SOIL GAS PROBE

In-Ground Radon Detection Accessory for the RAD7

Hardened Steel Soil Gas Probe
Stainless Steel Soil Gas Probe

User Manual

DURRIDGE
Radon Capture & Analytics

WARNING

The Soil Gas Probe is a heavy and long piece of steel. It has a sharp, hardened point. Take great care in handling it. Before and during use please make sure that the point does not pierce or damage any person, animal or object of value.

Please make sure that no gas, electric, telephone, water, sewage or other service lines or any objects of value lie in the path of the Soil Gas Probe before driving it into the ground.

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1 INTRODUCTION

It is essential to avoid outside air contamination when measuring radon in underground air. DURRIDGE offers two heavy-duty Soil Gas Probes for this purpose: the Hardened Steel Soil Gas Probe, and the Stainless Steel Soil Gas Probe.

The components for each Soil Gas Probe are shown in Figures 1 and 2 on the following page. Make sure you have all of the Soil Gas Probe components, as well as a RAD7 and Laboratory Drying Unit (sold separately).

1.1 Hardened Steel Soil Gas Probe

The DURRIDGE Hardened Steel Gas Probe offers simple, effective sampling in firm soil. It consists of a 36" (91 cm) hollow steel tube with gas inlet holes, capped with a screw-on tip of wider diameter to prevent soil from entering the sampling tube. Also supplied with the Probe is a Water Stop assembly consisting of a Vacuum Gauge mounted on a Water Shutoff Valve. An included slide hammer may be used to drive the Probe into the ground. A 10 ft (3.05 m) length of plastic tubing and a roll of Teflon tape are provided, along with the necessary adaptors, and a roll of Teflon tape to seal the connections.

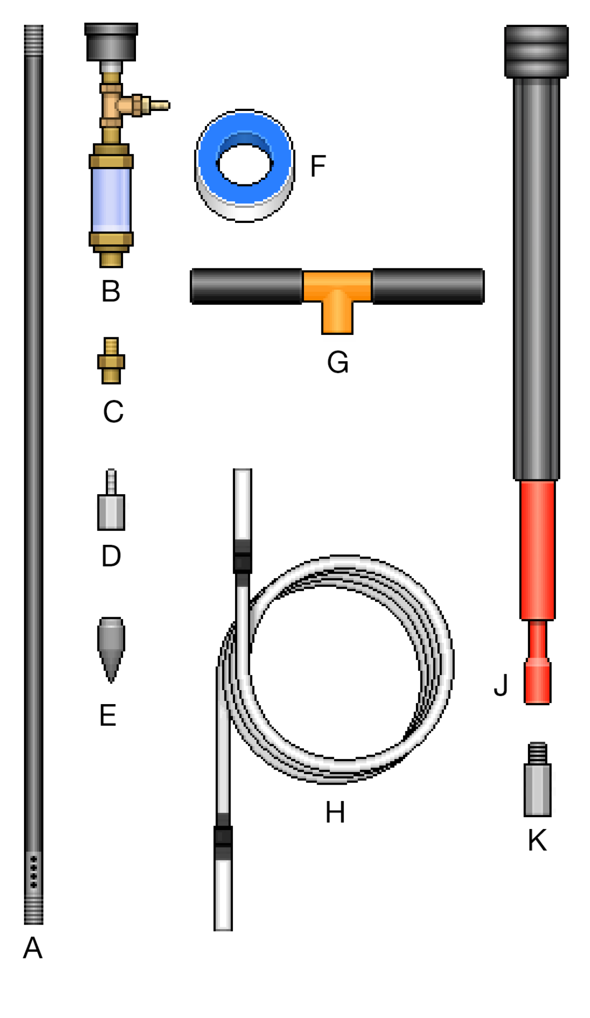
To assemble the Hardened Steel Soil Gas Probe, screw the Probe tip onto the bottom of the shaft, (the end with holes on the side). Gather the Slide Hammer, Water Stop, and T-Handle. These will be used for Probe insertion, soil gas sampling, and Probe removal, respectively.

1.2 Stainless Steel Soil Gas Probe

The Stainless Steel Soil Gas Probe is suitable for regular soil that is not extremely firm. The Probe assembly consists of a 14" (35.6 cm) long Probe Tip and a 36" (91.4 cm) long Probe Extension, both of which contain Rod Inserts. Also included is a T-handle and a barbed hose adapter. There are two couplers, one for the T-handle and the other between the Probe Extension and the Probe Tip. The two Rod Inserts also have a coupler to join them together. The Stainless Steel Soil Gas Probe also contains a Water Stop, which consists of a Vacuum Gauge mounted on a Water Shutoff Valve. Additionally, 10 ft (3.05 m) of plastic tubing, an adapter to 5/16" (0.8 cm) inner diameter, and a roll of Teflon tape are provided.

