DRYSTIK

Active Moisture Exchanger Accessory for the RAD7

User Manual

DURRIDGE [⦿]
Radon Capture & Analytics

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INTRODUCTION

The Durridge DRYSTIK consists of a Nafion membrane tube with a purge sheath coiled in a box with a pump, flow-control needle valves, and a Duty Cycle Controller.

Nafion, a material invented by DuPont and marketed by Perma Pure, consists of PTFE (Teflon) laced with hydrophilic molecules that will pass water molecules from one to another down a humidity gradient in the material. If the humidity inside the membrane tube is higher than the humidity in the purge sheath then water molecules will be transported from inside the tube to the purge sheath. This is purely a chemical process. There are no micro-pores and other gases cannot cross the membrane.

In the DRYSTIK, the air inside the membrane tube is compressed, thus increasing the humidity and making the system much more efficient. The desiccant in a laboratory drying unit can be made to last for many months of continuous use, without replacement, instead of 10 days in typical conditions without a DRYSTIK.

Compressing the incoming air causes water molecules to cross to the purge sheath even if the sheath is filled with fresh air at ambient humidity. Thus the system will start to dry incoming ambient air even without dry purging air in the sheath. If the dryer outlet air is circulated back to become purge air it will increase the efficiency of the drying process and the system becomes regenerative, bringing the air leaving the membrane tube to progressively lower humidity.

In all models except the ADS-1, a Duty Cycle Controller is built into the device to provide precise control of very low average sample flow rates. This is important for several applications including long-term soil gas monitoring.

Ideally, the Nafion tube should be purged with dry air flowing at two or three times the sample flow velocity. However, with the incoming air compressed, the device is still effective even though only the dried sample air is used to purge the system. With the 48-inch and 144-inch models, the relative humidity can be brought down below 10%, with no desiccant in the air path, but it is more efficient if desiccant is still used.

Nafion is an amazing material. It loves water vapor. But its function is inhibited by the presence of liquid water. Compression of ambient air in high-humidity conditions can produce condensation in the membrane tubing, that reduces the efficiency of the system. In those conditions, a cool trap between the pump and the membrane tube is recommended, and offered as an accessory. Reducing the duty cycle to around 20% also helps to mitigate the effect of condensation.

| DRYSTIK ADS-1 | DRYSTIK ADS-2 | DRYSTIK ADS-3 | DRYSTIK ADS-3R |

1 GETTING STARTED

1.1 Unpacking

First make sure your DRYSTIK package contains everything you are supposed to have. Examine the case contents and verify that you have all the items shown in the packing list. If anything is missing, please call DURRIDGE immediately at (978) 667-9556 or email sales@durridge.com.

1.2 General Safety Instructions

There is nothing hazardous to the user in the DRYSTIK package. To protect the DRYSTIK unit, do not let it come in direct contact with water. It is also important to prevent air samples containing liquid water from entering the unit's Sample In port. This is covered in the usage instructions later in this manual.

1.3 DRYSTIK Packing List

The DRYSTIK system consists of the following components:

- The main DRYSTIK console (with built-in Duty Cycle Controller in all models except ADS-1)
- Tubing Set consisting of the following sections (See Figure 1; tubing usage shown in Figure 12.)
    - A (x2): 36" long 1/8" ID
    - B (x1): 24" long 1/8" ID
    - C (x1): 3" long 5/15" ID to 36" long 3/16" ID to 3" long 1/8" ID
    - D (x1): 3" long 5/15" ID to 36" long 3/16" ID to 3" long 1/8" ID + Filter
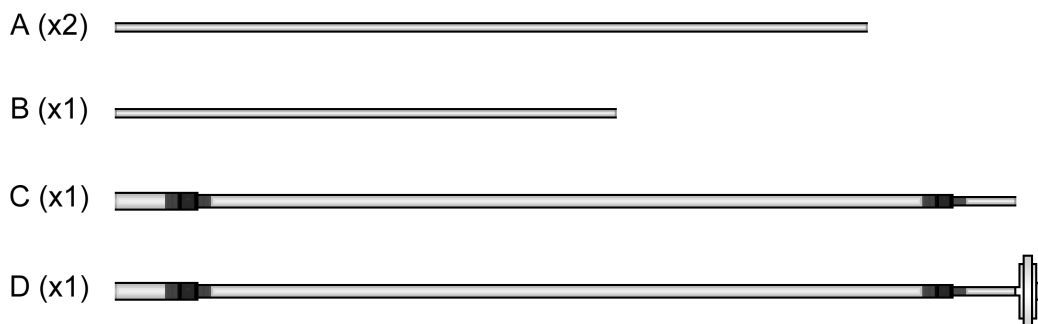- 12V 1.5 Amp DC Power Adapter
- Printed DRYSTIK User's Manual

Fig. 1 Tubing included with DRYSTIK

2 USING THE DRYSTIK

2.1 Connections and Controls

2.1.1 Front Panel

The current DRYSTIK models (ADS-3 and ADS-3R) contain hose connections for the pump input and output, plus three air outputs (labeled Low Airflow, High Airflow, and Adjustable Airflow), and In and Out ports for the purge airflow coming out of the RAD7.

The Low Airflow output produces a nominal airflow rate of 0.17 L/Min, while the High Airflow output produces a nominal airflow rate of 1.5 L/Min. Note that these values may vary if a constraint is put in the sample path, or if more than one air outlet is used simultaneously, or if the pump performance is degraded.

The discontinued DYSTIK ADS-2 is similar, but the labeling on the ports is different. The discontinued DRYSTIK ADS-1 (shown in Fig. 2) is simpler: it has only one air output connector, and all of the tubing outlets remain open at all times. The ADS-2, ADS-3, and ADS-3R use plugged tubing connectors, which pop in and out of the connection outlets.

On these newer devices all of the outlets remain open except for the Low Airflow, High Airflow, and Needle Valve ports, which are shut off except when a tubing plug is inserted. It is necessary to insert a plug whenever airflow is required.

The duty cycle controls, which are present on the ADS-2, ADS-3, and ADS-3R, consist of three buttons and an LCD display. Their function is context sensitive, based on the state of the unit as indicated on the display. The ADS-3 and ADS-3R use a membrane button interface and allow for the configuration of duty cycle profiles, while the ADS-2 uses an interface with mechanical buttons, and lacks the option to configure custom duty cycle profiles. The ADS-1 lacks a built-in duty cycle controller and any associated controls, and its pump remains active at all times unless an external Duty Cycle Controller (sold separately) is utilized.

Fig. 2 DRYSTIK ADS-1 Front Panel

Fig. 3 DRYSTIK ADS-2 Front Panel

Fig. 4 DRYSTIK ADS-3 Front Panel

Caution:

The Low Airflow, High Airflow, and Needle Valve outlets on the ADS-2, ADS-3, and ADS-3R are shut off except when a tubing plug is inserted into one of them. It is important to insert a plug into one of these outlets whenever airflow is required.

Fig. 5 DRYSTIK ADS-3R Front Panel

⚠️ **Caution:**

The Low Airflow, High Airflow, and Needle Valve outlets on the ADS-2, ADS-3, and ADS-3R are shut off except when a tubing plug is inserted into one of them. It is important to insert a plug into one of these outlets whenever airflow is required.

Different DRYSTIK models use different layouts for the tubing ports, and slightly different labels are used as well. The tubing port layouts of the ADS-1, ADS-3, and ADS-3R models are shown here. (The front panel port layout of the Model ADS-2 is essentially the same as that of the ADS-3.)

Fig. 6 DRYSTIK Front Panel Tubing Outlet Layouts

2.1.2 Rear Panel (Models ADS-2 and ADS-3)

The DRYSTIK ADS-2 and ADS-3 (non-ruggedized) are housed in cases containing both front and rear panels. The rear panel of the DRYSTIK ADS-2 and ADS-3 contains a series of switches and ports. These are, from left to right, the Internal Pump / DCC Output toggle switch, the 12V Power Out port, the 12VDC Power In port, the device ON/OFF switch, and the USB port (ADS-3 only).

The Internal Pump / DCC Output toggle switch is used to specify whether the DRYSTIK's Duty Cycle

Controller is used to cycle the internal pump, or an external device whose power is supplied by the DCC output port. The benefits of the duty cycle controller are thus available for a wide variety of other devices.

The USB port on the ADS-3 (and ADS-3R) may be used to connect the device to a computer running Durridge's CAPTURE software. CAPTURE can be used to activate the DRYSTIK, monitor the device's state, and configure its duty cycle profiles. This is discussed further in Section 2.1.7.

Fig. 7 ADS-3 Rear Panel (ADS-2 Rear Panel lacks USB Port)

2.1.3 The DRYSTIK ADS-2 User Interface

The ADS-2 and ADS-3 have significantly different user interfaces. For information on the ADS-3 interface, see section 2.1.4. (The ADS-1 does not have any software interface, so the ADS-1 duty cycle must be controlled using DURRIDGE's stand-alone Duty Cycle Controller, provided separately.)

The faceplate of the DRYSTIK ADS-2 contains a row of three physical buttons positioned under an LCD display. Pressing one of these buttons will cancel out of any DRYSTIK operation that may already be in progress, and cause the LCD screen to display a menu consist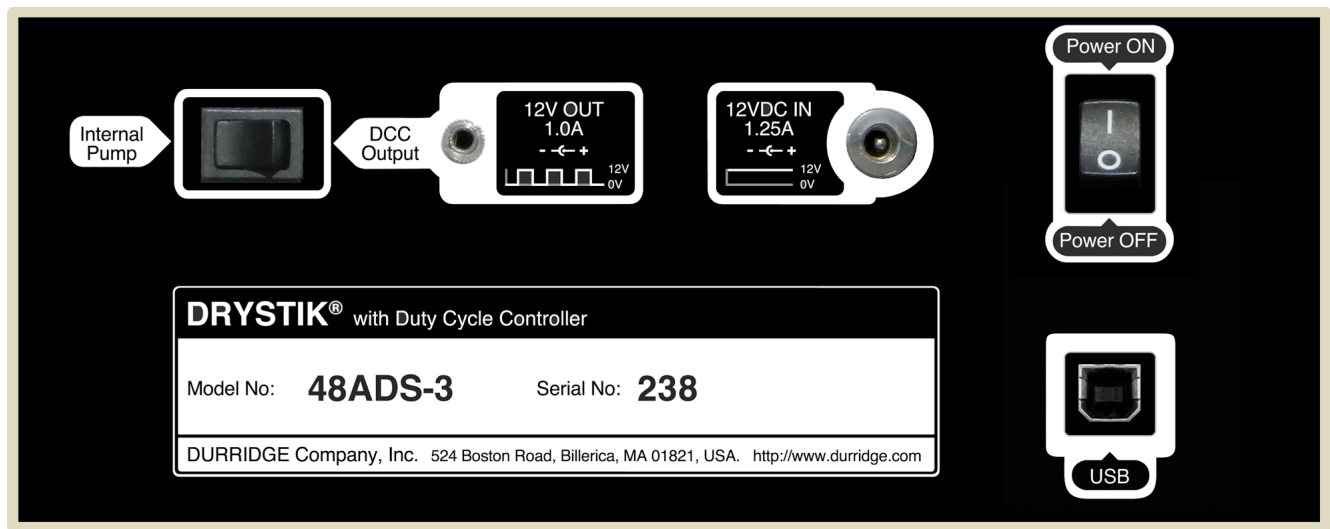ing of three options: 'On Time', 'Off Time', and 'Duty Cycle', with each of these labels corresponding to a different button, as shown below in Figure 8.

