and Auto for the Pump setting.

Finally, to program the User protocol with these values, she selects `>Setup SavUser` and answers Yes to the confirmation question. After that, she can easily return to the 72-hour protocol by selecting `>Setup, Protocol, User,` any time she wishes.

2.4.11 Setup Clock

Use `>Setup Clock` to change time zones, go in or out of daylight savings time, or to synchronize the RAD7 clock with another clock. The Real Time Clock (RTC) will maintain time-of-day and calendar date for as long as 10 years, and is accurate to within one minute per month at room temperature.

Select `>Setup Clock` to set the time and date of the RAD7 clock. You will see:

```
Time:   15:05:34
```

The arrow keys change the numbers. Holding an arrow key down will cause the numbers to change quickly. The cursor (blinking square) will start on the hour. Set the correct number with the arrow keys, then push `[ENTER]` to confirm. Do the same for the minutes and seconds.

Next you should see:

```
Date:   13-DEC-11
```

The cursor then moves on to date, month and year, in turn. Press `[ENTER]` after each figure is set.

2.4.12 Setup Review

The `>Setup Review` command allows you to display and print a listing of the current instrument settings, including Date and Time, Protocol, CycleTime, Recycle, Mode, Thoron,

Pump, Tone, Format and Units. Thus you can check that the instrument is set up properly, and confirm this, in hard copy, right on the data printout.

2.5 *Special*

Unless you have RADLINK, the remote control software, installed in the RAD7, you will see:

```
Not installed.
Install?   No
```

Use the arrow keys to toggle between Yes and No. If you confirm Yes, the RAD7 will sit, waiting for a data string at the RS232 port. To recover, push [MENU]. Note that this facility is normally not used for installation, because RADLINK, if purchased with the RAD7, or as part of a calibration and upgrade, will be installed at the factory.

If RADLINK is installed already, then >Special opens a menu of special commands available from the keypad of the RAD7. All the commands, both standard and special, will also be accessible from a remote PC, either directly, or by modem connection.

The following command set are those available with RADLINK version 0252. Earlier versions will have a subset of these.

2.5.1 Special Ident

Output the RAD7 identification sequence, including firmware version, hardware model number, unit serial number, and last calibration date.

2.5.2 Special SPrOn

Re-direct subsequent output from the infrared printer to the serial port. In other words, everything that would ordinarily be printed will shoot out the serial port, but nothing will be printed, even when you say "Print". One reason to use this might be to move the data very quickly into a computer without waiting for the (slow) infrared printer link. You can cancel the re-direction order and restore the use to the infrared printer with the "Special SPrOff" command.

When you turn off the RAD7 and turn it on again, it always restores output to the infrared printer.

Note that the spectra that would be printed on the infrared printer are not sent to the serial port by Special SprOn.

2.5.3 Special SPrOff

Cancel the printer to serial port re-direction, so that output can go to the printer again.

2.5.4 Special SetBaud

Set the serial port bit rate. The following standard speeds are available: 300, 600, 1200, 2400, 4800, 9600, and 19,200 bps. The other communication settings are always 8 bit, no parity, and 1 stop bit. The RAD7 remembers the serial port speed when you power down. Note that at the highest serial speed settings the RAD7 may not be able to keep up with incoming character strings unless the characters are "paced". An "echo-wait" strategy will avoid this problem. Also note that the RAD7 recognizes XOFF/XON flow control protocol when sending data.

2.5.5 Special Status

Gives a snapshot of the RAD7 status page, including run and cycle numbers, countdown timer, last reading, temperature, humidity, and so on. This is basically the same information that you can get with "Test Status", but it gives the data in one shot and does not continue to update every second.

2.5.6 Special Start

Same as "Test Start" (see Section 2.2.2, Test Start), but does not go into a continuously updating status display.

2.5.7 Special Stop

Same as "Test Stop" (see Section 2.2.2 Test Stop).

2.5.8 Special Comspec

Output the current test data, including the counts in all 200 alpha energy bins. These counts can be imported into a spreadsheet program and displayed as a graph of the energy spectrum.

2.5.9 Special ComAll

(Version 0244/940221 or later) - Output complete set of RAD7 test data (up to 1000 readings) to the serial port in comma delimited format.

2.5.10 Special SPrAll

Output complete set of RAD7 test data (up to 1000 readings) to the serial port in standard, readable 24 column printer format, without affecting the infrared printer.

2.5.11 Special S-Load

Used to load special software into the RAD7 through the serial port.

2.5.12 Special Version

Output the special extension version number.

2.5.13 Special Model

Output the RAD7 hardware version number.

2.5.14 Special Serial

Output the RAD7 unit serial number.

2.5.15 Special Beep

The RAD7 gives an audible beep tone. Does not make any sound if the tone setting is "Off".

2.5.16 Special Relays

Access the RELAYS set of commands. At the end of every cycle, if the function is enabled, the RAD7 will set or reset two external relays according to the individually set thresholds and the measured radon level. The commands consist of 'relay1', 'relay2', 'enable', and 'disable'. Use the arrow keys to scroll between these commands. Relay1 permits the user to set a level, above which the RAD7 will turn on relay1, and below which it will turn the relay off. Relay2 does the same for the second relay. 'Enable' causes the function to go into effect. Note that the command to the relays is sent after the RAD7 has finished printing data at the end of the cycle. 'Disable' stops the RAD7 from sending any commands to the relays.

2.6 Infrared Printer

The RAD7 uses an infrared link to print to the supplied Chamjin NewHandy 700 printer. The printer should be placed on the face plate, between the green lines as indicated. Because the print mechanism uses thermal technology, only thermal paper will work. Detailed instructions are provided in the Chamjin printer manual.

It should be noted that the printer has a time-out sleep control, which puts the printer out of action after ten minutes with nothing to print. This function is there to save batteries, and is automatically disabled if external power is supplied continuously.

Without batteries, external power will allow the printer to work normally, except that batteries are needed to print, properly, the bar chart of the run summary.

If the printer is placed in position and switched on before switching on the RAD7, it will print out identity information and a review of the setup, before the RAD7 goes to `>Test`. It is good practice to do this if the measurement data are to be printed out, because it automatically provides a header for the data printout, with instrument identity and setup:

```
DURRIDGE RAD7
Vers 2.5f   991128
Model 711
Serial 00512
Calib 20-MAY-11
Last used
   FRI 21-MAY-11  17:30

Current settings
   FRI 21-MAY-11  19:09

Protocol: 2-Day
Cycle: 00:60
Recycle: 48
Mode: Auto
Thoron: Off
Pump: Auto
Tone: Geiger
Format: Short
Units: pCi/L   EC
```

At the end of every cycle, the printer will print the data of that cycle, according to the format setting.

In short format, it prints:

```
0102   2.69  " 0.73   p   Sniff
   FRI  21-MAY-99   19:41
   26.8 EC   RH: 7%   B:7.06V
```

With the run and cycle number, radon level, two-sigma uncertainty, units and mode in the top row, date and time in the second, and temperature, humidity and battery voltage in the third.

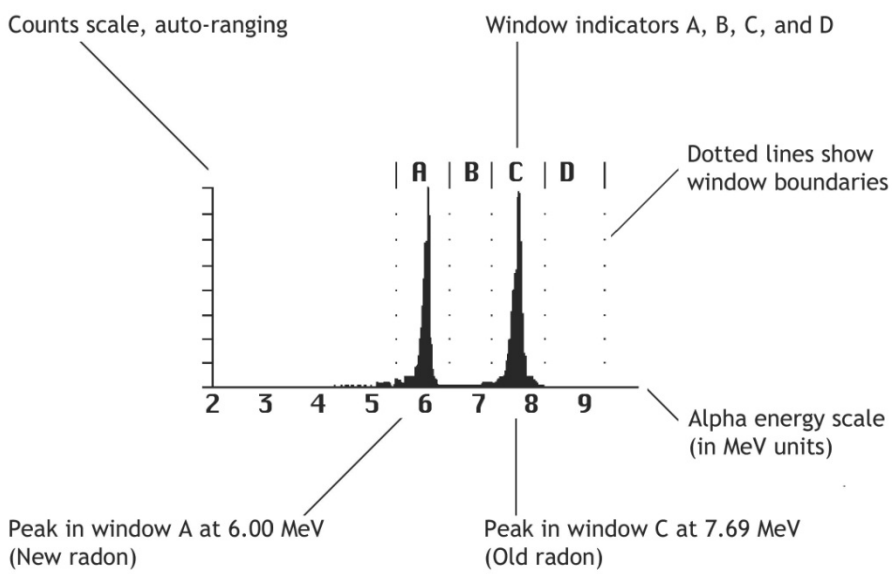
Medium format adds:

```
Total Counts:    357.
Livetime:   28.2 min
A: 5.74" 0.98 cpm 45.4%
B: 0.32" 0.29 cpm 2.5%
C: 6.13" 1.01 cpm 48.5%
D: 0.00" 0.14 cpm 0.0%
O: 0.46" 0.34 cpm 3.7%
```

Where the lifetime is the actual time spent waiting for an event, slightly less than the elapsed time. The windows, A, B, C, D, and all the rest, O, correspond to the different alpha energies in the spectrum.

Long format adds, to the short and medium formats, a printed spectrum of the alpha energies, as shown below.

At the end of a run, the printer will print a summary, see figure in Section 1.4. It will include an average of the radon concentrations, the high value, low value and standard deviation. These are followed by a bar chart, showing the variation of radon concentration from cycle to cycle throughout the run. Finally, it prints a cumulative spectrum, showing the distribution of energy of all the alpha decays counted during the run. This spectrum is very informative. It gives a good indication of the condition of the instrument and the quality of the measurement. It is a useful habit to look at the cumulative spectrum from time to time, just to be sure that it has not changed in character.



Alpha Energy Spectrum

3. BASICS OF *RAD7* TECHNOLOGY: HOW IT WORKS

3.1 Introduction

This chapter deals with a number of fundamental facts concerning radon and thoron, their measurement in general and their measurement, specifically, with the RAD7. It is not necessary to master the underlying physics to become proficient in the use of the instrument, but some understanding of what is happening is helpful.

It is recommended that the user read the whole of the manual, including this chapter, on first acquiring the instrument, and then again after gaining some experience in the field.

3.2 Radon Decay Chain

When the earth was formed, billions of years ago, there were probably many radioactive elements included in the mix of material that became the earth. Three, of interest, have survived to this day, namely uranium-235, uranium-238, and thorium-232. Each has a half life measured in billions of years, and each stands at the top of a natural radioactive decay chain.

A radioactive element is unstable. At some indeterminate moment, it will change to another element, emitting some form of radiation in the process. While it is impossible to predict exactly when the transformation of an individual atom will take place, we have a very good measure of the probability of decay, within a given time slot. If we started with a very large number of atoms of a radioactive element, we know quite precisely how long it would take before half those atoms had decayed (though we could not identify the decaying atoms individually, beforehand). This time interval is called the half-life of that particular element.

A natural radioactive transformation is accompanied by the emission of one or more of alpha, beta or gamma radiation. An alpha particle is the nucleus of a helium atom. It has two protons and two neutrons. Thus an 'alpha decay' will reduce the atomic number by two and reduce the atomic weight by four. A beta particle is an electron, with its negative charge. Thus a beta decay will increase the atomic number by one and leave the atomic weight unchanged. A gamma ray is just a packet of energy, so a gamma decay by itself would leave both the atomic number and atomic weight unchanged.

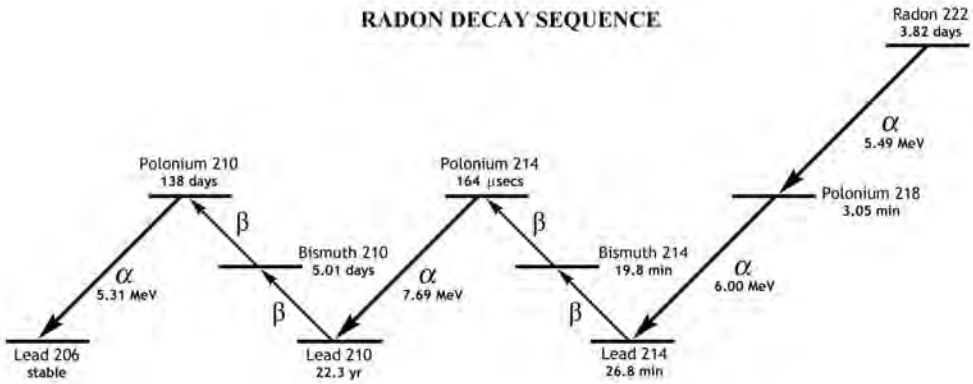
A decay chain is a series of distinct transformations. A uranium-235 nucleus goes through a series of 11 transformations to become stable lead-207. A thorium-232 nucleus goes through 10 transformations to become stable lead-208. And a uranium-238 nucleus goes through 14 transformations to become stable lead-206.

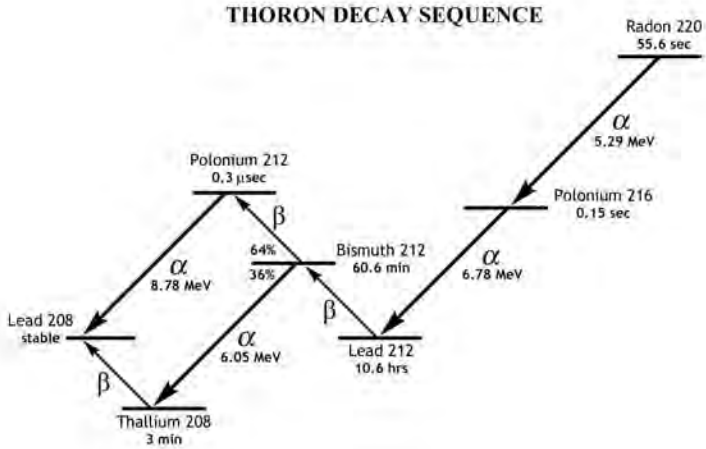
All three of these natural decay chains include isotopes of radon. Radon-219, or "actinon", is a link in the uranium-235 chain. You will probably never encounter actinon in indoor air, due to its scarcity and short half-life. Radon-220, or "thoron", is part of the thorium-232 decay chain. You will sometimes encounter thoron in indoor air, particularly near radon entry points, and, more often, in soil gas. Radon-222, or familiar "radon", is part of the uranium-238 decay chain. You will almost always be able to detect radon-222 in indoor air, outdoor air, and soil gas.

The radon isotope is the first element, in each of the decay chains, that is not a metal. It is, in fact, an inert, or "noble", gas. So it can escape any chemical compound its parent (radium) was in, and diffuse into the air.

To focus on these inert gases, the thoron and radon decay chains, shown below, are those parts of the thorium-232 and uranium-238 decay chains that include just these radioactive gases and their short-lived progeny.

It may be noted that only alpha decays change the atomic weight, and then only in steps of four. Thus the atomic weights of all the members of the radon-220, thoron, decay chain are divisible by four, while none of the radon-222 are.





Radon and Thoron decay chains

3.2.1 Radon-222 (Radon)

Every nucleus of radon-222 eventually decays through the sequence polonium-218, lead-214, bismuth-214, polonium-214, and lead-210. With each transformation along this path the nucleus emits characteristic radiations: alpha particles, beta particles, or gamma rays, or combinations of these. The RAD7 was designed to detect alpha particles only, so we will emphasize alpha radiation .

Radon-222 is an inert gaseous alpha-emitter that does not stick to or react with any materials. It has a half-life of 3.82 days. A particular radon nucleus may decay at any time, but it is most likely to decay between now and 8 days (two half-lives) from now. When the radon nucleus decays, it releases an alpha particle with 5.49 MeV of energy, and the nucleus transforms to polonium-218. The polonium nucleus can never go back to radon again. Polonium atoms are metals and tend to stick to surfaces they come in contact with, e.g., a dust particle in the air, or a wall, or the inside of your lung!

Polonium-218 nuclei have a short half-life, only 3.05 minutes, which means that most of them will decay within 6 minutes of their formation. The average polonium-218 nucleus lives for only 4.40 minutes before it decays (1.443 times the half-life gives the mean life). Like radon, polonium-218 emits an alpha particle when it decays, but with an energy of 6.00 MeV rather than radon's 5.49 MeV.

When polonium-218 decays, it transforms to lead-214, also a radioactive solid. But lead-214 has a half-life of 26.8 minutes, and it emits beta radiation rather than alpha radiation. When lead-214 decays, it becomes bismuth-214, also a radioactive solid and a beta emitter. Bismuth-214 has a half-life of 19.8 minutes, and transforms to polonium-214 when it decays.

Polonium-214 is a bit different. It has a half-life of only 164 microseconds (0.000164 seconds) and it emits a 7.69 MeV alpha particle when it decays. When polonium-214 decays, it becomes lead-210, which has a half-life of 22.3 years. This means that an average lead-210 nucleus takes 1.443 times 22.3 years, or 32.2 years, to decay. Because of its long half-life, we usually ignore lead-210 as a factor in radon measurement, though it adversely affects the background of some instruments (not the RAD7).

Lead-210 eventually undergoes beta decay to Bismuth-210 which quickly (5 days half-life) undergoes a further beta decay to Polonium-210. Polonium-210 has a half-life of 138 days and decays with a 5.30 MeV alpha particle to Lead-206, which is stable. The 5.30 MeV alpha particle from Polonium-210 creates unwanted background in most radon monitors, but not in the RAD7.

3.2.2 Radon-220 (Thoron)

Similarly to radon-222, every radon-220 (thoron) nucleus eventually decays through a sequence of 5 transformations to Lead-208. The main distinction is the very different half lives involved.

Thoron has a half life of only 55.6 seconds. It emits a 6.29 MeV alpha particle and transforms to polonium-216, which in turn has only a 0.15 second half-life before emitting a 6.78 MeV alpha particle and transforming to Lead-212.

Lead-212 hangs around for a long time, with a half-life of 10.6 hours. It transforms by beta decay to bismuth-212, which, in turn, has a half life of 60.6 min.

Bismuth-212 has a 2:1 split, with two thirds transforming by beta decay to polonium-212 and one third transforming by 6.05 MeV alpha decay to thallium-208. The polonium-212 decays immediately to lead-208, emitting an 8.78 MeV alpha particle in the process, while the thallium-208, with a half-life of 3 min, undergoes a beta decay to the same destination, lead-208.

3.3 Continuous Monitors

There are several types of continuous radon monitors on the market. Nearly all of these are designed to detect alpha radiation, but not beta or gamma radiation. Why? Because it is very difficult to build a portable detector of beta or gamma radiation that has both low background and high sensitivity.

Three types of alpha particle detectors are presently used in electronic radon monitors:

1. Scintillation cells or "Lucas cells"
2. Ion chambers
3. Solid state alpha detectors.

Each of these types has advantages and disadvantages relative to the others. All of these types can be used for low background alpha particle counting.

The DURRIDGE RAD7 uses a solid state alpha detector. A solid state detector is a semiconductor material (usually silicon) that converts alpha radiation directly to an electrical signal. One important advantage of solid state devices is ruggedness. Another advantage is the ability to electronically determine the energy of each alpha particle. This makes it possible to tell exactly which isotope (polonium-218, polonium-214, etc.) produced the radiation, so that you can immediately distinguish old radon from new radon, radon from thoron, and signal from noise. This technique, known as alpha spectrometry, is a tremendous advantage in sniffing, or grab-sampling, applications. Very few instruments other than the RAD7 are able to do this.

A distinction should be made between true, real-time continuous monitors, and other instruments and devices. With a continuous monitor, you are able to observe the variation of radon level during the period of the measurement. This can sometimes show big swings in radon concentration and may allow you to infer the presence of processes influencing the level. For good data, it is important that there be sufficient counts to provide statistically precise readings. Devices which give just a single, average reading, or whose precision is inadequate except after a long measurement time, are not, in this sense, continuous monitors.

Another important parameter is background. This is the reading given by the instrument when there is no radon in the air sample. For low level continuous monitoring, it is necessary that the background be extremely low and stable. Because of the high quality alpha detector, and unique, real-time spectral analysis, the RAD7 background is vanishingly small, and is immune to the buildup of lead-210, which plagues other instruments.

3.4 *Sniffers*

Sniffing means taking quick, spot readings. Thus you can get a rough idea of the radon level, without waiting for a full, 48-hour, EPA protocol test. The technique is often used to locate radon entry points in a building.

Any fast-response, continuous radon monitor, with a pump, can be used for sniffing. However, there are some factors to consider: One is the rate of recovery after exposure to high radon levels. When the sniffer finds a radon gusher, the whole radon decay chain builds up inside the instrument, and the various daughters become well populated. If the sniffer now moves to a low level region, it will take many hours for the lead/bismuth/ polonium-214 daughters to decay away. In the RAD7 this doesn't matter, because, in SNIFF mode, it looks only at the polonium-218 decays, and ignores the polonium-214 decays left over from previous sniffs. The polonium-218 has a three-minute half life, so the RAD7, sniffing for radon, has a 15 minute response time to both sudden increases and sudden decreases in level.

Unique to the RAD7 is the ability to sniff for thoron. Polonium-216 has a 150 ms half life, so the instrument response is virtually instantaneous. The only delay is the time required to put the air sample into the measurement chamber, which is about 45 seconds.

Another factor, when sniffing, is the vulnerability (of other instruments) to lead-210 buildup. Only with the RAD7 can you continue to sample high levels, without having to worry about increasing the background.

3.5 *Working Level*

Radon concentrations are determined by measuring the radioactivity of the radon or by measuring the radioactivity of the radon decay products. Instruments that measure radon decay products in the air are called "working level" monitors. Working level monitors sample air through a fine filter and then analyze the filter for radioactivity. The radon progeny are metal and they stick to the filter and are counted by a working level instrument. Radon-222, an inert gas, passes through the filter, so it is not counted

in such an instrument. Therefore, a working level instrument measures the radon progeny concentration (polonium-218, etc.), in the air, but not the radon gas concentration.

The RAD7, on the other hand, measures radon gas concentration. Radon daughters do not have any effect on the measurement. The RAD7 pulls samples of air through a fine inlet filter, which excludes the progeny, into a chamber for analysis. The radon in the RAD7 chamber decays, producing detectable alpha emitting progeny, particularly the polonium isotopes. Though the RAD7 detects progeny radiation internally, the only measurement it makes is of radon gas concentration.

In short, the RAD7 does not measure radon daughter concentrations (working levels), only radon gas concentrations.

3.6 RAD7 Solid-State Detector

The RAD7 's internal sample cell is a 0.7 liter hemisphere, coated on the inside with an electrical conductor. A solid-state, Ion-implanted, Planar, Silicon alpha detector is at the center of the hemisphere. The high voltage power circuit charges the inside conductor to a potential of 2000 to 2500V, relative to the detector, creating an electric field throughout the volume of the cell. The electric field propels positively charged particles onto the detector.

A radon-222 nucleus that decays within the cell leaves its transformed nucleus, polonium-218, as a positively charged ion. The electric field within the cell drives this positively charged ion to the detector, to which it sticks. When the short-lived polonium-218 nucleus decays upon the detector's active surface, its alpha particle has a 50% probability of entering the detector and producing an electrical signal proportional in strength to the energy of the alpha particle. Subsequent decays of the same nucleus produce beta particles, which are not detected, or alpha particles of different energy. Different isotopes have different alpha energies, and produce different strength signals in the detector.

The RAD7 amplifies, filters, and sorts the signals according to their strength. In SNIFF mode, the RAD7 uses only the polonium-218 signal to determine radon concentration, and the polonium-216 signal to determine thoron concentration, ignoring the subsequent and longer-lived radon daughters. In this way, the RAD7 achieves fast response to changes in radon concentration, and fast recovery from high concentrations.

3.7 RAD7 Spectrum

The RAD7 spectrum is a scale of alpha energies from 0 to 10 MeV. Of particular interest are the radon and thoron daughters that produce alpha particles in the range of 6 to 9 MeV.

When the radon and thoron daughters, deposited on the surface of the detector, decay, they emit alpha particles of characteristic energy directly into the solid state detector. The detector produces an electrical signal. Electronic circuits amplify and condition the signal, then convert it to digital form. The RAD7 's microprocessor picks up the signal and stores it in a special place in its memory according to the energy of the particle. The accumulations of many signals results in a spectrum.

The RAD7 divides the spectrum's 0 to 10 MeV energy scale into a series of 200 individual counters, each representing a 0.05 MeV channel. Whenever the RAD7 detects an alpha particle, it increments one of these 200 counters by one. Every so often, the RAD7 manipulates, condenses, prints out and stores data to long-term memory. Then it resets all 200 counters to zero, and begins the process anew.

The idealized spectrum of a 6.00 MeV alpha emitter looks like a single needle-thin spike at exactly 6.00 MeV.

Although the RAD7 approaches this ideal, the actual spectrum shows a broadened peak centered at or near 6.00 MeV with a characteristic "tail" that stretches into lower energy channels. Electronic noise in the detector and amplifier causes the peaks to widen, while alpha particles that enter the detector at glancing angles cause the tail. Higher than normal operating temperatures tend to increase electronic noise, and so increase the width of the peaks.

A combination of different alpha emitters appears on the spectrum as a series of different peaks. For example, a combination of equal amounts of Po218 and Po214 (as would occur in the case of radon daughter equilibrium) appears as twin alpha peaks. One peak (Po218) is centered at 6.00 MeV, while the other (Po214) is centered at 7.69 MeV.

The second example spectrum, shown in Section 3.13, is the characteristic signature of radon at equilibrium with its alpha emitting daughters. We would expect to see a spectrum like this after several hours at a constant radon level. The 5.49 MeV alpha particle directly emitted by radon-222 does not appear on the RAD7 spectrum, because it was created in the air, not on the surface of the detector. The radon-222 atom is inert and electrically neutral, and cannot be attracted to the solid state detector. Only after it decays to polonium-218 does the atom become positively charged and is thus driven to the detector surface.

The RAD7 spectrum shows radon daughters, but not radon itself. Do not confuse the RAD7's spectrum with that of a working level instrument. The alpha peaks may appear the same, but the RAD7 is really measuring radon gas, not working level.

3.8 Windows

The RAD7 groups the spectrum's 200 channels into 8 separate "windows" or energy ranges. Window A, for example, covers the energy range of 5.40 to 6.40 MeV. So window A includes the 6.00 MeV alpha particle from polonium-218. The first step toward converting raw spectral data to radon measurement is to add up all the counts in each window and divide by the detector "livetime" or duration of active data collection. The RAD7 microprocessor does this task and stores the results to memory in this form. You can recall and print window data from past measurements. The RAD7 adds windows E, F, G, and H together to form window O (for "other") before storing the data to memory. Spectrum printouts clearly mark windows A, B, C, and D with dotted lines.

