Using the LI-600N

Porometer/Fluorometer

Using the LI-600N
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Notice

The information in this document is subject to change without notice.

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Notes on Safety

This LI-COR product has been designed to be safe when operated in the manner described in this manual. The safety of this product cannot be assured if the product is used in any other way than is specified in this manual. The product is intended to be used by qualified personnel. Read this entire manual before using the product.

Equipment markings:

⚠	The product is marked with this symbol when it is necessary for you to refer to the manual or accompanying documents in order to protect against injury or damage to the product.
WARNING	Warnings must be followed carefully to avoid bodily injury.
CAUTION	Cautions must be observed to avoid damage to your equipment.
Manual markings:	
Warning	Warnings must be followed carefully to avoid bodily injury.
Caution	Cautions must be observed to avoid damage to your equipment.
Note	Notes contain important information and useful tips on the operation of your equipment.

CE Marking:

This product is a CE marked product. For conformity information, (typically EMC, Safety, RoHS, and/or Wireless) contact LI-COR Support at envsupport@licor.com for a Declaration of Conformity. Outside the U.S., contact your local sales office or distributor.

For ReaCH (Regulation (EC) n.1907/2006) related questions, information is available on the European Chemicals Agency maintained website for the Waste Framework Directive SCIP database.

You can search by product name (for this product "LI-600"), or request an "SCIP number" from the email above.

LI-COR scientific products are for professional use (non-consumer products). These products do not fall within the voluntary scopes of regulations: UNI EN ISO 14024, TCO Certified, EPEAT 2018, Blue Angel, TÜV Green Product Mark, Energy Star, EU GPP, or other similar regulations. The typical scope for these regulations is lighting, furniture, copiers, mobile phones, televisions, computer/servers, home appliances, to name a few. As such, our products do not use any labeling that indicates adherence thereof.

California Proposition 65 Warning

WARNING: This product contains chemicals known to the State of California to cause cancer and birth defects or other reproductive harm.

Federal Communications Commission Radio Interference Statement

WARNING: This equipment generates, uses, and can radiate radio frequency energy and if not installed in accordance with the instruction manual, may cause interference to radio communications. It has been tested and found to comply with the limits for a Class A computing device pursuant to Subpart J of Part 15 of FCC rules, which are designed to provide a reasonable protection against such interference when operated in a commercial environment. Operation of this equipment in a residential area is likely to cause interference in which case the user, at his own expense, will be required to take whatever measures may be required to correct the interference.

Waste Electronic and Electrical Equipment (WEEE) Notice

This symbol indicates that the product is to be collected separately from unsorted municipal waste. The following applies to users in European countries: This product is designated for separate collection at an appropriate collection point. Do not dispose of as household waste. For more information, contact your local distributor or the local authorities in charge of waste management.

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Section 1.
The LI-600N

The LI-600N Porometer/Fluorometer is a lightweight handheld instrument that takes combined stomatal conductance and Pulse Amplitude Modulation (PAM) chlorophyll *a* fluorescence measurements of a needle or leaf in seconds. It delivers precise, high-throughput stress evaluations over the same needle or leaf area and can quickly survey many conifer needles, narrow leaves, and grass blades under ambient conditions.

The LI-600N has a GPS receiver that records the latitude, longitude, and altitude for each measurement, allowing users to track, return to, and map locations. The LI-600N includes a magnetometer/accelerometer that measures the pitch, roll and heading of a needle/leaf.

The LI-600N computer software is available for both Windows® and macOS®. It is used to create and upload configurations to the instrument, download data from the instrument, record live data, and create barcodes. The software is available for download at licor.com/support/LI-600N/software.html

Components

The LI-600N components are as shown below.

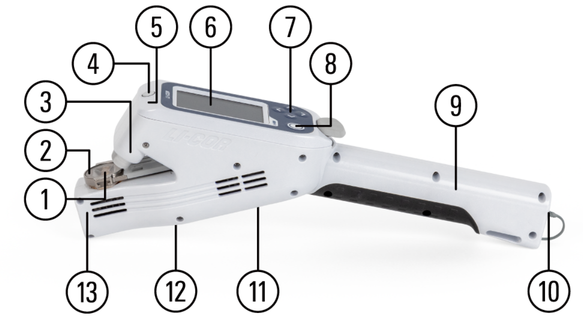


Figure 1-1*. LI-600N Components.*

1 **Chamber**. Surrounds the needle/leaf gasket, the site of the active measurement.

2 **Clamp**. Closes onto the needle/leaf.

3 **Fluorometer**. Takes PAM chlorophyll *a* fluorescence measurements.

4 **Quantum sensor**. Measures ambient light level.

5 **Accelerometer / Magnetometer** (internal). Measures pitch, roll, and heading.

6 **Display**. Shows measurement workflow, instrument settings, and variables data.

7 **Navigation arrows**. Moves up, down, right, and left through options and screens.

8 **Enter button**. Powers on the instrument, logs measurements, and selects options.

9 **Handle**. Encloses the rechargeable battery.

10 **Micro-USB port**. Connects the instrument to the computer or universal charging adapter via micro-USB cable.

11 **Barcode scanner**. Scans barcodes.

12 **Tripod mount**. (1/4-20 UNC) Attaches to a tripod.

13 **Porometer**. Takes stomatal conductance measurements.

Parts and accessories kit

The LI-600N comes with a kit that includes the following accessories and replacement parts. Additional parts and accessories can be purchased separately (see *Support* on the next page).

Table 1-1. LI-600N Parts and Accessories.

Description	Quantity	Part Number
Face seal O-rings	2	192-17935
8 mm O-rings	2	192-20197
6 mm O-rings	2	192-12028
M2 Socket head screws	6	151-16540
Tweezers	1	611-20606
Hex key	1	611-15953
Filters	2	301-19838
Foam swabs	6	610-16093
Aperture gasket	1	6360-369
Clip gaskets	1	6360-368
Microfiber cloth	1	229-16069
Radial seal O-rings	4	192-18368
Spare screws	20	150-14386
Zero adapter assembly	1	9960-327
Scrub tube zero kit	1	9968-258
Charging adapter	1	591-19074
Charger prong kit	1	591-19075
USB cable	1	392-19077
Wrist strap	1	610-19076

Support

The user manual, instructional videos, technical documents, webinars, FAQs, and other resources are available online at licor.com/600Nsupport. This manual can be downloaded as a PDF.

To contact LI-COR environmental support, go to https://www.licor.com/contact/.

Power and battery

The LI-600N is powered by a rechargeable lithium ion battery. The LI-600N is shipped partially charged. Before using it the first time, charge the battery to 100% following the instructions below.

Charging considerations

A power supply—either the universal charging adapter or an external battery pack—can be connected to the LI-600N. If using an alternate USB wall charger, ensure that it has at least 1 Amp at 5 VDC.

The LI-600N can be charged when powered on or off. Before using the LI-600N for the first time, charge the battery to 100%. Charging with the instrument powered off and using the universal charging adapter takes approximately 3.5 hours. Charging with the instrument powered off and from a computer USB port takes 8 to 10 hours and is not recommended. To charge in less than two hours, use a USB wall adapter that supports Qualcomm® Quick Charge™ (QC) 2.0 or 3.0. When fully charged, the instrument will operate for approximately 8 hours of active use; however, battery life can vary due to age and amount of use. External battery packs are suggested for expected use longer than 8 consecutive hours.

Charging temperature: the battery will only charge when the pack temperature is within 0 to 45 °C. If the pack reaches a temperature outside this range, it will automatically stop charging.

Powering the LI-600N on and off

To power on the LI-600N, press and hold the round Enter button on top of the instrument.

To power off the LI-600N, navigate to **Settings** by pressing the left arrow at the Select Configuration screen, then select **Shut Down** and press the Enter button. If the LI-600N is not responding and the settings cannot be accessed, power off the instrument by pressing and holding the Enter button for seven seconds; avoid this, as the last data record could be lost. Power off the instrument when not in use.

Using the universal charging adapter

The included universal charging adapter is compatible with main power in most localities globally (input: 90 to 264 VAC, 50 to 60 Hz; output: 5 VDC, 1 Amp). You may need to install different blades from the outlet adapter kit to fit your outlets.

Battery warnings and disposal

The LI-600N includes a rechargeable lithium ion battery (3.7 V, 5.2 AH) that must be disposed of safely. Contact LI-COR for a replacement battery. The exclamation point label on the exterior and a warning label on the interior indicate the location of the lithium ion battery compartment.

Caution: *Lithium ion batteries may cause environmental damage or damage to human health if they are disposed of improperly. Do not dispose of the batteries in unsorted municipal waste or an incinerator. Many localities have battery recycling facilities that accept lithium ion batteries. Contact your local distributor or the local authorities in charge of waste management to determine how to safely dispose of the battery.*

Section 2.
Using the LI-600N interface

The LI-600N user interface includes four arrow buttons, a round enter button, and the display. The up and down arrows navigate through options in the display, and the left and right arrows navigate through the screens. The **Enter button** powers the LI-600N on, selects highlighted options, and initiates or logs a measurement.

The LI-600N instrument display has four parts: GPS map pin (when GPS is on), time, and battery percentage icons at the top, headings and prompts, options or information in the main portion of the screen, and navigation icons and text at the bottom.

Select Configuration and Matching

Select Configuration appears when the LI-600N is powered on. It lists the configurations loaded onto the instrument (see *Configurations* on page 5-1).

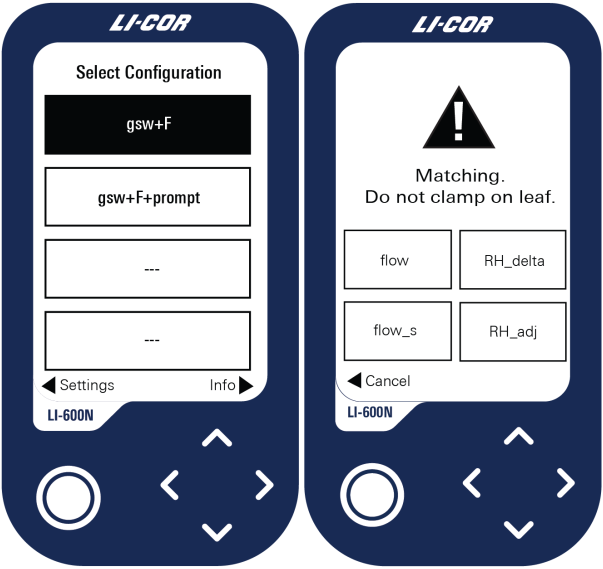


Figure 2-1. *The Select Configuration (left) and Matching screens.*

Select Configuration is the **Home** screen in the navigation, and from it you access **Settings** and **Info** with the arrow buttons.

After a configuration is selected, the LI-600N will go into **Matching.** Matching may include user prompts asking whether a leaf is in the chamber. For a full description of RH sensor matching and user prompts, see *Match mode* on page 3-7. Matching should only be done when the chamber is empty.

Measurement

After the instrument matches, it will beep and go to the **Measurement** screen. The main part of the display includes the variables and layout set in the configuration (see *Display Layout* on page 5-7). The bottom includes navigation to labels and remarks, and indicates whether to initiate a **New** measurement, or to **Log** it with the **Enter button.**

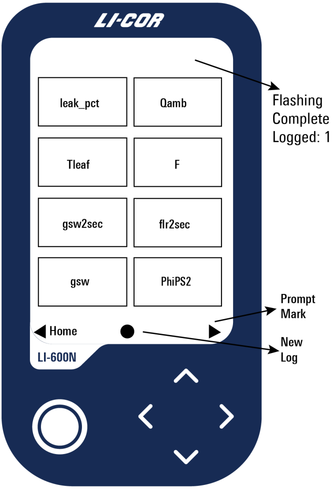


Figure 2-2. *The Measurement screen.*

When taking a measurement with the LI-600N Porometer/Fluorometer, the screen heading will indicate **Flashing**, **Complete**, then **Logged.** The left arrow navigates back to **Select Configuration (Home).**

At the Measurement screen, the leak percent and stability variables will invert to white text on a black background to alert that the leak percent is too high or the stability criteria set in the configuration are not met.

Figure 2-3. *Inverted variables on the Measurement screen.*

Depending on which size gasket is in the clamp, the *leak_pct* variable may or may not be inverted when the chamber is empty.

Data labels and remarks

Data labels and remarks are configured in the LI-600N computer software (see *Data Labels* on page 5-1 and *Remarks* on page 5-5) and correspond to **Prompt** and **Mark** on the instrument. The data labels heading is **Press enter to edit highlighted values**, and the remarks heading is **Mark Reason.**

Figure 2-4*. Data labels and remarks are selected in the "Press enter to edit highlighted values" and "Mark Reason" screens.*

The data label options appear (**Press enter to edit highlighted values**) *after* each measurement if **Prompt on log** is enabled in the configuration. If **Prompt on log** is not enabled, the options are accessed with the right arrow *before* taking a measurement. When accessed and selected manually, data labels and barcodes apply to subsequent measurements until a new label or barcode is selected. **Done** takes you back to Measurements. See *Data Labels* on page 5-1.

Remarks are accessed with the right arrow after logging a measurement (**Mark Reason**). You can select one of up to three remarks in a configuration. **Cancel** takes you back to Measurements. See *Remarks* on page 5-5.

Scan Barcode

Scan Barcode prompts you to scan a barcode when a barcode data label is selected and the onboard barcode scanner on the bottom of the instrument is activated. See *Using the barcode scanner* on page 3-9.

Settings

Settings options include Shut Down, Match, Instrument Settings, and Warning(s). Navigate to **Settings** with the left arrow from **Select Configuration**.

- **Shut Down** powers off the LI-600N.
- **Match** manually matches the RH sensors; it will beep when complete.
- **Instrument Settings** sets the time or clears all data. The percentage of memory used and the firmware version also appear at the top of the screen.
  - **GPS**: turn on or off. Indicates number of satellites, latitude, longitude, altitude, pitch, roll, and heading. Getting a GPS lock can take several minutes after turning on the instrument.
  - **Set Time**: sync with GPS, or set manually. For instruments with GPS, we recommend always syncing the time with GPS. See *Clocks* on page 9-19.
  - **Clear All Data:** erase all of the data on the instrument.
  - **Back**: go back to Select Configuration.
- **Warning(s)** shows instrument warnings (see *Instrument warnings* on page 7-4).

Info

From **Select Configuration**, navigate to **Info** with the right arrow button. The information lists porometer and fluorometer settings for the active configuration.

Section 3.

Taking Measurements

This section describes precautions, techniques, and procedures for taking measurements with the LI-600N.

Precautions and techniques

Observe these precautions and practice these techniques before and while taking measurements with the LI-600N.

Precautions

To protect the LI-600N when not in use, turn it off and place it in the carrying case. Before using the LI-600N, take the following precautions.

- **Charge the battery.** A fully charged battery provides approximately 8 hours of active use. See *Charging considerations* on page 1-4 for charging time.
- **Attach and use the wrist strap.** To protect the LI-600N, attach the wrist strap to the instrument and adjust it to your wrist size. Use the wrist strap at all times (or risk being "the person who dropped it").
- **Insert the USB port protector.** To protect the USB port from debris, keep the protector inserted when the instrument is not connected to a computer.
- **Allow the instrument to come to ambient temperature.** If you are moving the instrument to a site with a higher or lower temperature than it is stored in, wait fifteen minutes before taking a measurement so the instrument can acclimate.

Techniques

Following these techniques helps ensure the quality and accuracy of your measurements.

- **Align the needle or leaf with the opening in the aperture.** If they are not aligned, the IRT sensor will not accurately measure the sample.
- **Maintain the light conditions of the leaf.**Do not alter the light on or shade the leaf you are measuring.[1] If, while taking a measurement, you shade the leaf you plan to measure next, unshade the leaf and wait 60 seconds before measuring it. Changes to light at the leaf surface will affect *PhiPSII* and *gsw*.
- **Match the quantum sensor's light conditions to those of the leaf.**If the leaf you measure is in the light, ensure that the quantum sensor is also in the light. If the leaf you measure is in shade, ensure that the quantum sensor is also in the shade. A mismatch between the leaf and the quantum sensor may result in a significant error in *ETR* calculation.
- **Avoid measuring a needle or leaf with water on it.**If the needle or leaf you plan to measure has water or condensation on it, gently and thoroughly dry it. Measuring a wet needle or leaf may result in overestimation of stomatal conductance, and water ingress into the instrument may cause damage.
- **Maintain unblocked vents on the instrument.**Do not cover any of the vents on the instrument when taking measurements.
- **Turn GPS off when not in use.**GPS uses more power when it is searching for satellites. If you're indoors or in an area with poor satellite fix, turn off GPS to save

[1]This is referred to as a "Madsen Error" within LI-COR.

battery power. GPS can be turned off on the instrument by going to Settings (left arrow from Select Configuration), or can be turned off in a configuration by leaving "Use GPS and Leaf Angle" unchecked in the General screen in Configuration Management.