To assemble the Stainless Steel Soil Gas Probe, first wrap Teflon tape around the threads of the 14" Probe Tip and one end of the 36" long Probe Extension. Join the two together with the coupler provided. The coupler should be connected to the end of the Probe Extension containing the shorter length of screw threads. Connect a second coupler to the leading end of the longer insert. That way it will be possible to grip the Internal Rod and pull it from the assembled Soil Gas Probe when necessary. Make sure the threaded joints are airtight; this equates to approximately 30 lbs of tightening force. Couple the two Rod Inserts together and slide them inside the Soil Gas Probe. Attach the T-handle coupler to the end of the Probe, and then attach the T-handle itself. Keep the Water Stop assembly nearby; it will be needed once the Probe has been inserted into the ground.

1.3 Soil Gas Probe Components Table



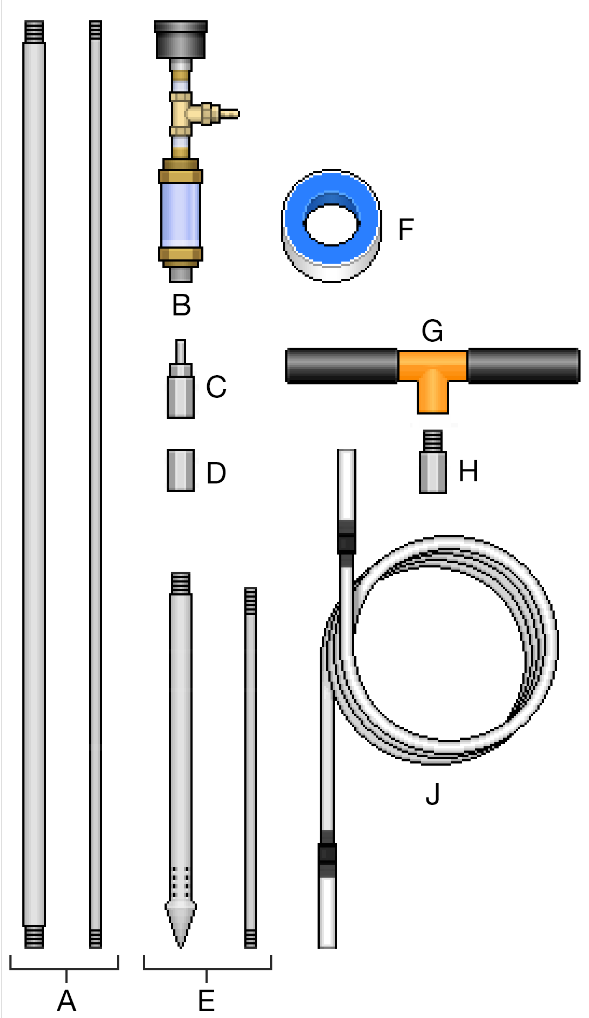


Figure 1 **Hardened Steel Soil Gas Probe Components**	**Figure 2** **Stainless Steel Soil Gas Probe Components**
A. Soil Gas Probe Main Shaft (5/8” x 36” Probe Extension with milled inlets)	A. Probe Extension - 36” with Rod Insert
B. Water Stop - Contains Vacuum Gauge and Water Shutoff Valve	B. Water Stop - Contains Vacuum Gauge and Water Shutoff Valve
C. B-RHF x 1/4” NPTM Adaptor	C. Hose Adapter
D. (5/8” fem fine threads) Original Barbed Adapter for 3/16" ID	D. Coupler for Extension Tube
E. 5/8” Extendible Tile Probe Tip	E. Probe Tip - 14” with Rod Insert
F. Roll of Teflon Tape	F. Roll of Teflon Tape
G. 10” T-Handle w/Grips, 5/8" Thread	G. 10” T-Handle w/Grips, 5/8" Thread
H. Tubing Set (10ft, 1/8in inner diameter)	H. Coupler for T-Handle
J. Regular Slide Hammer, 5/8" Thread	J. Tubing Set (10ft, 1/8in inner diameter)
K. 5/8” Male Thread x 5/8” Extendable Adapter	

2 SOIL GAS PROBE PLACEMENT

To place the Soil Gas Probe, first look for a location well above the water table, where the soil is uniform and generally free of rocks.

Caution: If at any point the Probe Tip strikes a rock, remove the Probe and choose a new location at least ten inches (25 cm) from the earlier spot. In this situation it is better to withdraw the Soil Gas Probe and find a new spot rather than to try to force the Probe past the rock. Use special care to avoid rocks when using the Stainless Steel Soil Gas Probe.

2.1 Hardened Steel Soil Gas Probe Placement

Attach the included Slide Hammer to the top of the Probe shaft using the supplied connector. Hammer the Probe into the ground to the depth required for sampling. Alternatively, push the Probe into the ground using the included T-Handle. Then screw the Water Stop assembly onto the top of the Soil Gas Probe.