Each window's function:

A. Radon Sniffer Mode counts. The total counts of alpha particles from the 3-minute, 6.00 MeV, Po218 decay.

B. Thoron 1 Window. The total counts in the region of the 0.15 second, 6.78 MeV decay of Po216. This window lies between windows A and C of the radon groups and may have some counts from spill-over from adjacent windows.

C. Radon Po214 counts. The total counts of the 7.69 MeV alpha particles from the decay of the great-great granddaughter of radon, which has an effective half-life of nearly an hour.

D. Thoron 2 Window. The total counts in the region of the effective 8.78 MeV decay of Po212, which has a half-life of about 10 hours.

E. High Energy Window. A diagnostics window that normally has close to zero counts. If the counts in this window are a large fraction of the counts in A or B or C or D, the RAD7 is probably not working properly.

F. Low Noise counts. A diagnostics window that gives the total counts in the first 10 channels. The count rate in Window F is a measure of the noise in the system. The counts may be high if the RAD7 is operated at very high temperatures.

G. Medium Noise counts. A diagnostics window that gives the total count in the region around channels 30 to 40. Window G normally has few counts, even when Window F shows a high count rate.

H. High Noise or Po210 Window. The total counts in the region of the 5.31 MeV alpha particle due to Po210 (polonium-210), the grand-daughter of Pb210 (lead-210). Since lead-210 (22 year half-life) results from the decay of the radon progeny we measure, this isotope will build up on the detector's sensitive surface through sustained measurement of very high radon concentrations, or many years of normal use. This window is not used in calculating radon levels, so the RAD7 will function well even with this isotope present, and the background will not be affected.

O. Composite window for "Others". The RAD7 groups windows E, F, G, and H together to form

the composite window O. Window O catches all the counts that did not go into the major windows A, B, C, and D. If window O consistently receives more than 30% of the total counts, you should inspect the spectrum printout for signs of trouble.

3.9 Isotope Equilibrium

Take a RAD7 that is completely clean, with no radon or daughters inside. What does the detector see? Close to nothing. Less than one alpha count per hour, due to unavoidable contamination of the materials of the instrument's construction. That is the instrument's intrinsic background. It is ignored by most people as of no consequence. Intrinsic background may add 0.01 pCi/L to a typical measurement, far below the radon concentration of outdoor air (usually 0.10 to 1.00 pCi/L).

Now introduce some radon into the RAD7. What do you see? At first, maybe nothing. But within a few minutes, you begin to get counts in the A window. The RAD7 chirps merrily with each count. That's polonium-218, a result of the decay of radon-222 within the RAD7 sample chamber.

For the first 5 minutes or so, the count rate increases, then begins to approach a steady level. After about 10 minutes, we say that the polonium-218 daughter has reached close to equilibrium with the radon-222 parent.

Equilibrium is when the activity of the daughter stabilizes, neither increasing or decreasing. At this point, nearly all of the counts land in window A, and you see a single peak in the spectrum printout.

But the total count rate is still increasing, more slowly now. You begin to see counts appear in window C. Just a few, but more and more of them over the course of the next hour or two. After 3 hours or so, we reach full equilibrium, when the activities of all the daughters stabilize. Now the spectrum shows the characteristic twin peaks: polonium-218 in window A and polonium-214 in window C. The peaks are of almost identical size.

Now flush the RAD7 with fresh, radon-free air. The count rate in window A immediately begins to drop, just as fast as it rose when you first put the radon in. Without radon inside the RAD7, there is no source to replace the polonium-218 that decays. So the polonium-218 disappears with its characteristic half-life of 3.05 minutes.

After 3.05 minutes, the count rate in window A is half of what it was before. After 6.10 minutes, the count rate is half of that, or one-quarter of what it was before. You get the picture. After 10 minutes, there are hardly any counts at all in window A. Not so for window C, however. The spectrum still shows a single strong peak in window C.

The peak in Window C takes hours to disappear. After half an hour, the count rate in window C has not even halved. Polonium-214 may have a very short half-life, but its parents, lead-214 and bismuth-214, certainly don't. One has a half-life of 26.8 minutes, and the other has a half-life of 19.8 minutes. And they are sequential, which makes matters worse.

After you completely remove the radon, it may be a good 3 or more hours before the counts really die down in window C. We call window C the "old radon" window, since it represents counts from radon that was present in the RAD7 an hour or more before.

The effects of time in windows B and D, is similar, but much more pronounced. There is no delay in the RAD7 to polonium-216, so the count rate in window B is always in equilibrium with the thoron gas in the measurement chamber. In contrast, there is a 10-hour half life in the decay chain down to polonium-212, so it will take days for window D to reach equilibrium. Window D is, therefore, not counted when sniffing for thoron.

Note however, that for every 66 counts in window D, there will be 34 counts in window A. This is because of the two-way split from Bismuth-212. So, in calculating radon concentration, the RAD7 corrects the counts in window A for any thoron daughters that show in window D.

3.10 Modes: Sniff and Auto

"Old" radon daughters can be a real pain in the neck if you can't tell them apart from "new" radon. Most radon monitors don't help you at all here, but the RAD7 does. Waiting around for equilibrium is also a trial if it means sitting around for more than 2 hours. It is possible to calculate your way out of that problem, but the "old" radon always comes back to bite you. With the RAD7, the solution is simple and painless. Put the RAD7 in SNIFF mode.

SNIFF mode means that the RAD7 calculates radon concentration from the data in window A only. It ignores window C. Now the instrument responds to changes almost instantaneously. Hit a "hot spot?" No problem. In SNIFF mode, you can purge the sample chamber and, in 10 minutes, you're ready to measure low levels again with reasonable accuracy. You can move from point to point in minutes, looking for radon entry points in foundation cracks or test holes.

For continuous monitoring in one location over many hours, NORMAL mode is the way to go. NORMAL mode means that the RAD7 uses both radon peaks, A and C, to calculate concentration. With double the count rate, you increase the precision of the measurement. In indoor environments, the radon concentrations rarely fluctuate quickly enough to justify using SNIFF mode for continuous monitoring.

The best of both worlds is provided by AUTO mode. Here, the RAD7 starts a test run in SNIFF mode, and then, after three hours, switches automatically to NORMAL mode. In this way, the first few cycles give readings without any bias from either "old" radon daughters left on the detector, or the slow build-up to reach equilibrium in window C, while the rest of the readings benefit from the higher precision given by twice the number of counts in each cycle.

For real-time monitoring, you are always better off to leave the mode in AUTO. The RAD7 is up to speed quickly, and is not influenced by old measurements. The final average of the run is therefore more accurate and more reliable.

CAPTURE can read a data file and force SNIFF mode presentation of the data, allowing the user to change the setting retrospectively.

Thus if, on looking at data taken in NORMAL mode, there is what appears to be a rapid change in radon concentration, changing to forced SNIFF mode presentation in CAPTURE will permit another look at the changes with better time resolution.

3.11 Background

"Background" in a radon detector refers to spurious counts that occur even in the absence of radon. Background can arise from the properties of the instrument or its components, other forms of radiation in the instrument's environment, or contamination of the instrument.

The RAD7's design makes it much less susceptible to background than other radon monitors, but one should still be aware of background in the RAD7 to avoid mistakes. The following list gives possible sources of background in the RAD7:

3.11.1 Short-lived Radon and Thoron Daughters

These are by far the most important components to background in the RAD7. Radon and thoron daughters that normally build up on the RAD7's solid state alpha detector continue to produce alpha counts for some time after the radon and thoron gases have been removed from the instrument. These lingering daughters can greatly confuse the result when you try to measure a low radon sample immediately after a high radon sample.

Many radon detectors require that you wait for the daughters to decay away (about three hours) before counting another sample. With the RAD7, however, you can go from high to low concentrations in a matter of minutes by counting in SNIFF mode, since the RAD7 distinguishes the different alpha-emitting daughters by their alpha energy. The resulting measurement responds with a 3.05 minute half-life. Thus, 10 minutes after the radon has been removed from the instrument, the

background will have been reduced by more than 90% and you can count a new sample.

Thoron daughters are worse behaved than radon daughters. One thoron daughter, Lead-212, has a half-life of 10.6 hours, so that, with other radon monitors, if you build up huge amounts of this daughter, you may have to wait one to two days before using your radon instrument again. The RAD7's ability to distinguish daughters by their alpha energy almost always makes it possible to continue working.

3.11.2 Adsorbed Radon Gas

Radon atoms can adsorb on or absorb into internal surfaces of the RAD7, on the inside of tubing or on desiccant granules. This radon can stay behind after you purge the instrument, then desorb (or out-gas) from these surfaces and enter the sample cell volume. This effect is ordinarily negligible since only a small fraction of the radon ever becomes adsorbed. But at very high radon concentrations (over 1000 pCi/L), even a small fraction can be significant, and you can expect to see some lingering radon after purging the instrument.

The best solution is to purge for 10 minutes every few hours until the count rate goes down. Even in the worst possible case, the radon must decay with a 3.82 day half-life, so you will eventually be able to use the instrument again.

3.11.3 Intrinsic Background

Due to very low concentrations of alpha emitting contaminants in the materials of the RAD7's construction, you can expect to get as much as one count every two hours (0.009 cpm) without any radon present. This count rate, corresponding to about 0.02 pCi/L, is low enough to neglect when doing routine indoor radon work. But for very low-leveled outdoor radon levels, or special clean room applications, this background may be significant. With painstaking technique, and long-term monitoring, it can be measured. Very low level readings can then be corrected for background, bringing the detection threshold of the instrument down below 0.02 pCi/L.

3.11.4 Long-lived Radon Daughters

After many years of use at elevated radon levels, your RAD7's detector will accumulate lead-210, an isotope with a 22-year half-life. Though Lead-210 is itself a beta emitter, one of its daughters is polonium-210, which produces a 5.3 MeV alpha particle. The RAD7 is able to distinguish this isotope by its energy, and exclude it from all calculations. We do not expect lead-210 buildup to contribute significantly to background in the RAD7, even after years of ordinary use.

3.11.5 Contamination by Radon, or Thoron, Producing Solids

If radon- or thoron-producing solids, such as radium-226 or thorium-228, become trapped in inlet hoses or filters, they may emanate radon or thoron gas that will be carried through the filters and into the instrument. Certain dusty soils may contain enough of these isotopes to make this scenario possible. If you suspect this kind of contamination, please call DURRIDGE. We would like to discuss your experience with you and help you solve your problem.

3.11.6 Other Alpha Emitters

As long as you filter the incoming air stream, there is little or no possibility for contamination of the instrument with other alpha emitters. Virtually all solids will be stopped by the inlet filters. The only naturally-occurring alpha-emitting gas other than radon and thoron is radon-219, or "actinon." Actinon, which has a very short half-life (less than four seconds), results from the decay of naturally-occurring uranium-235. But since uranium-235 is so much less abundant than uranium-238 (the ancestor of radon-222), we do not expect to ever see actinon in significant quantities apart from even more significant quantities of radon.

3.11.7 Beta and Gamma Emitters

The RAD7's solid state alpha particle detector is almost completely insensitive to beta or gamma radiation, so there will be no interference from beta-emitting gases or from gamma radiation fields. The most likely effect of high levels of beta or gamma radiation will probably be an increase in detector leakage current and increased

alpha peak width. Typical environmental levels of beta and gamma emitters have absolutely no effect on the RAD7.

3.12 Precision & Accuracy

3.12.1 Dry operation

"Precision" means exactness of measurement with regard to reliability, consistency and repeatability. "Accuracy" means exactness of measurement with regard to conformity to a measurement standard. An accurate instrument is necessarily precise, but a precise instrument can be inaccurate (due to mis-calibration, for example).

As long as the operator follows consistent procedures, counting statistics will dominate the RAD7's precision. Environmental factors have proven to be much less significant over normal ranges of operation. Aside from precision, the most important factor in RAD7 accuracy is calibration.

DURRIDGE calibrates all instruments to a set of four "master" instrument with a calibration precision of about 1%. The master instruments have been calibrated by way of inter-comparison with secondary standard radon chambers designed by the U.S. EPA. We estimate the accuracy of the master instrument to be within 4%, based on inter-comparison results. We estimate the overall calibration accuracy of your RAD7 to be better than 5%. We look forward to new developments in calibration standardization and traceability, which we expect will help improve calibration accuracy.

The table below summarizes the precision of the RAD7 according to the contribution of counting statistics. Counting statistics depend on sensitivity (calibration factor) and background count rate. The RAD7's intrinsic, or "fixed," background count rate is so low as to be a negligible contributor to precision, for the range of radon concentrations covered by the table. Environmental and other factors may affect precision by as much as 2%. The uncertainty values reported by the RAD7 are estimates of precision based on counting statistics alone, and are two-sigma values, as are the values in the following table.

Table: 3.12 Typical RAD7 precision based on counting statistics only.

NORMAL mode with sensitivity 0.500 cpm/pCi/L. Table values are two-sigma uncertainty (or 95% confidence interval) in units of pCi/L (percent).

	1 pCi/L	4 pCi/L	20 pCi/L	100 pCi/L
1 hr	0.37 (37%)	0.73 (32%)	1.64 (8.2%)	3.65 (3.7%)
2 hr	0.26 (26%)	0.52 (13%)	1.15 (5.8%)	2.58 (2.6%)
6 hr	0.15 (15%)	0.30 (7.4%)	0.67 (3.4%)	1.49 (1.5%)
24 hr	0.07 (7.4%)	0.15 (3.8%)	0.33 (1.7%)	0.74 (0.7%)
48 hr	0.05 (5.3%)	0.10 (2.6%)	0.23 (1.2%)	0.53 (0.5%)
72 hr	0.04 (4.3%)	0.09 (2.1%)	0.19 (1.0%)	0.43 (0.4%)

3.12.2 Humidity Correction

Much of the superior functionality of the RAD7 is a result of the high-precision real-time spectral analysis it performs. The high resolution of the energy spectrum is obtained by precipitating the radon daughters, formed by the decay of radon, right onto the active surface of the alpha detector. The high sensitivity of the RAD7 is a result of the large collecting volume of the measurement chamber. The combination of a precipitation process and large collecting volume means that humidity inside the measurement chamber will

affect the sensitivity of the instrument. The affect is a function of the absolute humidity

At normal room temperature and with good desiccant in the air sample path, the humidity in the measurement chamber at the start of a measurement will quickly be brought down below 10% RH and will eventually settle below 6%. In these conditions the collection has maximum efficiency and there is no humidity correction required. Should the desiccant expire and/or should the operating temperature rise well above normal room temperature, the absolute humidity may become significant and a humidity correction may be required to compensate for the drop in sensitivity.

While high humidity reduces the sensitivity of a RAD7, CAPTURE offers an automatic correction of the data, bringing readings back close to dry values. Please note, however, that the precision will be degraded, compared with readings taken in dry conditions. See Chapter 6.

3.12.3 Concentration Uncertainties

Obtaining accurate readings of a low radon concentrations often requires long cycle times, because when there are zero or very few counts within a given timeframe, the statistical uncertainty is proportionately high. Radioactive decays obey Poisson statistics, where the standard deviation (one-sigma) is the square root of the count. However, at very low counts Poisson statistics underestimates the uncertainty. To compensate, the RAD7 uses sigma = 1 + SQR(N +1), where N is the number of counts. Thus when there are no counts, instead of reporting a nonsensical zero uncertainty, the RAD7 reports an uncertainty value based on a two-sigma, 95% confidence interval, equivalent to +/- 4 counts for a cycle in which zero counts were recorded.

Typically, an average count rate of 0.2 cpm (i.e. one count in five minutes) would indicate a radon concentration of about 36 Bq/m3, but sigma would be 1 + SQR(N + 1) or 2.4 counts, and two-sigma would be 4.8 counts. Thus after 5 minutes, the uncertainty would be 0.96 cpm, or +/- 173 Bq/m3.

Large uncertainty values are often the product of the fact that it is impossible to measure low radon concentrations quickly. Greater certainty can be achieved by increasing the cycle time and/or by averaging multiple cycles. In Sniff mode, 218-Po (which has a 3.05 min half life) takes more than 10 minutes to reach equilibrium with the radon concentration in the RAD7 chamber. Note that in Sniff protocol, which uses 5-minute cycles, it is important not possible to start averaging the readings to reduce uncertainty only after the first two cycles.

It is possible to measure radon and thoron concentrations simultaneously, but since their requirements are sufficiently different, it may be desirable to optimize the measurement first for one gas and then for the other. For radon, it is advisable to select SNIFF protocol and then change the cycle time to 10 minutes. After starting a run, the first reading can be ignored, with only the second and subsequent readings being used. As more readings are recorded, more precise concentrations will be obtainable.

Occasionally, a concentration uncertainty greater than the base value may be reported, e.g. 0.00 +/- 83.1 Bq/m3. Such values are typical for cycles containing zero counts. This should not be taken to suggest that a negative concentration may have occurred. The RAD7 does not report different positive and negative uncertainties, and it is expected that the user will recognize that the negative uncertainty can never be greater than the base value of the reading.

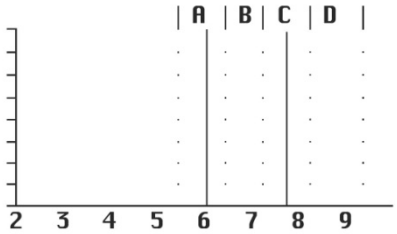
3.13 Spectrum Examples

3.13.1 Operational Radon Spectra

A. Idealized radon in equilibrium

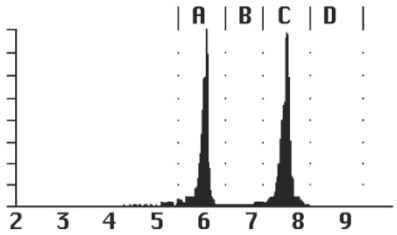
This is what you would see if both the detector and electronics reached theoretical perfection. At full equilibrium, both peaks are at the same height.

A	6.00 MeV	Po218
C	7.69 MeV	Po214



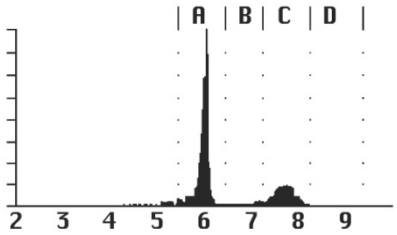
B. Radon in full equilibrium

After more than three hours at a constant radon level. The count rate in window C is about the same as in window A.



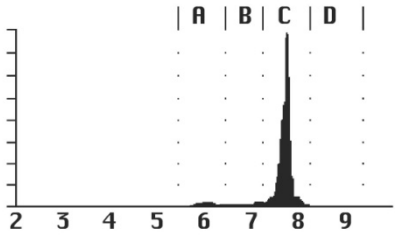
C. New radon

The RAD7 spectrum after less than one hour of exposure to radon. The peak in window C is just beginning to grow in, but its count rate is still much less than in window A.

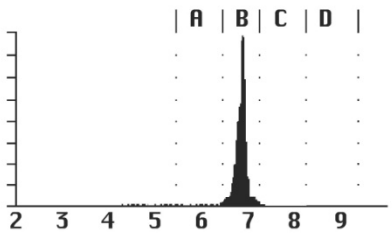


D. Old radon

The RAD7 spectrum after purging the instrument with radon-free air for more than 10 minutes, following exposure to radon.



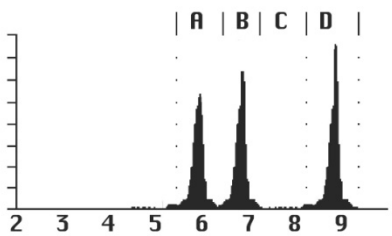
3.13.2 Thoron Spectra



A. New thoron

The RAD7 spectrum while continuously sampling thoron laden air

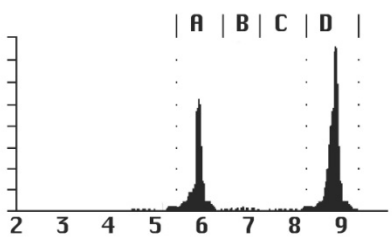
B	6.78 MeV	Po216



B. Thoron in equilibrium

The spectrum after continuously sampling thoron laden air for more than 12 hours. The count rate in window A should be about half the count rate in window D

A	6.05 MeV	Bi212
B	6.78 MeV	Po216
D	8.78 MeV	Po212



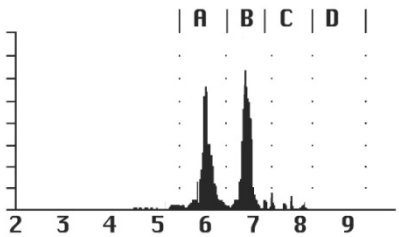
C. Old thoron

The spectrum after discontinuing a lengthy sampling of thoron laden air. The thoron peak, B, disappears immediately. The remaining two peaks decay together with a 10.6 hour half-life. The count rate in window A should be about half the count rate in window D.

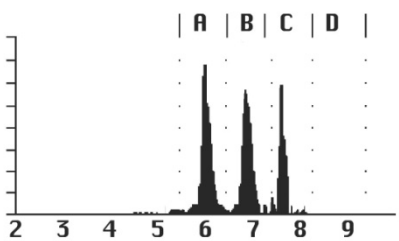
3.13.3 Combination Spectra

Radon and thoron spectra can add together to form combination spectra. Peaks in window B and/or D come from thoron, while a peak in window C comes from radon. The peak in window A is usually entirely from radon, but if there is a peak in window D, then there will a contribution of about half the D count rate to the peak in window A.

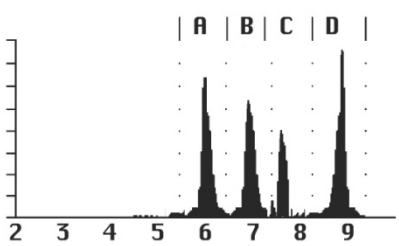
The RAD7 takes this into account, and always adjusts the window A count rate to correct for the Bi212 count, before calculating the radon concentration. The spectra below have comparable amounts of radon and thoron, but you will usually see one of the two much stronger than the other.



A. New radon with new thoron.



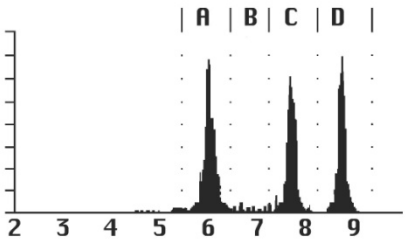
B. Equilibrium radon with new thoron



C. Equilibrium radon with equilibrium thoron.

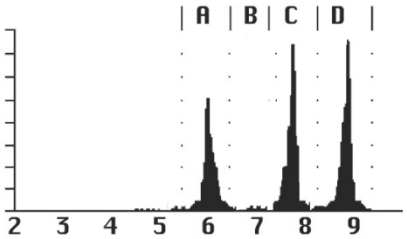
The count rate in window A is roughly the rate of window C plus half the rate of window D.

A	6.00 MeV	Po218
	+6.05 MeV	Bi212
B	6.78 MeV	Po216
C	7.69 MeV	Po214
D	8.78 MeV	Po212



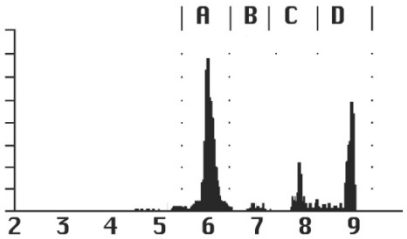
D. Equilibrium radon with old thoron

The count rate of A is roughly the rate of window C plus half the rate of window D.



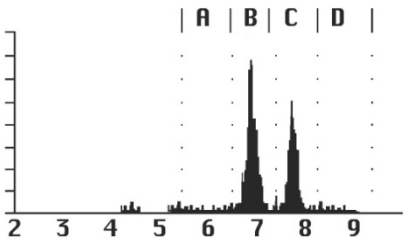
E. Old radon with old thoron.

The count rate in window A is no more than about half the count rate of window D.



F. New radon with old thoron.

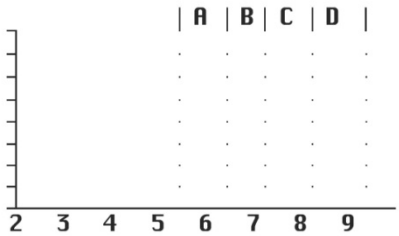
Looks like an old thoron spectrum, but the count rate of window A is significantly more than half the count rate of window D.



G. New thoron with old radon.

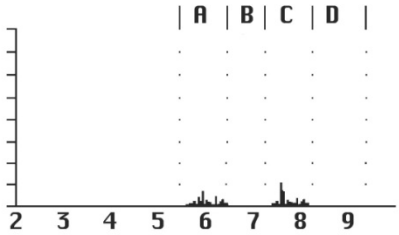
3.13.4 Pathological Spectra

If any of the following occur, and an external cause is not identified, the user should contact DURRIDGE immediately. Email to service@durridge.com would be a good way to initiate the contact.



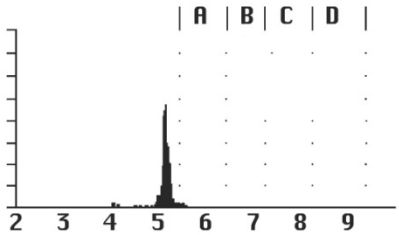
A. No counts.

Try a longer counting time. If there is not a single count in an hour, that is clear indication of instrument malfunction.



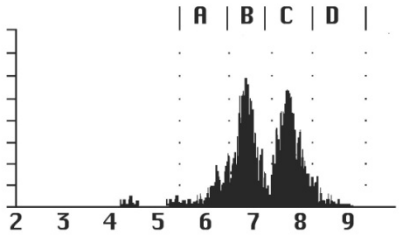
B. Few counts.

Normal for low radon levels and short counting times. Abnormally low counts could be caused by disruption of the air flow, or by malfunction in the high voltage circuit.



C. Lead-210/polonium-210.

A persistent peak at 5.3 MeV will develop from many years of regular use, or from sustained exposure to very high radon levels. It results from the buildup of lead-210 on the detector surface. Lead-210 has a 22 year half-life. It is not a problem for the RAD7 because the peak is outside window A, and thus does not contribute to the background.

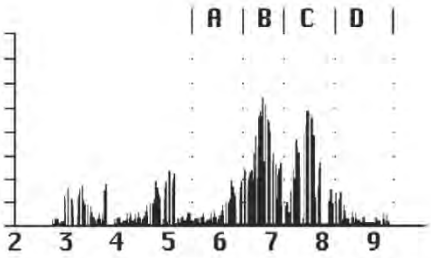


D. Wide alpha peaks.

Typically caused by electronic noise in the system. May be associated with vibration, with high operating temperature, or with degradation of the surface barrier detectors used in older model RAD7's, built prior to 1996.

