NATURAL ROCK SAMPLE

Performance Monitoring Accessory for the RAD8

User Manual

DURRIDGE

Radon Capture & Analytics

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1 INTRODUCTION

The Natural Rock Sample is a 35 oz (1 kg) sample of granite gravel, enclosed in a container that may be sealed using a pair of ball valves and end caps.

Granite generally contains trace amounts of both uranium and thorium that have been in the rock since it was formed, millions if not billions of years ago. Therefore all the progeny of both the uranium and thorium decay chains are fully supported and in full equilibrium down to radium-226 and radium-224.

When the Natural Rock Sample is kept under conditions of stable absolute humidity, it constitutes a rock-steady emitter of both radon and thoron. This manual shows how to take advantage of that property to check the performance of a RAD8.

Whilst the rate of radon and thoron emanation from the surface of the granite gravel is fixed by the uranium / thorium content, the efficiency with which radon and thoron atoms are able to escape the surface pores of the rock and enter the air stream is a function of humidity. For this reason, the Natural Rock Sample has several humidity control packs built into it for maintaining stable humidity conditions inside the device in between measurements, which may be months apart. This humidity control system works better the closer the internal humidity is to the external, ambient humidity. Typically, 58% relative humidity packs are used.

Conversely, the RAD8 works best (that is, achieves its maximum sensitivity to radon and thoron) when the incoming sample air is bone dry. To achieve this, use a Small Drying Tube with blue, active desiccant in it, immediately upstream of the RAD8's 'Titan3' inlet filter, and downstream of the Natural Rock Sample. If the desiccant in the Small Drying Tube gets used up it should be replaced or regenerated after the current Test.

After calibration at Durridge, and with the optional Thoron Calibration Check Kit, the Natural Rock Sample can be used for low-precision checking of both the radon and thoron sensitivities of any RAD8. The Natural Rock Sample can provide a means for monitoring long-term changes in both radon and thoron sensitivity.

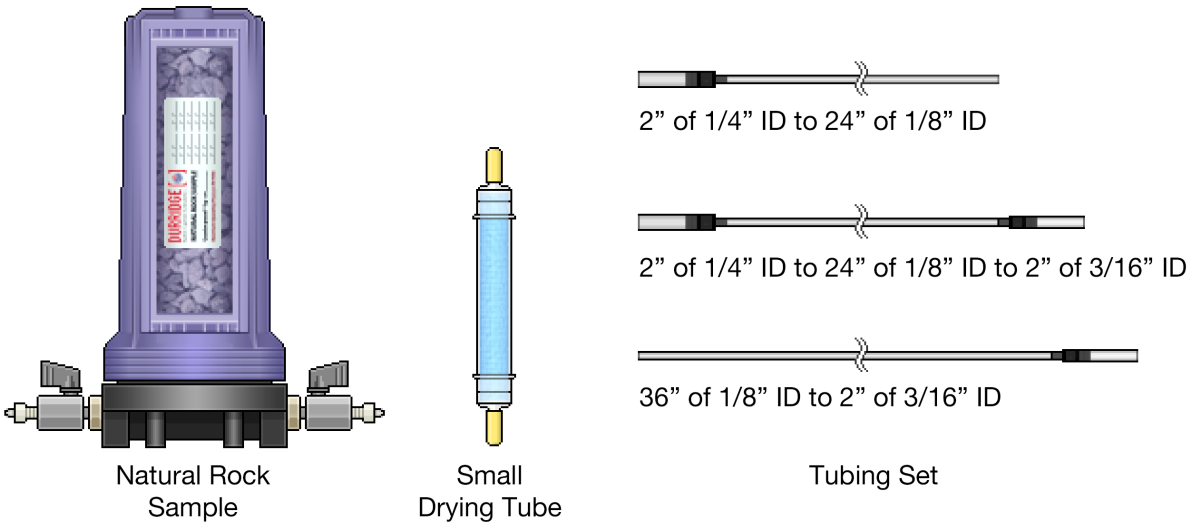

Figure 1 Natural Rock Sample Components

2 RADON SENSITIVITY CHECK

After sitting sealed on a shelf for one month, the radon in the Natural Rock Sample container will have reached within 1% of a steady value, in which the rate of emission of radon into the container is equal to the rate of loss by decay and leakage. If that quantity of radon is known, and if it is distributed around an air loop of known volume, then the radon activity concentration in the air is known. If one of the devices in the air loop is a RAD8, the RAD8's reported radon concentration may be compared with the known concentration, and thus the sensitivity of the RAD8 may be effectively checked. A correction may be applied to the Natural Rock Sample radon reading to account for the ambient air radon concentration (see Section 2.4).

