WATER PROBE

Passive, Slow Response Radon in Water Accessory for the RAD8

User Manual

DURRIDGE
Radon Capture & Analytics

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CAUTION

There is a potential for biofouling to occur in long-term monitoring applications. The Water Probe should therefore be inspected periodically to ensure that there is good contact between the radon exchange tubing and the surrounding water.

INTRODUCTION

The Water Probe is an accessory for the Durridge RAD8 Continuous Radon Monitor. It is a device to bring the radon concentration in a closed air loop into equilibrium with the radon concentration in the body of water in which it is submerged. It consists of a length of hydrophobic yet gas-permeable membrane tubing, called an "exchanger", that brings the radon in a closed air loop into equilibrium with the surrounding water. The radon in the air loop is monitored continuously by the RAD8.

The partition coefficient, the ratio of radon concentration in the water to that in the air at equilibrium, is determined by the temperature at the air/water interface. This temperature is measured with a temperature probe inserted into the water. As an example, at a water temperature of 10 degrees Celsius, the partition coefficient is about 1:3. That means there is a three-times-higher concentration of radon in the air than in the water, so there is, in effect, a gain of three times in the sensitivity of the system to radon in water, compared to radon in air.

It takes time for the water to deliver radon to the air loop and for the RAD8 to respond to the changed radon concentration. With optimum configuration the response time of the system is around 3 hours.

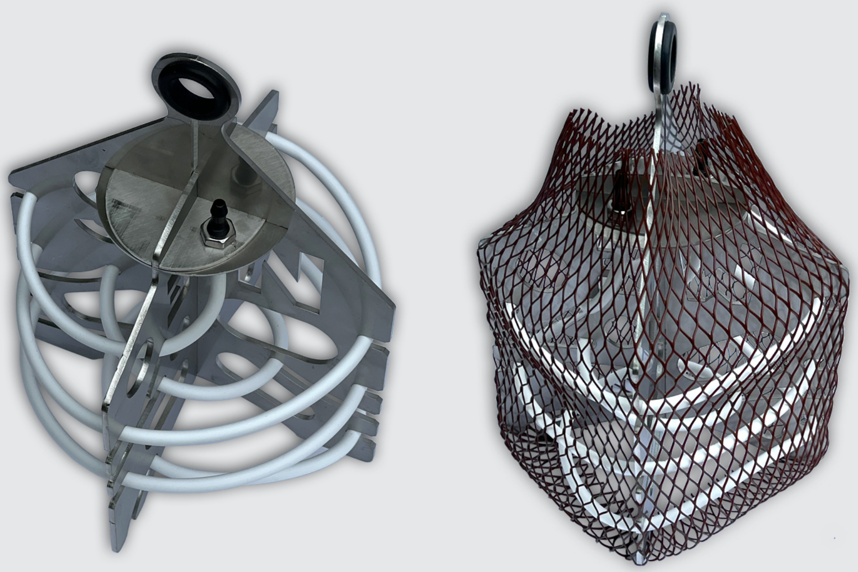

Figure 1 Assembled Water Probe (left); Water Probe with netting (right)

1 WATER PROBE SETUP

1.1 Connections

1.1.1 Air Loop

Two pieces of tubing connect the RAD8 and drying unit to the Water Probe air/water exchanger, as shown in Figure 2. These two pieces of tubing can be several tens of meters long. The standard tubing supplied with the RAD8/Water Probe is sufficient for a connection up to ten feet between the exchanger and the RAD8.

Connect the outlet of the RAD8 to either of the Water Probe air ports. For this, the 5ft long, 3/16" ID tubing, with a 1/8" ID section at one end, may be used. The 1/8" end fits on the RAD8 outlet, and the 3/16" end fits the Water Probe. Connect the other 3/16" hose connector between the other Water Probe air port and the Laboratory Drying Unit.

Connect the other end of the Laboratory Drying Unit (there should be at least one inch of blue desiccant left at this end) to the air inlet filter (with 1/8" ID tubing at the filter end), which is then placed on the RAD8 inlet. The white plastic barbed fittings ensure an airtight connection.