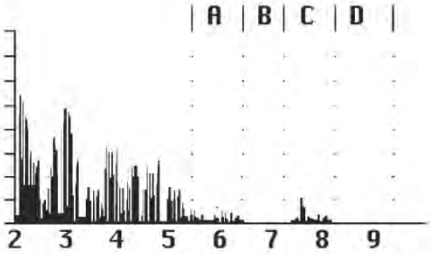
E. Smeared spectrum.

Alpha peaks cannot be discerned by the eye. Severe electronic noise.



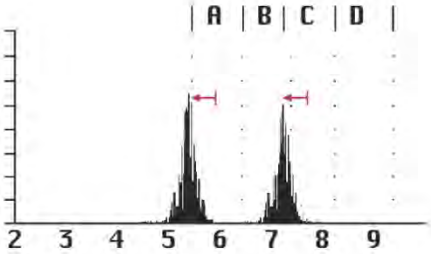
F. Low energy noise.

Independent of radon or thoron, such electronic noise may be intermittent or be associated with vibration.



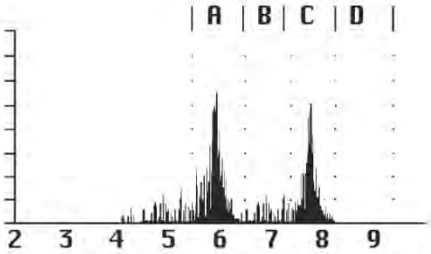
G. Shifted peaks.

Peaks appear normal, but are shifted in position. Shows a malfunction of the RAD7, which should be returned to DURRIDGE for service without delay.



H. Heavy tails on alpha peaks.

The peaks are narrow, but have unusually thick tails. This may be caused by electronic noise, or by malfunction of the alpha detector.



4. USING THE *RAD7*: GOOD OPERATING PROCEDURES

4.1 Introduction

The different ways of using the RAD7 may be arranged in six categories:

a) continuous monitoring of radon in air,
b) sniffing for radon and/or thoron,
c) testing air grab samples,
d) measuring radon in water,
e) testing soil gas, and
f) measuring radon and thoron emission from objects and surfaces.

While all six are discussed, it is primarily a) and d) that require standard operating procedures. The other applications tend to be more interactive, and individuals will develop protocols which work best for them.

4.2 Continuous Monitoring

4.2.1 Preparation

The RAD7 batteries should be fully charged so that, even if there is a power cut, the test will be completed. Similarly, there should be more than sufficient active desiccant in the Laboratory Drying Unit.

For an EPA protocol test, the house should be fully closed from 12 hours before the start of the test. This means that ALL doors and windows should be shut tight. No air exchange system, or ventilation fans, may be running.

In winter it is not difficult to satisfy the requirement. Continued operation of the furnace is permitted. Closed house conditions are usually maintained anyway, to save heating costs. Doors may be opened momentarily, for access, but should otherwise remain closed throughout the test.

In summer it may be impossible to satisfy the requirement, without the residents moving out for the duration of the test. If doors and windows are left open, it can nullify the test, except that if there is a radon problem under these conditions, then there will be a greater problem under closed house conditions.

Air conditioning often includes some fresh air ventilation, which dilutes the radon. Even if there is no ventilation, the cold air in the house will want to sink, increasing pressure in the basement, and thus reducing any flow of soil gas into the house. So air conditioning in the summer will tend to lower the radon level in the house.

For further detailed information, see the EPA "Indoor Radon and Radon Decay Product Measurement Device Protocols" publication, EPA 402-R-92-004, or view it at http://www.epa.gov/radon/pubs/devprot1.html

4.2.2 Purging

For the RAD7 to be all set to go, ready to start a test, it should be purged for at least five minutes beforehand. This may be done in the car, en route to the test site.

Locate an inlet filter, a piece of tubing with a sleeve at one end and small tube at the other, and the laboratory drying unit. Connect the filter to the tubing: It should be a tight fit into the small diameter section. Remove the plastic caps from the drying unit and push the sleeved end of the tubing onto the tube connector, on the drying unit, farthest from the metal screw cap. Now attach the filter to the inlet of the RAD7.

Switch on the RAD7, push [MENU], [ENTER], [→] four times, to see >Test Purge on the display, then push [ENTER]. The pump will start. The display will show Stop purge? No. Leave the unit purging for five minutes, or longer. When you are ready to start the test, the easiest way to stop purging is to push the Menu key, or switch off the instrument.

4.2.3 Test Location

In general, the test should be conducted in the "lowest area in the house that is used, or could be adapted for use, as a living area". This would include a full-height basement, but not a crawl space.

Place the RAD7 near the center of the room, about 3 - 4 feet above the floor. Avoid walls, vents, fireplaces, windows, draft, and direct sunlight.

Where possible, connect DC power to the RAD7, to conserve and recharge the batteries.

The air intake will be the connector of the drying unit without any tubing attached (nearest the end with the metal screw cap), or the far end of the tube if one is attached to this connector. Make sure the air intake is at least 30 inches (75 cm) above the floor, and away from the walls.

Once set up in location, let the RAD7 continue to purge until ready to start the test.

4.2.4 Test Protocol

In any location there is often a diurnal variation of radon level. It is preferable, therefore, that the test period be an exact number of whole days. The EPA protocols require an average taken over at least two days. The RAD7 gives time resolution as well. A choice must be made, therefore, of the cycle time and the number of cycles (recycle). For 24-hour and 48-hour tests, the RAD7 has preset protocols which will make the choice for you. You can always change the choices (even in the middle of a test!), and, if you wish, save your preferences as the user protocol. You may, for instance, prefer to conduct 3-day tests, and, perhaps, use 24 cycles, each 3 hours long. The longer the test, the greater the precision of the result.

For a 24-hour or 48-hour test, using the preset protocol, before starting the test, go to `>Setup Protocol [→] 1-day`, or `2-day`, and push `[ENTER]`. You need, also, to decide whether to leave the tone Off, Chime, or Geiger, and whether to have short, medium or long format of printouts at the end of each cycle, and set the parameters accordingly.

For very long term monitoring, use the Weeks protocol. This sets the RAD7 to run indefinitely, with 2-hour cycles. The internal memory capacity, of 1,000 cycles, will last nearly 12 weeks. If data is periodically downloaded to a PC, and erased from the RAD7, there is no limit to the measurement duration. With the laboratory drying unit used to dry the sampled air, the desiccant will have to be replaced every 7 to 14 days, depending on the humidity. The RAD7 needs external power for indefinite operation, but can survive, without loss of data, an interruption of power lasting up to 50 hours, or more, depending on the condition of the batteries.

For any other measurement period, you will need to set the parameters yourself. The cycle time, times the number of recycles, gives the duration of the total measurement. In almost every case, for continuous monitoring, choose Mode Auto, Thoron Off, and Pump Auto.

Once the RAD7 switches (after three hours) to NORMAL mode, the counts are included from Window C, which come from Po-214 atoms. These were once radon atoms, that entered the measurement chamber as much as an hour or more beforehand. Therefore, in NORMAL mode, the RAD7 is averaging the radon concentration from less than 20 minutes ago (Po-218) with the radon concentration from less than three hours ago (Po-214). So, for a long test in NORMAL mode, the cycle time should be set to one hour, or more.

Where there is a requirement for a fast response and detailed time resolution, then the cycle time may be set as short as half an hour, or even 20 minutes, but the Mode should then be set to Sniff, not Auto. Note, however, that counting only Window A, and for such short periods, the number of counts per cycle will be less than for longer cycles in NORMAL mode, and so the individual readings will have more scatter. Note, also, that short cycle times will fill up the memory more quickly (the capacity is 1,000 cycles), use up the desiccant more quickly, and, if the printer is being used, produce more printout.

4.2.5 To Print Or Not To Print

It is not necessary to run the printer during a measurement as all data, except for the detailed spectra, are stored at the end of every cycle, and are available for printing or downloading to a PC at any time. Furthermore, with no printer and the key pad locked, it is impossible for any unauthorized snooper to read the radon concentration during the run. On the other hand, use of the printer gives a convenient and informative hard copy of the results.

For routine continuous monitoring, it is usual to set the printer format to short (`Setup`, `Format`, `Short`, `[ENTER]`).

Place the printer on the face plate, apply external power and switch on. Note that the printer will sleep, after a time, if there is no external power. Switch the RAD7 off, then on again. Information about the RAD7, and the setup, will print out. Data will be printed at the end of every cycle, and a summary, bar chart and cumulative spectrum will print at the end of the run.

4.2.6 Running the Test

When everything is ready, start the test (`Test`, `Start`, `[ENTER]`). The pump will start running and the LCD display will go to the first status window.

The house should remain in closed condition for the duration of the run. At any time, the status windows can be viewed. The relative humidity, temperature and battery voltage are all parameters that are worth observing. Rising relative humidity may indicate that the desiccant is exhausted, or that there is a leak in the sample path. The temperature reading gives a base for future reference, see below. A dropping battery voltage may indicate that the power is not connected.

4.2.7 Security and Quality Control

For a good measurement, it is essential that the RAD7 (or any measurement device, for that matter) remain in its place, and the house remain closed, throughout the run.

Anti-tampering tapes are available for the windows and doors. A soft, plastic adhesive, such as Blue-Tack, HOLDIT or Tac'N Stik, under the RAD7, will stick better the first time than in subsequent placings. An experienced hand can tell if the RAD7 has been moved. But perhaps the best anti-tampering defense is the data itself. With the time resolution in the data provided by the RAD7, anomalies are clearly revealed. A sudden change in radon concentration and in air temperature, during the measurement, is a strong indication of tampering, either by moving the instrument, or by opening windows. The key-pad lock prevents tamperers from looking at the data, or interfering with the measurement.

A detailed and systematic quality control protocol must be established by any user seeking certification. This should include a description of the measurement process, and the steps taken to ensure that the readings are reproducible.

The RAD7 is too accurate for any procedure in the field to be able to verify that it is working within specifications. However, it is good practice, on a regular basis, to compare the RAD7 readings with some other device, such as a passive charcoal collector. The two devices should be placed close together, with the RAD7 sampling point near to, but not touching, the charcoal collector. The measurements should also cover the same time period. The charcoal reading may then be compared with the RAD7 mean for the period. Remember, however, that some charcoal devices, and labs, may give readings which are in error by as much as 25%. If the RAD7 and the charcoal device differ by more than 10%, repeat the comparison as soon as possible, preferably with a different charcoal device, from a different lab. Look at the RAD7 cumulative spectrum, printed out at the end of a run, to see if it appears normal. If the RAD7 mean is consistently, significantly different from the readings of other devices in side-by-side tests, or if the spectrum looks abnormal, please call , or email, DURRIDGE for advice. In any case, we recommend that the RAD7 be returned to DURRIDGE Company, for recalibration, annually.

An excellent quality test, for the RAD7, is simply an examination of the cumulative spectrum printed out at the end of every run. If the spectrum looks normal, and the humidity, temperature, and battery voltage, are within normal range, then that is very strong evidence that the RAD7 is working properly, and the readings are reliable.

4.2.8 Finishing the Run

Even if no printout has been made at the end of every cycle, it is still useful to have a printout at the end of the run. If the RAD7 can be accessed before the run is finished, simply place the printer in position on the face plate and switch it on. After the last cycle is completed, the RAD7 will print the run summary, including the mean value, the bar chart of all the readings, and the cumulative spectrum. If the instrument cannot be

accessed before the end of the run, the summary can be printed out later, but without the cumulative spectrum.

Switch off the printer and the RAD7. Disconnect the tubing from the desiccant and replace the plastic caps over the hose connectors. If the caps have been lost, a single piece of tubing may be attached between the two connectors, thus providing a seal to keep the desiccant dry.

Remove the inlet filter from the RAD7. It is good practice to leave the inlet filter attached to the plastic tubing. Replace the short piece of tubing connecting the inlet to the outlet. Putting the jumper between the inlet and outlet keeps the internal space of the instrument sealed, and thus dry, while still allowing air flow should the pump start running.

When moving the RAD7, please treat it with respect. It is rugged, but it is still an electronic instrument. Please avoid hard knocks and very harsh environments.

4.2.9 Examining the Data

In addition to the printout, data may be examined on the LCD, during or after a run. The records may also be downloaded to a PC, where they are then available for creating graphs and tables for printed reports.

On reviewing a set of data, first check that the relative humidity in the instrument stayed below 10% throughout the measurement. If it rose above 10%, it suggests that the desiccant was either removed, or became depleted. The RAD7 reads low if the internal RH rises above 10%.

The temperature during the measurement should remain fairly steady. Sudden changes of temperature in the record suggest that either the windows were opened, or the RAD7 was moved from its location.

If the house was not properly closed up until the measurement was started, you may expect to see a rising radon concentration during the first few hours of the run. If that is the case, any very low, early readings should be discarded in the calculation of the mean value for the house. That would mean manual calculation of the average, from the good readings. EPA protocols require at least 48 hours of continuous good data. If the house was not closed up beforehand, a 3-day test could satisfy the EPA requirement.

If the air sampling point was changed for a while, or some windows opened, during the run, you may expect to see a change in air temperature, and change in radon concentration, during that period. Simultaneous changes of these two parameters is an indicator of tampering.

4.2.10 Very Short Term Monitoring

Some Home Inspectors choose to use the RAD7 for a short-term test, just during the home inspection. This means that they have full control over the test, and they can take the RAD7 with them, when they leave, on completion of the home inspection.

They close up the house, set up the RAD7 in the basement, choose a half-hour cycle time and a total run length (recycles) of, typically, four or five cycles. At the end of the run, the RAD7 prints out a bar chart of the increasing radon concentration, at half-hour intervals. The data gives the Home Inspector, and his client, a good indication of the radon situation. Adding 50% to the final half-hour reading gives an estimate of what would be the average radon level, for closed house conditions. If, during those two hours of the test, the radon concentration climbs towards, or over, the 4 pCi/L mark, then they can be confident that, with a full, EPA protocol test, covering 2 days, or more, the result would surely exceed the 4 pCi/L action level.

4.3 Sniffing

4.3.1 Why Sniff?

There are two main reasons for sniffing. One is to obtain a quick, spot reading of radon concentration, as a simpler substitute for grab sampling, and the other is to locate radon entry points. For each application, the method will be slightly different.

4.3.2 Locating Radon Entry Points

There is a very good chance that thoron will be present in the soil gas entering the building. It

will, however, be detectable only close to the entry points. Thoron, therefore, if it is in the soil gas, can be considered as a tracer for fresh radon gas. Sniffing to locate radon entry points may, therefore, be focused on detecting thoron, if it is there, to speed, and simplify, the process. The same procedure will also give radon concentrations, provided that the sampling point is kept at one spot for at least 15 minutes.

4.3.3 Preparation

Detailed instructions are given in Section 1.5. Choose Thoron in the Setup Protocol menu, and set the Tone to Geiger. Employ a small drying tube and, preferably, just a yard of tubing to the inlet filter.

4.3.4 Purging

While it is always good practice to purge the instrument before using it, there is less necessity before sniffing. In SNIFF protocol, the pump runs continuously, so the air sample will be flushed through every minute or two, and the measurement chamber will quickly dry out, even if the relative humidity starts above 10%.

To bring the humidity in the instrument down without wasting desiccant, the RAD7 outlet may be connected to the open end of the drying tube, making a closed loop, during the purge cycle.

After detecting high concentrations of radon and/or thoron, it is good practice to purge the instrument immediately after use.

4.3.5 Running the Test

With the RAD7 strap over one shoulder, holding the small drying tube as a wand, start the test. The first status window will be displayed in the LCD. Push the right arrow five times, to reach the B window status screen. This will show the cpm for thoron. You may also listen to the beeps, which have a different pitch for different windows. Thoron has a high-pitched beep.

Floor/wall, wall/wall and split-level seams are common locations for radon entry points. So are sumps, wells, beam pockets and utility conduits, entering the building from below ground level. It is useful, before starting the sweep, to have a sketch map of the area, with the likely culprits marked, on which to write down the readings. While making this sketch map, the RAD7 can be taking a benchmark radon measurement in the center of the room. Take at least four 5-minute-cycle readings. Later radon readings, at likely entry points, can then be compared with this benchmark.

To start the sweep, hold the small drying tube as a wand, with the open end either in, or as close as possible to, the most likely radon entry point. Keep it there for at least five minutes. If the thoron count, in window B, during this time, exceeds 2 cpm, say, then you know a) that you were right in your suspicion, and that you are, indeed, close to a radon entry point, and b) that thoron is present in the soil gas, so you can concentrate on thoron for the rest of the survey. Move the wand a foot or so in any direction to see if the window B cpm changes appreciably, in the next cycle.

If there are few or no counts in window B, then either the location is not a radon entry point, or there is no appreciable thoron in the soil gas. You must, then, keep the wand in that position for another 10 minutes, or until the counts in window A start to rise rapidly. If, after fifteen minutes, there are still only a few counts in window A, and the radon concentration, displayed at the end of the third 5-minute cycle, is still very low, then you can be confident that the position is not a radon entry point. On the other hand, a high radon concentration, without thoron, does not necessarily indicate a radon entry point if the whole basement is high. In either case, you need to note the reading on your sketch map, and move to another likely point to repeat the process, first looking for thoron.

If no thoron is found at any time, then the map of radon concentrations, will help to identify entry points.

Once thoron has been detected, the whole search is made much easier. Reset the cycle time to two minutes. Spend one complete cycle at each suspected radon entry point, observing the counts in window B, or listening for the characteristic thoron beeps. You will quickly determine the location and relative strengths of the radon entry points, from the cpm in window B, for the different locations. Note that, in this procedure, you must ignore the counts in window A, because

they refer to radon that entered the measurement chamber as much as 10 minutes previous to the observed counts.

Even if thoron is present at some points, there is still a possibility that there may be a radon entry point showing little or no thoron. This could occur if the path taken by the soil gas was very long, or the flow was slow. Conduit for a utility service, or a path up a hidden shaft in a wall, could delay the entry of the soil gas by several minutes. Each minute's delay halves the concentration of thoron.

4.3.6 Drilled Sampling Points

Some mitigators drill a number of test holes through the concrete slab, to sniff the soil gas beneath and to test the communication between different areas of the slab. They then install the suction points of the mitigation system where the sub-slab radon readings are highest. This approach is complementary to the search for actual radon entry points, as described above. Both methods are likely to result in a similar, final configuration of the mitigation system, though locating the entry points can also indicate where additional sealing is required..

4.3.7 Spot Readings

A spot reading may be accepted only as a rough indicator of the radon level at any location. This is not only because a short-term reading is less precise, but also because it does not average out the fluctuations in radon level through a typical day. The EPA protocol calls for a measurement to cover at least two days. Quite often, the indoor radon concentration tends to be higher in the early morning, after a cold night, and lower at the end of a warm day.

Furthermore, the radon concentration, typically, takes hours to recover from open doors and windows so, unless the house was closed up tight for many hours beforehand, the spot-reading radon level will be significantly lower than an average, taken over several days, in closed house conditions.

For this spot reading, the sampling point should be away from walls and floor. Thoron is not an issue in this measurement, so the larger, laboratory drying unit may be used, instead of a small drying tube. The cycle time may be left at five minutes. At least four, better six, cycles should be taken, of which the first two should be ignored. Alternatively, increase the cycle time to 10 minutes, or more, and ignore the first reading.

To measure a radon level of 4 pCi/L, with a standard deviation of no more than 10%, needs a run of one hour (six cycles of ten minutes, say).

4.4 Grab Sampling

4.4.1 Applicability

When it is not possible to take the RAD7 to the location to be measured; when a grab sample is required while the RAD7 is pre-occupied with continuous monitoring; or when many grab samples are required, all within a short time, from different rooms of a building, then the grab sample capability of the RAD7 fills the need. However, if the RAD7 is available, and can be taken to the test location, then data quality is much improved by a) monitoring the radon level over an extended period of time, such as 1-day, or, if that is not a possibility, b) making a short-term measurement such as described in section 4.2.10, or else just sniffing for a spot reading, as described above.

Grab samples have the same shortcomings as spot readings, above. The radon concentration 'grabbed' is unlikely to be representative of the EPA average level at the location of the sample. The precision of the reading is also limited by the short time for counting.

4.4.2 Preparation

It is important that the RAD7 be well dried out prior to accepting the grab sample. First, purge the unit with fresh, dry air for five minutes. Then connect the laboratory drying unit in a closed loop with the RAD7 so that air from the outlet passes through the desiccant and back into the inlet. Note that air should always flow the same way through the desiccant. Purge for ten minutes then check the relative humidity (push [MENU] [ENTER] [ENTER], then [➔] [➔]). If the RH is not below 8%, repeat the process. Keep the pump running until ready to take the grab sample.

4.4.3 Protocol

Choose the `Setup, Protocol, Grab` menu selection, and push `[ENTER]`. This will set up all the measurement parameters correctly. For the printout, choose `Setup, Format, Short`.

4.4.4 Taking the Sample

If the RAD7 is at the location, simply start the test (`[MENU] [ENTER] [→] [ENTER]`).

Alternatively, samples may be taken in tedlar air sampling bags. Samples of at least five liters are required.. Any sampling pump may be used. Even the RAD7 could be used as a sampling pump, but remember to purge the instrument of old air first.

These bagged samples may be connected to the RAD7 and analyzed later. Make sure there is active desiccant and the inlet filter in place, between the sample bag and the RAD7.

4.4.5 Analysis

With the grab sample source connected to the RAD7, start the test (`[MENU] [ENTER] [→] [ENTER]`). The pump will run for five minutes, flushing the measurement chamber, and then stop. The RAD7 will wait for five more minutes, and then count for four 5-minute cycles. At the end of the run, the RAD7 will print out a summary, including the average radon concentration, a bar chart of the four cycles counted, and a cumulative spectrum. The measurement process takes 30 minutes.

If the analysis is made more than an hour after the sample was taken, a correction must be applied for the decay of radon in the sample.

4.5 Radon in Water

4.5.1 RAD H_2O

The RAD H_2O is an accessory to the RAD7 that enables you to measure radon in water with high accuracy, over a wide range of concentrations, obtaining your reading within an hour of taking the sample. It is particularly suited for well testing, where immediate results are often required.

The RAD H_2O uses a standard, pre-calibrated degassing system and pre-set protocols, built into the RAD7, which give a direct reading of the radon concentration in the water sample, itself. The method is, in fact, a special case of the grab sampling method above.

The RAD H_2O comes with its own manual, to which you are referred for further details.

4.5.2 RAD AQUA

This is another RAD7 accessory, for continuous monitoring of radon in water. It has a high sensitivity, and rapid response.

Air, in a closed loop, is brought into equilibrium with water passing through the exchanger. The RAD7 operates in continuous mode, as in Chapter 4.2.

The RAD AQUA also comes with its own manual, to which you are referred for further details.

4.6 Soil Gas Sampling

4.6.1 Application

The radon concentration in surrounding soil gas is one of many parameters that impact the radon health risk of a house. The construction of the house, the porosity of the soil, the height of the water table, and several other factors, are all important. Even if there is no radon in the surrounding soil, the house may still be at risk if it has a well in the basement, or is built on rock, over a fissure. Nevertheless, it is often of interest to determine the radon concentration in soil gas.

Thoron is usually associated with radon in the soil. When measuring soil gas, it is, therefore, particularly useful to determine the thoron content as well as the radon content. Should there be significant thoron, it may be used as a tracer, to find radon entry points, inside the house, see Section 4.3.2.

4.6.2 Soil Gas Probe

The cost, and complexity, of a soil gas probe increases with the depth to which it can be inserted. A variety of probes are available from DURRIDGE Company, the simplest of which will penetrate to a depth of 3 feet.

4.6.3 Preparation

Insert the probe. Make sure that there is a reasonable seal between the probe shaft and the surrounding soil, so that ambient air does not descend around the probe, to dilute the soil gas sample.

Between the probe and the RAD7 connect a water trap (which could be just a jar with two air-tight hose connectors in the lid), the laboratory drying unit, and the inlet filter. A water trap is included in the package when the DURRIDGE soil gas probe is purchased.

Set the protocol to Sniff. Soil gas is normally so high in radon that it is not necessary to use long cycle times to gain precision. Five minute cycle times are long enough.

4.6.4 Running the Test

Start the test. (`Test, Start, [ENTER]`). On the LCD you will see the first status window. Push the right arrow twice and the screen will display the temperature, relative humidity, battery voltage and pump current. Pay particular attention to the relative humidity and pump current. The relative humidity should gradually drop down to below 10%, and stay there.

If the pump current starts to rise much above 100 mA, it suggests that the soil is not porous, in which case it may be that a good soil gas sample cannot be drawn, no matter how powerful a pump is used. With the RAD7 pump current above 100 mA, the air flow rate will be significantly reduced from the nominal 1L/min. This will not affect the radon reading, but will reduce the effective sensitivity to thoron, as more of the thoron will decay en route to the RAD7. If desired, an additional pump may be used, but it should be placed upstream of the RAD7, so that the RAD7 is operating at normal pressure. In fact, with an external sampling pump in use, the RAD7 pump can even be switched off, altogether.

4.6.5 Interpreting the Data

As with any Sniff test, the first two 5-minute cycles should be ignored. The next one or two cycles should be averaged, to arrive at the radon concentration of the soil gas.

For thoron, some estimate has to be made of the time taken for the sample, after it has left the soil, to reach the RAD7. This requires an estimate of the volume of the sample path, including the probe, water trap, tubing and drying unit, and an estimate, or measurement, of the flow rate. For example, if the total volume of the sample path is 2L, and the flow rate is 0.5 L/min, then the sample delay is about 4 minutes. If the thoron decays by half every minute, then after four minutes the concentration will be just 1/16th of the concentration in the ground. So, whatever thoron concentration the RAD7 measures should be multiplied by 16.

4.7 Emission Measurements

4.7.1 Application

With its internal pump, sealed sample path, and inlet and outlet connectors, the RAD7 is well suited to emission measurements. Furthermore, the ability to count only the polonium-218 decays means that dynamic measurements are clean, and not complicated by long-half-life events.

4.7.2 Open or Closed Loop Configurations

Emission will occur from bulk materials in an emission chamber, or from an enclosed surface. The RAD7 will draw air from the enclosure, through the desiccant and inlet filter, into the measurement chamber. The air may then be returned to the enclosure, from the RAD7 outlet, to form a closed loop. Alternatively, in an open loop configuration, the air drawn from the enclosure may be replaced with 'zero' air, from a cylinder, or with ambient air, which has a low and measured radon concentration.