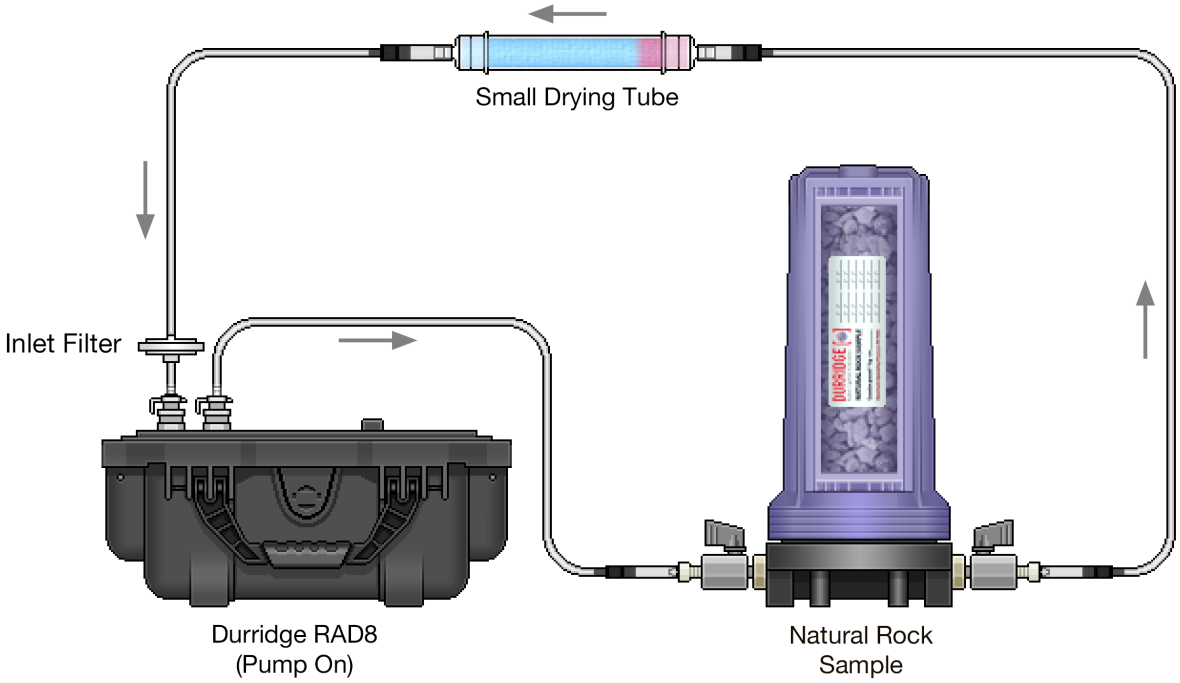

Figure 2 Radon Sensitivity Check Setup

In practice, provided the device and tubing configuration is identical to the calibration setup, all that is required to check the RAD8 sensitivity is to compare the 'standardized' average RAD8 reading (see Section 2.4) with the standardized average reading on the Natural Rock Sample calibration certificate. The ratio of the two will give a correction factor that may be applied directly to RAD8 readings.

2.1 Purge the RAD8

First, with a Laboratory Drying Unit on the inlet, purge the RAD8 with dry air in an open loop for at least 5 minutes (`Start Test > Purge`), then switch to 1-Day protocol (`Start Test > Preset Protocols > 1–Day`). Start a reading, still sampling fresh air through a drying unit. The RAD8 screen will display a real-time reading of the Relative Humidity. Wait until the Relative Humidity has been reduced to 8%, stop the test and power off the RAD8. If a correction is to be made to the Natural Rock Sample radon reading for radon added to the air loop by the ambient air, after purging the RAD8, (see section 2.4), this fresh-air measurement should be kept going until at least one and preferably three or more 30-minute Cycles are completed.

2.2 Hook up to the Natural Rock Sample

Hook the RAD8 up to the Natural Rock Sample in a closed loop, using the tubing and Small Drying Tube provided with the Natural Rock Sample. Use the configuration shown in Figure 2, with the Small Drying Tube upstream of the RAD8, and the Natural Rock Sample connection upstream of the Small Drying Tube. If one end of the Small Drying Tube has started to turn pink, indicating that it is wet, that end should be positioned upstream, toward the Natural Rock Sample.

2.3 Start a 3-Hour Test

Switch on the RAD8 and choose `Start Test > Manual Configuration`. Set up a test with 6 Cycles of 30 minutes each, and Analysis Mode set to 'Rapid'. The RAD8 will give you the opportunity to save your setup as a Custom Protocol. Open the ball valves on the Natural Rock Sample container and start the test.

Keep the measurement going until all six cycles are complete (3 hours). Average the last four readings. Record that average with the date. If a thoron test is to be conducted (see Section 3), the best time to do it would be 1 - 2 hours after the radon test (see Section 3.1.1 for details).

2.3.1 Re-Humidifying and Resealing the Natural Rock Sample

After a closed-loop radon test, the Natural Rock Sample will be slightly drier than when it started, due to the desiccant in the Small Drying Tube having adsorbed some of the water vapour in the closed air loop. The Natural Rock Sample should therefore be re-humidified and prepared for storage. To do this, simply connect the Natural Rock Sample to the inlet of a RAD8 as shown in Figure 3 below, and select `Start Test > Purge`. At this point, the Small Drying Tube that was used in the 3-hour test should be sealed with yellow caps and set aside until either the thoron calibration check in an hour or two (if applicable), or the next radon calibration check after a month or more.

