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LI-6200
Primer

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THE LI-6200 PRIMER

An Introduction to Operating the LI-6200 Portable Photosynthesis System

January 1989

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New editions of this manual will incorporate all material since the previous edition. Update packages may be used between editions and contain replacement and additional pages to be merged into the manual by the user.

The manual printing date indicates its current edition. The printing date changes when a new edition is printed. (Minor corrections and updates which are incorporated at reprint do not cause the date to change.)

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January 1989

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How to Use the Manuals

The LI-6200 Portable Photosynthesis System is a powerful and versatile tool for making gas exchange measurements. Three manuals are provided to help you learn to use the instrument.

The purpose of the **LI-6200 Primer** is to guide first-time users in a step-by-step fashion through the fundamentals of using the instrument. The manual also contains a summary of operating suggestions and guidelines for making accurate measurements, as well as a summary of the maintenance-related things that should be done. To learn to correctly use the LI-6200, set aside about a day and let the Primer guide you along. Or, if you simply want to get a feeling for how the instrument operates, take the few minutes necessary to read Chapters 2 (how it works), and 3 (the quick tour of the software).

The **LI-6200 Technical Reference** is, as its name implies, more technically oriented. It contains the derivations and equations used by the LI-6200, some details of the LI-6250 Gas Analyzer, and a reference section for the software. The user is encouraged to read through Chapter 3 of the **Technical Reference**; it is tutorial in nature, and introduces many of the powerful software features that are not discussed or only alluded to in the Primer. Chapter 4 covers the fundamentals of reprogramming the LI-6200. Chapter 5 will serve as a good guide if you have data communications problems with the LI-6200.

The pocket-sized **Condensed Reference** is provided as a quick means of determining some frequently needed facts, constants, and relationships.

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UNPACKING AND INITIAL INSPECTION

This procedure should be followed if you have just taken delivery on your LI-6200. You will be guided through a quick check to verify that everything appears to work normally.

If you had not planned on unpacking the LI-6200 for a while, pay close attention to this chapter. There are some storage precautions and considerations that you should know.

What's What

Check your packing list to be sure you have everything that you should. The picture on the next page indentifies the major pieces of the system. In addition to these, please check to make sure that you have received the following important items:

MANUALS - In addition to the manual that you are now reading, there is also a **Technical Reference**, and a pocket-sized **Condensed Reference**.

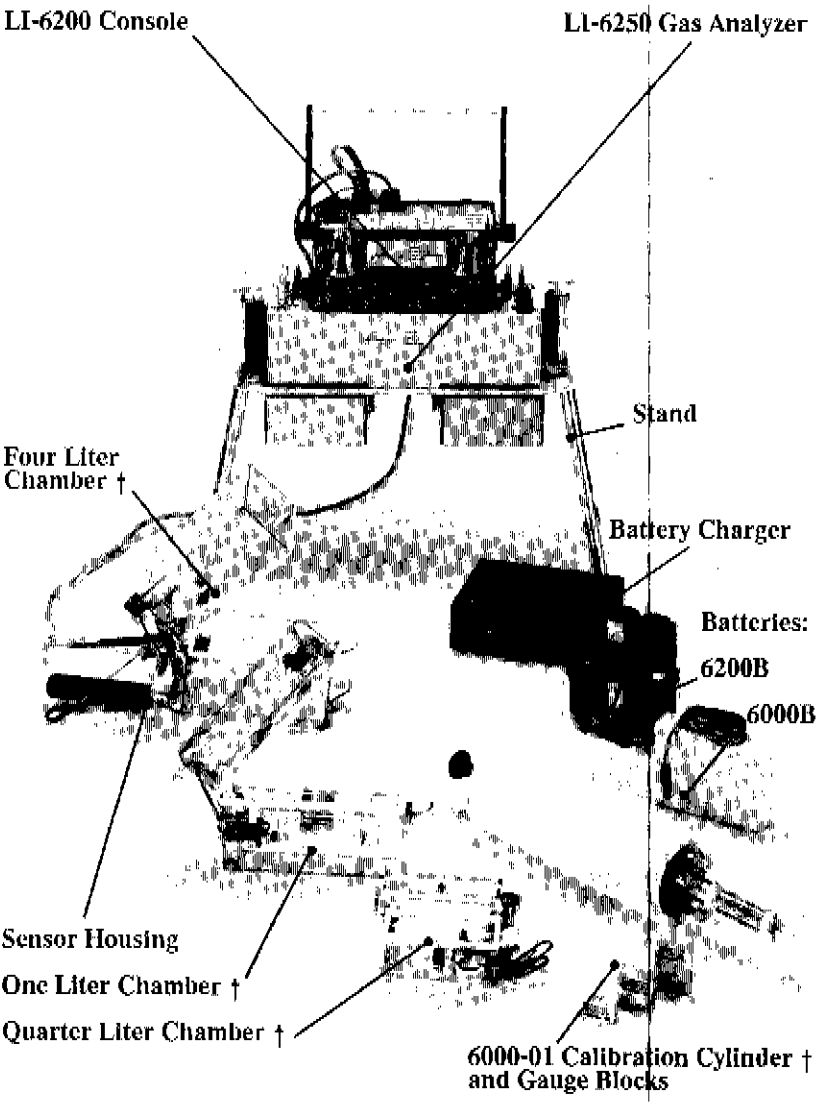
CALIBRATION DATA - This is a sheet of data pertaining to the calibration of the humidity sensor, quantum sensor, flow meter, and CO_2 analyzer. The information has been entered into the system console at the factory. You should keep this sheet in a safe place, however, in case you need to re-enter this data.

SPARE PARTS KITS - There are two bags with numerous replacement and test-related items. As you familiarize yourself with the system, you will learn which things you should keep close at hand, and which things can be stored away.

DATA COMMUNICATION CABLES - There are 2 cables that can be used for connecting the LI-6200 console to a computer or printer. One is a flat ribbon cable with a total of four connectors: a 25 pin male and

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female D connector at *each* end. The other cable has a 25 pin male connector at each end, and the cable itself is small and round. There is also a printed circuit card with several LEDs on it, with a 25 pin connector on each end. This is used for communications diagnostics.

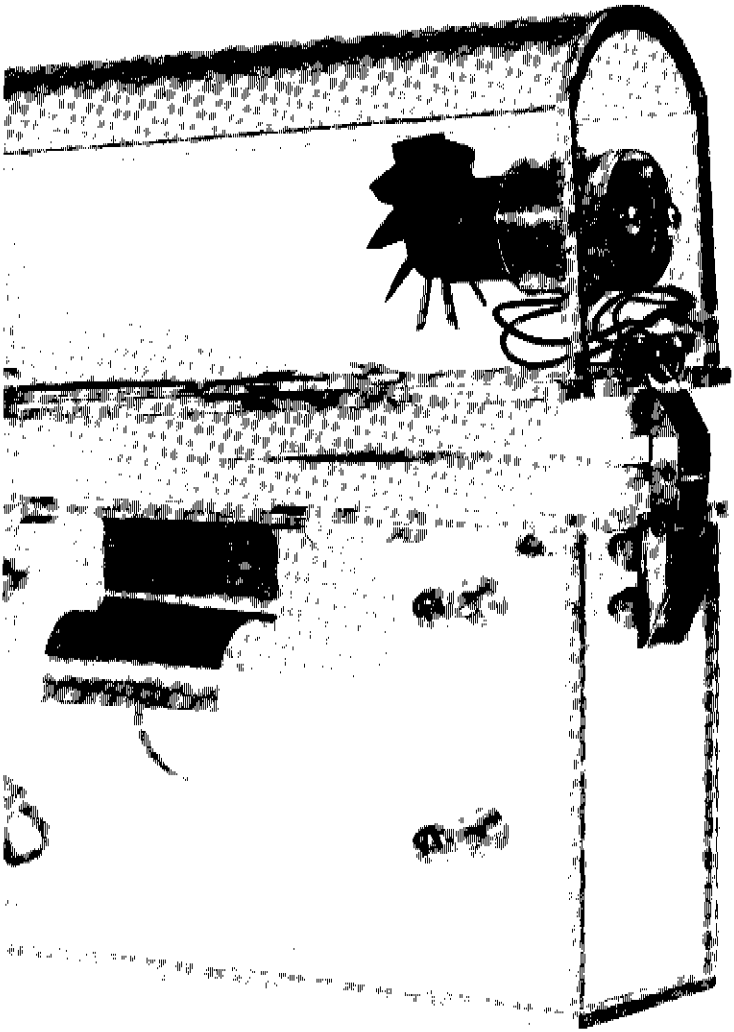


† Optional Equipment

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Leaf Chamber Care

It is important to take care of the foam gaskets on the leaf chambers. *NEVER LATCH THE CHAMBER CLOSED* unless you are actually making a measurement. The foam will *stay* compressed if you leave the chamber closed for several hours. As illustrated below, the latch can and should be used to prop the chamber open during when not in use.

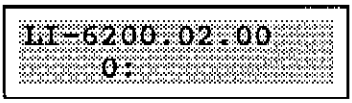


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Trying the Console

Test to see if the console is functioning.

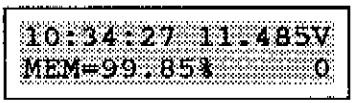
1. Plug a battery into either one of the two battery ports, and turn the power switch to ON. The display will flicker, then say 'Pad cleared' momentarily, then indicate something like



This means software revision 2.00

You may have a software revision later than 2.0. If it displays other messages, refer to Chapter 9.

2. Press the U key (which has a blue label STATUS above it). The display will change to



Battery voltage is about 11.5 volts

The number in the upper right is the battery voltage. A fully charged battery will be greater than 12 V. If the battery voltage drops below 10.5 V, the console will beep repeatedly. If the voltage drops below 10 V, the console will automatically shut off.

Checking the Batteries

Batteries are tested and fully charged when they leave the factory, but may discharge during shipping. It is a good idea to test each battery to see if it is charged. To do this, use the console in STATUS mode (as explained in the previous section).

To test the other batteries (besides the one currently powering the console), plug it into the other battery connector on the console, and then remove the first battery.

If the batteries are below 12 V, they should be charged. Refer to

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Chapter 8.

Power the console off when done.

NOTE

Never store batteries in a discharged state. Charge stored batteries every 3 months.

Charging Batteries

Make sure the voltage selector slide switch on the back of the battery charger is set to the appropriate line voltage (115 VAC or 230 VAC).

Plug the charger into mains power. The AC indicator will illuminate.

The CHARGE indicator will illuminate if ANY of the batteries connected to the charger are being charged. One method for testing a battery's charge is to connect it by itself into the charger. If it is charged, the CHARGE light will come on for only a second or two. If the CHARGE light illuminates with no batteries connected, then the AC voltage selector switch on the back is in the wrong position.

A fully discharged 6000B battery will require about 2 hours on the charger to recharge. Four discharged batteries connected all at once would require about 8 hours to recharge. Double these figures for 6200B batteries.

NOTE

Connecting a discharged battery and a fresh battery to the charger at the same time will result in overcharging the fresh battery.

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Trying the Analyzer

1. With the console powered OFF, connect the LI-6250 cable to the 9 pin D connector on the console.

2. Power the console ON.

DO NOT TURN THE LI-6250 PUMP ON. If the flow connectors on the LI-6250 housing are not connected to anything, their internal cutoff valves are closed. In this state, the pump will work very hard to create a vacuum.

After a few moments, you should hear a hum coming from the LI-6250. This is the chopper motor coming up to speed. In a few minutes, the READY indicator on the LI-6250 should illuminate. If it doesn't, don't worry too much about it at this point, as this would happen if a high CO_2 concentration had somehow gotten into the reference side of the analyzer. What you should do, however, is configure the LI-6250 as described in Chapter 4, and try again.

3. Power the console OFF.

Storage

Some important things to remember if storing the LI-6200:

• Make sure the leaf chambers are propped open in such a way as no parts of the foam gaskets are compressed.

• Make sure that all of the batteries are charged. Charge the batteries every 3 months during storage.

• Avoid high humidities and high temperatures.

• The following will shorten the life of the humidity sensor: cigarette smoke, vapors from solvents, sulphurous pollutants.

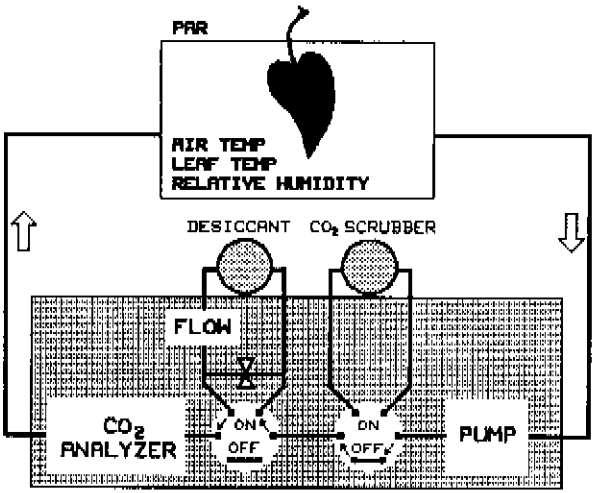
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HOW THE LI-6200 WORKS

This section gives an overview of how photosynthesis and conductance are calculated, the steps involved in making a measurement, and a description of the results as output in the default format.

System Description

The LI-6200 consists of 3 major components: a leaf chamber, within which temperature and humidity measurements are made; the LI-6250, which measures CO_2 concentration and flow rate, and a control console.



Air temperature, leaf temperature, and relative humidity are measured in the leaf chamber. The pump in the LI-6250 circulates air from the chamber to the analyzer, where CO_2 concentration is measured, and returns it to the chamber. The air flow through the LI-6250 can be diverted through soda lime to remove CO_2 for purposes of calibration.

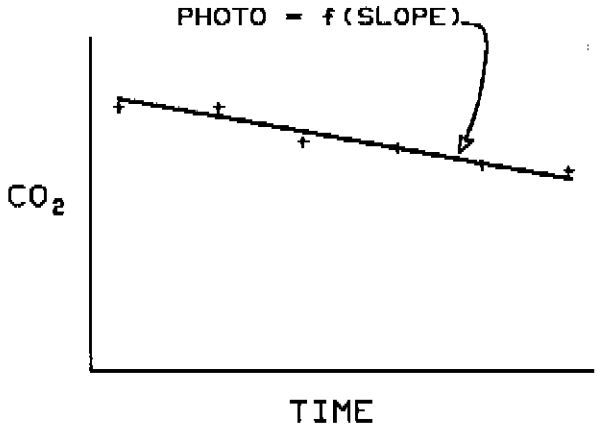
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The flow valve is used to force some fraction of the flow through a tube of desiccant, which dries the air. This proportional control feature is used to help maintain a steady humidity in the chamber during a measurement. The flow rate of the air going through the desiccant is measured by a flow meter.

The infrared gas analyzer (IRGA) can be used for absolute or differential measurement of CO_2. As used with the LI-6200, however, it is configured for absolute measurements. Consult the **Technical Reference** for information on using the LI-6250 for differential measurements.

Measuring Photosynthesis

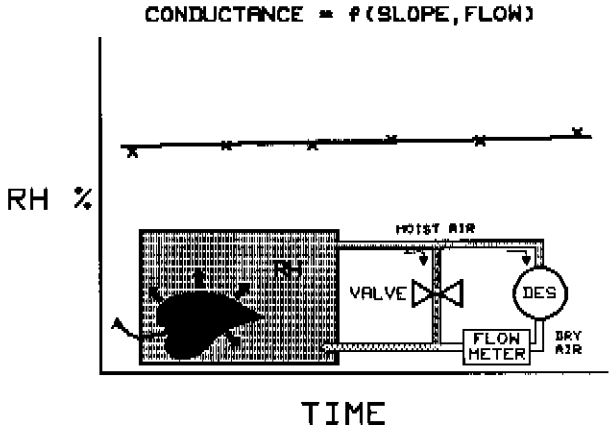
When a plant photosynthesizes, it takes up CO_2. As it respires, it gives off CO_2. The *net* exchange of CO_2 between a leaf and the atmosphere is measured with the LI-6200 by enclosing the leaf in a closed chamber, and monitoring the rate at which the CO_2 concentration in the air changes over a fairly short time interval (typically 10-20 seconds). The net photosynthetic rate is then calculated using this rate of change and some other factors, such as the amount of leaf area that was enclosed, the volume of the enclosure, temperature, and pressure.



