WATER PROBE

Passive, Slow Response Radon in Water Accessory for the RAD7

User Manual

DURRIDGE

Radon Capture & Analytics

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INTRODUCTION

The Water Probe is an accessory for the DURRIDGE RAD7 Electronic Radon Detector. 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 RAD7.

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 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 RAD7 to respond to the changed radon concentration. With optimum configuration the response time of the system is around 2 hours.

Fig. 1 Assembled Water Probe

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.

1 WATER PROBE SETUP

1.1 Connections

1.1.1 Air Loop

Two pieces of tubing connect the RAD7 and drying unit to the Water Probe air/water exchanger, as shown in Fig. 2. These two pieces of tubing can be several tens of meters long. The standard tubing supplied with the RAD7/Water Probe is sufficient for a connection up to ten feet between the exchanger and the RAD7.

Connect the OUTLET of the RAD7 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 RAD7 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 RAD7 INLET. The Luer taper ensures an airtight connection.

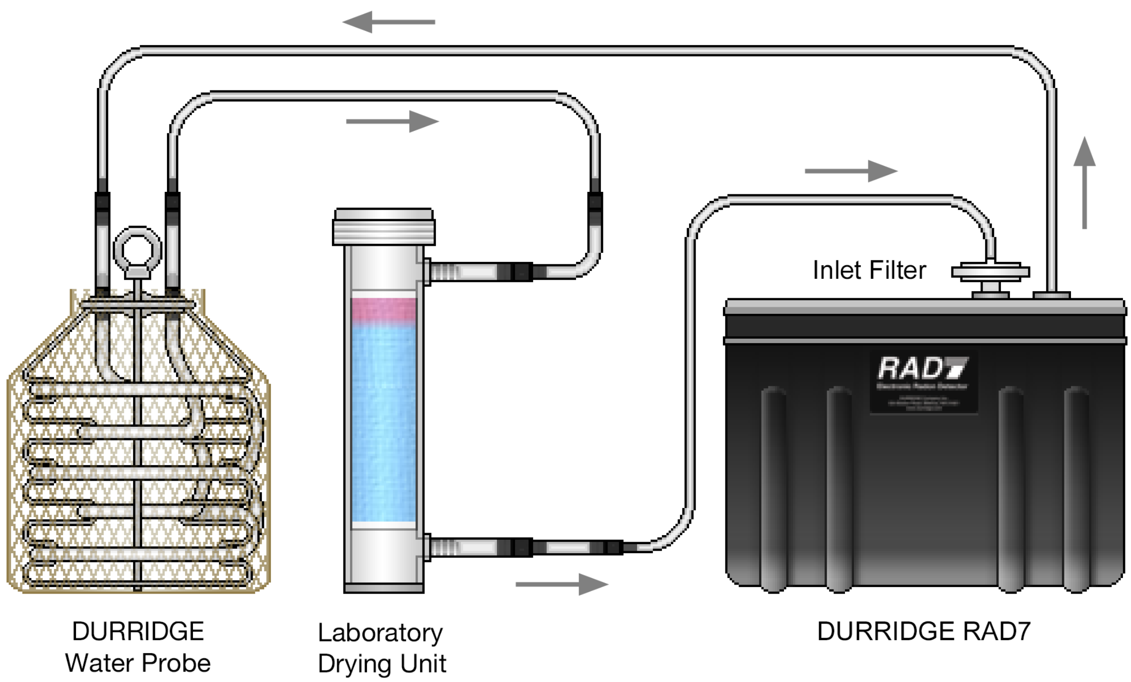

Fig. 2 RAD7 Water Probe Standard Setup

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 drying unit, and the outer sheath should be purged with dry air from the RAD7 outlet. See Fig. 3 in Section 3. More details are provided in the DRYSTIK user's manual.

1.1.3 RAD7 and Exchanger Location

Place the RAD7 on a clean, dry surface. If it has to be located in a harsh environment, then it should be protected from the elements (especially water). A simple way to do this is to place the RAD7 inside a large transparent plastic bag, such as the one in which it was originally shipped. The bag opening should be gathered around the inlet and outlet tubes, so that the instrument is inside a closed space, completely protected from the elements, while still allowing observation of the LCD and print-out, and operation of the key pad.