When the measurement is finished, the Hardened Steel Soil Gas Probe should be removed by attaching the T-Handle and pulling upward.

2.2 Stainless Steel Soil Gas Probe Placement

Place the tip of the Stainless Steel Soil Gas Probe at the insertion spot. Hold the Probe vertically and apply downward pressure on the T-handle while rotating it slowly in a clockwise direction to ensure that the Probe Tip remains firmly joined to the Probe Extension. (For the same reason, the Soil Gas Probe should also be rotated clockwise when being removed from the ground.) Please be careful not to bend the Probe, as there is no warranty coverage for misuse.

If the ground is firm it may be difficult to insert the Probe to a sufficient depth, and in this case the Hardened Steel Soil Gas Probe should be used instead of the Stainless Steel Soil Gas Probe.

Alternatively an optional Pilot Rod may be used to create a hole, into which the Stainless Steel Soil Gas Probe may be inserted. At the point where you wish to insert the Soil Gas Probe, first hammer the Pilot Rod down to the desired depth, then pull it out and insert the Soil Gas Probe. It should go in without too much difficulty. Once in place, the depth of insertion may be calculated by measuring the height of the T-handle above the ground and subtracting that height from the overall length of the Probe.

3 CONNECTION TO THE RAD7

To prevent fresh air from leaking down the outside of the Soil Gas Probe, thoroughly tamp down the ground around the Probe. Alternatively, pour some Plaster of Paris around the Probe and down into the hole around the Probe to seal it in, being careful not to the let the Paster of Paris penetrate too far into the ground. Leakage of fresh air into the sample acquisition path or down the outside of the Probe to the sampling point can be a major source of error in the measurement.

3.1 Connection to the RAD7

To connect the Soil Gas Probe to the RAD7, first remove Slide Hammer or the T-handle and T-handle coupler as necessary. A pipe wrench may be used to hold the Probe if helpful. Care should be taken to avoid damage to the tube and to the threads. Wrap Teflon tape around the thread on the Probe, applying the tape clockwise looking from above - that is in the same direction as the adapter when it is screwed on. Apply only enough teflon tape to cover the threads, otherwise the threads will be gummed up and a leak could occur.

Screw on the Water Stop assembly tightly. If there is a leak at this connection, ambient air will be sucked into the Probe, diluting the soil gas and reducing the radon concentration in the air sample delivered to the RAD7.

3.2 Tubing Connections

Attach one end of the supplied plastic tubing to the hose adapter on the Water Stop. Connect the other end of the tubing to the Laboratory Drying Unit. (Note that this connection should go to the upstream connection on the Laboratory Drying Unit; that is the one closest to the screw cap.) An optional dust filter may be installed if necessary, as shown in Figure 3 on the following page.

If a DRYSTIK accessory is being used to remove moisture from the air, it should be connected between the Soil Gas Probe and the Laboratory Drying Unit. For more details, see Section 5.