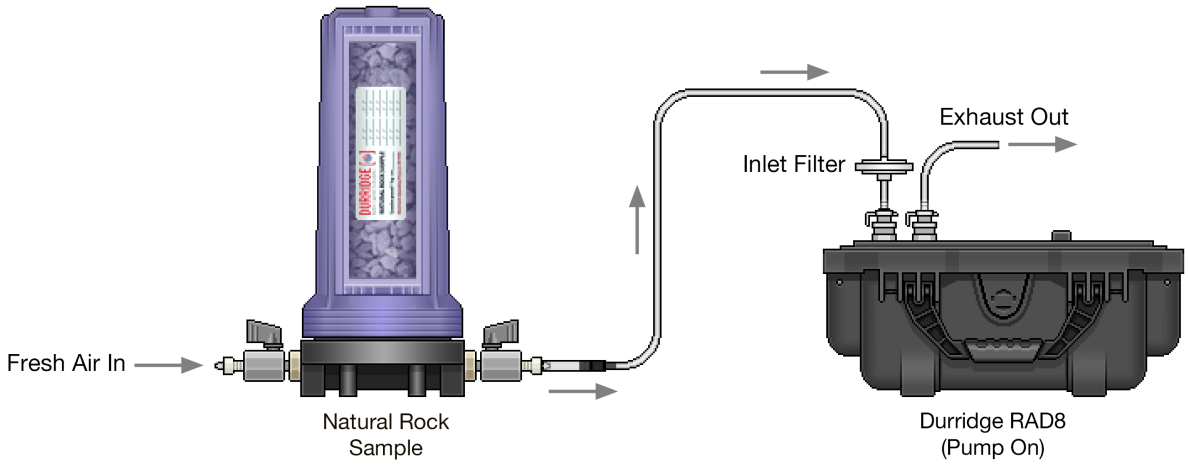

Figure 3 Natural Rock Sample re-humidifying configuration

After a day or so of purging, the RH inside the Natural Rock Sample will have reached the ambient RH. Close the ball valves, disconnect the tubing, and insert the end caps on the Natural Rock Sample tube. Mark the date on the label and store the Natural Rock Sample with its tubing and Small Drying Tube on a shelf for a month or more before repeating the process.

If the ball valves are opened for any reason on a later date, update the label showing the last date on which the valves were closed, and left closed. The rock sample will be ready for another radon check not before one month from that date.

2.4 Radon Data Assessment

If the Natural Rock Sample was never calibrated, keep the average of the last four readings (Cycles 3, 4, 5, and 6) in a record for future reference. Figure 4 on the next page shows a typical data set in Durridge's Capture software, with the last four readings selected. Every RAD8 should produce nearly the same result with that Natural Rock Sample if its sensitivity is as calibrated and if the humidity of the Natural Rock Sample's internal environment remains constant. For greater reproducibility, a portion of the ambient air radon concentration can be subtracted from the averaged readings to correct for the residual radon in the air in the system after purging. However, if the ambient radon concentration in the air is less than 100 Bq/m^3 (2.7 pCi/L), then the error introduced by ignoring it will be less than 1%.

If the Natural Rock Sample has been calibrated by Durridge, the calibration certificate gives the standardized average of readings 3, 4, 5 and 6, obtained with the standard setup, a well purged and dry RAD8 and 30-minute Cycles. Thus, the ratio of the value stated on the Natural Rock Sample calibration certificate to the measured standardized average gives you the correction factor directly. RAD8 readings multiplied by that ratio will give readings consistent with the Durridge calibration system to within 15%.

You may also, if you wish, calculate the total amount of radon in the air loop, and hence originally in the Natural Rock Sample container. If the radon amount is Rn and the volume of the air loop is V, then the radon concentration is Rn/V. The air volume in the Natural Rock Sample is about 1070 mL, a standard RAD8 is 590 ml, and the tubing with Small Drying Tube is 16ml, for a total volume of a standard Natural Rock Sample system of 1.676 L. If Rn is expressed in pCi, then the radon concentration will be Rn/1.676 pCi/L. If Rn is expressed in Bq, then the radon concentration will be Rn/1.676 Bq/L, or 1000 * Rn/1.676 Bq/m^3.

In pCi, Rn = 1.676 * radon concentration in pCi/L.

In Bq, Rn = 0.001676 * radon concentration in Bq/m^3

If the certified and observed standardized average values differ by more than 15%, we recommend that the RAD8 be returned to Durridge for service. If, after several monthly sensitivity checks, there is a consistent ratio between the observed and the certified standardized average radon concentration, you may consider applying a multiplier to all readings made with that RAD8, to bring them in line with the Natural Rock Sample standard. If you notice a big jump, up or down, in the reading, from the previous month, first look to see if the RAD8 was properly purged before the measurement was started. If there is no obvious reason for the jump, the RAD8 should be returned to Durridge for service.