The Water Probe may be lowered directly into the body of water that is to be measured. Alternatively, it can be placed in a container with the incoming water released at the bottom of the container and overflowing or exiting through an outlet at the top. The water in the container should be completely refreshed with incoming water at least twice an hour.

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 its own plastic bag to protect it, once it has been launched.

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 shorter than its response time (roughly 2 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 RAD7 pump should be set to Auto. The pump, in Auto operation, pumps for five minutes at the beginning of every cycle, and then for one minute in every five throughout the remainder of the cycle.

1.4 Protocol

1.4.1 RAD7 Protocol, Mode and Cycle

First, please read the RAD7 manual and learn how to use the instrument for measurement of radon in air. The RAD7 should normally be operated with mains power applied, to keep the batteries in a fully charged condition.

Set the RAD7's Mode to Auto, which starts the instrument in Sniff mode (counting 218-polonium decays only), and switched automatically to Normal Mode (counting 218-polonium and 214-polonium decays) after 3 hours, once secular equilibrium between 222-radon, 218-polonium and 214-polonium has been reached. Due to the radioactive half lives of intermediate radionuclides in the radon decay chain, the RAD7's response time in Normal 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 minimise the response time, the RAD7's Mode may instead be set to Sniff. 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 RAD7's sensitivity in Sniff mode is approximately 50% of its Normal mode sensitivity.

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.

1.4.2 Water Probe Protocol

Switch on RAD7. Push the `MENU` key. Go to:

`SETUP, CYCLE`, push `[ENTER]`. Set the cycle time required (as discussed above).

`SETUP RECYCLE` to `00`, for continuous operation.

`SETUP MODE`: As discussed above, choose `AUTO`.

`SETUP THORON`: Choose `OFF.`

`SETUP PUMP`: As discussed above, choose `AUTO.`

`SETUP TONE`: Choose what you like.

`SETUP FORMAT`: Choose what you like, but `LONG` format uses more paper. You will probably not need to use the printer at all, in the field.

`SETUP UNITS`: Your choice.

`SETUP SAVUSER`: Push `[ENTER]`. When it says "Are you sure?" choose "Yes" and push `[ENTER]`.

1.4.3 User Protocol

You now have your personalized USER protocol saved. To recall your settings, go to `SETUP, PROTOCOL, USER` and push `[ENTER]`. To make a change, simply display the parameters to be changed, make your changes then, once more, go to `SETUP SAVUSER` and save them.

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 RAD7 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

Switch on the RAD7 (have the printer switched on if you are using it. The RAD7 will then print a header for the data printout, including a review of the setup, before it gives you a 'Test' prompt.)

Provided that the RAD7 has been set up properly (see above), at the '`Test`' prompt, push `[ENTER]` then the right arrow, to see '`Test Start`' on the LCD, then push `[ENTER]` to 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 2 - 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 RAD7 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 218-polonium (Sniff mode), or the half lives of intermediary 214-lead and 214-bismuth (Normal mode). See the RAD7 manual, Section 3 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 RAD7's pump. However, even with the pump set to AUTO, this delay is only around 20 minutes, which is small compared with the 2-hour timescale for radon exchange across the membrane tubing and the 3-hour 95% response time of the RAD7 running in Normal mode. For this reason, it is almost always sufficient to set the pump to AUTO mode, in which the air is circulated around the closed air loop for one minute in every five. Air will remain stationary in the Water Probe for four minutes before moving to the Laboratory Drying Unit where it waits another four minutes before entering the RAD7. 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 about 15 to 20 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 about 20 minutes if the pump is set to AUTO

Having the pump set to AUTO would normally be associated with having the RAD7 cycle time of 30 minutes or longer. So an extra 15 to 20 minutes on the response time will not be excessive.

2.2.4 RAD7 Mode

In AUTO (the default) mode, the RAD7 will automatically switch from SNIFF mode to NORMAL mode after three hours into the run. This is to take advantage of the additional counts provided by the 214-polonium decays 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 AUTO mode for the RAD7 is appropriate. The RAD7's response time will be a couple of hours or so.