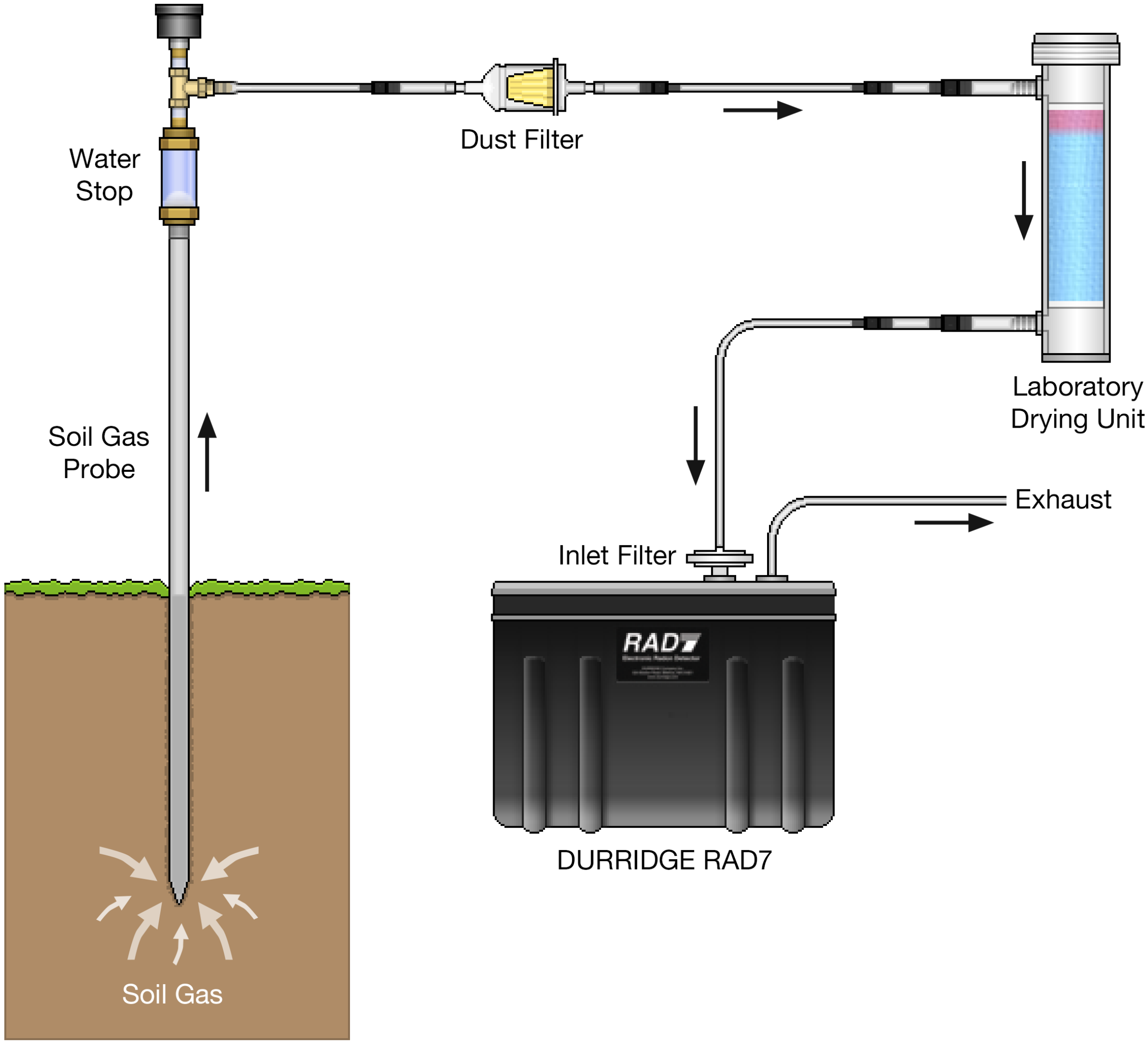


Figure 3 Soil Gas Probe standard configuration

4 MEASUREMENT

There are three modes of measurement used with the Soil Gas Probe. One is by obtaining a sample in GRAB mode; another by continuous monitoring using the standard protocol; and the third by operating the RAD7 in THORON mode, with the pump running continuously.

Before starting any measurement, make sure the RAD7 memory and run number are not full. (Press `Data, Free [ENTER]`) and read the number of free cycles - it should be more than 100, (Then press `Data, Read [ENTER]`) and see the run number of the last run - it should be less than 90. If the space or available run numbers are too few, download the data from the RAD7 to a computer and then erase the RAD7 memory (Press `Data, Erase, Yes, [ENTER]`).

4.1 GRAB Protocol

For GRAB protocol, it is necessary first to purge the RAD7 for ten minutes or more with dry, fresh air, before connecting the Probe. Disconnect the Probe, connect the Laboratory Dying Unit, and start purging (`Test, Purge, [ENTER]`). After at least 5 minutes push `[Menu]` to stop the purge. Let the RAD7 continue purging until the relative humidity drops below 6%.

If the RAD7 was previously used to measure a high radon concentration, it would be prudent also to measure the count rate in window A while the Sniff reading was continuing. Go to the fifth status window (from the third, just `Right Arrow, Right Arrow`). The lefthand number is the count rate. Typically, 0.25 cpm would be equivalent to a radon concentration of 1 pCi/L, or about 40 Bq/m^3. Soil gas is seldom less than 100 pCi/L, so if the count rate in window A has dropped to below 0.5 cpm and the humidity to below 6%, the RAD7 is ready to make the next GRAB protocol reading.

Set the protocol to "Grab" (`Setup, Protocol, Grab [ENTER]`) then turn off the RAD7. Connect the tubing to the Probe. Switch on the printer, switch on the RAD7 and let the printer print out a header for this measurement. Check the header to make sure the setup is what is required. Go to `Test, Start` and push `[ENTER]` to start the measurement. The RAD7 pump will run for five minutes. The instrument will wait another five minutes and then count for four five-minute cycles. At the end of the 20-minute period, the RAD7 will print out a summary of the measurement, including an average radon reading in the soil gas from the four 5-minute cycle measurements. This method gives a quick reading and uses the least amount of soil gas. The accuracy will depend on the radon concentration, and would typically be better than +/- 10%.

After the five minutes pumping at the start of the GRAB protocol, the RAD7 may be disconnected from the Probe and everything moved to a new site for the next measurement while the RAD7 continues to analyze the grab sample just taken, which will still be in the measurement chamber. When the analysis is completed it is necessary to purge the RAD7 again in preparation for the next sample.