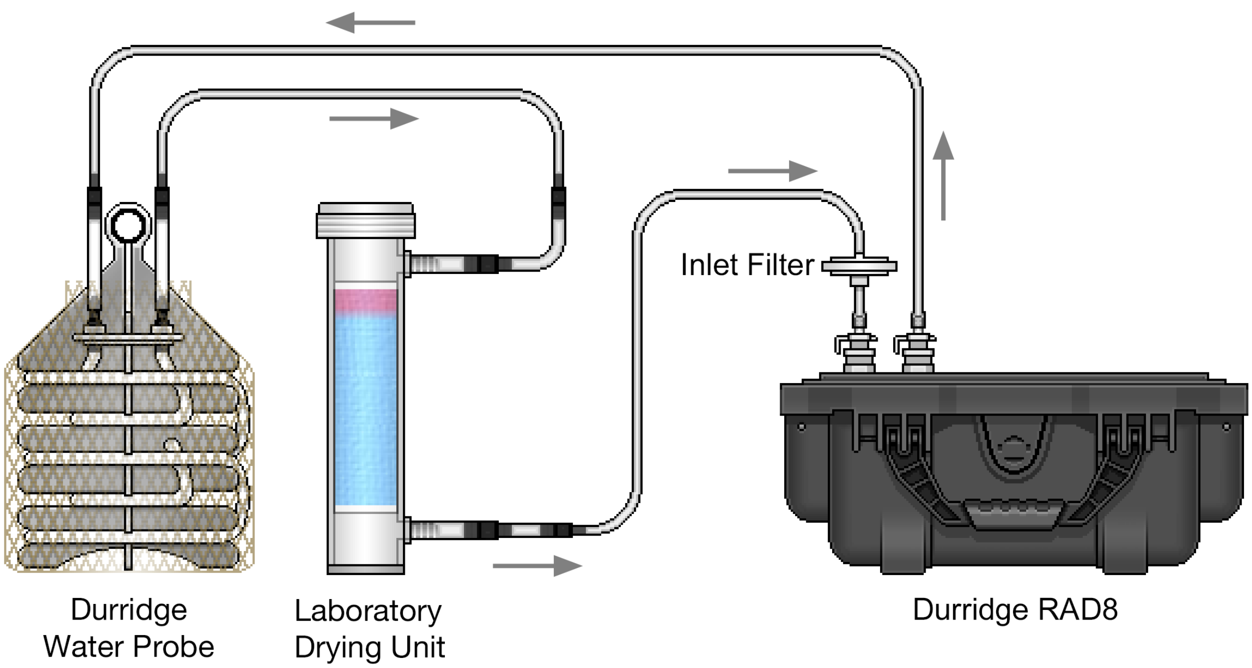

Figure 2 RAD8 Water Probe Standard Setup

1.1.2 Drystik

Please note that the above instructions are for use of the Water Probe without a Drystik humidity exchanger. A Drystik, if available, should be placed between the exchanger and the Laboratory Drying Unit, and the outer sheath should be purged with dry air from the RAD8 outlet. See Figure 3 in Section 3. More details are provided in the Drystik user's manual.

1.1.3 RAD8 and Exchanger Location

Place the RAD8 on a clean, dry surface.

1.1.4 Temperature Probe

If you are using a Temperature Probe (sold separately), it should be inserted into the water as close as possible to the membrane tubing where the water-air radon exchange is taking place. The probe should be plugged into the Temperature Data Logger, which should be put in a plastic bag to protect it, once it has been launched.

Cycle Count:	0, for continuous operation
Cycle Time:	1 hour
Pump Mode:	Standard (40% duty cycle)
Analysis Mode:	Auto
Thoron Display:	Off

1.2 Water Flow and Source

The Water Probe should be fully submerged below the surface of the water, which should be clean and free from debris. The flow of water through the Water Probe should be sufficient to replace the water around the device on a timescale significantly shorter than its response time (roughly 3 hours). This condition is easily met for any flowing body of water, but care should be taken when planning measurements of stagnant water.

1.3 Air Flow and Pump Setting

For proper air flow, the RAD8 Pump Mode should be set to Standard. The pump, in Standard operation, pumps for the first two minutes in every five (that is, with a 40% duty cycle).