For fastest response, the RAD7 can be forced to stay in SNIFF mode (`Setup, Mode, Sniff [ENTER]`). It will then always count only the 218-Po decays, giving it a 13-minute 95% response time. However, the improvement in overall response time is marginal due to the 2-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 NORMAL to SNIFF 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 ten days of continuous use in a temperate climate. In this application, however, it is operating in a closed, dry air loop where the only moisture entering the loop comes from tiny leaks of ambient air. Therefore, each Laboratory Drying Unit can be expected to last several weeks. When the remaining length of blue (dry) desiccant is less than one inch, the desiccant should be replaced. Please see the RAD7 manual on desiccant regeneration. If the desiccant is not replaced, and the relative humidity in the instrument rises above about 20%, 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 RAD7 is 1,000 records or cycles. If each cycle is two hours, that would be data for 2000 hours, or just over 80 days. Every time the desiccant is changed, therefore, all the stored data should be downloaded to a PC, backed up, and erased from the RAD7 memory. It is also possible to monitor the RAD7'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 Infrared Printer

The RAD7's infrared printer will print out data in short, medium or long format - see the RAD7 manual for details. In the long format, there will be a spectrum printed at the end of every cycle.

3.1.2 RAD7 Memory

The internal memory of the RAD7 stores numerous properties for each data cycle, including the date and time, radon concentration, live time, total counts, and a host of other parameters; see the RAD7 manual for details. The data can be downloaded to a computer at any time, during or after a run, using DURRIDGE's CAPTURE software, which is discussed below.

Once the data has been downloaded and backed up securely, you should erase the data on the RAD7, to prevent it from accumulating and filling the device's memory.

3.1.3 CAPTURE Software for Windows and macOS

Data recorded to the RAD7 may be downloaded and graphed using DURRIDGE's CAPTURE software, which is available from the DURRIDGE website [www.durridge.com/software/capture/].

To view Water Probe data in CAPTURE, first make sure RADLINK is installed on the RAD7, and connect the RAD7 to the computer using the provided USB to serial adaptor cable. Download the RAD7 data. Then, if using a Temperature Logger, obtain its data as explained in Section 3.1.4. After the radon data is opened in a Graph Window, select a run of Water Probe data, open the Run Parameters Window, and set the Radon Measurement Method to Water Probe as shown in Fig. 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.

3.1.4 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 take a moment to 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 Run 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.

3.1.5 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 the CAPTURE software.

3.2 Data Conversion Formulas

3.2.1 Fritz Weigel Formula

The RAD7 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):

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

where T is the temperature in degrees Celsius.

At 10 degrees Celsius, a 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 Run Parameters Window, as shown in Fig. 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.