Fig. 8 DRYSTIK ADS-2 button functions labeled on LCD display

Pressing the first button will make it possible to specify the On Time, which is the amount of time, in seconds, that the DRYSTIK's pump will remain active during each repetition of a cycle. The Off Time indicates the number of seconds the pump will remain off during each cycle. The Duty Cycle is expressed as a percentage value ranging from 0% to 100%, and it represents the On Time as a portion of the total cycle time (that is, the sum of the On Time and the Off Time.)

When the Duty Cycle percentage value is changed, the On Time and Off Time values will be adjusted automatically in accordance with the new Duty Cycle percentage. Similarly, changing the On Time and the Off Time will result in a different Duty Cycle. If the On Time and Off Time values are each specified,

there is no need to also specify the Duty Cycle. The reverse is true to an extent, however adjusting the Duty Cycle alone does not affect the total cycle time.

When adjusting any of these timing values, the first and second buttons assume the functions indicated by their physical labels, [−] and [+], which are highlighted in Figure 9, below. The [−] button decrements the value, while the [+] button increments the value. The [Enter] button is used to confirm any changes to these settings, and begin the operation of the device. The DRYSTIK ADS-2 will continue operating, with the pump cycling on and off in accordance with the specified timing settings, until one of the buttons is pressed again, at which point the 'On Time / Off Time / Duty Cycle' screen reappears.

Fig. 9 DRYSTIK ADS-2 button functions labeled on device faceplate

2.1.4 The DRYSTIK ADS-3 and ADS-3R User Interface

The ADS-3 and ADS-3R each use a water-resistant membrane switch interface, which contains a two-row LCD screen and three touch-sensitive buttons. The software interface differs significantly from that of the ADS-2, and it accommodates a much broader range of functionality. The three buttons are labeled with [↑], [↓], and [Enter] icons, respectively. The [↑] and [↓] buttons are used to cycle up and down through lists of options, as shown in Figure 10, and to increment and decrement numerical values, as shown in Figure 11. The [Enter] button is used to choose the currently highlighted menu option, or to confirm the currently specified numerical value.

Menu items are listed vertically, with a small horizontal arrow highlighting the currently selected option. Since the LCD screen only contains two rows of text, it is sometimes necessary to press [↓] several times before the desired menu command scrolls into view.

Fig. f The ADS-3 menu is navigated using the [↑], [↓], and [Enter] buttons

When the ADS-3 is powered on, a main menu screen appears, offering the following options:

`Manual Mode`: Used to specify the desired Period, Duty Cycle, and Solenoid values. After these values have been entered, the DRYSTIK ADS-3 becomes active, with the pump cycling on and off repeatedly in accordance with the chosen Period and Duty Cycle.

`Load Profile`: Used to select a preset DRYSTIK configuration from a list of several profiles. Each profile contains a particular Period/Duty Cycle/Solenoid configuration, plus more. DRYSTIK profiles are discussed in further detail in Section 2.1.5, below.

`ADS Info`: Used to display the DRYSTIK's model number, serial number, and firmware version. The device's firmware can be updated to the latest version using the CAPTURE software for Windows and macOS.
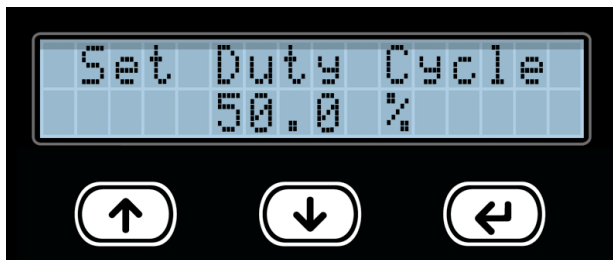

Fig. 11 The ADS-3 duty cycle configuration screen. Values are adjusted using [↑] and [↓].

While the DRYSTIK ADS-3 is running, the LCD screen displays the name of the profile currently in use. (If no profile is in use it displays "Manual Mode"). An on-screen timer counts down the number of minutes and seconds remaining before the current cycle reaches its end, at which point it repeats itself. If the optional solenoid is On, an [S] will appear on the second row of the DRYSTIK's LCD display. (See Section 2.1.6 for additional information on the Solenoid feature.) An LED indicating whether the pump is currently active is centered above the display.

When the DRYSTIK is running, pressing any button brings up a menu consisting of the following options:

`[Back]`: Cancels out of the menu and maintains DRYSTIK activity.

`Pause/Resume`: Pauses or resumes the DRYSTIK operation, and returns to the status display. When the DRYSTIK is paused, any pump activity is suspended.

`Stop/Exit`: Stops the DRYSTIK operation, disabling any pump activity, and returns to the main menu.

`Save to Profile`: Saves the current DRYSTIK configuration to a User Profile so that the current settings can be restored at a future date. DRYSTIK profiles are discussed in further detail in Section 2.1.5, below.

`Change Settings`: Adjust the DRYSTIK's current Period, Duty Cycle, or Solenoid setting.

2.1.5 DRYSTIK ADS-3 and ADS-3R Profiles

The DRYSTIK models ADS-3 and ADS-3R allow configurations to be saved for later use, in the form of DRYSTIK Profiles. Selecting a profile automatically sets multiple device properties, including the Period, Duty Cycle, and more. The core components of a DRYSTIK profile are as follows:

Property	Description
Period	Time from 0 to 99 Minutes
Duty Cycle	Percentage from 0 to 100%
Solenoid	Solenoid can be On or Off
Next Profile	Profile to switch to after a certain amount of time
Delay Before Next Profile	Time from 0 to 99 Minutes

DRYSIK models ADS-3 and ADS-3R contain several built-in profiles, designed for particular types of RAD7 experiments. For example, a profile titled '`Soil Gas Rn 80cm`' uses a period of 21 minutes and a duty cycle of 10%, and does not enable the solenoid. These particular values are suited for use with a DURRIDGE Soil Gas Probe, inserted to a depth of 80cm.

In addition to providing several built-in profiles, DRYSTIK models ADS-3 and ADS-3R can maintain a set of user-created profiles. To establish a user profile and save it for future use, set the DRYSTIK to run in Manual Mode, entering the desired Period, Duty Cycle, and Solenoid settings. Once these settings have been accepted and the DRYTIK is active, press any button to bring up the menu, and choose the `Save to Profile` option. Then select the user profile slot to which the current settings should be recorded. User profiles can also be created using Durridge's CAPTURE software. In addition, CAPTURE can be used to configure profile properties that can not be controlled using the DRYSTIK's physical menu alone. For more information see section 2.1.7, below.

2.1.6 Solenoid (Models ADS-3 and ADS-3R)

 DRYSTIK models ADS-3 and ADS-3R may be equipped with an optional solenoid device. When this solenoid is turned on, it pulls a High Airflow stream into a path that is otherwise occupied by Low Flow or Adjustable Flow air. This functionality is useful for interrupting the DRYSTIK's standard operation at regular intervals, so that a RAD7 can sample air containing short-lived thoron during a test that otherwise involves a lower air flow rate.

The solenoid may be turned On or Off as desired using the DRYSTIK's menu interface. In addition, DRYSTIK profiles can be configured to change the solenoid state, allowing for real time changes to the air path. This is discussed further below.

2.1.7 CAPTURE Software (Models ADS-3 and ADS-3R)

 Durridge's CAPTURE software for Windows and macOS can be used to monitor DRYSTIK ADS-3 activity, as well as to configure ADS-3 settings and update ADS-3 firmware. When the DRYSTIK is connected to the computer via USB, CAPTURE displays the device's current status, and provides controls for starting and stopping the device, and for modifying DRYSTIK profiles.

Certain profile properties may only be specified in CAPTURE. These include the Next Profile and Delay Before Next Profile properties, which once configured will allow a profile to run for a specified amount of time before another is automatically triggered. The second profile may in turn trigger yet another profile after a specified delay, or it may be left to run continually. By setting profiles with differing solenoid states to trigger one another at regular intervals, the DRYSTIK can change airflow rates to coincide with particular cycles of a RAD7 test.

Complete instructions on CAPTURE's DRYSTIK functionality are provided in the CAPTURE user's manual, which is accessible from within the application, and from the Durridge website, at durridge.com/software/capture/. The necessary software drivers for communication between the DRYSTIK and computer are also available at the Durridge website, at durridge.com/drivers/.

Note that the DRYSTIK models ADS-1 and ADS-2 lack USB interfaces and are not compatible with the CAPTURE software.

2.2 Monitoring Radon in Air

To configure the DRYSTIK for monitoring radon in air, tubing from the sampling point is connected to the pump input. The pump output is connected to the Nafion tube input with a small tubing bridge. The output may be taken from the low-flow outlet, which gives a nominal flow rate of 0.16 L/min. For fastest reduction, and lowest level, of humidity in the RAD7,

a drying unit with new or regenerated desiccant may be placed between the Nafion tube outlet and the RAD7 inlet. The outlet of the RAD7 is fed to the purge inlet of the DRYSTIK to provide a counterflow purge of the sheath around the membrane tubing. The purge outlet may be left with nothing connected, or can be connected to downstream instruments.
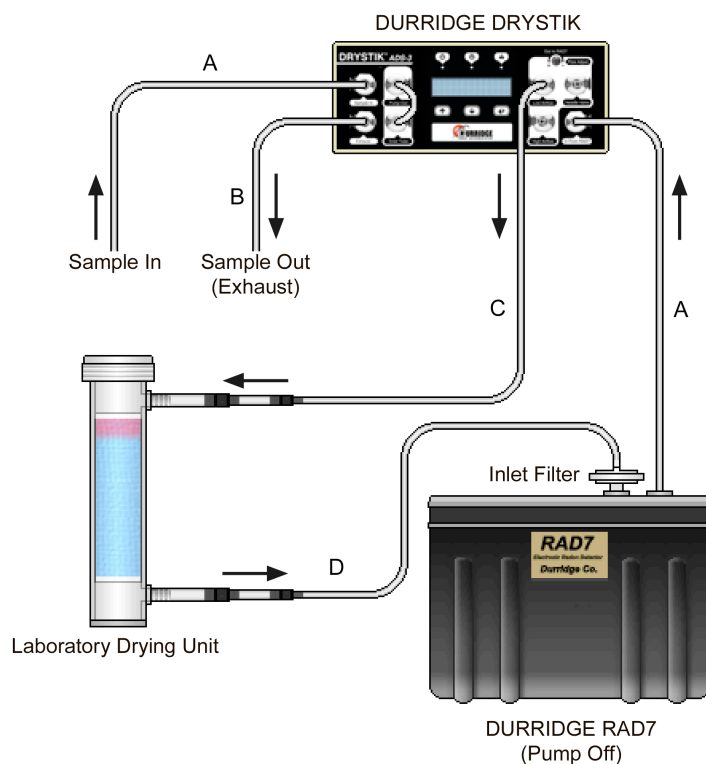

Fig. 12 Basic setup for monitoring radon in air

Before starting any measurement with the RAD7 it should first be purged for five minutes. This can be done by connecting the RAD7 to the high-flow output of the DRYSTIK and running it for five minutes with the RAD7 switched off, or by disconnecting the DRYSTIK and letting the RAD7 do its own purge (TEST, PURGE [ENTER]), to remove residual radon from any previous measurement. The RAD7's purge can be stopped by pushing the menu button. The RAD7 should then be set to a preset protocol, such as 1-day (for 48 half-hour readings), or weeks (for indefinite monitoring, with two-hour cycles). After the protocol has been set, the RAD7's internal pump be turned off (SETUP, PUMP, OFF [ENTER]). (It is important that the protocol be set FIRST.) The DRYSTIK can be turned on, with the duty cycle set to 100% and the duty cycle controller

12V output sent to the pump (not the external socket, see switch at back of the DRYSTIK). The RAD7 measurement can be started at any time (TEST, START [ENTER]). After an hour or so, the duty cycle of the DRYSTIK can be reduced to, say, 20%. This improves the efficiency and reduces wear and tear on the pump.