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Measuring Stomatal Conductance

When a leaf is enclosed in the LI-6200 chamber, the humidity within the chamber will tend to rise. This is balanced (more or less) by the flow of drier air that is being returned to the chamber from the analyzer, if desiccant is being used. The transpiration rate is calculated from the change in humidity (if any) with time and the rate of flow of dry air. Transpiration rate is then used with the leaf and air temperatures to calculate total leaf conductance and (after removing the boundary layer conductance) stomatal conductance.



When a plant's stomata are open so CO_2 can be taken in, water is lost from the nearly saturated leaf interior to the drier atmosphere surrounding the leaf. The rate at which this water is lost (the transpiration rate) depends strongly upon two conductances to the flow from the sub-stomatal surfaces to the free atmosphere: the conductance of the stomatal aperture, and the conductance of the thin boundary layer of air that envelopes the leaf. The stomatal conductance (and its inverse, stomatal resistance) is entirely physiological in response, so knowing its value indicates something about the state of the plant.

The boundary layer conductance, on the other hand, depends upon external factors, such as the size of the leaf and the speed of the wind passing over the leaf. Since the boundary layer conductance for a leaf in the leaf chamber is usually different than exists for the same leaf out of the chamber, *the measured transpiration rate is usually artificial*. That

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is, the transpiration rate determined in the leaf chamber may be quite different from the rate out of the chamber. However, a true measure of stomatal conductance is obtained from the transpiration rate because the boundary layer conductance of the chamber is known.

Basic Measurement Process

There are 3 basic steps to using the LI-6200 to measure photosynthesis and conductance:

1. Fixed parameters (such as the volume of the system) are entered into the console computer.

2. Before collecting any data, the user should check out the system by performing a few simple tests to be sure everything is working as it should.

3. A leaf is placed in the chamber, and the chamber closed and latched. The computer is directed to begin making its measurements, which it does about once every 2 seconds. When the CO_2 concentration has changed a predetermined amount (5 ppm, for example), the computer notifies the user that the measurement is over, and the leaf may be removed from the chamber. The photosynthetic rate, stomatal conductance, and intercellular CO_2 concentration can be viewed on the display of the instrument, and the data set stored away in the instrument's memory if desired.

The specifics of these steps are dealt with in subsequent chapters of this manual.

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The Data Page

Perhaps the most helpful introduction to the operation of the LI-6200 is to examine a sample of its output, as illustrated on page 2-6. This collection of data is known as a *Data Page*, and is the result of one measurement on a leaf.

PAGE PARAMETERS are printed first. They are:

PAGE - a sequential reference number assigned to each data page when it is stored.
TIME - the starting time of data collection.
SYSTM - a number that tells what system configuration was in use when the data was collected. This is generally 0.
P(mb) - barometric pressure.
Vt(cc) - the total system volume.
Vg(cc) - the IRGA volume, including hoses to the chamber.
A (cm2) - the leaf area within the chamber.
BC(mol) - the one-sided boundary layer conductance (mol m^{-2} s^{-1}) of one side of the leaf.
STMRAT - an estimate of the ratio of stomatal conductance of one side of the leaf to the other.
Fx(umol) - the maximum flow rate that can be achieved through the desiccant.
Kabs - water absorption factor.
A8, A9 - not used.

AUXILIARY DATA consist of prompts and values or remarks that the user can define as needed. The upper line has up to six 12 character prompts. The lower line contains the data entries, each of which can be up to 12 characters in length.

SAMPLES are the individual data values recorded over time during the measurement. In this example, there are 15 of them taken over a 32 second period. The labels are explained below.

OBSERVATIONS are groupings of samples on which summary statistics are calculated. Two types of observations are computed: mean, labelled 1M, 2M, etc., and range, labelled 1R, 2R, etc.

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Sample Data Page

PAGE	TIME	SYSTM
29	21 AUG 11:51:13	0

P(mb)	Vt(cc)	Vg(cc)	A(cm2)	BC(mol)	STMRAT	Fx(umol)	Kabs	A8	A9
972.9	1120.	120.0	9.450	1.400	3.000	999.9	1.100	0.0	0.0

CROP	PLOT	LEAF #	REMARKS	pr5	pr6
SOYBEAN	CONTROL	2	TGIF		

OB	TIME	QNTM	TAIR	TLEAF	CO2	FLOW	RH	EAIR	DE/DT	DC/DT
1	2.100	2093.	34.20	33.13	347.0	854.2	33.85	18.21	18.21	347.0
2	3.700	2093.	34.26	33.22	345.8	855.2	33.73	18.20	18.20	345.8
3	5.300	2061.	34.29	33.19	344.6	855.2	33.66	18.20	18.20	344.6
4	6.900	2091.	34.32	33.21	343.4	856.1	33.60	18.20	18.20	343.4
5	9.299	2093.	34.35	33.23	341.5	858.9	33.54	18.19	18.19	341.5
6	13.30	2097.	34.41	33.28	338.4	858.0	33.36	18.15	18.15	338.4
7	14.80	2093.	34.44	33.31	337.3	857.0	33.29	18.15	18.15	337.3
8	16.40	2080.	34.47	33.32	336.0	856.1	33.36	18.21	18.21	336.0
9	18.00	2097.	34.50	33.26	334.8	856.1	33.23	18.18	18.18	334.8
10	20.40	2110.	34.50	33.29	332.9	856.1	33.17	18.14	18.14	332.9
11	24.40	2108.	34.56	33.19	330.0	858.0	33.17	18.20	18.20	330.0
12	26.00	2047.	34.59	33.27	328.8	856.1	33.11	18.20	18.20	328.8
13	27.60	2104.	34.59	33.33	327.6	856.1	33.11	18.20	18.20	327.6
14	29.20	2099.	34.62	33.32	326.4	855.2	33.05	18.20	18.20	326.4
15	31.60	2086.	34.65	33.34	324.7	854.2	33.05	18.23	18.23	324.7
1M	5.460	2086.	34.28	33.20	344.5	855.9	33.68	18.20	-.0021	-.7656
2M	16.58	2095.	34.46	33.29	335.9	856.7	33.28	18.17	-.0004	-.7710
3M	27.76	2089.	34.60	33.29	327.5	855.9	33.10	18.21	.0026	-.7458
1R	7.200	31.72	.1492	.0994	5.495	4.726	.3087	.0157	.0019	.0040
2R	7.100	29.85	.0895	.0585	5.477	1.890	.1852	.0711	.0060	.0070
3R	7.200	61.57	.0895	.1558	5.386	3.781	.1235	.0301	.0025	.0054

OB	PHOTO	COND	CINT	RS	CS
1	34.02	.6325	222.3	.6020	1.661
2	34.21	.6279	212.8	.6061	1.649
3	33.03	.6367	209.7	.5975	1.673

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The column labels identify the channels for the samples and observations:

TIME	The number of seconds since the start time.
QNTM	The quantum sensor reading (μmol m^{-2} s^{-1}).
TAIR	Air temperature in the leaf chamber (°C).
TLEAF	Leaf temperature (°C).
CO2	CO_2 concentration (ppm).
FLOW	Flow rate through the desiccant (μmol s^{-1}).
RH	Relative humidity (%).
EAIR	Vapor pressure of the air in the leaf chamber (mb).
DE/DT	The difference in vapor pressure between the last two samples.
DC/DT	The difference in CO_2 concentration between the last two samples.

For all variables except DC/DT and DE/DT, the observation mean is the arithmetic mean of the samples in the observation, and the range is the difference between the largest and smallest sample. The observation mean values of DC/DT are the least squares slopes of CO_2 as a function of time for each observation. The mean values of DE/DT are the least squares slopes of vapor pressure for each observation. The observation range values of DE/DT and DC/DT are the standard errors of the slopes.

RESULTS are calculated from observation means, and are the last group of numbers on the page. The headings are

PHOTO	Net photosynthesis (μmol m^{-2} s^{-1}).
CMOL	Stomatal conductance (mol m^{-2} s^{-1}).
CINT	Intercellular CO_2 concentration (ppm).
RS	Stomatal resistance (s cm^{-1}).
CS	Stomatal conductance (cm s^{-1}).

Looking specifically at the example data page, we see that the CO_2 concentration began at 347.0 ppm, and decreased at an average rate of -.7656 ppm per second to 341.5 ppm, at which time the first observation ceased, since the change was greater than 5 ppm at that time. The first observation includes samples 1 through 5; the second, 6 through 10; and the third, 11 through 15. (How can you tell that? You have to figure it out from the CO_2 changes. But it can be made very simple: One of the examples at the end of the **Technical Reference** chapter on LI-6200 Programming shows an easy programming change that will cause time to be displayed as the time elapsed for *each* observation,

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with the first sample of each observation having time 0). The results of the first observation are a photosynthetic rate of 34.02 μmol m^{-2} s^{-1}, a stomatal conductance of .6325 mol m^{-2} s^{-1} (or 1.661 s cm^{-1}), and an intercellular CO_2 concentration of 222.3 ppm.

The error in photosynthesis due to analyzer noise can be determined by comparing the standard error of the slope of CO_2 concentration (the R value of DC/DT) with the slope itself (the M value of DC/DT). For all three observations, the standard errors are less than 1% of the slopes.

The air temperature is well behaved through the measurement, increasing by less than 0.5 C overall. The leaf temperature runs about 1 C cooler than air temperature, which is not surprising given the fairly high conductance and transpiration rate. (NOTE: quantities such as transpiration rate are also calculated and available to you in the data page, but are supressed in the default format (shown here). Details on accessing these values are discussed in the **Technical Reference**).

The dry air flow rate was set correctly, since the change in vapor pressure during the measurement was negligible. If the flow were too large, the vapor pressure would have dropped, and if the flow were too low, vapor pressure would have increased.

This data page shows three observations; computing more than one observation can be helpful in determining if the plant (or chamber conditions) remained in any sort of equilibrium during the measurement. Sometimes a leaf will react to being placed in a chamber with a fairly high wind speed. Also, because air is being circulated through the gas analyzer as well as the leaf chamber, it takes several seconds for the entire system to come to some sort of equilibrium after the leaf chamber is closed. The disadvantage of having the measurement include several observations is in memory consumed when the page is stored (about 200 bytes per observation).

It is also possible to NOT retain the samples with a data page. This also reduces the amount of memory required to store a page, as well as the volume of output.

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A QUICK TOUR

This section introduces the fundamentals of operating the LI-6200 with respect to the instrument's software. It is strongly suggested that the system's console be used to follow along with the examples given here. Nothing need be connected to the console to do this other than a battery.

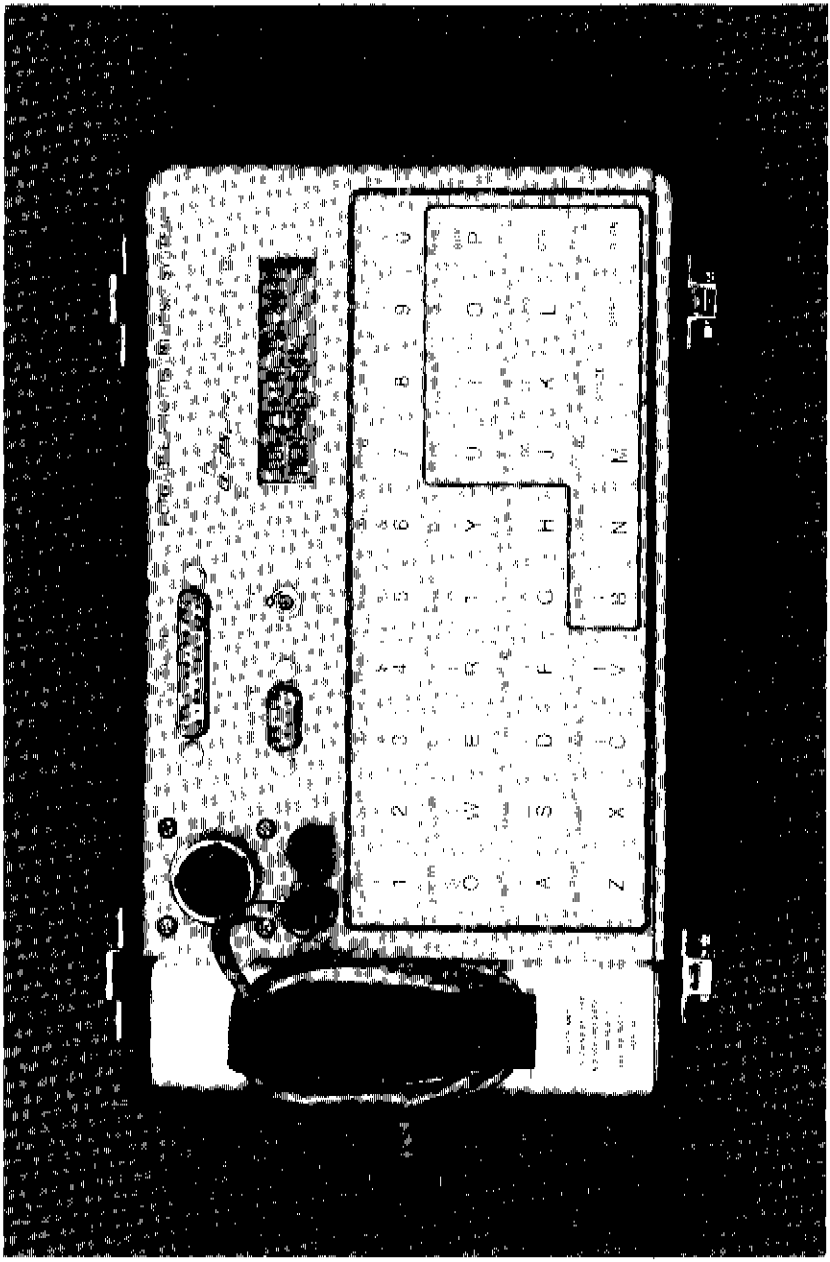
The Keyboard

Most of the keys have 3 labels associated with them. While operating the LI-6200, you will be looking at the blue labels above the keys to identify what the key will do. The normal "typewriter" definitions printed in black are used when entering a number or label; hold down **SHIFT** while pressing a key to access the upper black definition, as in **SHIFT** + **5** to get a percent sign (**%**).

Throughout this manual, the blue labels are indicated by a box. Thus, for example, PHOTO refers to the **Q** key.

There are 14 keys on the right side of the keyboard that are surrounded by a black border; these are *system keys*, while the other keys are termed *user keys*. User keys are defineable by you. Some of them have default definitions, as indicated by their blue labels, but any or all of them can be changed (**Technical Reference**, Chapter 3).

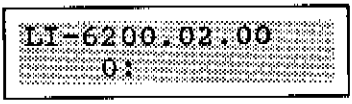
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Status, Monitor, Pause

1. Connect a battery to one of the two battery ports, and turn the power switch to ON. The display will show something like



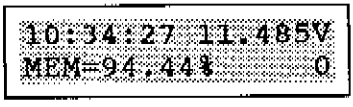
Software revision number: 2.00
Current system configuration number (0) and label (none).

Your LI-6200 may have a version of software more recent than 2.00.

The three main system keys are STATUS, MONITOR, and PAUSE. These represent the three "normal" states of operation. Everything else that the LI-6200 does can be thought of as *routines* that branch off from and return to these home states.

At the moment, you are looking at the PAUSE display.

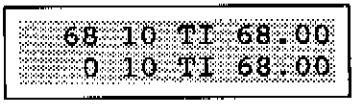
2. Press STATUS. The display will change to something like



Hour:Min:Sec Battery Voltage
% Available memory Number pages

STATUS mode shows the clock, battery voltage, available memory, and the highest data page number stored in memory.

3. Press MONITOR. The display will change to something like



Timer Channel# Label Value
#Obs Channel# Label Value

Monitor mode allows you to monitor any of the sensors in real time. In the figure above, both channels are set to the clock channel ('TI' is for time). Each channel has a different label, as the table below shows. Each channel also has a different code; time is 10, for example. Also shown on the display is a timer, and an observation number. These

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pertain to logging data, and are discussed later in this section.