1.4 Protocol

1.4.1 Analysis Mode and Cycle Time

First, please read the RAD8 manual and learn how to use the instrument for measurement of radon in air.

Set the RAD8's Analysis Mode to Auto, which starts off calculating the displayed radon concentration using Rapid Analysis Mode (using polonium-218 decays only), and switches automatically to Precise Analysis Mode (using the counts from both polonium-218 and polonium-214 decays) after 3 hours, once secular equilibrium between radon-222, polonium-218 and polonium-214 has been reached. Due to the radioactive half lives of intermediate radionuclides in the radon decay chain, the RAD8's response time in Precise Analysis Mode is around 3 hours. Short-term changes in radon concentration are not usually of interest in long-term monitoring applications, but in order to minimize the response time, the RAD8's Analysis Mode may instead be set to Rapid. In that case, the response time of the entire apparatus is limited by the exchange of radon from the water to the air, rather than by radioactive decay. Note that the RAD8's Rapid Analysis Mode sensitivity is approximately 50% of its Precise Analysis Mode sensitivity. When analyzing RAD8 data using Durridge Capture software, the Analysis Modes can be freely switched between.

The length of each Cycle is chosen by the user. Since the air-water equilibration takes 2 hours or more, there is little to be gained by choosing a Cycle Time shorter than, say, 1 hour. RAD8 data is stored internally with 5-minute time resolution. So, like Analysis Mode, Cycle Time can be freely changed when analyzing the data with Capture.

1.4.2 Example Water Probe Protocol

Switch on the RAD8 and navigate to `Start Test → Manual Config`. Enter the following settings:

1.4.3 Custom Protocol

After setting the test parameters in Manual Config, select `Save As` to create a custom protocol with a name of your choice. This can be recalled conveniently from the `Start Test → Custom Protocol` menu for subsequent tests.

2 MEASUREMENT PROCEDURE

2.1 Start Up

2.1.1 Temperature Probe

If you are using a Temperature Probe (sold separately), load the Temperature Logger software and connect the Temperature Logger to the PC using the serial cable provided. Configure the logger to take temperature readings at frequent intervals (these may be far more frequent that the RAD8 test cycles.)

Choose the second (external) temperature sensor. Connect the Temperature Probe to the logger and note that when you hold the probe the indicated temperature rises.

When everything is set, begin recording. The logger's LED may flash periodically. Once the logger has begun running, you may remove the serial cord from both the logger and the PC.

Warning! Make sure that previous temperature data has been downloaded before launching the logger. The launching process may erase previous data.

Insert the Temperature Probe into the water next to the Water Probe.

2.1.2 Start Measurement

Configure the RAD8 as suggested in Section 1.4.2, or recall a previously saved Custom Protocol as shown in Section 1.4.3. Start the test.

2.2 Speed of Response

2.2.1 Measurement in Progress

The instrument is now measuring the radon in the closed air loop that includes the Water Probe's membrane tubing. With high radon activity concentration in the surrounding water it will take half an hour or more before there is much of a reading, and roughly 3 hours before you can rely on the count rate being close to the equilibrium value. After that you need to accumulate sufficient counts for the precision desired. For example, 100 counts would give a reading with a standard deviation of 10%. At very low concentrations, it may take hours, and averaging over many cycles, to reach a sufficiently precise value.

2.2.2 Influencing Factors

There are two processes requiring time. One is for the air in the closed loop to approach equilibrium with the surrounding water and the other is for the RAD8 to respond to the changed radon concentration in the air loop. The first is a property of the exchange tubing and the second is determined by the half life of the first daughter of radon, namely polonium-218 (Rapid Analysis Mode), or the half lives of intermediary 214-lead-214 and bismuth-214 (Precise Analysis Mode). See the RAD8 manual, Section 4 for more details.