With the closed-loop configuration, the system is first purged, and then, once closed, the radon concentration within the loop is monitored in SNIFF mode, with short, e.g. 15 min., cycle times, for a few hours. It is necessary to know the

total volume of the closed-loop system. For this purpose, the volume inside the RAD7 may be taken as 1L. The initial rate of increase in radon concentration (neglecting the first 15-min cycle), multiplied by the volume, then gives the rate of emission of radon. A reduction in the slope, as the radon level builds up, may be due to leaks in the system, or to a reduction in the net emission.

With the open loop configuration, a steady, and known, flow rate must be established. If a cylinder of 'zero' air, or nitrogen, is used, then the RAD7 internal pump may be set to Off, and the pressure reduction valve used to control the flow rate. With ambient air, the internal pump may be set to On, for a continuos flow. In both cases, a flow meter is required.

A steady state should be achieved and a long-term measurement may be made. The rate of emission will equal the radon concentration times the flow rate. The precision will depend on the concentration and the duration of the measurement.

4.7.3 Bulk Emissions

An airtight box with two hose connectors, well separated, will usually work fine. The material is placed in the box. The box is connected, by tubing from one connector, to the laboratory drying unit, and thence to the inlet filter on the RAD7. The other box connector has tubing attached, which is either connected to the RAD7 outlet, for closed-loop operation, or, for open-loop operation, connected to a cylinder of zero gas, or left open to ambient air.

Note that bulk emissions are affected by pressure fluctuations and by temperature and humidity. All these parameters can, and should, be controlled in both the closed-loop and open-loop configurations. Radon emission is also dependent on the grain size of loose materials, and porosity of any bulk material.

Thoron emission can also be measured in the same apparatus. In the open loop mode, a correction will be required for the decay of the thoron during the time between emission and measurement in the RAD7. In the closed loop mode, another correction should be made for the proportion of the thoron that gets fed back to the enclosure. Note that, for thoron, both the closed loop and open loop modes are steady-state measurements.

4.7.4 Surface Emission

For these measurements, an enclosure, with two hose connectors, has one side open, which is sealed against the surface under investigation.

The alternative procedures are similar to those for bulk emission measurement, as described above. Once the total emission rate, within the enclosure, has been calculated, it may be divided by the area of the surface within the sealed boundary, to determine the emission per unit area.

4.8 Thoron Measurement

4.8.1 Thoron and Radon

Thoron is an isotope of the element radon having an atomic mass of 220, so it is also known as radon-220. The word "radon" without a mass number almost always refers to radon-222. Thoron and radon have very similar properties. They are both chemically inert radioactive gases that occur naturally from the decay of radioactive elements in soils and minerals. Both thoron and radon are members of decay chains, or long sequences of radioactive decay.

While radon results from the decay of natural uranium, thoron results from the decay of natural thorium. Both uranium and thorium are commonly found in soils and minerals, sometimes separately, sometimes together. The radioactive gases radon and thoron that are produced in these soils and minerals can diffuse out of the material and travel long distances before they themselves decay. Both radon and thoron decay into radioactive decay products, or progeny, of polonium, lead, and bismuth before finally reaching stable forms as lead.

Thoron and radon and their respective progeny differ very significantly in their half-lives and in the energies of their radiations. While radon has a half-life of nearly 4 days, thoron has a half-life of only 55 seconds. Since thoron is so short lived, it cannot travel as far from its source as radon can before it decays. It is commonly observed that compared to that of radon gas, a much smaller

fraction of the thoron gas in soil ever reaches the interior of a building. Even so, thoron can still be a hazard since its progeny include lead-212 which has a half-life of 10.6 hours, more than long enough to accumulate to significant levels in breathable air.

4.8.2 Thoron Measurement Issues

Many difficulties impede the accurate measurement of thoron gas. The presence of radon gas (often found together with thoron) can interfere with a measurement. The short half-life of thoron gas makes some aspects of the measurement easier, but makes sampling method a critical issue. Thoron concentration can vary greatly through a space, depending on the speed and direction of air movement as well as turbulence. The position of the sample intake can strongly affect the results.

For many instruments, radon and thoron interfere with each other. Generally speaking, it is difficult to measure one isotope accurately in the presence of the other. But compared to other instruments, the RAD7 is much less susceptible to radon-thoron interference due to its ability to distinguish the isotopes by their unique alpha particle energies. The RAD7 separates radon and thoron signals and counts the two isotopes at the same time with little interference from one to the other.

Some issues of concern in measuring radon do not apply to thoron. The short half-lives of thoron (55 seconds) and its first decay product (Po-216 - 0.15 seconds) mean that thoron measurements can be made quickly and in rapid succession, since there is little concern with growth and decay delays. The RAD7 responds virtually instantly to the presence of thoron; its time constant for response to thoron is less than 1 minute. The chief limit on the thoron response speed is the pump's ability to fill the internal cell. And the RAD7 clears just as rapidly when you purge the instrument with thoron-free air. In fact, you need not purge the instrument at all as thoron's short half-life ensures that it will be gone in a few minutes.

In thoron measurement the sample pump must run in a continuous fashion, at a steady consistent flow rate. If the flow rate of the sampling pump changes, then the RAD7 thoron result will also change. Flow rate affects the amount of thoron in the internal cell, since a significant fraction of the thoron decays in the sample intake system as well as within the instrument. For the most accurate thoron measurements we recommend that you use a consistent sample intake system (always use the same hose and filter arrangement) and pay special attention to air flow rate. Be sure the filters, hoses, and RAD7 inlet and outlet ports remain free from obstruction. Use a flow meter (rotameter or "floating ball" type) to check that the flow remains consistent. Note that the flow rate affects the thoron reading, but not radon due to its much longer half-life.

The RAD7 measures thoron concentration in the air at the point of sample intake. Since thoron varies from place to place depending on the motion of the air, the instrument operator may find it necessary to make measurements in several locations to properly assess a thoron situation. Fortunately, rapid-fire thoron measurements are very easy to do with the RAD7.

4.8.3 Calculation and Interference Correction

The RAD7 calculates thoron concentration on the basis of the count rate in spectrum window B which is centered on the 6.78 MeV alpha line of Po-216, the first decay product of thoron gas. To further avoid interference from radon, the RAD7 applies a correction to the thoron count rate to compensate for a small percentage of "spillover" from window C.

As of version 2.5, RAD7 calculates radon concentration from the count rate in window A (SNIFF mode) or windows A plus C (NORMAL mode). The RAD7 compensates for interference from the long-lived progeny of thoron (10.6 hours) by applying a correction to the radon count rate in both Sniff and NORMAL modes. The correction is based on a fixed fraction of the count rate in the D window (around the 8.78 MeV peak of Po-212) which predicts the amount of thoron progeny activity in the A window (due to the 6.05 and 6.09 MeV peaks of Bi-212). Note that the uncertainty figures given with each reading include the effect of these corrections.

4.8.4 Avoiding Longer Lived Decay Products

Although the RAD7 now corrects for the buildup of the long-lived thoron progeny (10.6 hour), we recommend that you avoid unnecessary exposure

of the instrument to high levels of thoron for long periods of time. The presence of these long-lived progeny can make low level radon measurements somewhat less accurate than would otherwise be possible. But if you err, the 10.6 hour half-life of the thoron progeny makes for a temporary inconvenience of a few days at worst.

4.8.5 Decay Correction, Flow Rate, and Thoron Calibration

As discussed above, thoron's rapid decay causes the intake path and the air flow rate to become important factors in calibration. The RAD7 factory calibration for thoron is based on a standard RAD7 inlet filter, a standard 3-foot long, 3/16 inch inner diameter vinyl hose, and a standard small (6 inch) drying tube. Deviation from this arrangement can change your thoron results. For example, if you were to use a very long hose for thoron sampling, then the sample might decay significantly before it ever reached the instrument inlet. The same thing might happen if you substituted the small drying tube with the large drying column. If you were to use a non-recommended inlet filter, the flow might be restricted enough to greatly lower the result.

4.8.6 Calculating Sample Decay

The thoron concentration at the inlet of the RAD7, C1, can be expressed mathematically as

$$C1 = C0 * \exp(-L * V1 / q)$$

where C0 is the original sample concentration, V1 is the volume of the sample tube + drying tube + filter (around 50 mL), q is the flow rate (around 650 mL/min), and L is the decay constant for thoron (.756 /min). A typical value for C1/C0 is then

$$C1/C0 = \exp(-.756 * 50 / 650) = .943 = 94.3\%$$

This is the number DURRIDGE assumes in the factory calibration. Adding a few extra feet of hose will not matter much (about 0.5% per foot), but if we were to use a 100 foot hose instead (V1 is around 580 mL) then the same calculation would give .509 or 50.9%, a significant reduction from 94.3%!

4.8.7 Calculating Internal Cell Concentration

The sample decays slightly in going from the RAD7 inlet to the internal cell, due to internal hose and filter volumes. This decay can be calculated in a similar fashion to the above, giving the internal cell inlet concentration, C2, about 95.5% of C1. Within the RAD7 internal cell, the equilibrium thoron concentration, C3, will be determined by the following formula:

$$C3 = C2 / (1 + L * V2 / q)$$

where L and q are as above, and V2 is the volume of the internal cell (around 750 mL). Typical values then give C3/C2 as

$$C3/C2 = 1/(1+.756 * 750/650) = .534 = 53.4\%$$

Multiplying this result by the sample decay factors calculated above, we obtain an overall concentration in the internal cell of 48.1% of the original sample. Recognizing the uncertainty of several of the inputs to these formulas, particularly the flow rate, we will round the overall result to 50%.

4.8.8 Internal Cell Thoron Sensitivity Calibration

Preliminary investigations have shown that the RAD7's internal cell thoron sensitivity in cpm/(pCi/L) is identical to its radon SNIFF mode sensitivity, to within 25%. We have no reason to expect any sizable difference between the thoron and radon SNIFF mode sensitivity values, so we are presently assuming that the two values are indeed nearly equal, and claim an uncalibrated thoron precision of +/- 30%.

With calibration against a thoron standard assessed by gamma spectrometry we are able to state the thoron sensitivity with much higher certainty. This thoron calibration is offered as an option and for this we claim an overall accuracy of +/- 20%. Otherwise we estimate the overall thoron sensitivity to be 50% of the radon Sniff sensitivity to account for sample decay in the intake and internal cell. The RAD7 has a typical radon Sniff sensitivity of .25 cpm/(pCi/L), so we estimate the typical thoron sensitivity to be around .125 cpm/(pCi/L).

4.8.9 Setting up a Thoron Measurement

Sniffing for thoron is much the same as sniffing for radon, except it tends to be a little faster. If you are just "prospecting", you probably will not be very interested in getting the most accurate results possible, so technique is not critical. But if you are trying to make an accurate measurement, technique is of great importance.

For accurate thoron measurement, always use the same sample taking arrangement. Keep the sample tubing short: no more than 6 feet (2 meters) total length. Use one of the small drying tubes supplied with the instrument, filled with fresh (blue) desiccant. Always use an inlet filter, free from flow restrictions or clogs. Avoid obstructing the intake of the sample tube. For the most accurate results, check the flow rate with a flow gauge to be sure it is consistent from measurement to measurement. Use the RAD7's Setup Protocol command to choose Thoron protocol for a 5 minute repeating cycle. Be sure the instrument has been "dried out" before making a measurement. Position the sample tube intake and start the test.

4.8.10 Thoron Mode

Thoron mode causes the RAD7 to print both thoron and radon concentrations (in pCi/L or Bq/m3) in continuous data logging or in subsequent printing of data. Thoron mode also directs the automatic pump setting to continuous pump operation to assure a fresh sample.

The setup parameter "Setup Thoron" allows you to select Thoron mode On/Off, for configuring a particular test to perform thoron readings.

The protocol "Protocol: Thoron" provides a standard test for sniffing both radon and thoron in 5 minute cycles.

4.9 Managing Background

A major concern in radon testing is background. The RAD7 has a number of features that help to keep short and long-term background under control. These are discussed in Chapter 3.11. Following a few simple rules will help to keep background to a minimum.

Short term background is activity left in the detector after the air sample has been flushed from the measurement chamber. The higher the radon concentration and the longer the sample is held in the cell, the more daughter activity it leaves behind. So, to avoid background, when you see high radon readings, finish your measurement, and purge the sample cell promptly. Take the instrument somewhere with little radon, such as outdoors. Make sure the drying tube is connected, and select `>Test Purge`. Let the RAD7 purge for 5 to 10 minutes, or longer if the sample was exceptionally "hot".

The two alpha peaks decay at different rates. The polonium-218 peak, in window A, decays with a 3.05 minute half-life. So in 10 minutes it will be down to about one-tenth of its original count rate. The peak in window C, however, will take over two hours to get down to one-tenth its count rate.

Rather than wait around for hours, you can start the next test in SNIFF mode, which ignores window C. In fact, the preset, one and two-day, monitoring protocols, in the RAD7, use AUTO mode, which starts a measurement in SNIFF mode and automatically changes to NORMAL mode after three hours. This takes care of all but extreme exposure to very high radon.

You can always measure the short-term background, with 5-minute SNIFF mode tests. Run a few to see that the background is low.

4.10 Harsh and Hazardous Environments

4.10.1 Splashing Water

Avoid allowing water to splash onto the face plate of the RAD7. If the RAD7 is to operated in a harsh environment, such as a cave or mine, where water may splash around, the RAD7 may be protected in two ways:

a) A thin plastic film may be stretched over the face plate and down the sides of the case. It can be pushed down around the hose connectors and plugs can be pushed into data and power sockets, pushing the plastic film down around the pins. The result is to make

the instrument almost waterproof.

b) The RAD7 can be enclosed in a large transparent plastic bag with the opening gathered, and held with an elastic band, around the incoming air-sample tubing.

c) The dry air from the RAD7 outlet may be exhausted to the interior of the bag, so ensuring that the RAD7 is operating in a clean and dry environment.

4.10.2 Dusty Environment

Dust may contaminate the desiccant and cause elevated radon background due to radon emitted by trace amounts of radium deposited in the desiccant by the contaminating dust. To prevent this, a dust filter should be attached to the tubing at the sampling point, upstream of everything.

A suitable dust filter is supplied with every RAD7. The filter should be replaced when it becomes soiled. Replacements may be purchased from a car-parts supplier as 1960's VW Beetle in-line gasoline filters, part number 803-201-511C, or FRAM G4164, or from DURRIDGE Company.

Please note that any restriction to air flow, including a plugged dust filter, upstream of a passive DRYSTIK will reduce the effectiveness of the DRYSTIK. In a dusty environment, with a dust filter in place, an Active DRYSTIK will continue to work well even if the dust filter becomes partially blocked.

4.10.3 Radiation Hazard

If the RAD7 is to be placed in a position hazardous to the health of individuals, remote communication may be established either through the a wireless network or over telephone lines. Please see Chapter 6 and the CAPTURE user's manual for details.

For extended use without maintenance, an Active DRYSTIK can keep the relative humidity in the RAD7 low without the need for any desiccant.

5. PC Connection

5.1 *RS-232 Serial Port*

5.1.1 Capabilities

The RAD7's built-in serial port allows you to transfer data to your personal computer. Once the data has been transferred, you may use CAPTURE or the software of your choice to manage the data and create tables, graphs and reports.

The standard RAD7 firmware, with RADLINK remote control software installed, enables two-way communication between the RAD7 and another device.

The RAD7 serial port follows RS-232 convention commonly found on personal computers. For computers without a serial port, a USB/RS232 adaptor is provided standard with every new RAD7.

In order to take advantage of the RAD7 data transfer capability, you will need appropriate hardware (PC with USB or RS232 serial port and null-modem serial cable), as well as appropriate software (CAPTURE for Windows, Mac or Linux), which will be explained below.

5.1.2 Hardware Bridge

If there is no RS232 serial port on the computer, a USB/RS232 adaptor is required. The latest driver for the particular device and for the PC operating system should be downloaded and installed in the PC.

You will need the proper cable to link the RAD7 serial port to your computer. The cable should be a "null-modem" type, as the RAD7 serial port emulates a computer rather than a modem. If you prefer, you can use a normal "modem" cable along with a "null-modem" adapter on one end or the other.

5.1.3 Software Bridge

In order to receive data on your computer, you will need software that can "capture" the data and store it to memory or disk file. DURRIDGE CAPTURE software for Windows and Macintosh is designed to make this task easy. It also offers sophisticated graphing and data analysis capabilities.

The latest version of CAPTURE may be downloaded from the DURRIDGE website (www.durridge.com).

5.1.4 Applications

CAPTURE is intended to provide all the analytical and visual capabilities likely to be required. It also stores copies of the data in various formats for exporting into spreadsheet and database programs. CAPTURE is described in greater detail in Chapter 6.

5.1.5 Technical Specifications for the RAD7

The RAD7 serial port follows RS-232C convention for signal levels. Positive voltage (+3V to +15V) indicates logic state 0 (SPACE), while negative voltage (-3V to -15V) indicates logic state 1 (MARK).

The connector pin-out follows the IBM PC convention for the 9 pin serial port. The handshaking lines (DTR, DSR, RTS, and CTS) are not fully implemented, and should be considered non-functional (NF), but X-on/X-off flow control can be used.

RAD7 Serial Port Pin Assignments

Pin	Deg. C	Comment
1	Carrier Detect (CD)	NF
2	Receive Data (RD)	
3	Transmit Data (TD)	
4	Data Terminal Ready (DTR)	NF
5	Signal Ground (SG)	
6	Data Set Ready (DSR)	NF
7	Request To Send (RTS)	NF
8	Clear To Send (CTS)	NF
9	Ring Indicator (RI)	NF

The RAD7 serial port has complete hardware implementation for two-way communication at 300, 600, 1200, 2400, 4800, 9600, and 19,200 bits per second (baud); these speeds are available

through the 'Special' commands of the RADLINK remote control package. The default speed is 1200 bps.

RAD7 Communication Parameters

Default Rate	1200 bps
Data Bits	8 bits
Parity Bit	None
Stop Bits	1 bit

5.1.6 Serial Port Output

All stored test data are available for serial port output through the "`>Data Com ##`" command. Specify the run number in the command line.

Output from the RAD7 serial port is entirely ASCII numeric. Each cycle produces a record containing 23 fields. Carriage-return line-feeds separate the records. Within each record, commas separate the fields. Fields may have leading zeros, extra space characters, trailing decimals, etc., but these will not bother CAPTURE or most database or spreadsheet programs.

RAD7 Data Record - 23 data fields per record:

ID	Field Name	Notes
1	Test Number	Ranges from 001 to 999
2	Year	2 digit value
3	Month	2 digit value
4	Day	2 digit value
5	Hour	2 digit value
6	Minute	2 digit value
7	Total Counts	Integer indicating total counts recorded during test
8	Live Time	Expressed in minutes
9	Percent of total counts in win. A	These 4 windows will not always add up to 100% since counts can come into channels below or above these window.
10	Percent of total counts in win. B	
11	Percent of total counts in win. C	
12	Percent of total counts in win. D	
13	High Voltage Level	Ranges from 2200V to 2300V
14	High Voltage Duty Cycle	Ranges from 0-100%; typically 10-20%
15	Temperature	Measured in °C or °F depending on RAD7 setup
16	Relative humidity of sampled air	Should be kept below 10% for most accurate test
17	Leakage Current	Ranges from 0 to 255. Above 20 is cause for concern.
18	Battery Voltage	Below 6.00V is a discharged battery. Does not affect accuracy of test but indicates need for recharge.
19	Pump Current	Ranges from 0-260mA. Typically 40-80mA; Above 100mA possible clogged filter or obstruction.
20	Flags Byte	Individual bits store settings: Bit 0 indicates pump is in TIMED mode Bit 1 indicates pump ON continuously Bit 2 is not defined Bit 3 indicates tone is in GEIGER mode Bit 4 indicates beeper is activated Bit 5 indicates spectrum will print after each test Bit 6 indicates multiple (recycle) tests Bit 7 indicates SNIFF test mode. Clear is N
21	Radon concentration	Expressed in pCi/l, Bq/m3, cpm, or # counts, depending on the units the RAD7 has been set to use.
22	Radon concentration uncertainty	2 sigma error - of concentration in the SAME units as the concentration (not %).
23	Units Byte	Individual bits store settings: Bits 0 and 1 indicate concentration unit: 00 = cpm, 01 = # of counts, 10 = Bq/m3, and 11 = pCi/L. Bit 2 through Bit 6 are not defined. Bit 7 indicates temperature unit (0 = °F, 1 = °C)

A run can contain many cycles of data, with one record per cycle. Here is an example of a single record:

```
009,99,10,29,04,18,4823.,337.8,45.4,
2.9,46.6,0.3, 2201,14, 23.7, 5, 7,
7.09, 00, 125, 28.32743, .8500846,
255<CRLF>
```

5.2 *RADLINK*

5.2.1 Capabilities

The remote control package, now installed standard with every RAD7 sold, enables the RAD7 to be controlled from a distance by sending commands through the built-in serial port. This package makes all the ordinary RAD7 keypad commands available through a remote device connected to the serial port. Using a remote terminal or computer you may, for example, change the RAD7's operating parameters, start a test, stop a test, or receive data from the RAD7. The package permits users to implement automated communication between the RAD7 and computing equipment for the purpose of remote centralized data collection or control.

RADLINK also provides several additional functions, not otherwise available. For instance, with RADLINK you can change the baud rate, download the entire data stored in the RAD7 with a single command, and control relays directly from the RAD7.

5.2.2 Requirements

Remote control software resides in non-volatile memory (NVRAM), but does not decrease the amount of memory available for storing radon data.

The most simple implementation of remote control is through a direct wire link from the RAD7 to a personal computer or terminal. This requires a serial null-modem cable from the RAD7 to the serial port connector on the computer or terminal or USB adaptor.

The simple, direct serial port to serial port connection has a range limited to around 50 feet (15 meters) by the RS-232-C standard. Options for extending this range include RS-232 line boosters, current-loop and other types of interface converters, short-haul modems, and leased-line modems.

You may use standard data modems to communicate over the telephone system to one or more remote RAD7 monitors, so that when you want to get some data or start a new run, just "dial up" the instrument of your choice. The modem should be Hayes compatible and should be set to auto-answer.

If you intend to use a personal computer to communicate with and control an instrument, you will need terminal emulation software for your computer. Several low-cost commercial software products are available for data communication that allow you to send commands, receive replies, and transfer data in and out of your computer using its serial port or USB port with an adaptor.

5.2.3 *RAD7* Remote Command Format

The format of commands to the RAD7 serial port match, as closely as possible, the format of the commands available to the user at the RAD7 keypad. For example, the command to change the cycle time to 1 hour is "`SETUP CYCLE 01:00`". The command to turn off the audio beeper is "`SETUP TONE OFF`". The command to send over the data from run number 3 in comma-delimited form is "`DATA COM 3`". The upper/lower case of the command does not matter, nor does the numeric format of numbers. In the last example, "`data com 03`", "`Data Com 3`", and "`dAtA coM 03.00`" all work equally well.

You can use any of the ordinary RAD7 commands, but a few extra commands have been added that you may also use, or in some cases substitute for other commands. These commands all start with the word "SPECIAL". One such extra command is the command "`SPECIAL STATUS`" which gives information about the current status of the instrument, just like "`TEST STATUS`", but does not continue to update the information every second; instead, it returns control to the user.

The Control-C character functions as a remote "menu" key that can be used to interrupt certain activities and get ready for a new command. The

RAD7 replies with a prompt, the greater-than character ">", that tells you it is ready for a new command. When using a terminal emulator program, you will always type commands at the prompt.

All commands must be followed by a carriage return character, denoted here as <CR>. No command will be activated until the <CR> goes through. Once you have typed a command, always end with a carriage return keystroke. This key may be marked "Enter" or "Return" on your keyboard.

If the RAD7 cannot understand your command, such as if you typed words in the wrong order or misspelled something, it will respond with

?ERROR

followed by a list of acceptable command words.

5.2.4 Special Keys

If you are using a terminal emulator package, you can gain a few special keys by making sure your terminal has been setup to give ANSI standard escape codes for the function keys and cursor control keys. Set your terminal for either ANSI, VT-52, or VT-100 mode to get these functions. The function keys F1, F2, F3, and F4 act as a remote RAD7 keypad, corresponding to the RAD7 keys [MENU], [ENTER], [←], and [→]. As mentioned previously, the Control-C character also acts as a remote [MENU] key. The backspace/delete key on your keyboard allows you to correct misspelled commands before the carriage return. If this key does not work, then Control-H may do the same function.

5.2.5 Special Commands

A series of special commands have been added to the ordinary RAD7 commands to provide functions of special interest to remote control users. See Section 2.5 Special.

6. CAPTURE

6.1 Introduction

CAPTURE is intended to simplfy the transfer of data from the RAD7 to a computer. It also provides a wealth of graphing and data analysis options, and offers the ability to export data to other programs for further review. The software is available for Windows XP/Vista/7, and Macintosh OS X. The latest version of CAPTURE can be downloaded from the DURRIDGE website (www.durridge.com) at no charge.

This chapter serves as a brief introduction to the CAPTURE software. It is recommended that RAD7 users examine the complete CAPTURE documentation available within the program's Help menu. This information may also be found on the DURRIDGE website. (From the main page, Choose Software → CAPTURE and click the User's Manual link at the bottom of the page.)

6.2 Installation

Download the appropriate version of CAPTURE (Windows or Macintosh) from the DURRIDGE website. In Windows an installer program will install the necessary components and place shortcuts in the Start Menu and on the desktop, if desired. To install CAPTURE for the Macintosh, open the downloaded .dmg file and drag the CAPTURE application into the Applications folder or to the location of your choice.

To operate CAPTURE on a computer without a serial port, it is necessary to install the Keyspan Serial to USB adaptor driver, which is included on the DURRIDGE Software CD, bundled with each RAD7. This software is also availabe from the Tripplite website, (http://www.tripplite.com/). On the site, click the Keyspan Products link and look for the USA-19HS section to access the appropriate driver software.

For connecting more than one RAD7 to a computer, it is possible to use several USA-19HS

adaptors simultaneously, with each plugged into a USB port on the computer (i.e. do not plug multiple adaptors into a single USB hub.) Alternatiely, the Keyspan USA-49WG 4-Port Serial to USB adaptor may be used to connect to up to four RAD7s using a single USB port.

Although other Serial to USB adaptors are known to work with CAPTURE, they have not been thoroughly evaluated, and DURRIDGE recommends the Keyspan adaptor for most uses.

6.3 Feature Summary

CAPTURE's capibilities fall into three main categories: downloading RAD7 Data, graphing and analysis, and real-time RAD7 monitoring. Each is described briefly below.