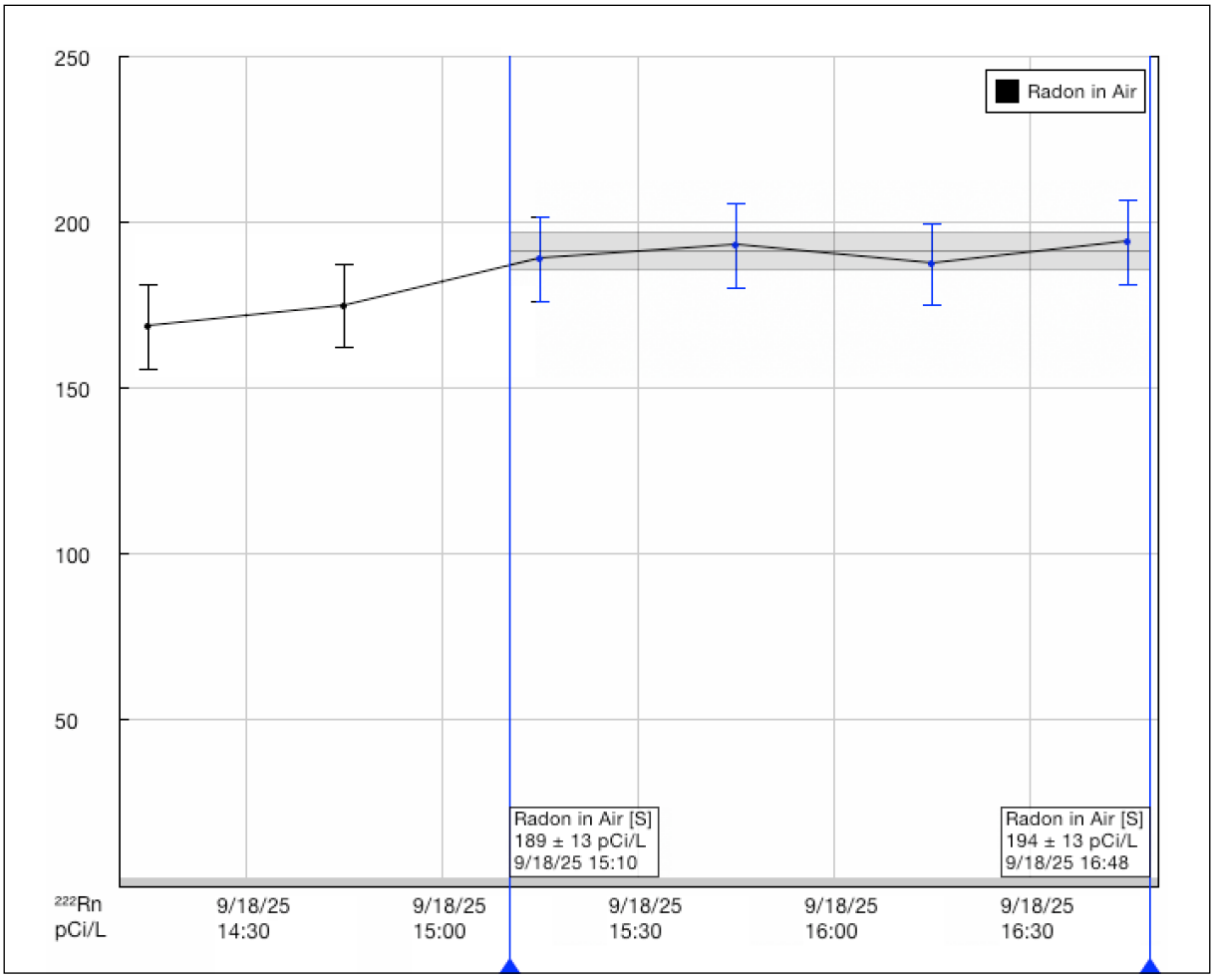

Figure 4 Graph of Natural Rock Sample sensitivity test data

2.5 Multiple RAD8s

Before using the Natural Rock Sample to check a RAD8's radon sensitivity, the Natural Rock Sample must be left sealed for a month, in order for the radon inside the container to reach equilibrium. That means a RAD8 can have its sensitivity checked each month on a regular basis. However, there is nothing to stop us hooking up multiple RAD8s in series in the loop connected to the Natural Rock Sample. This increases the volume of the loop and hence decreases the radon concentration in the loop, but by a predictable and reproducible amount. This method is recommended for checking up to six RAD8s on a monthly basis.