2.2.3 Air Flow Rate

There is also a small contribution to the response time from mixing of the radon-laden air around the closed air loop. This depends on the duty cycle of the RAD8's pump. However, even with Pump Mode set to Standard, this delay is only around 10 minutes, which is small compared with the 3-hour timescale for radon exchange across the membrane tubing and the 3-hour 95% response time of the RAD8's Precise Analysis Mode. For this reason, it is almost always sufficient to set the Pump Mode to Standard, in which the air is circulated around the closed air loop for two minutes in every five. Air will remain stationary in the Water Probe for three minutes before moving through the Laboratory Drying Unit and into to the RAD8. While in the Water Probe, the stationary air may approach equilibrium with the water thus inhibiting further radon transfer from the water to the air. It will be several minutes before that parcel of air returns to the Water Probe. We can therefore estimate that the response time of the system will be increased by a few minutes if Pump Mode is set to Standard rather than On.

Having Pump Mode set to Standard would normally be associated with having a RAD8 Cycle Time of 30 minutes or longer. So, an extra few minutes on the response time will not be excessive.

2.2.4 RAD8 Analysis Mode

In Auto (the default) Analysis Mode, the RAD8 will automatically switch from using Rapid to Precise Analysis Mode after three hours into the run. This is to take advantage of the additional counts provided by the polonium-214 decays ('C' Window) that will, by then, have approached equilibrium with the (steady) radon concentration in the measurement chamber.

For slow, long-term measurements with long Cycle Times, setting Analysis Mode to Auto is appropriate. The RAD8's response time will be approximately three hours.

For fastest response, Analysis Mode can be set to Rapid. The RAD8 will then always use only the polonium-218 decays ('A' Window) when calculating its output radon concentration, giving it a 13-minute 95% response time. However, the improvement in overall response time is marginal due to the 3-hour timescale for radon exchange across the membrane tubing, and this has to be weighed against the reduction in sensitivity (and consequent reduction in precision) that comes with switching from Precise to Rapid mode.

2.3 Long-Term Measurement

2.3.1 Desiccant

As set up, above, the system will continue making measurements indefinitely. There are, however, various resources that are being used up in the process, and which must be replenished. The most obvious is the desiccant. A new, or regenerated, Laboratory Drying Unit will normally last for about 5 days. When the remaining length of blue (dry) desiccant is less than one inch, the desiccant should be replaced. Please see the RAD8 manual on desiccant regeneration. If the desiccant is not replaced, and the relative humidity in the instrument rises above about 10%, then the sensitivity drops off and the reading is lower than the true value.

2.3.2 Memory

The capacity of the internal memory of the RAD8 is 16 GB, which is sufficient for a lifetime's worth of measurements. That said, it is good practice to back up data (to Capture Cloud, your own FTP server, computer, or USB stick), just in case anything happens to the RAD8 during the measurement. It is also possible to monitor the RAD8's output remotely, including the relative humidity, which can be used as an indicator that the desiccant needs to be replaced. Please see the Capture manual for more information on remote monitoring.

3 DATA

3.1 Data Handling

3.1.1 RAD8 Memory

The internal memory of the RAD8 stores numerous properties for each data cycle, including the timestamp, raw alpha energy spectrum, calculated radon concentration, and a host of other parameters; see the RAD8 manual for details. The data can be downloaded to a computer using Durridge's Capture software, which is discussed below.

3.1.2 Capture Software for Windows and macOS

Data recorded to the RAD8 may be downloaded and graphed using Durridge's Capture software, which is available at https://durridge.com/software/capture/.

To view Water Probe data in Capture, first transfer it to the computer via Wi-Fi, Capture Cloud, or USB stick. If using a Temperature Logger, obtain its data as explained in Section 3.1.3. After the radon data is opened in a Graph Window, select a run of Water Probe data, open the Test Parameters Window, and set the Radon Measurement Method to Water Probe as shown in Figure 3 on the following page. Next specify the water temperature source as instructed. The water temperature information is used by Capture to calculate the radon-in-water concentrations. For detailed instructions, please see the Water Probe information in the Capture user's manual, which is available from the Durridge website.

3.1.3 Temperature Data

To obtain the water temperature data (optional), connect the Temperature Logger to the computer and run its software to download the data. The program will download the entire memory of the logger, and then display it as a graph. You should save it to your hard drive before doing anything else. You can then export it to a comma-delineated .txt file for use with Capture, or for incorporating into a spreadsheet or database program.