DURRIDGE's CAPTURE software, which is available for Windows and macOS, may always be used to download data from the RAD7. If no desiccant is used, particularly in hot and humid conditions, there may, even with the 144 inch model, still be a measurable correction to be applied for humidity in the RAD7. CAPTURE provides this correction to readings automatically provided the "correct for humidity" checkbox is checked.

2.3 Monitoring Thoron in Air

The significant difference between measuring radon and measuring thoron is the half life of thoron (56 seconds). Because this is so short, the delay between the air being sampled at the sampling point and being measured in the instrument is a cause of loss of sample by radioactive decay during sample acquisition. Thus it improves thoron sensitivity to minimize the volume of the sample acquisition path and use a high flow velocity. To that end, the "high flow" output is chosen and either no desiccant is put in the path to the RAD7 (Figure 13) or a small drying tube is put there (Figure 14).

The DRYSTIK duty cycle should be set to 100% (use the 'Thoron in Air' profile on the ADS-3). Set the RAD7 protocol to 'Thoron' (SETUP, PROTOCOL, THORON [ENTER]) and then change the cycle length to your choice and turn off the RAD7 pump (SETUP, PUMP, OFF [ENTER]). It is important the RAD7 protocol be set to 'Thoron' BEFORE the RAD7 pump is set to OFF. For long term monitoring we would recommend longer cycle times than the default 5 minutes; 15 or 30 minutes would be good. If a printer is in position, turn on the RAD7 and let it print out the header. Check the setup review to be sure all settings are what you expect.
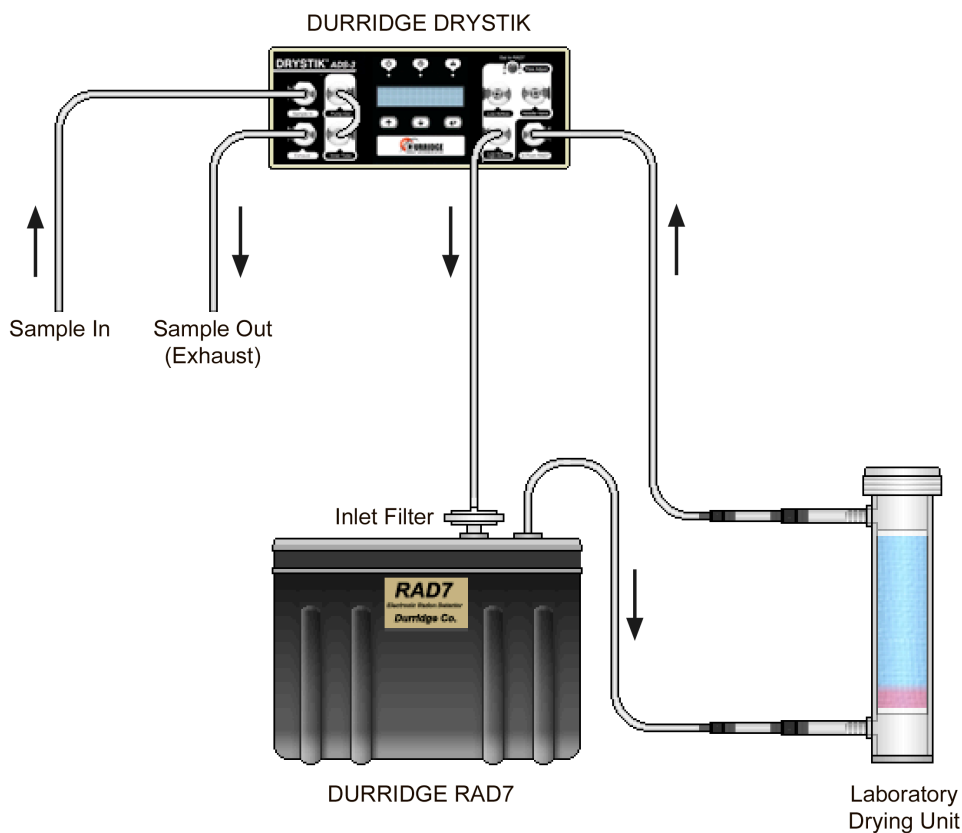

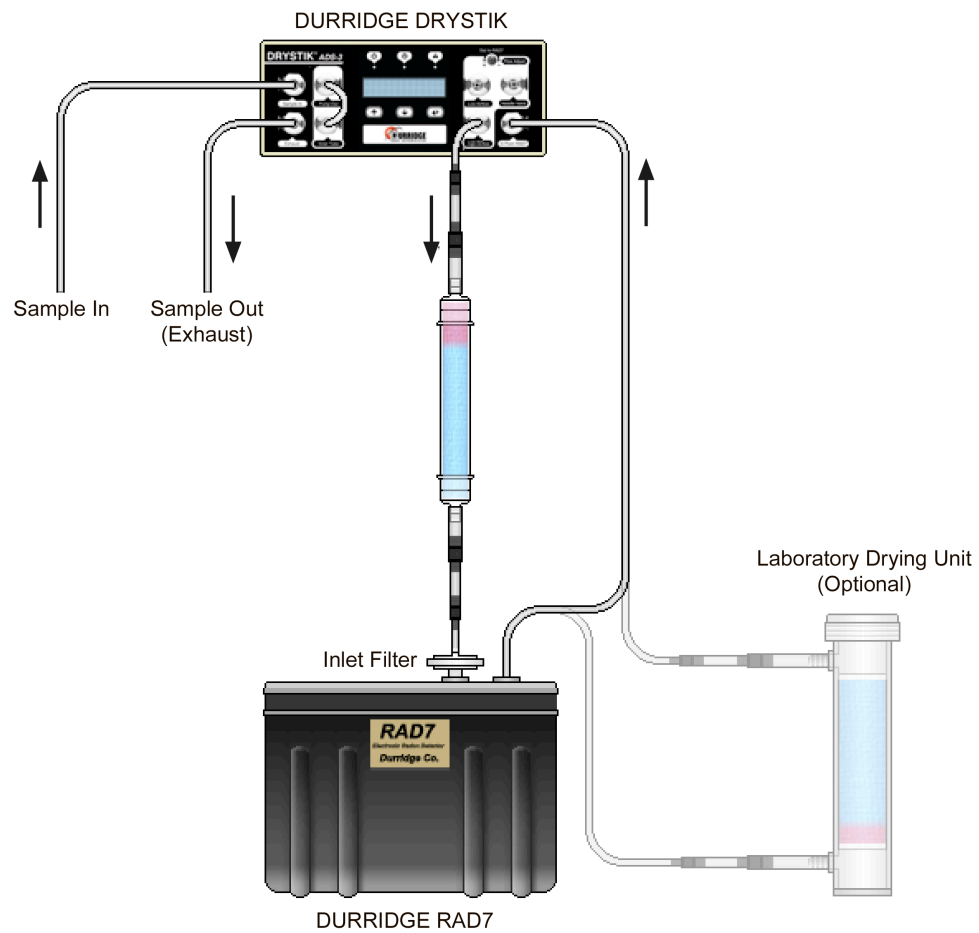**Fig. 13 Basic setup for monitoring thoron in air**

DURRIDGE DRYSTIK

Sample In

Sample Out
(Exhaust)

Laboratory Drying Unit
(Optional)

Inlet Filter

RAD7

DURRIDGE RAD7

Fig. 14 Alternative setup for monitoring thoron in air

2.4 High Humidity Conditions

If condensation occurs in the tube bridge, between the pump and the Nafion tube input, water will make contact with the Nafion. This should be avoided if possible. The most efficient way to deal with it is with a Cool Trap. DURRIDGE offers two sizes of Cool Trap, one that would fit in a mug and one that would fit in a bucket. The bucket size is more efficient, but has more volume . Either one can be placed in a container with ice water or other coolant, or mounted in the door (to avoid refrigerant tubes) of a refrigerator.

The cool trap is intended to reduce the dew point of the compressed air down towards the temperature of the cool trap, preferably close to zero degrees celsius. Condensate is expelled through the drain. The drain needle valve should be adjusted so that a bubble appears occasionally. If the drain blows a bubble occasionally, we know that water is not accumulating in the reservoir. If the compressed air leaving the cool trap has a dew point below ambient temperature we can be confident that condensation will not occur inside the teflon membrane tube.

If no cool trap is available, slowing down the average flow rate reduces the rate of condensation and helps the nafion tube to deal with the condensed water. Use the low-flow output of the DRYSTIK and set the duty cycle to 20% or less. The lower the duty cycle, the lower the average flow rate, the easier the Nafion tube will deal with condensate and the less wear and tear on the pump.

Please note, however, that very low flow rates may influence the performance of the RAD7. With a 10% duty cycle and a 0.16 L/min flow rate when the pump is ON, the average flow rate will be 0.015 L/min. The volume of the RAD7 and inlet tubing will be around 1L, so that without any desiccant it will take about 1/0.015 = 1 hour for 1L of sample air to flow out of the DRYSTIK. That will require 1% to be added to the RAD7 reading to correct for the decay of the radon in the sample during sample acquisition. With a laboratory drying unit in the sample acquisition path the correction should be nearly doubled. Please note, also, that the response time of the system with such a flow rate cannot be less than 70 minutes even if the RAD7 is put into SNIFF mode. For normal, long-term measurements, with the RAD7 in NORMAL mode after the first three hours, neither the 1% or 2% correction nor the one- or two-hour response time are of any concern.

For continuous soil gas measurements, see below, the very low flow rate is a distinct advantage.
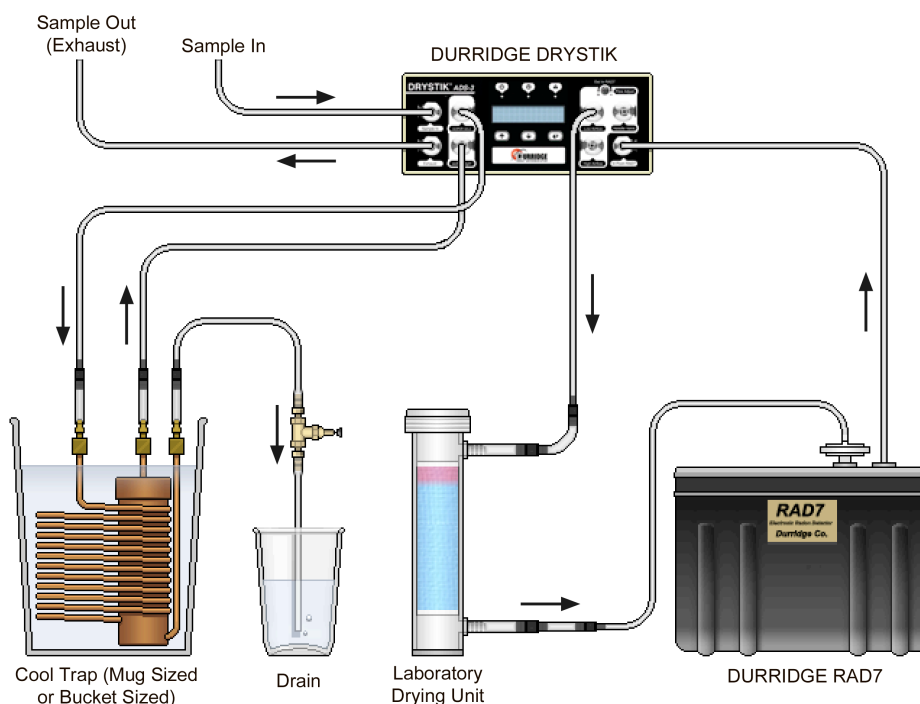

Fig. 15 DRYSTIK Configuration with Cool Trap

2.3 Monitoring Radon in Water

The DRYSTIK can be used to aid operations using the RAD AQUA and RAD H$_2$O accessories, significantly extending desiccant life and in certain cases eliminating the need for desiccant altogether. Basic information on using the DRYSTIK with each of these accessories are provided below, but it will be necessary to refer to the manuals specific to each accessory for complete instructions.