For the sake of argument, using rounded figures, let us assume that the total activity of radon inside the Natural Rock Sample container, when in equilibrium, is equal to 2 Bq. Let us also assume that the Natural Rock Sample and tubing has an air volume of 1.086 L, while a RAD8 is 0.590 L. Then when the RAD8 is connected up to the Natural Rock Sample and the radon distributed around the loop, the radon concentration will be 2 / 1.676 = 1.193 Bq/L = 1193 Bq/m^3. If every additional RAD8 adds 0.590 L to the loop, then four RAD8s would total 3.446 L, including the Natural Rock Sample and tubing. The radon concentration in the loop would then become 2 / 3.446 = 0.580 Bq/L = 580 Bq/m^3. While this is less than 1676 Bq/m^3, it is still enough to make a good reading with an extended two hour measurement.

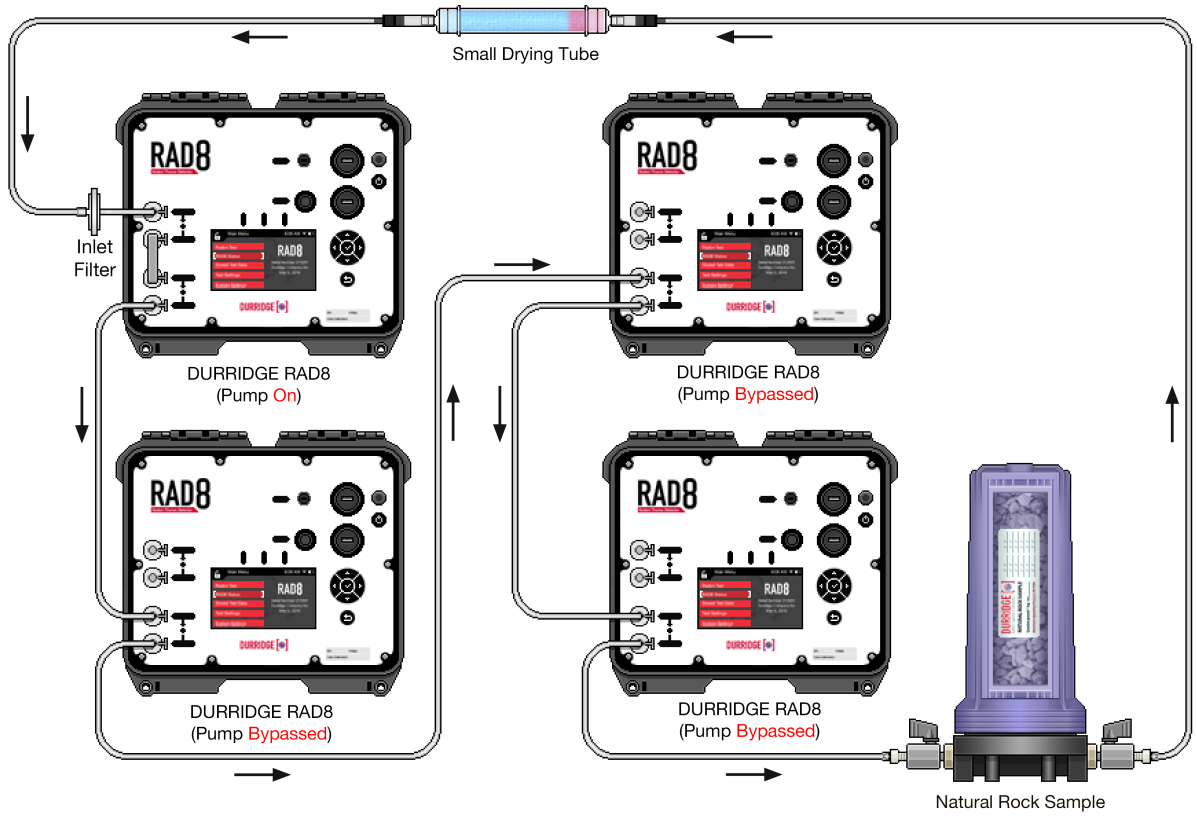

Figure 5 Multiple RAD8 Sensitivity Check Configuration

Each month, all four RAD8s can be connected in series with one another and thoroughly purged and dried out, before being connected to the Natural Rock Sample to obtain a sensitivity check. Each month the setup should be identical, with the same number of RAD8s and the same pieces of tubing to connect up the entire loop. During the measurement all the RAD8 pumps, except one, should be bypassed by using only the bottom two air fittings on the front panel (see Figure 5).

If any of the RAD8s had developed a leak, the radon concentration in the loop would fall rapidly. Thus, in addition to keeping a record of the average readings during the check, for each month, a record of the slope of the average for all RAD8s should also be maintained, as the radon concentration falls off over time from decay and any leakage. If during one month the slope is steeper than usual, that would be an indication of a leak in the loop somewhere.