Gaskets

The LI-600N comes with both lower aperture and upper clamp gaskets installed.

Clamp gaskets

The LI-600N includes three sets of clamp gaskets for use with needles and leaves of varying diameters.

Clamp gasket sizes

Depending on the diameter or thickness of the needle or leaf you're measuring, you may need to change the clamp gaskets before taking measurements.

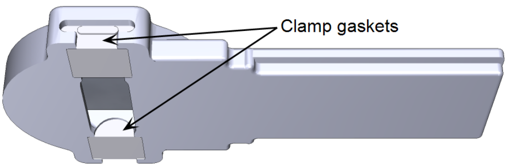


Figure 3-1*. The LI-600N clamp with size 0 clamp gaskets installed.*

Needles or leaves can be from 1–3.5 mm wide, and must be a minimum of 14.2 mm long to cross the aperture.

The diameter or thickness of the needle or leaf to be measured determines which clamp gaskets to use. The **0** gasket is for needles or leaves of up to 2.6 mm in diameter/thickness, and the **1** and **2** gaskets are for needles or leaves of up to 2.8 mm in diameter/thickness.

Cutting clamp gaskets

Additional clamp gaskets, included in the accessories kit (part number 6360-368), come uncut, as shown below. The numbers indicate the absence (0) or size (1, 2) of the notch on the bottom of the gasket.

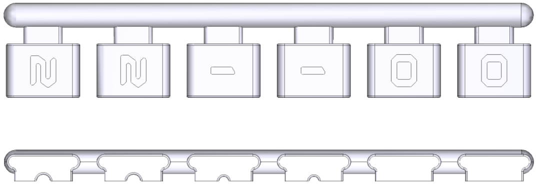


Figure 3-2*. Uncut clamp gaskets, top and side views.*

Cut the gaskets off using a sharp razor blade or pen knife. Carefully cut as close to the side of the gasket as you can without cutting into the gasket.

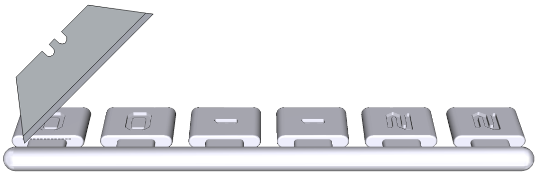


Figure 3-3*. Cutting the clamp gaskets.*

Changing clamp gaskets

Remove the installed gaskets from the clamp. The material is pliable, and you can pull one side out of its notch and lift the gasket out. Store them in the ziplock bag.

> **Tip:** Bring your patience; this can be fussy.

1 With the cut side facing out, take a lipped edge of the gasket you want to install and push it into its notch on the clamp.
2 Push the other edge inwards to fold the gasket until the other lipped edge can be pushed into its notch.
3 If needed, use the tweezers (included in the accessories kit) to adjust the position of the gasket.

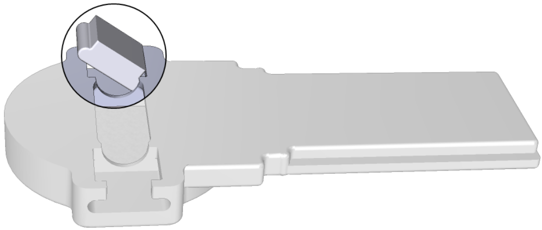


Figure 3-4. *Insert one lipped edge of the clamp gasket first.*

If, when taking measurements, you have problems with high leak percent (especially if the chamber is empty), check again that these gaskets are fully seated.

Aperture gasket

The LI-600N comes with a spare aperture gasket (part number 6360-369). The aperture gasket may need to be changed after periods of heavy use.

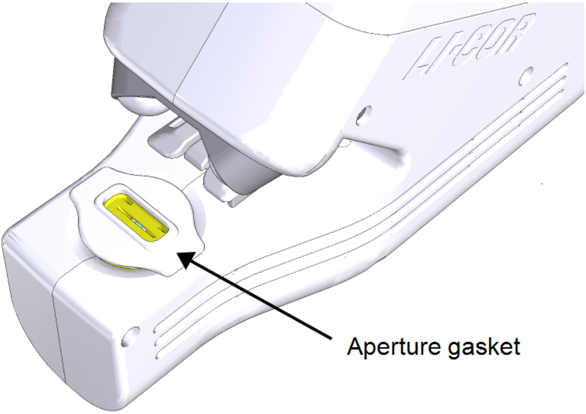


Figure 3-5. *The aperture gasket on the instrument.*

To remove the aperture gasket from the instrument, gently pull on one of the outside ends to slightly stretch the gasket over the edge of the aperture, then lift it off.

To install the new gasket, place one end of the gasket over an outer edge of the aperture, and stretch slightly to pull the other end over the other edge.

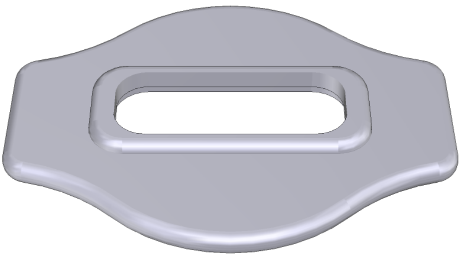


Figure 3-6. *The aperture gasket.*

The gasket should cover the outer edges of the aperture.

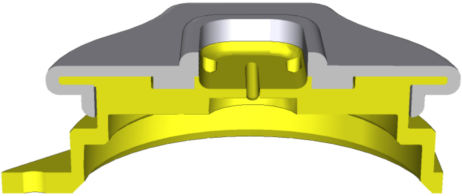


Figure 3-7*. A cross-section view of the aperture gasket fitted onto the aperture.*

For information on cleaning the gaskets, see *External cleaning* on page 8-1.

Taking a measurement

The workflow for taking a measurement on the LI-600N will vary depending on two settings in the active configuration: whether **Prompt to edit during measurements** is enabled for leaf area or width, and whether **Prompt on log** is enabled for optional data labels.

Match mode

After selecting a configuration and at intervals specified in the configuration (default is 10 minutes), the instrument goes into match mode, as indicated on the instrument screen. In match mode, the instrument checks to make sure the RH sensors are reading the same.

The LI-600N performs two types of matches: valved and serial. Which type of match is performed depends on the leak percent of the chamber when it is empty. The leak percent varies depending on which clamp (top) gaskets are installed.

If the leak percent is lower than the leak maximum allowed for a good measurement, the LI-600N will prompt the user to ask if a leaf is in the chamber. If the user answers **yes**, the instrument prompts the user to remove the leaf. If the user answers **no**, the instrument waits 10 seconds and computes the match adjustment without the valve. This is a serial match. This match is most likely with the flat (0) or small-notch (1) gaskets.

If the leak percent is higher than the leak maximum, the LI-600N activates the match valve, waits 10 seconds, computes the match adjustment, then deactivates the match valve and goes to the measurements screen. This is a valved match. This type of match is most likely with the larger notch (2) gaskets.

Do not enter match mode with a needle or leaf in the chamber. Matching with something in the chamber will ruin subsequent measurements.

Measurement workflow

To take a measurement:

1. **Power on** the LI-600N.
2. **Select a Configuration** and press Enter. The instrument will go into match mode. Follow any match prompts that appear. The instrument will then go to the Measurement screen.
3. **Clamp to a needle or leaf.** Watch for stability in the g_{sw} variable.
4. **Press the Enter button** (Log) to log the measurement when your stability criteria are met.
5. **Unclamp** the needle or leaf. If the leaf width/area prompt and/or "prompt on log" are enabled, the Data labels screen will appear. Use the arrow keys and Enter button to edit the leaf area or width, and to select the values in the labels or scan a barcode.

Select Done and press Enter to return to the Measurement screen.

6 **Add remark** (optional). Press the right arrow (Mark) to add a remark. Select the remark and press the Enter button. You will go back to the Measurement screen.

7 **Press Enter** (New) to initiate a new measurement.

8 **Repeat** from step 3 for subsequent measurements.

When you're done taking measurements, press the left arrow (Home) to go back to the **Select Configuration** screen, then press the left arrow again to go to **Settings.** Select **Shut down** and press the Enter button to safely turn off the instrument.

Using the barcode scanner

To enable the barcode scanner for a configuration, see *Remarks* on page 5-5.

You will scan a barcode either before or after a measurement is logged, depending on whether **Prompt on log** is enabled in the configuration (see *Data Labels* on page 5-1). If it is enabled, you are prompted to scan a barcode after each measurement. If it is not enabled, you can scan the barcode before a measurement by pressing the right arrow (Prompt) from the Measurement screen, and then selecting the barcode label. If you scan the barcode before a measurement, that barcode will apply to subsequent measurements until you scan another barcode.

To scan a barcode:

1 At the Data labels screen, navigate to the barcode label and press the Enter button. The barcode prompt will appear.

2 At the Scan Barcode prompt, pass the red light from the barcode scanner on the bottom of the instrument over the barcode.

When it reads the barcode the LI-600 will beep and return to the Data labels screen and display characters from the scanned barcode..

The barcode scanner will time out after a few seconds. If this happens, repeat the process. When finished, navigate to Done and press Enter to return to the Measurement screen.

Viewing measurement data

Data from the most recent measurement appear on the Measurement screen after taking a measurement, and before pressing the Enter button for a new measurement. For information on configuring the variables shown on the Measurement screen, see *Display Layout* on page 5-7.

Section 4.

Using the computer software

The LI-600N computer software is the interface for managing configurations and data, performing user calibrations, and for generating custom barcodes. The software can be used with or without an LI-600N connected.

Download the software and connect the LI-600N

Take the following steps to download the software and connect the LI-600N to your computer.

1. Install the computer software, which is downloaded at licor.com/600Nsoftware
2. Press and hold the **Enter button** to power on the LI-600N.
3. Connect the LI-600N to your computer using the micro USB cable.

   The LI-600N will automatically connect with the computer software if the computer software and instrument firmware are up to date. If the software and firmware are not up to date, the computer software will prompt you to update.

Connection Overview

Connection Overview is the software startup screen, and shows the firmware and computer software versions. From here, you can proceed with or without a connected LI-600N or safely eject a connected instrument.

The software may display warning messages. See *Software warning when connecting the LI-600N* on page 7-2 and *Software warning when updating the firmware* on page 7-3.

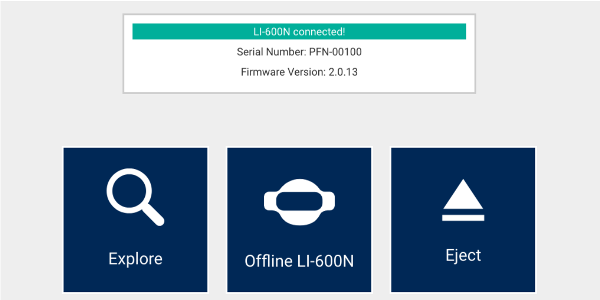


Figure 4-1. *Connection overview.*

At the Connection Overview screen, you will receive one of two prompts.

LI-600N connected! An LI-600N is powered on and has been discovered by the computer software.

- Select **Explore LI-600N** to access Configuration Management, Data Management, Live View, Connection Overview, and Barcode Generator.
- Select **Offline Mode** to access the Configuration Management, Data Management, Connection Overview, and Barcode Generator options that are available without an LI-600N connected.
- Select **Eject LI-600N** to safely disconnect and power down the instrument.

No LI-600N detected! Connect the instrument to the computer via USB, then wait for the **LI-600N connected!** prompt to appear, or select **Offline Mode** to proceed.

Home screen

When the LI-600N is connected, select **Explore LI-600N** to access the Home screen. The Home screen includes a toolbar, a drop-down menu, and tiles for accessing Configuration Management, Data Management, Live View, Connection Overview, and Bar Code Generator.

Toolbar

The Toolbar includes a drop-down menu in the upper left and three buttons in the upper right.

Drop-down menu

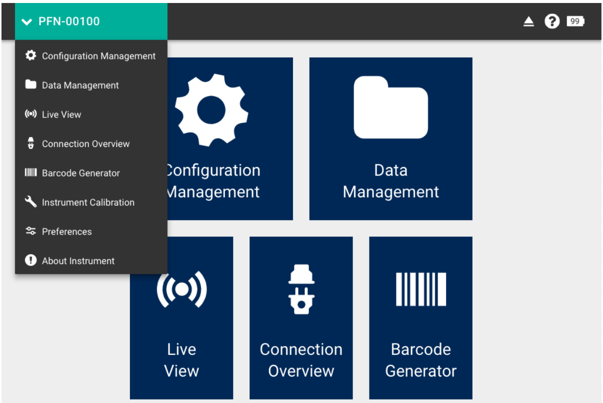


Figure 4-2. *The drop-down menu (LI-600N connected).*

In addition to Configuration Management, Data Management, Live View, Connection Overview, and Bar Code Generator, the drop-down menu offers access to the following:

Instrument Calibration shows user calibration coefficients and user-adjustable parameters. Calibration parameters can be adjusted for the relative humidity (RH) sensors, flow sensors, and fluorescence detector. See *Calibrating the sensors* on page 8-10 and *User calibration procedures* on page 9-10 for instructions.

Factory Calibration appears in the drop-down menu when Allow Factory Calibration is checked in Preferences. Fluorometer, Intensity, Flow In, Flow Out, IRT, RH, and Miscellaneous values can be edited. Perform a factory reset, download a calibrations file from the LI-COR web-site, or perform a manual reset using a downloaded file. Select RH in the left menu to change the RH sensor serial number and to calibrate.

Preferences: select the text delimiter for data and log files (comma or tab). Check **Allow Factory Calibration** to enable Factory Calibration.

About Instrument displays the instrument serial number, instrument firmware version, instrument time, porometer serial number, fluorometer serial number, and the RH sensor serial number.

Buttons

Table 4-1. Toolbar buttons.

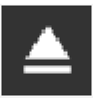
	**Home**: Goes back to the home screen.
	**Safely Eject Instrument**: Safely powers down and ejects the LI-600N from the computer software.

Table 4-1. Toolbar buttons. (...continued)

	**View Help**: Goes to the LI-COR support website.
	**Battery Level**: Displays the percent battery charge of the connected instrument.

Configuration Management

When an LI-600N is connected, the Configuration Management menu shows two configuration lists: LI-600N Configurations (those stored on the instrument) and Local Configurations (those stored on the local computer).

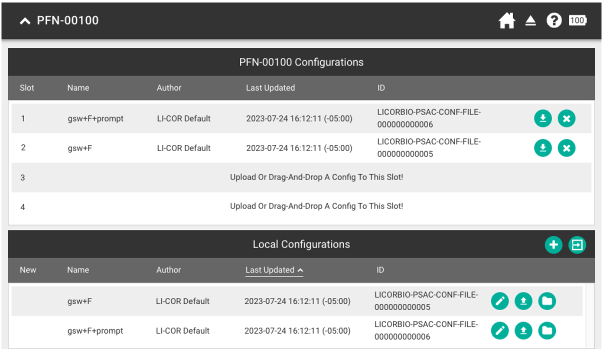
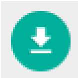


Figure 4-3. *Configurations loaded onto the LI-600N(top) and those saved in the software (bottom).*

LI-600N Configurations

Two configurations come preloaded onto each LI-600N: gsw+F and gsw+F+prompt. They cannot be edited but can be saved as new configurations. The author name **LI-COR Default** cannot be used for any other configurations.

Table 4-2. Buttons to download and remove configurations from the instrument.

	*Download To Computer:* Downloads the configuration to Local Configurations. Select **Download** on the confirmation prompt to finish.
	*Remove From Instrument*: Removes the configuration from the LI-600N. Select **Remove** on the confirmation prompt to finish.

Local Configurations

Local Configurations are the configurations created in the computer software. **New** indicates a configuration that has not been uploaded to an LI-600N since its creation or most recent edit. Double-click on a column heading to sort. Configurations with the same name as another are assigned a randomly generated name to avoid a naming conflict. Configurations can be exported and imported as PSAC files and shared among users.

