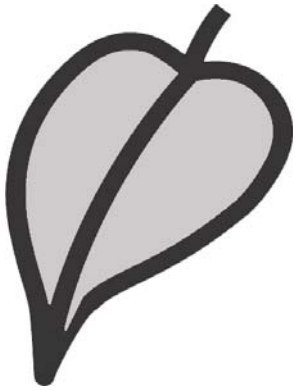


Leaf Porometer

Operator's Manual

Version 7.0

DECAGON DEVICES

Decagon Devices, Inc.
2365 NE Hopkins Court
Pullman, WA 99163
Tel: (509) 332-2756
Fax: (509) 332-5158
www.decagon.com

Table of Contents

1. Introduction

Thank you for purchasing Decagon Devices' Leaf Porometer. The Leaf Porometer is a device used to measure stomatal conductance in leaves. This manual is designed to help you understand the functions of your Leaf Porometer, make high-quality stomatal conductance measurements, and help you get the most out of your Leaf Porometer.

Customer Support

When contacting us, via fax or e-mail, include your Leaf Porometer's serial number (this can be found on the inside of the battery cover), the firmware version you are currently using, your name, address, phone and fax number, and a description of your problem.

Phone:
United States/Canada (toll free): **1-800-755-2751.**
Outside of the U.S./Canada: **1-509-332-2756.**

Fax: 1-509-332-5158

E-Mail: support@decagon.com.

Warranty

The Leaf Porometer is covered by a standard, one-year warranty on parts and labor, and is activated upon the arrival of the instrument at your location.

Seller's Liability

Seller warrants new equipment of its own manufacture against defective workmanship and materials for a period of one year from the date of receipt of equipment (the results of ordinary wear and tear, neglect, misuse, accident and excessive deterioration due to corrosion from any cause are not considered to be a defect); but Seller's liability for defective parts shall, in no event, exceed the furnishing of replacement parts f.o.b. the factory where originally manufactured. Material and equipment covered hereby which is not manufactured by the Seller shall be covered only by the warranty of its manufacturer. Seller shall not be liable to Buyer for loss, damage, or injuries to persons (including death), or to property or things of whatsoever kind (including, but not without limitation, loss of anticipated profits), occasioned by or arising out of the installation, operation, use, misuse, nonuse, repair, or replacement of said material and equipment, or out of the use of any method or process for which the same may be employed. The use of this equipment constitute's Buyer's acceptance of the terms set forth in this warranty. There are no understandings, representations, or warranties of any kind, express, implied, statutory or otherwise, (including, but not without limitation, the implied warranties of merchantibility and fitness for a particular purpose), not expressly set forth herein.

Repair Instructions

If your Leaf Porometer should ever require a repair, call Decagon at **(509) 332-2756** or **1-800-755-2751** (United States and Canada). We will ask you for your address, phone number, your Leaf Porometer's serial number, and your current firmware version. For non-warranty repairs, we will also ask for a method of payment.

Before shipping your instrument to Decagon, please contact Decagon to obtain a Request Maintenance Authorization Number (RMA). This will allow Decagon's repair staff to keep track of your porometer. Once you have acquired an RMA, send your Leaf Porometer to Decagon. Please include a document listing the complete shipping address, name, and department of the person responsible for the instrument, as well as a description of the problem. This will better help our technicians and shipping department to expedite repair on your Leaf Porometer, and ship it back to you.

Please pack your Leaf Porometer carefully. Ship it back in the carrying case, preferably inside a cardboard box. Ship to:

Decagon Devices Inc.
2365 NE Hopkins Court
Pullman, WA 99163

Repair Costs

Manufacturer's defects and instruments under warranty will be repaired at no cost. For non-warranty repairs, costs for parts, labor, and shipping will be billed to you.

2. About the Leaf Porometer

The Leaf Porometer is a battery-operated, menu-driven device used to measure stomatal conductance of leaves. Stomatal conductance is a function of the density, size, and degree of opening, of stomata, which are pores in plants that open to the outside air. The Leaf Porometer measures stomatal conductance by putting the conductance of a leaf in series with two known conductance elements, and comparing the humidity measurements between them. It can display information in three selectable units:

- **mmol/m^{2}s** (millimoles per meter squared seconds)
- **m^{2}s/mol** (meters squared seconds per mole)
- **s/m** (seconds per meter)

The first is a unit of conductance, while the other two are units of resistance. To change between them, use the arrow keys when taking a reading (see "Making a Measurement," pp. 16). They can also be altered by using the Units screen under the Configuration Menu.

Specifications

Operating Environments: 5 - 40^o C; 0 - 90% relative humidity (non-condensing). *NOTE: At temperatures less than 10° C, Automatic mode may experience errors, despite corrections that have been made.* (See Chapter 3 more information about Auto mode.)

Accuracy: 10%
Sample Chamber Aperture: 6.35mm (0.25 in)
Measurement Range: 0 to 1000 mmol/m^2s^1
Microcontroller Dimensions: 15.8 x 9.5 x 3.3 cm (6.2 x 3.75 x 1.3 in)
Data Storage: 4095 measurements
Data Retrieval: Direct via RS-232
Keypad: Six-key, menu-driven
Clock: 24-hour, +/- one minute per month
Interface Cable: RS-232 serial cable (included)
Power Supply: Four type "AA" batteries (included)

Overview of the Leaf Porometer

The Leaf Porometer features an easy-to-use, six-button, menu-driven interface. There are three primary menus: the Main Menu, Data Menu, and Configuration Menu (See "Menus," Chapter 3). You can navigate between each of these by pressing the Menu button.

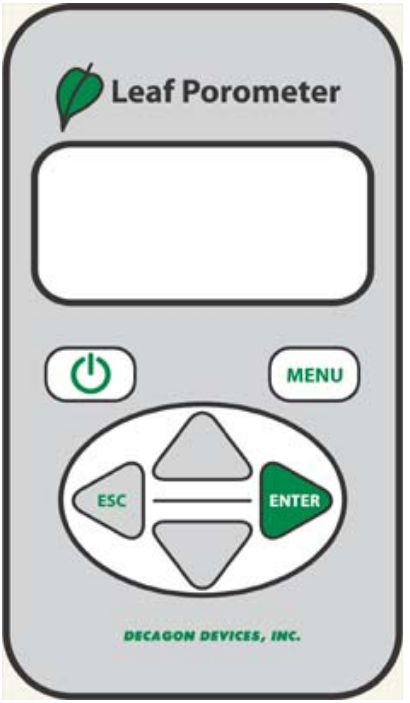
Components of the Leaf Porometer

The Leaf Porometer and its components come to you in a foam-padded carrying case. You should find the following items inside when your Leaf Porometer arrives:

- Leaf Porometer controller
- RS-232 cable
- Operator's manual, including a CD-ROM with the Leaf Porometer Utility
- Sensor head
- Teflon filter disks
- Replacement leaf pad/outer leaf pad (see p. 8)

- Calibration plate
- Bottle of distilled water
- Tweezers
- Calibration filter paper disks

Keyboard Functions



Here is a brief overview of each key's function:

Power: This key activates and deactivates the Leaf Porometer. (*NOTE: The device will automatically turn off if not used for more than 10 minutes or 60 minutes if running in manual mode.*)

Menu: This key cycles between the three menus at the top of the screen. *NOTE: Pressing Menu while changing a setting will cancel any operations.*

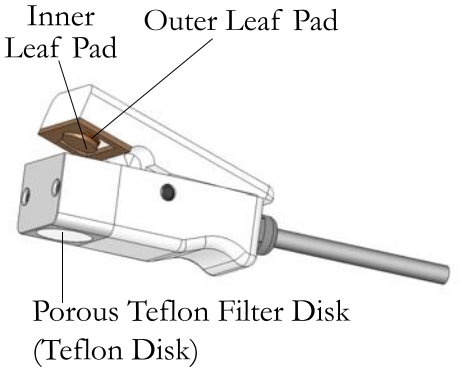
Arrow Keys: These keys navigate within menus and sub-menus, and modify numerical values in sub-menus, as well as select different units. Holding down an arrow key allows you to scroll between different options quickly.

Escape: This key backs out of sub-menus and can be used to cancel certain actions.

Enter: This key is used to make selections within menus and sub-menus, and also begins taking measurements.

The Sensor Head

The Leaf Porometer cannot take measurements without the aid of the sensor head. This sensor head is responsible for gathering the information (vapor pressure, humidity, etc.) that the Leaf Porometer uses to calculate stomatal conductance in a leaf. The following illustration shows the external components of the sensor head.



Setting the Time

You should make sure that the system time on the porometer is correctly set. This will make sure the timestamps on downloaded readings are accurate (see "How Saved Data is Organized," Chapter 4). You can do this manually in the porometer (see "Time" in Chapter 3), or by using the Leaf Porometer Utility (see "Setting The Date & Time" in Chapter 5).

Calibration Number

Each sensor head comes with a default five digit calibration number that can be found on the tag on the sensor head cable and on the calibration certificate. This default calibration number has been entered into the leaf porometer readout unit and will be applied to each measurement until a user initiated calibration is performed. When a user initiated calibration is performed, a new calibration number is generated and stored. This new calibration number will be applied to all subsequent measurements instead of the default calibration until a new user initiated calibration is performed or the user requests a reset to the default calibration.

Manual Mode vs. Auto Mode

When the porometer is in Manual Mode (see pg 15 for instructions on how to configure the porometer to Manual Mode), the stomatal conductance is measured directly from the theory presented in Chapter 6 and displayed continuously. The real time conductance measurement can be saved at any time during a Manual Mode measurement. Manual mode should only be used at low conductances (i.e. < 20 mmol $m^{-2}s^{-1}$). At higher conductances, the readings become inaccurate and can take an exceptionally long time to complete. For the theory in Chapter 6 to accurately predict the stomatal conductance using the steady state diffusion technique, true steady state conditions must exist in the diffusion path. The amount of time necessary to reach steady state conditions is proportional to the conductance. At conductances less than 20 mmol $m^{-2}s^{-1}$, steady state conditions are generally reached in less than 5 minutes. At higher conductances, steady state conditions can take up to 30 minutes. Please note that leaving the sensor head on the leaf surface for more than a few minutes can cause the stomatal conductance to change in response to the presence of the sensor head clip. Some common uses for manual mode are measuring dark conductance in plants and measuring conductance of static conductance materials (e.g. fruit peels, waterproof fabric).

Auto Mode makes an accurate stomatal conductance measurement in 30 seconds. To do this, the porometer takes the first 30 seconds of stomatal conductance data and applies a "look ahead" algorithm to predict the final stomatal conductance reading that would be achieved if unlimited time were allowed for true steady state conditions to occur. Auto

Mode has several advantages over Manual Mode and other porometers. First, the 30 second Auto Mode measurement duration ensures that stomatal conductance doesn't change due to the presence of the sensor head. Second, Auto Mode takes only 30 seconds per measurement, ensuring that your measurements are completed in a timely manner. Finally, Auto Mode sets a definite endpoint for the measurement, meaning that the user doesn't have to pick an arbitrary endpoint, as is common with other diffusion porometers and with Manual Mode measurements.