Alternatively, the Temperature Logger data can be read directly into Capture using the controls in the Test Parameters Window; see the instructions in the Capture user's manual for details.

Warning! Make sure that the Temperature Logger data is properly downloaded and saved to the computer before starting the logger again. Restarting the logger operations may erase its previous data.

3.1.4 Time Relationship

A water temperature reading is made at the moment in time indicated with the reading. A radon reading, in contrast, is the average value taken over the Cycle whose end occurred at the time indicated. For constant radon and temperature values this is of no consequence, but if the temperature was changing quickly then the temperature readings during the course of the radon cycle should be averaged to give the average temperature at the air-water interface when the radon being measured was leaving the water. This is handled automatically by Capture.

3.2 Data Conversion Formulas

3.2.1 Fritz Weigel Formula

The RAD8 gives an accurate reading of the radon concentration in the closed air loop. With the Water Probe, this air reaches equilibrium with the surrounding water. To convert the air concentration to water concentration, the air concentration must be multiplied by the partition coefficient, which is given by the Fritz Weigel equation (Weigel, 1978):

$$k = 0.105 + 0.405 * \exp(-0.0502*T)$$

where T is the temperature in degrees Celsius.

At 10 degrees Celsius, k is around 0.35, giving, at equilibrium, a three-to-one ratio of radon in air to water. The Fritz Weigel formula is applied automatically in Capture when the Water Type is set to Fresh Water in the Test Parameters Window, as shown in Figure. 3, below.

3.2.2 Schubert et al. Formula

If the Water Type is set to Saline Water in Capture's Run Parameters Window, the radon in water concentration is calculated using the Schubert et al. formula, which is a function of both water temperature and salinity. (See Schubert et al., 2012.)

The Run Parameters Window provides a field for specifying the salinity of the water, in parts per thousand. Note that this formula is suitable for water samples with any degree of salinity, including zero. When the salinity value is set to zero, it produces results that are nearly identical to those produced by the Fritz Weigel formula.

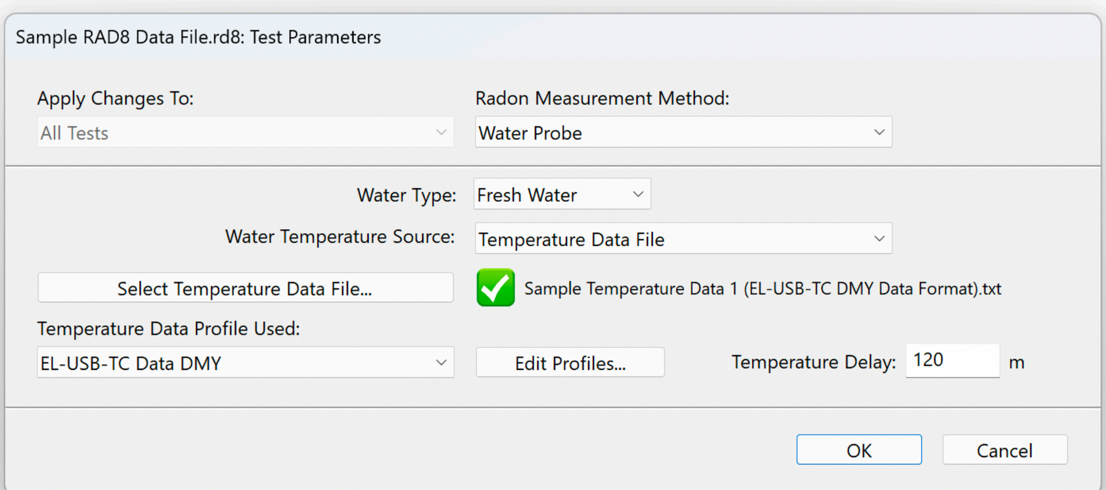

Figure 3 The Capture Test Parameters Window

4 Drystik

4.1 Passive Drystik

A passive Drystik may be installed in the Water Probe system without modifying the operating conditions. In this configuration, the Water Probe connects directly to the inlet filter on the RAD8's Sample In port. The inner membrane tube plugs into the Pump Out port on the RAD8 front panel (downstream of the internal pump), followed by the desiccant, and thence to the Detector In port. The outer sheath is purged by dry air from the RAD8 outlet. The two flows should be in opposite directions along the Drystik. A 12" Drystik will increase the life of the desiccant by a factor of about five.