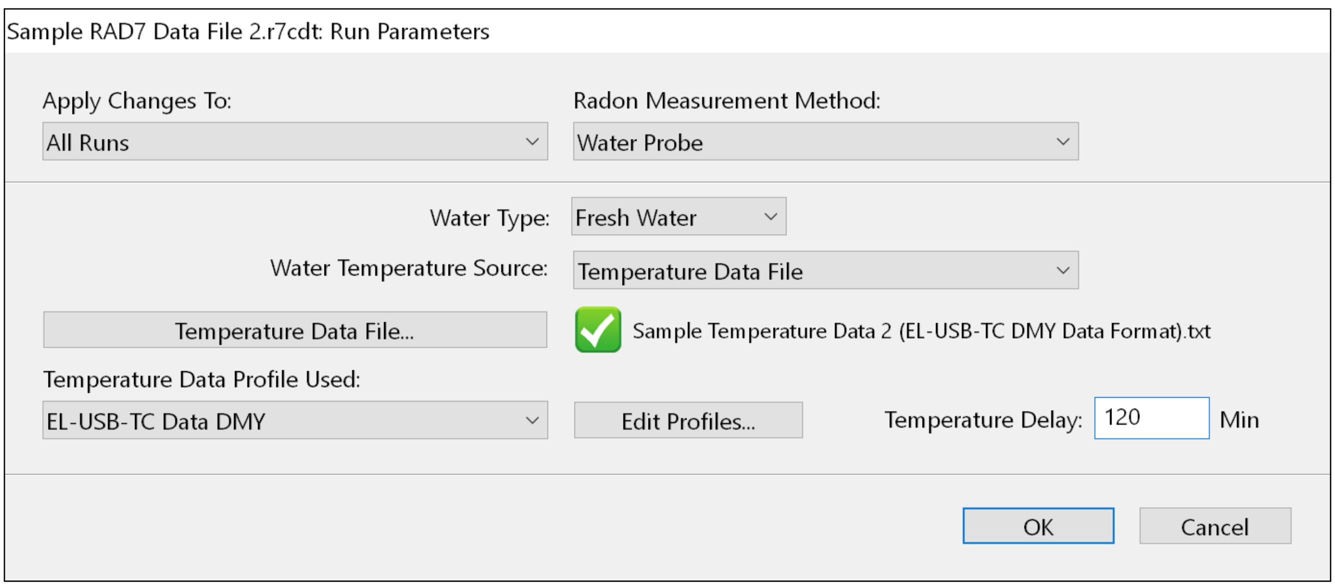

Fig. 3 The CAPTURE Run Parameters Window

4 DRYSTIK

4.1 Passive DRYSTIK

A passive DRYSTIK may be installed in the Water Probe system without modifying any other part of the system or the operating conditions. The inner membrane tube goes between the exchanger and the desiccant while the outer sheath is purged by dry air from the RAD7 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.

A typical setup has the RAD7 pump set to OFF (`Setup, Pump, Off [ENTER]`), 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 air sample in the RAD7 below 7% RH. It should be inserted between the DRYSTIK air outlet and the inlet filter on the RAD7, as shown in Fig. 4 on the following page. The desiccant will last for a very long time, and the drying tube will add only a tiny volume to the air loop.

4.3 Effect on Response Time

With a flow rate of only 0.2 L/min it will take about 20 minutes for the air in the loop to go around once. This will add an extra 10 or 15 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 matches the average flow rate of a RAD7 in AUTO mode, 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.