If necessary, the soil gas sample can be pumped out of the ground by a sampling pump, and fed to a Tedlar sample bag for later analysis by the RAD7. In this case the sample bag should contain at least 5 liters of soil gas from the sampling point. Later when analysis is made with the RAD7, the instrument should first be purged thoroughly, so that the humidity inside the instrument drops below 6%. Then the bag should be connected to the drying unit and a grab sample protocol measurement started. The result should be corrected for the decay of radon in the sample due to the delay before analysis. Note that it is impossible to measure thoron with a grab sample due to thoron's very short half-life.

4.2 Continuous Monitoring

Continuous monitoring is a simple method of measuring the soil gas radon concentration and provides time resolution in the event that the weather or barometric pressure is changing. The setup is as above, but the RAD7 preset protocol may be set to `[Weeks]`. It is still desirable to purge the RAD7 before starting the measurement, but the continuous monitoring process will itself serve to purge the instrument and dry it out. In this protocol, once the relative humidity drops below 10%, the RAD7 will pump for the first five minutes of every two-hour cycle, and then for only one minute in every five.

A reading is printed out and stored in the RAD7 memory every two hours. The first reading will be slightly (5%) low because, due to the 3 minute half life of 218-Po, its decay rate takes over 10 minutes to reach equilibrium with the parent radon decay rate. The accuracy of the readings will be +/-5% for the typical high radon activity concentrations found in soil gas.

This method will draw from the sampling point a volume of soil gas equal to the flow rate of the pump (L/min) times 28 minutes, in every two-hour cycle. (Five minutes at the start and then one minute in every five for the rest of the cycle.) In a typical porous soil the pump flow rate may be around 0.5 L/min. So the soil gas extraction rate will be around 14 litres every two hours.

For continuous monitoring, it is important that the sample air has time to come into secular equilibrium with the parent radium 226 in the soil before it is drawn into the RAD7. With a Probe depth of 3 ft (1 m), the volume of the sphere from which gas is drawn, and which just touches the soil surface, is roughly 4190 L. If the porosity of the soil is 50%, the volume available for occupation by soil gas is 2095 L. With a soil gas draw rate of 14 L every 2 hours, it will take approximately 12.5 days for air from the surface to be drawn down through the soil and into the probe tip. After 12.5 days in contact with the radium in the soil, this air will contain radon at 90% of the equilibrium activity concentration. So, a sampling depth of 3 ft (1 m) may be considered sufficient for indefinite continuous monitoring. This analysis assumes isotropic air draw (no preferred direction). In practice, soil is seldom perfectly homogeneous, and instead contains preferential pathways of higher permeability along which air more easily flows. One likely preferential pathway is along the length of the probe itself, which is why it is so important to ensure that there is a good seal along the full length of the Probe. See Figure 4, below.

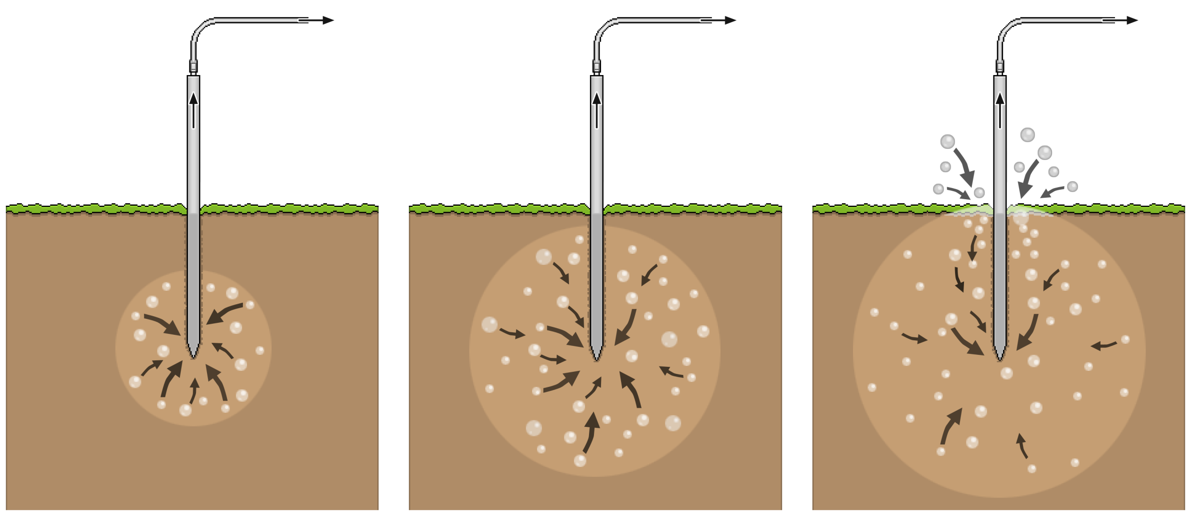


Figure 4A
Soil gas from a spherical region surrounding the Probe tip is drawn into the RAD7.

Figure 4B
The sphere expands toward the surface.