Other channels may be viewed by pressing the appropriate channel key on the top row of the keyboard (TIME through RH). The arrow keys [↑] [↓] exchange the upper and lower channels on the display.

The top row of user keys on the console access the following values:

KEY	CHANNEL CODE	LABEL	DESCRIPTION
TIME	10	TI	Number of seconds since PAD cleared.
PAR	11	QN	Quantum sensor (μmol m^{-2} s^{-1}).
TLEAF	13	TL	Leaf Temperature (°C).
TCHAM	12	TA	Air temperature in the chamber (°C).
TIRGA	14	TC	Air temperature in the CO_2 analyzer (°C).
CO2	15	CO	CO_2 concentration (ppm).
FLOW	16	FL	Flow rate (μmol s^{-1}).
RH	17	RH	Relative Humidity (%).

4. Example: To monitor CO_2 and relative humidity simultaneously on the display, press CO2 and the display will become

```
92    15 CO 123.4
0     10 TI    92
```

CO_2 is channel 15, label 'CO'
TIME is channel 10, label 'TI'

5. Now press either arrow key ([↑] or [↓], it doesn't matter), and the display will become

```
105   10 TI   105
0     15 CO 123.4
```

Note the channels have reversed their order.

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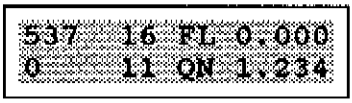
6. Now press [RH], and the display will show relative humidity and CO_2 together.



RH is channel 17.

7. Here's an exercise to see if you understand monitor mode: put flow rate (FLOW) on the top line of the display, and the quantum sensor (PAR) on the bottom line.

When you're done the display will look like this:



Flow is channel 16, label 'FL'
PAR is channel 11, label 'QN'

You now know how to monitor any combination of sensors: Enter monitor mode, and use the top line of keys and the arrow keys to select and position what you want.

One last point: PAUSE, MONITOR, and STATUS are sometimes referred to as the LI-6200's *home states*. This has nothing to do with Nebraska, but rather means that when the instrument finishes doing "something else" (we'll see examples shortly), it will return to PAUSE or MONITOR or STATUS, depending upon which state it was in most recently.

The Function (FCT) Key

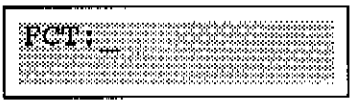
Another system key is [FCT], known as the function key. This is a crucial key, in that it allows access to all routines, even those that don't have a user key assigned to them.

To demonstrate, let's now monitor leaf temperature, and do it WITHOUT pressing [TLEAF].

1. Press [MONITOR], so the channels are being displayed.

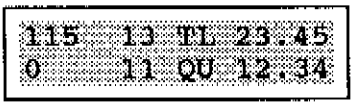
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2. Press FCT, and the display will become



The FCT prompt.
Enter any valid 2 digit code

3. Now press 1, and then press 3. The display will become



Leaf temp is channel 13, label 'TL'

The point of this exercise is this: All functions that the LI-6200 performs can be accessed through the FCT key. The user keys that are defined (those having blue labels) are simply defined by a code. For example, TLEAF is defined to do a 'FCT 13'; CO2 does a 'FCT 15', etc.

Many other routines are more involved than simply selecting a channel to look at; the AREA key, for example, performs a routine (the code is 4A) that prompts the user for a new leaf area. It can be accessed by pressing AREA, or by pressing FCT 4 A.

2 facts to remember:

- All non-system tasks that the LI-6200 can perform are assigned a 2 character code. Each task can be performed by pressing FCT, then entering the code.

- User keys are simply a 1 key predefined alternative to using the FCT key. All 26 user keys can be re-defined by the user as needed.

It is not necessary to remember code numbers to perform various routines. The next section introduces a convenient method of accessing various tasks without ever having to enter the codes.

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Viewing/Editing Lists

A list is simply a sequence of numbers and/or words that is stored in the instrument, and can be recalled and viewed on the display two at a time, since the display is a 2 line display. (Some lists have long entries that take two lines. These are shown one entry - 2 lines - at a time.) The LI-6200 has a large number of lists, but we'll concentrate on the few that are used the most.

1. Press SETUP. The display will show

```
40 ** SETUP **
41 set pg parms
```

What you are seeing is the first two entries of the SETUP list. This is a special type of list known as an *execute* list. This particular execute list (there are 3 others) contains the routines that have something to do with setting up the LI-6200. In fact, this list contains most of the basic operations with which you should be familiar.

40 ** SETUP **	(Title of the execute list)
41 set pg parms	View/edit page parameters.
42 set opr parm	View/edit operational parameters.
43 set clock	Set the month, day, hour, minute, second.
44 set QNTM cal	View/edit the quantum sensor calibration.
45 set CO2 cal	View/edit the CO_2 calibration data.
46 set FLOW cal	View/edit the flow meter calibration data.
47 set RH cal	View/edit the relative humidity calibration.
48 zero FLOW	Set the zero for the flow meter.
49 CO2 ref	The reference function for the CO_2 analyzer.
4A leaf area	Enter the leaf area.
4B aux data	Enter auxiliary data.
4C	(Undefined)
4D	(Undefined)
4E	(Undefined)
4F	(Undefined)

The arrow keys are used to scroll through the list.

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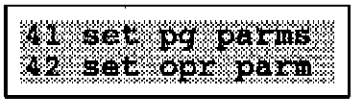
2. Press ↑. The display will scroll up, and look like this:



3. Press ↑ or ↓ repeatedly, and watch the list scroll on the display. Note that it is continuous; when you come to the end of the list, it wraps around to the beginning.

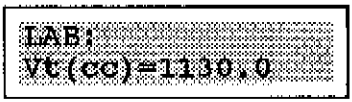
The numbers on the left (41 through 4F) are the codes for accessing the routine directly, using the FCT key. But that's the more difficult method. You can access any routine in this execute list simply by putting the desired entry on the *top* line of the display, then pressing the **RTRN** key. As an example, try the page parameter routine:

4. Press ↑ or ↓ until the display shows:



To access Page Parameters, first put it on the top line.

5. Press **RTRN**, and you will have accessed the list of page parameters, which are the constants and parameters that are used in the computation of a data page, and are stored along with the measured data. The display will show



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The entire list looks like this (although your values may differ)...

LAB:	List label (12 characters or less).
Vt(cc)=1130.0	System volume (cm^3).
Vg(cc)=120.00	IRGA and hose volume (cm^3).
P(mb)=979.99	Atmospheric pressure (millibars).
BC(mol)=1.3000	1 sided boundary layer conductance (mol m^{-2} s^{-1}).
STOM RAT=1.0000	Ratio of stomatal resistances.
Fx(umol)=999.99	Estimate of maximum flow rate.
Kabs=1.100	Water absorption factor.
A8=0.0	Not used.
A9=0.0	Not used.
pr1:	User defined prompts.
pr2:	
pr3:	
pr4:	
pr5:	
pr6:	

This list is a *parameter* list, which is simply a list of values that you can edit.

To change any entry in a parameter list, position it on the top line of the display, then press EDIT. For example, let's change the page parameter 'P(mb)' to 1004.

6. Press ↑ or ↓ until the display looks like this:

```
P(mb)=979.99
BC(mol)=1.3000
```

7. Now press the EDIT key. The display will become:

```
P(mb)=979.99
NEW=_
```

The current value of pressure.
Enter a new value.

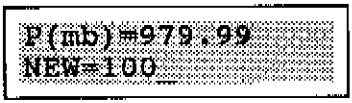
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8. Press the keys **1 0 0 R** (but DON'T press **RTRN** yet), and the display will show



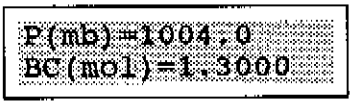
A typing mistake we'll fix.

9. Typing mistakes may be corrected with the **DEL** key (**SHIFT** + **K**). Press the **DEL** key, and the cursor will back up 1 space, erasing the R:



Use DEL to fix mistakes.

10. Now complete the entry by pressing **4**, then pressing **RTRN**. The display will show:



There are a couple of ways to exit from a list:

- Pressing **RTRN** while in a parameter list takes you back to where you were prior to entering the list - either an execute list, or the home state.
- Pressing MONITOR, PAUSE, or STATUS will take you to those respective places.
- Pressing FCT will take you anywhere, if you know what code to enter.
- Pressing any user key that is associated with a routine and not a channel will take you to that routine.
- Pressing **BRK** (that is, **SHIFT** + **P**) will take you to the home state.

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NOTE

There is one list (the I/O parameter list, **FCT 51**), that MUST be exited by pressing **RTRN** in order to be properly implemented; any other method of exit will "undo" any changes made while viewing the list.

11. Press the **RTRN** key to return to the SETUP list.

12. Now press MONITOR to return to Monitor mode.

Log, Store, and Get

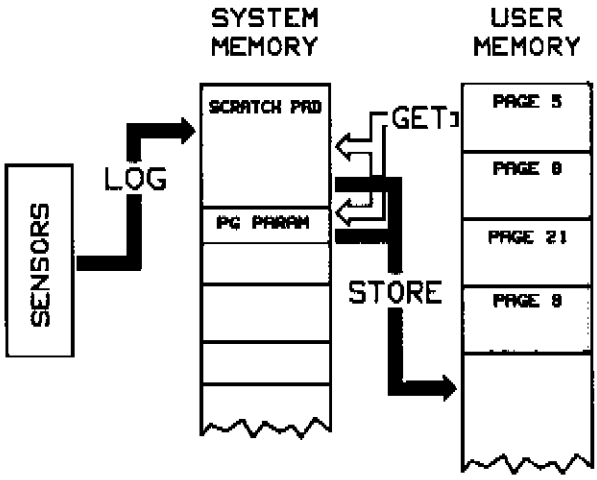
The last major topic to cover in this quick tour of the LI-6200's software pertains to logging, storing, and retrieving data pages. The data page concept was introduced previously; a page is simply the data and calculations associated with a measurement. It is important to remember that when a data page is being formed (that is, while you are making a measurement), the data is being accumulated in temporary work space, not the permanent storage space. This temporary work space is called the *scratch pad*, or more simply, the pad.

When data is logged during a measurement, it is added to the pad. When the measurement is over, you can examine the contents of the pad to see the results of the measurement. If you wish to retain the data, it must be stored (STORE), or copied, to the storage memory of the instrument. Before collecting the next set of data, the scratch pad is cleared. One can examine stored pages on the instrument's display by copying a selected page to the scratch pad (GET).

The GET and STORE keys only work for pages while you are viewing the pad, as will be explained on page 3-15. GET and STORE will do nothing in MONITOR, STATUS, or PAUSE mode.

It is important to remember that *both* the scratch pad *and* the page parameter list are affected by getting and storing pages.

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LOG: the process of adding samples to the scratch pad. STORE: copying the scratch pad and the current page parameters into memory, where it is known in general as a file, or more specifically, a data page. GET: copying a previously stored data page into the pad and page parameter list.

In the following example, you will simulate a measurement by logging data (the analyzer and sensor head need NOT be connected to the console; this is just a simulation). You will then view the results, store the data page, clear the pad, then retrieve the stored data back into the pad.

Since the sensors are not attached, one thing you'll have to do is to configure the instrument so that the observation period is based upon elapsed time, rather than a change in CO_2. This will serve as an opportunity to introduce another list, known as the OPERATIONAL PARAMETER list.

1. Begin in MONITOR mode. If you are not there, press MONITOR.

2. Press SETUP, then ↑, then ↓ again. The display should show

```
42 set opr parm
43 set clock
```

The operational parameter list

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3. Press RTRN to access the OPERATIONAL PARAMETERS list. The complete list looks like this (although your values may differ):

LAB=	The list label
CHANGE=10.000	10 ppm change defines 1 obs.
CHANNEL=15	Channel 15 is CO_2.
OBS/PAGE=1	1 observation per page.
STEP(s)=1	Record samples every 1 second.
BEEP LOG(Y/N)=Y	Beep after each observation.
KEEP SMP(Y/N)=N	Discard the samples after each obs.
PRN FMT(U/S)=S	Page format (System or User).
AREA MULT=1.0000	Leaf area entry multiplier.

One observation period consists of the total time necessary for a certain channel ('CHANNEL') to change by a certain amount ('CHANGE'). During this time, samples are recorded every 'STEP' seconds. The number of observation periods that the page is to hold is given by 'OBS/PAGE'.

For this example, you need to change several values in this list. Instead of sampling the CO_2 concentration for a change of 10 ppm, sample the clock for a change of 5 seconds:

LAB=	Doesn't matter.
CHANGE=5	* 5 sec change defines 1 obs.
CHANNEL=10	* Channel 10 is TIME.
OBS/PAGE=3	* 3 observations per page.
STEP(S)=1	* Record samples every 1 second.
BEEP LOG(Y/N)=Y	* Beep after each observation.
KEEP SMP(Y/N)=Y	* Preserve the samples.
PRN FMT(U/S)= S	Doesn't matter.
AREA MULT= 1.0	Doesn't matter.

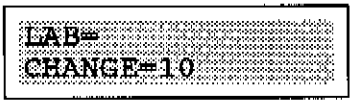
This will tell the LI-6200 that the observation period is based on a change of 5 (seconds) in channel 10 (the clock), and to stop logging after 3 observations are completed.

Since you are changing many of the entries in the list, this is a good place to use SHIFT + EDIT, rather than just plain EDIT. SHIFT + EDIT starts at the current entry in the list, and prompts you for ALL of the entries until it reaches the end of the list. Recall that EDIT by itself

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only prompts for the current entry (the one on the top line of the display). (Incidentally, you can terminate this continuous edit mode simply by pressing **CTRL + P**.)

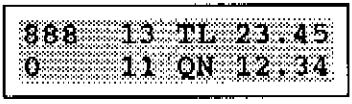
4. Starting with the display looking like



Start at the top of the list.

press **SHIFT** + EDIT, and enter the desired values. If a value does not need to be changed, or it doesn't matter, just press **RTRN** without making any entry.

5. When you are done entering values, and the list is properly changed, press MONITOR, to get directly to MONITOR mode.



Back in Monitor mode.

The numbers of primary concern on the display now are the Timer (upper left), and the Observation # (lower left).

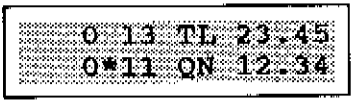
The Timer (888 in the figure) is simply the number of seconds since the scratch pad was last cleared. The number of observations (0 in the figure) is how many observations are in the scratch pad. Note that the Obs# is NOT the number of samples, but rather the number of observations.

6. Press LOG to begin taking data. The display will show:



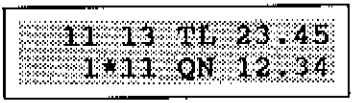
for about 5 seconds (some system overhead is performed), followed by

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Timer reset to 0.
* indicates Logging ON.

When 5 seconds has elapsed, the instrument will BEEP, the display will remain unchanged for 2 or 3 seconds, then the # of observations will increment:



At 11 seconds,
2nd obs started.

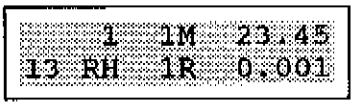
The extra delay that follows the beep is the time it takes to calculate the results, such as photosynthesis and conductance.

After another 5 seconds, a beep will signal the end of the second observation. This is followed by a brief delay for computing the second observation from the sample. The third observation similarly follows.

When the 3rd (and last) observation is finished, you will hear 2 beeps (one for "end of observations", the other for "end of measurement") and the display will indicate



and change to VIEW mode, in which the scratch pad can be viewed:



Page # Obs# Value
Code Label Obs# Value

In VIEW mode, the display acts like a 2 line window that can be moved over the scratch pad. In the figure above, we are looking at the mean and range of humidity for the first observation. If stored, the data would become page 1.

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The arrow keys will scroll through the observations of whatever variable is being viewed. To change variables, press any of the keys TIME thru RH, or PHOTO, COND, Ci, Rs, or Cs.

KEY	CHANNEL CODE	LABEL	DESCRIPTION
PHOTO	30	PH	Photosynthetic Rate (μmol m^{-2} s^{-1}).
COND	31	CO	Stomatal Conductance (mol m^{-2} s^{-1}).
Ci	32	CI	Intercellular CO_2 concentration (ppm).
Rs	33	RS	Stomatal Resistance (s cm^{-1}).
Cs	34	CS	Stomatal Conductance (cm^3 s^{-1}).