For the porometer to "detect" the presence of a transpiring leaf and begin the Auto Mode measurement, the measured stomatal conductance must reach 5 mmol $m^{-2}s^{-1}$. So, if you are making measurements on leaves with extremely low conductances, it may be necessary to make the measurements in Manual Mode.

Precautions

Before using or calibrating the porometer, remember:

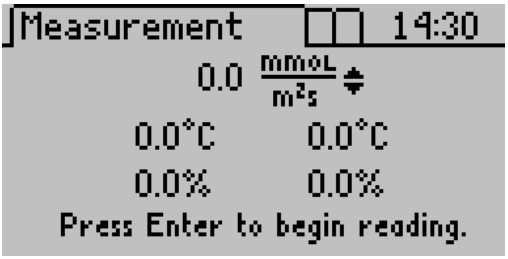
- Avoid leaves that are wet or heavy with dew; never take readings in the rain.
- Do not touch the Teflon disk, or get your fingers near it, during a reading. This will cause inaccurate readings.
- If you blow into the sensor, it will take a few minutes for the stomatal conductance reading to return to normal.
- Clean the sensor periodically to keep it free of dirt and pollen that can build up during use and affect readings. (See "Cleaning the Sensor Block," in Chapter 7.)
- Avoid chemical fumes. Fumes can be extremely harmful to the sensor (i.e. alcohol, gasoline, foam).

3. The Menus

The Leaf Porometer features three main menus, designed for easy navigability and use.

The Measurement Menu

The Leaf Porometer displays the Measurement Menu when first powered on.



At the top of the screen is the stomatal conductance number at left, and the currently selected unit of measurement at right. Below are two columns of numbers. The left is the sensor closest to the leaf, and the right is the sensor farthest from the leaf. Each column has the temperature of that sensor, and its percent humidity. The Leaf Porometer uses these to calculate the stomatal conductance value (see "How the Leaf Porometer Works" in Chapter 5).

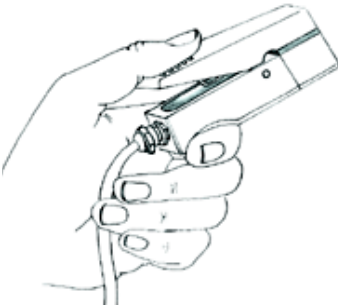
Making a Measurement

The following sections discuss making a measurement in both automatic and manual modes.

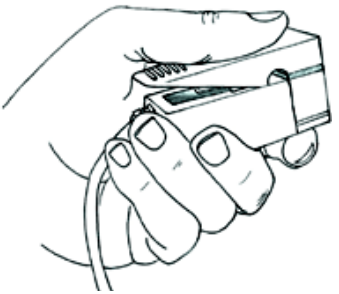
Before beginning a reading, make sure that the Leaf Porometer is turned on, and that the sensor head is clean and properly connected.

NOTE: Make sure you are holding the sensor in the correct manner. Holding the sensor head correctly is extremely important. If you do not, you can expose the Teflon disk to extra humidity and cause inaccurate readings. The pictures below illustrate the correct way to hold the external sensor:

Correct



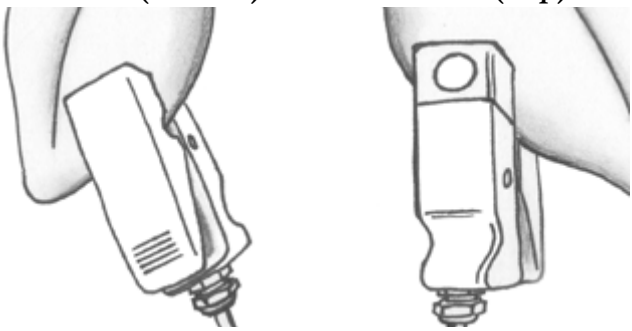
Incorrect



Once you are holding the sensor head properly, place it on the leaf as shown below.

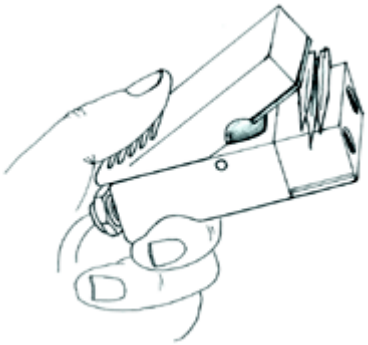
NOTE: It is important to consider if you will be measuring adaxial conductance (on the top of the leaf) or abaxial (the bottom). Since the stomates of most leaves are on the bottom of the leaf, most measurements will be abaxial:

Abaxial (Bottom) **Adaxial (Top)**



Measuring Small Leaves & Needles

When measuring small needles or leaves, they should be inserted into the sensor as shown below. This is because single needles or small leaves (including blades of grass) may not adequately cover the apature of the sensor.



Taking a Measurement in Auto Mode

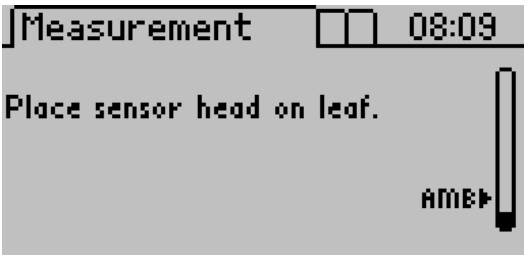
There are two modes in which to make measurements, Automatic and Manual. The following illustrates how to make a measurement in Auto mode:

Caution: Before using, allow the sensor to equilibrate to the ambient temperature.

1. Select Auto mode. (Please see the "Manual Mode" section later in this Chapter for instructions on how to select an Auto mode from the Configuration Menu.)

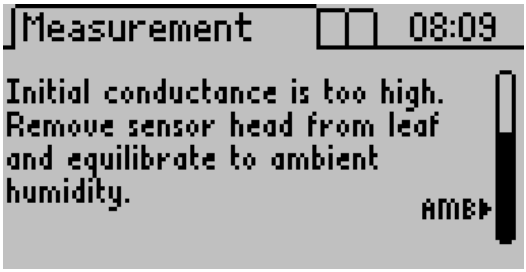
2. Return to the Measurement Menu. You will be prompted to press Enter to begin a reading.

3. After pressing Enter, the following screen will be displayed:

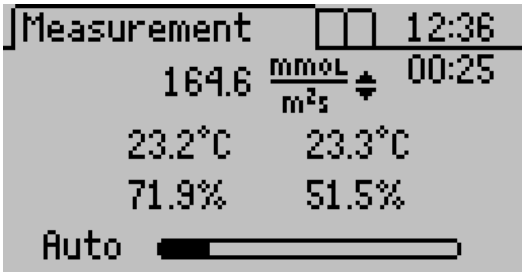


4. The reading will begin once the sensor head is placed on a leaf, and a conductance value greater than ambient is detected. A progress bar will also indicate the reading is underway.

If the following screen appears when you press Enter, open the sensor and gently wave it in the air. You should not blow into the sensor, as this will throw off readings for a few minutes.



5. The measurement screen will resemble the following. *NOTE: In Auto mode, a timer will appear in the upper right hand corner of the screen that indicates how many seconds remain.*



6. Once the time limit has expired, the porometer will display the final conductance. You may save or discard your data. See "Saving Data" on the next page for instructions.

Taking a Manual Mode Measurement

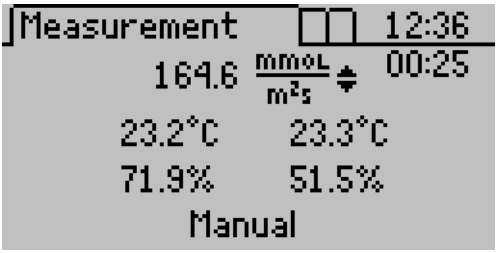
Caution: Before using, allow the sensor head to equilibrate to the ambient temperature.

1. Select Manual mode from the Configuration Menu. Please note that manual mode is only for special situa-

tions with conductances below 20 mmol m^{-2} s^{-1}. See the section "Manual Mode vs.Auto Mode" in Chapter 2 for details.

2. Return to the Main menu and press Enter.

3. Place the sensor on a leaf. Unlike Automatic mode, there is no time limit for taking readings, and the elapsed time is displayed directly below the system time.

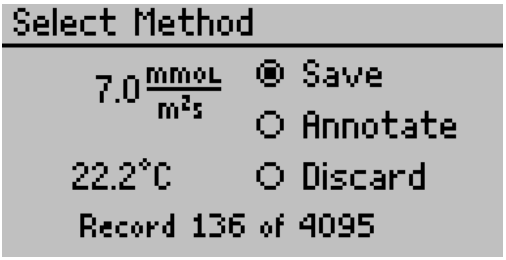


4. You may save your data at any point during the reading by pressing Enter. See below for instructions on how to save your data.

Saving Data

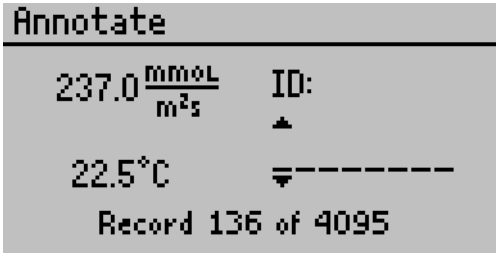
In Automatic mode, you can save data as soon as the timer has expired; in Manual mode, you save your data without interrupting your reading. To save your data in either mode,

1. The following screen will appear (you have to press Enter in Manual mode to access it):



2. You have three options:
   1) Select "Save" and press Enter to save your information as-is.
   2) Select "Discard" and press Enter to return to the main screen and start over with a new reading
   3) Select "Annotate" and press Enter to give your data a file name.

3. **How to annotate a reading:** Selecting "Annotate" will cause the following screen to appear:



   You will see a series of lines, with a set of arrows above and below the first. If you have annotated a previous reading, the old annotation will remain to be changed or deleted. Use the arrow keys to select a letter or number and press Enter to move to the next character.

4. Repeat this until you reach the last character. If you wish to stop before the end, you will still have to press Enter until you reach the end of the row.

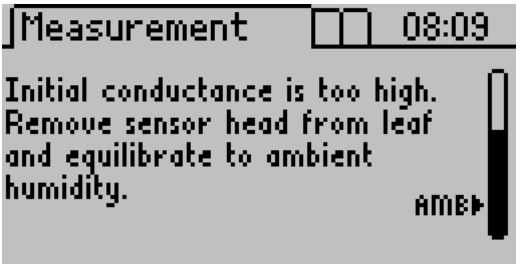
Averaging Readings

A leaf's stomatal conductance depends on the amount of shade and sunlight it receives, the age of the leaf, and its position on the plant. To obtain a plant's stomatal conductance average, you must take a variety of readings from different positions on the plant. The average is proportional to the type of readings taken. For example, if you know your plant receives 70% sunlight, you might consider taking seven readings from the sunny part, and three from the part in the shade.

You can also obtain the average readings for a field of plants. For example, if you had a field of corn, you might decide to take a reading from the third leaf from the top on each stalk of corn on that particular plot. These readings together would give you the average for that field.

Measurement Troubleshooting

If the following screen appears before starting a reading:



Remove the sensor from the leaf and wait until the bar on the right drops below the AMB> marker (this may take a while), at which time the "Place sensor on leaf" screen will reappear. Or, to reset more quickly, hold the sensor firmly, open the sensor head, and wave in the air lightly to equalize the humidity. Do not blow into the sensor; this can cause inaccurate readings when the measurement begins. Once the ambient humidity has been reset, you will be prompted to place the sensor head on the leaf again.