6.3.1 Downloading RAD7 Data

CAPTURE's original and primary function is to download RAD7 data. Once connected to a RAD7, the program can download all of the device's data, or a particular data run. For a more complete record set, supplementary output containing thoron concentration records may also be obtained. When a download operation is complete, the results are saved to disk in the format of the user's choice.

In addition to being able to download data from RAD7s connected directly to the computer, CAPTURE can obtain data from remote RAD7s, connected via a network or modem.

6.3.2 Graphing and Analysis

Once RAD7 data has been downloaded and saved to disk, it may be displayed as a graph. CAPTURE's Graph Window allows for the display of thoron, temperature, and humidity data, in addition to radon. Navigation controls make it possible to select the data points within a specific date range and zoom in to that region for a closer look.

Accompanying the graph display is a statistics panel showing information about the point nearest to the cursor, the points within the selected region, as well as the points comprising the entire data set.

A synthesized spectrum display appears in another panel, providing an indication of the changes that occur within the RAD7 as a testing session progresses.

RAD7 profiles based on device calibration data may be applied to data graphs to improve result accuracy. Data points may also be corrected for temperature, humidity, and other variables. Any problematic data records will be handled by CAPTURE's comprehensive error catching system and reported to the user.

CAPTURE supports the exporting of both raw RAD7 data and more complete error-corrected RAD7 data in a number of formats, for use in spreadsheets and other analysis tools. Summary reports may also be generated, providing general overviews of the collected data.

6.3.3 Real-Time RAD7 Monitoring

CAPTURE is capible of monitoring multiple local and remote RAD7s simultaneiously in a Chart Recorder, displaying status details and plotting radon concentrations in real time as they are recorded. A statistics panel is automatically refreshed as new information arrives.

Besides tracking the sate of each connected RAD7, it is also possible to issue menu commands, performing such tasks as starting and stopping tests and setting the protocol. All of the functionality of the RAD7's physical controls are accessible from within CAPTURE's graphical interface.

As stated above, it is suggested that users examine the complete CAPTURE documentation, which is available from the DURRIDGE website, and from within the program's Help menu.

7. Maintenance

Provided the RAD7 is treated with respect, the only maintenance required by the instrument is its regular recalibration. For this, it should be returned to DURRIDGE Company, who will check the health of the instrument, and who will incorporate the new calibration factors in the instrument firmware.

If the instrument is to be used in a harsh environment, where water and/or mud may be splashed on the face plate, the RAD7 should be put in a box or large transparent plastic bag. The air input may be brought into the container by a plastic tube from the sampling point. The air outlet should be left in the container, so that the RAD7 becomes surrounded by clean and dry air.

7.1 Accessories - Usage and Care

7.1.1 Desiccant

Two sizes of desiccant tubes are supplied. In the NORMAL mode, use the large 2" diameter tube (laboratory drying unit). This unit will last for days under continuous operation at high humidity before it needs regeneration.

When used as a Sniffer, the small desiccant tube is recommended. It will last for several hours before replacement or refilling of the tube is necessary. To regenerate the desiccant, the granules should be removed from the tube and spread evenly in a thin layer on a metal or Pyrex glass tray. Heat at about 200°C (400°F) for at least two hours or until granules turn uniformly blue. Allow the desiccant to cool in a closed, but not airtight, container before refilling the acrylic laboratory drying unit or small drying tube.

How long will the desiccant last? This is a common question, and the following information should be helpful.

7.1.2 Laboratory drying unit

The column holds approximately 500 grams of Drierite desiccant. This desiccant can adsorb at least 10% of its weight in water, so the water capacity of the column is at least 50 grams. The RAD7 pump develops a flow rate of about 1 liter per minute. With the RAD7 set for continuous monitoring with timed pump operation, the pump operates 20 to 30% of the time. We will assume an average flow rate of 0.3 liters per minute.

The following table shows the moisture content of air at various conditions of temperature and humidity, and the expected lifetime of a charge of desiccant in the Laboratory Drying Unit.

RH	Deg. C	Deg. F	Column Life Days
30%	20	68	23.1
30%	35	95	9.8
50%	20	68	13.3
50%	25	77	10
90%	10	50	13.7
90%	15	59	10
90%	20	68	7.4
90%	25	77	5.5
90%	30	86	4.2

7.1.3 Small drying tube (small tube)

The small drying tubes each contain 30 grams of Drierite desiccant. The water capacity of each tube is 3 grams. We will assume that the RAD7 pump operates continuously, for an average flow rate of 1.0 liter per minute. The table shows the expected lifetime of a small drying tube under various humidity conditions.

RH	Deg. C	Deg. F	Tube Life Hours
30%	20	68	10
30%	35	95	4.2
50%	20	68	5.7
50%	25	77	4.3
90%	10	50	5.9
90%	15	59	4.3
90%	20	68	3.2
90%	25	77	2.4
90%	30	86	1.8

7.1.4 Cascading Drying Tubes

To extend the time before desiccant depletion, you may cascade several drying tubes in series. Two factors limit the number of drying tubes you can use. First, each additional drying tube or column adds a small amount of resistance to the air flow, so the pump will have to work a little harder. But the resistance added by a drying tube is much less than the resistance of the inlet filter, so you should be able to cascade several without severely restricting the air flow. Second, each additional tube adds a time lag between sample intake and instrument response.

For continuous monitoring, a 10- to 20-minute lag may be perfectly acceptable, but for sniffing it may not be. You can conservatively estimate the time lag by taking four times the volume of the drying system and dividing by the average flow rate. Consider a continuous monitor application using a laboratory drying column of volume 0.8 liter with the pump in timed operation, giving an average flow rate of 0.2 liters per minute. Four times the volume divided by the flow rate gives 16 minutes for the estimated lag time. This would be perfectly acceptable for continuous monitoring. For radon sniffing, you will usually use the small drying tubes (volume .032 liter), which create negligible delays of less than a minute, even at low flow rates. You can cascade several small drying tubes without trouble.

Do not cascade drying tubes when sniffing for thoron, since thoron's 56-second half-life necessitates that you keep delays to an absolute minimum. For thoron sniffing, use a single small drying tube, and set the pump for continuous (on) operation. Keep hose length to 6 feet (1.8 meter) or less.

7.1.5 Filters

Inlet filters are supplied that fit the metal inlet fitting (male Luer type). These filters block ultra fine dust particles and all radon daughters from entering the RAD7 test chamber.

The filters are manufactured in various pore sizes by several companies, including Millipore and SRI. We favor pore sizes of 1.0 microns or less; pore sizes as small as 0.4 microns can be used with the RAD7 pump.

The filter should be replaced when it has become noticeably discolored or has clogged enough to impede the flow of air. If you cannot suck air easily through the filter yourself, it's time to change the filter.

When you operate the RAD7 in construction areas or basements, dust can quickly build up in sampling hoses, drying tubes, and inlet filters. This dust will slowly clog the filter, restrict air flow, and create strain on the pump. You will have to replace the inlet filter. To greatly slow the buildup of dust, we recommend that you attach a "prefilter" to the intake of the sampling hose, to prevent coarse dust particles from entering. Then, the inlet filter will remove the ultra-fine dust particles that pass through the prefilter and drying system.

We find that automotive gasoline filters can serve as convenient and inexpensive prefilters. A particular filter, intended for Volkswagens, is a small, disposable, clear-plastic capsule containing a pleated paper filter. This filter effectively removes most dust from the air stream, greatly extending the life of the inlet filter. You can buy this type of filter in almost any auto parts store for around $3.

7.1.6 Batteries

Your RAD7 has enough battery capacity to go for two to three days without any external power source. Electronic circuits control the charging and discharging of the battery, avoiding overcharge or destructive discharge. If you maintain the batteries according to the following directions, you can expect to get two to five years of heavy service from them.

Keep the batteries fully charged as much as possible. Try to recharge promptly after use. The RAD7 batteries charge whenever the unit has DC power. With the power cord plugged in and the RAD7 measuring radon, the batteries will charge slowly. Full recharge takes about 48 hours.

With the power cord plugged in and the RAD7 in fast charge mode (not measuring radon), the batteries will charge more quickly. Full recharge takes about 24 hours. The battery voltage indicator on the display (go to Status Window 1) will reach 7.10 to 7.20V when the batteries are

fully charged and the power cord is still plugged in.

If the batteries are deeply discharged, to the threshold of battery damage, an electronic circuit will completely disconnect them to avoid further discharge. The circuit will then not allow battery operation until they are completely recharged. If this occurs, you may still be able to operate the *RAD7* from DC power until the batteries recharge. Expect the recharge to take 48 hours.

Never store the RAD7 without first recharging the batteries. If you intend to store the RAD7 for a long period of time, you must recharge the batteries at least every four months, as they can be damaged by self-discharge on the shelf. Otherwise, you may have to replace the batteries before you can use your instrument again.

Battery voltage can be read from the Status display, and appears on printed output. A fully charged battery will rest at 6.40 to 6.50V. As the battery discharges, its voltage drops steadily to 6V. If the battery voltage ever goes below 6.00V, it is fully discharged and should be recharged as soon as possible. As the battery charges, its voltage rises steadily until it goes above 7V. Consider the battery fully charged if it charges at or above 7V.

7.1.7 Real-time Clock and Non-volatile Memory

The RAD7's Real-Time-Clock (RTC) and Non-Volatile Memory unit (NVRAM) allows the RAD7 operator to switch power off without losing data or disrupting the clock time and date. These functions are powered by a lithium cell with an expected lifetime of ten years.

7.1.8 Printer and Adapter

The printer is manufactured by Chamjin I&C. It comes with its own manual, and you should familiarize yourself with its operation. Specifically, you should be aware that it operates through an infrared optical link and should be positioned on the top of the RAD7 to match the data link on the detector. It runs on its own batteries.

7.2 Operating ranges

Parameter	Minimum Value	Maximum Value
Temperature	0°C (32°F)	40°C (104°F)
Relative Humidity, external (*Must be non-condensing*)	0%	95%
Relative Humidity, internal	0%	10%
Battery Voltage	6.00V	7.20V
Pump Current *(pump off)*	0mA	10mA
Pump Current *(pump on)*	30mA	90mA
High Voltage	2100V	2400V
HV Duty Cycle	8%	20%
Leakage Current *(room temp.)*	0mA	20mA
Leakage Current *(max. temp.)*	5mA	80mA
Signal voltage level	0.15V	0.30V

7.3 Service and Repair

7.3.1 Calibration

DURRIDGE maintains a radon calibration facility that includes a controlled, standard source of radon gas, and a controlled-temperature environmental chamber. All RAD7 alignment and calibration is done here, as well as basic testing and quality assurance. We determine calibration factors by direct comparison to "master" RAD7's, which were themselves compared with EPA and DOE instruments, and which have participated in international inter-comparisons of radon instrumentation. The calibration accuracy is independently verified by direct determination of the radon chamber level from the calibrated activity and emission of the standard radon source. In addition, we periodically intercompare with other radon chambers. We generally achieve a reproducibility of better than 2% with our standard RAD7 calibration. Overall calibration accuracy is in the range of 5%.

The EPA recommends (and we agree) that all continuous radon monitors be calibrated at least every six months in a radon calibration chamber, although most RAD7 users are satisfied with annual recalibration. DURRIDGE's standard RAD7 calibration requires four to five working days from the receipt of the instrument. As a preliminary to recalibration, we give every RAD7 a brief inspection, and test one or two critical parts. If additional service is required, this may delay the return of the instrument.

We recommend that you arrange for your calibration ahead of time, to avoid possible delays. When sending your RAD7 for calibration, please send the instrument only, without the accessories, and please pack it well, with at least an inch of packing all round.

At present, only DURRIDGE can make adjustments to your instrument's alignment and calibration factors. If you determine, on the basis of an independent intercomparison (e.g., another calibration chamber) that you would like to adjust your RAD7's calibration by a known amount, we can generally perform this service and send back your instrument within one day. Requested calibration adjustments of more than 10% are considered highly unusual and require the written permission of the instrument's owner.

7.3.2 Repair

If you discover that your RAD7 is malfunctioning, we recommend that you first call DURRIDGE and talk to a technician. A surprising number of minor "disasters" can be avoided by long-distance consultation. The next step, if consultation fails, usually is to send your instrument in for evaluation and repair. Please send any documentation of the problem that you might have (notes, printouts, etc.) and a short note describing the problem. Be sure that you put your name and telephone number on the note. Within 48 hours of our receipt of the instrument, we will call you to give a prognosis.

Bear in mind that a repaired instrument often requires complete re-calibration, so a one-week turn-around may be the best we can do. If you absolutely need an instrument during the repair time we can sometimes arrange to send you a "loaner" instrument.

7.3.3 Shipping

The RAD7 is shipped to you in a plastic bag, packed in a box with styrofoam peanuts, and finally packed inside another box that also holds all the accessories. The inner box, by itself, is too small for the return trip, when you need a calibration or repair job. You need to find a bigger box, with space for one inch packing all round the RAD7. A 14" cube box is fine. Pack and seal the box carefully.

Please do not ship any accessories, unless they are relevant to the problem.

All return shipments to DURRIDGE must be prepaid, and unless you instruct us otherwise, we'll return it to you via the same shipping method you used to get it to us - from "slow boat" to "next day air", freight collect.

7.3.4 Upgrades

Whenever you send your RAD7 in for repair or calibration, you have the option of having the latest available software installed. Most RAD7's can be upgraded to the latest hardware configuration as well. You will be informed

periodically of whatever new features are available for your RAD7. Please advise us if you want to have an upgrade made. We intend to keep our RAD7 customers happy by keeping their instruments up-to-date, state-of-the-art.

7.4 RAD7 Quality Assurance

While the annual inspection and calibration, carried out by DURRIDGE Company, is the most effective quality assurance, and the prime requirement of EPA, there are other tests and observations that may be made that will give assurance of good performance throughout the year.

7.4.1 Spectrum

At least once a month, the spectrum printed by the IR printer should be observed. The cumulative spectrum, printed at the end of a run, has the most data points and is, therefore, the most useful for this purpose. All that is required is that the printer be placed on the face plate at the end of a 1-day or 2-day run. It doesn't matter what format is chosen, the summary printed at the end of the run will conclude with a cumulative spectrum, after the bar chart.

Alternatively, the RAD7 will print a spectrum at the end of every cycle if the format is set to LONG. However, this will include only the counts during that cycle. For the spectrum to be useful it should have at least 100 counts. There should be clearly defined peaks and little or no noise across the spectrum. The peaks should be located in the middle of the windows. A clean spectrum is indicative of an instrument in perfect working order, and hence of reliable and accurate readings.

7.4.2 Spill Factor

Due to the occasional alpha particle emitted, from a polonium atom on the detector surface, at grazing incidence to the surface, there is always a small, low-energy tail to the peaks. This may be observed in the printed spectra. There is thus a spill of 214-Po counts from window C into window B. It is normally around 1% to 1.5% in a current production RAD7. The actual value is measured during the calibration process and the spill factor used to compensate for this phenomenon when measuring thoron in the presence of radon.

If the detector becomes contaminated in use, or either electronic or detector failure causes noise in the system, thus making the low-energy tail thicker, or the peaks broader, then this spill factor will increase. The value can be calculated from any reading, provided that it is known for sure that there was no thoron in the chamber. The percentage of counts in windows B and C is given in fields 10 and 11 of each record in memory (see section 5.1.6). The spill factor is simply the ratio of the values in those two fields.

It is recommended that the spill factor be noted every month. Any sudden change is cause for further study of the instrument, and an examination of the spectrum.

8. TROUBLESHOOTING

8.1 Display

8.1.1 Blank Display

If the unit is switched on, the most likely cause of a blank display is discharged batteries. Please see Section 7.1.6.

Make sure the RAD7 is properly plugged in to an external power source and is switched on.

If the instrument has been run on the batteries and not recharged, or if it has been left untouched for a lengthy period, the batteries may be completely flat. In that case, the instrument should be left plugged in and switched on for many hours, preferably 24 hours or more. If this fails to restore the display, the RAD7 should be returned to DURRIDGE Company for service.

8.1.2 Frozen Display

If the display shows "DURRIDGE RAD7" and does not respond to key strokes, the key pad has been locked. Hold down the ENTER and two arrow keys until you hear a beep, release the three keys and immediately push MENU. You should then be rewarded by "Test" on the display. If the tone was set to OFF, then you will not hear the beep, so hold the three keys down for three to four seconds, before releasing them and pushing MENU, - try hold-down times a little longer, or shorter, if at first you do not succeed. Please refer to paragraph 2.2.6.

8.1.3 Incomplete Or Garbage Characters

Incomplete or garbage characters may indicate a faulty LCD display. Please return RAD7 to DURRIDGE Company for service.

8.2 Readings

8.2.1 No Counts

The total number of counts so far in any cycle is displayed in the bottom righthand corner of Status Window 1. If, near the end of a cycle, there are no counts, or less than 10, say, it probably means the cycle length is too short. Increase the cycle length to increase the number of counts in a cycle and to improve the precision of the individual readings (`>Setup Cycle`, `HH.MM [ENTER]`).

If, with a cycle time of one hour or more, the total count near the end of a cycle continues to be zero and it is known that there is radon in the sample, then either the sample path is blocked or there is a fault with the RAD7 and it should be returned to DURRIDGE Company. Check that air is flowing using any of the following measures:

a) Feel the air exiting the outlet when the pump is running.
b) Stop the outlet of the RAD7 and feel the buildup of pressure.
c) Clamp the sample input tubing, hear the change in pump sound and see the change in pump current (third status window).
d) Feel the suction at the sampling point.

8.2.2 Excessive Uncertainty In Reading

If the uncertainty in the reading is greater than the base concentration value or if there is a large scatter in the readings, the cycle length is too short for the radon concentration being measured.

Increase the cycle time to reduce the scatter. Four times the cycle time will produce half the scatter and half the uncertainty. For past data, use CAPTURE to graph the data and use "Smoothing" to smooth out the statistical scatter in the data.

8.2.3 Run/Cycle Number 0000

A Run/Cycle number of `0000` indicates that the RAD7's memory is full. Download the RAD7's contents to a computer using CAPTURE. Then erase the RAD7 data using `>Data Erase`. The memory will be emptied and the data structure reset.

8.3 Relative Humidity high

Relative humidity (displayed in the third status window) normally starts high unless the instrument has been well purged just before

starting the run. Depending on how long it has been since the last measurement, it may take an hour or more of measurement to bring the relative humidity down to below 10%.

If it takes too long to bring down the relative humidity, check the following:

a) The desiccant is used up. Replace it.
b) The desiccant insufficiently regenerated. Follow the instructions in Section 7.1.1.
c) There is a leak in the drying unit. Clean the O-ring and seating before replacing the desiccant. Be sure to draw the air sample from the end furthest from the screw cap.
d) There is a leak in the connection to RAD7.
e) There is a blockage in the air path. Squeeze the inlet tubing and note any change in the sound of the pump. Feel for suction at the sampling point.

If none of the above succeed in lowering the relative humidity, there may be a problem with the humidity sensor. Measure the relative humidity of the air leaving the RAD7. If no humidity sensor is available, another RAD7, if one is available, would do. The two RAD7s can be connected in series. Set the downstream RAD7 pump to OFF (Setup, Pump, Off [ENTER]). If the downstream RAD7 reads a lower relative humidity than the upstream one, then the upstream humidity sensor is wrong and should be replaced. Return the RAD7 to DURRIDGE Company for service.

If none of these solutions are applicable, measurements made at high humidity can be corrected automatically using CAPTURE. See Section 3.12.2.

8.4 Battery Voltage Low

Keep the RAD7 plugged into external power and switched on until the battery voltage (Status Window 3) recovers to about 7.1V. The RAD7 may safely be left charging all night.

8.5 Pathological Values and Error Messages

A Bad Offset Voltage error message, a 100% duty cycle, or leakage (L) above 15 (Status Window 4) all indicate faults in the RAD7, which should be returned to DURRIDGE Company without delay.

Appendix: RAD7 Specifications

Specifications for the RAD7 exceed those of all radon gas monitors made in North America, as well as those in its price range world-wide. This is a partial list of specifications that make the RAD7 so highly regarded in the field.

Part 1 Functionality

Modes of Operation	SNIFF Rapid response and rapid recovery radon measurement THORON Radon and thoron measured simultaneously and independently NORMAL High sensitivity AUTO Automatic switch from SNIFF to NORMAL after three hours run GRAB Analysis of grab samples WAT Automatic analysis of water samples with RAD H_2O accessory
Measurements	Radon in air with Sniff protocol for quick, spot reading Thoron protocol for searching for radon entry points Radon in air 1-day, 2-day or weeks protocol for long term measurement Radon in water batch samples with RAD H_2O and Big Bottle RAD H_2O Continuous radon in water with RAD AQUA and Radon-in-Water Probe Radon in soil gas with Soil Gas Probe and Active DRYSTIK Radon emission from soil and hard surfaces with surface emission chamber Bulk radon emission from bulk materials and objects
Data Storage	1,000 records, each with 23 fields of data Log of printer output also stored
Sample Pumping	Built-in pump draws sample from chosen sampling point Flow rate typically 800ml/min
Print Output	Short, medium or long format data printed after each cycle Run summary printed at end of run, including averages and spectrum
PC Connectivity	RS232 serial port, full remote control implemented in CAPTURE Software
Audio Output	GEIGER Tone beeps for radon and thoron counts CHIME Chime only at the end of each cycle, otherwise silent OFF No sound
Tamper Resistance	TEST LOCK command locks keypad to secure against tampering

Part 2 Technical Specifications

Principle of Operation	Electrostatic collection of alpha-emitters with spectral analysis Passivated Ion-implanted Planar Silicon detector SNIFF mode counts polonium-218 decays NORMAL mode counts both polonium 218 and polonium 214 decays
Built-In Air Pump	Nominal 1 liter/minute flow rate Inlet and outlet Luer connectors
Connectivity	RS-232 port up to 19,200 baud rate USB adaptor is included with every RAD7
Measurement Accuracy	+/-5% absolute accuracy, 0% - 100% RH

Nominal Sensitivity	SNIFF mode, 0.25 cpm/(pCi/L), 0.0067 cpm/(Bq/m³) NORMAL mode, 0.5 cpm/(pCi/L), 0.013 cpm/(Bq/m³)
Radon Concentration Range	0.01 - 20,000 pCi/L (0.4 - 750,000 Bq/m³)
Intrinsic Background	0.005 pCi/L (0.2 Bq/m³) or less, for the life of the instrument
Recovery Time	Residual activity in Sniff mode drops by factor of 1,000 in 30 minutes
Operating Ranges	Temperature: 32° - 113°F (0° - 45° C) Humidity: 0% - 100%, non-condensing
Cycle Range	User controllable number of cycles, from 1 to 99 to unlimited, per run User controllable cycle time, from 2 minutes to 24 hours
CAPTURE Software	Compatible with Microsoft Windows XP and 7, and Mac OS X Automatic RAD7 location, connection and data download Graphs radon, thoron, temperature and humidity over time Automatic humidity correction Statistical analysis tools track concentration averages and uncertainties Chart Recorder mode provides real-time RAD7 status monitoring Control RAD7 operations from computer via direct or remote connection Automatic calculation and display of radon in water for RAD AQUA Automatic combination of multiple RAD7 data

Part 3 Physical Specifications

Dimensions	11.5" x 8.5" x 11" (29.5 cm x 21.5 cm x 27.9 cm)
Weight	9.6 pounds (4.35 kg)
LCD Display Output	2 line x 16 character, alpha-numeric display
Case Material	High density polyethylene
Infrared Printer	Chamjin NewHandy 700 Wireless Infrared Printer included
Power Supply	11-15V DC (12V nominal) @ 1.25A, center pin positive, or internal rechargeable batteries (5Ah) Optional AC input for non-EU customers
Battery Longevity	24 hours in SNIFF mode; 72 hours in Monitor mode

SOP2: Procedure for Femto Tech 510F

<u>Pictured at Right:</u> Femto-Tech 510F in its case.

<u>Pictured below:</u> Quick start Reference Card for testing and printing with the device, and key to operate device.

CRM-510LP Operation (Sample)

To Start A Test

		Screen Shows
(1)	Turn Key to RUN position =	Blank
(2)	Push the PRINT button once =	RUN, then goes to: pCi/l, "Hg, °F or: Bq/M^3, kPa, °C
(3)	Push the PRINT button again =	DATE 01/21/04
(4)	Push and release both buttons at the same time =	TIME 14:06
(5)	At this time, the unit goes into Self-Test Mode =	SELF TEST ACTIVE
	This takes about 20 seconds. When the test passes, the screen shows =	PASSED SELF TEST TEST STARTED!
	At this time the test is running =	Count 0 Then Blank
	If the screen says = Turn the key to OFF and push a button, Start from the beginning. If the Unit fails for a second time, Call *femto*-TECH, INC. for guidance	SELF TEST FAILED

To End A Test

(1)	Turn the Key to the OFF position and push either of the buttons =	TEST ENDED !

To Print Test	Screen Shows
(1) Attach Printer Cable to Unit and Printer.	Blank
(2) Turn the key to I/O, turn Printer on.	Blank
(3) Press PRINT button once =	TIME: xxxx min.
(4) Press PRINT button again =	pCi/l, "Hg, °F
(5) Press PRINT button again =	TABLE
(6) If you want a graph press I/O then proceed To step # 7	GRAPH
(7) Press PRINT button again =	Use All Data

(8) **Press PRINT button and data will begin printing.**

(9) **Data may be printed again by repeating the above steps.**

Note: Once you start a new test, the old data will be CLEARED!

Note: When Closed House conditions were not met and test time was extended: ***During the print set up step #6 press the I/O button and the screen will say (Skip 1st 12 hrs) then push print.*** **This will skip the first 12 hours of data from the test average.**

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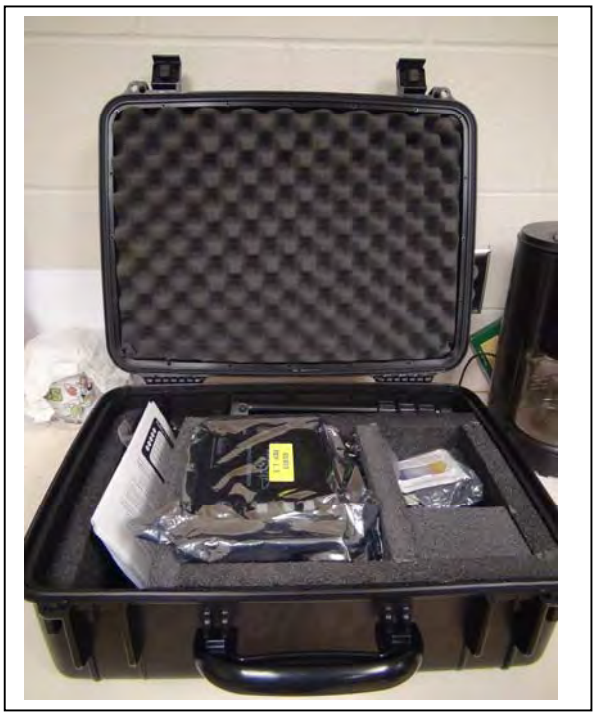
SOP3: Procedure for RadStar RS800



RadStar RS800 Quick Start Guide

1. Plug power adapter marked "RadStar Power Supply" into any 120VAC outlet. Plug free end of power adapter into left side of RS800 – green LED should come on.