As a point of reference, the pad at this point may look something like this:

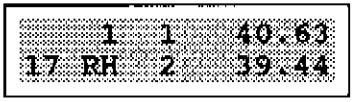
OB	TIME	QNTM	TAIR	TLEAF	CO2	FLOW	RH	EAIR	DE/DT	DC/DT
1	2.000	0.0	32.42	36.18	0.0	0.0	47.06	22.91	22.91	0.0
2	3.600	0.0	33.43	37.51	0.0	0.0	51.51	26.55	26.55	0.0
3	5.200	0.0	33.43	37.58	0.0	0.0	52.68	27.15	27.15	0.0
4	7.600	0.0	33.43	37.73	0.0	0.0	53.86	27.76	27.76	0.0
5	11.60	0.0	33.34	37.78	0.0	0.0	54.91	28.16	28.16	0.0
6	13.20	0.0	33.28	37.71	0.0	0.0	54.66	27.94	27.94	0.0
7	15.60	0.0	33.25	37.71	0.0	0.0	54.97	28.05	28.05	0.0
8	17.20	0.0	33.25	37.69	0.0	0.0	54.84	27.99	27.99	0.0
9	21.90	0.0	33.22	37.67	0.0	0.0	54.84	27.94	27.94	0.0
10	23.50	0.0	33.22	37.68	0.0	0.0	55.03	28.03	28.03	0.0
11	25.10	0.0	33.25	37.71	0.0	0.0	54.97	28.05	28.05	0.0
12	27.50	0.0	33.25	37.71	0.0	0.0	54.97	28.05	28.05	0.0
1M	4.600	0.0	33.22	37.36	0.0	0.0	51.94	26.49	.8397	0.0
2M	14.40	0.0	33.30	37.73	0.0	0.0	54.78	28.03	-.0366	0.0
3M	24.50	0.0	33.22	37.67	0.0	0.0	54.87	27.95	.0279	0.0
1R	5.600	0.0	1.015	1.627	0.0	0.0	7.533	5.180	.2750	0.0
2R	5.600	0.0	.0895	.0889	0.0	0.0	.2470	.2202	.0137	0.0
3R	5.600	0.0	.0597	.0812	0.0	0.0	.3087	.1879	.0143	0.0

OB	PHOTO	CMOL	CINT	RS	CS
1	0.0	.0086	0.0	44.69	.0223
2	0.0	-.0003	0.0	-1016.	-.0009
3	0.0	.0002	0.0	1328.	.0007

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Obviously, the values are meaningless, with the exception of TIME. Notice too that TIME is measured to the nearest 0.1 seconds, and the interval between samples is not fixed; instead, it tends to be 1.6 seconds or 2.4 seconds. The complete explanation is beyond the scope of this manual, but suffice it so say that this is normal.

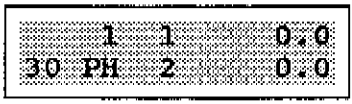
7. Suppose you wish to view all the samples and observations of relative humidity. Press [RH]. The display will change to:



1st two samples of RH

8. Now repeatedly press [↑], and watch the obs counter count through each group of samples, followed by the summary observations: 1, 2, 3, 4, 1M, 1R, 5, 6, 7, 8, 2M, 2R, etc.

9. Now let's look at the 3 values of photosynthesis that have been computed, one for each observation period. Press [PHOTO]. The display will show



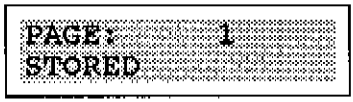
1st two obs of photosynthesis.
This is channel 30.

10. Repeatedly press [↑] or [↓], and note that there are only three entries - one for each observation period.

Now let's store this data as data page 1. (If your instrument already has some pages stored, this data will be stored as some other number, as indicated by the number in the upper left of the display in VIEW mode.)

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11. Press STORE. The display will momentarily show the message



12. Press MONITOR, and you will return to MONITOR mode. Note that the display indicates that there are 3 observations still in the scratch pad.

The data in the scratch pad can be re-computed. For example, suppose you wished to change the value of leaf area:

13. Press AREA, and enter some number for leaf area. Then press RTRN.

14. Press VIEW to re-compute and view the pad.

15. Press STORE to store the pad again. Since the pad has already been stored once, you will be prompted



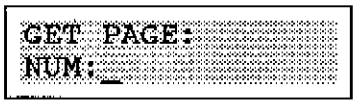
Occurs if you STORE a PAGE again.

Press N, then RTRN, and the page will be stored as page 2. If you had entered Y, this page would have been stored as page 1, and the previous page 1 lost. Pressing RTRN without entering a response, or any response other than Y, will be taken as a N, and generate a new data page.

You might have asked yourself why the prompt was 'THIS FILE EXISTS' instead of 'THIS PAGE EXISTS'. The LI-6200 not only can store data pages, but also other types of data, such as parameter lists. In general, each list is a different type of file. Consult the **Technical Reference** if you wish to pursue this. Otherwise, comfort yourself with the knowledge that you can totally ignore other file types besides pages and still use the LI-6200 effectively.

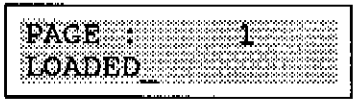
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16. Now retrieve page 1. Press GET. The display will show



Enter the page number.

17. Enter 1 (or whatever the first stored page's number was), and press **RTRN**. The display will show



and you will then be looking at the previous page.

To store and retrieve pages, one must be in VIEW mode. If the pad is empty, pressing VIEW will automatically access the GET routine.

18. Press CLR PAD. The display will tell you that the pad has been cleared, and then go to its home state.

19. Press VIEW. Since there is no data in the pad any more, the GET routine will be accessed. Enter **1**, then **RTRN**.

20. Press **MONITOR** to exit VIEW mode.

Deleting Pages

Now that you know how to create data pages, you should also know how to get rid of them. The MEMORY key will access an execute list of routines involving file handling. Only one of these routines will be discussed, however, and that is the one that deletes files.

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1. Press MEMORY. The display will show

```
D0 *** MEM ***
D1 delete files
```

The memory execute list.
This one deletes pages.

The complete list of items is not given here, although you are certainly free to scroll through the list and take a look. Just don't DO any of them yet, however.

2. Position the delete files routine on the top line

```
D1 delete files
D2 renum files
```

3. Now press **RTRN**. You will be prompted

```
DELETE FILES
ENTER FTYPE:
```

Data page is type '1'

NOTE

If you do not wish to actually delete any pages, just press **RTRN** without entering a file type, then keep reading to see what would have happened.

---

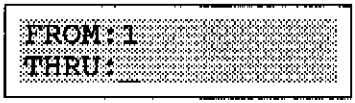
4. Press **1**, then press **RTRN**. The display will show

```
DELETE 1:PAGE
FROM:_
```

Lowest number page

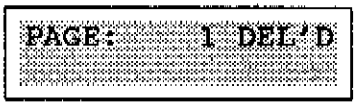
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5. Enter the lowest number page of the group you wish to delete. Let's suppose we want to get rid of pages 1 through 5. We would press **1**, then press **RTRN**. The display will then show



Highest page to include

6. To delete pages 1 through 5, we would now press **5**, then **RTRN**. While the instrument is finding and deleting pages, the display will show



Counts 1 through 5

NEVER PRESS **BRK** WHILE THE INSTRUMENT IS SHOWING THIS DISPLAY. Doing so will likely cause loss of data - perhaps well beyond what you had intended to delete.

Suppose you "inadvertently" got into this file deletion routine. How can you get out without deleting any files? There are a number of ways:

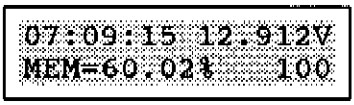
- Make a null entry (just press **RTRN**) to *any* of the three prompts (FTYPE, FROM, or THRU).
- Enter an invalid FTYPE code, such as 0.
- Make the FROM file number *larger* than the THRU file number.
- Press **BRK** *provided you do it BEFORE responding to the 'THRU' prompt.*

Two final notes concerning the deletion of data pages:

First of all, the page space is always recovered, but the page numbers may not be. If intermediate pages are deleted, those numbers are not re-used unless you expressly renumber all the pages. If pages at the high end are deleted, those numbers are automatically recovered. For example, suppose pages 1 to 100 are stored in the instrument.

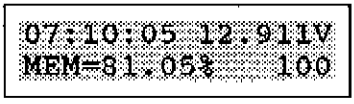
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STATUS mode might indicate



Before deleting

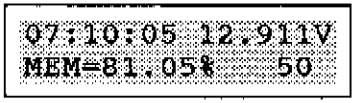
Now suppose pages 1 to 50 are deleted. STATUS might now indicate:



After deleting 1 - 50

The next new stored page would have number 101.

If, on the other hand pages 51 to 100 were deleted instead of 1 to 50, STATUS would have indicated:



After deleting 51 - 100

The next new stored page would be number 51.

How do you recover page numbers? Use the file renumbering routine (code D2). Details can be found in the **Technical Reference**.

NOTE

The last entry in the memory execute list is '`DF clear mem`'. Before you use this, be advised that this deletes ALL file types, not just pages. Just be sure you are willing to lose everything.

You have now been familiarized with the fundamentals of operating the LI-6200 software: monitoring the sensors; viewing and editing lists; collecting, storing, retrieving and deleting data pages.

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ASSEMBLING THE SYSTEM

This section tells you how to prepare the LI-6200 to take data. If you have not familiarized yourself with the software, now would be a good time to work through the section entitled 'A Quick Tour'.

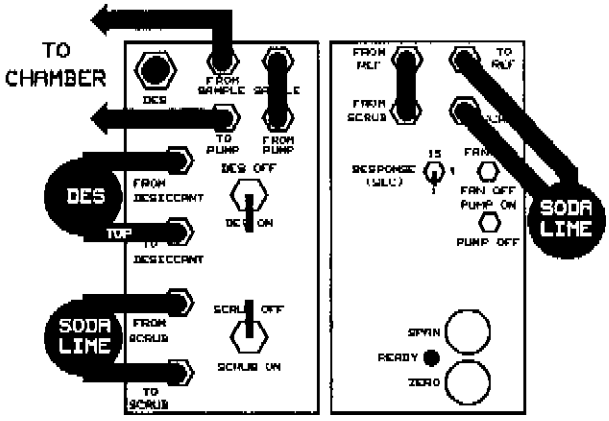
The procedure given in this section is important, and should be performed each day prior to using the LI-6200.

If you do not have desiccant and soda lime tubes prepared, do so now. Instructions and precautions are given in the Maintenance section of this manual.

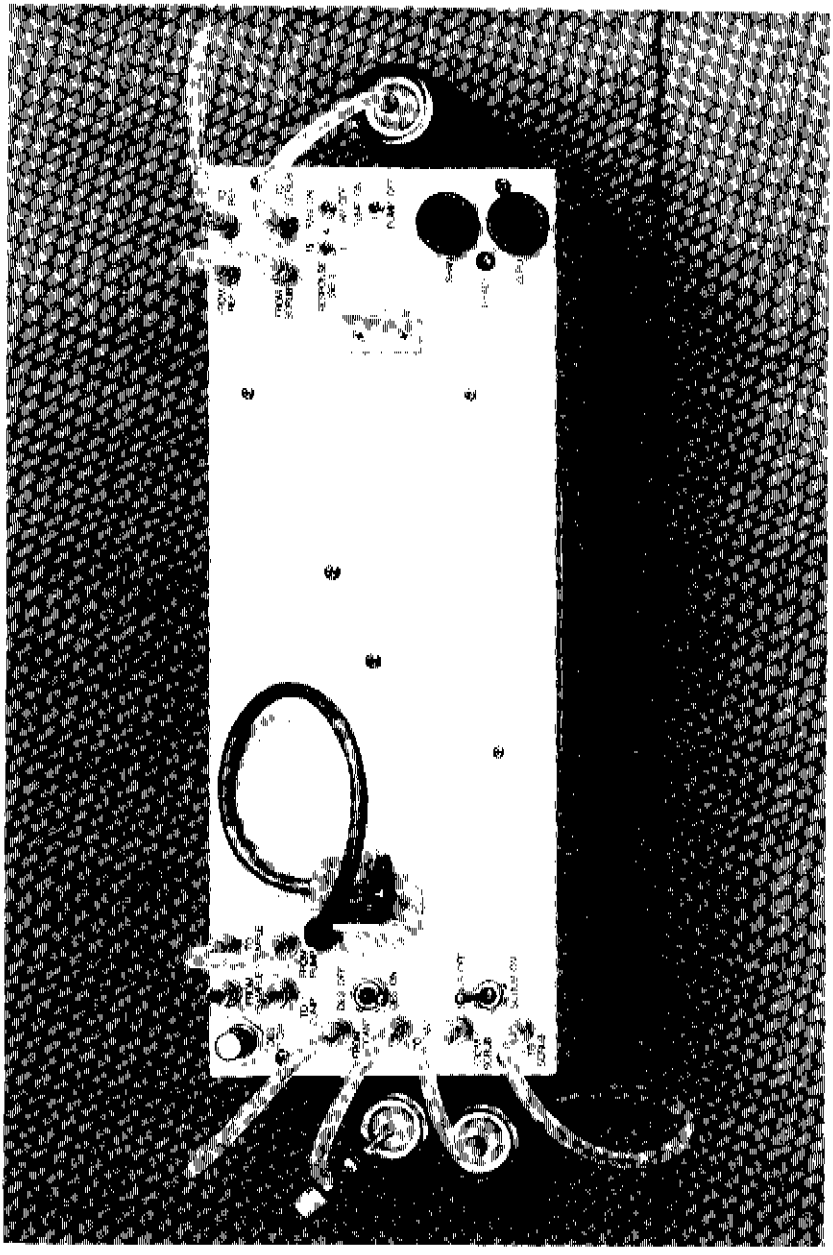
Configuring the LI-6250 Analyzer

Attach two soda lime tubes and a desiccant tube to the LI-6250 as indicated in the following figure and photograph. Connect a short jumper hose between the ports marked **TO SAMPLE** and **FROM PUMP**, and another short hose between the ports marked **FROM REF** and **FROM SCRUB**.

The **RESPONSE (SEC)** switch should be in the 1 position, the desiccant flow switch should be in the **DES ON** position, and the scrub flow switch should be in the **SCRUB OFF** position.



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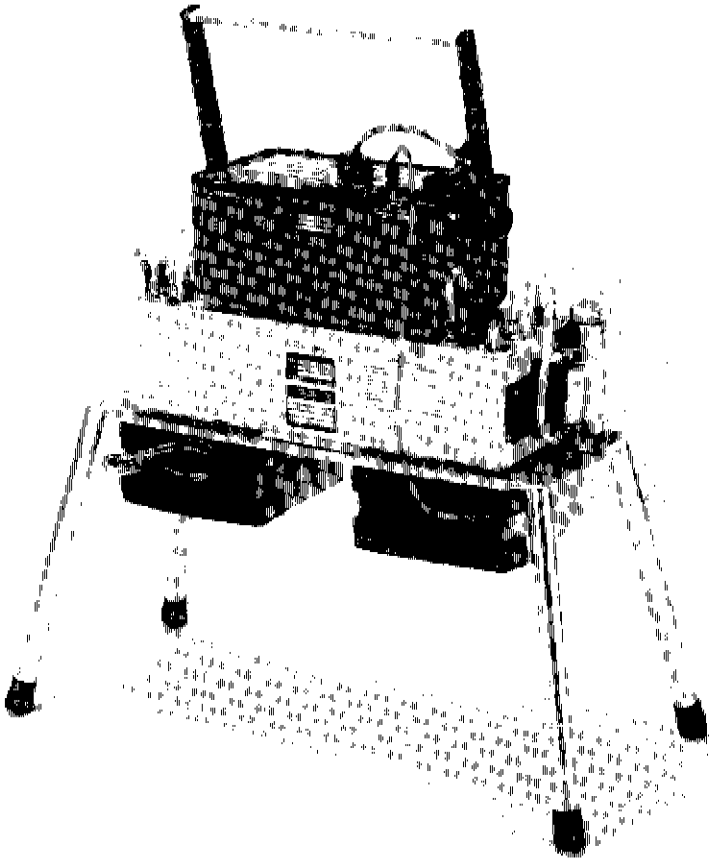
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Console, Stand, and Sensor Head

1. If using the portable stand, attach it to the mounting plate beneath the LI-6250. Note that the LI-6250 should mount on the stand so that the stand's battery pockets are AWAY from the user.