2.5.1 RAD AQUA

When using a passive or active DRYSTIK with the RAD AQUA, the DRYSTIK should be connected to the RAD AQUA apparatus between the RAD AQUA exchanger and the laboratory drying unit, as shown in Figure 16, below. If there is any chance of liquid water entering the DRYSTIK, precautions should be taken to prevent it from happening. The airtight water switch is a good solution. It should be inserted in the air sample path upstream of the DRYSTIK. The water switch is connected to a 12V supply and the 12V output of the water switch is connected to the DRYSTIK 12V power inlet. When water enters the water switch, it raises a float that interrupts the 12V supply, thus stopping the pump in the DRYSTIK. More information on using the DRYSTIK with the RAD AQUA is available in the RAD AQUA manual, Chapter 5: DRYSTIK.
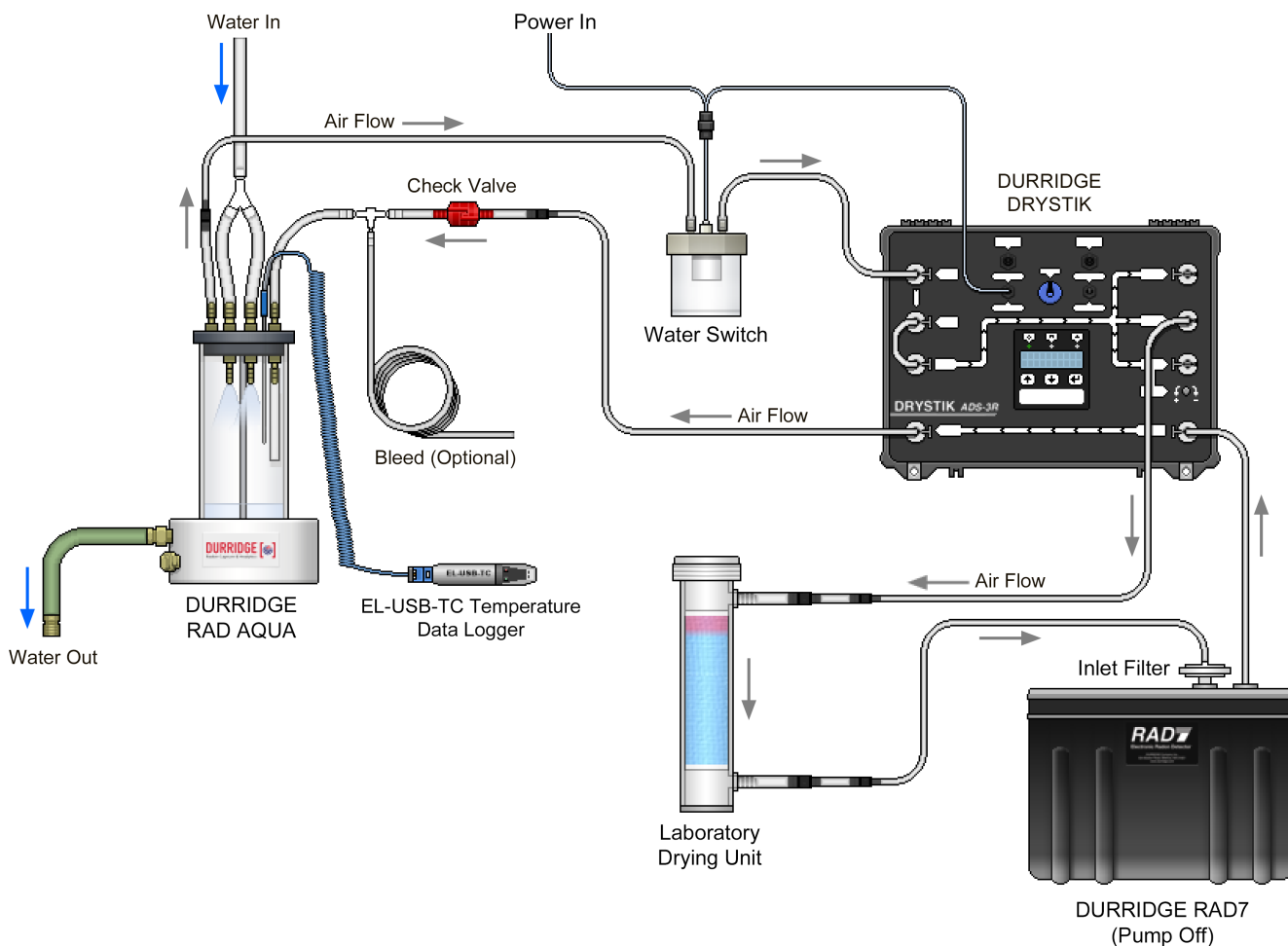

Fig. 16 DRYSTIK Configuration with RAD AQUA

2.5.2 RAD H$_2$O

Using the DRYSTIK in a RAD H$_2$O experiment, it is possible to aerate the water completely and keep the RAD7 dry for the duration of the measurement. This section provides details on the necessary procedure.

2.5.2a System Setup

As shown in Figure 17, a small drying tube is connected to both the low flow and the needle-valve-controlled outputs of the DRYSTIK, with a clip on the tubing from the controlled output. Make sure that the correct aerator cap is chosen for the vial size being used.

Several variations of the experimental setup are supported. The setup shown here works with the 40ml and 250ml bottles included with the RAD H$_2$O. Larger bottles require the Big Bottle System and involve a larger laboratory drying unit and a different type of aerator bottle cap, which affects the air volume of the apparatus. Big Bottle System configurations therefore require adjustments in the CAPTURE software for a proper data analysis.

2.5.2b Needle Valve Adjustment

The DRYSTIK's needle valve should be adjusted such that the sample can be aerated without any water entering sensitive equipment and damaging it. To determine the proper needle valve setting, fill an unused vial with water similar to the sample. (If the sample is plain tap water then use plain tap water. If the sample is contaminated with foaming agents then use water similarly contaminated.) Attach the filled vial to the aerator cap. Check that the glass frit nearly (but not quite) touches the bottom of the vial. With the clip open, close the needle valve and run the DRYSTIK with 100% duty cycle. There will be some bubbles in the vial. Open the needle valve slowly until bubbles start to rise up in the tube above the aerator cap. Adjust the needle valve so that there is no chance that bubbles will climb all the the way up and enter the DRYSTIK. Finally, turn off the DRYSTIK and remove the vial.

2.5.2c RAD7 Setup

If external power is available, plug in the RAD7. Turn on the RAD7 and press [MENU]. Change the protocol to the required RAD H$_2$O protocol (SETUP, PROTOCOL, WAT250 (or WAT-40) [ENTER]). Turn
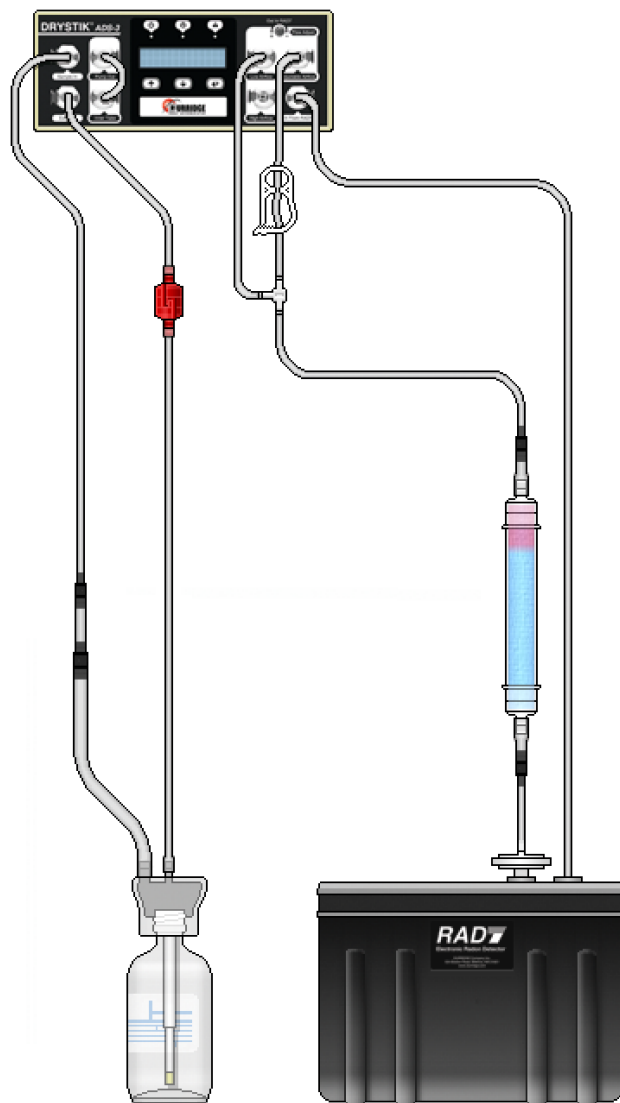

Fig. 17 DRYSTIK Configuration with RAD H$_2$O

off the RAD7 pump (SETUP, PUMP, OFF [ENTER]). Then turn off the RAD7 and turn on the printer. Turn the RAD7 back on and let it print out the measurement header. Make sure the pump is listed as Off.

2.5.2d DRYSTIK Setup

The DRYSTIK is going to run with 100% duty cycle for 5 minutes (with clean water) or longer, perhaps 10 minutes or more, if the water is foamy and the controlled flow rate is reduced to prevent bubbles reaching the DRYSTIK. It can then switch to, say, 30% duty cycle with the clip closed, to reduce the

average flow rate to around 0.05 L/min, just to keep the RAD7 dry. The changes can be made manually, or a DRYSTIK profile can be set up using CAPTURE, to make the changes automatically after a certain amount of time has passed. An optional solenoid valve can control the DRYSTIK, making the whole process completely automatic, under the control of the DRYSTIK micro-controller.

If a manual procedure is used, the aeration process will proceed with a 100% duty cycle and the clip open. When the aeration is complete, change the duty cycle to 30% and close the clip.

If the procedure is semi-automatic, load two DRYSTIK profiles using CAPTURE, and have the first (100% duty cycle) automatically switch to a second (30% duty cycle) after the required aeration time.

If the procedure is fully automatic, close the clip at the same time the switch is made to the second profile.

2.5.2e Measurement

Start the DRYSTIK operation, above. Less than five minutes before the end of the aeration phase start the RAD7 run (TEST, START [ENTER]). The RAD7, without the pump running, will show two 5-minute cycles with no data and then four reading cycles. It then finishes the run and prints the summary.