If the stomatal conductance reaches a value beyond the recommended range of the instrument(0 to 1000 mmol/m^2s), an "approximate" symbol will appear to the left of the reading. If the stomatal conductance reaches a value greater than or equal to 6000 mmol/m^2s, an "infinity" symbol is shown in place of the measurement. Most often, the excessively high values are caused by water on the leaf surface. If you consistently are getting high readings, check your leaf surface for the presence of water.

Measurement Precautions

General Precautions

- Before using the sensor, allow it to equilibrate to the ambient temperature. This may take 10 minutes or longer to complete; if the temperature of the porometer is very different from the sampling environment, e.g. from a cool air conditioned room to a hot outdoor environment.
- The first reading in Auto mode after the sensor has been removed from a leaf for more than five minutes

will always read low. Discard this reading and begin recording with the second.

• Avoid leaves that are wet or heavy with dew; never take readings in the rain.

• Do not cover the white Teflon disk with your finger, or place your fingers near it, when taking a measurement; this will cause inaccurate readings for several minutes.

• If you blow into the sensor head, it will take a few minutes for the stomatal conductance reading to return to normal.

• Clean the sensor periodically to keep it free of dirt and pollen that can build up during use and affect readings.

Chemical Effects

Chemical vapors can interfere with the polymer layers used to form the humidity sensors. These fumes can diffuse through the sensor and throw off the sensor's accuracy. It is a good idea, therefore, to never bring the sensor into contact with any sort of chemical vapor (i.e. glue, alcohol, gasoline, foam). See section on "Sensor Head Reconditioning" if you suspect your sensors have been affected by chemical contamination.

Environmental Effects

When making a measurement, the following effects must be accounted for.

Light. The amount of CO_2 required for a plant changes depending on the amount of sunlight available to it. In broad daylight, more CO_2 is required, so the stomata remain open. At dusk, the stomata close, and in darkness they are often closed completely. Readings taken on over-

cast days, for example, generally have lower conductances than those taken on sunny ones. Additionally, leaves in shadow or in shade usually have lower conductances than those in greater light. Therefore, make sure to consider the lighting conditions you will be measuring in.

Temperature. A plant's stomatal conductance is also affected by temperature. For most plants, on a very hot or a very cold day, photosynthesis will slow down or stop, and the stomata will narrow or will not open, to prevent internal water loss. Therefore, be sure to consider the temperature before conducting measurements.

Humidity. A factor that will cause the stomatal conductance to change is the humidity at the leaf's surface. As the outside humidity increases, the stomata will open. Porometers that dry the air around the stomata decrease conductance; likewise, those that allow surface humidity to increase do the opposite.

Carbon Dioxide (CO_2). One purpose of the stomata is to regulate the leaf's usage of CO_2, which is important to controlling the balance of humidity. An increase in CO_2 will cause stomata to close, while a decrease will cause them to open. Thus, it is important to consider the CO_2 levels of your measuring environment. You, the Leaf Porometer operator, can adversely affect readings by exhaling CO_2 directly on the plant you are measuring. This is particular important in growth chambers or greenhouse, where CO_2 from an operator's breath can double or triple ambient levels.

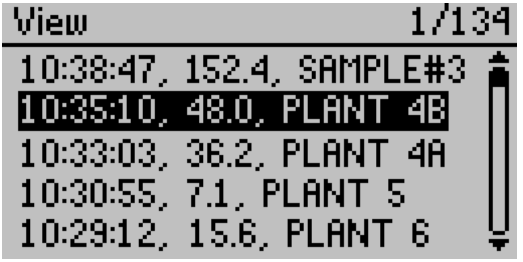
The Data Menu

In this menu, you can view any saved data, download data to a computer, and erase all data stored in the Porometer's memory. This menu features three sub-menus.

View

Here you can view measurement data stored on your porometer. To do this:

1. Press Enter to select the view sub-menu.



2. For each measurement, you will see the time acquired, stomatal conductance/resistance value (depends on which unit you have set as your default) and its annotation (if that measurement was saved with an annotation).

Download

This menu option sends the data saved in the porometer to the terminal software running on your computer.

NOTE: Your Leaf Porometer comes with the Leaf Porometer Utility software for Microsoft Windows. The Utility makes downloading data to your computer very easy. In general, you should use the Leaf Porometer Utility to download data instead of this menu option on the Porometer. See Chapter 4 for more information.

If you are unable to use the Leaf Porometer Utility, you can use terminal software to transfer the data from your porometer to your computer. The following steps should apply to most terminal software programs:

1. Configure your terminal software with the following settings:
   - 9600 baud
   - 8 data bits, 1 stop bit, no parity
   - No software/hardware flow control
   - Append line feeds to incoming line ends
   - Echo typed characters locally.

2. Connect your Leaf Porometer to an available serial port on your computer using the included RS-232 serial cable.

3. Set your terminal software to capture received data if you want to save the data.

4. Select "Download" from the Data Menu of the Leaf Porometer.

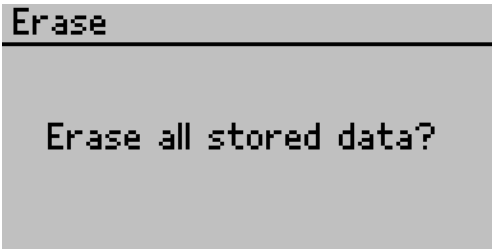
Erase

This will erase **all** your stored data records in your Leaf Porometer memory.

WARNING! Once this feature is activated, all data will be permanently deleted from the Poromter, and cannot be recovered!

To erase data:

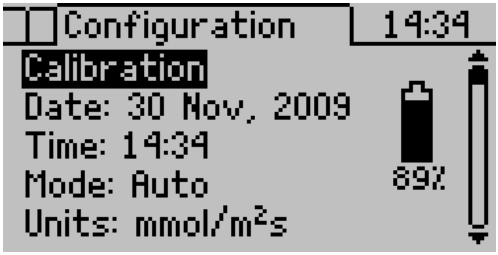
1. Press Enter to select the Erase sub-menu. The following screen will appear.

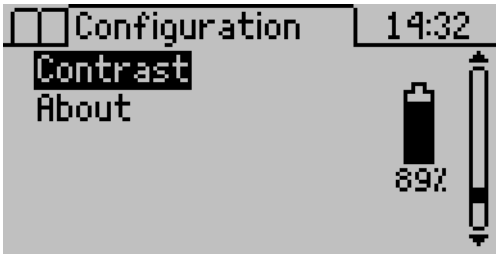


2. Press Enter again to erase the memory, or ESC if you decide not to erase the data. "Erasing..." will be displayed as data is being removed, which usually takes about 6 seconds.

3. When this is complete, you will be returned to the Data Menu.

The Configuration Menu





This menu allows you to alter system settings, such as the current time, date, and operating mode, select the appropriate units for your readings, and view information about your Leaf Porometer. There is also a battery icon to the right, indicating how much battery power is currently available. This menu features seven sub-menus:

Calibration

See Chapter 4 for a thorough explanation of the calibration menu.

Date

1. To change the current date,Press Enter to select the Date display.

2. The current date will appear in the center of the screen, in day/month/year format. A pair of arrows will be present (above and below) the first number.

3. Use the arrow keys to change this number. (Holding down the up/down arrow will allow you to scroll quickly between values.)

4. Press Enter to move to the next value, and repeat step #3. If you need to return to the previous number, press Escape.

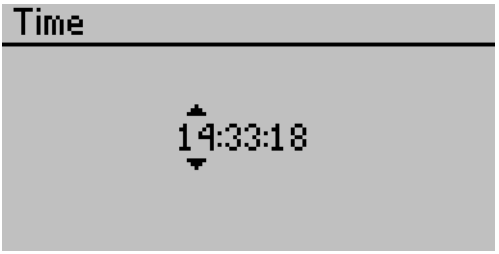
5. When you have finished changing the last number, press Enter and you will be returned to the Configuration Menu.

Time

To change the current time,

1. Press Enter to select the Time display.

2. The current time will appear in the center of the screen, in 24-hour format. A pair of arrows will be present (one above and below) the first number



3. Use the arrow keys to change this number. (Holding down the up/down arrow will allow you to scrollquickly between values.)

4. Press Enter to move to the next number, and repeat step #3. If you need to return to the previous number, press Escape.

5. When you have finished changing the last number, press Enter and you will be returned to the Configuration Menu.

Mode

The Mode Menu allows you to choose which type of measurement mode to use in the Main menu. Press Enter to select a mode. See the end of Chapter 2 for the descriptions of Manual and Auto Modes. Here is a description of how to use each:

• **Auto mode.** Takes readings automatically for 30 seconds. You must press Enter *before* placing the sensor on the leaf for Auto mode to work properly. In this mode, you are unable to save your information mid-reading. You must wait until the timer runs out after 30 seconds, then you may save your reading. Also, if initial conductance is less than 5 mmol/m^2 s, you will see a screen prompting you to place the sensor on a leaf. Conversely, if the initial conductance is too high, a warning screen will appear.

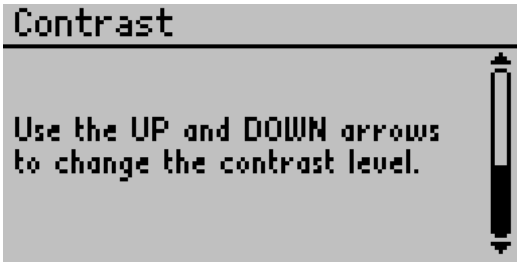
• **Manual mode.** Continuously measures conductance and updates the screen. This mode is only suitable for low conductances (<20 mmol $m^{-2}s^{-1}$). The user can decide when equilibrium has been reached. Pressing Enter will give you the option to save your data at any point during the reading.

Units

Data in the Leaf Porometer can be displayed in three units. These can be accessed on the Main Screen, as well as under the Configuration Menu**.** When in the Configuration Menu, select "Units" and press Enter to select a unit.

Contrast

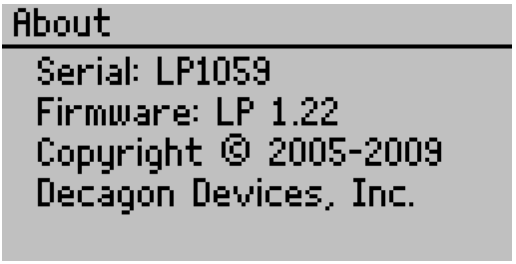
This menu allows you to alter the screen contrast settings. To access it, use the Down arrow key to scroll to it and press Enter. The following screen will appear:



Use the arrow keys to alter the contrast level. Press Enter to save or Escape to cancel adjustments.

About Screen

This menu displays your Leaf Porometer's serial number and firmware version.