2. Remove the lid from the console box. Open the lid, and slide it off to the right.

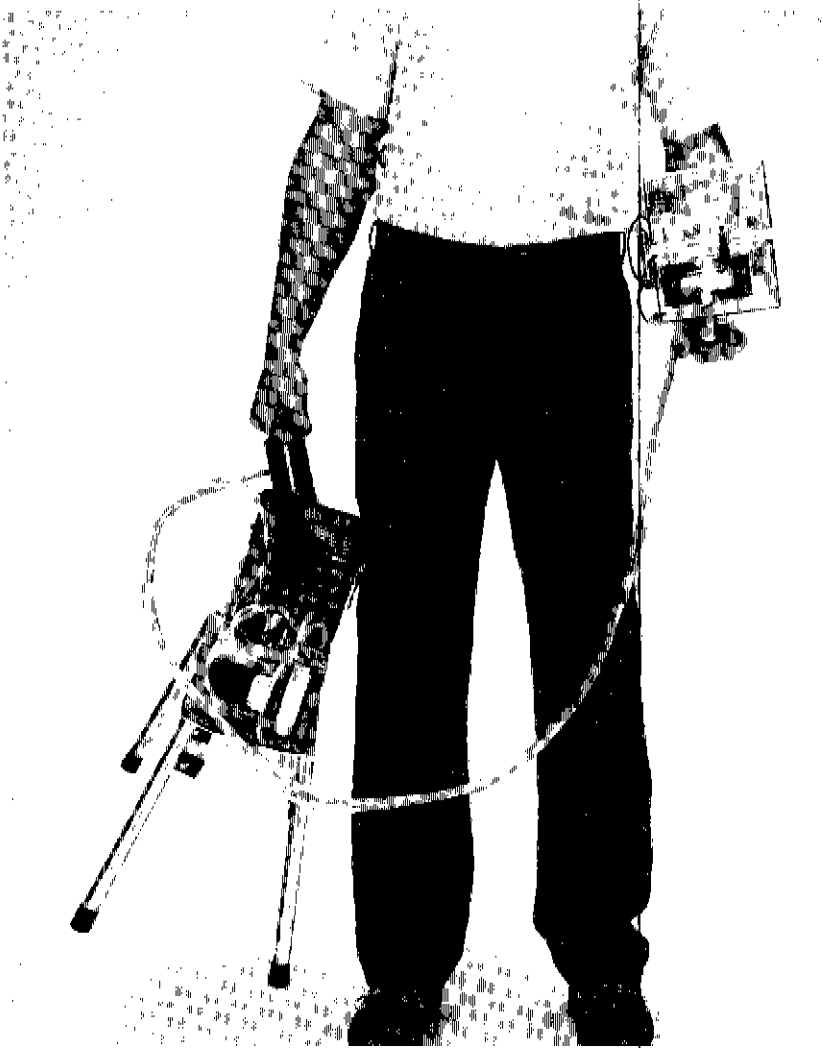
3. Loosen the wing nuts on each side at the bottom of the console, and slide the console into the retaining brackets on the LI-6250.



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4. The handle on the console is adjustable. Loosen the black plastic mounting knobs 1 or 2 complete turns, then move the handle to the desired location, and tighten the knobs. For ease in carrying, tilt the handle as shown in the photo below. This will cause the stand's legs to swing out away from you when you pick it up, reducing the chances of your kicking one of them while you walk.

5. Connect a fresh battery to one of the battery ports on the console. If using a 6200B battery, mount it in the bracket beneath the carrying stand.

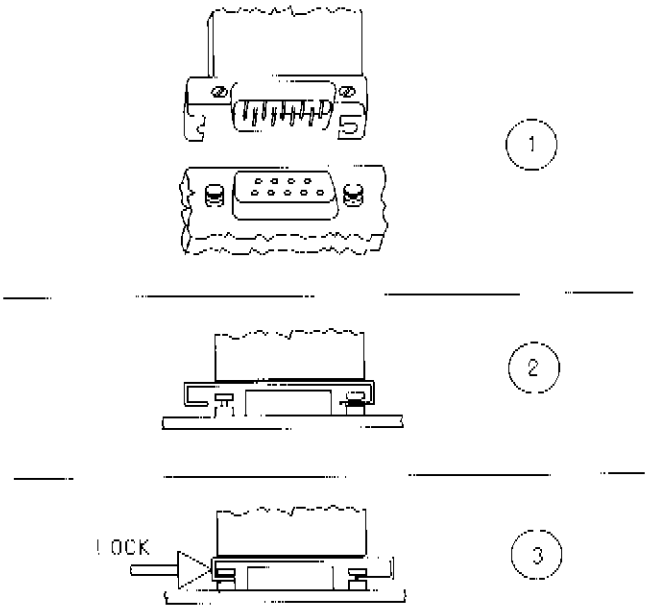


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6. If the console is ON, power it OFF. Attach the sensor head cable to the round connector on the console.

7. Connect the air hoses from the sensor head to the ports on the left side of the analyzer marked **FROM SAMPLE** and **TO PUMP**. It does not matter which hose goes to which port.

8. Connect the power cable from the L1-6250 to the 9 pin D connector on the console marked **ANALYZER**. This is a locking connector, as shown below:



9. **ALWAYS LEAVE THE CHAMBER PROPPED OPEN SO THE FOAM GASKET DOES NOT BECOME COMPRESSED.** This can be done with the latch, as shown in the photo on page 1-3 of this manual.

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Power On and Warmup

If the instrument fails to respond as expected while working through this section, refer to Chapter 9 on Troubleshooting.

1. Make sure the switches on the LI-6250 are set to **PUMP OFF** and **FAN OFF**, and that the fan switch on the sensor head is in the off position (switch positioned toward the inside).

2. Turn the console power switch to ON. The display should show "Pad cleared" after about 2 seconds, then go to PAUSE mode. After several seconds, you should hear the chopper motor running in the analyzer.

3. Check to see that the leaf temperature thermocouple wire is clear of the fan blades in the chamber, and turn the chamber fan(s) on just to check for proper functioning, then off.

4. Turn the LI-6250 fan switch to **ON**, as this will shorten the time required for the analyzer to reach thermal equilibrium. The fan should be fairly quiet and hard to hear, but if you place your hand next to it (right end of the LI-6250 housing), you should feel air blowing out of the housing.

5. Turn the LI-6250 pump switch momentarily to **ON**, just to make sure it will operate. Turn it **OFF**.

IMPORTANT

The air hose connectors on the LI-6250 have internal shut-off valves, with the exception of the connector marked **FROM SAMPLE**. These valves are shut off when the mating connector is not *fully* screwed onto it. **DO NOT** run the pump unless all of the connectors on the left side of the analyzer have their valves open. (The desiccant and scrub connectors are utilized only when the **DES** and **SCRUB** flow switches are ON.)

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6. Press MONITOR and check each sensor channel to see if it appears to be operating:

NOTE

Calibration factors were entered at the factory prior to shipping. If for some reason they have been changed or otherwise lost from the instrument's memory, the channels for PAR, RH, FLOW, and CO_2 may read a constant 0. If you find this to be the case, just proceed ahead. Instructions for remedying the situation are given in the next section.

6a. Press PAR. Cover and uncover the quantum sensor, and see if the QN reading responds to the light changes. If it reads a zero, (is the sensor in fact connected to the sensor housing?), then the calibration factor is probably entered as 0.

6b. Press TLEAF, ↑, and TCHAM. Close the chamber onto a small piece of paper (as if it were a leaf), with the paper in contact with the leaf temperature thermocouple. Turn the chamber fan(s) on and watch the display. The leaf and air temperature sensors should be within 0.1 degrees. If they aren't, the instructions for adjusting the leaf temperature offset are in the Chapter 8 of this manual.

Now turn the fan off, open the chamber, and place your finger lightly on the thermocouple bead of the leaf temperature sensor. This should cause the reading to depart from air temperature. If you are somewhat cold-blooded and your finger seems to be at air temperature, then try blowing across the sensor to warm it. The point of this exercise is to make sure the leaf temperature will *depart* from the air temperature; if the thermocouple is broken, the leaf and air temperature readings will be in constant agreement.

6c. Press TIRGA. This is the temperature of the airstream inside the analyzer, and should be a few degrees warmer than the chamber air temperature at this point. When the analyzer is fully warmed up and its fan is on, the analyzer temperature will be from 3 (cool shade) to 7 (hot sun) degrees C warmer than ambient air temperature.

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6d. Press **RH**. Make sure the humidity sensor responds to your breath. Don't try and saturate the sensor - a quick puff should suffice. If you have a sling psychrometer or other method of determining humidity, it's a very good idea to check the humidity sensor's accuracy periodically.

6c. Press **FLOW**. Turn the LI-6250's pump **ON**. You should be able to control the flow rate using the needle valve on the LI-6250 *if the flow switch is set to* **DES ON**. Clockwise raises the flow, counterclockwise lowers the flow. The flow valve has about 11 turns, and the dynamic range of the flow should be from about 200 μmol s^{-1} (valve turned fully counterclockwise and opened) to something around 1000 μmol s^{-1}.

If one of the flow connectors (especially the **TO PUMP** one) is closed (no mating connector attached), then there will be no flow.

Note that when the switch is set to **DES OFF**, the needle valve and flow meter are taken *out* of the flow path, and the indicated flow rate should be zero.

It is important to remember that the flow rate displayed is not the total flow through the analyzer, but rather only the flow through the desiccant.

6f. Press **CO2**, and check for proper functioning of the analyzer. With the pump still on, and **DES OFF**, the reading should respond to the **SCRUB** switch being **ON** or **OFF**. When the scrubber is on, the reading should quickly fall, and with it off, the reading will rise. Turn the pump off when you've verified this response.

The **READY** light on the LI-6250 takes anywhere from 2 to 5 minutes to light up. After that, you should wait another 10 minutes or so before calibrating the analyzer. This is a good time to check some software tables in the instrument, and make sure everything is OK.

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Software Check

To check the software, we'll work through 9 items on the SETUP list. Press SETUP.

THE PAGE PARAMETERS

1. Press ↑ so the display shows

```
41 set pg param
42 set opr parm
```

then press **RTRN**.

2. Press SHIFT + EDIT, and you'll be prompted for each entry automatically. Enter the desired character(s), and press **RTRN**. If you do not wish to change a parameter's value, simply press **RTRN** without making any other entry.

Here are some comments and suggestions for each of the page parameters.

LAB - Enter a label (up to 12 characters) of your choice. This is just an identification label that you might define if you were going to store the list as a file. You can safely ignore it.

Vt(cc) - This is the volume of the entire system (chamber + analyzer). This value is important - an error in volume will yield a proportional error in photosynthesis or stomatal conductance. Consult the LI-6200 calibration sheet, and enter the volume based upon what chamber you are using, whether or not chamber inserts are used, etc. Typical values using LI-COR chambers are 390 cm^3 for the Quarter Liter chamber, 1150 cm^3 for the 1 Liter chamber, and 4120 cm^3 for the 4 Liter chamber.

Vg(cc) - For the LI-6250, use 130 cm^3. This volume includes everything except the chamber itself.

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P(mb) - The station pressure (that is, *not* corrected to sea level) in millibars. If you have no way of determining this (barometer, or a weather station you can call), a very rough rule of thumb for most inhabited elevations on Earth is that pressure decreases by a rate of roughly 1 mb per 10 meters. Sea level pressure according to the U.S. Standard Atmosphere is about 1013 mb. Thus, if your elevation is 1000 feet above sea level, something near 980 mb would be a reasonable guess. Pressure enters in to both the photosynthesis and stomatal conductance calculations.

BC(mol) - The boundary layer resistance of ONE SIDE of a leaf. This is a function of leaf size and what chamber you are using. It is a good exercise to actually measure this, but nominal values for LI-COR chambers are: 4 Liter Chamber: 0.8 mol m^{-2} s^{-1}. 1 Liter Chamber: 1.3 mol m^{-2} s^{-1}. Quarter Liter chamber: 1.6 mol m^{-2} s^{-1}, although this a strong function of leaf area. The higher the stomatal resistance that you measure, the less important the BLR becomes.

STOM RAT - This is the ratio of stomatal resistance of one side of the leaf to the other side, and is used together with the BLR to compute the "true" boundary layer resistance of the leaf. This parameter does NOT need to be known to any great degree of accuracy at all. If you are measuring leaves with stomata on one side only, enter 0. If the leaves have stomata on both sides in roughly equal amounts, enter 1. If you think you're somewhere in between, enter 0.5. Any value of STOM RAT has the same effect as 1/STOM RAT, so 2 would be the same as 0.5, 3 as 0.333, etc.

Fx(umol) - This is an estimate of the maximum flow rate that can be achieved if ALL of the flow is diverted through the desiccant tube (**DES ON** and **DES FLOW** valve turned fully, but not tightly, clockwise). To determine this value, monitor flow rate, and divert all of the flow through the desiccant.

Kabs - This is a factor that helps correct the data when you make a measurement in which the vapor pressure is not held constant. There is a test (known as the "K test") described in Chapter 5 of this manual that is used to determine the value of K_{abs} for your system at any given moment. Otherwise, just set this parameter to 1.1.

pr1 through *pr6* - These are the auxiliary data prompts. If you wish to store information such as 'PLOT #' or 'SPECIES' along with the data,

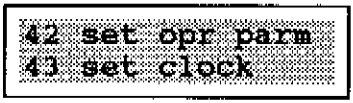
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then enter these labels here. The prompts can be as many as 12 characters in length. To "erase" an existing prompt, edit that line, enter a SPACE (generated by SHIFT + .) for the new label, then press RTRN.

3. When you've finished with the page parameters, return to the SETUP list by pressing RTRN.

THE OPERATING PARAMETERS

1. Press ↑ so the display shows



then press RTRN.

2. Press SHIFT + EDIT, and you'll be prompted for each entry automatically.

Here are some comments and suggestions for each of these parameters.

LAB - A label (if any) of your choice, up to 12 characters in length.

CHANGE - Enter 5. This is the change in CO_2 concentration in ppm that must occur to complete an observation. 5 is certainly not a hard and fast rule for this; you will probably want to adjust this number depending upon the chamber size, leaf size and photosynthetic rate. As a very rough rule, this parameter should be adjusted so that a measurement takes between 10 seconds and 1 minute.

CHANNEL - Enter 15. This is the channel number that is to be monitored for a change of 5. For normal operations, this will always be the CO_2 channel, which is channel 15.

OBS/PAGE - Enter 1. This is the number of observations per page.

STEP(s) - Enter 1. This is the time interval between samples.

BEEP LOG(Y/N) - This depends on personal preference: Enter Y if

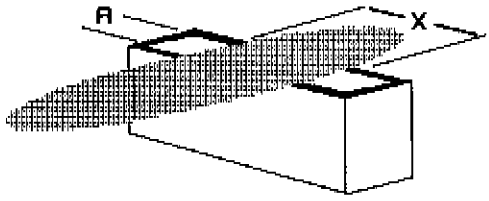
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you want the computer to beep at you when it is finished with an observation (that is, when the CO_2 concentration has dropped by 5 ppm); otherwise, enter N.

KEEP SMP(Y/N) - This is normally N. This determines whether or not samples are stored along with the observation. Each observation (we're only asking for 1) is made up of 2 or more samples, depending upon how long it takes to achieve the 5 ppm drawdown we've specified. The samples will be spaced 1.5 seconds apart (or more, if STEP is not set to 1), so not storing them will save a lot of memory.

PRN FMT(U/S) - Set this to S. This determines what format is used when you print out data pages. S is the system format, and U is a user defined format.

AREA MULT - This is the leaf area entry multiplier, and is normally set to 1. Whenever you enter a leaf area (which is done by pressing the AREA key), whatever value that you enter is automatically multiplied by the value of AREA MULT. This feature is useful when measuring long leaves across a narrow chamber, as shown below. If AREA MULT is set to the value of 'A' (in cm), then when each leaf is measured, the area is set by measuring distance 'X', then pressing AREA and entering that value.