Although it is possible to combine several RAD8s in a loop for monthly radon sensitivity checks, this technique will not work for checking thoron sensitivity, due to the decay of thoron in the air as it travels around the loop (see Section 3.1). However, there is no need to wait between successive thoron checks, and all the RAD8s can undergo the rough thoron check individually, sequentially, without any delay between measuring the thoron response of one RAD8 and the next. The monthly protocol may therefore be:

1. Connect all RAD8s in series. Bypass all but the single operational pump by using only the bottom two front panel tubing ports on three of the four RAD8s. Put a Laboratory Drying Unit upstream of the line, with one end open to fresh air.
2. Set the RAD8 with an active pump to Purge, for 15 minutes, to purge all residual radon out of the RAD8s and start to dry them out.
3. Select `Start Test > Preset Protocols > 1–Day` on the RAD8 with the operational pump. Manually configure the other three RAD8s with exactly the same Protocol settings as a 1-Day test, except with the pump set to Off, and start these, too.
4. After at least two Cycles (1 hour), or preferably 3 Cycles (1.5 hours), stop the tests.
5. Disconnect the Laboratory Drying Unit. Connect the string of RAD8s to the Natural Rock Sample and Small Drying Tube as described in Section 2.2.
6. Open the valves and repeat step 3 (above), ensuring that all four tests begin at the same time.
7. Depending on the precision required, after between 3 and 24 hours, the tests may be stopped and the RAD8s disconnected.
8. If required, rough thoron checks may then be performed with each RAD8, separately connected to the Natural Rock Sample. Wait 1-2 hours before doing this, to allow time for the C window radon counts to decay away (see Section 3.1.1).
9. Careful notes should be kept of all actions and readings, and all data downloaded from each RAD8 to a computer using Durridge's Capture software and/or uploaded to Capture Cloud.
10. The Natural Rock Sample should be re-humidified and stored for a month or more, using the procedure described in Section 2.3.1, before making the next calibration check.

2.6 Cumulative Spectrum

It is important that the cumulative spectrum (based on counts from multiple cycles) be inspected periodically. It gives excellent diagnostic information on the health of the instrument. Using the Natural Rock Sample to check the calibration of the RAD8 every month is a convenient opportunity to inspect the cumulative spectrum. The current Cycle's spectrum can be viewed on the RAD8 touchscreen (`Test Status > Spectrum`), whilst the cumulative spectrum can be viewed for a completed Test under `Manage Test Data > [Test Name] > Spectrum`, or for a data selection of your choice in Capture. That spectrum should show a sharp peak in the A window, about midway between the boundaries. There may also be peaks in the other three windows and at 5.3 MeV (polonium-210) just to the left of the A window. Please see the RAD8 manual for a description and image of some possible pathological spectra to watch out for.

3 THORON SENSITIVITY CHECK

3.1 Thoron Measurement

The RAD8 is capable of making a direct measurement of thoron gas concentration in air. It does this by counting polonium-216 decays inside its measurement chamber. However, Thoron has a short half life, 55.6s, so most of the thoron in the sample will be lost during acquisition if the time from sampling to entering the measurement chamber exceeds even a minute. Therefore when measuring thoron the sample acquisition time must be as short as conveniently possible, and always consistent. Additionally, the exact same setup should be used for thoron calibration as for thoron measurement. This setup necessarily involves a specific length of tubing and a Small Drying Tube full of desiccant, as the RAD8 is less sensitive in a humid environment. Just as with radon, the Natural Rock Sample's thoron output is a function of humidity at the rock-air interface, so it is important to ensure that the humidity inside your Natural Rock Sample remains stable.

The setup assumed in the RAD8 data processing and stated as standard in the manual consists of a Small Drying Tube, which may be used as a wand for sniffing, along with a standard input tubing of 36" (91.4cm) length and inner diameter of 3/16" (4.8mm), as shown below.

This typically gives the RAD8 a thoron sensitivity of around 0.08 cpm/pCi/L. The polonium-216 daughter of thoron has only a 145 ms half life so the main component in the response time of the RAD8 to a step change in thoron concentration is the time taken to pump the sample air into the measurement chamber. The response is virtually instantaneous.