Table 4-3. Configuration management buttons.

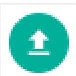
	*Create New Configuration*: Creates a new configuration and saves it to the Local Configurations list.
	*Import Configuration*: Imports a configuration PSAC file.
	*Edit Configuration*: Edits a configuration locally. Edited configurations must be re-uploaded to the LI-600N.
	*Upload To Instrument*: Uploads a configuration to LI-600N. To replace a configuration, select **Replace**. Select **Upload** to complete.
	*Export To File*: Exports the configuration as a PSAC file.

Table 4-3. Configuration management buttons. (...-continued)

	*Delete Configuration*: Removes the configuration from the Local Configurations list.

Data Management

From Data Management, you download data from a connected instrument to the software, and export it to your computer as text and Excel files.

LI-600N data

Data on LI-600N lists the date of the last data download. This section indicates the instrument's serial number and percent of data storage used.

Table 4-4. Data management buttons.

	*Download Instrument Data*: Downloads all processed data on the LI-600N to the computer software. A copy of raw data is also downloaded as a precaution.
	*Clear Instrument Data*: Removes all data from the LI-600N.

Local Files

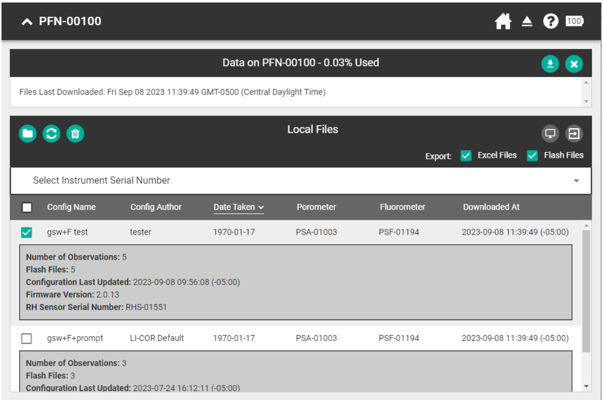


Figure 4-4*. Local data files.*

Local Files lists data and metadata stored in the computer software. You can sort the files by column and toggle the metadata view.

Exporting files

The two check boxes and icons in the upper right give you options for exporting Excel files with embedded equations and fluorometer flash files. The two icons above the check boxes are for exploring and importing data dumps (see *Data dumps* on page 6-3).

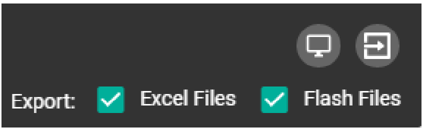


Figure 4-5*. Export checkboxes and data dump icons.*

Data files are managed and exported using the buttons listed in the table below.

Table 4-5. Data file buttons.

	*Export Selected Files*: Downloads the selected data files to the computer's local file system.
	*Toggle Selected Metadata*: Shows or hides selected metadata for the selected file.
	*Delete Selected Files*: Removes the selected data files from the Local Files.

Live View

Live View streams data from a connected LI-600N and is useful for educational settings. Live data for each selected variable in graph format are displayed, allowing you to view and log data while taking measurements.

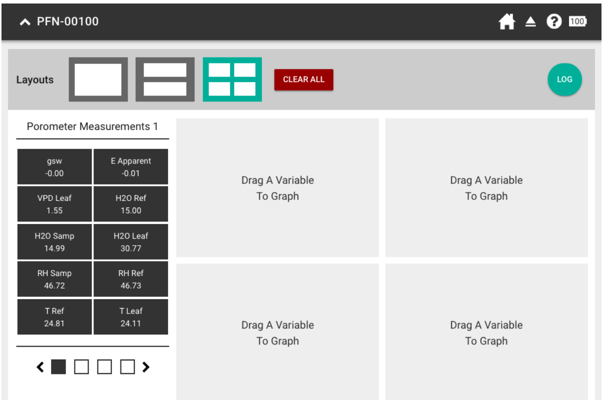


Figure 4-6. *Live view.*

To set up your parameters, select a layout from the top of the screen. Navigate through the five variable screens by selecting one of the five squares or by using the arrows. Drag and drop the desired variables into graph boxes; not all boxes need to be filled. Select **CLEAR ALL** to remove all variables and reset the graph boxes.

If the screen does not adequately display units, select the graph titles to toggle between chart title and units.

Table 4-6. Edit and remove variables buttons.

	*Edit* a variable's YMin, YMax, and XSize.
	*Remove* deletes a variable from the graph box.

When taking a measurement, data will appear in real time in the graph boxes. Using the connected LI-600N, select a configuration, match, and allow the graphs to stabilize, then take a measurement. Measurement data will appear on the computer screen and any additional connected screen.

Select **Log** in the upper right corner to save the last sixty minutes of data on a per-second basis to the local computer; measurement data can also be downloaded from the LI-600N in the Data Management menu at any given time. If you navigate away from the Live View menu, sixty minutes of live data are automatically saved.

Connection Overview

Connection Overview returns to the computer software startup screen.

Offline Mode

Offline Mode can be accessed with or without a connected LI-600N.

When you launch the software without an instrument connected, you go to the Connection Overview screen, where you choose the instrument you're working with.

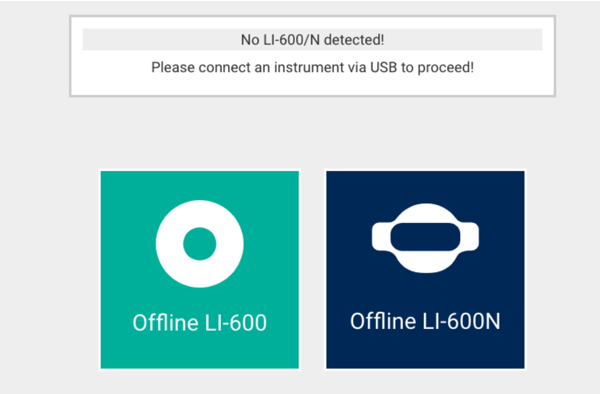


Figure 4-7*. The Connection Overview screen in offline mode.*

After you select an instrument, you're taken to the Offline Mode Home screen. The drop-down menu includes access to Configuration Management, Data Management, Connection Overview, Barcode Generator, and Preferences. If you have both an LI-600 and an LI-600N and want to switch instruments, go back to Connection Overview.

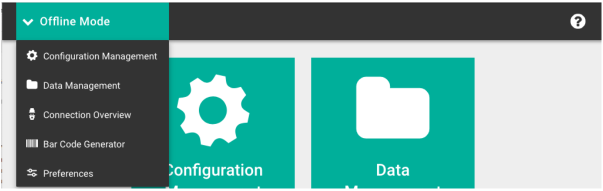


Figure 4-8*. Offline Mode drop-down menu.*

When an LI-600 or LI-600N is not connected to the software, you can create and edit configurations locally, manage data that's been downloaded from the instrument, manage preferences, and create barcodes. The functionality of these features is the same as when an instrument is connected, with the exceptions of not being able to upload configurations, download data, or view live measurements.

Barcode generator

The LI-600N computer software can generate custom barcodes for use with the LI-600N barcode scanner.

From the home screen of the LI-600N computer software, select **Bar Code Generator.**

Barcode generator screen

The barcode generator screen includes options for barcode format, importing and pasting text, and the barcodes text area.

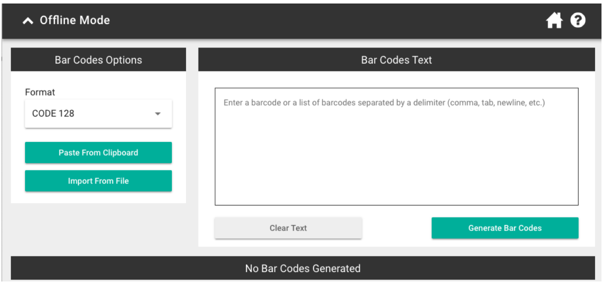


Figure 4-9*. The barcode generator screen.*

Barcodes Text: Type, paste, or import delimited text into this field. Each barcode is limited to 31 characters.

Format: Choose from CODE128 or QRCODE.

Code 128 QR Code

PASTE FROM CLIPBOARD: Paste delimited text that has been copied onto your computer's clipboard.

IMPORT FROM FILE: Select a delimited text file from your computer and import it to the Barcodes Text field.

CLEAR TEXT: Clear the contents of the Barcodes Text field.

GENERATE BARCODES: Generate barcodes from the text field and displays them in the bottom portion of the window. The length of the text determines the width of the barcode.

PRINT PREVIEW: View the barcodes with text as they will appear on a printed page.

REMOVE ALL: Clear the generated barcodes.

You can continue to add barcodes in either format until you're ready to print or save them as a PDF.

Once generated, barcodes can be edited or removed individually by using the icons in the upper right corner.

Figure 4-10*. An editable barcode.*

Print preview screen

The **Print Preview** screen displays barcodes as they will appear on a page, with options for paper size and page template.

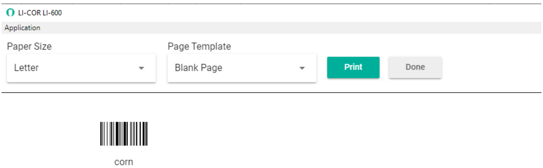


Figure 4-11*. The Print Preview screen.*

Paper Size: U.S. Letter (8.5 x 11") or A4 (8.25 x 11.75")

Page Template: Blank page: plain paper; U.S. Letter: Avery 5163 labels 10 per page; A4: Avery L7992 labels 10 per page.

Print: Print or save as a PDF.

Done: Go back to the barcode generator screen.

When used with the LI-600 barcode scanner, the barcode text for each measurement appears in the **USERDEF** group in LI-600 data files.

Section 5.
Configurations

The LI-600N Porometer/Fluorometer comes with two default configurations preloaded: gsw+F and gsw+F+-prompt. Configurations are uploaded to the instrument from the computer software (see *Configuration Management* on page 4-5).

gsw+F	LI-COR Default	2023-07-24 16:12:11 (-05:00)	LICORBIO-PSAC-CONF-FILE-000000000005
gsw+F+prompt	LI-COR Default	2023-07-24 16:12:11 (-05:00)	LICORBIO-PSAC-CONF-FILE-000000000006

Figure 5-1*. Default configurations on the LI-600N.*

Configuration settings

Configurations include settings for porometer and fluorometer options, measurement settings, data labels, remarks, and the instrument display layout.

General

General settings specify the name and author of the configuration, and the fluorometer and GPS/leaf angle options. If the fluorometer option is unchecked, the settings for the fluorometer will be hidden.

Data Labels

Data Labels are user-specified labels that can be applied to each measurement, for example genotype, plot number, or replicate. A label can be formatted as a number, list, or barcode. A configuration can have up to three labels, and at least one label must be a barcode to enable the barcode scanner on the instrument.

Remarks

Remarks are optional comments that can be added to each measurement. You can create up to three remarks; one of those remarks can be applied to each measurement. Remarks are selected on the instrument when a user chooses to mark a record after taking a measurement. See *Taking a measurement* on page 3-7.

Measurement Settings

Measurement Settings control the following aspects of measurements taken with the LI-600N.

Leaf Area or Leaf Width is where you can enter values for either leaf area or leaf width, and enable a prompt to edit the leaf width during measurements.

Flow is the flow rate generated by the pump to the leaf aperture: Low (75), Medium (115), or High (150).

Match Frequency indicates how often a match of the RH sensors is triggered, specified in minutes.

Flash indicates whether the measurements are light or dark adapted, type of flash, flash intensity, and flash length in milliseconds.

Fluorescence Constants are Leaf Absorptance (*abs*) and Fraction Abs PSII (*PS2/1*).

Modulation (*modrate*) is the modulation rate of the LEDs used to take the fluorescence measurement. The input Actinic Modulation Rate in Hz is shown with the automatically calculated Integrated Modulation Intensity.

Display Layout

Display Layout determines the layout of the instrument display. The options include a 2- or 8-panel layout that displays selected variables after a measurement is taken.

Creating custom configurations

Custom configurations can be created in the LI-600N computer software with or without an LI-600N connected.

Go to **Configuration Management** from the drop-down menu in the upper left. At **Local Configurations**, use the green plus icon to **Create New Configuration**. You can also open a default configuration and save it as a new one.

General

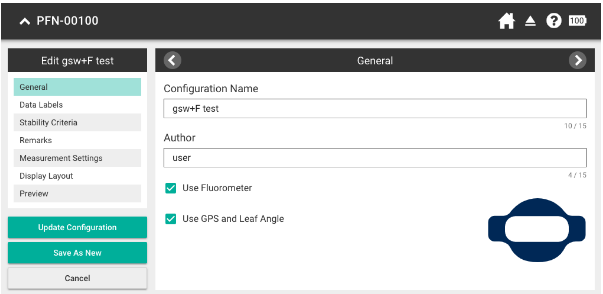


Figure 5-2. *The General screen.*

At the **General** screen, add a **Configuration Name** and an **Author**. Check **Use Fluorometer**; fluorometer options are hidden if unchecked. Check **Use GPS and Leaf Angle** to utilize the GPS receiver and accelerometer/magnetometer.

Data labels

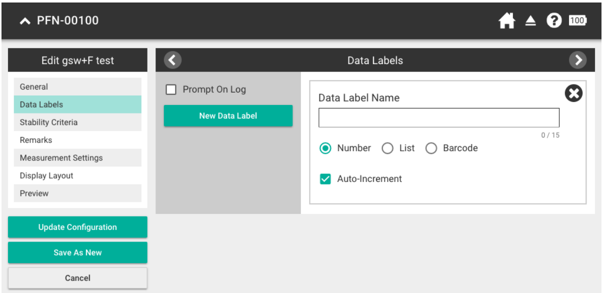


Figure 5-3*. The Data Labels screen. This configuration would enable the barcode scanner and have a list of three labels to choose from.*

In **Data Labels**, you can create labels using a number, list, or barcode format. One label must be a barcode to enable the barcode scanner. Each configuration can have up to three labels.

Check **Prompt On Log** if you want to set a data label after taking each measurement. If Prompt On Log is not checked, you set data label values prior to taking a measurement.

Enabling Prompt On Log is useful when measuring a variety of leaves that require individual labeling, for example, when screening different genotypes.

When Prompt On Log is unchecked, each label selected prior to taking a measurement will apply to subsequent measurements until a new label is chosen.

Select **New Data Label**. Add a Data Label Name, then select Number, List, or Barcode.

Number: Check the Auto-Increment box for automatic numbering.

List: Add up to three selections with the plus button; drag and drop them to change their order.

Barcode: Enable the barcode scanner.

Stability Criteria

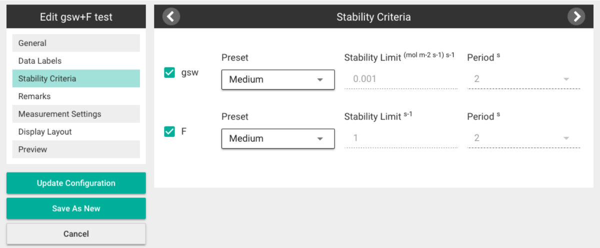


***Figure 5-4**. The Stability Criteria screen.*

Stability criteria for fluorescence (*F*) and stomatal conductance (*gsw*) are set here. Shown are the default criteria for the LI-600N.

Table 5-1. Stability Criteria variable options.

Preset	Stability Limit (g_{sw})	Slope Limit (F)	Period (s)
Fast	0.005	5	2
Medium	0.001	1	2
Custom	user specified	user specified	1, 2, or 4

Remarks

Remarks are optional comments that can be added to a measurement to help exclude outlier data during analysis. Select **Add Remark** and add text. You can create up to three remarks to choose from (e.g. "Poor clamp").

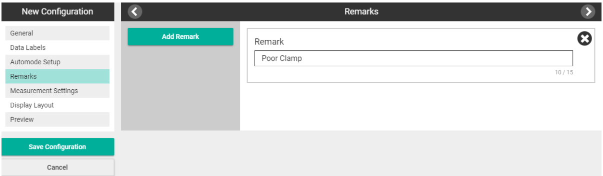


Figure 5-5. Remarks screen.

Measurement Settings

In **Measurement Settings**, you can select values for Flow Rate, Leaf Area or Leaf Width, and Match Frequency for the porometer, and Flash, Fluorescence Constants, and Modulation values for the fluorometer.

Low flow is recommended for most applications to provide a measurement speed with no observed reduction in sensitivity.