4. Sensor Head Calibration

For the leaf porometer to make accurate readings of stomatal conductance, the two humidity sensors in the sensor head must behave in a very repeatable manner. Over the past several years, we have found that the sensors occasionally change characteristics over time. While the endpoint humidity measurement may still be accurate, the response time of the sensors can change subtly which creates inaccurate conductance measurements. The best way to ensure accurate conductance measurements is to calibrate the porometer before taking measurements. We recommend that the porometer be calibrated every day that it is used or every time it is used under a different set of environmental conditions (i.e. > 15° C temperature change or 20% humidity change). Visit our website at www.decagon.com/porocal for an online video tutorial of the calibration process.

Requirements

All Leaf Porometers with firmware Revision 1.30 or greater have the ability to be calibrated by the user. If your porometer has firmware lower than Revision 1.30, you may upgrade the firmware. See Chapter 7 for instructions on how to upgrade your firmware to the latest version.

In addition to current firmware, you will need a calibration kit from Decagon to perform the calibration. If you do not have a calibration kit, please contact Decagon (support@decagon.com) for a kit. Please have your sensor head serial number available when you contact Decagon for the kit.

The kit contains:

- Calibration plate
- Tweezers
- Bottle of DI water
- Calibration filter paper disks
- Spacer pin

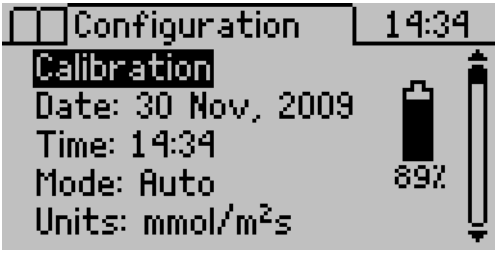
Procedure

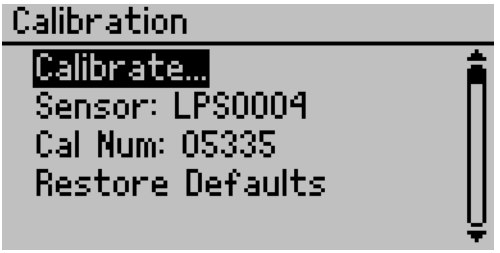
1) Equilibrate to field conditions

It is critical that the porometer sensor head is in thermal equilibrium with the environment where measurements will be taken. If you bring the porometer from an air-conditioned environment into hot field conditions, it can take 10 minutes or more for thermal equilibrium to be reached. You can check for thermal equilibrium by putting the porometer in "manual" mode and monitoring temperature readings until they are steady.

2) Start Calibration

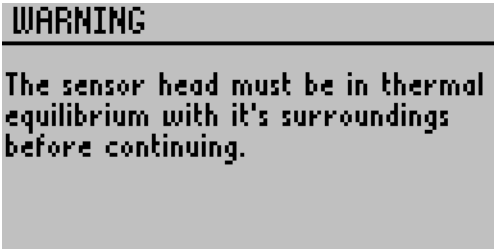
To start calibration, select the "Calibrate" option on the Configuration/Calibration submenu.





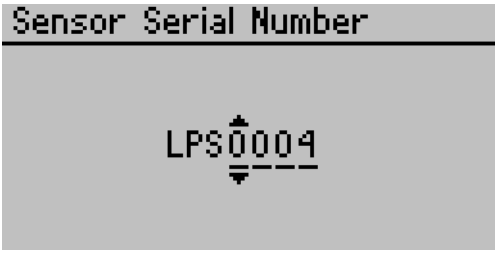
3) Verify Sensor Head Equilibrium

You will be reminded to make sure the sensor head is in thermal equilibrium with its surroundings (see #1 above). Press Enter to move to the next step.



4) Enter Serial Number

You will be prompted to enter the sensor head serial number. This number can be found on a tag attached to the sensor head. Select the number by pressing the up and down arrow keys to select a number and pressing enter after each digit.



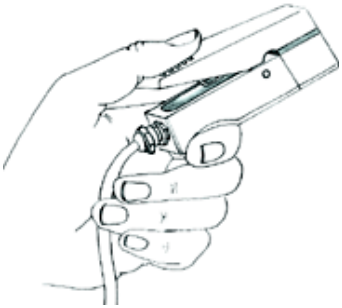
5) Sensor Offset/Stability

The sensors must give similar humidity readings for accurate stomatal conductance measurements. Before beginning a calibration, the leaf porometer checks to make sure that the two sensors in the sensor head agree well with each other. For the sensors to agree, the air in the diffusion path should be well mixed.

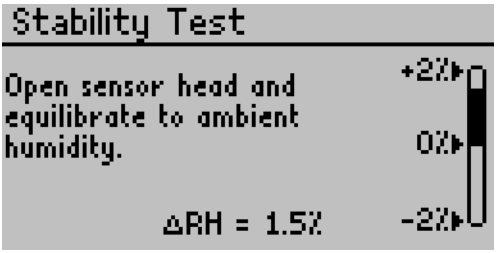
Holding the Sensor Head

Holding the sensor head in the correct manner is very important. If held incorrecly, water vapor from your fingers can expose the Teflon disk to artificially high humidity and cause inaccurate readings. The pictures below illustrate the correct way to hold the external sensor.

Correct **Incorrect**



Open the sensor head and wave the sensor head in the air to mix the air in the diffusion path. To assist in holding the sensor head open for long periods of time a notch in the upper clip will hold a spacer pin, included in your kit, in place. As the sensors come to equilibrium, you should see the indicator bar move closer to the 0% offset line. DO NOT blow into the leaf porometer sensor head, the water vapor in your breath will affect subsequent readings.



Once the sensor readings stabilize and are confirmed to be within 2% relative humidity of each other, the calibration routine automatically advances to the next screen. If the sensors don't equilibrate to similar humidity values, check for water on the sensor head or on the Teflon filter. If no water sources are found, then the sensors may have been chemically contaminated or be otherwise malfunctioning. If this case occurs, contact Decagon (support@decagon.com) to discuss re-conditioning the sensors (see Chapter 7 for more details on re-conditioning the sensors).

6) Preparing Calibration Apparatus

The leaf porometer calibration apparatus consists of a plastic calibration plate with a precisely drilled hole with known

conductance of 240 mmol $m^{-2}s^{-1}$. For the conductance value of the calibration plate to be correct, a flat, moist surface must be placed across the hole on the side marked "Filter Paper." This condition is achieved with a circular disk of wet filter paper that is included in your calibration kit. Additional filter disks may be purchased if you run out.

NOTE: Do not touch the calibration filter paper disk with your fingers because oils in your skin will contaminate the disk and result in improper readings. To aid in handling the filter paper disk and to keep it clean, use the tweezers included in the calibration kit to hold the calibration filter paper disk.

Wetting the filter paper

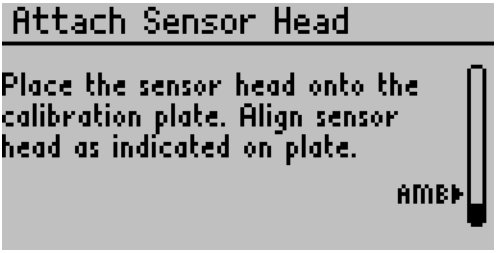
The wetness state of the filter paper is critical for an accurate calibration. The paper must be wet enough to provide a 100% humidity surface, but must not be too wet. If the paper is too wet, free water will be pulled into the hole on the calibration plate by surface tension and will change the effective dimensions of the hole thereby changing the conductance. The best method of ensuring the proper wetness state is to use the "wet and flick" method. Use tweezers to pick up the filter disk and then add one drop of the DI water to the filter disk to saturate it. Then, while holding the disk with the tweezers, give the filter paper a sharp flick of the wrist or two to knock off any excess water. The resulting paper should glisten, but there should be no drop of excess water clinging to the disk. Please see the video of proper Leaf Porometer calibration technique on the Decagon website (www.decagon.com) for visual representation of the dip and flick technique and the proper filter paper wetness state.

NOTE: If you need to obtain a Material Safety Data Sheet (MSDS) for DI water, a printable version is available on our website at www.decagon.com/msds.

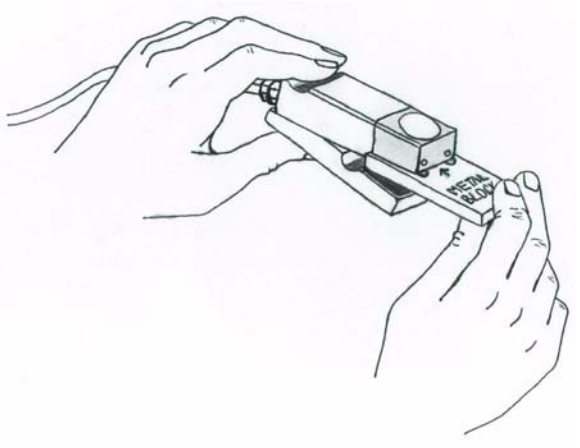
After wetting the filter paper, using tweezers, lay it flat over the hole in the calibration plate on the side marked "Filter Paper." It is critical that the filter paper lay flat over the hole. Make sure that the paper is not caved into the hole or bubbled out from the hole. The filter paper also has to cover the entire hole. Turn the calibration plate over and carefully examine the hole to make sure that no meniscus of excess water is present in the hole. If excess water is observed, remove the filter paper, dry the calibration plate, and repeat the wet and flick procedure with a more aggressive flick.

You should not have to re-wet the filter paper during the calibration procedure. However, if the filter paper becomes too dry to adhere to the calibration plate, then it needs to be re-wet. If this occurs during a calibration, you will need to re-start the calibration procedure. Note that the first two readings after re-wetting the filter paper will typically be in error because of thermal instability in the system.

7) Attach Sensor Head to Calibration Plate

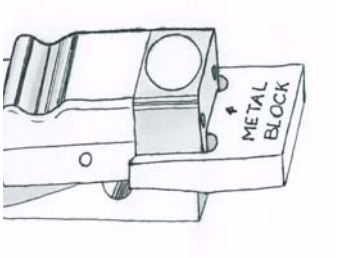


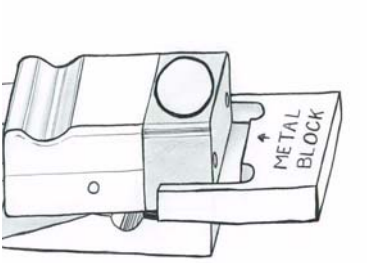
With the moist filter paper in place, slide the calibration plate into the sensor head, making sure you've oriented the side of the plate marked "Metal Block" toward the aluminum block side of the sensor head.



Be sure that the calibration plate is inserted until the aluminum block is seated firmly against the hard stop on the calibration plate.

Correct **Incorrect**

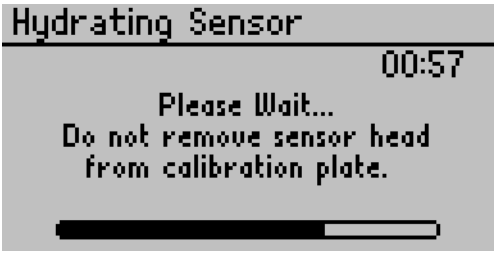




This will ensure that the hole is properly aligned with the diffusion path in the sensor head. Once the sensor head is attached to the calibration plate, the Leaf Porometer will automatically sense the calibration plate and begin the hydration process.