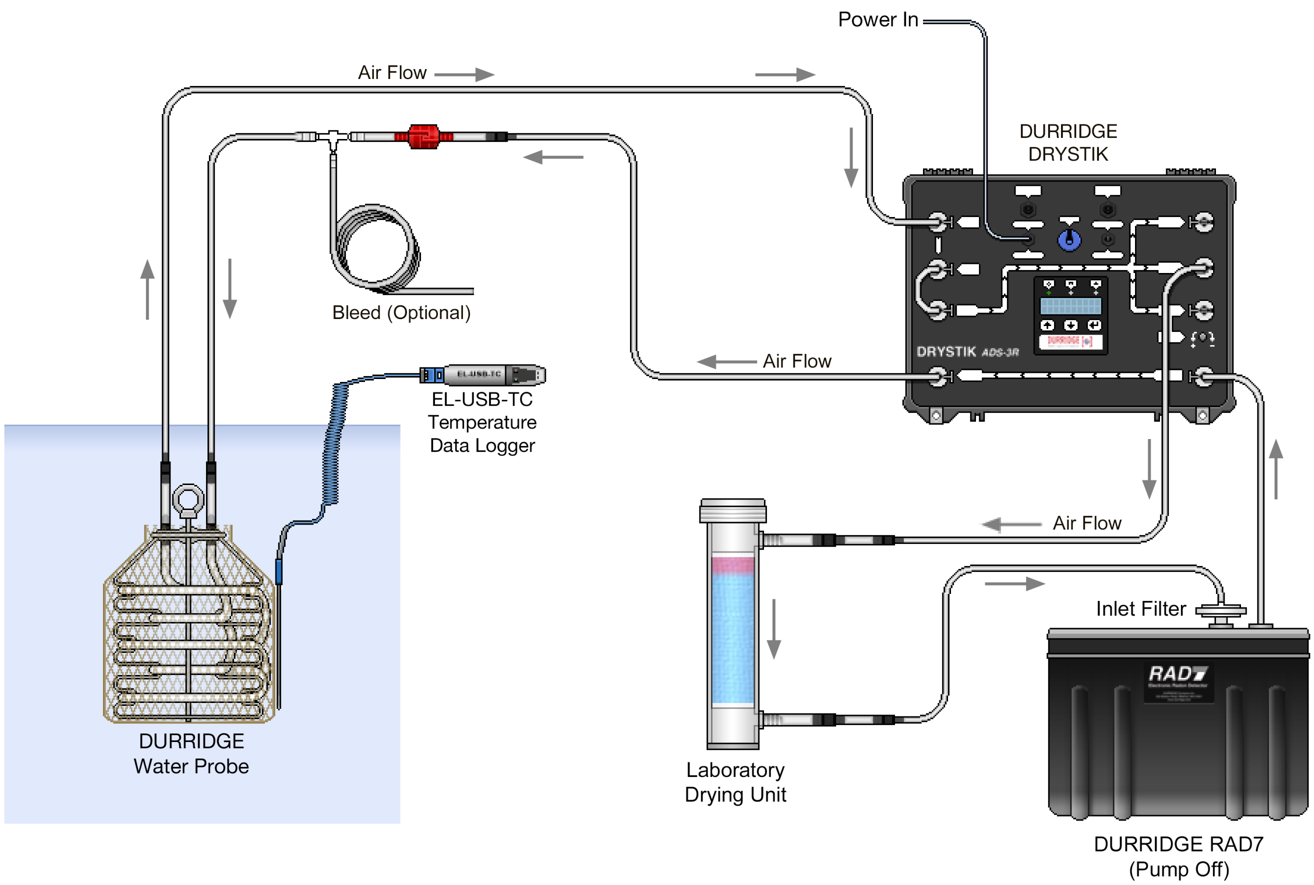

Fig. 4 Water Probe configuration with Active DRYSTIK

5 CARE, MAINTENANCE, AND TROUBLESHOOTING

5.1 Water Catastrophe

If water ever enters the RAD7, or if the RAD7 ever goes swimming in the water, it will probably cease to operate and immediate steps should be taken to minimize the impact on the instrument.

Keep the RAD7 upright. This will prevent water from touching the detector, which is close to the face plate at the top of the dome. Put a piece of tubing on the RAD7 outlet with the other end in a sink. Use the RAD7 pump if it still works or, otherwise, an external pump into the inlet, to blow air through the instrument. When water ceases to be blown out of the outlet, put desiccant upstream of the RAD7 to dry out the air path. When the air path is fully dry (after dry air has been blown through it for approximately one hour), remove the face plate from the case, empty the water out of the case and blow dry the case and the RAD7 electronics.

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 RAD7 drops below 10% RH. After this treatment further corrosion will be prevented, and the RAD7 will boot once more and you can use the 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 RAD7 Care

Water, particularly salt water, is hostile to electronic instruments. Please keep the RAD7 in a relatively clean and dry environment. One way is to enclose the instrument in a large, transparent plastic bag; see Section 1.2.3. Should it ever be seriously splashed with salt water, please follow the instructions in Section 7.1, above.

As a preventive measure, plastic cling wrap can be placed over the RAD7 face plate and down the sides of the RAD7. Push it down around the hose connections, push the power and RS232 plugs into their sockets, and push the lid onto its hinges. The wrap will make the RAD7 almost watertight. If it tears it can be easily replaced at any time. The instrument should, in any case, be returned every year for recalibration.

It is useful to look at a cumulative spectrum periodically. This may be obtained by having the printer on and allowing the RAD7 to complete a run. The "Recycle" number may be set to the current cycle number (`Setup, Recycle, NN [ENTER]`). When the RAD7 reaches the end of the current cycle it will then print out the end of run summary including the cumulative spectrum. Look to see that the peaks are clean and in their normal positions.

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 RAD7 manual for information on the care and regeneration of the desiccant. Regenerated desiccant, after a few regenerations, loses most of its indicating ability (due, we believe, to migration of the cobalt chloride to the interior of the calcium sulphate crystals). 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. This way, 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 of the Laboratory Drying Unit) in the air loop, particularly upstream of the RAD7. In the event of unexpectedly low radon values, check the air path for integrity.

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