Figure 4C
The sphere touches the surface, pulling fresh air into the soil. This is not a problem if the Probe is sufficiently deep that air takes at least ~ 2 weeks to reach the Probe tip.

The cycle time can be changed as required. Longer cycle times would use less memory and take slightly less soil gas per hour out of the ground. Shorter cycle times would give higher time resolution but require deeper penetration to avoid dilution with ambient air filtering down through the soil to the sampling point in less than three weeks.

4.3 Thoron Protocol

Thoron protocol uses 5-minute cycles and prints out both the radon and thoron concentrations at the end of every cycle. However, thoron has a short half-life (one minute) so the pump has to run continuously. For radon the first two cycles should be ignored while the radon reading reaches equilibrium. Thereafter, there will be a reading every five minutes. The print format should be set to `[SHORT]` to save paper. The thoron reading will be valid for all except the first cycle.

Because of the short thoron half life, some estimate of sample acquisition time is needed if the thoron readings are to be properly interpreted. During acquisition, a flow meter may be connected to the RAD7 outlet. This will show how fast the air is flowing from the sampling point. An estimate of the sample acquisition volume will then allow a calculation of the time delay between sampling and measuring. Call the RAD7 one litre, and the Laboratory Drying Unit one litre. The Soil Gas Probe has a volume of around 150 ml while about 10 ft of 3/16" tubing has another 50 ml for a total of 200ml. The total acquisition delay, then, will be 2.2 litres divided by the flow rate. If that is 0.5 L/min, the delay will be 4.4 minutes. The thoron sensitivity stored in the RAD7 anticipates an acquisition delay of about 1.4 minutes, so the extra delay in this application will be about 3 minutes. During that time, the thoron will decay to about 0.125 of its original concentration, so the thoron reading should be multiplied by 8 to give the thoron concentration at the sampling point.

The final value of the thoron concentration has large uncertainties and the absolute accuracy is probably no better than +100/-50 %. For a soil gas radon concentration of 200 pCi/L (8,000 Bq/m^3) the 5-min radon readings however, after the second 5-minute cycle, will have a precision of +/-10 % (95% confidence interval). Higher radon concentrations in the soil will improve the accuracy of the short term readings.

Averaging several readings over a longer period than five minutes will also give a more precise measurement.

One disadvantage of the Thoron and Sniff protocols is that the pump runs continuously, so that much soil gas is drawn from the sampling point. Compared with 'Weeks' protocol, Sniff protocol will draw nearly five times as much gas per hour. This means that the sphere of gas taken from the sampling point will be 1.7 times the radius of the sampling sphere for 'Weeks' protocol in the same total time. So, after a while, ambient air may filter down through the soil to the sampling point before its radon can reach equilibrium with the surrounding radium 226. This may thus dilute the radon concentration. On the other hand, thoron has such a short half life (less than 1 minute) that if the sampling point is deeper than 2 ft (25 cm) the thoron in any air filtering down from the surface will have more than sufficient time to reach equilibrium with the radium 224 in the soil. So, with a sampling point 2 ft or more below the surface, the thoron concentration can be monitored indefinitely, even as the radon readings start to drop due to dilution with fresh air from the surface.

5 SOIL GAS MONITORING WITH DRYSTIK

5.1 Overview

The DURRIDGE DRYSTIK removes moisture from the air entering the RAD7, improving the instrument's accuracy and prolonging the life of the desiccant. The DRYSTIK has a built-in pump with a Duty Cycle Controller, which can be configured to cycle the pump on and off at regular intervals, controlling the effective air flow rate. The Duty Cycle Controller enables the average air flow rate to be reduced enough to prevent fresh air from diffusing down through the soil to the sampling point, facilitating the long-term monitoring of radon concentrations in soil gas. With the Duty Cycle set appropriately, continuous monitoring of soil gas from one sample point may be performed indefinitely.