3. When these parameters have been adjusted to your satisfaction, return to the SETUP list by pressing **RTRN**.

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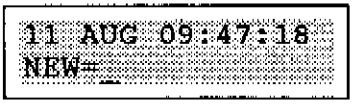
SETTING THE CLOCK

1. Press ↑ so the display shows



then press **RTRN.**

The display will show the current time and date, and wait for you to set a new one if you wish.



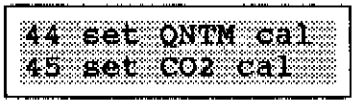
Current DD MMM HH:MM:SS
Enter new, or RTRN.

2. If you wish to enter a new time and/or date, do it now. The format of entry is as shown above, and any nonnumeric character (such as a period) can be used as a delimeter. For example, the entry **18.OCT.14.10** would be interpreted as the 18th of October at 2:10 pm. Entering a value for seconds is optional. A null entry (press only **RTRN**) leaves the clock unchanged.

Upon pressing **RTRN**, you will automatically return to the SETUP list.

THE QUANTUM CALCONSTANT

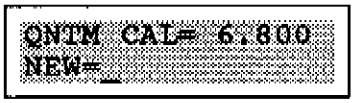
1. Press ↑ so the display shows



then press **RTRN.**

The display will show the current value of the quantum sensor calconstant, and wait for you to enter a new one, if you wish.

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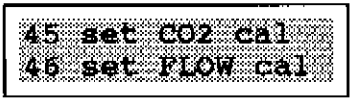
Current value
Enter new or RTRN

2. Enter the value, or just press **RTRN** if you do not wish to change the existing value. The correct value for your sensor can be found on the sheet of calibration information shipped with the LI-6200. This value typically is between 4 and 8. If this value is entered incorrectly, it will affect the accuracy of the measured light value, but does not enter in to any other calculations that the LI-6200 performs in its default configuration.

Upon pressing **RTRN**, you will automatically be returned to the SETUP list.

CO_2 CALIBRATION LIST

1. Press ↑ so the display shows



then press **RTRN**.

You will now be viewing a list which might look something like this:

```
LAB:860723 411          Date and Serial Number
TEMP= 38.000C
K= 19800.
A= .14285
B= 1.9311E-05
C= 2.1453E-09
```

2. Use ↑ or ↓ to scroll through this list, and make sure it matches the information provided on the calibration sheet. If something does not match, use the EDIT key to change it.

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3. When you have checked this list, press **RTRN** to return to the SETUP list.

FLOW CALIBRATION LIST

1. Press ↑ so the display shows



then press **RTRN**.

You will now be viewing a list which might look something like this:

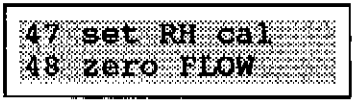
```
LAB:860723 411          Date and Serial Number
A= .0081320
B=-2.3199E-05
C= 1.0380E-07
D= 1.1240E-08
```

2. Use ↑ or ↓ to scroll through this list, and make sure it matches the information provided on the calibration sheet. If something does not match, use the EDIT key to change it.

3. When you have checked this list, press **RTRN** to return to the SETUP list.

RH CALIBRATION LIST

1. Press ↑ so the display shows



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then press **RTRN**.

You will now be viewing a list which might look something like this:

```
LAB:860723 411          Date and Serial Number
NPTS=     5             Number of points.
 1:    0.0   -0.5       True RH  Indicated RH
 2: 15.00    15.50
 3: 60.00    59.00
 4: 80.00    80.00
 5: 100.0    104.0
```

2. Use ↑ or ↓ to scroll through this list, and make sure it matches the information provided on the calibration sheet. If something does not match, use the EDIT key to change it.

3. When you have checked this list, press **RTRN** to return to the SETUP list.

FLOW METER ZERO

The purpose of the flow meter zeroing routine is to compensate for drift in the flow meter; we simply need to tell the computer what voltage output the flow meter has when there is *no* flow at all. This value will drift roughly 10 mV (equivalent to about 3.5 μmol s^{-1} of flow) per C, so this function should be performed frequently whenever the ambient temperature is not reasonably steady.

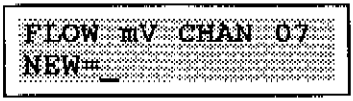
1. Press ↑ so the display shows

```
48 zero FLOW
49 CO2 ref
```

then press **RTRN**.

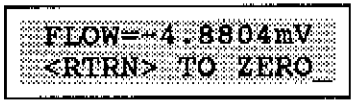
2. You will be prompted for the channel number for the raw millivolt reading for flow. This will be 07, unless you have reconfigured your system.

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Should be channel 07.
Just press RTRN.

3. You will then be shown the current flowmeter signal in millivolts: Make sure the gas analyzer pump is **OFF**, that there is no other source of flow through the system, and the analyzer is not tilted. Then press **RTRN**.



Flow meter mV output.
Just press RTRN.

Upon pressing **RTRN**, you will automatically be returned to the SETUP list.

CO_2 REFERENCE ROUTINE

The CO_2 reference routine tells the computer what gas concentration is in the reference side of the analyzer, which is 0 ppm as used with the LI-6200. Also, a gain adjustment based on the current pressure (set in FCT 41) is calculated. This routine should be done after setting the pressure parameter, and prior to calibrating the analyzer.

1. Press [↑] so the display shows



then press **RTRN**.

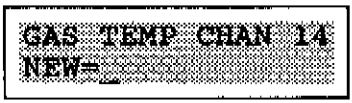
2. You will be prompted for the reference concentration, which is 0 ppm when using the LI-6200.

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Should be zero ppm.
Just press RTRN.

3. You will then be prompted for the channel to be considered as the temperature of the gas analyzer. This is 04.



Should be 14.
Just press RTRN.

The computer will then do some brief computations, and return to the SETUP list.

This completes the software checkout of the instrument. Press MONITOR to exit the SETUP list, and return to MONITOR mode.

Calibrating the CO_2 Analyzer

There are 2 aspects of calibrating the LI-6250 CO_2 analyzer. The first, which we have just completed, is verifying that the calibration information in the CO_2 calibration list matches the information provided on the factory calibration sheet. It's a good idea to check this at the start of each day of operation, just to make sure that this data hasn't been accidentally modified.

The second aspect is to actually measure some known CO_2 concentrations, and adjust the zero and span on the analyzer until the readings are correct. This should also be done *at least* once a day, prior to operating.

This procedure is best done after the LI-6250's **READY** light has been on for about 10 minutes.

1. Press MONITOR to enter monitor mode. Use the FLOW key, ↑, and the CO2 key to monitor CO_2 and flow rate.

3. Set the following switches on the LI-6250: **PUMP ON, RESPONSE**

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1, **DES ON**, and **SCRUB ON**.

4. Close the needle valve (fully clockwise, *but not tight*) to divert all of the flow through the desiccant. The flow rate as indicated on the display should be somewhere in the 900 to 1000 or more range (μmol s^{-1}).

5. The displayed value of CO_2 should quickly approach zero. Wait about 30 seconds, then unlock the **ZERO** knob by turning the lower ring counterclockwise (it only goes about 1/8 turn). Now adjust the zero knob itself until the CO_2 reading is 0. When finished, lock the knob in place by turning the locking ring clockwise.

Note: The **ZERO** and **SPAN** knobs (not the locking ring, but the knob) tend to stick a bit when you first try to turn them. Once turned, they'll turn very freely.

6. Now set the span. Set the following switches: **SCRUB OFF, PUMP OFF.**

7. Connect your span gas to the port on the upper left corner marked **TO PUMP.** The span gas should be at a concentration just above where you will be working; 400 or 500 ppm would be a good choice for many applications.

8. Flow rate is important when setting the span, since this determines the pressure in the sample cell of the analyzer. Adjust the flow so that the rate is equal to the rate achieved in step 4, above.

9. The measured value of CO_2 should fairly quickly approach the true concentration. Wait about 30 seconds, then unlock the **SPAN** knob and adjust it until the reading is correct. When finished, lock the knob in place.

10. Disconnect the span gas, and re-check the zero by repeating steps 3, 4, and 5.

11. Now re-check the span by repeating steps 6, 7, 8, and 9.

The zero is easy to check, since it requires no external gasses. The zero is a bit temperature sensitive (roughly 3 ppm per 10° C), and it is a good idea to check the zero periodically during the day.

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The span is mostly sensitive to pressure, both due to flow rate and atmospheric pressure. Day to day pressure changes make it necessary to check the span on a daily basis, and more often if practical. If one were going to use the analyzer all day, a good policy would be to check the span in the morning, at noon, and once again in the middle of the afternoon. Of course, elevation change by definition implies a pressure change, so check the span at the same elevation that you plan on working.

The CO_2 reading is independent of the value of 'P(mb)' that is in the page parameters at any given moment, unless FCT 49 is performed again to update the current gain factor.

12. Now is a good time to check the 'Fx' parameter. Monitor flow rate, turn **DES ON**, turn the flow valve all the way down, and see what the flow rate is. Round this number up a bit, and enter it as the 'Fx' parameter.

The instrument is now ready to use. The next section details some system tests that can be performed, and the section following that discusses the procedure for measuring plants.

NOTE

The factory recalibration, which generates the numbers on the calibration sheet, is recommended on an annual basis.

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SYSTEM TESTS

This section describes some simple tests that are recommended prior to making careful measurements. Or, if you are just now familiarizing yourself with the instrument, these tests are a very good exercise to do before going any further.

If you are unable to achieve satisfactory results on these tests (due to a hardware problem, software problem, or your own lack of familiarity with the system), you will be wasting your time trying to measure plants.

Leak Test

The system should have a minimum of leakage for accurate measurements. If there is a leak, as CO_2 is depleted in the system during a measurement, ambient CO_2 will tend to diffuse through the leak into the system and decrease the apparent photosynthetic rate.

This test will create a CO_2 differential between the system and ambient conditions, and then measure the rate of CO_2 diffusion into the system in terms of a photosynthetic rate.

1. Set the following OPERATIONAL PARAMETERS (accessed via SETUP, or else FCT 4 2):

```
CHANGE=60
CHANNEL=10
OBS/PAGE=1
STEP(s)=1
```

2. Turn on the chamber fan(s), open the chamber, and be careful not to breathe in it. Let it get a good sample of the ambient CO_2 concentration.

3. On the LI-6250, set **SCRUB OFF, DES ON, PUMP ON**. Set the flow rate to about 500 μmol s^{-1}, so about half of the flow goes through

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the desiccant plumbing.

4. Now close and latch the chamber, and monitor CO_2 on the console display. (Press MONITOR, then CO2). Wait about 30 seconds to 1 minute for the reading to stabilize. Note what the value of CO_2 is.

5. Now set **SCRUB ON**, and scrub CO_2 from the system for a certain period of time: 5 or 10 seconds with the 1/4 Liter chamber; 20 seconds with the 1 Liter chamber, and about 1 minute with the 4 Liter chamber.

6. Now set **SCRUB OFF**, and wait about a minute for the CO_2 concentration to become steady (or rising very very slowly). Make a note of the CO_2 concentration differential (that is, the difference between the current CO_2 reading and the one measured in step 5) that you have achieved.

7. Press LOG to begin the measurement. At the end of 1 minute, the measurement will be over, and VIEW mode entered.

8. Press FCT 1A and read the slope (the M value) of the CO_2 versus time response.

9. Multiply the value found in step (8) by 10, and divide it by the CO_2 differential noted in step (6). The result is the rate of change of CO_2 with time that would be expected with a 10 ppm differential. This value should be at least 100 times smaller than the rate of change of CO_2 with time that you expect during a measurement (0.1 to 1 ppm per second).

Example: 500 ppm before scrubbing, and 200 ppm after scrubbing is a CO_2 differential of 300 ppm. After logging data, the M value of DC/DT was -0.015. This value, divided by 300, and multiplied by 10 is -0.0005 ppm per second.

You might wish to try this test again, and this time make a tiny gap in the chamber seal. This will give you a quantitative appreciation for how large a leak you can afford to have.

A good technique for finding the location of a leak is to close the chamber (fan and pump running), and monitor CO_2 concentration. Use a length of tubing to direct high concentration CO_2 air (such as your breath) toward various suspected leak areas:

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• Foam gaskets. Replace if needed.
• Sensor head / chamber O-ring seal. Make sure the knurled knobs are tight, and no debris is between the O-ring and the chamber wall.
• Desiccant caps. Are they tight?
• Cracked tubing.
• Inside the analyzer. Test this by blowing into the intake filter with the analyzer housing fan on. A leak in the sample side plumbing will cause the CO_2 concentration to rise, and a leak in the reference side plumbing will cause the CO_2 concentration to go negative. Refer to the Troubleshooting chapter for more details.

Note that leaks are increased when a leaf or stem is protruding through the gasket material. Soft putty or Vaseline can be used to seal around the stem or branch where it encounters the gasket material. Also, the chamber can be modified for larger stems by cutting a small notch in the chamber wall for the stem to fit into, and filling in with extra foam.

TO PROLONG THE LIFE OF THE GASKETS, ALWAYS KEEP THE CHAMBER OPEN WHEN NOT IN USE.

Boundary Layer Conductance

Boundary layer conductanc (BC) is a function of chamber size and shape, leaf size and shape, and fan speed. The importance of knowing this value is proportional to the stomatal conductance that you expect to measure. Thus the BC can be neglected when determining cuticular conductances, but is absolutely crucial when the stomata are wide open.

It is also true that determining BC can be a valuable check of the system. For example, you may know (from repeated measurements) that a certain size of blotter paper "leaf" in a particular chamber will give you BCs of 1.3 to 1.4 mol m^{-2} s^{-1}. If, however, you measure it one day and find it to be 0.9, or 1.7, then that should alert you to the fact that something has changed, such as the calibration of the humidity sensor, or the desiccant is no good, or a parameter is incorrectly set, etc.

These are the steps in determining BC:

1. You'll need a piece of filter paper (there is some Whatman #1 supplied in the spare parts kit). Cut the paper to the size of the leaf in

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question.

2. Access the operating parameters (FCT 4 2), and set them as follows:

LAB:	Doesn't matter.
CHANGE= 10.00	10 Seconds.
CHANNEL=10	Channel 10 is time.
OBS/PAGE=1	
STEP(s)=1	
BEEP LOG(Y/N)=Y	Doesn't matter.
KEEP SMP(Y/N)=N	Doesn't matter.
PRN FMT(U/S)=S	Doesn't matter.
AREA MULT= 1.000	

3. Press AREA, and enter the area (cm^2) of the filter paper that will be exposed inside the chamber.

4. Access the page parameter list (**FCT 41**), and edit it to be:

LAB:	Doesn't matter.
Vt(cc)= xxx	Enter system volume in cm^3.
Vg(cc)=120.0	For LI-6250.
P(mb)= xxx	Enter Atmospheric pressure (millibars).
BC(mol)= 0.0	* * * This MUST be zero.* * *
STOM RAT= 1.000	Doesn't matter when BC is 0.
Fx(umol)=999.99	You determine this.
Kabs=1.1	Typical value.
A8=0.0	Doesn't matter.
A9=0.0	Doesn't matter.
prl:	Doesn't matter.
:	
pr6:	

5. Prepare the LI-6250: **DES ON, SCRUB OFF, PUMP ON.** Turn the needle valve all the way clockwise to get the maximum flow through the desiccant.

6. Thoroughly moisten the filter paper with water (deionized is best), until it is dripping wet. Gently shake the excess water from the paper. Once the paper is put into the chamber, you do not want it to drip.

7. Place the filter paper into the chamber, making sure it comes in

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contact with the leaf temperature thermocouple.

8. Turn the chamber fan(s) on, close and latch the chamber, and monitor relative humidity. Adjust the flow so that RH is steady if possible. For larger sizes of filter paper in the larger chambers, this will not be possible.

9. Open the chamber and remove the filter paper, and re-wet it.

10. Return the filter paper to the chamber, close and latch it, and press LOG. When the measurement is over, remove the filter paper.

11. The computed conductance (press COND) is twice the value of BC. Thus, if the COND value is 2.7, then the BC is 1.35. (One way to make the COND reading directly correspond to what the BC value should be is to multiply the leaf area by 2 before entering it.)