8) Hydrating the Sensor

The sensors in the leaf porometer must be hydrated before stable readings can be taken. The calibration routine allows the sensors to hydrate on the calibration plate for three minutes. During this time, the sensor head should not be removed from the calibration plate. The progress of the hydration period can be tracked on the indicator bar at the bottom of the screen and the timer in the top right corner.



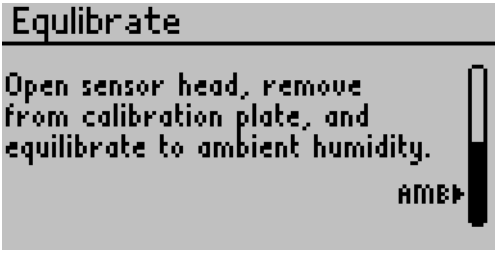
9) Orienting the Sensor and Calibration Plate

Once the hydration, a calibration measurement, or a regular measurement begins, it is important not to block the flow of moisture from the Teflon filter at the bottom of the aluminum block. You can hold the sensor in the air or lay it on its side or upside down with the Teflon filter up. Do not set the porometer down with the Teflon filter oriented down or

vapor diffusion will be impeded. It is best to hold the porometer head and calibration plate still or set them down during the calibration. Excessive movement can introduce error into the calibration.

10) Equilibrate Sensors

Once the three minute hydration period is finished, you will be prompted to remove the sensor head and equilibrate the sensors to ambient humidity.



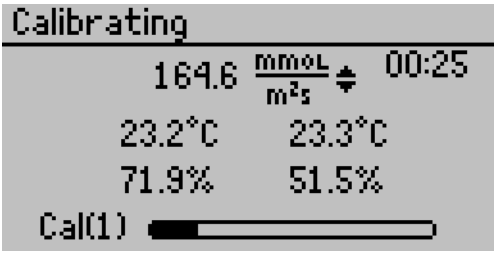
Remove the sensor head from the calibration plate, open the sensor head and wave the sensor head in the air to mix the air in the diffusion path. You can use the spacer pin to hold open the sensor head if desired. As the sensors come to ambient conditions, you should see the indicator bar move closer to the "AMB" line. Once the sensors have equilibrated to ambient conditions, the Attach Sensor Head screen will automatically re-appear.

11) Attach Sensor Head to Calibration Plate

Once the sensors have equilibrated to ambient conditions, the Attach Sensor Head screen will automatically re-appear. Follow directions (#7 above) to correctly attach sensor head to the calibration plate.

12) Calibration Measurements

Once the sensor head is attached to the calibration plate, the Leaf Porometer will automatically sense the calibration plate and begin the first calibration measurement.



Each calibration measurement will take 30 seconds. The indicator bar at the bottom of the screen and timer at the top right of the screen indicate the status of the calibration measurement. Once the measurement is finished, you will be prompted to Equilibrate Sensors (#10 above) and then Attach Sensor Head (#7 above). This will begin another calibration measurement.

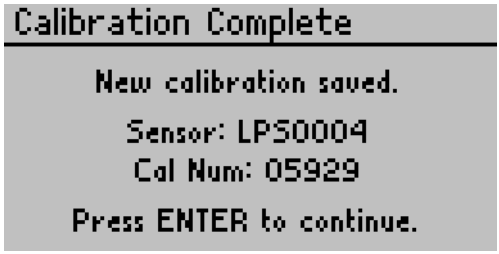
The leaf porometer will continue to take calibration measurements until three consecutive measurements are all within 7.5% of each other. This ensures that the porometer is well hydrated, and has stable readings. Normally, the calibration should end after 3-5 calibration measurements are performed. The routine will continue for a maximum of 10 measurements. If stable readings haven't been achieved in

10 readings, then there is a problem with the calibration and the following screen will appear.

The most common problem is that thermal equilibrium hasn't been reached. Let the porometer equilibrate for a few minutes and repeat the calibration process. If you still can't achieve a good calibration, then contact Decagon for help (support@decagon.com).

13) Calibration Complete

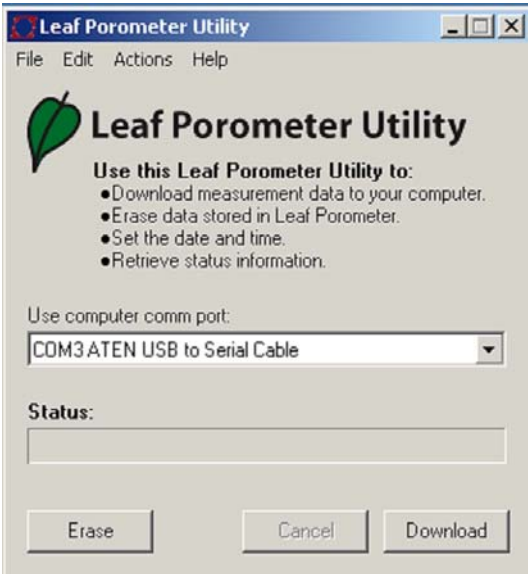
Once the calibration is complete, the new calibration number is automatically saved into the handheld unit and the following screen is displayed. At this point, you are ready to take measurements with your leaf porometer. Note that the most recent saved calibration number will be applied to all subsequent measurements until a new calibration is completed or you request that the factory default calibration number be applied.



14) Accuracy Verification

It is always a good idea to verify that the calibration was effective. If you wish to do this, go to the measurement menu and make a measurement on the calibration plate. The measured conductance should be close to 240 mmol $m^{-2}s^{-1}$. Please note that the first 2-3 measurements after the sensors have not been used for a while will be significantly low due to sensor dehydration, and that the first two measurements after re-wetting the filter paper will also be inaccurate due to thermal disequilibrium.

5. Leaf Porometer Utility



Leaf Porometer Utility main screen

The Leaf Porometer Utility is a program designed specifically for interfacing with the Leaf Porometer. Use this program to download measurement data to your computer, erase the Leaf Porometer's data, set the date and time, and see information about your Leaf Porometer.

SYSTEM REQUIREMENTS: To use the Leaf Porometer Utility, you must meet the following minimum system requirements:

- Microsoft Windows 98 or NT 4 (SP 5) or better
- Intel Pentium Pro or better processor

- One available serial port *or* one available USB port (most models of USB-to-serial adapters supported)
- Microsoft Excel 97 or better (for saving data as .xls files)

You can install the Leaf Porometer Utility using the included CD-ROM (found in the inside cover of the Leaf Porometer Operator's Manual). You can also download and install the latest version of the Utility from http://www.decagon.com/home/downloads.php .

Downloading Your Data

This will transfer all saved measurement data on the Leaf Porometer to your computer. Do the following:

1. Make sure the RS-232 cable is connected to the Leaf Porometer, and to a serial communication (COM) port on your computer.

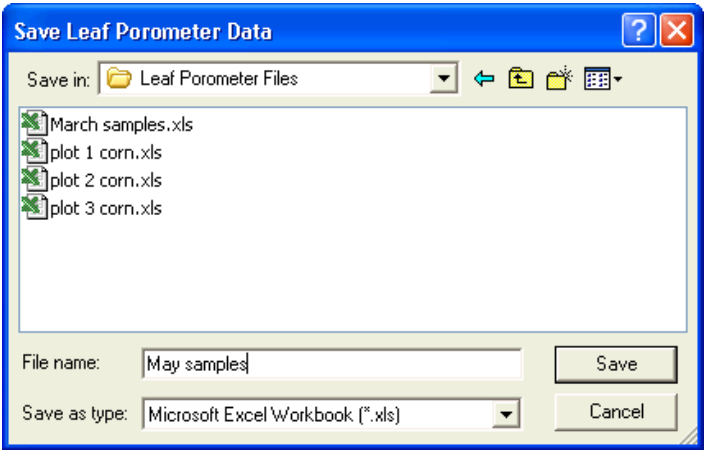
2. Open the Leaf Porometer Utility.

3. Choose the appropriate COM port from the "Use computer communication port" control on the main screen.

4. Click the "Download" button in the lower right-hand corner, or "Download Data" in the File Menu.

   If you encounter an error message after clicking this button, please refer to the Troubleshooting section for instructions.

5. The following screen will then appear:



Save Leaf Porometer data dialog

Name your data file, select where it will be saved to, and in what format. You may choose between the following formats:

- Microsoft Excel Workbook (*.xls);
- Text (Tab delimited) (*.txt);
- CSV (Comma delimited) (*.csv);
- Raw data (Comma delimited) (*.txt)

6. Click "Save" to download your data to the specified location. The progress bar shows the status of the download process.

NOTE: You can cancel a download in progress using the cancel button. If you cancel, no downloaded data are saved.

How Saved Data Are Organized

Data are organized in the same way regardless of what format it was saved in. The information will be divided into six columns:

1. **Measurement Time**

2. **Stomatal conductance/resistance**

3. **Temperature in °C or °F**

4. **Sample ID** (if saved with measurement)

5. **Sensor head serial number**

6. **Calibration number**

NOTE: The utility formats measurement dates according to the Windows Local settings found in the Control Panel under "Regional and Language Options" ("Regional Settings" in Windows 98). You may override this and set the format to day/month/year by going to the Edit Menu, click Preferences, Units tab, and by clicking "Use template" under Date/Time Format for Data Files.

Erasing Your Data

This will erase all data stored on your Leaf Porometer.

WARNING! Once this feature is activated, all data will be permanently deleted from the Leaf Porometer, and cannot be recovered!

To erase your data, do the following:

1. Make sure that the RS-232 cable is connected to the Leaf Porometer, and to a COM port on your computer.

2. Choose the appropriate COM port from "Use computer communication port" control on the main screen.

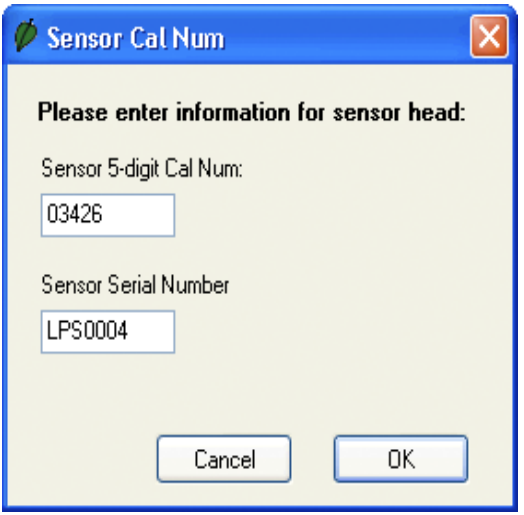
3. Click "Erase," in the lower left-hand corner, or "Erase Data..." in the File Menu. **If you encounter an error message after clicking this button, please refer to the Troubleshooting section for instructions.**

4. The progress bar shows the status of the erase process.

Setting the Date and Time

You can set the Leaf Porometer's date and time by selecting "Set Porometer Date/Time" from the Actions Menu. This will automatically synchronize the Leaf Porometer's date and time to your computer's date and time.

Calibration Number



Sensor Calibration Number screen

You can use the Leaf Porometer Utility to enter a calibration number for the external sensor. To do this, go to Actions > Set Sensor Cal Num... . The above screen will appear. Enter the desired calibration number then click OK. All five numbers must be entered, even if the first number is a zero! If the number is not correct, an error message will be displayed. Note that the calibration number is generally saved in the unit through the user initiated calibration routine, so it is not anticipated that a calibration number should ever be entered in this manner.