2.5.2f Preparing for the next measurement

Remove the water sample from the aerator, but leave everything else in place. Open the clip and run the DRYSTIK with the duty cycle at 100% for 3 - 5 minutes. This will purge the system of residual radon. Stop the DRYSTIK pump. Then go to 2.5.2e, above.

2.5.2g Data analysis

The summary print out shows the average of the four readings and their standard deviation. The one-sigma uncertainty of the average is the standard deviation of the readings divided by SQR(number of readings) - or divided by two. The two sigma uncertainty of the average is therefore equal to the standard deviation of the readings when there are four readings. The RAD7 printout therefore gives you the radon concentration in the water and the two-sigma uncertainty of that measurement. You can get the same information in graph format by using CAPTURE to download the data and graph it.

Additional details are provided in the Big Bottle RAD H_2O manual, Section 1.4.5: Running the test with the DRYSTIK.
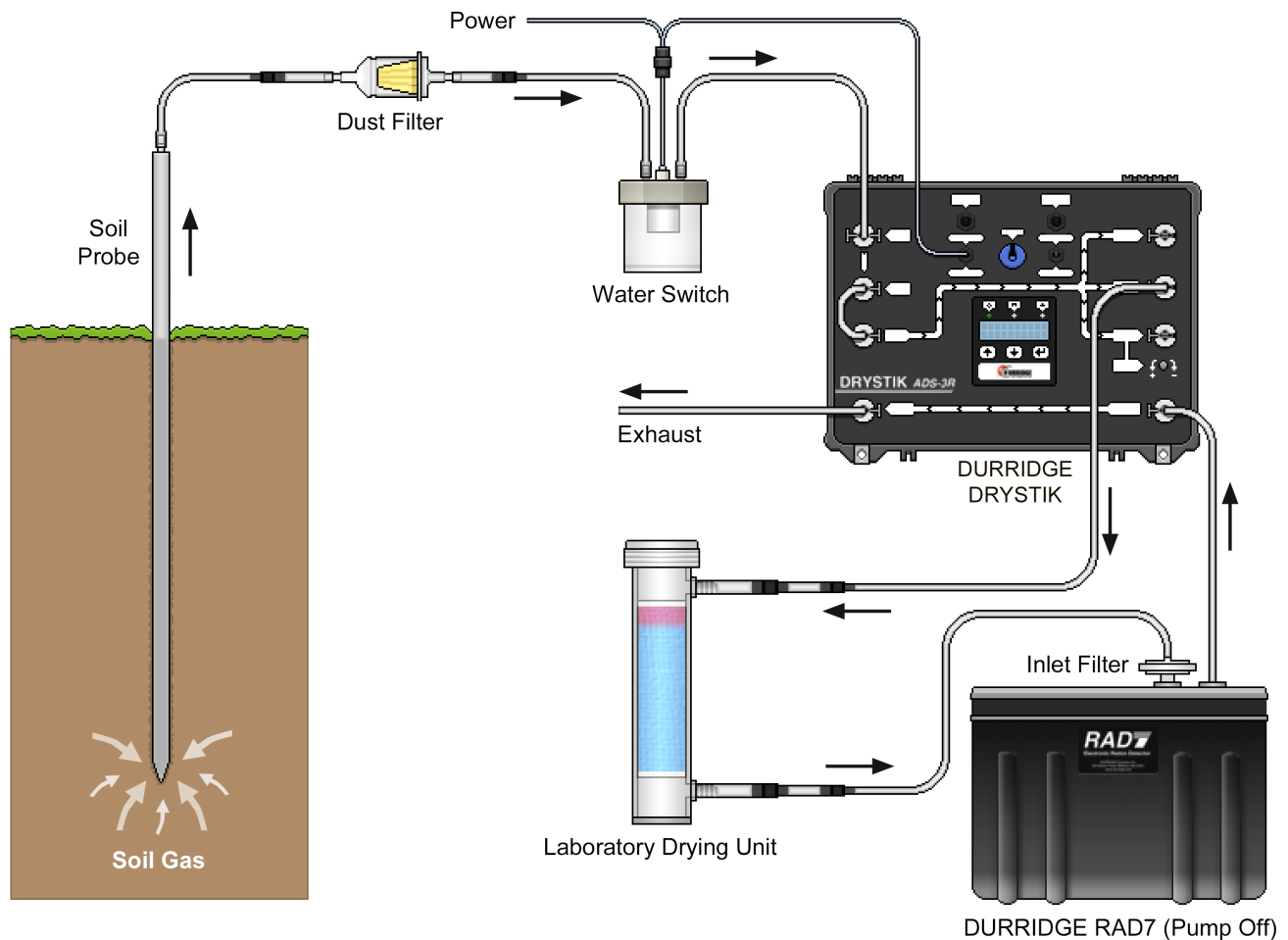
2.6 Soil Gas Monitoring

Fig. 18 DRYSTIK Configuration for monitoring radon in soil gas

2.6.1 Monitoring Radon in Soil Gas

The Duty Cycle Controller built into the DRYSTIK (except for the ADS-1 model) is ideally suited for the long-term monitoring of radon concentrations in soil gas using a RAD7 and soil gas probe. The Duty Cycle Controller enables the average flow rate to be reduced to prevent fresh air from diffusing down through the soil to the sampling point. With the Duty Cycle set appropriately, continuous monitoring of soil gas from one sample point may be performed indefinitely. The maximum permissible flow rate depends on the porosity of the soil and the depth of the 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 figures 19, 20, and 21.) If that 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.

Maximum flow rate, F, is roughly given by:

$$F = D^3 / 10^7 \text{ litre/min}$$

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 0.16 L/min, which is comparable to the average flow rate of a RAD7 whose pump, operating at 1 L/min, runs for one minute in every five. On the ADS-3 simply select the desired 'Soil Gas' profile. On the 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 61cm 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 77cm, will allow double the flow rate, assuming uniform soil porosity down to 2m or so.

2.6.2 Minimum Flow Rates

Radon has a half life of 3.8 days. If the air sample takes more than an hour or two to reach the 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 0.017 L/min. Flow rates lower than this will require a correction factor for radon decay, as discussed below.
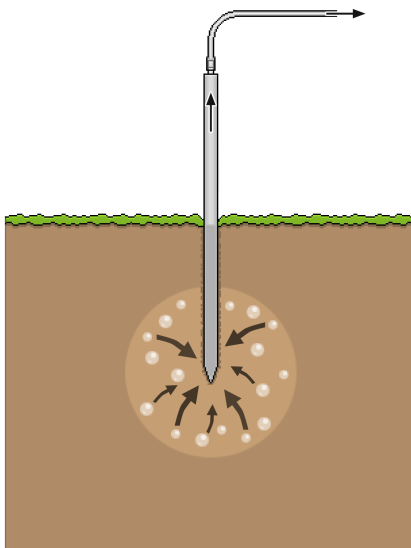

Figure 19
Soil gas is drawn upwards. The spherical region from which the gas is being pumped expands.
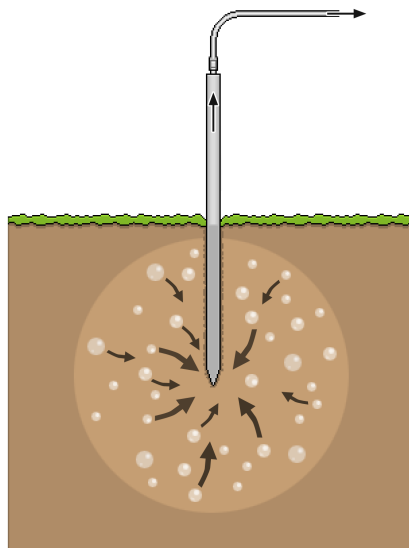
Figure 20
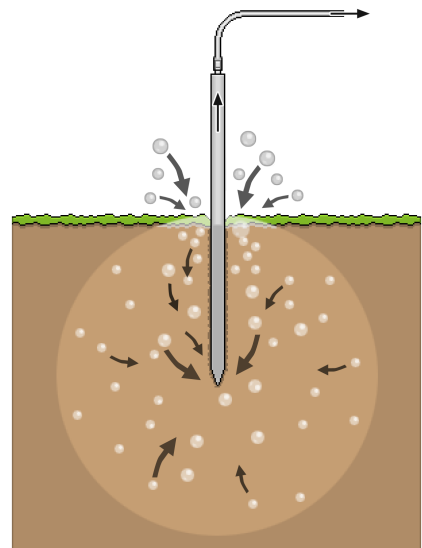The sphere should not expand enough to touch the surface during the test.

Figure 21
Unwanted Result: Sphere radius exceeds probe depth. Fresh air diffusion occurs.

Figures 19-21 Underground Soil Gas Sphere

2.6.3 Correcting for Very Low Flow Rates

In the examples above, it may be seen that for a probe depth of 61cm, to avoid dilution of the air sample after a week or two of sampling, a flow rate of no more than 0.01L/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 2ft 6inches (77cm) 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 2ft (61cm), 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 2ft (61cm) and keep the flow rate at 0.01 L/min. Assuming a sample volume of 2L, 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.

2.6.4 Measuring Thoron in Soil Gas

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 needle valve should be bypassed and the pump should be set to run continuously. The flow rate will then be close to 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.

3 DRYSTIK Technology

3.1 Pump Airflow

The DRYSTIK's Sample In and Pump Out ports are bridged internally with tubing connecting to an air filter and pump, as shown in Figure 22. When operating the DRYSTIK in a dusty environment, an additional air filter should be added to the tubing bridge on the outside of the instrument. See Section 4.2 for details.
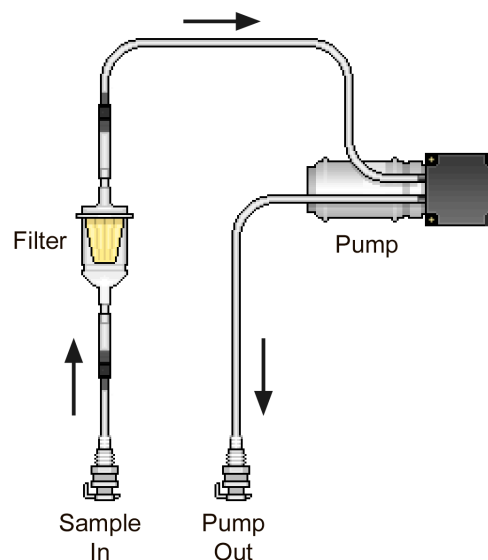
Fig. 22 DRYSTIK Pump Airflow