4.2 Drystik ADS-3 and ADS-3R

Durridge's Drystik ADS-3 and ADS-3R models include a pump upstream of the inner membrane tube, and a needle valve downstream of the tube. This increases the pressure inside the tube, which increases its efficiency. The 4 air ports on the RAD8 front panel allow the RAD8's pump to be bypassed to avoid interfering with the operation of the Drystik pump.

A typical setup has the RAD8 Pump Mode set to 'Off', the Drystik pump running continuously and the needle valve adjusted to give a flow rate of about 0.2 L/min.

When using an active Drystik, a Small Drying Tube or larger Laboratory Drying Unit full of desiccant can be added to keep the RH in the RAD8's air sample low. It should be inserted between the Drystik air outlet and the inlet filter on the RAD8's Detector In port, as shown in Figure 4 on the following page. The desiccant will last for a very long time.

4.3 Effect on Response Time

With a flow rate of only 0.2 L/min it will take about 5 minutes for the air in the loop to go around once. This will add a few extra minutes to the response time for radon. For long-term studies the slower response is generally not important, whereas the frequency of replacing the desiccant may be. So, an active Drystik may be of considerable benefit.

4.4 Custom Drystik Settings

The standard 0.2 L/min flow rate of the Durridge Drystik is typically used because it roughly matches the average flow rate of a RAD8 running with Pump Mode set to 'Standard', and it also matches the performance of the installed pump at a pressure of 44 PSI (3 atmospheres). Durridge's Active Drystik models can be set to maintain a 44 PSI pressure inside the inner membrane tubing and a flow rate of 1L/min or even more, to restore the speed of response of the system while virtually eliminating the need to periodically replace the desiccant. See the Drystik user's manual for details.