12. Do several repetitions, re-wetting the paper each time. The BC value should be quite repeatable. Be careful not to drip water into the chamber. If you do, blot it out thoroughly before continuing.

13. The value of BC that you finally settle on should be entered into the page parameters (the BC entry) for subsequent measurements of leaves.

If you have trouble getting expected values, try the K test (described in this chapter), and also refer to the Troubleshooting chapter.

Soda Lime Test

The LI-6250 has two soda lime tubes. The one on the left is used when setting the zero of the analyzer. The one on the right is used continually; it keeps the reference side of the analyzer free of CO_2. The tube on the left will need to be replaced before the one on the right.

The procedure is this: Test the tube on the left. If it needs to be replaced, put fresh soda lime in it, and exchange the left and right tubes. This puts the freshest soda lime on the right hand side.

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The actual test of the left tube is quite simple:

1. Set the following switches on the LI-6250: **SCRUB ON, DES OFF, RESPONSE 1, PUMP ON.**

2. Open the leaf chamber, and leave the fan(s) off.

3. Monitor the CO_2 reading by pressing MONITOR, then CO_2.

4. When the reading has stabilized (it should be very near 0), breathe into the leaf chamber, and close and latch it. Then turn on the chamber fan(s).

5. The displayed value of CO_2 should be unchanged, even with your breath (on the order of 50,000 ppm) going through the soda lime. If the CO_2 reading rises, the soda lime should be replaced.

6. Open the chamber, turn off the chamber fan(s), turn off the analyzer pump.

This test *does* shorten the life of the soda lime, so perform it sparingly, such as once every 2 weeks to 1 month.

K Test

The K test computes the ratio K between a cause and an effect. The "cause" is dry air of a known flow rate entering the chamber, and the "effect" is the rate of change of vapor pressure in the chamber. If everything were perfect, K would be 1. Some things that would keep perfection out of reach are water adsorption and absorption (we will use the term absorption, but mean it in a very loose sense) in the chamber and hoses, inadequate desiccant, a flow or humidity sensor out of calibration, or a chamber that is not yet equilibrated.

Thus K is an assurance test. If it is near 1, things are OK (or else there are cancelling errors!). If K is not near 1, then there is a problem that must be addressed.

Refer to the **Technical Reference**, Chapter 1 for a more rigorous description of K.

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To compute K, perform the following steps:

1. Access the operational parameters, and set them to the following:

CHANGE= 1	
CHANNEL=18	Channel 18 is vapor pressure.
OBS/PAGE=2	
STEP(s)=1	

2. Set the following switches on the LI-6250: **DES ON, SCRUB OFF, PUMP ON, RESPONSE 1.**

3. Press MONITOR, then FLOW, and turn the flow valve all the way counterclockwise. You should have a flow in the neighborhood of 200 μmol s^{-1}.

4. Press FCT 18 to monitor the vapor pressure. The label is EAIR, so it will be EA on the display.

5. Turn the chamber fans on, and close and latch the chamber.

6. When you see vapor pressure start to drop, press LOG.

7. When the vapor pressure in the chamber has dropped 1 mb twice, logging will cease. Open the chamber and turn the fan(s) off. Turn the analyzer pump off.

8. Press FCT 24, to access the channel that computes the K factor.

	1	1	1.057
24	K	2	1.068

1st K value.
2nd K value.

The displayed values should be in the 1.05 to 1.15 range. A value greater than 1 means that more dry air went into the chamber than was accounted for by the rate of change of vapor pressure, and this is usually the case. A value of less than 1 would mean that the rate of change of vapor pressure were greater than what could be explained by

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the dry air flow. Because the vapor pressure is dropping for this test, the second K value is generally a bit larger than the first, since the vapor pressure is further from the walls' equilibrium vapor pressure by the second observation.

The computed value of K can be entered for the 'Kabs' page parameter. As a rule, however, be very reluctant to use values less than 1 or greater than 1.3, since either would indicate a problem somewhere.

Water absorption will always cause K to be greater than 1. A clean chamber should yield a K value in the above mentioned range of 1.05 or so. A dirty chamber will cause this to increase; a visibly dusty (inside) 1 liter chamber will yield a K of over 2. Also, a dirty chamber may give good K test results in a cool, dry lab (vapor pressure of 10 or 12 mb), but bad results outdoors in the heat and humidity (vapor pressure 25 mb or so).

Inadequate desiccant will cause K to be greater than 1, since the flow of "dry" air is not as effective, since it's not really dry. The K test is a good way to quantify when to change desiccant; replace the desiccant when K gets up to 1.25 or so, provided that is why K is that high.

The K test can also indicate when the system is in equilibrium with the environment. If you take a chamber that is equilibrated to an air conditioned lab out into the hot, humid summer air and immediately do a K test, you will likely get a value less than 1. As the chamber (and system) equilibrate, the K value will climb back up to where it belongs. Surprisingly, this process can take 30 minutes to an hour, even with the chamber open, fans on, and pump running (but not though the desiccant!) to help equilibrate the system.

With good desiccant, and a clean chamber, the only other possibilities for calculating a "bad" K value are the calibration of the humidity sensor, the calibration of the flow meter, and the possibility of a leak somewhere in the system.

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MAKING MEASUREMENTS

This section describes the process that you go through in making measurements with the LI-6200. It is assumed that the pre-operation procedures described earlier have been performed.

One general piece of advice which you'll be tempted to ignore until you get caught once or twice: Be very methodical. There are a lot of things that can trip you up if you aren't careful: parameters that must be set correctly, hoses to connect and flow switches to set. Learn to think things through before you start, and then double check everything.

Using the Instrument

What follows is a summary of things that should be done.

SOFTWARE

1. Check the PAGE PARAMETERS (via SETUP or FCT 4 1) (page 4-9):

LAB:	Doesn't matter.
Vt(cc)=1140.0	System volume in cm^3.
Vg(cc)=120.00	IRGA and hose volume in cm^3.
P(mb)=979.9	Approx. 1013 - (1 mb per 10 meters elevation).
BC(mol)= 1.3	Your measured value for this chamber.
STOM RAT= 1.000	One side 0; both sides 1; otherwise 0.5.
Fx(umol)=999.99	You measure.
Kabs=1.1	You determine, but should be close to this.
A8=0.0	Not used.
A9=0.0	Not used.
pr1:	As needed.
:	
pr6:	

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2. Check the clock and the calibration lists (page 4-13):

FCT 4 3: Clock
FCT 4 4: Quantum sensor
FCT 4 5: CO_2 analyzer
FCT 4 6: Flowmeter
FCT 4 7: Humidity sensor

---

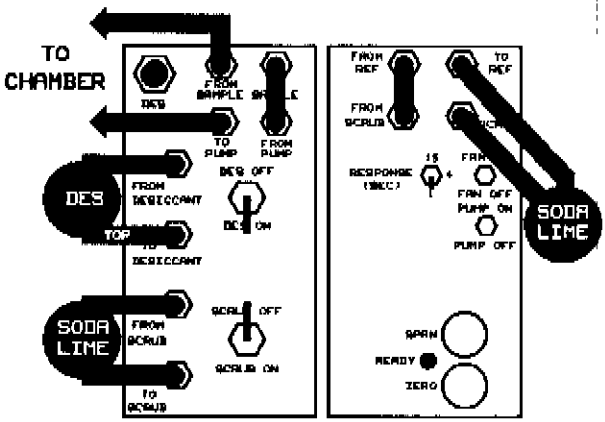
3. Let the system (analyzer and chamber) equilibrate with the conditions in which you will be working. This may mean setting everything outdoors in the shade for 30 minutes, for example.

PRE-OPERATION

4. Zero the flowmeter (FCT 4 8). Repeat frequently during the day (Page 4-16).

5. Set the analyzer reference (FCT 4 9), (Page 4-17).

6. Set the LI-6250: **DES ON, SCRUB OFF, FAN ON, RESPONSE 1, PUMP ON**. Are all the hoses connected in the right places?



7. Calibrate the CO_2 analyzer: ZERO and SPAN (Page 4-18).

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8. Compare the humidity reading to a standard that you trust. Check the RH stability in a closed chamber without desiccant in the circuit to be sure that the chamber has equilibrated to the humidity of your working environment.

9. Check for leaks (Page 5-1).

10. Do the K test (Page 5-6).

11. Set the OPERATING PARAMETERS (via SETUP or FCT 4 2) for taking data. Suggested values are:

LAB:	Doesn't matter
CHANGE=5	5 ppm for an observation
CHANNEL=15	Channel 15 is CO_2
OBS/PAGE=3	Your choice
STEP(s)=1	Time between samples
BEEP LOG(Y/N)=Y	Beep after each obs
KEEP SMP(Y/N)=N	Your choice
PRN FMT(S/U)=S	Doesn't apply here
AREA MULT=1.000	Unless you know otherwise

MAKING MEASUREMENTS

12. Press MONITOR, CO2, ↑, and RH.

13. Determine the flow rate you will be using. Select a leaf that is typical of the ones you plan to measure, and enclose it in the chamber (fans on). Monitor vapor pressure (FCT 18) on the display, and adjust the flow rate so that it stays fairly constant.

If the lowest flow still draws the humidity down, then replace the top cap of your desiccant tube with the 9960-067 Desiccant Flow Restrictor (one is provided in the LI-6250 spare parts kit), as shown in the photo on the next page. Closing this device's valve will further restrict flow, and allow you to maintain constant humidity regardless of how small the transpiration rate is in the chamber. *When using low flows, check the flow zero regularly.*

14. To make a measurement, place the leaf into the chamber, and latch

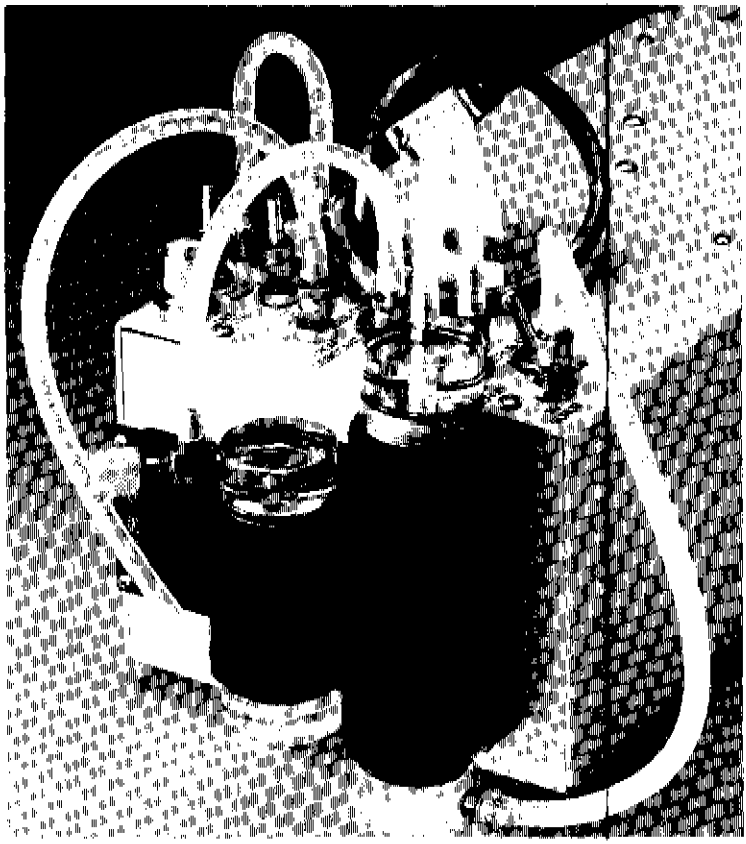
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it closed. Monitor CO_2. When the CO_2 starts to drop steadily (it will take a few seconds for this to happen), press LOG. When logging is completed, remove the leaf from the chamber.

15. If you need to change the value of leaf area, press AREA, enter the new value, and then press VIEW to recompute the pad and see the new values.

16. If you wish to enter auxiliary data (responses to the prompts defined in the Page Parmaeters), do it now by pressing AUX. Then use EDIT or SHIFT + EDIT to enter selected or all of the auxiliary data responses.

17. If you wish to store the data you have just logged, press STORE while in VIEW mode. Otherwise, just press MONITOR to return to MONITOR mode. Move on to the next leaf.



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Are the Results Any Good?

The LI-6200 allows you to view the results of your measurement immediately. It is usually wise to take advantage of this and check a few key numbers in the scratch pad before storing the data away. This can allow a configuration error or measurement technique error to be corrected right then, rather than after the fact when it might be too late.

The following is a general list of some things to be watchful for in your data. Obviously, any of these may or may not apply to your particular situation.

Time range. This of course directly depends on the requested change in CO_2 for an observation, the size and photosynthetic rate of the leaf, and the volume of the chamber. If you wish to shorten the time to complete an observation, the operational parameter CHANGE can be lowered, or a smaller chamber used, or increase the measured leaf area. If the chamber is too small, or leaf area too large, the time for an observation will be very short - just a few seconds. Draw down rates should be kept below about 1 ppm per second if possible; 0.5 ppm per second is "ideal", but you can certainly do well with very much lower rates.

Vapor pressure range. This affects the conductance measurement. The larger the change, the larger the uncertainty in the conductance calculation due to water absorption, although the 'Kabs' parameter will help compensate.

Another way to evaluate this is to look at the K value (FCT 24) that was computed for your measurement. (Not to be confused with the 'Kabs' page parameter that you set. When you do the K test, you can interpret the channel 24 K value to be what 'Kabs' should be. For a normal measurement, channel 24 is still computed, although the value should be much different). The channel 24 value will be the ratio of the flow term to the vapor pressure rate of change term. If the rate of change is near zero, K will be large. If the rate of change term were just as dominant as the flow term, then K would be 1. Typically, you should see numbers in the 5 to 20 range, but the larger the better. The 3 K values for the data page shown on page 2-6 are 189, 925, and -151.

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Leaf temperature range. If the chamber is kept at air temperature, then the leaf temperature should not increase more than about 1°C per minute in full sun. If the chamber is allowed to get warm, however, the leaf temperature will quickly jump when the leaf is placed in the chamber. Between measurements, keep the chamber shaded and open, and the fans running.

PAR range. This indicates how steady the light was during the observation. Since the PAR sensor is not in the same place as the leaf, it is possible to shade one and not the other.

Ci. The intercellular CO_2 concentration, C_i, is dependent upon the photosynthetic rate as well as the stomatal conductance. If one or the other calculation is out of line, C_i will reflect this fact. As a rough rule of thumb for non-stressed, fully sunlit plants at an ambient CO_2 concentration of about 340 ppm, and a 20mb vapor pressure difference, C_i for a C3 plant will be in the 220 to 240 range, and C_i for a C4 plant will be in the 100 to 120 range.

C_i is inversely proportional to photosynthetic rate, and proportional to conductance.

C_i values that seem out of line may be due to bad measurement technique, a sensor out of calibration, or a parameter that has been erroneously entered. For example, if a leaf equilibrated to full sunlight is suddenly shaded and put into the chamber, C_i will likely be high because the reduced light will lower photosynthesis faster than it will cause stomatal closure. Or, if you pull a shaded leaf into the sun and measure it, C_i will be low, since the suddenly increased photosynthesis will use up the intercellular CO_2 faster than the stomata can open to adjust.

Some Do's and Don'ts

• If the time needed for a measurement takes longer than 1 minute, or less than 10 seconds, then adjust the CHANGE parameter accordingly. These numbers (10 seconds to 1 minute) are not divine law by any means, but here are some things to keep in mind: If your measurement goes a long time, make sure that leaf temperature, CO_2 concentration, and vapor pressure are still within a tolerable range. For short

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measurements, probably the biggest thing to be concerned about is getting enough samples into the observation. With few samples, the standard error (the R value) of DC/DT may be larger than you might like. Typically, the R value is less than 1% of the M value. If there are only a few samples involved, it can be much higher, however.

• The flow meter has a fairly long time constant. *Do not make large flow adjustments during a measurement*, as the flow readings will be in error for several seconds following the adjustment.

• Every 10 or 15 minutes, shake the desiccant tube to keep the $Mg(ClO_4)_2$ as powdered as possible. It becomes quite crusty as it absorbs water vapor.