2. Insert key and turn to [MEASURE ON] position to begin testing. **NOTE: If unit beeps then the previous test data has not been erased from memory.**

3. After the test is complete (normally 48 hours) insert key and turn to [KEYPAD ON]. Test data may be VIEWED, PRINTED or DOWNLOADED by selecting the appropriate function with the [NEXT] button and pressing the [ENTER] key.

4. Test data is cleared by selecting the ERASE? function and holding down the [ENTER] button. The unit will beep and clear memory and then display DATA ERASED!.

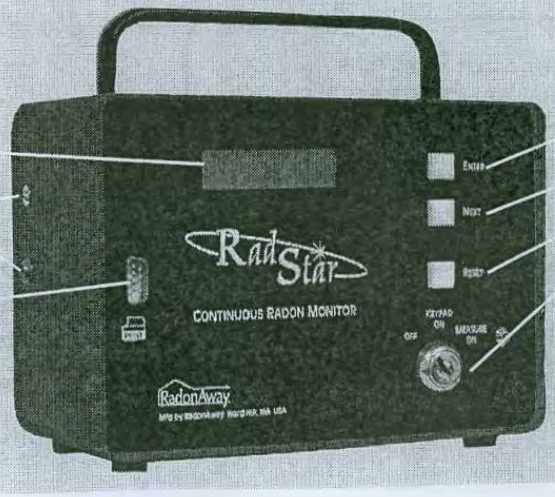
View?	Selecting this function with the ENTER button allows the user to view test data stored in memory.
Print?	Selecting this function with the ENTER button allows the user to print test data stored in memory.
Download?	Selecting this function with the ENTER button allows the user to send test data to a PC.
Erase?	Pressing and holding the ENTER button will clear the test data stored in memory.
Delay Mode?	**No Delay?** *(Normal test option)* **12 Hr Delay?** *(Delay to set-up closed house conditions)* **24 Hr Delay?** *(Delay to set-up post mitigation testing)* Use the NEXT button to scroll through delay options and select by pressing ENTER.
Battery Saver?	**On?** **Off?** Use the NEXT button to scroll through battery saver options and select by pressing ENTER. Turning Battery Saver ON will turn off the LCD display 10 seconds after initiating a test to reduce power consumption and make the battery charge last longer.

IN058-Rev B

RadStar RS800 Operating Instructions

RS800 FEATURES

- Hourly and average readings
- Internal memory to retain data
- Accurate measurement in a wide range of temperatures and relative humidity
- Sensors to measure relative humidity and temperature
- Nominal sensitivity: 24 cph/pCi/L



INO27 - Rev C

S/n 1727

1.0 SETTING UP THE RS800:

1.1 Plug power adapter marked "RadStar Power Supply" into any 120VAC outlet.

1.2 Plug free end of power adapter into left side of RS800 – green LED should come on – indicating that the NiCad batteries are charging. Leave power cord plugged in at all times during a radon test to ensure that the batteries remain charged. If no power is available, as in new construction, the unit may be run on the batteries alone for a typical 48hr test as long as the unit has been charging overnight with the power adapter.

Note: The RadStar sample LCD display shown below indicates #.#. The actual screen will show a version number such as Ver 1.4

2.0 TURNING UNIT ON:

Insert key into unit and turn it one click to the right to the [Keypad On] position. The unit will beep and the display will activate and read:

```
RS800 Ver #.#
VIEW?
```

3.0 SETTING UP PARAMETERS:

3.1. ERASING STORED DATA

3.1.1 Using the [Next] button on the front panel, scroll through the options until the display reads:

```
RS800 Ver #.#
ERASE?
```

3.1.2 Press and hold the [Enter] button (there will be an audible tone coming from the unit) until the display reads:

```
RS800 Ver #.#
DATA ERASED!
```

This will erase any prior test stored in the memory so that the unit will test from the first hour.

Important: If prior data is not erased, new test data will be appended to the previous test data.

Note: If at any time there is some confusion during the setup of parameters, simply press the [Reset] button to re-initialize the unit so that you can scroll through the parameters again. This process will not change any of the other parameters that are entered [Delay Setting, Battery Saver] .

3.2 DELAY MODE

This mode allows you to choose to run the unit with no delay, a 12 hour delay (the unit will print out or download from the 13th hour), or a 24 hour delay (the unit will print out or download from the 25th hour). The unit will still test from the first hour no matter which delay mode is selected. All of the data can be retrieved by simply entering the "No Delay" mode.
The 12 hour delay can be used to delay start of a test if closed house conditions were not in place on arrival at a home to be tested and the 24 hour delay can be used for post-mitigation testing.

3.2.1 With the key still in the [Keypad On] position, use the [Next] button to scroll to the delay mode. The display will read:

```
RS800 Ver #.#
DELAY MODE?
```

3.2.2 Press [Enter] button once. The display will read:

```
RS800 Ver #.#
NO DELAY?
```

3.2.3 Press [Next] button again. The display will read:

```
RS800 Ver #.#
12 HR DELAY?
```

3.2.4 Press [Next] button again. The display will read:

```
RS800 Ver #.#
24 HR DELAY?
```

3.2.5 After selecting the desired delay mode, press the [Enter] button once. The display will read:

```
RS800 Ver #.#
VIEW?
```

3.3 BATTERY SAVER MODE

This mode (if activated) will shut off the display ten seconds after testing has begun (recommended). It allows for longer battery backup time in case of a power outage or if running the unit on batteries only.

3.3.1 With the key still in the [Keypad On] position, use the [Next] button to scroll to the Battery Saver Mode. The display will read:

```
RS800 Ver #.#
BATTERY SAVER?
```

3.3.2 Press [Enter] button once. The display will read:

RECOMMENDED:

```
RS800 Ver #.#
ON?
```

3.3.3 Press [Next] button once. The display will read:

```
RS800 Ver #.#
OFF?
```

3.3.4 After the battery saver mode is selected (if you go by the mode you wanted, just keep pressing the [Next] button. This is also true for the Delay Mode, press the [Enter] button once. The display will read:

```
RS800 Ver #.#
VIEW?
```

4.0 MONITORING FOR RADON GAS:

4.1 After the Delay mode and Battery Saver mode have been entered, you may begin monitoring for radon gas by turning the keyswitch to the [Measure On] position. The key may be removed in this position to prevent tampering with the unit. The display should read:

```
RS800 Ver #.#
TESTING 1
```

4.2 The red LED next to the "Measure On" logo will stay on for forty seconds, then go out. This is a normal condition. Every thirty seconds while the RadStar is operating the red LED will blink.

Note: When the key is turned to the [Measure On] position to start a new radon test and the display is reading any other hour besides 1, the unit will "beep." This means the data needs to be erased from the prior test. See Section 3.1.

5.0 OBTAINING A READING FROM THE RS800 DISPLAY:

5.1 Any time during or after a test, turn the keyswitch to [Keypad On] position. The display will read:

```
RS800 Ver #.#
VIEW?
```

5.2 Press [Enter] button once. The display will read:

```
RS800 Ver #.#
001 005.1 pCi/L
```

Hour — Radon Reading (Typical)

5.3 Press [Next] button to scroll through the hourly readings. To continue testing, simply turn the keyswitch to [Measure On] position. The unit will "beep" to signify continued testing.

Note: When a test is continued by going from [Keypad On] to [Measure On], the hour in which you were testing starts over again. Also, note that if you try to view the readings before the first hour is up, the display will read:

```
RS800 Ver #.#
NO DATA.
```

6.0 SETTING UP THE OPTIONAL PRINTER:

6.1 Plug the AC/DC adapter (the one marked "Printer Power Supply") into any 120VAC outlet. Plug the power jack from the adapter into the back of the printer.

6.2 Connect the D-Sub cable supplied with the unit to the printer and the Radstar.

6.3 Turn the printer on via the rocker switch. The red LED should come on.

7.0 OBTAINING A TEST REPORT PRINTOUT:

7.1 After completing a test, turn the keyswitch to [Keypad On] position. The display will read:

```
RS800 Ver #.#
VIEW?
```

7.2 Press [Next] button once. The display will read:

```
RS800 Ver #.#
PRINT?
```

7.3 Press [Enter] button once. The unit will print the test report. See Fig. A for an explanation of the printout. **Note: if you try to get a printout within the first hour of testing, the RadStar display will read "No Data."**

8.0 DOWNLOADING DATA FROM THE RADSTAR:

The RadStar comes with a Data Capture Utility Program (Windows XP and Vista compatible), and a USB/Serial Adapter Cable with driver. The accompanying RadStar Documentation Library describes the set-up and operation of these items. You may also view the Documentation and download the Program from the AccuStar Labs website www.accustarlabs.com

8.1 Install the RadStar Data Capture Utility Program and cable driver on your PC. In the Program, setup the correct RadStar model number and the correct COM port. Refer to the RadStar Documentation Library for specific instructions.

8.2 Connect the PC cable to the Print Port on the RadStar, and to your PC. Turn the RadStar keyswitch to [Keypad On] position. The display will read:

```
RS800 Ver #.#
VIEW?
```

8.3 Press the [Next] button on the RadStar twice. The display will read:

```
RS800 Ver #.#
DOWNLOAD?
```

8.4 In the Data Capture Utility Program on your PC, click Download. On the RadStar, press the [Enter] button once. The data will download to the PC. After the RadStar has finished downloading, the RadStar display will read:

```
RS800 Ver #.#
VIEW?
```

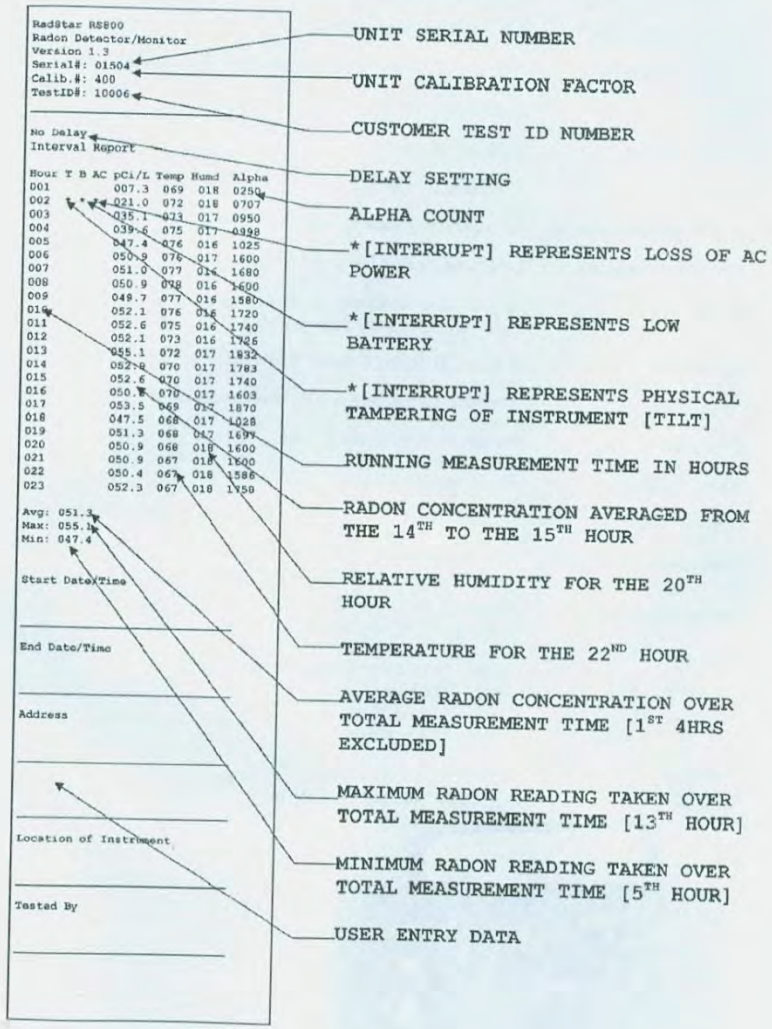
Note: If you try to download data from the RadStar within the first hour of testing, the display will read "No Data".

8.5 The test data downloaded into the Data Capture Utility can then be exported into a text file, comma delimited file or Excel chart. README files with the software describe the set-up and operation of the Data Capture Utility.

9.0 TRANSPORTING THE RADSTAR TO A PC OR PRINTER:

If desired, you may transport the RadStar to a PC or printer to retrieve the data. Turn keyswitch to [Off] position. The test data will be retained in the RadStar memory until you erase it. Remove key and disconnect power supply. When your destination is reached, simply insert key into unit and turn to [Keypad On] and print or download the data.

FIGURE A
EXAMPLE RS800 TEST RESULT PRINTOUT



RS800 Instrument Specifications

Mode:	Continuous Monitor, Passive Diffusion
Principle of Operation:	Pulse Mode Ionization Chamber
Minimum Sensitivity:	0.4 cpm/pCi/L (minimum 96 alpha counts per hour @ 4 pCi/L)
Units:	picoCuries per liter (pCi/L)
Dynamic Range:	0.3 to 200 pCi/L
Linearity:	+/- 5% Best Straight Line
Data Storage (Nonvolatile):	Up to 240 hourly readings, wrap on over-run.
User Selectable Modes:	Continuous, 12 Hour Delay, 24 Hour Delay
Power:	120VAC 60Hz Transformer, 5-8 days rechargeable battery operation. User Selectable Battery Saver Mode (turns off LCD display during test)
Indicators:	2 X 16 LCD Display, Green AC Power LED, Red Testing LED
Key Switch:	3 Position, Removable Key [Off] [Keypad On] [Measure On]
Pushbuttons:	Momentary [Enter] [Next] [Reset]
Communications:	RS-232 port for printing or computer uploads
Tamper Protection:	Tilt switch, AC power fail detection, key switch lock-out, LCD blackout.
Environmental Sensors:	Relative Humidity 0% - 80% +/- 5% Temperature 50 °F– 90 °F +/- 2 °F
Operating Range:	Temperature 50 °F – 90 °F Humidity 0-80%, non-condensing
Size:	Height 7 inches (includes Carrying Handle) Width 8 inches Depth 4 ½ inches Weight 2 ½ pounds
Color:	Blue/Black
Mounting:	(2) ¼"x 20 Threaded Tripod Mounts

Technical Support, Calibration and Repair Service.

800-767-3703
M-F 8:30am - 5:30pm ET

Manufactured by
RadonAway
3 Saber Way
Ward Hill, MA 01835

QUICK START: INSTRUCTIONS FOR USE

1. Plug in the instrument and it will automatically come on.
2. To verify memory is cleared, hold the "AVG" button and the "CUR" button and it will show three dots in the view screen. If this happens skip step 3.
3. If a radon level shows up in the view screen then the memory must be cleared by pressing and holding both "AVG" and "CUR" buttons until the yellow LED underneath turns on. The Yellow LED will blink. Then Press and hold the "CUR" button until the blinking yellow LED turns off and turns back on and is solid with no blinking. Let go of the "CUR" button and the display will blink once and then display three dots.
4. Radon test starts automatically.
5. Device has a battery back-up in case AC power is lost but battery must be turned on. Green light blinks if running on battery. If running on battery ensure at end of test the on/off switch is turned to off.

SUN NUCLEAR CORPORATION

continuous radon monitor

Model 1027

CRM

User Caution

This device is intended for the detection and measurement of ionization radiation. It should be used only by persons who have been trained in the proper interpretation of ots readings and the appropriate safety procedures to be followed in the presence of radiation.

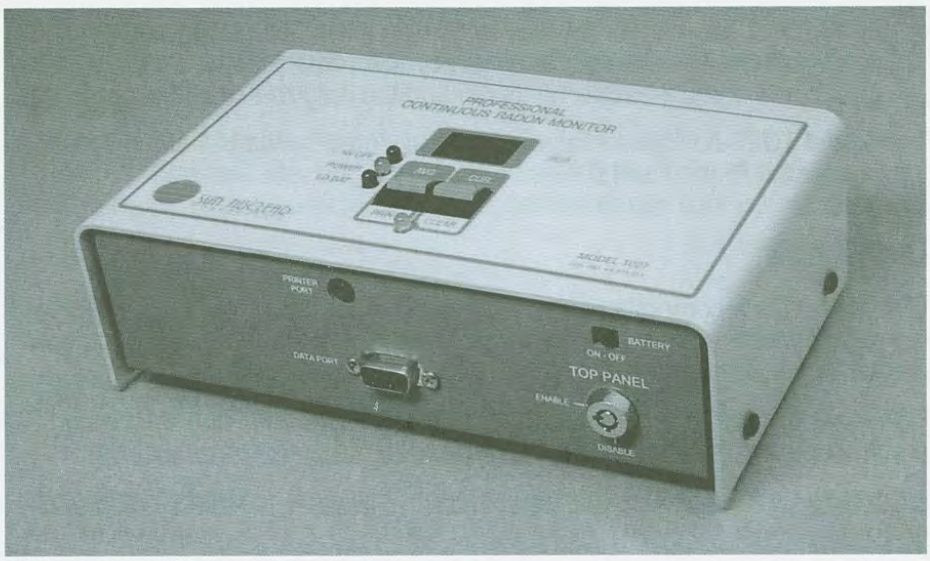
All instruction and warnings contained in this manual or on the instrument must be read before use and must be strictly followed. Failure to follow these instructions and warnings may result in inaccurate readings and/or hazard.

READ THE MANUAL CAREFULLY

DESIGNED AND MANUFACTURED IN THE U.S.A.
BY
SUN NUCLEAR CORPORATION
425A PINEDA COURT, MELBOURNE, FL 32940-7508
http://www.sunnuclear.com e-mail:Mail@sunnuclear.com

Professional Continuous
Radon Monitor

Model 1027



U.S. Patent #4,871,914

Document No. 102711C
November, 2000

To stay current on the accessories, applications, and software for the Radon monitor, please visit Sun Nuclear's website, http://www.sunnuclear.com.

Sun Nuclear Corporation
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Melbourne, FL 32940-7508
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telephone: 321-259-6862
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Introduction

Description

The Model 1027 Professional Continuous Radon Monitor is a patented electronic detecting device using a diffused-junction photodiode sensor to measure the concentration of radon gas. The unit is operated from standard line power and includes a 9-volt battery which provides backup power. A numerical display shows the average radon gas concentration. Using the data ports, you can print a complete report or download the data to a personal computer.

The Model 1027 has been evaluated and accepted by the U.S Department of Environmental Protection (EPA).

About Radon

EPA maintains a comprehensive web site on radon at: http://www.epa.gov/iaq/radon/ where you can also find html-ready versions of all of EPA's documents, brochures, and publications relating to radon.

Below are descriptions of three of the more common EPA publications on radon, copied from site http://www.epa.gov/iaq/radon/pubs/index.html.

A Citizen's Guide to Radon (second edition) *The Guide To Protecting Yourself And Your Family From Radon.*

> This booklet was developed by the EPA, The U.S. Department of Health and Human Services, and the U.S. Public Health Service. This is the complete guide to taking action to lower the radon level in your home. It offers strategies for testing and discussions of what steps to take after you have tested, discussions of the risk of radon, and radon myths. EPA Document Number 402-K-92-001, September 1994. (www.epa.gov/iaq/radon/pubs/citguide.html)

Consumer's Guide to Radon Reduction *How to Reduce Radon Levels in Your Home...*

> This booklet is for people who have tested their home for radon and confirmed that they have elevated radon levels. EPA Document Number 402-K-92-003. (www.epa.gov/iaq/radon/pubs/consguid.html)

Home Buyer's and Seller's Guide to Radon

> This guide has been developed for anyone buying or selling a home who wants to learn about Radon. For sale by the U.S. Government Printing Office, Superintendent of Documents, Mail Stop: SSOP, Washington, DC 20402-9328. Order Number - ISBN: 0-16-041680-9. EPA Document Number: 402-R-93-003, March 1993. (www.epa.gov/iaq/radon/pubs/hmbyguid.html)

Application

In a typical test, you locate the Radon Monitor in the home to be monitored, connect power, and leave it unattended for a period of two or more days.

Ambient room air, laden with radon, diffuses into the monitor's detection chamber. Radon decay by-products emit alpha particles which are detected by the photodiode.

At the end of the monitoring period, the results are available in any of three forms: numerical display on the control panel, printed report on the accessory printer, or computer display. Once down-loaded to the computer, a report can be printed using standard programs.

After obtaining the report data, you can clear the memory and immediately begin another test. The instrument is completely reusable and requires no supplies except power and an optional backup battery.

The printer need not be present during testing. The radon monitor can be moved from the test site, and the report printed later. If multiple tests must be run simultaneously, a single printer or computer can support many radon monitors.

Specifications

Description	Value
Power Supply	Transformer converts 120 VAC, 1-phase, 60 Hz to 12 VDC, 200 mA
Measurement Range:	0.1 to 999 picocuries/liter (pCi/l)
Operating Range:	45 degrees F to 95 degrees F
Accuracy	±25% or 1 pCi/l, whichever is greater after 24 hours
Disturbance Sensor:	Inertial switch
Data Port:	RS-232, 9-pin, D-connector allows printer data to be sent to PC
Detector:	Diffused-junction photodiode
Measurement Interval:	1 hour (4, 8, or 24-hour intervals available by special order)
Sensitivity:	2.5 counts per hour per picocurie per liter
Display:	3-digit display LED
Battery Backup:	One 9V alkaline battery supplies approximately 20 hours of operation. LED indicates low battery.
Weight:	2 Lbs
Size:	8" x 4.7" x 2.5"
EPA Evaluation:	US EPA accepted

Controls

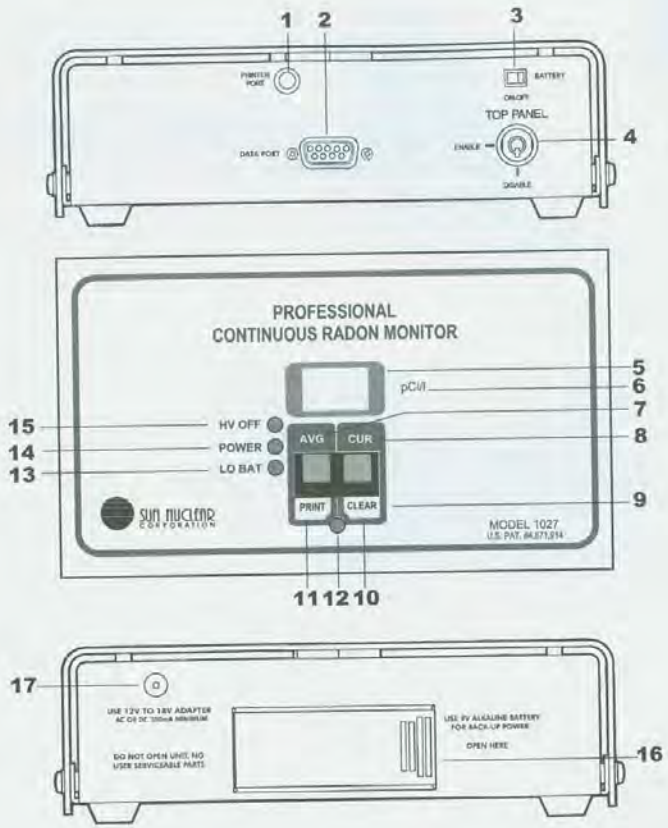


Figure 1. Controls, displays, and connections

1 **PRINTER PORT:** Only the Model 020030 portable printer can be connected to this port. The printer must be connected and powered-on before the information transfer is initiated. (See "Optional Portable Printer" on page 10.)

2 **DATA PORT:** This RS-232 data port is designed to provide a means to transfer the information from the monitor to a personal computer. The information transferred is identical to that which is sent through the printer port. (For further information, see "Data Transfer to a Personal Computer" on page 14.)

3 **BATTERY ON-OFF**: This switch connects and disconnects the battery. When ON, the battery will power the monitor whenever line power is not available. When OFF, the battery will not power the monitor when line power is disconnected. This switch should be in the OFF position any time the monitor is not deployed for a test. This is important for two reasons: first, the battery life will be reduced, and second, the monitor will continue making measurements as long as battery power is available, which could inadvertently affect the results of a recent test. A fresh battery will provide about 20 hours of backup power if line power fails.

4 **TOP PANEL-ENABLE/DISABLE:** The key switch enables and disables the digital display and buttons on the top panel of the monitor. When in the DISABLE position, the monitor's measurement performance is not affected. The monitor will function effectively in either key position. This feature is designed to mitigate the temptation to tamper with a test.

5 **DISPLAY:** 3-digit LED display. Three decimal points appear when AVG or CUR is pressed after memory is cleared.

6 **pCi/l:** Picocuries per liter – the units of radon gas concentration shown on the display.

7 **AVG:** When this button is pressed, the measured long-term average radon gas concentration in pCi/l is displayed on the 3-digit display. This is the cumulative average of the entire period since the memory was last cleared. This value is not lost if the monitor loses all power.

8 **CUR:** When this button is pressed, the measured short-term radon gas concentration is displayed. This is a rolling average of the most recent 12 hours. This value is lost if the monitor loses power.

9 **PRINT** or **CLEAR:** These two buttons function as PRINT and CLEAR only when the YELLOW LED is blinking. To get into this mode, hold both buttons down until the YELLOW LED turns on. Then release the buttons, and the YELLOW LED will begin to blink.

10 **CLEAR:** (the YELLOW LED must be blinking) When the button is pressed, the YELLOW LED will turn off. Hold the button down until the YELLOW LED turns on again; then release the button. The YELLOW LED and display LEDs will blink once followed by a single blink of the YELLOW LED. The monitor memory has been cleared. The disturbance switch is inactive for the next 15 seconds.

11 PRINT: (the YELLOW LED must be blinking) When this button is pressed, the monitor sends a report of the information contained in memory to the both the PRINTER and DATA ports. When the button is pressed, the YELLOW LED will turn on. When released, the LED will turn off and the data is then transferred. When the information transfer is complete, the YELLOW LED will blink once.