Leaf Area or **Leaf Width** is input by the user. The default is a leaf width of 1.8 mm. Check "Prompt to edit during measurements" if you want to change the width after taking a measurement. You will be prompted after each measurement to edit the width along with any other prompts set up in the configuration (see "Data labels" on page 5-4).

Match frequency determines how often the instrument will automatically match. Enter the interval in minutes.

Flash sets the fluorometer flash to light (default) or dark adapted, whether the flash will be rectangular or multiphase (light-adapted measurements), and sets flash intensity and flash length.

If the **Dark Adapted** box is checked or the **Rectangular** or **Multiphase Flash** options are selected, values in Flash and Modulation automatically set to default.

Fluorescence Constantsinclude Leaf Absorptance and Fraction Abs PSII.

Modulation inputs the Actinic Modulation Rate. Integrated Modulation Intensity is automatically calculated.

Display Layout

In **Display Layout**, you can customize the layout and variables that are visible on the LI-600N Measurement screen.

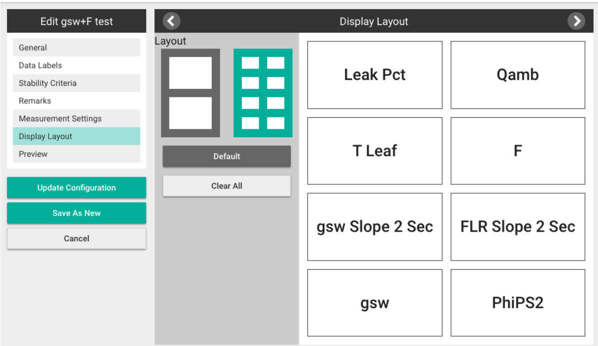


Figure 5-6. *Select a 2- or 8-panel layout for the Measurement screen.*

To change variables, click into the variable box then select a variable from the list. Select **CLEAR** to leave a variable box blank, **Clear All** to remove all variables, and **Default** to reset the layout.

All variables are recorded in the data files; this setting only indicates the variables seen in the display.

Preview

In **Preview**, you can view a simulation of the Measurement and Data labels screens.

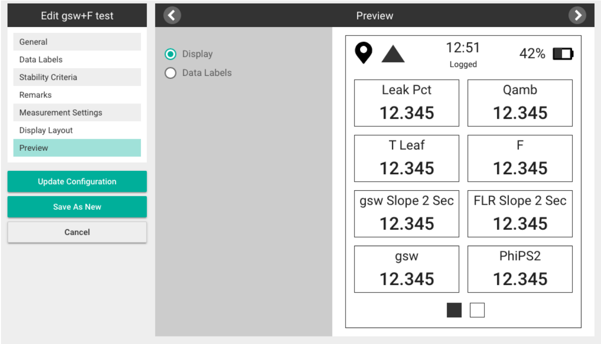


Figure 5-7. Display preview.

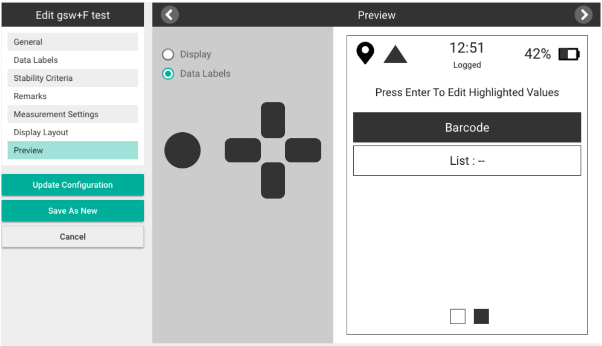


Figure 5-8. Data Label preview.

Save Configuration

Select **Save Configuration** to save the configuration.

Upload configuration to instrument

If your instrument is not connected, go to **Connection Overview** from the drop-down menu and connect it. Once conneted, select the **Upload** button under Local Configurations to add it to the LI-600. Up to four configurations can be loaded onto the instrument at a time.

Section 6.

Data files

Getting data from the LI-600N onto your computer for use in a spreadsheet application is done in two steps: download the data from the instrument to the software, then export it from the software to your computer.

Downloading data from the LI-600N

To download data from the LI-600N to the computer software, launch the LI-600N software and connect the instrument. Select **Data Management.**

Under **Data** on LI-600N, select **Download Instrument Data** then **Download** on the prompt.

All data on the LI-600N will be downloaded to the computer software.

Clear on the confirmation prompt to clear all data from the instrument or **Cancel**. Clearing removes all data from the LI-600N, not from the computer software.

It is a good practice to clear the data from the instrument after it is downloaded to the software. Otherwise, new measurement data are appended to existing data, which are downloaded again.

Exporting data files from the computer software

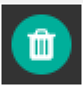
To export data files from the computer software to your computer file system, select files to download under Local Files. Check the box next to **Flash Files** to save the fluorometer files with the data file.[1] To export Excel files with embedded equations, check the box next to **Excel Files**.

The Excel files are useful in instances where a user needs to adjust parameters, such as leaf width, and have the spreadsheet recalculate values.

The delimiter for data files is set in the software preferences from the dropdown menu, and is comma-delimited by default. Tab-delimited files are for users in locations where the comma is used as a decimal separator.

Select **Toggle Selected Metadata** to view a data file's metadata. Metadata is also recorded in the exported data file for each measurement.

Select **Export Selected Files** to save the selected data files to the computer's local file system.



Select **Delete** to delete the data from the software after exporting it. This will not delete the exported files.

All data files are saved as .zip files that contain text files in .csv or .txt format, as well as optional Excel files with embedded equations and flash files. When unzipped, the files are in directories organized by configuration and date.

[1]For information about software that can help with flash file analysis, see *FlashAnalysis App* on page A-1.

Data dumps

Data dump files are data that have been unsuccessfully imported to the software. These are useful in the event of download errors. They are stored in the following locations:

Windows OS
C:/Users/Username/AppData/Roaming/licor-li600/data_dump

To view this hidden folder, type **%AppData%** into the Windows search bar and press **Enter**.

MacOS
Macintosh HD/Users/Username/Library/Application Support/licor-li600/data_dump

You can access and import data dump files from Data Management in the LI-600N Software (see *Data Management* on page 4-7).

Data file structure

After a data file is exported from the computer software as a tab-delimited or comma-delimited text file, it can be imported into a spreadsheet application. Data are organized into groups as indicated in the first row. The second row contains the data label, and the third row contains additional information such as unit, format, or equation.

Groups, variables, and units

To view a variable's unit of measure or format, see the third row of the data table as imported into a spreadsheet application. The example below shows information in the fluorometer configuration group.

FL_CONFIG	FL_CONFIG	FL_CONFIG	FL_CONFIG	FL_CONFIG
flash_intensity	modrate	flr_limit	flr_period	P1_dur
umol+1m-2s-1	Hz	s-1	s	ms

Figure 6-1*. Variables and units in the fluorometer configuration group.*

Groups, labels and descriptions

Following is a list of groups and labels in each data file, and the description for each label. See *Flash files* on page 6-11 for information on flash files. The tables are organized as follows.

Group	
label	Description

System

The System group consists of five parameters for each measurement. *Time* and *Date* are set manually in **Settings** or synced from GPS (recommended) on the device. See *Settings* on page 2-6 and *Clocks* on page 9-19.

SYS	
Obs#	Observation/record number
Time	Time of observation: HHMMSS
Date	YYYYMMDD
configName	Configuration name
configAuthor	Configuration author

User Defined

The User Defined group contains the remarks and labels created in **Configuration Management** in the computer software. See *Remarks* on page 5-5 and *Configurations* on page 5-1 for configuring them. See *Taking a measurement* on page 3-7 for adding them to measurements. At least one label must be formatted as a barcode to enable the barcode scanner.

USERDEF	
remark	Mark reason -alphanumeric
barcode	Label 1 barcode, list, or number
	Label 2 barcode, list, or number
	Label 3 barcode, list, or number

Porometry

The Porometry Group contains the data collected from the LI-600N porometer.

PORO	
gsw	Stomatal conductance
gbw	One-sided boundary layer conductance
gtw	Total conductance
E_apparent	Transpiration
VPcham	Chamber vapor pressure
VPref	Reference vapor pressure
VPleaf	Leaf vapor pressure
VPDleaf	Vapor pressure deficit
H2O_r	Reference H_2O mole fraction
H2O_s	Chamber H_2O mole fraction
H2O_leaf	Leaf H_2O mole fraction
leaf_area	Leaf area in cm^2
leaf_width	Leaf width in mm

Fluorometry

The Fluorometry Group contains the data collected from the LI-600N Fluorometer.

FLUORO	
flashID	Flash file ID
Fo	Minimum fluorescence in dark
Fm	Maximum fluorescence in dark

FLUORO	
Fv/Fm	Quantum efficiency in dark
Fs	Minimum fluorescence in light
Fm'	Maximum fluorescence in light
PhiPS2	Quantum efficiency in light
PS2/1	Ratio of PSII to PSII absorptance
abs	Leaf light absorptance
ETR	Electron transport rate
TRANS	Transmission factor

Sensor

The Sensor group contains the values recorded by the relative humidity, temperature, flow, pressure, and PAR sensors as well as the battery voltage. The output in the SENSOR group is calculated from the SENSOR_V and calibration coefficients determined at the factory.

SENSOR	
rh_s	Sample relative humidity
rh_r	Reference relative humidity
Tref	Block reference temperature
Tmeas	IRT leaf (sample) temperature
Tleaf	Calculated leaf temperature
P_atm	Atmospheric pressure
flow	Flow rate to cuvette
flow_s	Exhaust flow leaving cuvette
leak_pct	Flow percent leak
Qamb	Ambient light
batt	Battery voltage

Leaf angle

The leaf angle group contains measurements from the magnetometer, accelerometer, GPS, and calculated variables. See *Leaf angle and GPS* on page 9-16.

LEAF_ANGLE	
pitch	Slope from horizontal
roll	Rotation from horizontal
heading	Rotation from North
angle_inc_leaf	Angle of incidence between the leaf and the sun
direct_pct	Proportion of direct irradiance incident on leaf
slope_leaf	Leaf inclination from horizontal
az_leaf	Leaf rotation from south
dec_solar	Angular position of sun with respect to equator
az_solar	Solar rotation
zenith_solar	Solar zenith angle

GPS

The GPS group contains the GPS coordinates, altitude, number of satellites, and horizontal dilution of precision. For important information about GPS time, see *Clocks* on page 9-19.

GPS	
gps_time	YYYYMMDD
gps_date	HHMMSS
latitude	Latitude
longitude	Longitude
altitude	Altitude (meters)
gps_sats	Number of GPS satellites
gps_HDOP	GPS horizontal dilution of precision

Match

The Match group records the time and date of the RH sensor matching and the sensor correction. See *Measurement Settings* on page 5-6 and *Taking a measurement* on page 3-7

MATCH	
match_time	Match time

MATCH	
match_date	Match date
rh_adj	Relative humidity sensor correction
type	Valved (0) or serial (1) match

Stability

The Stability group records the measurement stability of stomatal conductance(g_{sw}), and slope and fluorescence (flr) at 1, 2, and 4 seconds. See *Taking a measurement* on page 3-7, step 6.

STABILITY	
gsw1sec	Stomatal conductance at 1 sec
gsw2sec	Stomatal conductance at 2 sec
gsw4sec	Stomatal conductance at 4 sec
flr1sec	Slope and fluorescence at 1 sec
flr2sec	Slope and fluorescence at 2 sec
flr4sec	Slope and fluorescence at 4 sec

Porometer configuration

See *Measurement Settings* on page 5-2.

P_CONFIG	
auto	Auto mode (0 for LI-600N)
flow_set	Flow set point
gsw_limit	g_{sw} slope limit
gsw_period	g_{sw} period
aw	Area to width conversion factor
Bla	Boundary layer coefficient a
Blb	Boundary layer coefficient b
Blc	Boundary layer coefficient c
Bld	Boundary layer coefficient d
Ble	Boundary layer coefficient e
chamber	Standard (0) or Needle (1)

Fluorometer configuration

See *Measurement Settings* on page 5-2.

FL_CONFIG	
dark	Dark adapted or not
flash_type	Flash type
flash_intensity	Flash intensity
modrate	Modulation rate
flr_limit	Flr slope limit
flr_period	Flr period
P1_dur	MPF phase 1 duration
P2_dur	MPF phase 2 duration
P3_dur	MPF phase 3 duration
P1_Fmax	Phase 1 maximum fluorescence
P2_ramp	Phase 2 ramp depth
P2_slp	Phase 2 regression slope
P3_Fmax	Phase 3 maximum fluorescence
P3_Pred	Phase 3 predicted fluorescence
P3_DeltaF	Phase 3 measured–phase 3 predicted

Sensor voltage

The Sensor Voltage group reports the voltage for each of the sensors. The output in the SENSOR group is calculated from the SENSOR_V values and calibration coefficients determined at the factory.

SENSOR_V	
v_humA	Reference RH sensor (poro)
v_humB	Sample RH sensor (poro)
v_flowIn	Inlet flow sensor (poro)
v_flowOut	Outlet flow sensor (poro)
v_temp	Thermistor (poro)
v_irt	IRT target temperature (poro)
v_pres	Pressure sensor (poro)
v_par	Quantum sensor (poro)
v_F	De-modulated fluorescence (fluoro)

SENSOR_V	
i_LED	LED current (optional) (fluoro)

User calibrations

See *Calibrating the sensors* on page 8-10 and *Drop-down menu* on page 4-3.

USERCAL	
b_rhr	Ref RH sensor zero intercept (poro)
m_rhr	Ref RH sensor slope (poro)
span_rhr	Ref RH sensor span (poro)
b_rhs	Sam RH sensor zero intercept (poro)
m_rhs	Sam RH sensor zero slope (poro)
span_rhs	Sam RH sensor span (poro)
z_flowIn	Flow in zero (poro)
z_flowOut	Flow out zero (poro)
z_quantum	Quantum sensor zero (poro)
z_flr	Fluor zero (optional) (fluor)

Metadata

The metadata for each measurement includes instrument and sensor serial numbers, embedded firmware version, and when the configuration was last updated. Metadata for each data file can be viewed in the LI-600N computer software. See *Local Files* on page 4-8.

META	
flashId	Flash ID (fluoro)
lciSerNum	Instrument serial#
lcpSerNum	Porometer serial#
lcfSerNum	Fluorometer serial#
lcrhSerNum	RH sensor serial number
version	Embedded version
configUpdatedAt	Configuration update date

Flash files

Flash files are fluorometer data files. If a data file contains fluorometer measurements, a flash file for each measurement is downloaded and included in the .zip file exported from the computer software. See *Measurement Settings* on page 5-2.

Flash Files	
flashId	Flash file ID
time	HHMMSS
date	YYYYMMDD
lciSerialNumber	Instrument serial#
lcpSerialNumber	Porometer serial#
lcfSerialNumber	Fluorometer serial#
Fm	Fm
Fo	Fo
Fv/Fm	Fv/Fm
Fm'	Fm'
Fs	Fs
PhiPS2	ΦPSII
LightIntensity	Light intensity

Section 7.
Troubleshooting

This section describes how to identify possible issues with the LI-600N and any warnings that may appear on the instrument display. If you cannot find a solution in this section, contact your local distributor or LI-COR support (see *Support* on page 1-4).

Instrument issues

This section describes the potential issues with the LI-600N and how to address them.

Instrument will not power on

If the instrument will not power, ensure that your battery is charged and the power supply is adequate when charging; the power supply needs to source at least 1 Amp at 5 VDC.

Ensure that your cable and battery are functioning properly (see *Removing and inserting a battery* on page 8-8).

Instrument will not seal on a leaf or needle

If the instrument will not seal on a leaf or needle when taking a measurement, check to see if there is debris in the clamp or gasket, and carefully remove it with a foam swab then re-clamp.

The display layout is blank

A blank layout will appear on the display if no variables are selected in the configuration. A measurement can still be taken if the display layout is blank. The user selects variables for the display layout in configuration management in the software (see *Display Layout* on page 5-7).

A blank layout will appear on the display if a configuration was removed from the instrument before exiting a corresponding menu. Upload the configuration using the computer software then select it on the instrument.

A completely blank display (without time, battery percentage, or other indicators) indicates a problem with the display itself.

Software warning when connecting the LI-600N

If the computer software displays a warning message when connecting the LI-600N, the firmware version or computer software version may require updates.