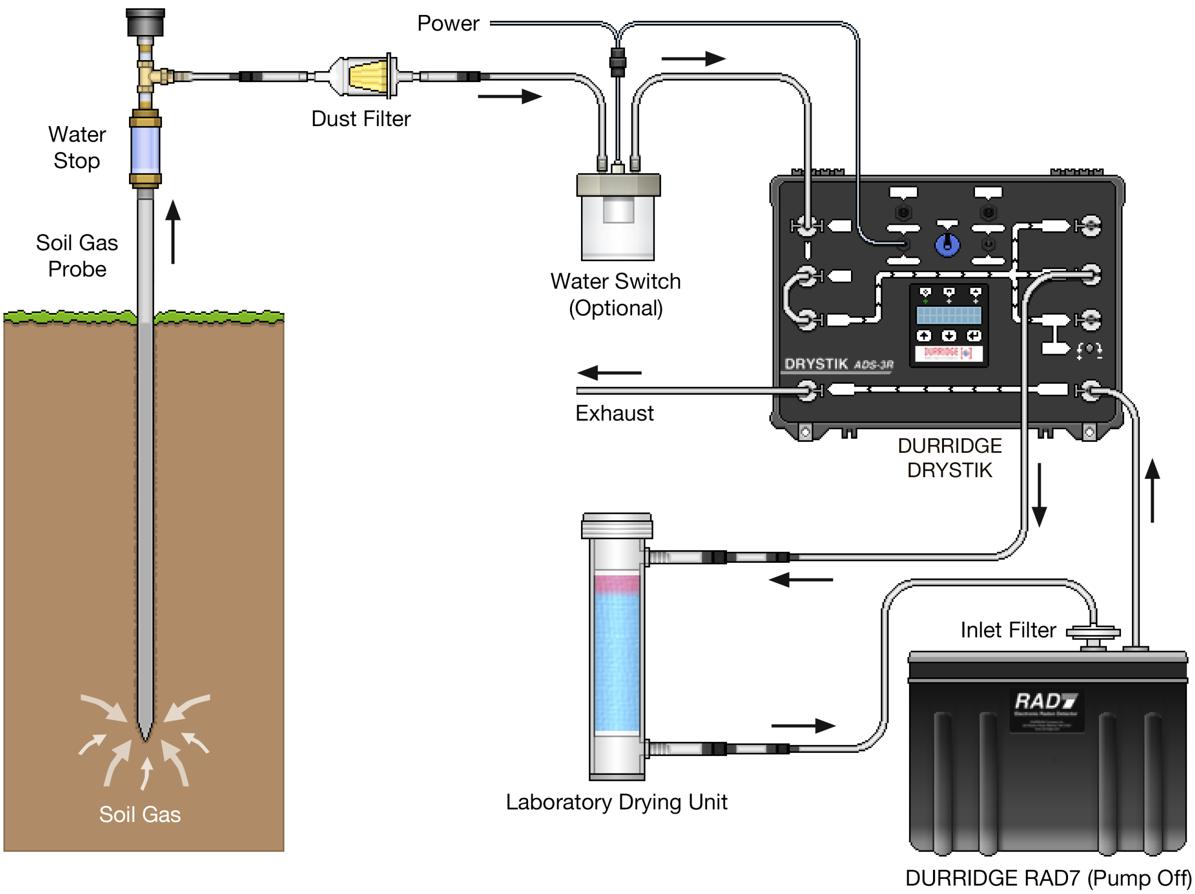


Figure 5 Soil Gas Probe configuration with DRYSTIK

An optional Water Switch can be installed upstream of the DRYSTIK, as shown in Figure 5. If water enters the Water Switch the power supply to the DRYSTIK's pump is automatically cut. Please see the Water Switch user's manual for detailed instructions.

5.2 Maximum Flow Rates

The maximum permissible flow rate depends on the porosity of the soil and the depth of the Soil Gas Probe. The half life of radon is 3.8 days. The air sample may be considered to be drawn from a sphere centered on the sampling point (see Figure 4 in Section 4.2). If the sphere takes two weeks to grow before it just touches the ground surface, then it takes two weeks for air to filter down to the sampling point. We may then accept that the air at the sampling point continues to stay very close to equilibrium with the radium in the soil.

For a Probe depth of D cm, the maximum sphere volume will be $4\pi D^3/3{,}000$ litres. If the porosity of the soil is 50%, the corresponding air volume will be $2\pi D^3/3{,}000$. Two weeks is about 20,000 minutes. So the average flow rate must be less than $2\pi D^3/60{,}000{,}000$ litre/min. If we allow that 2π is close to 6, the rate must be less than $D^3 * 10^{-7}$ litre/min where D is the Probe depth in cm.

The maximum flow rate, F, is roughly given by:

$F = D^3 / 10^7$ litre/min

where D is the Probe depth in cm.

If, for example, D is about two feet, or 61cm, the maximum flow rate to meet this criterion for continuous sampling will be 0.022 L/min. Uncertainties in the porosity and other assumptions may make it advisable, for this depth, to keep the flow rate less than 0.01 L/ min.

Typically, the ON flow rate of the DRYSTIK is set to about 0.2 L/min to match the average flow rate of a RAD7 where the pump, pumping at 1 L/min, runs for one minute in every five. On the DRYSTIK ADS-3 or ADS-3R simply select the desired 'Soil Gas' profile. On the DRYSTIK ADS-2, the Duty Cycle should be set to about 5%, or to an ON time of 60 seconds and an OFF time of 1200 seconds. This produces an average flow rate of 0.01 L/ min from the Soil Gas Probe.

With a Probe depth of 61 cm and a porosity of 50%, this setting will enable continuous, indefinite sampling of the soil gas for radon concentration without significant dilution of the sample by fresh air diffusing down from the surface. Increasing the depth by 26%, to 77 cm, will allow double the flow rate, assuming uniform soil porosity down to 2 m or so.