12 YELLOW LED: The yellow LED is a function indicator. Normally it is off. When the unit is powered up, it blinks twice, followed by a single blink, indicating that the startup test is complete and that the unit is functioning normally. During monitoring, the YELLOW LED blinks each time an alpha particle is detected. If the monitor fails during monitoring, the yellow LED will blink rapidly. When the buttons are in the PRINT/CLEAR mode, the Yellow LED is blinking. In this mode:

- When the PRINT button is pressed, the YELLOW LED will turn on. When PRINT is released, the LED will turn off and the data is then transferred. When the information transfer is complete, the YELLOW LED will blink once.
- When the CLEAR button is pressed, the YELLOW LED will turn off. Hold the button down until the YELLOW LED turns on again; then release the button. The YELLOW LED and display LEDs will blink once followed by a single blink of the YELLOW LED. The monitor memory has been cleared.

13 LO BAT: When the red LED is on, battery has about two hours of life remaining. Note: Power adapter must be unplugged for this LO BAT test.

14 POWER: The green LED is on continuously when the monitor is powered by line power, blinks when monitor is powered by batteries only, and off when LO BAT is on.

15 HV OFF: The red LED is normally off. When on, the High Voltage circuit is off, indicating that the monitor has failed. The unit must be returned to the manufacturer for service.

16 Battery compartment: A single 9-volt alkaline battery is used as a power backup for the monitor. The battery is NOT recharged by the monitor. A new battery will operate the monitor for approximately 20 hours.

17 Power connection: The power adapter should be plugged into the monitor BEFORE the adapter is plugged into line power.

Operation

Unpacking

Unpack the monitor. The package contains a monitor and key, a power adapter, the user's manual, and a 3.5 inch floppy disk.

NOTE: Save the packing material if you plan on returning the monitor for periodic re-calibrations.

Startup

1. Place the radon monitor in the desired position within the space to be monitored for radon gas. The monitor does not need to be level.
2. Plug the power adapter into the power input jack on the monitor (Figure 2).
3. Then plug the power adapter into a 120 VAC, 60 Hz wall outlet. The green POWER LED will turn on. **Avoid using switch-controlled outlets.**

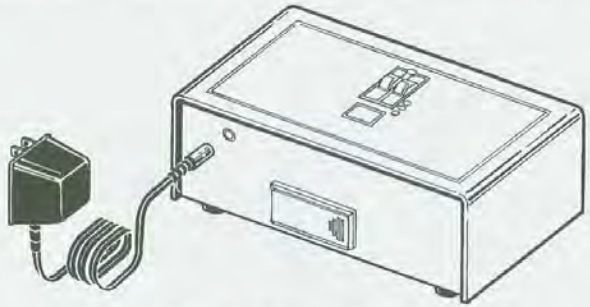


Figure 2. Connecting power to the radon monitor

4. The YELLOW LED will blink twice followed by a single blink. This indicates the monitor has performed all internal diagnostics and is functioning properly.
5. Activate the Top Panel controls by inserting the key and turning to the ENABLE position.
6. Press the AVG button. If the memory is clear, three decimal points will appear in the display area. If the memory is not clear, the AVG button will cause the long term average radon concentration to be displayed.

Clear Memory

1. Press and hold both push button switches on top until the yellow LED turns on; then release the push buttons. The yellow LED will begin to blink.

CAUTION: Clear the memory before starting a new measurement. If you don't clear the memory, the average values will be wrong because the old measurements still in memory from the previous test will be averaged with the new measurements.

2. While the yellow LED is blinking, press and hold the CLEAR button. At first the yellow led turns off; then the yellow LED turns on continuously, not blinking.
3. Release CLEAR button while the yellow LED is on continuously.
4. When the yellow LED and display LEDs blink, followed by a single blink of the yellow LED, the monitor has been cleared.

Conduct Test

1. If desired, switch on the backup battery. A fresh battery will provide about 20 hours of back-up operation.
2. Switch the Top Panel key switch to the DISABLE position and remove the key.

NOTE: The tamper sensor is always active except for a 15-second period immediately following the Clear command. To avoid a tamper notation on the first reading, be sure that you do not move or jar the monitor after the tamper sensor becomes active. In earlier models of the 1027, there were TILT and LEVEL indicators that illuminated during this 15-second period. The original TILT sensor has been replaced with a DISTURBANCE sensor which is more sensitive to movement. To test this feature, CLEAR the 1027 memory and conduct a test for several hours. During the test, try lifting or sliding the monitor. Print the results. A "T" should appear in the interval when the disturbance was made.

3. At the end of the monitoring period, insert the key and turn the Top Panel switch to the ENABLE position.

Display Result

1. Press AVG to display the average radon concentration in pCi/l over the total monitoring period.
2. Press CUR to display the radon concentration in the current 12-hour period.

NOTE: The AVG and CUR display values continue to update during the entire test, even if the test period exceeds the maximum storage of 90 intervals. The interval storage stops updating after 90 intervals until the next memory clear.

Print Report

To print out a report on the accessory printer, see "Print Report" on page 11.

To interpret the report, see "Typical Printer Report" on page 12.

Download Report

To display and/or print out a report on a computer (PC), see "Data Transfer to a Personal Computer" on page 14.

Shutdown

1. Unplug the power adapter from the wall outlet.

CAUTION: Switch off the backup battery. If the battery is on, the monitor continues to operate.

2. Switch off the backup battery to avoid measurement interference with the completed test and prevent depletion of the battery.

Delayed Reports and Displays

You can also display, print, or download the results of the test later at another location, provided you understand the following differences:

- When you remove all power, the value of the latest partial interval and the CUR value are lost from temporary memory.
- If power is on (including battery power) the unit continues to operate, providing values that are averaged into the result.

If you take an AVG reading, disconnect power, then restore power later and take a second reading; the second AVG reading may be slightly different from the first. This is because the first AVG reading includes the value for the partial 1-hour interval in process. This partial value is stored in temporary memory and is lost when power is disconnected. The second AVG value is calculated using only completed intervals stored in non-volatile memory.

Optional Portable Printer

Description

The Model 020030 is a small, portable, dot-matrix impact printer (Figure 3). It uses an inked ribbon to generate the printed image. This allows the printer to utilize ordinary adding machine tape paper (2.25" wide; 2.5" outer diameter & 0.44" inner diameter).

The printer is controlled by a three-position switch.

- The left position is OFF.
- The center position is ON.
- The right position, which is only momentary, has two functions:

1. When the printer is first turned on, you can pass through the center position to the right position, and the printer will begin a print test. This will continue until the printer is turned OFF.
2. During all other times, the right position of the switch is the PAPER ADVANCE.

Figure 3. Optional portable printer

Connection

1. Connect the printer data plug to the PRINTER PORT receptacle on the radon monitor (Figure 4).
2. Connect the power converter output plug to the matching 2-pin plug from the printer cable. There is no preferred polarity on the two pins.

3. Connect the printer power converter to the wall plug.
4. Connect the radon monitor power converter to the radon monitor.
5. Connect the radon monitor power converter into the wall plug.

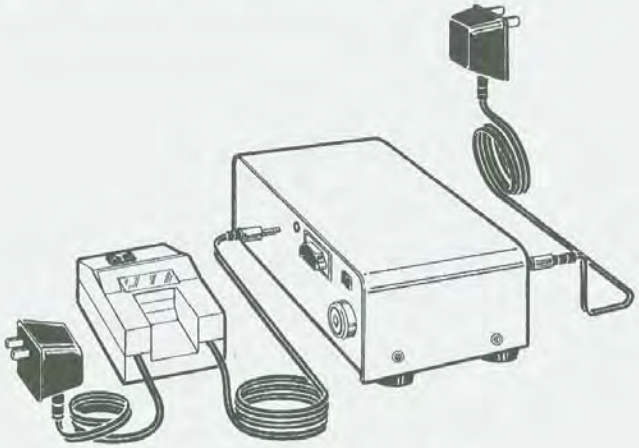
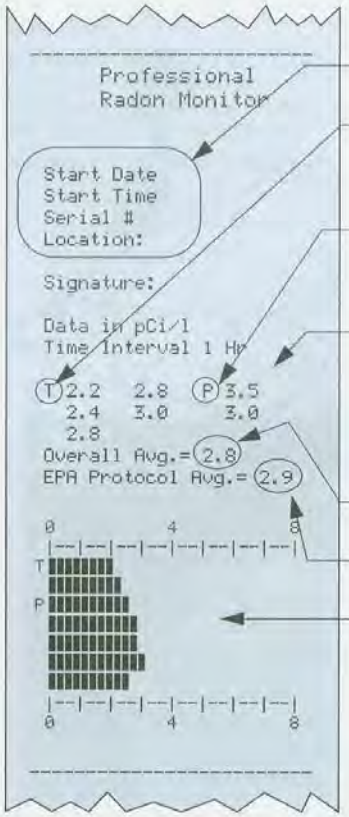


Figure 4. Connecting the printer

Print Report

1. Connect and power up the printer and radon monitor.
2. Press and hold both push button switches on top of the radon monitor until the yellow LED turns on continuously. Then release the buttons, and the yellow LED begins to blink.
3. While yellow LED is blinking, press and hold the PRINT button until the yellow LED turns on solid, not blinking.
4. Release the PRINT button.
5. The printer will begin printing out a paper report on the optional printer.
6. When the yellow LED blinks once, information transfer is complete.

Typical Printer Report



Information to be written in by testing professional.

"T" (tamper) Indicates movement occurred during this interval. The unit may have been tampered with.

"P" (power) Indicates power interrupt during this interval. Again, the unit may have been tampered with.

TABULAR DATA. Average radon gas concentration during each measurement interval is printed in sequential order; reading in rows from left to right up to a maximum of 90, 1-hour measurement intervals.

Long term average since last memory CLEAR.

Long term average less the first 4 hours of data.

PROFILE DATA Each concentration value is graphically represented in the same order as the tabular printout. Scale is automatically adjusted to show maximum value in pCi/l.

Figure 5. Typical Printer Report

Changing Printer Ribbon

The inked ribbons will become light over time from either use or natural drying of the ink.

1. Press down on the groove marks located on either side of the clear plastic window below the paper-tear bar (Figure 6). This will cause the back end of the panel to pop up.
2. Remove the panel exposing the ribbon cartridge.
3. Press down on the left end of the cartridge and it will pop up.
4. Remove the cartridge and replace it with a new cartridge (SNC part number 850013).

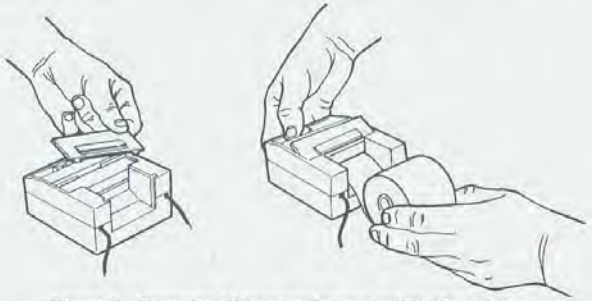


Figure 6. Changing ribbon and paper roll in the printer

Changing Paper

The Model 020030 uses ordinary adding machine tape paper (SNC part number 850037).

1. Lifting up on the paper roll removes it from the printer. The printer spindle (SNC part number 850035) will be through the center of the paper roll.
2. Remove the spindle and transfer it to the new paper roll.
3. Turn the printer ON, wait a few seconds to avoid activating the print test function, and then press the switch to the right position. The paper feed mechanism will begin.
4. While holding the switch in the right position, begin to feed the end of the new paper roll into the slot near the bottom front of the well in which the paper normally sits (Figure 6). The printer mechanism will grab the paper. Do not force it.
5. Once the paper is being pulled into the printer, continue to hold down on the switch until the paper appears at the top of the printer.
6. Release the switch, and replace the paper roll in the well by pressing the two ends of the spindle into the small notches on either side of the paper well.

Data Transfer to a Personal Computer

Description

The DATA PORT on the Model 1027 Professional Continuous Radon Monitor provides an alternate method of printing the information report that is normally obtained from the Sun Nuclear Corporation Model 020030 paper tape printer.

Connection

1. To utilize the DATA PORT, you must have a standard "9 pin D" serial extension cable with one male and one female connector. These cables are available from your local computer store.
2. Connect the cable from the Model 1027 Data Port to Com 2 or any unused RS-232 serial port on a standard IBM compatible PC or laptop (Figure 7). Serial ports are sometimes identified as Com 1 or Com 2.
3. If your PC has only a 25-pin connector, you will need a 9-pin to 25-pin adapter or a different cable. These are also available from your local computer store.

Figure 7. Connecting the data port to a computer

Windows Software

A 3.5 inch floppy disk is included with your Model 1027 radon monitor. This disk contains a program named SETUP.EXE. When executed, this setup file installs the Radon 1027 application software on any personal computer using the Microsoft Windows operating system (see "System Requirements" on page 15).

The Windows software application lets you:

- print reports from any printer connected to your computer,

- apply headers, footers, dates, and serial numbers to reports,
- annotate and edit reports,
- store reports as text files,
- store reports that can be imported into a spreadsheet.

System Requirements

The software runs on any PC operating on Microsoft Windows 95, 98, ME, NT 4.0, or Windows 2000. Approximately 1 MB of disk space and 32 MB or RAM are required.

Installing the Software

1. Insert the program diskette in the floppy drive of your computer.
2. Click Start at the bottom of the screen, and select Run from the Start menu. The Run dialog box opens.
3. Use the Browse button to find the SETUP.EXE file on the floppy diskette. The floppy drive is normally the A: drive in most systems.
4. Highlight the file SETUP.EXE and click Open. The file SETUP.EXE will now appear in the Run dialog box (Figure 8).

Figure 8. Run the Setup.exe file on the floppy disk

5. Click OK. The Welcome screen will appear (Figure 9).

Figure 9. Welcome screen

6. Click the Next button and follow the on-screen directions.
7. When the installation is complete, click the Finish button. The installation screen will close. In Windows 95 and higher, the Radon 1027 icon will appear on the desktop.

Starting the Software

1. Double-click on the desktop icon (Figure 10) to start the program. If the desktop icon is not visible, click Start > Programs > SNC Group > Radon 1027.

Figure 10. Desktop icon

2. The program opens with a blank screen (Figure 11). On the menu bar, the Get Data is dimmed because the Com Port is not selected.

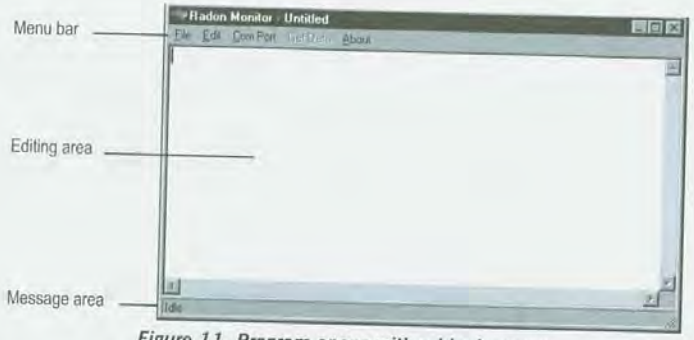


Figure 11. Program opens with a blank screen

Com Port Setup

Most PCs have at least two Com Ports (serial communications ports), identified as Com Port 1 and Com Port 2, with connectors located at the back of the computer. A few computers also have Com Ports 3 and 4. You can connect to any open Com Port.

1. To select, click Com Port on the menu to display the available Com Ports. Unavailable Com Ports will be dimmed.
2. Click the Com Port to which the radon monitor is connected. A bullet will appear next to the selected port (Figure 12).

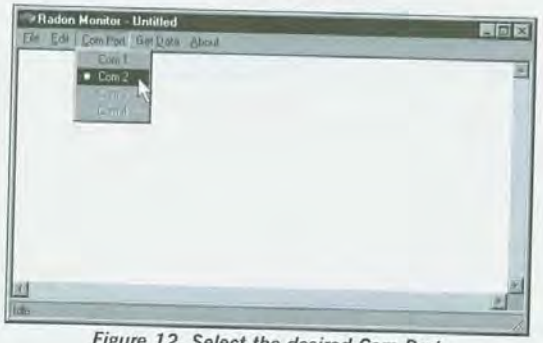


Figure 12. Select the desired Com Port

3. If you accidentally select the wrong port, reselect the correct port.

Information Setup

If desired, you can automatically add header and footer information to each report when the data is transferred from the radon monitor. This information is entered in a special dialog box before the data is transferred.

1. Click Edit > Info... to open the Information Setup dialog box (Figure 13).

Figure 13. Information setup

2. Enter the desired information as follows:
   - **Enable Info**—select this item if you want the information to be placed in the report. If you clear this box, none of the information will appear on the report.
   - **Monitor S/Ns**—enter the serial number for each of the Model 1027 radon monitors you are using, and press the down arrow. This inserts the numbers in the list below. Prior to transferring a report to your PC, double-click the serial number you want to appear in the Radon Monitor S/N box. To remove a S/N from the list, click on it, and press the Delete key.
   - **Header Info**—enter any text you want to appear at the top of the report.
   - **Start Date/Start Time**—select the date and time the test started.
   - **End Date/End Time**—select the date and time the test ended.
   - **Radon Monitor S/N**—select the serial number of the radon monitor used in the test by double-clicking the correct serial number from the list of serial numbers in the box at the left.
   - **Location**—enter the location of the monitor during the test.
   - **Footer Info**—enter any text you want to appear at the bottom of the report.

3. Click the down arrow in the date box to open a calendar (Figure 14). Then scroll to the desired month and double-click the desired date. The selected date appears in the Date box. You can also type in the date directly or highlight the month, day or year and increment or decrement the value with the up/down arrow keys.
4. In the time boxes, type in the times desired, or highlight the hours, minutes, or seconds and click the arrows to increment or decrement the selected value.

Figure 14. Using the calendar to select the date

5. Click OK to save the information.

Data Transfer

To perform data transfer to your personal computer, perform the following steps:

1. Be sure the Model 1027 Radon Monitor is properly connected and powered-up.
2. Start the Radon 1027 application program by clicking on the desktop icon or selecting it from Start > Programs > SNC Group > Radon 1027.
3. When the program opens, verify that the proper Com Port is selected.
4. Click on Get Data on the menu. The message at the bottom of the screen will say "Listening for data on Com 1..."
5. Hold down both buttons on top of the Model 1027 until the yellow LED comes on continuously. Then release both buttons. The yellow LED will now be flashing.
6. With the yellow LED flashing, press and release the Print button to transmit the data. The message at the bottom of the screen will say "Acquiring data on Com 1, please wait..."

7. The Model 1027 report will appear on the computer screen (Figure 15).

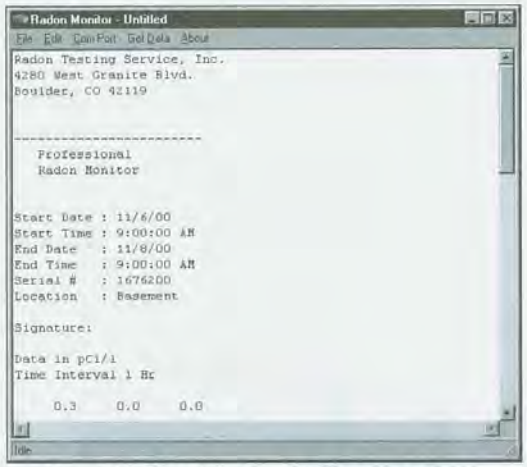


Figure 15. Report displayed in the editing screen

8. Use the scroll bars at the right side and bottom to view other parts of the report.

Editing and Printing Reports

1. The entire central part of the screen is an editing window. You can add to, delete from, or change any part of the report.
2. Use standard Windows keystrokes to enter or delete characters.
3. Use the Cut, Copy, and Paste commands on the Edit menu to make major changes to the report.
4. To interpret the results of the report, see Figure 5, page 12. The data between the header and footer is the same as on the optional printer tape.
5. To print the report, select File > Print. The standard Windows Print dialog box opens.
6. Click OK to print.

Saving Reports

1. A report can be saved in one of two formats:
   - Normal ASCII text format ("Text Files"). The program adds the suffix "_t" to the filename.

   - Text format suitable for spreadsheet use ("Import Friendly Files"). The program adds the suffix "_s" to the file name. In this format, the numerical data is tab-delimited so that when imported into a spreadsheet program, numerical values are placed in individual cells. This lets you use graphing functions and other spreadsheet tools on the data.
2. Click Save As on the File menu. The Save As dialog box opens. By default, the files are saved in the Data subdirectory of the Radon directory of the C:\ drive.
3. Use the pull-down list to select the type of format to use (Figure 16).

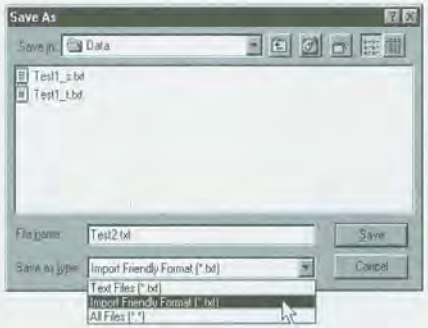


Figure 16. Save As dialog box

4. Type a name for the file. Use a naming scheme that is suitable to your purpose. It could be the client name, address, date, serial number, or some combination. The appropriate suffix will be added automatically depending on what file format you have chosen.
5. Click Save.

Alternate Power Supplies

Alternate Power Converter Specifications

If your line power is different from 120 VAC, 60 Hz you may use locally available AC line adapters that conform to the following specifications:

Radon Monitor Model 1027 Input Power Specification:

- 9-12 VDC or VAC, 200 mA minimum
- Plug: 5.5 mm OD, 2.5 mm ID

Printer P/N 020030 Input Power Specification:

- 9 VAC, 1.5 A
- Printer plug: 1.6 mm ID, spaced 3.81 mm, center-to-center
- Connector is a 2-wire socket which can be cut from the 110 VAC adapter and spliced onto the locally provided adapter.

Optional 115/230 VAC 50/60 Hz Power Supply

A separate, optional power supply, SNC part number 113195, is available as an accessory (Figure 17). This power supply operates from 115 VAC or 230 VAC (switch selectable) at a frequency of 50 or 60 Hz.

Figure 17. 115/230 VAC power converter

The "Power to Printer" output supplies 10 VAC at 1 amp continuous, 3 amps peak. The "Power to Unit" output is 5-25 VDC adjustable at 7 watts or 1 amp. The internal adjustment is factory-set to approximately 18.2 VDC for use with the Sun Nuclear Model 1027 Radon Monitor.

User Maintenance

Troubleshooting

Trouble	Recommended Action
YELLOW light continuously blinking	Monitor has failed – return for service
HV OFF LED is on continuously	High Voltage supply is off. Monitor has failed - return for service.

Trouble	Recommended Action
Printed report states "NO DATA" after a test	Monitor did not have power – run monitor again in location with known reliable power. Make certain battery switch is on and POWER LED is on.
Printed report has only a partial report	Printer was not READY when print button was depressed – re-print report.
Average measured value is higher or lower than expected and a change in hourly readings occurred in mid-report.	Count the number of hourly measurements to make sure the number coincides with the number of hours actually deployed. If the number is greater, then the monitor was not properly cleared prior the most recent test, and previous measurements are being averaged in with data from the current test.
Battery is dead	Battery switch was left on when line power was removed. The unit continued to monitor until battery was depleted.
Printer is printing report too light	Replace printer ribbon cartridge.
Monitor has an AVERAGE value, but no CURRENT value	The monitor has lost power recently, which cleared the CURRENT value. However the AVERAGE is maintained until it is deliberately CLEARED.

For more help, see Sun Nuclear Corporation's web site for Product FAQs, information, and bulletin board: http://www.sunnuclear.com.

Changing the Backup Battery

To change the backup battery, pull out on one end of the hinged battery compartment door (Figure 18).

Remove the battery from the connector, install a new 9V alkaline battery, and close the door.

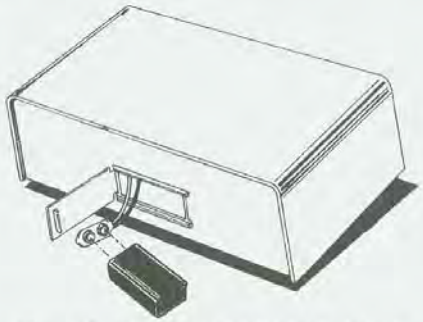


Figure 18. Changing the 9 V backup battery

Service and Calibration

WARNING: The unit contains high-voltage circuits. Do not open the case. There are no user-serviceable parts inside the unit.

For service or calibration, return the unit to Sun Nuclear Corporation as instructed in the Warranty statement on the inside back cover.

The recommended calibration frequency for the 1027 radon monitor is one year.

Accessories

Contact Sun Nuclear Corporation to order any of the following accessories:

Number	Description
Model 020030	Printer, portable, dot matrix, impact (includes 115 VAC, 60 Hz power converter)
850013	Cartridge, ribbon, for printer, model 020030
850035	Spindle, paper, for printer, model 020030
850037	Paper, adding machine, for printer, model 020030
113195	Power supply, 115/230 VAC, 50/60 Hz (includes connection cable set to connect to Model 1027 radon monitor and Model 020030 printer)
102377	Report, Radon Gas Measurement, blank
102378	Sign, self-adhesive, "Warning, Closed Building Procedure"
102379	Sign, plastic, hanging, "Caution, Radon Test in Progress"

Warranty

1.Instrumentation

A. This instrument and its accessories, excluding those listed in (1.D.) below, are warranted by Sun Nuclear Corporation, against defects in materials and workmanship for a period of one year from the date of original purchase from Sun Nuclear Corporation. During the warranty period, Sun Nuclear Corporation will repair, or, at its option, replace an instrument found to have such defect, at no charge to the customer.

There are no Warranties, expressed or implied, including without limitation, any implied warranty of merchantability of fitness, which extend beyond the description on the face hereof. This expressed warranty excludes coverage of and does not provide relief for incidental or consequential damages of any king or nature, including but not limited to loss of use, loss of sales or inconvenience. The exclusive remedy of the purchaser is limited to repair, recalibration or replacement of the instrument at the option of Sun Nuclear Corporation.

B. This warranty does not apply if the product, as determined by Sun Nuclear Corporation, is defective due to either abuse, misuse, or modification or service performed by someone other that a Sun Nuclear Corporation authorized repair and calibration facility. Misuse and abuse include, but are not limited to, subjecting the instrument to environmental conditions outside the specified limits or allowing the instrument to become contaminated by radioactive materials.

C. In order to obtain warranty repair service, the instrument must be returned freight prepays, to the facility cited in (3.B.) below. The purchase date, vendor invoice or customer purchase order should be included, along with a statement of the problem. Instruments will be returned transportation prepaid to points within the United States.

D. Because the original manufacturer's warranty applies, the following items are specifically excluded from this warranty: photomultiplier, geiger-mueller and proportional tubes; batteries; ancillary devices including, but not limited to, printers, computers, display devices, etc.; and other components as may be specified in this manual.