3.2 Nafion Tubing Airflow

Fig. 23 illustrates the DRYSTIK's second air path, which contains Nafion tubing and the ports used to separate moisture out of the air sample. This image applies to DRYSTIK models ADS-2, ADS-3, and ADS-3R. Once the sample has been dried, it exits the system through one of three outputs: a High Airflow port, a Low Airflow port, and an adjustable Needle Value port. (Model ADS-1 contains only one output port, the Needle Valve port.)
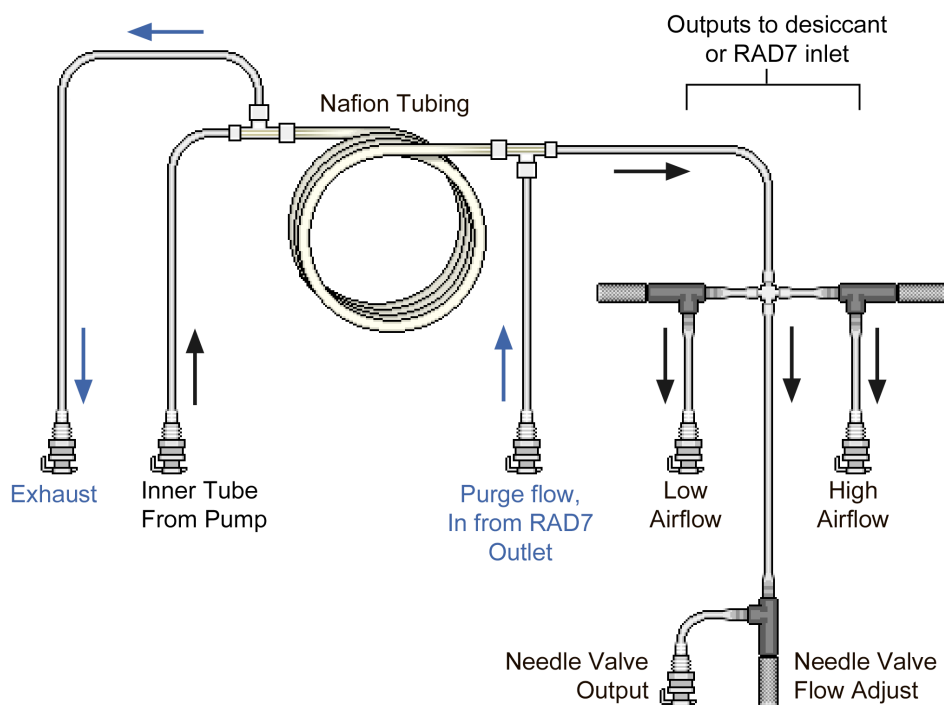
Fig. 23 DRYSTIK Pump Airflow (Models ADS-2 and ADS-3)

3.3 DRYSTIK Circuitry

Figure 24 illustrates the basic connections between the switches and ports on the rear panel of the DRYSTIK models ADS-2 and ADS-3. (Model ADS-3R contains the same elements, but on the top faceplate.) When turned on, the Power Switch enables all system functions. The Pump/Output toggle switch controls whether the Duty Cycle Output feeds power to the internal pump or to the Duty Cycle Controller output port. The latter option makes it possible to use the Duty Cycle Controller to control a different instrument, such as an external pump.
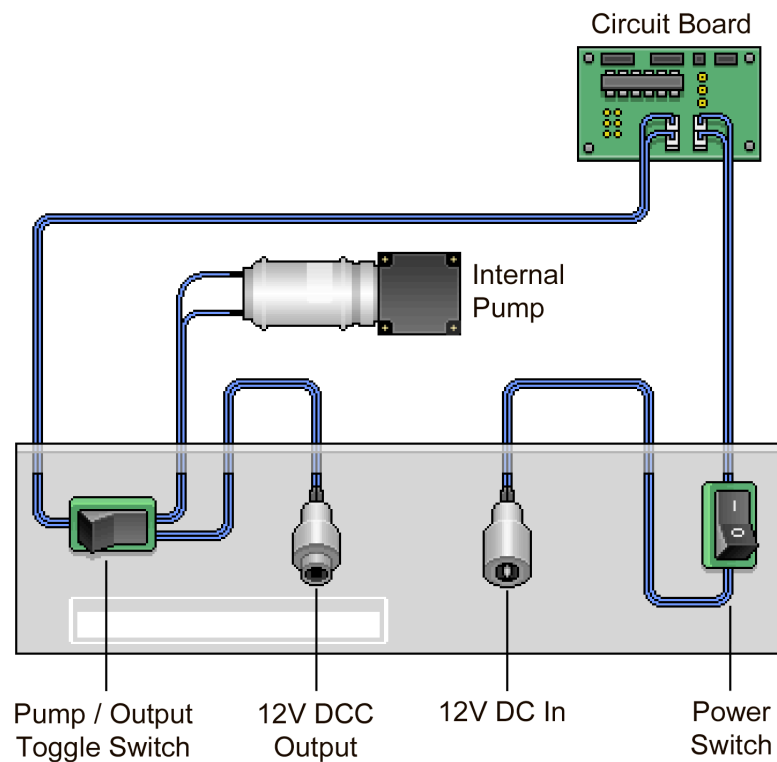

Fig. 24 DRYSTIK Circuitry (Models ADS-2 and ADS-3)

4 Troubleshooting

4.1 Water Enters The DRYSTIK

If water enters the DRYSTIK, the following actions should be taken to ensure that the instrument does not sustain permanent damage.

1. Connect a tube to the high-flow output of the DRYSTIK. Start the pump and make sure that a) air is coming out of the tube and b) there is no liquid coming out. If you see liquid coming out, keep pumping until you see no liquid. To speed the drying, you can connect the sample output to the purge input, preferably, but not necessarily, through a drying unit containing good desiccant.

2. Once you are sure that the DRYSTIK will not spit out any liquid, connect the high-flow output of the DRYSTIK directly to the RAD7 inlet filter, connect the RAD7 outlet to a drying unit with good desiccant, and connect the other end of the drying unit to the purge input on the DRYSTIK. There will be no desiccant in the sample path leading to the RAD7, but the purge flow will be dry.

3. Turn on the RAD7, but do not start any test. Make sure the pump is not running and go to the third status window ([Menu], [Enter], [Enter], Rt. Arrow, Rt. Arrow), where the RH is given in the top righthand corner.

4. Set the DRYSTIK duty cycle to 100%. Set the Period to 1 minute, and then start the DRYSTIK. Check that there is flow out of the purge outlet. The flow rate should be around 1.5 L/min.

5. When the RH in the RAD7 drops to below 50%, change the DRYSTIK duty cycle to 50%.

6. When the RH in the RAD7 drops below 15%, change the tubing connection to the DRYSTIK low flow output.

7. Eventually, and it may take a day or two, the RAD7 RH should drop down to below 5% if the DRYSTIK is working well.

4.2 Dust Enters The DRYSTIK

It is important to prevent dust from entering the DRYSTIK and becoming lodged in the instrument's Nafion tubing. If there is any dust in the air entering the DRYSTIK, a 5-micron dust filter should be included in the air path, preferably in the bridge between the pump output and the Nafion tubing input. An additional dust filter resides inside the DRYSTIK enclosure, upstream of the pump, but it is not designed to handle extremely small particles. This internal filter can be replaced by DURRIDGE technicians as needed.

If dust lands inside the Nafion tubing it may affect results by a) raising the RAD7 background due to trace amounts of radium in the dust, b) contaminating the Nafion so that it loses its efficiency, and c) reducing the flow rate by partially blocking the capillary tubing.

In these cases it may be possible to address the problem by removing the Nafion tubing and carefully washing it, but it is more typically necessary for the DRYSTIK to be returned for service so that the Nafion tubing can be replaced by DURRIDGE personnel.

4.3 CAPTURE Software Fails to Detect The DRYSTIK

The CAPTURE User's Manual contains troubleshooting instructions that can help to resolve DRYSTIK connection failures. The manual can be accessed from the CAPTURE page on the Durridge website (durridge.com/software/capture/), and from within the CAPTURE application itself, using the Help menu in the menubar. Please refer to the "Device Detection Failure" section of the Troubleshooting chapter in the CAPTURE manual.

Appendix 1: DRYSTIK Model Comparison

The following table shows the differences between DRYSTIK models ADS-1, ADS-2, ADS-3, and ADS-3R. These models were developed in the order shown, and each is intended to replace its predecessor, with the exception of the ADS-3R, which is essentially a ruggedized version of the ADS-3 with no specific added functionality.

	DRYSTIK Model ADS-1	DRYSTIK Model ADS-2	DRYSTIK Model ADS-3	DRYSTIK Model ADS-3R
Available Nafion Lengths	12 inch, 48 inch, 144 inch			
Available Pump Types	Brushed Pump	Brushed Pump, Brushless Pump		Brushless Pump
Built-in Duty Cycle Controller	Not Included	Included		
Savable DCC Configurations			√	√
Can be controlled by Computer via CAPTURE			√	√
LCD Display		√	√	√
Low Vibration Pump Mount		√	√	√
Solenoid Support	Not Supported		Supported	
Enclosure Type	Black ABS Plastic Case	Beige ABS Plastic Case		Rugged Black Pelican Case
Faceplate Controls	Top Accessible	Front Accessible	Front Accessible	Top Accessible
Power In	12V DC in (1.25A)			
Power Out	None	12V out (1.0A)		
Internal Air Vol: Pump Path	Not Specified		34 mL	
Internal Air Vol: Sample Path	Not Specified		31 mL (12 inch); 36 ml (48 inch); 47 mL (144 inch)	
Internal Air Vol: Purge Path	Not Specified		5 mL (12 inch); 18 mL (48 inch); 52 mL (144 inch)	
Internal Air Volume (Total)	Not Specified		70 mL (12 inch); 88 mL (48 inch); 133 mL (144 inch)	
Outer Dimensions	8.4" x 7.4" x 3.4" (21 cm x 19 cm x 9 cm)	11.5" x 7.75" x 3.25" (29 cm x 20 cm x 8 cm)		13.75" x 11.5" x 5.75" (35 cm x 29 cm x 15 cm)
Weight	1.80 lbs (0.82 kg)	2.98 lbs (1.35 kg)	3.40 lbs (1.54 kg)	7.20 lbs (3.27 kg)