Retrieving Leaf Porometer Information

Choose "View Porometer Information..." from the Actions Menu to see information about your Leaf Poro-meter:

Leaf Porometer Information screen

If you encounter an error message after clicking this button, please refer to the Troubleshooting section for instructions.

This is a good way to find the serial number, firmware version, battery status, and number of stored measurements for your Leaf Porometer.

The Menus and Their Functions

The four menus across the top of the screen allow you to change program settings, and settings on the Leaf Porometer. Below is a brief overview of the options each menu contains.

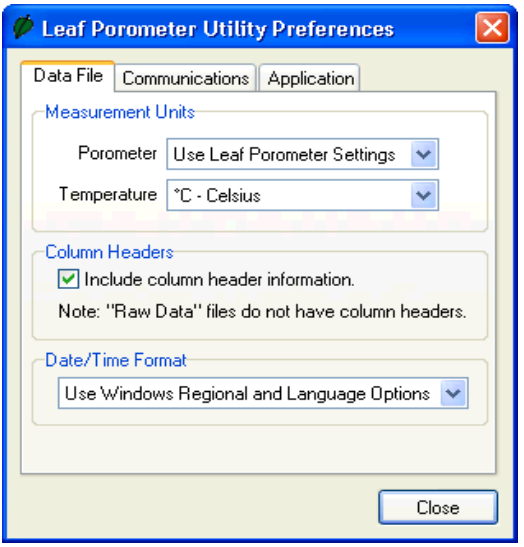
File

Download Data. Saves measurement data stored in your Leaf Porometer as a data file on your computer (see instructions above).
Erase Data. Erases all data in your Leaf Porometer (see instructions above).
Exit. Quits the program.

Edit

Preferences... This consists of three sections:

1. **Data File**



Preferences - Units screen

Measurement Units: If you select "Get units from Leaf Porometer settings," this will save all downloaded measurement data in the units used on the Leaf Porometer. You can also choose to override the set-tings in the Leaf Porometer and save your measurement data in one of three units:

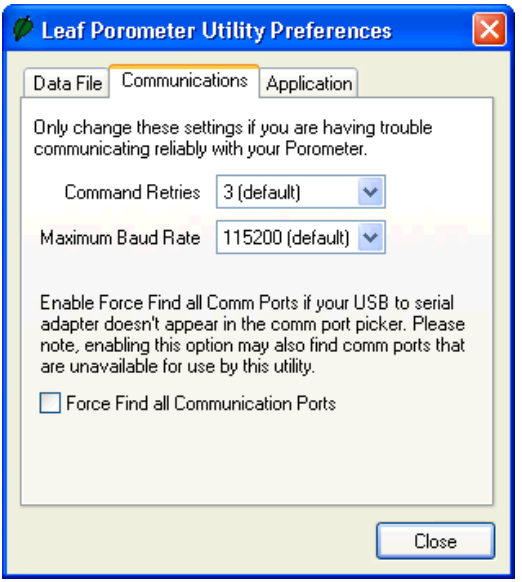
- **mmol/m^2 s** - stomatal conductance (millimoles per meter squared seconds);
- **m^2 s/mol** - stomatal resistance (meters squared seconds per mole);
- **s/m** - stomatal resistance (seconds per meter).

Temperature Units: This allows you to choose what unit of temperature data files will be saved with, °C (Celsius) or °F (Fahrenheit).

Column Headers: This option sets column headers (i.e "Date/Time," "Temperature") for saved data files. This feature is on by default. It does not apply to raw data files, which do not have column headers.

Date/Time Format: Here you can set the format the date and time will be displayed in saved data files. By default, the program will use Windows Regional and Language Options (accessible in the Control Panel in Windows), the system settings on your computer.

2. Communications



Preferences - Communications screen

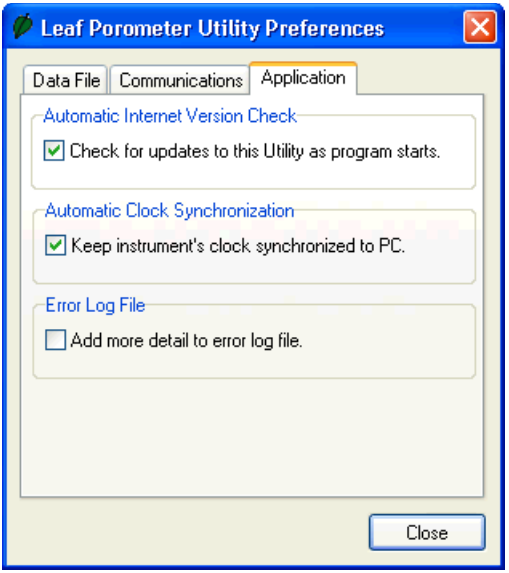
Command Retries: If you encounter difficulty communicating with your Leaf Porometer, you can set the number of times the computer should automatically try resending communications commands (up to 10).

Maximum Baud Rate: You can set the maximum baud rate for talking to your Leaf Porometer. Choose a lower baud rate if you are not getting reliable communications from your device.

Force Find all Communication Ports: This will detect all COM ports on your computer, and should be used if

your serial-to-USB adapter does not appear in the drop-down menu.

3. **Application**



Automatic Internet Version Check: When selected, the utility will automatically check for utility updates for the Leaf Porometer Utility when you are connected to the Internet. You can also check for these manually by selecting "Check for Updates..." from the Help Menu.

Automatic Clock Synchronization: Automatically sets the Leaf Porometer's time to your computer's time, when you are connected to it. (See instructions above for setting this manually.)

Error Log File: This adds more troubleshooting messages to the error log, which can be sent to Decagon.

Actions

Set Porometer Date/Time. See the section on "Setting Date and Time" above.

Set Sensor Cal Num... Here you can set the sensor head's calibration number. See page 35.

View Porometer Information... This shows the serial number, firmware version, the number of stored readings in the Leaf Porometer, the firmware status, battery status, current date and time, and the sensor calibration number.

Help

Help... Accesses the Leaf Porometer Utility help file, which provides detailed information on how to use the program.

Send Feedback to Decagon... Provides the user with a way to submit feedback to Decagon.

Check for Utility Updates... Goes online and checks for utility updates.

Check for Firmware Updates... Goes online and checks for firmware updates for the Leaf Porometer controller.

About. Displays the current program version and Decagon contact information.

6. Leaf Porometer Theory

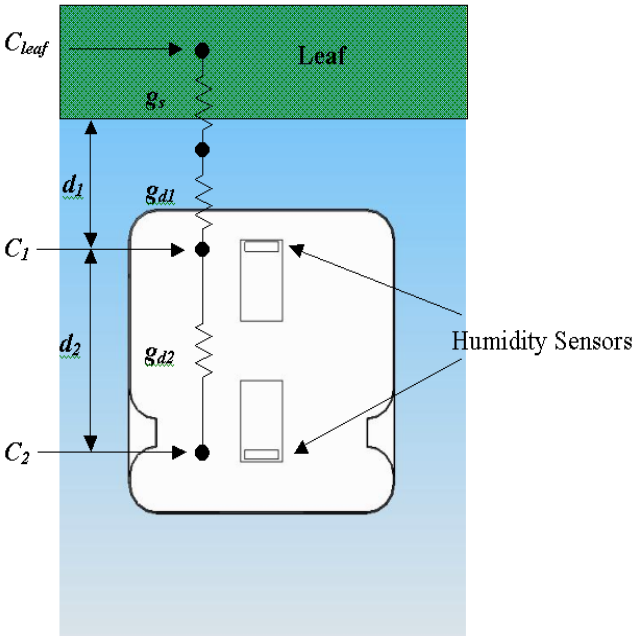
Stomatal Conductance

By definition, stomatal conductance is the measure of the rate of passage of carbon dioxide (CO_2) or water vapor through the stomata of a leaf. Stomata are small pores on the top and bottom of a leaf that are responsible for taking in and expelling CO_2 and moisture from and to the outside air. The Leaf Porometer measures the rate at which this happens.

How the Leaf Porometer Works

The Leaf Porometer measures the stomatal conductance of leaves by putting the conductance of the leaf in series with two known conductance elements. By measuring the humidity difference across one of the known conductance elements, the water vapor flux is known. The conductance of the leaf can be calculated from these variables.

We know the humidity at three places: inside the leaf, and at both of the humidity sensors. The Leaf Porometer effectively calculates the resistance between the inside and outside of the leaf: the stomatal conductance. Resistance is measured between the leaf and the first humidity sensor, and the first and second sensors. The following diagram schematically illustrates this:



The parameters listed above represent the following:

C_{leaf}	The mole fraction of vapor inside the leaf
C_1	The mole fraction of vapor at node 1
C_2	The mole fraction of vapor at node 2
g_s	Stomatal conductance of the leaf surface
gd_1	Vapor conductance of the diffusion path between leaf surface and node 1
gd_2	Vapor conductance of the diffusion path between node 1 and node 2
d_1	Distance between the leaf surface and the first humidity sensor
d_2	Distance between the two humidity sensors

The variable of interest is g_s or the stomatal conductance. First the vapor flux along the diffusion path will be determined using the relative humidity difference between nodes 1 and 2 as follows:

$$F_{vapor} = g_{d2}(C_1 - C_2) \tag{1}$$

Where the *C*'s are related to relative humidity by

$$C_i = \frac{h_r e_s(T_a)}{p_{atm}} \tag{2}$$

where h_r is the relative humidity, $e_s(T_a)$ is the saturated vapor pressure at air temperature, and P_{atm} is atmospheric pressure. Saturated vapor pressure is calculated by the Tetens formula with appropriate coefficients for water vapor:

$$e_s(T_a) = 0.611\exp\left(\frac{17.502T}{T + 240.97}\right) \tag{3}$$

NOTE: T must be in degrees Celsius.