5.3 Minimum Flow Rates

Consider the air flow rate against the 3.8 day half life of radon. If the air sample takes more than an hour or two to travel from the sampling point to the RAD7 measurement chamber, there may be enough sample loss to call for a sample decay correction. With a Laboratory Drying Unit in the air path, you can assume a sample path volume of about 2 litres, plus more if the Probe is so far from the RAD7 that the volume of the tubing becomes significant. If the Probe is close to the RAD7 (within about 10m) and the maximum acceptable delay before corrections have to be applied is 2 hours, then the minimum permissible flow rate will be 2L/120min, or 0.016 L/min. Flow rates lower than this will require a correction factor for radon decay, as discussed below.

5.4 Correcting for Very Low Flow Rates

In the examples above, it may be seen that for a Probe depth of 61 cm, to avoid dilution of the air sample after a week or two of sampling, a flow rate of no more than 0.01 L/min is desired, but with this flow rate the sample will lose some radon by radioactive decay during sample acquisition.

One solution to this problem would be to increase the sampling depth to 2 ft 6 inches (77 cm) or more and draw at an average flow rate of 0.02 L/min. This may be obtained with a duty cycle of 10% (for example, an ON time of 3 sec. and an OFF time of 30 sec.) with a flow rate of 0.2 L/min.

Another solution would be to leave the sampling point at 2 ft (61 cm), draw at an average flow rate of 0.02 L/min, taking note of any long-term change in the average after one week of sampling, and then apply a correction for fresh air infiltration to readings after three or four weeks of sampling.

A third solution would be to keep the Probe at 2 ft (61 cm) and keep the flow rate at 0.01 L/min. Assuming a sample volume of 2 L, this will cause an acquisition time of around 2/0.01 min = 200 minutes. In 200 minutes, about 2.5% of the radon will have been lost by radioactive decay. A factor of 1.025 may therefore be applied to the reading to correct for the loss.

5.5 Measuring Thoron in Soil Gas with the DRYSTIK

Thoron has a half life of less than a minute. Using the DRYSTIK with a typical configuration will inevitably cause sample acquisition delays far in excess of one minute. Therefore changes are needed for the measurement of thoron.

To measure thoron in soil gas, the DRYSTIK's High Airflow port should be used and the pump should be set to run continuously. The flow rate will be at least 1 L/min if the soil is porous.

At a flow rate of 1 L/min, with a Laboratory Drying Unit in the sample path, the sample delay increase over standard thoron protocol will be about 1 minute. Therefore the thoron readings should be multiplied by a factor of 2. If the flow rate is reduced and/or the sample volume is larger, a greater correction factor will be needed. CAUTION: increasing the airflow rate may increase the risk of water entering the RAD7.

6 CONTINUOUS LONG-TERM OPERATION

It has been proposed that continuous monitoring of soil gas for radon may be a useful technique for predicting earthquakes. For this purpose, an array of Soil Gas Probes and RAD7s covering a wide area may be more informative than a single sampling point. Such an array can be more easily monitored if the RAD7s are moved to a central location, and connected to the respective Soil Gas Probes with long lengths of narrow plastic tubing. The RAD7s can be monitored in real time by connecting them to a computer running CAPTURE software.

Alternatively, the RAD7s may be located near the respective Soil Gas Probes, and Bluetooth adaptors or wireless networking accessories can be connected to the RAD7s. In this way the computer running CAPTURE does not have to be located near the RAD7s. Please refer to the RAD7 and CAPTURE software manuals for more details.

7 CARE AND MAINTENANCE

To ensure the longevity of the Soil Gas Probe, avoid hitting rocks with excessive force. Remove all dirt and contaminants from the Probe after each use and store the Probe components in a dry place. Applying oil to the Probe will help to prevent rust from forming. This is particularly important for the Hardened Steel Soil Gas Probe, which is not constructed from rust-resistant material.

If the Soil Gas Probe is being disassembled between uses, the teflon tape should be removed from the threads, and reapplied before the next project.

For technical assistance please contact DURRIDGE Company at support@durridge.com.

8 SPECIFICATIONS AND COMPONENTS

8.1 Soil Gas Probe Specifications Table

	Hardened Steel Soil Gas Probe	Stainless Steel Soil Gas Probe
Suited For	Hard packed soil	Soft soil
Probe Material	Hardened Steel	Stainless Steel
Water Stop	Included	Included
Insertion Method	Use Slide Hammer or push into ground using T-Handle	Push into ground using T-Handle
Removal Method	Pull out using T-handle	Pull out using T-handle
Hose Adapter	Female NPT thread and O-ring	Female Hose Adapter
Maintenance	Clean and oil after use	Basic cleaning recommended
Additional Notes	—	Metal joints may be taped to prevent outside air from entering

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