2 Calibration

A. This instrument is warranted to be within its specified accuracy at the time of shipment. If a question arises and Sun Nuclear Corporation determines that the initial calibration is in error, the instrument will be recalibrated by sun Nuclear Corporation at no charge. Sun Nuclear corporation is not responsible for calibrations performed by independent laboratories, nor any calibration fees incurred prior to or subsequent to Sun Nuclear Corporation warranty service.

B. The return policy is as states in (1.C.) above.

3. Non-Warranty Service

A. Repairs and/or replacements not covered by this warranty may be performed by Sun Nuclear Corporation or a factory authorized service location. Estimates of repair charges may be requested, however, a charge for estimate preparation may apply if the repair is later not authorized by the customer.

B. The cost of transportation into and out of the service location will be the responsibility of the customer. The instrument should be shipped to:

Sun Nuclear Corporation
425A Pineda Court, Melbourne, Fl 32940 7508 U.S.A.

SPER-1E Reader Manual

The SPER-1E is a new addition to the Rad Elec family of SPER (**S**urface **P**otential **E**lectret **R**eader) readers. New hardware and software enhancements provide for higher sensitivity and more reliable operation. At the same time, microprocessor technology allows for a range of capabilities to be provided through variations of the firmware installed. At a future date, it is anticipated that there will be several different models of the SPER-1E Reader. This document details the operation of the basic version.

Introduction

All models of the SPER-1E family have the same external appearance. The face of the reader is shown in Figure 1. At the top of the reader is the display where user prompts, data, and results are displayed. Below the LCD display is the electret receptacle with the shutter in the closed position. At the lower right is the shutter handle. Pulling this towards you opens the shutter and starts a reading.

Figure 1 SPER-1E Front Panel

Note: The sensor behind the shutter is very sensitive and easily damaged. For this reason, the shutter must be left in the closed position except when performing readings. **Do not touch or allow objects to come into contact with the sensor board behind the shutter.**

On the right side of the reader are several connection interfaces. These are shown in Figure 2. Near the shutter handle is the RS-232 serial port. Moving to the right are a PS/2 port, a USB connector and a power jack. On the basic model, neither the USB port nor the PS/2 port is enabled. The power jack allows for an external power supply for those units that are used only in the lab and do not require portability. It may also be used to extend the life of the batteries. The external power supply is an option available from Rad Elec, Inc. Using the external supply does not preclude using the unit with batteries. There is no conflict in having both installed at the same time.

Figure 2 External Connections

Note: The unit should not have anything connected to the PS/2 port unless specifically called for by the appropriate procedures. Using the PS/2 port will shorten the battery life significantly!

closed position. This turns on the reader. The display will show some diagnostic information during power-up including the battery condition and temperature in Fahrenheit. When the message "READY" is displayed, the unit is ready for use. If an error message is displayed, it is necessary that corrective action be taken. (See the section below on diagnosing problems.)

5. Pull the shutter handle again and hold it down until the voltage reading is displayed. The voltage will be displayed in the middle of the screen. The battery condition will be pictured to the left and the number in the upper right corner indicates the time it takes to pull the shutter open (in milliseconds). If it is pulled too quickly or too slowly, an appropriate message will be displayed and it is necessary to repeat this step.

6. After leaving the shutter closed for several seconds, repeat step 5 and read the voltage again. If this new value is different, repeat step 5 until a minimum of two successive readings are the same. This repeated value is the correct electret voltage reading.

7. Remove the electret from the reader and protect it either by placing the "keeper cap" over it or by installing it in an appropriate chamber.

8. If additional electrets are to be read at this time, repeat steps 1, 2, 3, 5, and 6 to obtain the desired readings. This may be repeated as often as necessary.

9. The SPER-1E reader will automatically turn off after two minutes of no slide activity.

10. Return the SPER-1E reader to its carrying case and close the cover to allow the desiccant to maintain the low humidity environment recommended by the manufacturer.

Using the Reference Electrets

As mentioned above, calibration of the Reader is performed only by the manufacturer. However, due to the sensitivity of the instrument, it is important that the calibration be verified periodically by the user. This is done using the Reference Electrets and Zero Electret (Standards) provided under the flap in the SPER-1E reader case. A Reference Electret is one that is highly stable and has been measured with a calibrated reader. The Reference Electrets provided are generally in the range of approximately 250 volts. A record of the calibration including the date and exact voltage accompany the Reference Electrets. Whenever the Reader is returned to the manufacturer for recalibration, the Reference Electrets should accompany it for re-certification as well. The "Zero Electret", which consists of a metal plate, verifies that the Reader zeros properly. A weekly record of all three Standards should be maintained and are used as part of your Quality Assurance/Quality Control Program. The Reference Electrets are read in the same manner as those used in radon monitoring. Whenever they are not being read, they must be covered by their protective "keeper cap". If the weekly readings remain constant within acceptable limits, you can be confident that your SPER-1E reader is functioning correctly. (Please see the information sent with the Reference Electrets).

RS232 Serial Port – normally the voltage reading is manually inputted into your calculation software. However, the serial port capability can be used to send the reading signal to your computer through special programming.

Diagnosing Problems with the Reader

- **Fluctuating Electret Readings** – this can happen on very humid summer days or when moisture condenses inside the reader from being cold and damp. The reader uses ultra high impedance components which work properly only in a relatively dry environment. **It is recommended that the reader be used in air conditioned rooms with a relative humidity of less than 75%.** The reader should also be kept in its carrying case and the desiccant checked frequently. Please see the "Handling and Storage" section earlier in this manual for proper use of the desiccant. The electret receptacle on the Reader can also become dirty which may not allow good contact with the electret. The receptacle may be wiped cleaned with alcohol wipes while the shutter is kept closed. **Do not open the shutter and expose the interior while cleaning the receptacle.**

- **"LO BAT" appears on the display** – this display is a warning to change the batteries. The SPER-1E uses two AA alkaline batteries. Always replace the batteries with new ones and follow the diagram inside the battery case for placement.

- **"ER FAST" appears on the display** – this means the slide was pulled too fast. Pull the slide back gently, hold until it is finished reading and the voltage appears. Then release the slide.

- **"ER OPEN appears on the display** – this means the slide was held open too long. Release the slide and pull again. Once the reading appears, release the slide to avoid this message.

- **"ERSLIDE" appears on the display** – this means that there was an error when pulling the slide. Pull the slide back gently, hold while displaying "READING" and release the slide once the voltage is displayed.

- **"ERSLOW" appears on the display** – the slide was pulled too slow. Pull the slide a little faster.

- **"ER WAIT" appears on the display** – the memory has not cleared from the previous reading before taking the next reading. Wait a second before pulling the slide between readings.

- **No display** – Pulling the shutter handle should turn on the reader. If this does not happen, most likely the batteries are too low. Replace the batteries. If the Reader will not turn on with fresh batteries, return the reader to Rad Elec for servicing and repair estimates.

- **Reader does not automatically turn off** – The SPER1-E should turn automatically off the display if not used within two or three minutes. If this does not happen and the display remains on, it indicates a defect in the auto off switch. Please return the Reader to Rad Elec for servicing and repair estimates.

- **Repair Services** – if your reader needs repair, ship it back to Rad Elec. Rad Elec will evaluate the problem and contact you with an estimate before performing any services.

- **Reader does not automatically turn off** – The SPER1-E should turn automatically off the display if not used within two or three minutes. If this does not happen and the display remains on, it indicates a defect in the auto off switch. Please return the Reader to Rad Elec for servicing and repair estimates.

- **Repair Services** – if your reader needs repair, ship it back to Rad Elec. Rad Elec will evaluate the problem and contact you with an estimate before performing any services.

SOP6: Procedure for Air Chek activated charcoal devices

RADON TEST KIT

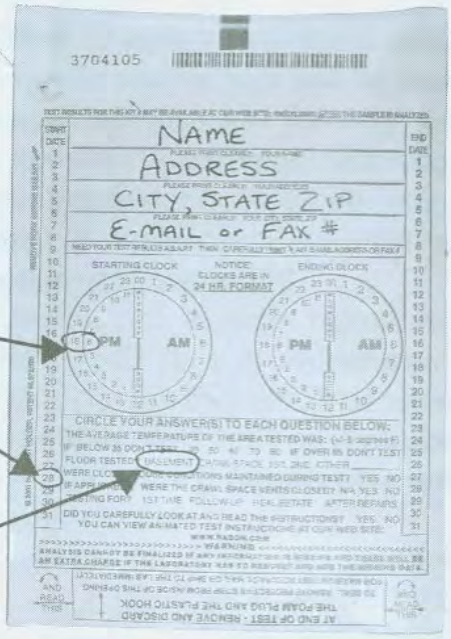
PLACEMENT & RETRIEVAL

INSTRUCTIONS

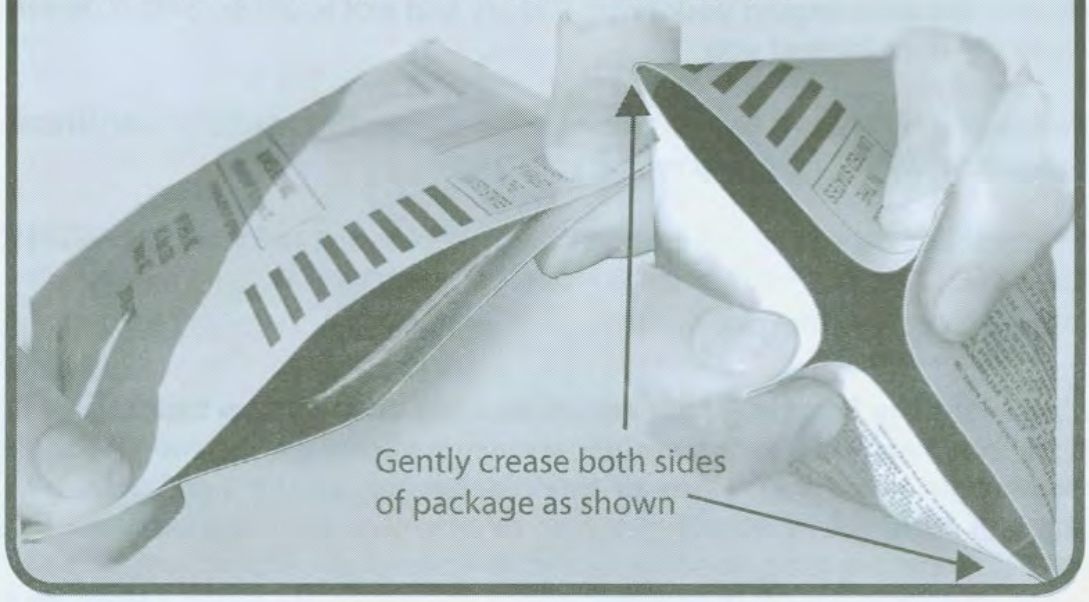
Test Duration 3-7 Days

Air Chek, Inc.
www.radon.com
800-AIR-CHEK

1. Record **YOUR** test kit number:
   HERE:_____
   Save this until you get your report.
2. Using a pen (no pencils please), **clearly print,** your name and full address.
3. Circle the starting hour and day of the month.
   (In this example the test started at 6:00PM on the 28th)
4. Circle the location of the test in the building. Please note that crawl-spaces are **not** considered livable areas.



5. While holding the packet as shown, push the opposite edges together. When released, this will cause the open end of the packet to assume a diamond (or square) shape. **DO NOT tear the brown paper.**



6. Holding the square foam filter by its plastic tab, place it into the opening of the packet. **The foam is not the active ingredient, as it simply controls airflow into the test kit.** There is charcoal behind the brown paper in the test kit and that is what collects the radon. Push the foam in far enough to fill the opening. If you do not have the foam filter, contact us prior to opening the innermost plastic layer.

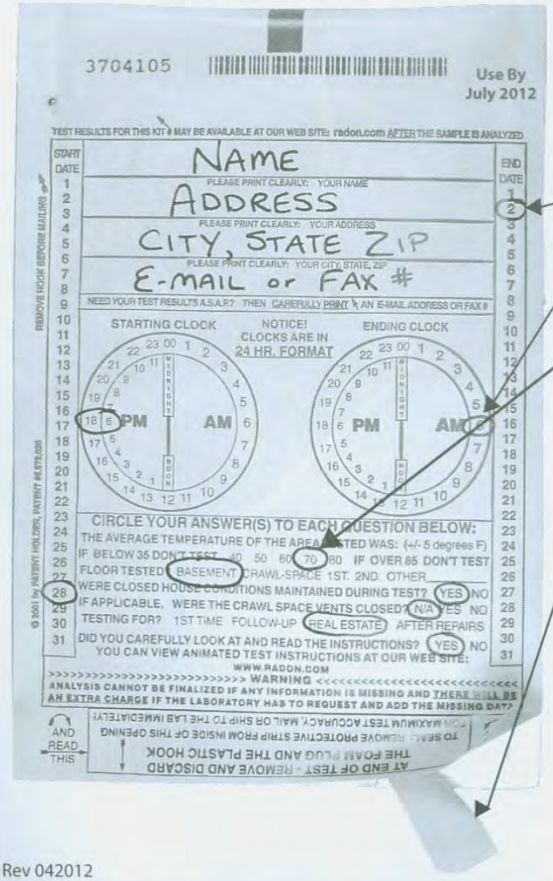
- Match the outer surface of the foam with the edge of the packet opening.
- Make sure the corners of the foam filter fill the corners as shown here.

7. Hang the packet, from the hook provided, at your normal breathing level.

Test for a minimum of 72 hours (three days) and no longer than seven days. Tests longer than 1 week will be invalid.

TEST ENDING INSTRUCTIONS

DO NOT remove from the test area until the packet is sealed.



Please make certain that you have provided all start and ending times as shown above and below.

MISSING INFORMATION WILL INVALIDATE YOUR TEST

1. **REMOVE AND DISCARD the FOAM FILTER and the PLASTIC HOOK.** DO NOT PLACE OR LEAVE EITHER IN THE PACKET.
2. **CIRCLE** the ending hour and day of the month. *(In this example the test was stopped at 6:00AM on the 2nd day of the month.)*
3. **CIRCLE** the average indoor temperature of the room tested and answer ALL remaining questions.
4. **FOLD** back the envelope flap. Remove the thin white strip lining the edge of the opening to expose an adhesive layer and press both flaps together to seal. Do Not cut off the end of the test kit envelope! Make certain the packet is **sealed air-tight**. Repair any tears with a **small** piece of plastic tape. Excessive tape or labels may invalidate your test.
5. **RECORD** and keep the sample serial number, located to the left of the bar-code above the name/address panel. This is your only connection to YOUR sample's test result.

For the most accurate result, return for analysis ASAP, preferably by courier services such as FedEx or UPS. (See flipside of this instruction sheet for further shipping details.

FedEX / UPS Address
Air Chek, Inc.
1936 Butler Bridge Road
Mills River, NC 28759

USPS Address
Air Chek, Inc.
PO Box 2000
Naples, NC 28760

TEST RESULTS MAY BE AVAILABLE AFTER ANALYSIS AT:
www.radon.com

Rev 042012

ADDITIONAL TESTING INSTRUCTIONS

When is the best time to use this test kit?

Testing for radon gas levels can be conducted any time of year, as long as closed house conditions can be maintained. **Closed house conditions** means that **all** windows and external doors should be kept closed for 12 hours before starting the test, until the end of the testing period. This doesn't mean changing your normal entry and exit routines, only that you close the door behind you.

Radon testing should not be started if severe weather, extreme rain/snow, or unusual winds are predicted for your area.

Use two kits side by side(~6 inches apart) if this test is for a REAL ESTATE TRANSACTION. EPA Real Estate protocols are available at:
www.epa.gov/radon/pubs

Can I run my heating / air conditioning during the test?

If the building has a radon mitigation (removal) system, central air conditioning, de-humidifier, air-to-air heat exchanger, and/or combustion air supplies for furnaces, etc., they should be operated normally. However, DO NOT operate any attic, window, or whole house fans. Normal use of bathroom and kitchen fans is acceptable. DO NOT place the radon test kit in a draft.

Where should the test kit be placed?

The USEPA suggests you test the lowest area of the building that is used on a regular basis, or the lowest level that could be used by a potential buyer. EXCEPTION: Citizens of Pennsylvania are required to test the lowest LIVABLE area of the building.

Hang this device where it will not be disturbed. The preferred method is to hang it centrally in the room or area being tested. It should be hung within the normal breathing zone (2 to 6 feet from the floor). String may be useful to hang the device from a light fixture or non-operating ceiling fan. Samplers may also be hung on an interior non-masonry walls. Hang it 3 feet or more away from doorways, hallways, windows, exterior walls, and heating or air-conditioning vents.

DO NOT place it near any heat source such as a stove, fireplace, or baseboard heater and keep it out of direct sunlight.

DO NOT test areas of high humidity such as bathrooms, kitchens, laundry rooms, closets, or damp basements. If you must test a damp humid room (over 50% RH), then test for only 3-4 days.

Crawl-space testing is NOT recommended for an initial screening test unless a previous test indicated high radon and an entry point is being investigated.

How long should I run the test?

This test device is designed to be exposed from 72 to 168 hours (three to seven days). This means you must leave it in place for at least 3 days, but no longer than 7 days. **Tests longer then 7 days will be invalid.**

Additional Reminders for Your Radon Test

√ Use this test before the "Use By" date for best results.

√ Throw away the small white moisture packet when starting the test.

√ Record the 7-digit serial number of your test kit.

√ Make sure to circle all test dates, times and indoor temperature.

√ Hang the kit from the plastic hook on the corner of the kit during the test. Do not lay the kit on a table during the test.

√ Do not tear the brown paper, containing the charcoal, inside the test.

√ Test the lowest livable area.

√ Keep ALL windows in the entire home closed during the test.

√ **Throw away the black square foam at the end of the test.** The foam is not the active ingredient as it simply controls airflow into the test kit during the test.

√ Seal the kit correctly once the foam has been removed.

√ Do not cut or tear away pieces of the test kit.

√ Adding extra weight (large labels or excess tape) may invalidate your test.

RETURNING YOUR SAMPLE FOR ANALYSIS

When your test is finished, send us your exposed sample ASAP!! Because of normal radioactive decay, one-half of the radon gas in the sample is no longer available for analysis after the 4th day. A sample taking more than 7 days to reach our lab will not provide as accurate a result as one that arrived within 3 or 4 days. If the sample takes over 8 days to reach our lab, your results will be estimated. Over 12 days, NO result can be provided. All radon-in-air samples are analyzed the day of arrival. If you are returning multiple samples for analysis, place them inside the same box or envelope to make sure they all arrive at the same time.

Important Notice Regarding US Postal Service

The budget crisis at the United State Postal Service (USPS) is causing severe delays in First Class Mail. USPS officials have warned of even slower service as facilities are closed. **Although some of our test kits may include Free First Class postage, we strongly urge you to consider an alternate shipping method!**

Recommended Shipping Options

- FedEx or UPS Overnight, 2-day, 3-day, or Ground Service
- USPS Express Mail
- USPS Priority Mail with delivery confirmation

For most accurate analysis, return your sample so it arrives at our lab within 4 days from the end of the test.

FedEx/UPS Address	USPS Address
Air Chek Inc	Air Chek Inc
1936 Butler Bridge Rd	PO box 2000
Mills River, NC 28759	Naples, NC 28760

Air Chek, Inc. makes every reasonable effort to maintain the highest possible quality control during the manufacture and analysis of our test devices, however, we cannot control what the end-user does with or to our test samplers (when they are NOT in our possession). Our manufacturing, analysis, and reporting procedures include several checks and verification steps (such as double-entry of user-provided information). Therefore, we cannot provide a warranty of any kind, expressed or implied, including without limitation any implied warranty of merchantability or fitness with respect to any item furnished, information supplied or services rendered by Air Chek, Inc. Before any action is taken on the basis of test results or analysis provided to you by Air Chek, Inc., we recommend that further testing be conducted. Neither Air Chek, Inc., nor any of our employees or agents, shall be liable under any claim, charge or demand whether in contract, tort or otherwise for any and all losses, costs, charges, claims, demands, fees, expenses, injuries, or damages (including without limitation incidental or consequential damages which are hereby excluded) of any nature or kind arising out of connected with, resulting from, or sustained as a result of any item furnished, information supplied or service rendered to by Air Chek, Inc

Appendix L Calibration Certificates

femto-TECH Laboratories

CERTIFICATION OF CALIBRATION

Instrument Model
CRM510

Instrument Type
Continuous Radon/Pulsed Ion Chamber

Unit Serial Number
CRM 510 6149

Test Type	Test Length	Background Level
Background	4045	0.15 (+/- 10%) CPM

Test Type	Test Length	Conversion Factor
Calibration	1440	0.347 +/- 0.01(1δ) CPM per pCi/*l* (9.33+/- 0.3) x 10^{-3} CPM per Bq/m^3

Test Length is stated in minutes.
CPM = counts per minute.
Default = background test was not performed; the default value for the instrument was used to calculate the conversion factor.

pCi/l = picoCuries per liter of air.
Bq/m3 = Becquerels per cubic meter of air.
Other = the background level used to calculate the conversion factor was provided by the customer or other source.

Instrument Calibration Description

Although a nominal instrument calibration factor is established by the electronic and physical design, an individual factor is determined for each production unit referenced to the calibration of a *femto*-TECH, Inc. "master" unit. *femto*-TECH "master" units are calibrated in the Bowser-Morner Radon Calibration Laboratory, which maintains intercomparison traceabilities to U.S. Environmental Protection Agency and U.S. Department of Energy (EML) radon laboratories. Background levels for individual units are determined at *femto*-TECH by an exposure to aged air or nitrogen for a minimum of 24 hours.

Date: 9.24.2012

D. Craig Britton
Calibration Technician

femto-TECH, Inc.®
P.O. Box 8257, 25 Eagle Court
Carlisle, OH 45005

RadonAway™

CERTIFICATE OF CALIBRATION
RadStar RS800 Continuous Monitor

This instrument has been calibrated in accordance with the procedures set forth by the manufacturer. Please retain this certificate with your records.

Calibration Date: 5-7-12 Next Calibration Due: 5-7-13

Serial Number 1727

Chamber Temperature 77.32 Deg F Chamber Humidity 51.78 %RH

Radon Concentration 15.35 pCi/l

Sensitivity Factor 320 Calibrated By: [illegible]

RadonAway 3 Saber Way Ward Hill, Massachusetts 01835 978.521.3703

This RadStar Continuous Radon Monitor has been calibrated by the manufacturer using a standard operating procedure for calibration of the RS800, TP010 Rev A. This procedure provides for the following performance checks:

- System Functional Checks
- Battery Check
- Background Check in Nitrogen Chamber
- Chamber Exposure in Known Radon Concentration
- Adjustment to Sensitivity Factor, if necessary
- Verification Chamber Exposure, if necessary

The manufacturer, RadonAway performs quarterly inter-comparisons with a Secondary Chamber which, in turn, performs quarterly inter-comparisons with the USEPA Primary Chamber in Las Vegas, Nevada.

RS800 - NEHA-NRPP Device Code 476 Device Group 18 USEPA Verified

The RadStar RS800 is distributed by AccuStar Labs 888.580.9596

DURRIDGE COMPANY Inc.
524 Boston Road, Billerica, MA 01821
Tel: (978) 667-9556, Fax: (978) 667-9557
www.durridge.com

Certificate of Calibration
RAD7 PROFESSIONAL RADON DETECTOR (NRSB device code - 31810 CR)

Calibration Date: 18·OCT·2012

Serial Number: 433 — *Date of last Calibration:* 18·AUG·2011

Model Number: RAD7 - 711 — *Sensitivity, Normal mode:* .506 CPM/(pCi/l)

Software Revision: 2.5F — *Sensitivity, Sniff mode:* .245 CPM/(pCi/l)

Dates of Calibration run: 16·OCT to 18·OCT·2012 — *Spill factor:* .013

Reference Unit Number: 961

Mean Temperature: 25.8 °C

Mean Concentration: 60.9 pCi/l 22533 Bq/m3

Sensitivity, Normal mode: .472 CPM/(pCi/l) .013 CPM/(Bq/m3)

Sensitivity, Sniff mode: .227 CPM/(pCi/l) .006 CPM/(Bq/m3)

Spill factor: .017

Calibration uncertainty: 2 % 2-sigma (Notes 1, 2)

Conversion factor - Normal: 2.12 (pCi/l)/CPM 78.44 (Bq/m3)/CPM

~~Conversion factor - Sniff: 4.40 (pCi/l)/CPM 162.8 (Bq/m3)/CPM~~

(Note 1) Based on counting statistics of the reference and this unit.
(Note 2) No account has been made for the calibration uncertainty of the reference unit relative to an absolute standard, which we estimate to be within +/- 5%.

NRSB Accredited Radon Chamber Certificate Number: NRSB TRC0003

Calibrated by: CKE NRSB certification number: 12SS018

Signature: Charles Ressler Date: 18·OCT·2012

It is recommended that this unit needs to be recalibrated on/before: 18·OCT·2013

SUN NUCLEAR corporation

425-A Pineda Court
Melbourne, FL 32940-7508 U.S.A.
Ph: 321 259 6862 Fax: 321 259 7979
http://www.sunnuclear.com

Radon Certificate of Calibration

The following radon monitor was placed in the calibration chamber:

SNC Serial No: 47810011

Model No: 1027

Actual Reading	Error %	Correction Factor	Background
267.0 pCi/l	1.1%	0.98876	0.2

The Rn-222 gas concentration in the chamber, over the measurement interval was:

264.0 pCi/l, ±10% as measured with 100ml scintillation cells

The correction factor is a multiplicative and can be applied to the displayed value on the monitor.

The accuracy of this radon monitor per EPA and Proficiency recommendation is ± 25% or 1 pCi/l, which ever is greater, after a 24 hour period of deployment.

This instrument has been calibrated in accordance with the specifications set forth by the manufacturer. Radon gas calibrations are traceable to the NIST SRM 4973 Radon emanation standard.

The error of the chamber concentration is a best estimate based upon typical inter-comparison results with Bowser Morner Reference Laboratory. The most recent inter-comparison in which Sun Nuclear participated, February 2012, resulted in a 1.2% error in our reported measurement.

Frequency of re-calibration may vary depending upon local, state, or proficiency program requirements.

Sun Nuclear Corporation has successfully met the established and published requirements for Accreditation by the National Radon Safety Board as an accredited chamber. Certification No: NRSB TRC6001 expiring November 2012.

Calibration Date: 10/25/2012 Next Calibration Date: 10 / 2013

Technician: CG

Please retain this document for record keeping purposes.

1027-01-01 Rev A