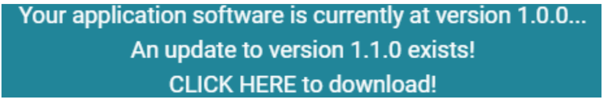


Figure 7-1*. A software update is available.*

Your application software is currently at version...": An updated version of the LI-600N computer software is available for download. **CLICK HERE to download!** to update the computer software and proceed to *LI-600N connected!*.

LI-600N Firmware Is Incompatible With Software!: An LI-600N is powered on and has been discovered by the computer software via USB, but the instrument firmware is incompatible with the computer software. Select **Install**

Bundled Firmware to update the firmware and proceed to the *LI-600N connected!* screen. Select **Offline Mode** to access the Configuration Management, Data Management, and Connection Overview menus without updating the firmware.

Software warning when updating the firmware

If you get a warning message when updating the firmware, the instrument may have been disconnected while updating the firmware.

An LI-600N is powered on and has been discovered by the computer via USB, but was disconnected while updating the firmware. Power cycle the LI-600N by turning it off and on, then **Reattempt Identification**, or reinstall the firmware. Check the USB cable and connection.

The new RH sensor serial number has not updated

If the new RH sensor has not updated, it may have been installed without updating the serial number. The RH sensor serial number does not automatically update and must be updated in the computer software to obtain the correct calibration information.

If a new RH sensor is installed without updating the serial number, the LI-600N will continue logging data using the previous RH sensor serial number. Ensure that the new RH sensor serial number has been updated in the computer software(see *Changing the RH sensors serial number* on page 8-21).

The RH values and sample RH are high

If the RH values on the display are 95% or above, water may have entered the cuvette (see *External cleaning* on page 8-1). If the sample RH (RH Sample) value on the display is 95% or above, clamp onto a stable object, such as a piece of printer paper, and flush the instrument's system until the sample RH value drops to match the reference RH (RH Ref).

Instrument warnings

This section describes the warnings that can appear on the LI-600N display and how to address them.

Instrument warnings will appear with this symbol on the instrument display.

To determine the warning type, open **Instrument Settings** by pressing the left arrow from the Select Configuration screen, then select **Warnings.**

Matching. Do not clamp on leaf.

Matching happens automatically when the LI-600N is powered on, and when you select Match on the Instrument Settings screen. Always allow the instrument to match before clamping onto a leaf.

Low memory

The Low Memory warning appears when there is less than 10% of data storage space remaining. Stop using the instrument; download the data, then clear all data from the instrument.

Low battery

The Low Battery warning appears when there is less than 10% of battery charge remaining. Stop using the instrument and charge the battery.

Blower off

The Blower Off warning appears when the blower is off. To turn the blower on, power on the LI-600N and select a configuration; the blower should automatically turn on.

If the warning persists, power on the LI-600N then connect it to a computer via USB. Open the computer software. From the drop down menu select Instrument Calibration. Select and begin any of the four calibrations then **Turn Blower On.**

Pump

The Pump warning appears when the Flow In sensor is < 90% of the flow set point (i.e., unable to reach the desired flow). Ensure that the inlet is not blocked. If the warning persists, ensure that the filter is clean; if it is dirty, replace the filter. If the warning persists, replace the pump (see *Support* on page 1-4).

No GPS map pin

It can take several minutes after powering on the instrument to get a GPS satellite lock.

If, after 5 minutes, no GPS map pin appears in the top of the instrument display, go to Settings and make sure GPS is enabled. If GPS is enabled and still no map pin, go to GPS settings from **Instrument Settings** on the device and check *NumSats*; if <3, move to a location away from buildings and wait to see if GPS can get a satellite lock. If you are working inside, you may not have the necessary reception. GPS can be turned off to conserve battery power.

Data download errors

Data download error messages pop up with "Data Download Failed!" However, if a data download error occurs, the raw data file is still saved to your local computer. Find and open the data file, and reference the error message to identify the problem. Following are known data download errors and their causes.

Duplicate Flash ID

This is caused by a user taking measurements, manually changing the clock back an hour from Daylight Saving Time to Daylight Standard Time, then continuing to take measurements that result in a duplicate Flash ID (time stamp).

Unpaired Flash ID Detected

This error occurs when the fluorometer option is enabled "on the fly." The user picks a configuration with the fluorometer disabled and takes measurements. With the instrument connected to the computer, the user enables the fluorometer option and re-uploads the configuration to the same spot on the instrument and continues taking measurements.

Orphaned Flash ID Detected

This error occurs when the fluorometer option is disabled "on the fly." The user picks a configuration with the fluorometer enabled, takes measurements, then connects the instrument to the computer. The user then disables the fluorometer option, and uploads the updated configuration to the same spot on the instrument and takes more measurements.

Unrecognized Row Type

This error occurs when a barcode with a newline character is scanned.

Malformed Flash Data Reading

If this error repeatedly pops up, each time referencing a different row, then the problem is likely a bad USB cable.

Section 8.
Maintenance

This section describes typical maintenance procedures for the LI-600N. For many of these procedures, support videos are available at:
licor.com/support/LI-600/videos.html

Storing the LI-600N

Follow these guidelines when storing the LI-600N.

- Power down and store it in the carrying case when not in use; this will keep dust, insects, and other contaminants out of the aperture.
- Store it in a climate-controlled environment.
- Charge the battery to 60% capacity prior to long-term storage.
- Disconnect the power supply.

External cleaning

These are basic cleaning procedures for the exterior components of the LI-600N.

Caution: Always turn off the LI-600N before cleaning.

Barcode window and quantum sensor

Regularly check that the barcode window and quantum sensor are clean, as dirt and debris may accumulate after active use.

Use a foam swab and deionized water to clean the quantum sensor and barcode window. Use the microfiber cloth to dry the surface if necessary.

Chamber clamp and gaskets

Remove the chamber clamp by gently but firmly pulling it straight out.

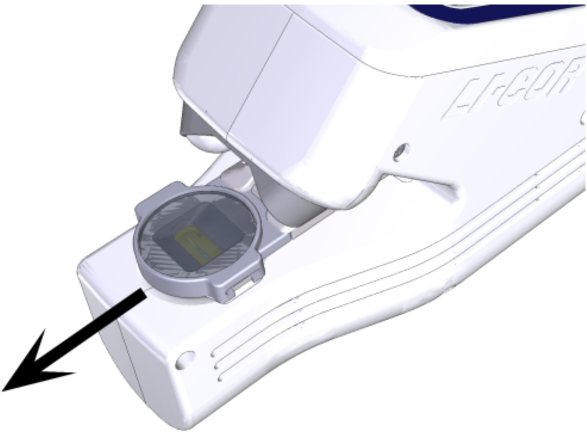


Figure 8-1*. Removing the chamber clamp.*

Remove the clamp gaskets and aperture gasket. The aperture gasket can be gently pulled from one edge then lifted off.

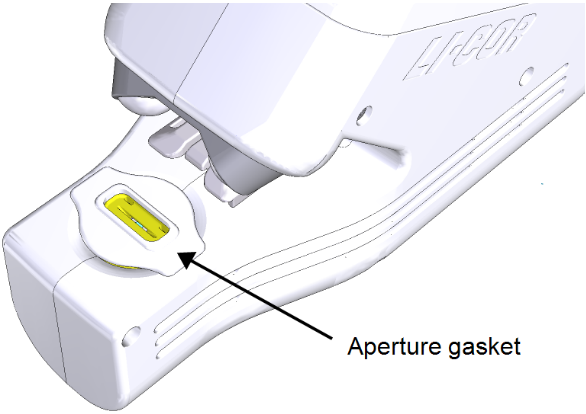


Figure 8-2. *The aperture gasket.*

Remove the clamp gaskets. The material is pliable, and you can push one side out of its notch and lift out the gasket.

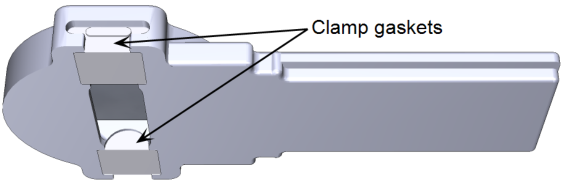


Figure 8-3. *The clamp gaskets.*

Do not clean the gaskets while they are on the instrument as water can damage the parts.

Use foam swabs and DI water to carefully clean the clamp window and gaskets.

If dirt remains on the gaskets and clamp, gently wash them in water and a mild detergent and completely dry them before reinserting. If needed, replace the gaskets.

Avoid water entering the cuvette.

Water can damage the chamber and the flow path. If water enters the cuvette, disassemble the instrument and remove the water using a foam swab.

Fluorometer

Regularly check that the fluorometer LEDs and fluorescence detector are clean. Use foam swabs, a microfiber cloth, and isopropyl alcohol to carefully clean the fluorometer optics.

Figure 8-4. *The fluorometer LEDs and fluorescence detector.*

Internal cleaning

Internal maintenance procedures require removal of the instrument head shells.

Caution: Always turn off the LI-600N before cleaning.

Removing the instrument shells

Work indoors in a clean environment when removing the instrument shells. Use a #1 Philips screwdriver to remove the screws.

1 Remove seven screws on the left side of the instrument.

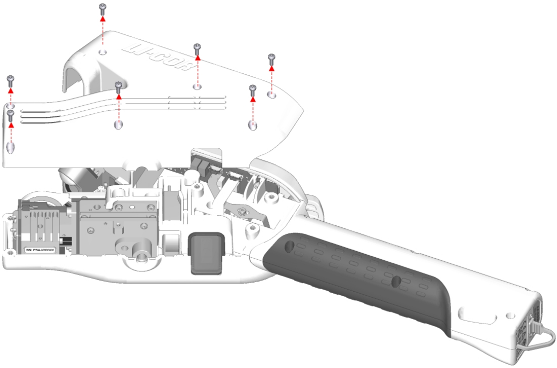


Figure 8-5*. Seven screws secure the left shell.*

2 Remove five screws on the right of the instrument.

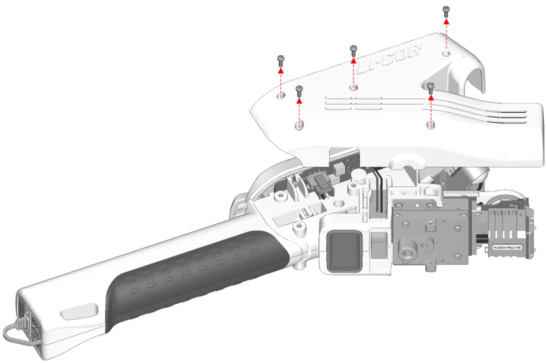


Figure 8-6*. Five screws secure the right shell.*

Reassembly is the reverse of removal.

Cleaning the shell vents

Check that the four vents on the instrument head shells are clean. With the shells removed, use compressed air to carefully clean the vents and other enclosure parts.

IRT sensor

Check that the IRT sensor is clean after periods of heavy use, when switching species, or before or after long-term storage. A dirty IRT sensor will throw off *tleaf* values.

1. To access the IRT sensor, first remove the clamp, aperture gasket, and instrument shells.
2. Remove the aperture by unscrewing the three hex screws with the hex key provided in the accessories kit.

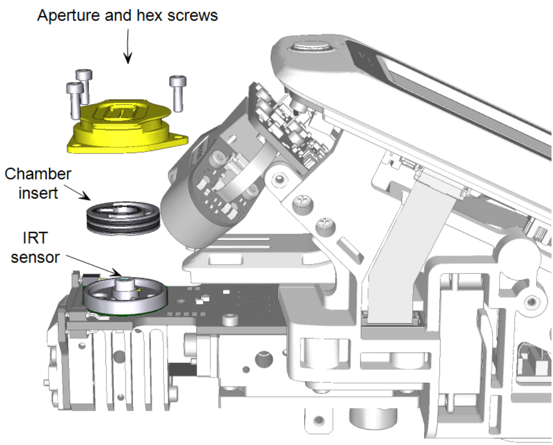


Figure 8-7*. Accessing the IRT sensor.*

3. Lift out the chamber insert. You don't need to remove the o-rings around and next to the IRT sensor.

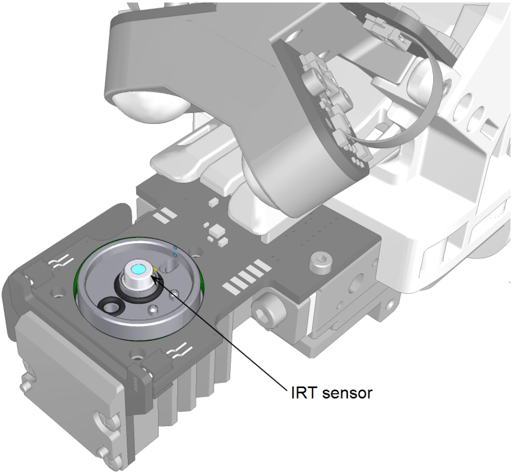


Figure 8-8. *The IRT sensor.*

4 Use a foam swab and isopropyl alcohol (IPA) to carefully clean the IRT sensor. **Do not touch the sensor**, and skin oils and scratches can damage it.

5 Reset the chamber insert by aligning the indentations on the bottom of the insert with the pins in its base.

6 Reattach the aperture with the hex screws. It's helpful to loosely set all three screws before evenly tightening them. Don't over-tighten.

7 Replace the head shells, aperture gasket, and clamp.

RH sensors

Regularly check that the RH sensors are clean, for example after a campaign, before extended storage, or if a shift in ambient RH is noted.

1 Use a squeeze bottle with deionized water to carefully rinse the RH sensors.

Do not touch the active side of the sensors with your fingers or a swab. Do not use isopropyl alcohol.

2 Dry them with compressed air, then bake them for 6 hours at 100 to 120 °C.

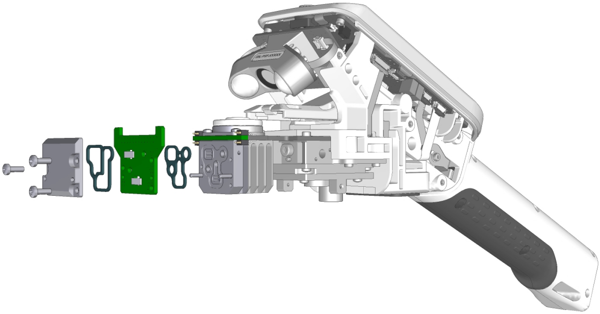


Figure 8-9. *The RH sensors board.*

Never touch the RH sensors or H_2O buffer material in the instrument head, as oils on the skin and scratches can affect the instrument's performance.

Removing and inserting a battery

Removing and inserting the battery is only required when the battery no longer functions and needs replacement.

1 Power off the instrument and ground yourself to avoid potential electrostatic discharge.

2 Remove the shells.

Remove the shells on the instrument head. Set the shells safely aside.

3 Unplug the battery connector.

On the right side of the instrument head, locate the cable clip. Push down on the clip and disconnect the battery connector.

4 Remove the coverings on the instrument handle.

Remove the six screws nearest the USB port on the handle using a Phillips screwdriver; do not remove the two hex screws at the end of the handle. Gently spread apart the left and right handle coverings but do not remove completely.

5 Detach the endcap.

The dust cap may dislodge while removing the endcap. Set both safely aside.

6 Remove the old battery.

To the right of the connector slot, ease the wires out from behind the tab. Gently remove the old battery from the handle, guiding the battery connector out through the connector slot in the instrument head.

7 Insert the new battery.

Gently insert the new battery into the handle, guiding the battery connector in through the connector slot in the instrument head. Place the wires behind the tab.

8 Replace all parts in reverse order.

Replace the dust cap, endcap, and instrument handle coverings. Plug in the battery connector and replace the instrument head shells.

After a battery replacement or any other repair, verify the safe state of the instrument by checking that the display and the fan are powered off.

Replacing the air intake filter

A 0.45 micron filter (part number 301-19838) serves to remove solid particles from air before it is drawn through the LI-600N porometry system.

Follow these steps to replace the air intake filter.