Next we must determine the value of gd_2 by the equation

$$g_{d2} = \frac{\hat{\rho} D_{vapor}}{d_2} \tag{4}$$

where $\hat{\rho}$ is the molar density of air and D_{vapor} is the diffusivity of water vapor. Both of these quantities are temperature and pressure dependent, however when multiplied together as in equation (3) some of this dependency drops out:

$$\hat{\rho} = 44.6 \frac{P_a}{101.3}\left(\frac{273.15}{T}\right) \tag{5}$$

$$D_{vapor}(T, P_a) = D_{ref}(273.15, 101.3)\left(\frac{101.3}{P_a}\right)\left(\frac{T}{273.15}\right)^{1.75} \tag{6}$$

If

$$D_{ref}(273.15, 101.3) = 2.12x10^{-5} \quad (m^2/s)$$

Then

$$\hat{\rho}D_{vapor} = (44.6)(2.12x10^{-5})\left(\frac{T}{273.15}\right)^{0.75} \tag{7}$$

Using these *C* and *g* values we can now solve equation 1 for the flux:

$$F_{vapor} = \left[\frac{\hat{\rho}D_{vapor}}{d_2}\right]\frac{1}{P_{atm}}\left[h_{r1}e_s(T_{a1}) - h_{r2}e_s(T_{a2})\right] \tag{8}$$

Now that the vapor flux has been determined, the stomatal conductance, g_s , can be found. This requires some assumptions. First, we assume that the relative humidity within the leaf tissue is 1.0, so by equation

$$C_{leaf} = \frac{e_s(T_a)}{p_{atm}} \tag{9}$$

Next, we assume that all conductance values are in series so that the flux is constant between any two nodes. **We also assume that the temperature of the leaf is equal to the temperature of the first humidity sensor.** (The sensor block head has been constructed from aluminum to eliminate the temperature difference.) This means that we can write equation (1) for node 1 and the leaf node and then set it equal to equation (8):

$$F_{vapor} = g_{s+d1}(C_{leaf} - C_1) \tag{10}$$

$$F_{vapor} = g_{s+d1}\left(\frac{1}{P_{atm}}\right)\left[e_s(T_{a1})(1-h_{r1})\right] \tag{11}$$

$$\frac{g_{s+d1}}{P_{atm}}\left[e_s(T_{a1})(1-h_{r1})\right] = \frac{1}{P_{atm}}\left(\frac{\hat{\rho}D}{d_2}\right)\left[h_{r1}e_s(T_{a1}) - h_{r2}e_s(T_{a2})\right] \tag{12}$$

Solving for g_{s+d1}:

$$g_{s+d1} = \frac{\left(\frac{\hat{\rho}D}{d_2}\right)\left[h_{r1}e_s(T_{a1}) - h_{r2}e_s(T_{a2})\right]}{e_s(T_{a1})(1-h_{r1})} \tag{13}$$

Using the rule for series combination of conductance, we can solve for g_s:

$$\frac{1}{g_s} = \frac{1}{g_{s+d1}} - \frac{1}{g_{d1}} \tag{14}$$

Hence,

$$\frac{1}{g_s} = \frac{e_s(T_{a1})(1-h_{r1})d_2}{\hat{\rho}D\left[h_{r1}e_s(T_{a1}) - h_{r2}e_s(T_{a2})\right]} - \frac{d_1}{\hat{\rho}D} \tag{15}$$

so:

$$g_s = \frac{\hat{\rho}D_{vapor}}{\frac{\left[e_s(T_{a1})(1-h_{r1})\right]d_2}{h_{r1}e_s(T_{a1}) - h_{r2}e_s(T_{a2})} - d_1} \tag{16}$$

Therefore, g_s is a function of the distances between humidity sensors, temperature, and the two relative humidity readings.

When the conductance is small, the humidities are nearly the same, and the denominator of the denominator of eq. 6 goes to zero, causing problems. Multiplying top and bottom by the denominator gives

$$g_s = \frac{\hat{\rho}D_{vapor}\left[h_{r1}e_s(T_{a1}) - h_{r2}e_s(T_{a2})\right]}{\left[e_s(T_{a1})(1-h_{r1})\right]d_2 - \left[h_{r1}e_s(T_{a1}) - h_{r2}e_s(T_{a2})\right]d_1} \tag{17}$$

NOTE: *The resulting g_s is in units of mol/m^2s.*

From the Leaf Porometer, the two distances are:

d_1 = 3.35 mm
d_2 = 11.43 mm

Cooling of the evaporating surface. The equations developed so far assume that the evaporating surface temperature is equal to the sensor 1 temperature. A more realistic assumption is that it cools in proportion to the flux of water vapor, which is proportional to the vapor pressure difference between 1 and 2. The effect of this cooling is to reduce the apparent humidity at the evaporating surface. The actual vapor pressure at the evaporating surface is

$$e_o = e_s(T_{a1}) - sP_{atm}(T_{a1} - T_{ao}) \tag{18}$$

Where s is the slope of the saturation vapor concentration function. The temperature difference can be computed from an energy balance for the evaporating surface:

$$H = c_p g_H (T_{a1} - T_{ao}) = \lambda F_{vapor} = \lambda g_{d2}(C_1 - C_2) \tag{19}$$

Where λ is the latent heat of vaporization, so then

$$T_{a1} - T_{ao} = \frac{\lambda g_{d2}}{c_p g_H}(C_1 - C_2) = \frac{C_1 - C_2}{\gamma^*} = \frac{\Delta_1}{\gamma^* P_{atm}} \tag{20}$$

Where

$$\gamma^* = \frac{c_p g_H}{\lambda g_{d2}}$$

Is an apparent psychrometer constant and c_p is the specific heat of air.

And

$$\Delta_1 = [h_{r1} e_s(T_{a1}) - h_{r2} e_s(T_{a2})] \tag{21}$$

Substituting this into eq. 18 gives

$$e_o = e_s(T_{a1}) - \frac{s}{\gamma^*}\Delta_1 \tag{22}$$

The vapor pressure difference between the leaf surface and the first humidity sensor then becomes

$$e_o - e_1 = e_s(T_{a1})\left(1 - \frac{s\Delta_1}{\gamma^* e_s(T_{a1})} - h_{r1}\right) \tag{23}$$

The equation therefore becomes

$$g_s = \frac{\hat{\rho} D_{vapor} \Delta_1}{e_s(T_{a1})(1 - q\Delta_1 - h_{r1})\, d_2 - \Delta_1 d_1} \tag{24}$$

Where q is

$$q = \frac{s}{\gamma^* e_s(T_{a1})} = \frac{s P_{atm}}{P_{atm} \gamma^* e_s(T_{a1})} = \frac{0.071 - 4.3x10^{-4} T}{P_{atm} \gamma^*} \tag{25}$$

Both the saturation vapor pressure and its slope have strong temperature dependence, but their ratio is a weak linear function of temperature, so the final form of the equation for q gives a value which is fairly constant with temperature (though the temperature correction is made in code). At room temperature a value of $q = 0.1$ appears to work well.

7. Care and Maintenance

Changing the Batteries

Although the Leaf Porometer has been designed to provide an excellent battery lifespan, the batteries will eventually require changing. When this happens, a low-battery indicator will appear in the upper left hand corner of the screen.

1. Carefully turn over the Leaf Porometer and locate the battery cover.

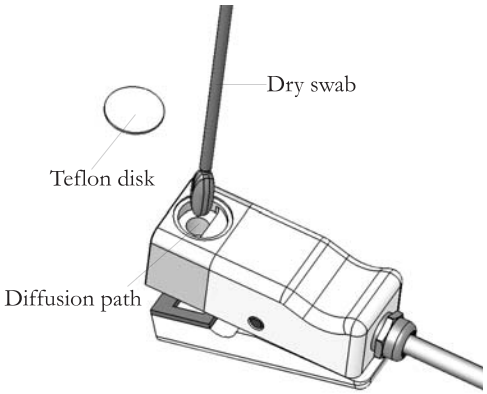
2. Place your thumb on the grooves and push upward to loosen the cover.

3. Remove the old batteries and insert new ones. Be sure to orient the fresh batteries properly.

4. Use the Leaf Porometer or the Leaf Porometer Utility to update the time and date.

Cleaning the Sensor Block

It is necessary to clean the Sensor Block periodically to remove dust and pollen that can build up during routine use. Follow these instructions to clean the Sensor block.



1. Carefully remove the Teflon disk with a sharp object such as pair of tweezers or point of a knife. The Teflon Disk should be handled around the edges as much as possible, and always kept free of dust and moisture. Should the disk get wet, allow it to air dry for 24 hours before continuing use of the instrument.

2. Hold the sensor head open and use a dry swab to clean out the diffusion path. Swabs are included with your kit. Do not use a damp swab, alcohol or other organic liquids to clean the diffusion path! Direct contact with water on the sensors as well as chemical vapors can cause damage!

3. Reinsert the Teflon Disk. Remember to handle around edges as much as possible. Use something dry to press the filter completely into its counter bore. If the Teflon Disk becomes damaged discard and replace. Five replacement disks are included, if additional disks are need please contact Decagon Devices.

Maintaining the Seals & Teflon Disk

When you clean your sensor head, be sure to check the condition of the seals, and make sure that they are making full contact with the leaf. If the seals require replacement, a spare set has been included in your Leaf Porometer shipment. Also, the Teflon disk should be replaced if it becomes excessively dirty. If you need more replacements of either component, contact Decagon.

Replacing the Seal. In the event a seal falls off, you can simply replace it by peeling off the adhesive paper on the back and replacing the old seal. If the seal is very loose, it is best to peel it off and replace it in the same manner. When you replace a seal, look to see if the area you will be applying has dirt or soil particles, as these can prevent the adhesive from applying fully. You might try wiping the area with a slightly damp cloth before applying the new seal.

Replacing the Teflon filter disk. A spare set of Teflon filter disks have also been included. To replace the disk, use a sharp object and *carefully* remove the disk. Then, handling the disk around the edges (using tweezers is advised), insert the spare.

Porometer Sensor Head Re-Conditioning

In some situations, the humidity sensors in the leaf porometer can be adversely affected by exposure to chemicals. This is most commonly encountered when the leaf porometer has been exposed to vapors from volatile organic compounds. We have confirmed reports of sensors being affected by obvious sources of volatile organics such as storing the porometer in a shed with gasoline cans. The signs of sensor "poisoning" can be manifest as a lack of

agreement in humidity measurements between the two sensors, or as nonsensical humidity values from one or both sensor (e.g. >100%).

If you suspect that your leaf porometer has been affected by chemical exposure, then the sensors can be re-conditioned to return them to their natural state using the following procedure:

1. Remove the sensor head from the hand held readout unit.

2. Use the metal pin from the calibration kit to hold the leaf clamp open.

3. Place the entire sensor head (and cable) into an oven with good temperature control.

4. Bake the sensor head in dry heat at 80° C for at least 24 hours.

5. Remove the sensor head and let cool.

6. Re-hydrate the sensor head by exposing it to 70-80% relative humidity at 20-35° C for 12 hours. A 75% humidity atmosphere can be conveniently generated by a saturated NaCl solution. To hydrate with saturated NaCl, the porometer head should be placed in a sealed container above a slurry of NaCl (table salt is fine) and water. There should be both liquid water and plentiful salt crystals present in the slurry.

7. After hydration, the sensor should be left at ambient conditions for 8 hours before calibrating the sensor. Please note that re-conditioning the sensors will change the

sensor calibration, so the sensor must be calibrated prior to using.

General Precautions

While the Leaf Porometer has been designed for quality and durability, it should be kept clean and the batteries always fresh to ensure proper working condition. Here are a few things to remember when using this device:

- Allow the sensor head to equilibrate to the ambient temperature before using.
- Keep the external sensor clean, as the accuracy of readings can decline if there is excess humidity or dirt present.
- Do not touch the Teflon disk. Touching it will offset your readings. Let it dry for 24 hours or until the ambient humidity reading returns to normal.
- While this device is water-resistant, do not use it in rain, and do not use it on leaves covered with dew or water droplets.

Upgrading Firmware

From time to time Decagon will release firmware updates for the Leaf Porometer that contain bug fixes and new features to improve the performance of your instrument. You can view and download firmware updates by going to our website (www.decagon.com) and navigating to the Software Downloads page. Once there, scroll down to the Leaf Porometer section and download the latest Firmware Updater.

Precautions:

- Any data records on the instrument will be erased during a firmware update so make sure to download any data you wish to save before loading new firmware.
- Do not turn off or disconnect your instrument from the communications port while the firmware is updating.