Appendix 2: Performance Comparison

Eight sets of performance tests were conducted to determine the absolute and relative capabilities of each DRYSTIK model under a variety of operating conditions. In tests involving desiccant, a large drying tube containing fresh desiccant was placed between the RAD7 air outlet and the DRYSTIK's Purge In port. Each test ran in an open loop configuration for
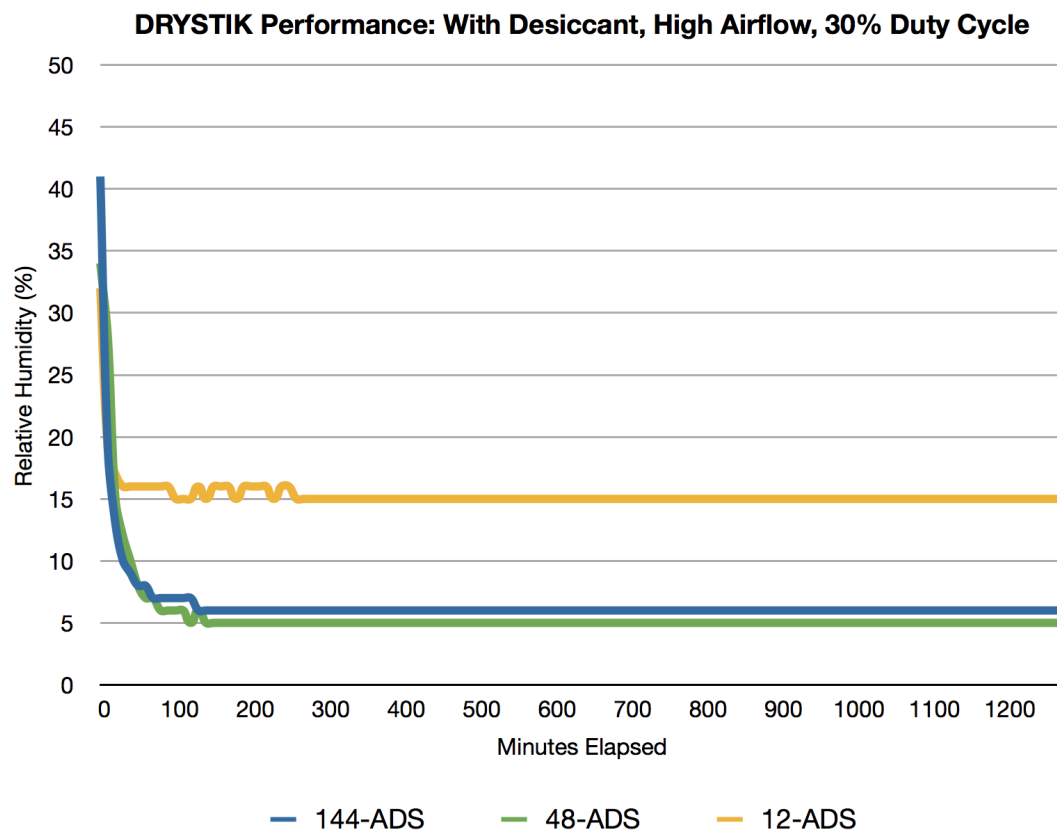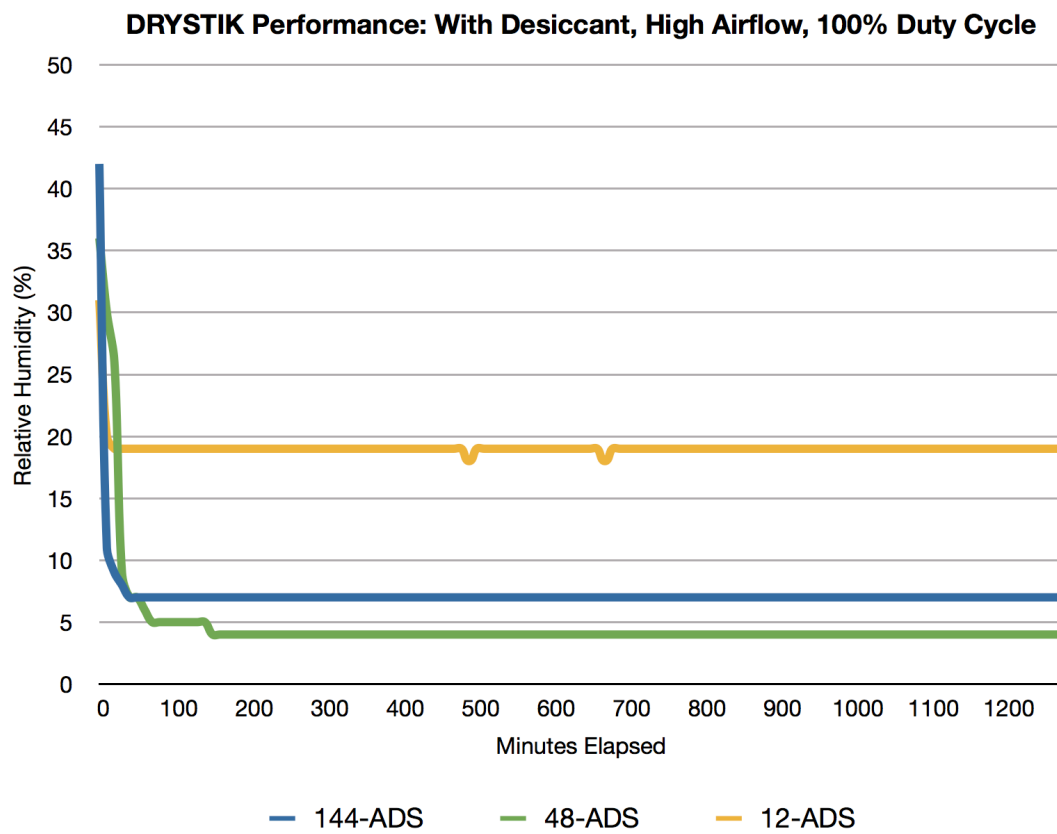
1200 minutes, with 10 minute cycle intervals. Changes in the reported humidity were observed over time and graphed. These performance test results apply to all DRYSTIK ADS-2, ADS-3 and ADS-3R models, with both standard and brushless pumps. The table below contains the parameters of the tested DRYSTIK configurations.
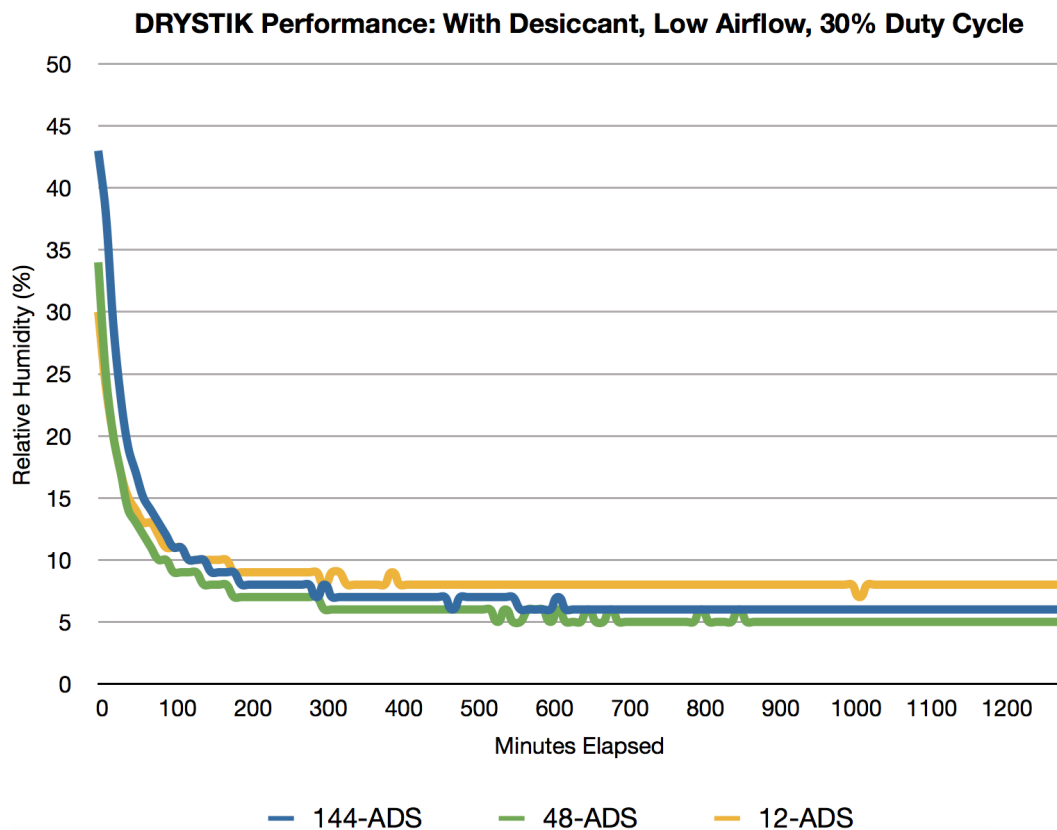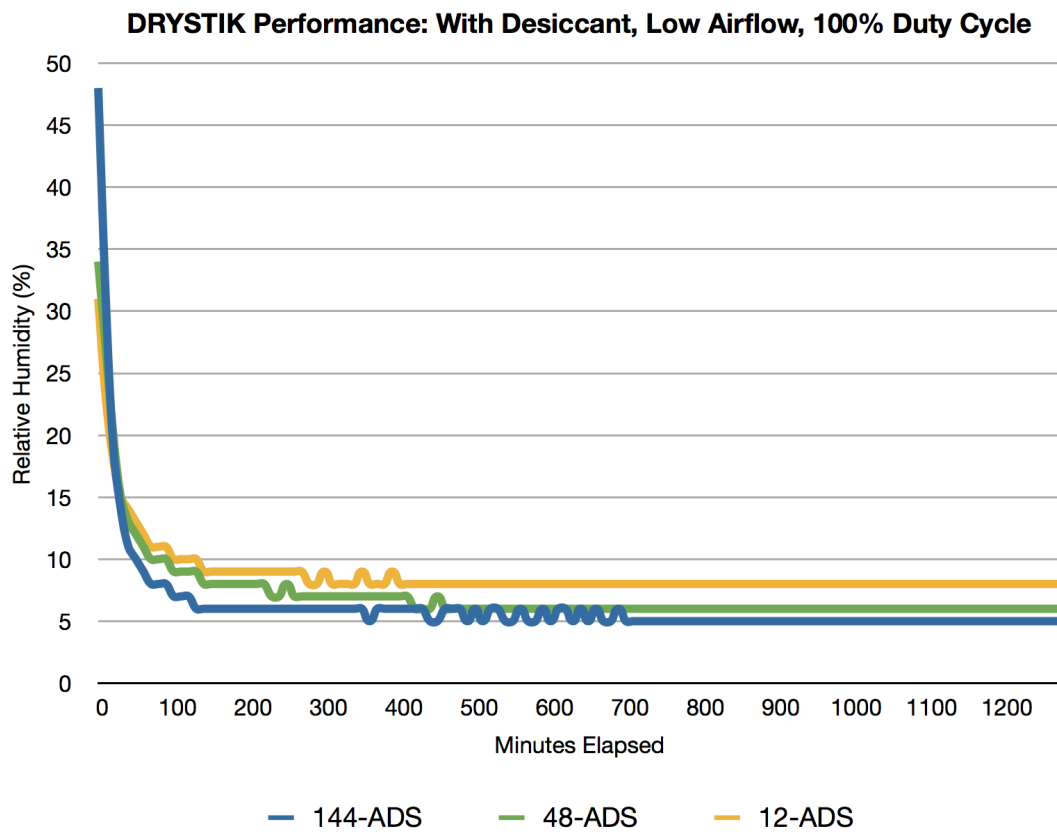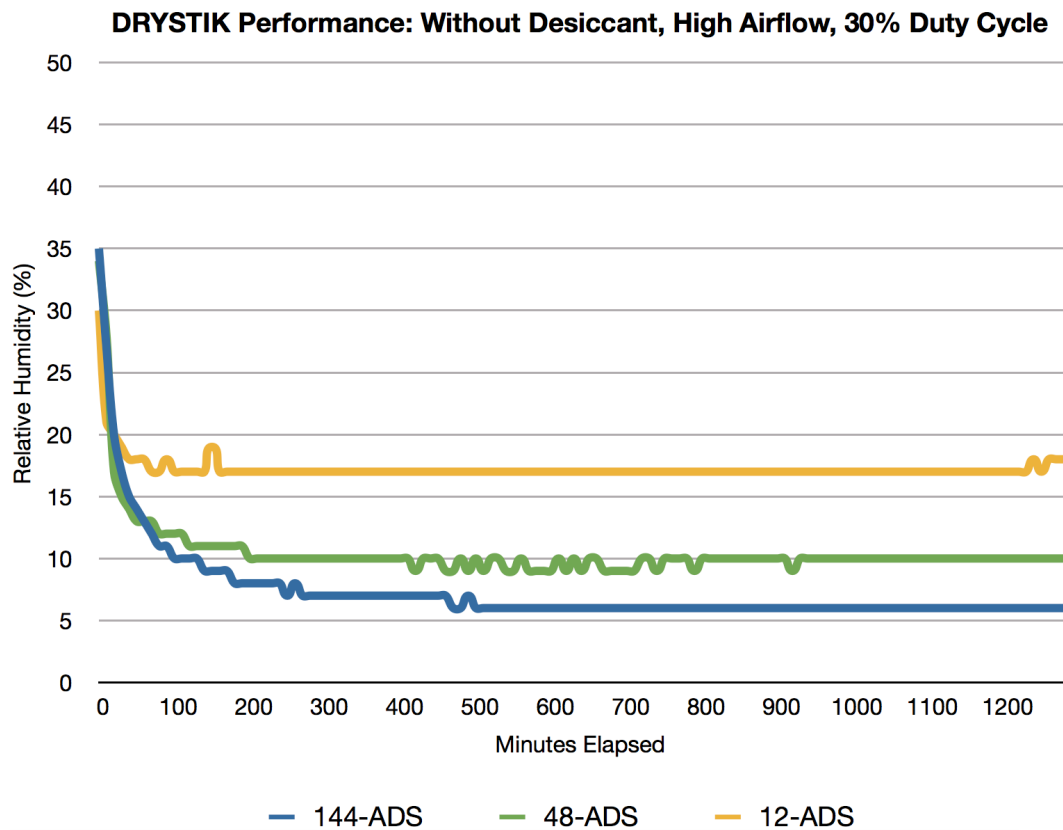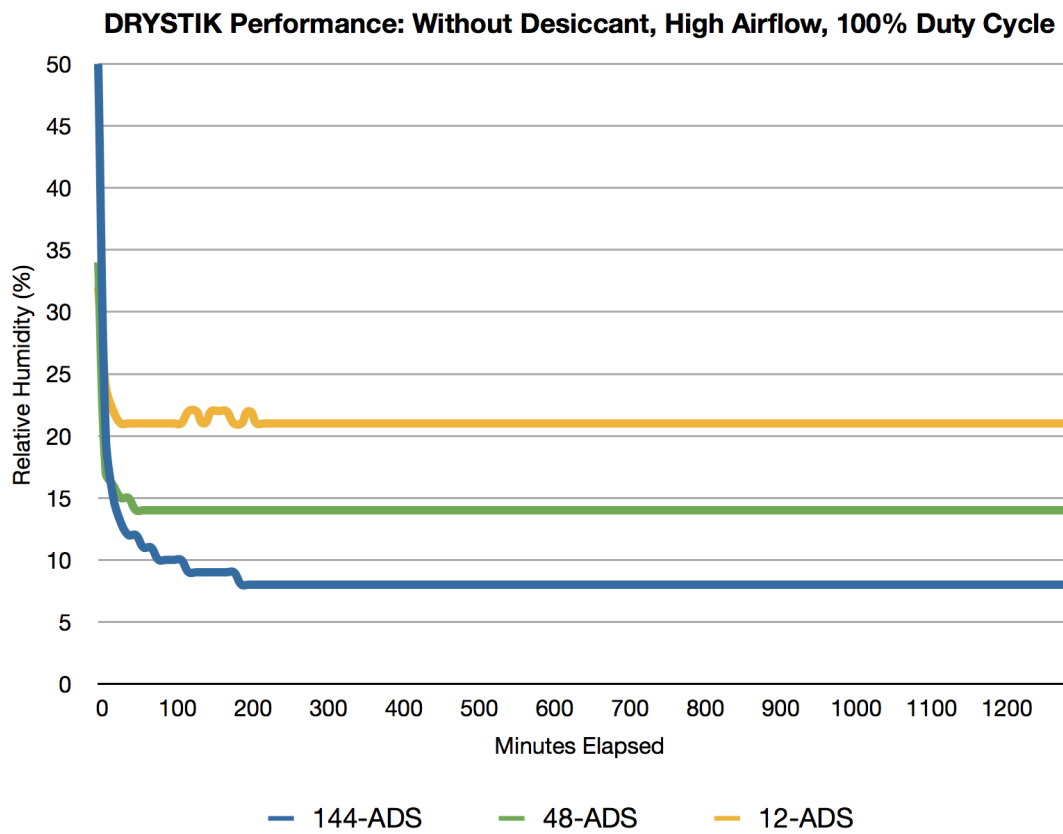
A2.1 DRYSTIK Performance Table