1 Remove the shells.

2 Remove the filter cover.

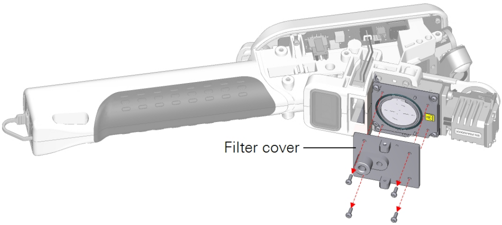


Figure 8-10. *Remove the screws to remove the filter cover.*

3 Remove the filter using gloves or tweezers.

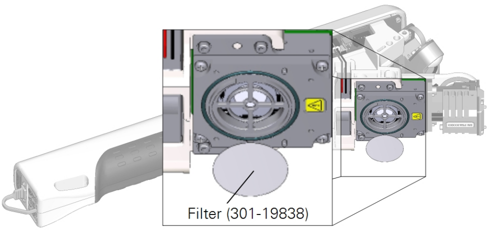


Figure 8-11. *Filter part number 301-19838.*

4 Install the replacement filter from the accessories kit.

Always use gloves or tweezers, as oils on the skin and scratches can damage the filter.

5 Replace the filter cover and instrument head shells.

Calibrating the sensors

The LI-600N includes sensors whose calibration parameters can be adjusted by the user: relative humidity (RH) sensors, flow sensors, and a fluorescence detector. This section describes the process of setting the available parameters for each sensor.

To view user calibration coefficients and change the user-adjustable parameters, connect the LI-600N to the computer software. In the drop-down menu on the Toolbar, select Instrument Calibration. (For sensor equations, see *Theory of operation* on page 9-1)

All calibration coefficients can be viewed in **Factory Calibration** if enabled in the software Preferences. See *Drop-down menu* on page 4-3.

RH sensors

RH sensor parameters include Zero, or the sensor's response to dry air, and Span, or the sensor's response to a known dew point or H_2O mole fraction.

Using the LI-600N pump

Take the following steps to dry the RH sensors using the internal pump and zero kit.

1. Power off the instrument.
2. Remove the shells (see *Removing the instrument shells* on page 8-5).
3. Remove the filter cover and filter.

   The H_2O buffer material is in the flow path and must be removed to zero the RH sensors. Remove the filter cover and filter using gloves or tweezers.

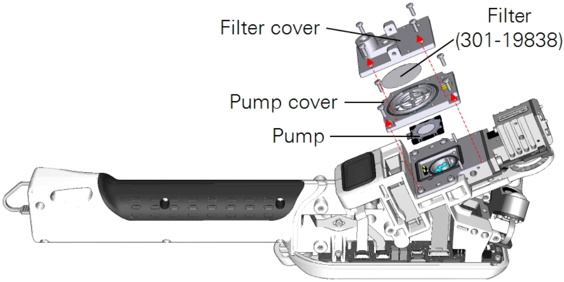


Figure 8-12*. Filter part number 301-19838 is a direct replacement for the original filter (part number 301-16918).*

4 Remove the pump cover and pump.

Remove the four screws on the pump cover then remove it. Using gloves, remove the pump to gain access to the H_2O buffer material.

Handle the black plastic corners only.

5 Remove the H_2O buffer material.

Use gloves or tweezers to remove the H_2O buffer material, as skin oils and scratches can reduce its buffering efficacy.

Alternatively, turn the LI-600N over a container to collect the H_2O buffer material.

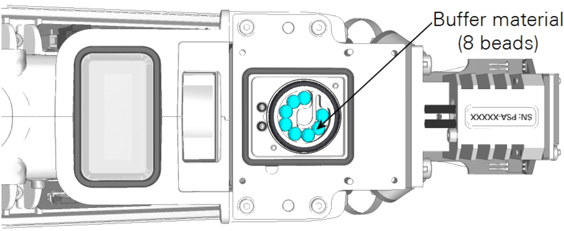


Figure 8-13*. The buffer material.*

6 Reinstall the filter cover, filter, pump cover, and pump.

Reinstall the parts with the H_2O buffer material removed.

7 Connect the zero kit.

Attach the zero kit to the air inlet next to the tripod mount via the 10-32 fitting.

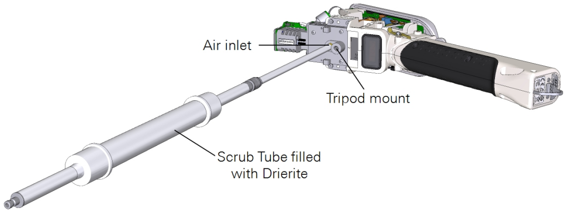


Figure 8-14*. Attach the zero kit.*

8 Seal the leaf aperture.

To seal the leaf aperture, clamp on a plastic bag or similar material.

9 Open Instrument Calibration.

Power on the LI-600N. Connect it to a computer via USB then open the computer software. Click the drop-down menu on the Toolbar then select Instrument Calibration.

10 Power on the internal pump.

Select RH Zero then click **Begin RH Zero Calibration** to view the RH Ref and RH Sample. Click **TURN PUMP ON.**

11 Dry the RH sensors.

Wait for RH to stabilize at ±1% then select Zero in the computer software. If trending down, zeroing is not required.

Ensure that the chemicals are fresh, such as Drierite® (P/N 622-10509), to provide a low dew point.

12 Reinstall all parts in reverse order.

Reinstall the H_2O buffer material, pump, pump cover, filter, filter cover, and instrument head shells.

Using a user-supplied airstream

Follow these steps when drying the RH sensors using a user-supplied airstream from an air tank. Alternatively, you can use a user-supplied pump and the zero kit (P/N 9968-258) with chemicals to dry the RH sensors. If using an external pump with the zero kit, ensure that the chemicals are fresh, such as Drierite, to provide a low dew point.

Using an airstream in the RH sensor zeroing process requires the least disassembly.

1 Prepare the LI-600N.

Power on the instrument.

2 Open Instrument Calibration.

Connect the LI-600N to a computer via USB then open the computer software. Click the drop-down menu on the Toolbar then select Instrument Calibration.

3 Power off the pump.

Select RH Zero then click **Begin RH Zero Calibration** to view the RH Ref and RH Sample. Click **TURN PUMP OFF.**

4 Remove the leaf clamp.

Gently but firmly pull on the leaf clamp to remove it from the instrument.

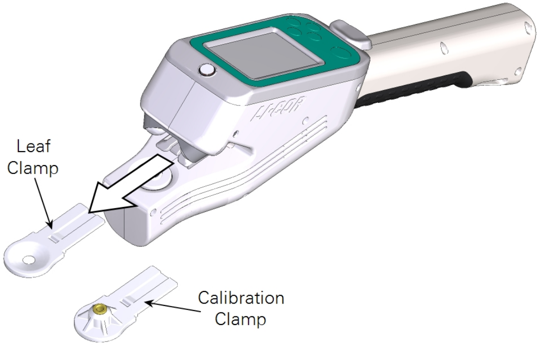


Figure 8-15*. The leaf and calibrations clamps.*

5 Attach the calibration clamp.

Gently but firmly attach the calibration clamp. The calibration clamp is equipped with a 10-32 hose barb for tube connection (P/N 9960-327).

6 Attach the air tank.

Connect a tank of ultrapure dry air to the calibration clamp, ensuring that the tube connection does not prevent the clamp from sealing properly.

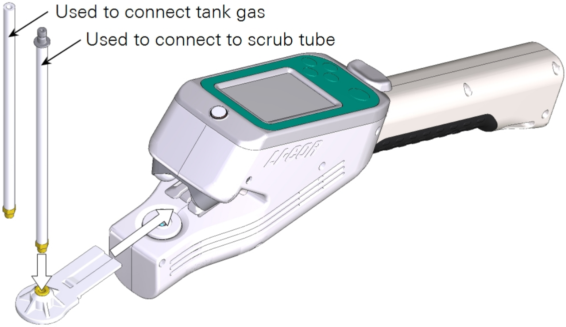


Figure 8-16*. Attach a tank of ultrapure dry air to the calibration clamp.*

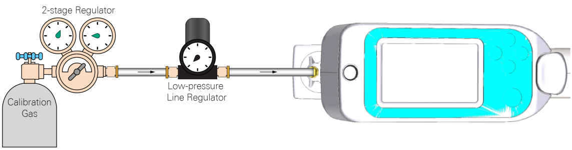


Figure 8-17*. Visual representation of an attached air tank*

7 Dry the RH sensors.

Deliver an airstream across the RH sensors for 30 minutes to 1 hour. Do not allow maximum airflow to exceed 0.25 LPM. The flow or inlet flow sensor will read negative values (i.e., approximately -30 to -100 µmol s^{-1}) due to the air flow toward both the air exhaust and air inlet. *Flow_s* will read positive values (i.e., approximately 100 to 200 µmol s^{-1}).

RH sensor zero

Follow these steps when zeroing the RH sensors.

1 Pump for drying the RH sensors.

Proper drying of the RH sensors can take up to 30 minutes, as water adheres to all surfaces in the flow path. This ensures that no water remains in the system.

Dry the sensors using one of two methods: using user-supplied airstream or using the LI-600N pump. If drying the sensors by delivering an airstream across the sensors using either a tank of dry gas (recommended) or an alternate airstream method, see *Using a user-supplied airstream* on page 8-14. If delivering airflow across the sensors via the LI-600N pump only, see *Using the LI-600N pump* on page 8-11. If the resulting RH is <1% and trending down after several minutes, the zero does not require resetting.

2 Open Instrument Calibration.

Connect the LI-600N to a computer via USB then open the computer software. Click the drop-down menu on the Toolbar then select Instrument Calibration.

3 Power off the pump and power on the blower.

Select RH Zero then click **Begin RH Zero Calibration** to view the RH Ref and RH Sample. Click **TURN PUMP OFF** then click **TURN BLOWER ON.**

4 Zero the RH sensors.

When the RH stabilizes, click **Zero** for RH Ref then again on the confirmation prompt to reset the zero. Click **Apply** on the second confirmation prompt to finish. Repeat for RH Sample.

RH sensor span

A known H_2O input is required to span the RH sensors using another H_2O analyzer or a dew point generator. Take the following steps to span the RH sensors.

1 Prepare the LI-600N.

Power on the instrument.

2 Open Instrument Calibration.

Connect the LI-600N to a computer via USB then open the computer software. Click the drop-down menu on the Toolbar then select Instrument Calibration.

3 Set the H_2O input.

Select RH Span then click **Begin RH Span Calibration** to view the RH Ref and RH Sample. Select either Dew Point or Mole Fraction then enter the desired H_2O input.

4 Power off the pump.

Select Utility then click **TURN PUMP OFF.**

5 Remove the leaf clamp.

Gently but firmly pull on the clamp to remove it from the instrument.

Figure 8-18. *Removing the clamp.*

6 Attach the calibration clamp.

Gently but firmly attach the calibration clamp. The calibration clamp is equipped with a 10-32 hose barb for tube connection.

7 Attach the dew point generator.

Connect a dew point generator to the calibration clamp, ensuring that the tube connection does not prevent the clamp from sealing properly.

8 Span the RH sensors.

Deliver an airstream across the RH sensors then click **Span** in the computer software when they stabilize, which can take approximately 30 minutes. Do not allow maximum airflow to exceed 0.25 LPM. The Flow or inlet flow sensor will read negative values (i.e., approximately -30 to -100 $\mu mol\ s^{-1}$) due to the airflow toward both the air exhaust and air inlet. Flow_s will read positive values (i.e., approximately 100 to 200 $\mu mol\ s^{-1}$).

Flow sensors

The flow sensors' response to no active flow can alter over time and can be reset. Take the following steps to reset the flow sensors. No disassembly is required.

1 Open Instrument Calibration.

Connect the LI-600N to a computer via USB then open the computer software. Click the drop-down menu on the Toolbar then select Instrument Calibration.

2 Power off the pump and blower.

Select Flow Zero then click **Begin Flow Zero Calibration** to view Flow In Zero and Flow Out Zero. Click **TURN PUMP OFF** then click **TURN BLOWER OFF.**

3 Zero the flow sensors.

When Flow In Zero and Flow Out Zero stabilize, click **Zero** for Flow In Zero then again on the confirmation prompt to reset the zero. Click **Apply** on the second confirmation prompt to finish. Repeat for Flow Out Zero. If Flow In Zero stabilizes at ±1 or Flow Out Zero at ±5, the zero does not require resetting.

Fluorescence detector

The fluorescence detector can be reset to remove any offsets in the detector electronics. Take the following steps to reset the fluorescence detector.

1 Open Instrument Calibration.

Connect the LI-600N to a computer via USB then open the computer software. Click the drop-down menu on the Toolbar then select Instrument Calibration.

2 Check the fluorometer response.

Select FLR Zero then click **Begin FLR Zero Calibration** to view FLR Zero. Click **Zero** then ensure that the Flr Response with an empty cuvette is approximately ±5 units.

3 Zero the fluorescence detector.

If Flr response is not approximately ±5 units, click **Zero** to reset the zero for the fluorescence detector.

Changing the RH sensors serial number

The RH sensors board can be user replaced. However, the RH sensors serial number does not automatically update and must be updated in the computer software to obtain the correct calibration information. If a new RH sensors board is installed without updating the serial number, the LI-600N will continue logging data using the old sensor serial number.

1. Connect the LI-600N to a computer via USB then open the computer software.

   In **Explore the LI-600N**, open the drop-down menu and select **Preferences.**
2. Check the **Allow Factory Calibration** box then click **Close**.

   Select the drop-down menu again to allow the software to register the change then click **Factory Calibration.**
3. Select RH under Factory Calibration then click **Calibrate**. Click **OK** on the confirmation prompt.

   The **Change RH Sensor Serial Number** and **Automatic RH Sensor Calibration** buttons will appear. Click **Change RH Sensor Serial Number** then input the serial number.
4. Click **OK** on the confirmation prompt.
5. Click **Automatic RH Sensor Calibration** to calibrate the RH sensor.

Section 9.
Theory of operation

The LI-600N is equipped to measure two different aspects of leaf photosynthesis. The porometer uses a mass balance for water vapor flux from the leaf to compute stomatal conductance. The fluorometer uses optical techniques to probe the quantum yield of photosystem II.

The LI-600N also has a GPS receiver and an accelerometer/magnetometer that measures the pitch, roll, and heading of a leaf. Those measurements, along with GPS information, are used by the LI-600N software to calculate a leaf's angle of incidence.

This section describes the theory and equations behind these measurements and provides an overview of other sensors in the LI-600N.

Leaf porometer

The LI-600N porometer is a steady-state open flow-through gas exchange system. Stomatal conductance is computed from apparent transpiration measured in the leaf cuvette and leaf temperature. Apparent transpiration is computed from the water vapor differential across the leaf cuvette and the molar flow rate of air through it (*Figure 9-1* on the next page).

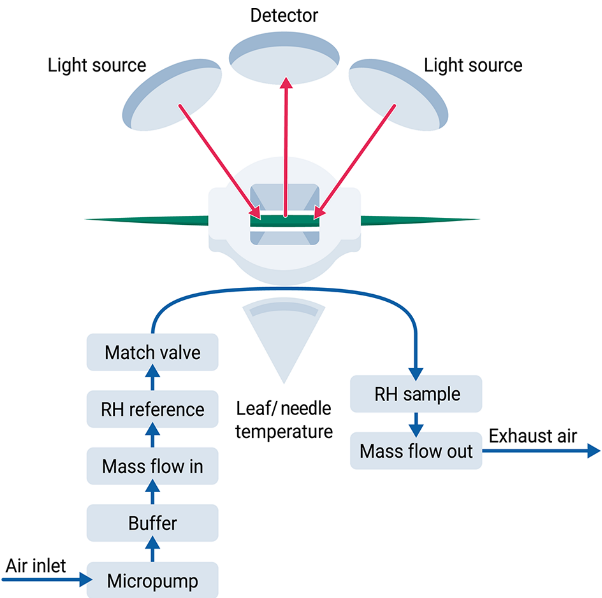


Figure 9-1*. Flow path and optical arrangement of the LI-600N.*

Relative humidity (RH) sensors on either side of the cuvette measure the air stream before and after it interacts with a leaf or needle. Flow rates are measured before and after passing through the cuvette, though only the flow rate of air entering the cuvette is used in the calculation of apparent transpiration. Leaf temperature is measured in the cuvette via a non-contact infrared thermometer (IRT).

Derivation of equations

Apparent transpiration and stomatal conductance from the LI-600N are both expressed on a per unit area basis and as such the sampled leaf area (s_a) in the cuvette must be known. Other calculations in the instrument are dependent on leaf width (s_w). Both leaf area and leaf width therefore must be known to make a measurement. Either leaf area or leaf width, not both, may be input by the user (see *Measurement Settings* on page 5-2), and the other is calculated:

$$s_a = s_w aw \quad (9\text{-}1)$$

$$s_w = \frac{s_a}{aw} \quad (9\text{-}2)$$

Where *aw* is a ratio relating leaf width to projected area for a leaf crossing the full length of the cuvette.