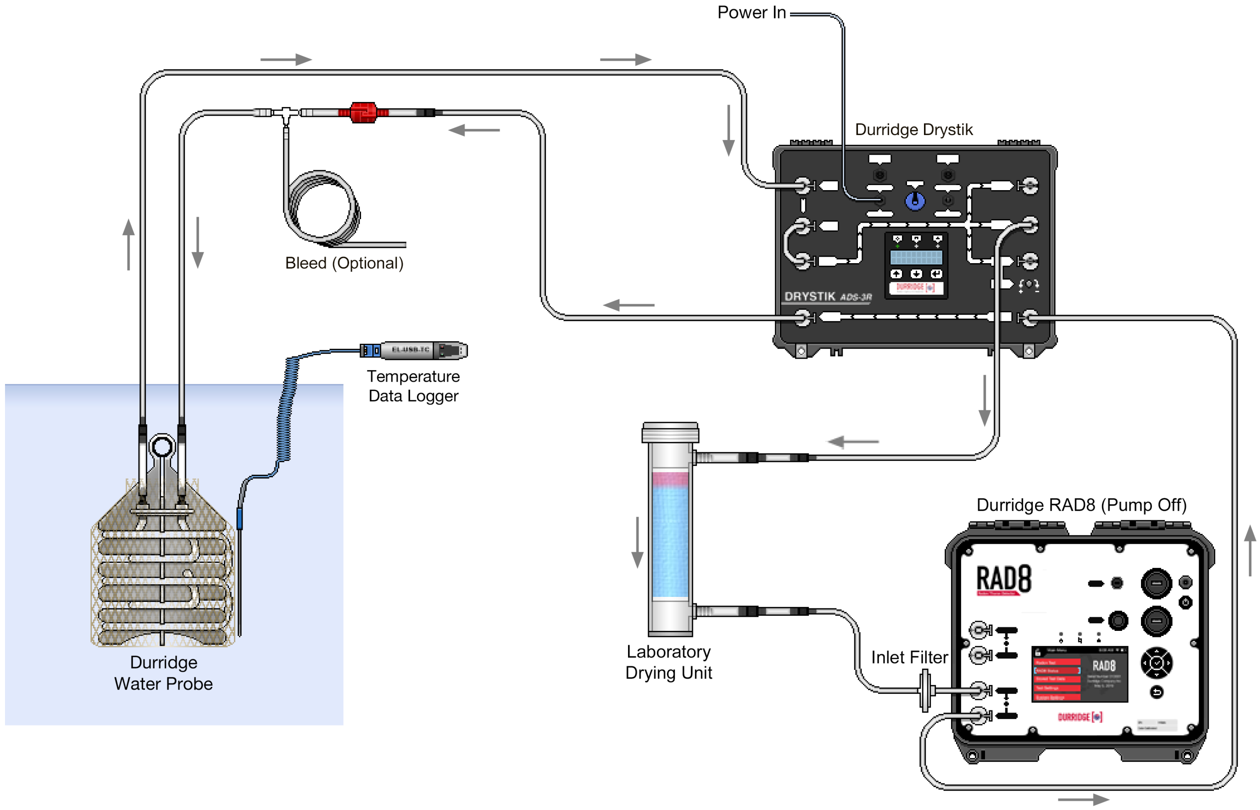

Figure 4 Water Probe configuration with Drystik

5 CARE, MAINTENANCE, AND TROUBLESHOOTING

5.1 Water Catastrophe

If water ever enters the RAD8's sample path, it will probably cease to operate and immediate steps should be taken to minimize the impact on the instrument.

Keep the RAD8 upright. This will prevent water from touching the detector. Put a piece of tubing on the RAD8 outlet with the other end in a sink. Use the RAD8 pump if it still works or, otherwise, connect an external pump into the Sample In port, to blow air through the instrument. When water ceases to be blown out of the outlet, put desiccant upstream of the RAD8 to dry out the air path. This may take several hours.

Once there is no visible water in or on the instrument, it can be put in an oven at 50°C for a few hours to dry out completely. Additionally, desiccated air can be passed through the air path until the air leaving the RAD8 drops below 10% RH. After this treatment the RAD8 can be booted up once more, and you can use the RAD8's internal RH sensor to measure how dry the air path is. At this point the instrument should be returned to Durridge for service.

5.2 RAD8 Care

Water, particularly salt water, is hostile to electronic instruments.

Whilst the RAD8 is IP67-rated against water and dust ingress, keeping its front panel as clean and dry as possible will help to prevent premature aging. As mentioned above, care should also be taken to avoid drawing liquid water or dusty air into the sample path. The instrument should, in any case, be returned every year for recalibration.

It is useful to look at a cumulative spectrum periodically (`Test Status → Spectrum`). Check to see that the alpha energy peaks are well-separated, no broader than usual, and well-positioned in the centre of their respective spectrum windows.

5.3 Exchanger Care

There is a potential for biofouling to occur in long-term monitoring applications. The exchanger should be kept as clean as possible in the circumstances. The Water Probe should therefore be inspected periodically to ensure that there is good contact between the radon exchange tubing and the surrounding water, and no clogging with weeds, algae, etc.

5.4 Desiccant Regeneration

Please see the RAD8 manual for information on the care and regeneration of the desiccant. Regenerated desiccant, after a few regenerations, loses most of its indicating ability (due to migration of the cobalt chloride to the interior of the calcium sulphate grains). One way to 'indicate' the status is, every time you refill the Laboratory Drying Unit with regenerated desiccant, you first add half an inch or so of new, blue desiccant, out of the jar. If you then make sure to always use the lower fitting as the air outlet, you can always tell if the unit is still working, as the new desiccant will only turn pink when the rest of the desiccant, upstream, has become hydrated.

5.5 Water Probe Troubleshooting

5.5.1 Air Path Integrity

When drawing a sample from a remote location, air path integrity is essential to prevent dilution of the sample with ambient air. Always make sure that there are no loose connections or leaky fittings (such as the screw cap or ribbed fittings of the Laboratory Drying Unit) in the air loop, particularly upstream of the RAD8. In the event of unexpectedly low radon values, check the air path for integrity.

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Durridge Company Inc.
900 Technology Park Drive
Billerica, MA 01821

Telephone:	(+1) 978-667-9556
Fax:	(+1) 978-667-9557
Web:	https://durridge.com
Email:	service@durridge.com

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