Updating Firmware:

1. Open the firmware updater application.

2. Connect you Leaf Porometer to an available communications port on your computer.

3. Select the same communications port in the drop down list on the firmware updater application.

4. Click Start to begin updating the firmware.

5. Wait for the firmware updater to finish before disconnecting your Leaf Porometer and closing the firmware updater application.

8. Troubleshooting

The Leaf Porometer is a high performance, low maintenance instrument, designed to have few problems if used with care. Unfortunately, some-times even the best operators using the best instruments encounter technical difficulties. Below is quick reference guide that will direct you to detailed solutions of some problems that may occur. If these remedies still don't resolve your problem, then please contact Decagon for help (see Customer Support in Chapter 1). Here is a list of some problems that may occur.

NOTE: If you purchased your Decagon instrument from one of our international distributors, please contact them for local service and support.

Troubleshooting Quick Guide

Troubleshooting Quick Guide (continued)

If this problem occurs:	Refer to:
Missing bootstrap loader message	Problem #7
Firmware corrupted message	Problem #8
Communication port is already in use	Problem #9
USB to Serial Port adapter not shown	Problem #10
Download data to the utility failed	Problem #11
No information is being displayed	Problem #12
Conductivity is not as expected	Problem #13

1. PROBLEM:
Instrument won't turn on.

SOLUTION:
Make sure that the batteries are inserted correctly, and/or if they have enough power to activate the machine.

2. PROBLEM:
The display is difficult to see.

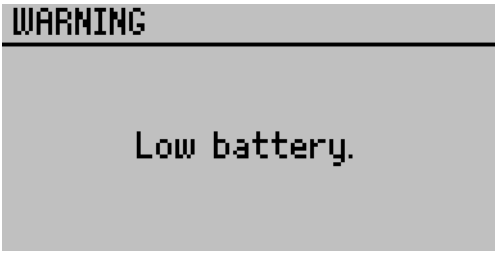
SOLUTION:
Turn off the Leaf Porometer and then turn it on again. If this does not fix the problem, the Leaf Porometer features a built-in screen for changing screen contrast. See "Contrast"

in Chapter 3 for details. You may be able to fix the contrast manually, which can be done using a terminal port program. Contact Decagon for information regarding this procedure.

3. PROBLEM:
Message on screen displays the following:

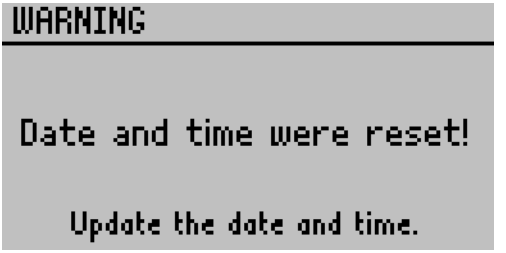
SOLUTION:
Verify that the sensor head is securely connected to the Leaf Porometer's serial port receptacle and restart the reading. If you are still having difficulties, it's possible that the sensor cable is faulty and needs to be replaced.

4. PROBLEM:
Message on screen displays the following:



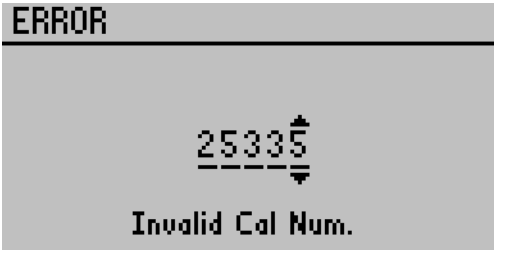
SOLUTION:
The batteries in the instrument may not be properly inserted in the battery holder or they may need to be replaced. If the batteries aren't inserted properly, reseat the batteries into the battery holder and cycle the power on the instrument.

5. PROBLEM:
Message on screen displays the following:



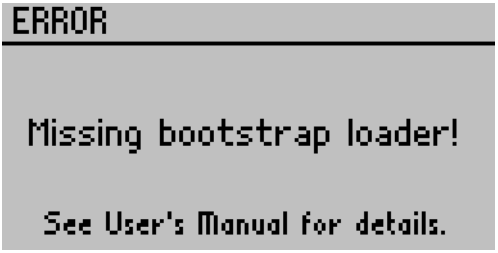
SOLUTION:
After changing the batteries or loading new firmware onto an instrument, this message may appear. Navigate to the configuration menu and verify that the date and time are set properly.

6. PROBLEM:
Message on screen displays the following:



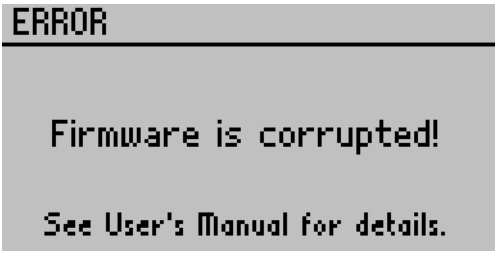
SOLUTION:
This screen will only be displayed when manually entering a calibration number. The best solution to this problem is to perform a user initiated calibration. Another option is to enter the default calibration from the sensors head's label.

7. PROBLEM:
Message on screen displays the following:



SOLUTION:
The instrument cannot download new firmware updates. To down-load new firmware to the Leaf Porometer, or to stop this message from displaying, the instrument must be serviced by Decagon.

8. PROBLEM:
Message on screen displays the following:



SOLUTION:
This screen means that your firmware was not loaded properly, and that an update is needed. (The firmware for the Leaf Porometer is user-upgradeable.) To obtain this, visit Decagon's website to see if new updates are available; if not, contact Decagon for the newest firmware version. Note: You will lose any saved data records when you install the new firmware. Therefore, download any data you wish to save before re-loading the new firmware. If this is not an option, contact Decagon for further help. To obtain new firmware for your Leaf Porometer, see the section on "Updating Firmware" in Chapter 7 for more information.

9. PROBLEM:
The Leaf Porometer Utility tells me the communication port I want to use is in use by another application, but I don't think any other programs are running.

SOLUTION:
Some PDA synchronization software monitor serial communication ports. Disable Microsoft's ActiveSync or Palm's HotSync system software while using the serial port with the Leaf Porometer Utility.

10. PROBLEM:
My USB to Serial adapter is not showing in the communication port picker.

SOLUTION:
Enable "Force find all Communication Ports" in the Preferences Menu by going to the Edit Menu, clicking Preferences, then the Communication tab, and enabling the check

box at the bottom of the screen. Enabling this option may find other serial ports that are not available for use by the Leaf Porometer Utility (for example, modems installed in your computer).

11. PROBLEM:

Downloading data stops in the middle with an error message saying the utility lost connection with the Leaf Porometer.

SOLUTION:

A noisy serial connection can disrupt the connection between the Utility and the Leaf Porometer. If this error happens regularly, you can try setting your baud rate lower or increasing the number of times a command is sent to the Leaf Porometer. Choose the "Communications" tab in Preferences to alter this.

12. PROBLEM:

No information is being displayed.

SOLUTION:

Any conductivity that is lower that 5 $mmol/m^2s^1$ will not be displayed in Automatic mode. Therefore, check to see what mode you're in before beginning. It is advisable to use Manual mode if you know that your leaf has a conductivity that is lower than the minimum threshold for Auto mode. Also, remember that you must press "Enter" in Automatic mode before you begin taking a reading. You may also have gotten moisture inside the sensor assembly or Teflon disk by touching it with your finger. This will distort the sensor's abilities to take accurate readings.

13. PROBLEM:
You are not getting the conductivity reading you expected.

SOLUTION:
Try recalibrating the sensor head. Navigate to the Calibration option in the configuration menu to begin a calibration. If you're still having problems, the inside of the sensor assembly may be dirty. Remove the Teflon disk and clean it thoroughly (see Chapter 7). The Teflon disk also may either be wet or dirty and may need to be dried out or replaced. Additionally, if your sensor was exposed to any out gassing materials, it may require repairs or re-conditioning.

Further Reading

For more information on porometry, stomatal conductance, and how porometers work, consider reading:

Campbell, G. S and Norman, J.M. An Introduction to Environmental Biophysics. Springer-Verlag: New York, Heidelberg, Berlin. Second Ed. 1998. pp. 90-92

Jones, H.G. Plants and Microclimate. Cambridge University Press: Cambridge. 1983.

Marshall, B. and Woodward, F.I. Instrumentation for Environmental Psychology. Cambridge University Press: Cambridge. 1985.

Pearcy, R.W. et al. Plant Physiological Ecology: Field-Methods and Instrumentation. Chapman and Hall: New York, London. 1989. Pp. 137-158.

CE Compliance

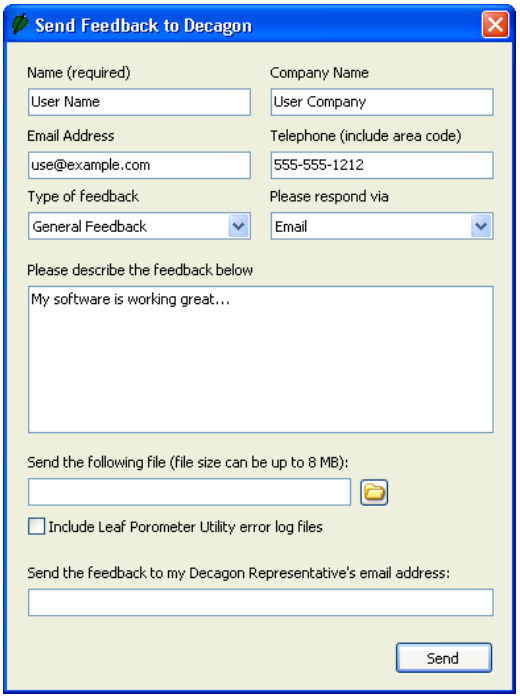
DECLARATION OF CONFORMITY

Application of Council Directive:	**89/336/EEC**
Standards to Which Conformity is Declared:	**EN61326 : 1998** **EN55022 : 1998**
Manufacturer's Name:	**Decagon Devices, Inc.**
Type of Equipment:	**Leaf Porometer**
Model Number:	**SC-1**
Year of First Manufacture:	**2005**

This is to certify that the Leaf Porometer, manufactured by Decagon Devices, Inc., a corporation based in Pullman, Washington, USA, meets or exceeds the standards for CE compliance as per the Council Directives noted above. All instruments are built at the factory at Decagon and pertinent testing documentation is freely available for verification.

Appendix A – Send Feedback

Decagon Software makes it easy to send feedback, bug reports, and feature requests to Decagon or your Decagon Distributor. Choose "Send Feedback to Decagon..." from the help menu. This opens the window shown below.



Enter your name, and other contact information. Tell us what type of feedback you are sending (General Feedback, Feature Suggestions, Bug Report, or Other). Indicate how you want us to respond to your feedback (E-mail or telephone).

Use the description area to give details for your feedback. If you are reporting a bug, it is very helpful for you to tell us what steps you took for the bug to happen and any error message you saw. By default, bug reports also include the software error files.

You can send Decagon a file using this form too. This is useful for sending data files that you have questions about.

If you work directly with a Decagon representative, put their E-mail address in the field at the bottom of the form. This sends the contents of the form to them. Your Decagon representative can follow-up with you directly.

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