Table 9-1. Default leaf geometry parameters for the LI-600N, found in P_CONFIG or PORO groups in the data file.

Symbol	Label	LI-600N	Units
aw	aw	0.16585000	dimensionless
s_a	Leaf_area	0.29853000	cm^2
s_w	Leaf_width	1.80	mm

The mass balance of water vapor in an open system at steady state is given by:

$$SE = \mathrm{M}_s W_s - \mathrm{M}_r W_r \quad (9\text{-}3)$$

where S is leaf area (m^2), E is apparent transpiration (mol m^{-2} s^{-1}), M_r and M_s (mol s^{-1}) are molar flow rates into and out of the leaf cuvette, respectively, and W_r and W_s are water vapor mole fractions into and out of the leaf cuvette (mol H_2O mol air^{-1}).

Flow out of the cuvette (sample flow) in the LI-600N is not measured with sufficient precision to be used in the water vapor mass balance, and is accounted for by noting that:

$$\mathrm{M}_s = \mathrm{M}_r + SE \quad (9\text{-}4)$$

Substituting 9-3 into 9-4:

$$SE = (\mathrm{M}_r + SE)W_s - \mathrm{M}_r W_r \qquad 9\text{-}5$$

Solving 9-5 for E gives the mass balance used on the LI-600N:

$$E = \frac{\mathrm{M}_r(W_s - W_r)}{S(1 - W_s)} \qquad 9\text{-}6$$

It is important to note here that the units in 9-6 for most variables are different than the measurement units on board the instrument. Water vapor mole fractions in the LI-600N (w_x) are reported in mmol H_2O mol air^{-1}, not mol H_2O mol air^{-1} ($w_x = W_x\ 10^3$), flow (μ_r) is reported in µmol s^{-1}, not mol s^{-1} ($\mu_r = M_r\ 10^6$), and area (s_a) is in cm^2, not m^2 ($s_a = S\ 10^4$).

Total conductance to water vapor (g_{tw}, mol m^{-2} s^{-1}) is given by:

$$g_{tw} = \frac{E\left(1 - \frac{W_l + W_s}{2}\right)}{W_l - W_s} \qquad 9\text{-}7$$

Where W_l (mol H_2O mol air^{-1}) is the mole fraction of water vapor in the leaf's intercellular air space. W_l is calculated from saturated vapor pressure ($e_{(T)}$, kPa) at the leaf temperature ($T = T_l$, C) following Buck (1981):

$$e_{(T)} = 0.61365 exp^{\frac{17.502T}{240.97+T}} \qquad 9\text{-}8$$

$$e_{(T_l)} = 0.61365 exp^{\frac{17.502T_l}{240.97+T_l}} \qquad 9\text{-}9$$

And atmospheric pressure (P, kPa):

$$W_l = \frac{e_{(T_l)}}{P} \qquad 9\text{-}10$$

Calculation of stomatal conductance (g_{sw}, mol m^{-2} s^{-1}) from g_{tw} requires separating boundary layer conductance (g_{blw}, mol m^{-2} s^{-1}):

$$g_{sw} = \frac{1}{\frac{1}{g_{tw}} - \frac{1}{g_{blw}}} \quad \text{9-11}$$

Boundary layer conductance

Boundary layer conductance in the LI-600N is characterized as a function of flow rate through the cuvette (μ_r, µmol s^{-1}) and leaf width (s_w, mm), using a series of model leaves (saturated fiber cylinders of known temperature) where g_{blw} is assumed to be the only limitation to E.

$$g_{blw} = Bl_a + Bl_b \mu_r + Bl_c \mu_r {s_w}^2 + Bl_d s_w + Bl_e {\mu_r}^2 \quad \text{9-12}$$

Table 9-2. Default boundary layer conductance coefficients for the LI-600N, found in the P_CONFIG group in the data file.

Symbol	Label	LI-600N	Units
Bl_a	Bla	2.5397	dimensionless
Bl_b	Blb	0.0015	dimensionless
Bl_c	Blc	0.0061	dimensionless
Bl_d	Bld	-0.0118	dimensionless
Bl_e	Ble	0.0001	dimensionless

Water vapor sensors

Water vapor measurements in the LI-600N are made using a pair of relative humidity (RH) sensors. Voltage output from each of these sensors is related to relative humidity (rh_x, %) through a unique polynomial fit determined at the factory:

$$rh_r = a_{rh_r} {y_{rh_r}}^3 T_{ref} + b_{rh_r} {y_{rh_r}}^2 T_{ref} + c_{rh_r} {y_{rh_r}}^2 + d_{rh_r} y_{rh_r} \quad \text{9-13}$$

$$rh_{s_{raw}} = a_{rh_s} {y_{rh_s}}^3 T_{ref} + b_{rh_s} {y_{rh_s}}^2 T_{ref} + c_{rh_s} {y_{rh_s}}^2 + d_{rh_s} y_{rh_s} \quad \text{9-14}$$

Where a_{rhx}, b_{rhx}, c_{rhx}, and d_{rhx} are the factory calibration coefficients of the polynomial fit, T_{ref} is the reference temperature measured by a thermistor embedded in the block adjacent to the RH sensors and y_{rhx} is the sensor voltage (V_{rhx}, volts) corrected for zero (Z_{rhx}) and span (S_{rhx}) offsets:

$$y_{rh_r} = (V_{rh_r} - Z_{rh_r})S_{rh_r} \tag{9-15}$$

$$y_{rh_s} = (V_{rh_s} - Z_{rh_s})S_{rh_s} \tag{9-16}$$

Initial values for both the zero and span offsets (both nominally 1.0) are determined at the factory but can be adjusted by user calibration (see *Calibrating the sensors* on page 8-10).

There is a residual temperature dependence in the zero adjustment that is calculated from a linear fit to T_{ref} using two additional factory determined coefficients (m_x and b_x):

$$Z_{rh_r} = m_r T_{ref} + b_r \tag{9-17}$$

$$Z_{rh_s} = m_s T_{ref} + b_s \tag{9-18}$$

To reduce errors in the mass balance a cross-calibration, known as matching, is done between the reference and sample RH measurements. Match adjustment (rh_{adj}, %) is calculated as the mean difference between the reference and sample RH measurements when the instrument is in match mode:

$$rh_{adj} = \overline{rh_r - rh_{s_{raw}}} \tag{9-19}$$

This adjustment is applied to the raw, uncorrected, sample RH measurement (rh_{sraw}) to get the sample RH (rh_s) reported by the instrument (see *Match mode* on page 3-7):

$$rh_s = rh_{s_{raw}} + rh_{adj} \tag{9-20}$$

Water vapor mole fraction (w_x, mmol H_2O mol air^{-1}) in the reference and sample air streams is calculated by first converting the measured RH to vapor pressure (P_{vx}, kPa):

$$P_{v_r} = \frac{rh_r}{100} e_{(T_{ref})} \tag{9-21}$$

$$P_{v_s} = \frac{rh_s}{100} e_{(T_{ref})} \tag{9-22}$$

Where $e_{(Tref)}$ is the saturation vapor pressure at T_{ref} calculated following 9-8 ($T = T_{ref}$). Mole fraction is then given from the ratio of the vapor pressure to atmospheric pressure (P, kPa):

$$w_r = \frac{P_{v_r}}{P} 1000 \tag{9-23}$$

$$w_s = \frac{P_{v_s}}{P} 1000 \tag{9-24}$$

Flow sensors

Flow in the LI-600N is determined using a pair of flow sensors positioned to measure flow entering the cuvette (μ_r, µmol s^{-1}) and that exiting it (μ_s, µmol s^{-1}). Voltage output from each of these sensors is related to molar flow rate through a unique polynomial fit determined at the factory:

$$\mu_r = a_{\mu_r} y_{\mu_r}{}^4 + b_{\mu_r} y_{\mu_r}{}^3 + c_{\mu_r} y_{\mu_r}{}^2 + d_{\mu_r} y_{\mu_r} \tag{9-25}$$

$$\mu_s = a_{\mu_s} y_{\mu_s}{}^4 + b_{\mu_s} y_{\mu_s}{}^3 + c_{\mu_s} y_{\mu_s}{}^2 + d_{\mu_s} y_{\mu_s} \tag{9-26}$$

Where $a_{\mu x}$, $b_{\mu x}$, $c_{\mu x}$, and $d_{\mu x}$ are the factory calibration coefficients of the polynomial fit and $y_{\mu x}$ is the flow sensor voltage ($V_{\mu x}$, volts) corrected for zero ($Z_{\mu x}$) and span ($S_{\mu x}$) offsets:

$$y_{\mu_r} = \left(V_{\mu_r} - Z_{\mu_r}\right) S_{\mu_r} \quad \text{9-27}$$

$$y_{\mu_s} = \left(V_{\mu_s} - Z_{\mu_s}\right) S_{\mu_s} \quad \text{9-28}$$

Initial values for the zero (nominally 0.6) and span (nominally 1.0) offsets are determined at the factory but can be adjusted by user calibration (see *Flow sensors* on page 8-19).

Leaf temperature sensor

Leaf temperature (T_l, C) is computed from T_{ref} and the IRT voltage (V_l, volts) using a set of factory determined calibration coefficients (a_{Tl} to g_{Tl}):

$$T_l = a_{T_l} V_l^2 + b_{T_l} V_l + c_{T_l} T_{ref}^{\ 2} + d_{T_l} T_{ref} + e_{T_l} V_l T_{ef} + f_{T_l} V_l^2 T_{ref}^{\ 2} + g_{T_l} \quad \text{9-29}$$

Note that in the LI-600N a low emissivity aperture sets between the IRT and the leaf and serves to restrict the field of view of the IRT to a narrow band along the center of the cuvette. This aperture introduces a geometric dependence to the IRT response that is accounted for by determining the IRT calibration coefficients with the aperture in place.

PAR sensor

Photosynthetically active radiation (Q_{amb}, µmol photons $m^{-2}\ s^{-1}$) is measured with a photodiode. Voltage output by the photodiode (V_Q, volts) is related to Q_{amb} using a single factory determined calibration coefficient (Q_{coeff}) and a user-settable zero adjustment (Z_Q):

$$Q_{amb} = \frac{V_Q - Z_Q}{499000} 10^6 - Q_{coeff} \quad \text{9-30}$$

Vapor pressure deficit

Vapor pressure deficit (*VPD*, kPa) is calculated as the difference between the saturation vapor pressure in the leaf ($e_{(Tl)}$ and the vapor pressure in the cuvette (P_{vs}):

$$VPD = e_{(T_l)} - P_{v_s} \tag{9-31}$$

Leak rate

The cuvette leak rate (*L*, %) is calculated from the difference in flow across the cuvette:

$$L = \frac{\mu_r - \mu_s}{\mu_r} 100 \tag{9-32}$$

Note that due to the difference in accuracy between the reference and sample flow sensors, the reported leak rate at times may be greater than 100% when the cuvette is open or empty, and less than 0% when sealed. This behavior does not impact quality of any measured parameter.

Stability criteria

A measurement is considered stable based on monitoring changes over time to both the computed stomatal conductance g_{sw}, and the de-modulated fluorescence signal *F*. In a given configuration, a user selects which variables to monitor (g_{sw}, *F* or both) and a stability limit, and the periods over which to calculate the change. Since the LI-600N is designed for rapid survey measurements, the time period is limited to 1, 2, or 4 seconds.

The LI-600N retains up to 4 seconds of 2 Hz data to calculate stability criteria as follows:

$$X_{1sec} = X[t] - X[t-1] \tag{9-33}$$

$$X_{2sec} = \frac{1}{2}\sum_{t=-1}^{0} X - \frac{1}{2}\sum_{t=-3}^{-2} X \tag{9-34}$$

$$X_{4sec} = \frac{1}{4}\sum_{t=-3}^{0} X - \frac{1}{4}\sum_{t=-7}^{-4} X \qquad 9\text{-}35$$

where X is either the computed stomatal conductance g_{sw}, or the de-modulated fluorescence signal F if a fluorometer is used, and t is the time for a given measurement.

Since a limited number of data points (2, 4 or 8) are used, the stability criteria is not a regression slope, but represents the amount of change in the parameter over the selected time period. When two consecutive data points are below the threshold of the slope limit, then the measurement is considered stable.

User calibration procedures

Users can adjust calibrations for the flow sensors (zero only) and the RH sensors (zero and 1-point span). See also *Calibrating the sensors* on page 8-10.

RH sensor zero

Resetting the zero set-point on an RH sensor will alter the offset parameter for a given sensor. A prerequisite to starting a calibration is access to tank air or a column of chemical to scrub H_2O from the airstream. Ensure dry conditions prior to resetting a zero, which can take 30 minutes or more of flowing dry air across the sensors.

Upon initiation, the calibration routine averages 10 seconds of data for T_{ref} and V_x and then recalculate the zero intercept:

$$b_{xnew} = V_x - (m_x * T_{ref}) \qquad 9\text{-}36$$

After calculating b_{xnew}, the user must confirm the new setpoint. The new value will then stored to memory.

RH sensor span

Resetting the span setpoint is an adjustment of the parameter S_x. A prerequisite to starting a calibration is access to a known H_2O source, such as a dewpoint generator. The known quantity might be in a dewpoint temperature, or potentially in mole fraction units. The software will accept either unit and convert to the correct relative humidity at the sensor, with *Press* coming from the LI-600N pressure sensor and T_{ref} coming from the LI-600N reference thermistor.

The span setting requires all calibration parameters for a given sensor, as well as rh_{true}, current reference temperature T_{ref} and the voltage of the sensor V_x.

Upon initiation, the calibration routine averages 10 seconds of data for T_{ref} and V_x and then re-calculate the span

$$S_{xnew} = \frac{f^{-1}(rh_{true}, T_{ref})}{V_x - (m_x * T_{ref} + b_x)}) \qquad 9\text{-}37$$

where T_{ref} and V_x are the current values read by the RH and temperature sensors, and m_x and other parameters are the current calibration values for the sensor. After calculating S_{xnew}, the new value is stored to memory.

Flow sensors zero

Resetting the zero setpoint on a flow sensor will alter the offset parameter for a given sensor ($Z_{\mu x}$in 9-27 and 9-28). If you select the option to zero the flow sensors, the software powers down the pump and the blower before resetting the zero. The calibration routine averages 10 seconds of data for $V_{\mu x}$ to determine the new zero:

$$Z_{\mu_r} = \overline{V_{\mu_r}} \qquad 9\text{-}38$$

$$Z_{\mu_s} = \overline{V_{\mu_s}} \qquad 9\text{-}39$$

Fluorometer

The LI-600N fluorometer is a Pulse-Amplitude Modulated (PAM) fluorometer with a measuring beam provided by two LEDs focused on the portion of leaf in the porometer cuvette. Fluorescence is detected via a single detector located between the LED measuring beams, filtered by a 740 ± 40 nm band-pass filter. Fluorescence is detected then from ~700 to 780 nm, which gathers the majority of fluorescence from PSII but is also contaminated with PSI fluorescence in a similar fashion to the LI-6800 Portable Photosynthesis System fluorometer (Genty et al., 1989, Pfundel et al., 2013).

Actinic light is not provided by the LI-600N fluorometer but rather by ambient light which could be natural sunlight or any number of artificial light sources. The two LEDs are both modulated at a constant frequency and provide both the measuring beam and saturating flash. One unique aspect of the design is that the saturating flash is not delivered as a constant output but is modulated at high frequencies to achieve the necessary high light intensity. The use of both LEDs for providing the measuring beam and saturating flash has a few advantages over using a single LED for each purpose, including improved light uniformity from light reaching the leaf from multiple angles and increased peak intensity for the measuring beam, leading to 3) improved signal-to-noise ratio.

Maximum fluorescence and saturating flashes

The LI-600N can perform two types of saturating flashes, either a traditional rectangular flash to measure F_m or F_m', or a MultiPhase Flash™ (MPF) to measure F_m'. MPF is typically used in situations where achievable flash intensities are either too low to be saturating or may be damaging to the leaf (see Loriaux et al., 2013). MPF is the flash type in the pre-loaded factory default configurations.

A rectangular flash is of a single fixed intensity (Q_{flash}, µmol photons m^{-2} s^{-1}) held for a single fixed duration. F_m or F_m' is taken as the maximum de-modulated fluorescence signal (F, dimensionless) observed during the flash.