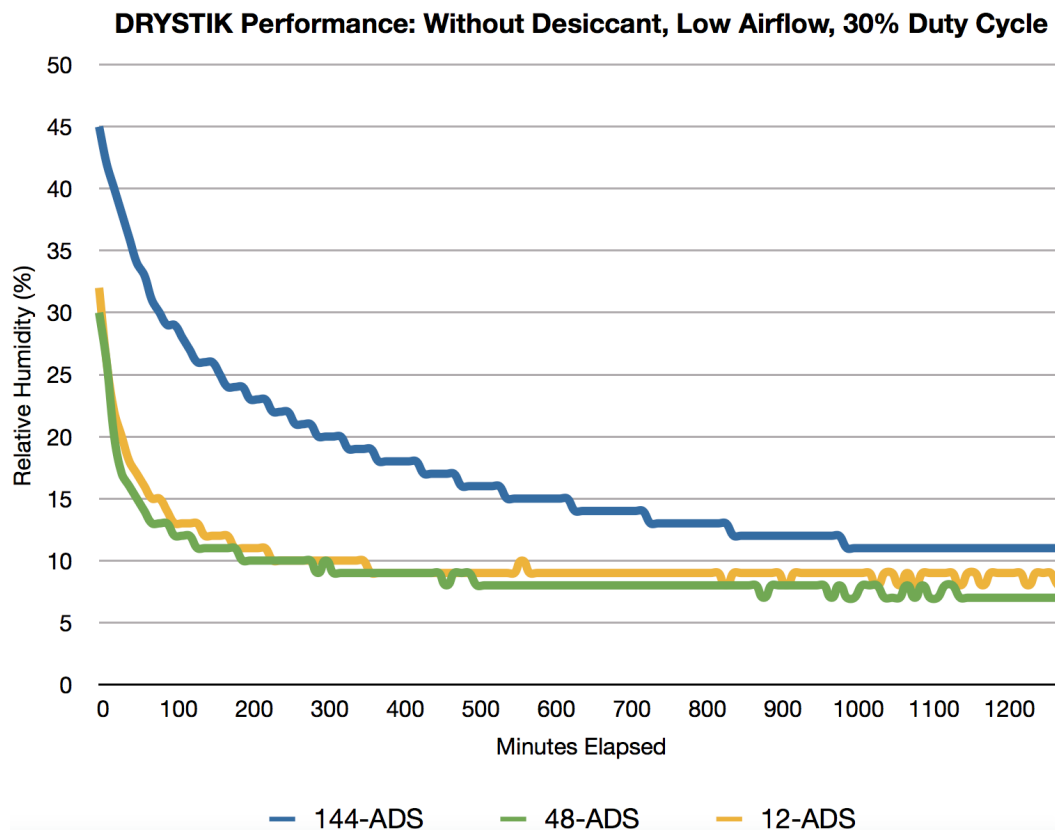| Test ID	Desiccant	Flow Rate	Duty Cycle	Ambient Temp (144"/48"/12")	Ambient RH (144"/48"/12")
1	Yes	High Flow	100%	28° C / 24° C / 22° C	42% / 34% / 31%
2	Yes	High Flow	30%	29° C / 24° C / 23° C	40% / 34% / 32%
3	Yes	Low Flow	100%	33° C / 24° C / 23° C	43% / 34% / 31%
4	Yes	Low Flow	30%	29° C / 23° C / 23° C	41% / 34% / 30%
5	No	High Flow	100%	28° C / 24° C / 23° C	48% / 34% / 32%
6	No	High Flow	30%	29° C / 23° C / 23° C	40% / 34% / 30%
7	No	Low Flow	100%	29° C / 24° C / 22° C	39% / 34% / 27%
8	No	Low Flow	30%	28° C / 24° C / 23° C	48% / 30% / 32%

A2.2 DRYSTIK Performance Tests

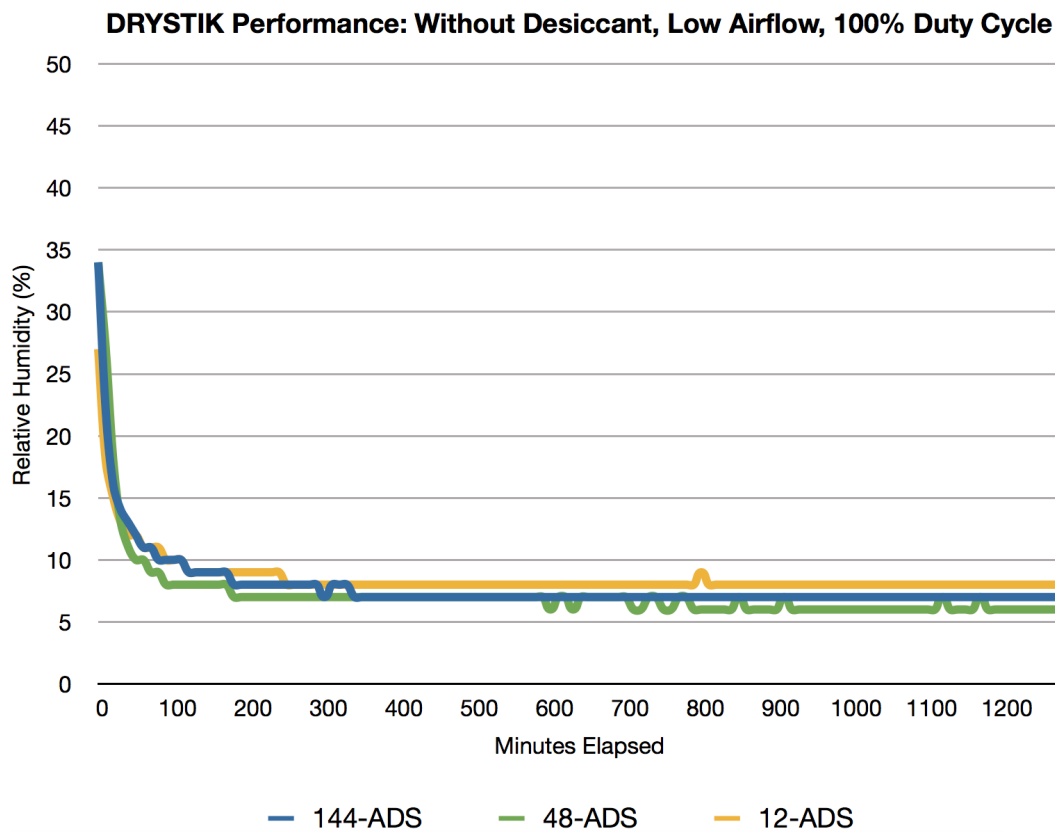Graphs showing the results of each performance test can be seen on the following pages. Each graph contains three lines, colored blue, green, and yellow. These lines indicate the humidities recorded by the 144-inch, 48-inch, and 12-inch DRYSTIKs, respectively.

DRYSTIK Performance: With Desiccant, High Airflow, 100% Duty Cycle

DRYSTIK Performance: With Desiccant, High Airflow, 30% Duty Cycle

DRYSTIK Performance: With Desiccant, Low Airflow, 100% Duty Cycle

DRYSTIK Performance: With Desiccant, Low Airflow, 30% Duty Cycle

DRYSTIK Performance: Without Desiccant, High Airflow, 100% Duty Cycle

Relative Humidity (%) vs Minutes Elapsed

— 144-ADS   — 48-ADS   — 12-ADS

DRYSTIK Performance: Without Desiccant, High Airflow, 30% Duty Cycle

Relative Humidity (%) vs Minutes Elapsed

— 144-ADS   — 48-ADS   — 12-ADS

DRYSTIK Performance: Without Desiccant, Low Airflow, 100% Duty Cycle

DRYSTIK Performance: Without Desiccant, Low Airflow, 30% Duty Cycle

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Note: DURRIDGE frequently updates its product manuals with new information. The latest version of this manual can be downloaded in PDF format from the following location: www.durridge.com/support/product-manuals/

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