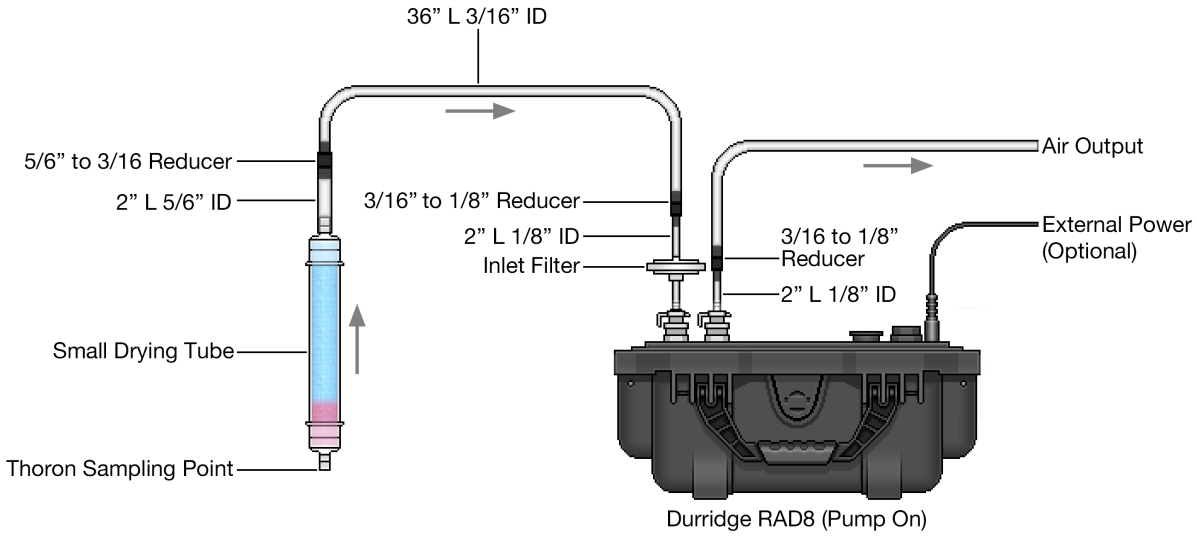

Figure 6 Thoron Measurement Standard Setup

3.1.1 Radon Interference

The alpha particle from polonium-216 decay has an energy of 6.78 MeV, which is between the polonium-218 and polonium-214 peaks in the ^{222}Rn decay chain. That places it within the B window of the RAD8 spectrum, while the polonium-214 peak lies in the C window. About 2% of the polonium-214 counts are in a low energy tail from the peak, and spill into window B. This 'CB Spill Factor' is measured during calibration and the count in window B is corrected for that spill by the RAD8 and by Durridge's Capture software when calculating the thoron concentration. Nevertheless, the presence of a large spill from window C would increase the uncertainty of the thoron count in window B. It is therefore important that the C window count be low when performing a thoron calibration.

If a radon calibration check of a RAD8 has been performed with a Natural Rock Sample, it is good practice to wait an hour or two for the count rate in window C to drop below 10 cpm, before proceeding with the thoron calibration check. During this time, the Natural Rock Sample can be left purging with a RAD8 (`Start Test > Purge`) pumping ambient humidity air, which will ensure that the Natural Rock Sample is re-humidified before the measurement begins.

3.2 Rough Thoron Check

Start a measurement with the preset Sniff Protocol, which has the pump set to On, and is therefore appropriate for thoron. Let it run for at least 15 minutes (three 5-minute Cycles), or more if you would like a higher-precision average. Average all the thoron readings. Store the thoron average reading with the radon average.

This thoron reading cannot be used to check the thoron sensitivity of the RAD8, as the reading is heavily dependent on the pump flow rate and even the position of items in the setup. For example, if the desiccant is placed upstream instead of downstream of the Natural Rock Sample it will make no difference to the average radon reading, but will make a big difference to the thoron readings. Even just switching the connections to the Natural Rock Sample can affect the thoron readings. However, if the setup remains identical in every respect from one monthly check to the next, if the RAD8 pump is still working at close to the same flow rate, and if the inlet filter is not blocked, then thoron readings made with this setup will be similar from one month to the next. After several months of experience the user will know the typical variation and will recognize an anomalous shift, should it occur.

3.3 Better Thoron Check

A more accurate thoron sensitivity check involves the Thoron Calibration Check Kit, which is sold separately. To check the thoron sensitivity of a RAD8 using this kit, the measurement must be made in precisely the same conditions and using the same configuration as thoron measurements in regular use. In standard thoron configuration, the RAD8 has 3 ft of 3/16" ID tubing between the inlet filter and a Small Drying Tube, which may be used as a wand for sniffing purposes.

The thoron check process therefore requires that the sampling point at the end of the Small Drying Tube must be open to the air. It is the thoron concentration at that sampling point that we measure. Thus we put a T-connector at that location, inject thoron at a known rate, using carrier air with less than the RAD8 flow rate, and with fresh air from the other arm of the T-connector supplying the balance of air to make up the RAD8 flow rate. This configuration is illustrated in Figure 7.