An MPF is split into three phases, each of an independent duration. The first and third phases are similar to a traditional rectangular flash and are both of a fixed intensity. F_m' is calculated using only fluorescence observed during the second phase. During the second phase a linear ramp, of a user specified depth, is applied to the flash intensity. F_m' is calculated from the intercept of a linear regression of F over $1/Q_{flash}$ during the linear ramp in flash intensity.

While the target Q_{flash} is a user specified parameter in the configuration, reported values are calculated from the modulation rate (f, Hz) and the width of each modulated pulse:

$$Q_{flash} = 6.67e^{-7} \tau f Q_{peak} \tag{9-40}$$

Where τ is a cuvette specific transmission factor (0.97 for the LI-600N) and Q_{peak} (µmol photons m^{-2} s^{-1}) is the combined output of the LEDs:

$$Q_{peak} = Q_{left} + Q_{right} \tag{9-41}$$

Q_x is calculated from each LED's digital to analog converter setpoint (V_{DACx}) and calibration factor (Q_{coeffx}), both determined at the factory:

$$Q_{left} = V_{DAC_{left}} + Q_{coeff_{left}} \tag{9-42}$$

$$Q_{right} = V_{DAC_{right}} + Q_{coeff_{right}} \tag{9-43}$$

Modulation rate during the flash is calculated from the target Q_{flash} specified in the instrument configuration as:

$$f = \frac{\frac{Q_{flash}}{2\tau}}{Q_{peak} 6.67e^{-7}} \tag{9-44}$$

Minimum and steady-state fluorescence

Minimum fluorescence in the dark (F_o) and steady-state fluorescence in the light (F_s) are measured when only a low frequency (4 to 8 Hz) modulated light is applied to the leaf. Logged values for both are taken as the last value of the de-modulated fluorescence signal before the saturating flash is initiated. The light intensity during the modulation is calculated from the user specified modulation frequency analogously to the intensity during the flash (9-40).

The de-modulated fluorescence signal (F, dimensionless) used to determine F_o and F_s can be subject to measurement biases that arise from imperfect discrimination of the fluorescence signal and noise from the measurement circuitry. A user settable zero adjustment (Z_F) is applied to the raw voltage from the fluorescence detector (V_F) compensate for this:

$$F = V_F - Z_F \tag{9-45}$$

Fluorescence output parameters

The LI-600N calculates one of two fluorescence yields depending on the instrument configuration. Because the LI-600N uses ambient light as its actinic source, the instrument must be told by the user whether the fluorescence measurements will be light- or dark-adapted and measurements must be made in a light environment that matches the instrument configuration (e.g., don't try to make dark-adapted measurements at mid-day outside, or light-adapted measurements at night).

When configured for dark-adapted measurements the LI-600N reports the maximum quantum yield (F_v/F_m, dimensionless):

$$\frac{F_v}{F_m} = \frac{F_m - F_o}{F_m} \tag{9-46}$$

And when configured for light-adapted measurements, it reports the operating efficiency of PSII (Φ_{PSII}, dimensionless):

$$\Phi_{PSII} = \frac{F_m^{'} - F_s}{F_m^{'}} \tag{9-47}$$

Additionally, when configured for light-adapted measurements the LI-600N will make an estimate of linear electron flow (ETR, µmol electrons m^{-2} s^{-1}) from Φ_{PSII}:

$$ETR = \Phi_{PSII} Q_{amb} \alpha p_{\frac{PSII}{PSI}} \tag{9-48}$$

Where α (dimensionless) is light absorption by the leaf under the measurement (actinic) lighting and $p_{PSII/PSI}$ (effectively dimensionless) is a proportioning coefficient that describe the partitioning of absorbed photons between PSII and PSI. On the LI-600N, α is set by default to 0.8, but can (and should) be adjusted by the user for their specific plant material and light source. $p_{PSII/PSI}$ is set by default to 0.5. Where the user has a more appropriate value, it too can be adjusted.

Leaf angle and GPS

Using measurements from the accelerometer / magnetometer and GPS receiver, the LI-600/LI-600N computer software calculates the leaf angle relative to the sun at a given time and place, which is the **angle of incidence.**[1]

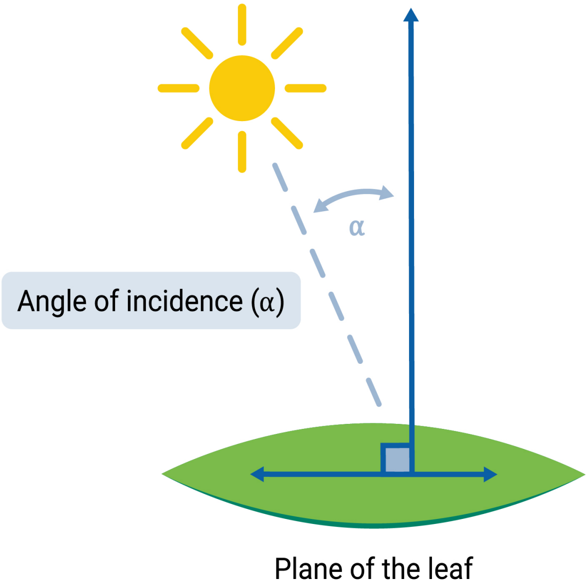


Figure 9-2. *The angle of incidence of a leaf.*

Accelerometer/Magnetometer

The accelerometer and magnetometer measure three aspects of a leaf's angle:

Pitch: slope from horizontal in degrees (accelerometer)

[1] GPS and the accelerometer/magnetometer are included in LI-600 models with a serial number higher than PFA-00553, and in all LI-600N.

Roll: rotation from the horizontal in degrees (accelerometer)

Heading: rotation from North in degrees (magnetometer)

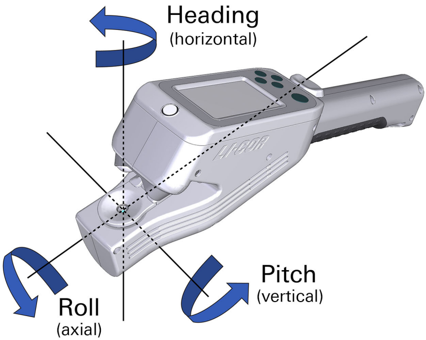


Figure 9-3. *Pitch, roll, and heading.*

GPS

If GPS is enabled in the instrument settings and there are a minimum of 3 satellite signals, a GPS map pin will appear in the upper left of the device screen. To view the number of satellites available, go to **Instrument Settings** on the device, select **GPS**, then **NumSats.**

> **Note:** It can take up to five minutes after powering on the instrument to get a satellite fix. Therefore, if you take measurements before seeing the GPS pin at the top of the instrument display, those measurements will not include GPS/leaf angle data.

Leaf angle software calculations

The LI-600/LI-600N software application combines data from GPS and rotational information to compute parameters related to solar position and leaf angle position relative to the sun. The angle of incidence of a surface (here, a leaf) arbitrarily oriented with respect to the sun at a given time and place can be given by:

$$cos(angle\_inc_{leaf}) = cos(slope_{leaf})cos(zenith_{solar}) + sin(slope_{leaf})sin(zenith_{solar})cos(az_{solar} - az_{leaf}) \quad 9\text{-}49$$

where $angle\_inc_{leaf}$ is the incidence angle between the leaf and direct sunlight ($angle\_inc_{leaf} = 0$ for leaf plane perpendicular to direct sunlight). The equation above is Equation 47 from Reda & Andreas 2004. Input parameters are calculated from either GPS location information or accelerometer/magnetometer information as follows below.

The proportion of direct sunlight incident on the leaf at the given angle can also be calculated

$$direct_{pct} = 100 \times cos(angle\_inc_{leaf}) \quad 9\text{-}50$$

where $direct_{pct}$ is the % of available photons incident on the leaf relative to the amount of photons if the leaf were normal to direct sunlight.

Solar position calculations

Location and time from GPS are used to calculate solar parameters. The solar parameters can be solved using equations from Michalsky 2008. Those equations are valid for the years 1950-2050 with uncertainty of ±0.01°.

Leaf plane calculations

Two parameters are needed to describe the plane of the leaf:

$slope_{leaf}$ Inclination of a surface from the horizontal position

az_{leaf} Surface azimuth angle or deviation of the normal to the surface with respect to the south

The following equations are similar to those from Escribano-Rocafort et al. 2014, with modifications to fit the LI-600/LI-600N framework.

$$slope_{leaf} = acos(cos(pitch) \times cos(roll)) \quad \text{9-51}$$

$$az_{leaf} = heading - atan\left(\frac{tan(roll)}{sin(pitch)}\right) \quad \text{9-52}$$

Clocks

With the addition of GPS, the LI-600/LI-600N reports two different time stamps in the data file: a date/time stamp in the SYS group, and a date/time stamp in the GPS group. The date/time stamp in the SYS group is either set manually by the user or synced to GPS (when available).

GPS not available

If the user is unable to get enough satellites for GPS, the clock needs to be set manually (Instrument Settings > Set Time > Manual). In this case, the SYS Date/Time will update based on user settings. GPS time will not be available and is logged as time = '0:00:00' and date = '0000-00-00'.

GPS available

When GPS is available, the GPS clock will reflect Universal Time. The user can use the SYNC function to update the SYS clock and set their UTC offset for local time (Instrument Settings > Set Time > GPS Sync).

If SYS is not synced to GPS, the time reported in the SYS group reflects the last manual update, and may not match the GPS clock. The real-time clock for the

SYS group will drift over time, typically a few seconds a month, therefore it is good practice to sync with GPS once lock is achieved before taking measurements. In a logged data set, the SYS and GPS times can be compared to determine the UTC offset. UTC offset is maintained through power cycling of the instrument.

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589) See also C code and a web calculator here: https://mid-cdmz.nrel.gov/spa/

Section 10.
Specifications

General

Measurement time:

Porometer: 5 to 15 seconds typically, depending on species, leaf or needle surface characteristics, and conditions

Fluorometer: 1 second

Operating conditions:

Temperature: 0 to 50 °C

Pressure: 50 to 110 kPa

Humidity: 0 to 85%; non-condensing

Weight:0.73 kg

Dimensions: 32.4 cm x 16.9 cm x 6.2 cm (L x W x H)

Display:

Dimensions: 6.8 cm diagonally

Resolution: 400 x 200 pixels; sunlight readable monochrome

Keypad: 5-button membrane pad

Battery:

Built-in Li-ion

Operating hours: 8 hours typically

Capacity: 5200 mAh

Recharging time: 3.5 hours typically; 2 hours with Qualcomm® Quick Charge™ 2.0 or 3.0

Data storage: 128 MB

USB specifications:

Communication/charging interface: Micro-B

Qualcomm® Quick Charge™ 2.0 or 3.0 for rapid charging

Universal charging adapter:
Input: 90 to 264 VAC; 50 to 60 Hz
Output: 5 VDC; 1 Amp
Configuration Software: Windows® and macOS® applications
Data Output: Plain text files (comma or tab delimited), and Excel files with embedded equations.
Barcode scanner: 1-D and 2-D, including Code 39, Code 128, PDF417, 100% UPC, Data Matrix, QR Code
Photosynthetically Actively Radiation (PAR) measurement:
Units: Photosynthetic Photon Flux Density (PPFD); $\mu mol\ m^{-2}\ s^{-1}$
Calibration accuracy: ±10% of reading; traceable to NIST
Cosine correction: Cosine corrected up to 60° angle of incidence

Porometer

Leaf and needle sizes:
1–3.5 mm width
14.2 mm minimum length
2.8 mm maximum thickness
Flow rates:
Low: 75 $\mu mol\ s^{-1}$
Medium: 115 $\mu mol\ s^{-1}$
High: 150 $\mu mol\ s^{-1}$
RH sensor accuracy: ±2% RH
Reference temperature: ±0.2 °C
Leaf temperature sensor accuracy: ±0.5 °C
Inlet flow measurement: ±1% of reading from 75 $\mu mol\ s^{-1}$ to 150 $\mu mol\ s^{-1}$
Exhaust flow measurement: ±5% of full scale up to 150 $\mu mol\ s^{-1}$
Parameters:

g_{sw} mol m^{-2} s^{-1}; g_{bw} mol m^{-2} s^{-1}; g_{tw} mol m^{-2} s^{-1}; E mmol m^{-2} s^{-1}

VP_{cham} kPa; VP_{ref} kPa; VP_{leaf} kPa; VPD_{leaf} kPa

H_2O_{ref} mmol mol^{-1}; H_2O_{samp} mmol mol^{-1}; H_2O_{leaf} mmol mol^{-1}

Fluorometer

Flash types: User configurable Rectangular and Multiphase Flash™ (MPF)

Measuring light peak wavelength: 625 nm

Measuring light peak intensity:
0 to 10,000 µmol m^{-2} s^{-1}

Flash intensity: 0 to 7500 µmol m^{-2} s^{-1}

LED Risk Group: Exempt group in acc. with IEC 62471:2006. The LED does not pose any photobiological hazard.

Parameters:

F_o; F_m; F_v; F_v/F_m; F_s; F_m'; Φ_{PSII}; ETR

GPS Receiver

GPS: Accuracy 2.5 m CEP (circular error probable)

Appendix A.
FlashAnalysis App

FlashAnalysis is an application to help optimize flash protocol, and also to summarize and export data of interest. You can import downloaded and extracted flash files saved to your computer into the application, then plot and graph the flash variables for analysis (see *Flash files* on page 6-11.)

FlashAnalysis was built on Windows® 10 and macOS® Catalina 10.15.6 with Python 3.8, with limited testing on other operating system versions. The macOS® version of the app is not signed by Apple, so you have to allow the system to open the app by going to System Preferences > Security & Privacy > General to allow the system to open the application.

For more information on the FlashAnalysis application, and for links to the download, go to:

licor.com/support/Photosynthesis/topics/flash-analysis-application.html

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4. Payment Terms. All payments shall be made in immediately available U.S. Dollars net thirty (30) days from the date of invoice for qualified accounts, without set-off, deduction or withholding of any kind, unless otherwise stated by LI-COR in writing and may be paid by check (drawn on a U.S. bank), wire transfer or major credit card. All open account invoicing must be pre-approved. Any amounts not paid when due will accrue interest at the rate of 1 1/2% per month, or the maximum amount allowed by law, if lower. In the event that any payment is more than thirty (30) days late, LI-COR shall have the right to suspend doing business with Buyer until all past due balances are made current. Buyer shall pay for all costs (including reasonable fees) incurred by LI-COR in connection with the collection of late payments. Each accepted purchase order is a separate, independent transaction, and Buyer has no right of set-off against other purchase orders or other transactions with LI-COR. Buyer hereby grants LI-COR a security interest in the Products or any deliverable in the amount of the unpaid balance of the purchase price until paid in full. LI-COR may file a financing statement for such security interest and Buyer shall sign any such statements or other documentation necessary to perfect LI-COR security interest.

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6. Delays In Performance. LI-COR shall not be liable for any delay in performance hereunder due to unforeseen circumstances or due to circumstances beyond its control including, but not limited to, acts of nature, acts of government, labor disputes, delays in transportation, delays in customs clearance and delays in delivery or inability to deliver by LI-COR suppliers.

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8. Partial Shipments. LI-COR reserves right to make delivery in partial shipments (“Installments”). Any Products delivered in Installments may be invoiced individually and is payable subject to Section 4 of these Conditions. Additional shipping and handling charges for Installments may apply. Delay in delivery of any Installment shall not relieve Buyer of Buyer’s obligation to accept remaining deliveries.

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f) Notwithstanding anything herein to the contrary, LI-COR makes no warranty with respect to any third party products provided under these Conditions. Buyer's sole remedy with respect to such third party products shall be pursuant to the original manufacturer's or licensor's warranty, if any, to Buyer, to the extent permitted by the original manufacturer or licensor.

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18. Force Majeure. Shipping/delivery dates are approximate and may be delayed absent prompt receipt from Buyer of all necessary information. LI-COR shall not be responsible for any failure to perform or delay attributable in whole or in part to any cause beyond its reasonable control, including but not limited to Acts of God, government actions, war, civil disturbance, insurrection, sabotage, labor shortages or disputes, failure or delay in delivery by LI-COR suppliers or subcontractors, transportation difficulties, customs clearance, shortage of energy, raw materials or

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19. Governing Law and Venue. These Conditions and performance by the parties hereunder shall be construed in accordance with the laws of the State of Nebraska, U.S.A., without regard to provisions on the conflicts of law.

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