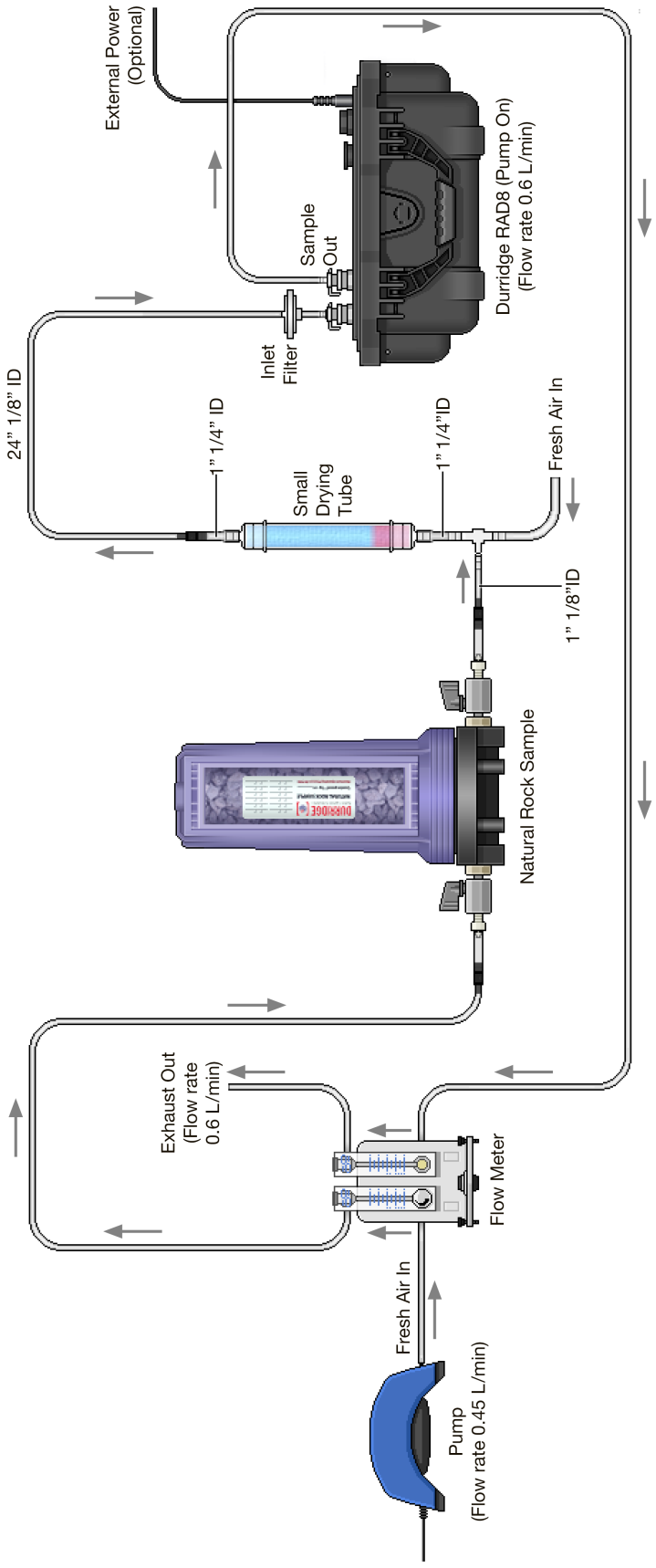

Figure 7 Thoron Sensitivity Check configuration

3.3.1 Experimental Protocol

a) Set up the experiment exactly as in the diagram above, or else with the RAD8 sampling path in exactly the same configuration as will be used for measuring thoron.

b) Adjust the flow rate through the Natural Rock Sample to 0.45 L/min. A flow rate of 0.45 L/min is chosen as a standard flow rate for injecting thoron into the RAD8 sample path because that may be relied upon to be less than the RAD8 pump flow rate, which is nominally 0.6 L/min, but may range from 0.5 L/min to 1 L/min or higher, depending on flow restrictions. With the set up as shown in the diagram above, run the external pump and adjust the needle valve so that the air flowing through the Natural Rock Sample is 0.45 L/min.

c) Connect the flow meter without the needle valve to the RAD8 outlet.

d) Change the RAD8 to Sniff Protocol. Use the preset Sniff Protocol (`Start Test > Preset Protocols > Sniff`), or choose Manual Configuration and set up individual parameters (e.g. Cycle Time) as desired.

e) Start a reading.

3.3.2 Calculation

With an identical air flow rate (0.45 L/min) through the Natural Rock Sample and identical tubing attached to the T connector, for every thoron calibration check, the rate of injection of thoron into the sample flow will always be the same. Let this be Th. The units of Th are pCi per minute or Bq per minute.

If the total RAD8 flow rate, measured at the RAD8 outlet, is V L/min, then the thoron concentration in the sample air flow at the sampling point (which is very close to the T connection) will be Th/V. If Th is expressed in pCi/min and V is in L/min then Th/V will be pCi/L. If Th is expressed in Bq/min and the flow is in L/min then Th/V will be Bq/L. To convert to Bq/m^3 multiply by 1000.

3.3.3 Assessing The Thoron Data

For an uncalibrated Natural Rock Sample, note the average thoron reading and the total RAD8 flow rate. Multiply the thoron reading by the flow rate to get Th, the rate of injection of thoron into the sample flow (for units of Bq/m^3 and L/min, divide the product by 1,000 to get Bq/min). The experiment may be repeated as often as desired; there is no need to wait for any ingrowth. However, after conducting this experiment, the Natural Rock Sample must be left sealed for at least a month before a radon check may be performed. The obvious time to do this experiment is 1 - 2 hours after a radon check.

For a small fee, Durridge will calibrate a Natural Rock Sample for thoron. With a setup as above and a flow rate of 0.45 L/min through the Natural Rock Sample, we give you the rate of injection of thoron into the RAD8 sample path. You may then divide that by the flow rate of the target RAD8 to obtain the thoron concentration at the sampling point. This may be compared with the thoron reading in the RAD8 and a correction factor derived.

Records of the radon and thoron readings should be kept safely for later reference and comparison.

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