• Every 30 minutes:
→ Zero the CO_2 analyzer. (**SCRUB ON**, and adjust **ZERO** knob).
→ Zero the flow meter (**FCT** 4 8).

• Perform the K test (page 5-6) every so often, depending upon how humid it is, and how much you are using the desiccant. The value should be near 1.1 with good desiccant, and will increase as the desiccant becomes spent. When the K value (for the K test, not for a normal measurement) gets above about 1.25, change the desiccant.

• If desiccant is not stored tightly sealed, it will absorb water and become spent before it is even used.

• You can extend the life of the desiccant by flipping the desiccant switch to **DES OFF** between measurements, or by turning the pump off between measurements. Give the flow meter time to get caught up, however, when you turn it back on again.

• If you connect the desiccant tube to the LI-6250 such that the top hose is the incoming air (as the diagram on page 4-1 shows), then the desiccant on top of the tube will become crusted first, and the desiccant at the bottom will stay dry. This is preferrable to the opposite manner where the desiccant at the bottom will become crusted first, and the filter paper on the bottom end will get damp.

• In humid environments, you may want to consider using a larger desiccant tube (a spare soda lime tube, for example). When the desiccant on top (air flow top to bottom) gets crusty, remove the top

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cap, dump the crusty stuff out, then replace the top, and add some fresh desiccant to the bottom end.

• This may sound trivial, but don't forget to turn the pump on if you shut it off between measurements. Since the LI-6250 makes noise anyway (the chopper motor), sometimes you might think the pump is on when it's really not. The usual indicator of this situation is when the CO_2 won't respond to leaves in the chamber or the soda lime scrubber, and you start thinking the analyzer is broken...

• Hold your breath while putting a leaf into the chamber (especially in low wind conditions) to prevent elevating the CO_2 concentration in the chamber.

• Even though the chamber is made of clear material, it will heat up in the sun. Between measurements, *keep the chamber opened, fans on, and shaded* if at all possible. As long as the chamber remains near air temperature, the leaf temperature will not rise very rapidly during a measurement. If, however, the chamber walls become warmer than the air, the leaf temperature will rise almost immediately after being enclosed in the chamber.

• Try and work facing the sun to prevent inadvertently shading the leaf before or during the measurement. Also, when putting a leaf into the chamber, do so with a minimum of agitation to the leaf. Orient the chamber to the leaf, not vice versa; the leaf should have the same orientation while being measured as it had before being placed in the chamber. HOWEVER: If the foam on the sides of the chamber is fairly thick (such as on the 1 liter chamber), it will cast a shadow on part of the leaf when inclined relative to the sun. Shadows reduce transpiration and photosynthesis, and introduce uncertainty into the measurement.

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DATA COMMUNICATIONS

This section tells you how to get data from the LI-6200 to a printer or computer. The term "I/O" appears frequently - this is just shorthand for "Input/Output", meaning data communications.

Details of interfacing the LI-6200 are found in the Technical Reference Manual.

Using a Computer

A simple way to interface the LI-6200 to a computer is to use a communications program, such as (for the IBM PC and compatibles) PC-TALK™ (Freeware, P.O Box 862, Tiburon, CA 93920) or ProComm™ (PIL Software Systems, P.O.Box 1471, Columbia, MO 65205). Either of these programs will allow ASCII data sent from the LI-6200 to be displayed on the computer's screen and optionally stored in a disk file. They are also very inexpensive.

The LI-6200 has an alternative format for sending data that is very compressed, and allows data to be loaded back into the LI-6200 from a computer. The LI-COR software packages (6200-25 for IBM PC and 6200-26 for HP Series 200) support this binary format as well as the more conventional ASCII format.

If you do not wish to make use of the binary transfer features of the LI-6200, then you will not need the LI-COR software.

Using a Printer

The LI-6200 can communicate successfully with virtually any printer having an RS-232 interface. One example is the 6000-03 printer from LI-COR, which is an Epson printer with an RS-232 interface installed.

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Which Connector?

Most of the time, RS-232 connectors on computers and printers are a 25 pin D connector. However, this is not always the case. For example, the backplane of a typical IBM PC might have 2 such connectors - one male and one female. The female connector is for a parallel interface, and the male connector is the RS-232 interface port (usually). In general, a computer's RS-232 port (if it has one at all) might use any sort of connector imaginable, so verify what's what before you connect anything to it. *It is possible to damage an interface by connecting it to another type of interface.*

The serial interface on other computers (such as an IBM AT) may in fact be a 9 pin connector, in which case you will need consult your computer supplier for an adapter cable.

The 6000-03 Printer is less complicated. There are two connectors, but only one of them is a 25 pin D connector, and that is the one you want.

The important thing is to make sure you plug the LI-6200 into the correct port on your computer or printer. A trivial point, perhaps, but one over which many have tripped.

Which Cable?

The LI-6200 is shipped with two cables: a flat ribbon cable, with both a male and female connector on each end, and a round cable with a male connector on each end known as the Printer Cable.

The best advice for what cable to use is this: *If it doesn't work WITH the Printer Cable, then try it WITHOUT the Printer Cable.*

Note that sometimes BOTH cables will be needed if 1) the Printer Cable is required, and 2) the device into which you need to plug the Printer Cable has a male connector.

If you are using the 6000-03 Epson printer, use the Printer Cable.

If you are using an IBM PC, you will probably need both cables.

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Configuring the I/O port

1. Press COMM. You will access an execute list that looks like

```
50 ** COMM **
51 set I/O parms          We'll use this one...
52 terminal
53 dump pages             ...and this one.
54 binary dump
 :
5F
```

2. Press ↑ so 'set I/O parms' is on the top line of the display, and press RTRN. You will then have accessed the I/O PARAMETERS, which is the following list:

```
LAB:
BAUD=4800                 Baud rate: 50 thru 38,400
DATA BITS=8               7 or 8
STOP BITS=2               1 or 2
PARITY=None               None, Odd, Even, 1's, 0's
CHECK CD=N                Check Carrier Detect
CHECK DSR=Y               Check Data Set Ready
ENQ/ACK HSHK=N            Pacing mechanism
XON/XFF HSHK=N            Pacing mechanism
XON CHAR=11               XON character (HEX)
XOFF CHAR=13              XOFF character (HEX)
FLAG PARITY=N             Notify on parity error
FLAG FRAME=N              Notify framing error
LOCAL ECHO=N              For terminal mode
SOM=00                    Start of message (HEX)
EOL=0D,0A                 End of line sequence (HEX)
EOL WAIT=0                End of line maximum delay (ms)
EOM=00                    End of message (HEX)
```

The configuration shown above will work with the 6000-03 Epson printers as delivered by LI-COR.

If you are using the 6200-25 IBM PC interface software, the above configuration is OK with one exception: the XON/XFF HNDSHK parameter must be set to Y.

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NOTE

The LI-6200 does not actually implement the configuration until the I/O CONFIGURATION list is exited normally, by pressing **RTRN**. **BRK** or **FCT** are not considered a normal exit.

Dumping Data

Any list or the scratch pad can be sent to the serial interface by pressing **PRINT** while viewing the pad or list on the display. A range of stored data pages can also be sent to the serial interface by the DUMP PAGES routine (**FCT 5 3**).

When determining the proper configuration, it is probably easiest to try printing the COMM execute list to test the configuration:

1. Press **COMM** to access the execute list.

2. Press **↑** to put 'set I/O parms' on the top line of the display.

3. Press **RTRN** to access the I/O CONFIGURATION list. Edit it as needed.

4. Press **RTRN** to leave the I/O CONFIGURATION list, *and to enable the configuration.*

5. Press **PRINT** to print the execute list. If it does not work correctly, and the configuration is at fault, go back to Step (3).

To print a range of pages, use the DUMP PAGES routine:

1. Press **FCT 5 3**. The display will show

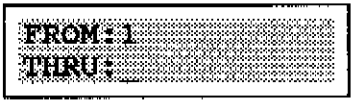
```
DUMP PAGES
FROM:_
```

Enter starting page number

2. Enter the starting page number, the press **RTRN**. The display will

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show



Enter ending page number

3. Enter the ending page number, then press **RTRN**. As each page is output, the message DUMPING PG n is displayed on the display.

Some Common Problems

NOTHING HAPPENS. THE LI-6200 IS LOCKED UP AND WON'T RESPOND.

(1) Press **BRK** (that's **SHIFT** + **P**) to get control of the instrument again. (If that doesn't work, power it off, then on). The reason for the apparent hang-up is that the LI-6200 must see line 5 (Clear to Send) high before it will send or receive anything.

If you are using an old-style Printer Cable (with labels "LI-6000 ONLY" and "PRINTER ONLY" at either end), reverse the cable. This type of cable will work with the LI-6200 only if you ignore the labels, and connect the "PRINTER ONLY" end to the LI-6200.

(2) If you are not using the Printer Cable, try it. If you are, then try not using it.

"CTS NOT HIGH" or "DSR NOT HIGH" or "CD NOT HIGH"

The LI-6200 is attempting to send data out the RS-232 interface, and one of the control lines of the RS-232 interface is not in the correct state. CTS is pin 5, and must be seen for the LI-6200 to transmit data. DSR is pin 6, and must be seen if the I/O parameter CHECK DSR is set to Y. CD is pin 8, and must be seen if the I/O parameter CHECK CD is set to Y.

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WHAT IS PRINTED IS JUST GARBAGE.

(1) If some of the characters are correct, then it's probably a parity problem. Try a different setting; there are 5 to choose from (O,E,N,1,or 0 for Odd, Even, None, 1's or 0's).

(2) If none of the characters are correct, or if only a few characters come out at all, then the problem is probably with the baud rate.

(3) If the first two suggestions don't help, then try a different number of data bits and stop bits.

LARGE SECTIONS OF THE DATA APPEAR TO BE MISSING WHEN IT GETS PRINTED. WHAT'S THERE IS OK, BUT EVERY SO OFTEN IT SEEMS TO SKIP A LOT OF DATA.

This is a handshake problem. The printer can't print as fast as the LI-6200 can send data, and when the printer's buffer gets full, it tries to signal the LI-6200 to stop. For some reason, the LI-6200 ignores the stop request, and keeps on sending data, which the printer ignores until its own buffer empties out.

Determine how the printer is trying to handshake. It is probably either XON/XOFF, or it is using a control line such as DTR. The LI-6200 supports both of these methods, which are implemented by setting the appropriate entry in the I/O PARAMETER list to 'Y'.

XON/XOFF comments: Make sure that the XON character and XOFF character as defined in the I/O PARAMETER list are 11 and 13 respectively. These are the standard characters used for this handshake; these are HEX values specifying the <DC1> and <DC3> control characters.

CHECK DSR comments: The LI-6200 looks at pin 6 (DSR) when this handshake is enabled. If your printer or computer is using some other line for a pacing mechanism, then it must be somehow tied to pin 6 so the LI-6200 will see it. Note that the Printer Cable exchanges lines 6 and 20 (DTR), so if your printer is using DTR as a handshake, the LI-6200 will see it on pin 6 when you use the Printer Cable.

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MAINTENANCE

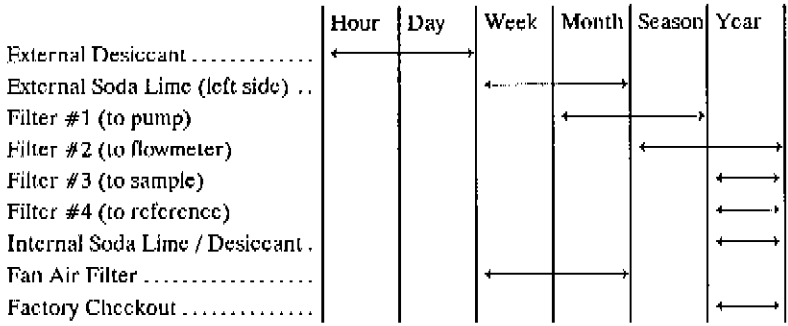
This chapter details the major maintenance procedures that you should follow for the LI-6250 Gas Analyzer, for leaf chambers, and for the rechargeable batteries.

We strongly recommend the LI-6200 be returned to LI-COR on an annual basis for a thorough check out and recalibration. Refer to 6200CAL on the price list.

LI-6250 Gas Analyzer

The LI-6250 has a maintenance sticker attached reminding you of important things to check, and how frequently they should be done:

LI-6250 Maintenance

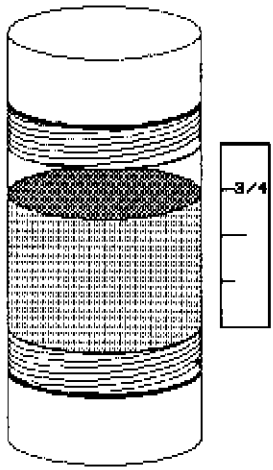


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DESICCANT TUBE

A test for the adequacy of the desiccant is described on page 5-6 of this manual.

No desiccant is shipped with the LI-6200; it must be supplied by the user. Magnesium perchlorate $Mg(ClO_4)_2$ is the recommended desiccant, since it does not interact with CO_2. *Do not use any other desiccant.* Several grades of magnesium perchlorate are available from commercial suppliers. In general, the more granular (as opposed to powdery) the grade the better. One type that works well is marketed under the name *Dehydrite*, and is available (catalog number C260-M61) from Aurthur Thomas Company, Vine St. & 3rd, Philadelphia, PA 19105. (215) 574-4500.



Make sure that the filter paper discs on either end cap are not clogged (reduces the maximum flow rate) or torn. Adhesive-ringed replacement discs are included in the spare parts kit.

Fill the desiccant tube 3/4 full. This leaves room for the desiccant to be shaken periodically.

Magnesium perchlorate cannot be regenerated after use. Dispose of down a sink drain with a generous amount of water.

CAUTION

Magnesium Perchlorate is a strong oxidizing agent. Contact with skin or mucus membranes may cause irritation. Avoid bringing it into contact with acids and organic substances such as cotton, rubber, grain dust, etc. Consult the container label.

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SODA LIME TUBES

A test for the adequacy of the soda lime is described in the Pre-operation Tests section of this manual. This test should be done on at least a monthly basis.

There are two soda lime tubes attached to the outside of the LI-6250. The one on the left (attached to the **TO SCRUB** and **FROM SCRUB** fittings) is an optional one that only is utilized when the flow switch is set to **SCRUB ON**. Its main purpose is for providing 0 ppm for purposes of setting the zero when calibrating.

The other soda lime tube is on the right side of the LI-6250 housing. Its purpose it to keep the air in the chopper housing of the CO_2 analyzer's optical bench purged of CO_2. When configured for absolute mode, the reference cell of the analyzer is also included in this closed circuit.

As the optional scrub soda lime (left side) loses its ability to scrub CO_2 from the air stream, it will be noticed as a slight loss of stability when zeroing the analyzer. That is, rather than the reading being very stable when zeroing, it will jump around a little bit - especially if you breathe into the leaf chamber. Good soda lime will easily remove all the CO_2 from your breath, and worn out soda lime won't. (Obviously, this "breath test" *does* shorten the life of the soda lime a little bit, so should be done sparingly).

As the chopper-scrub soda lime (right side) becomes depleted, it will be noticed as a general loss of stability and linearity. The analyzer will start responding to ambient CO_2 fluctuations (blowing your breath into the LI-6250 housing will cause the CO_2 reading to decrease, for example), and there will be a tendency for the zero to decrease over time.

How often should the soda lime tubes be changed? This obviously depends upon how much CO_2 they've been forced to remove. If the chopper scrubber is left connected, it should last several months; once it removes the initial CO_2 from the circuit, the only other CO_2 it will see will be from the tiny leaks that exist in the system. The left hand soda lime will not last as long, since it will be (should be) used many times each day to keep the analyzer zeroed.

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A suggested maintenance pattern: whenever you find the left hand soda lime tube needs fresh soda lime, replenish it and then exchange it with the tube on the chopper circuit. This will keep the best soda lime in the place where it's hardest to detect when it will need changing.

The soda lime tubes should be packed full, and a small wad of fiberglass or polyester wool filling put in to keep the pellets from shaking.

REPLACING VELCRO

Spare velcro style fastening material is provided in the spare parts kit for replacing the loop-material on the desiccant and soda lime tubes when it wears out.

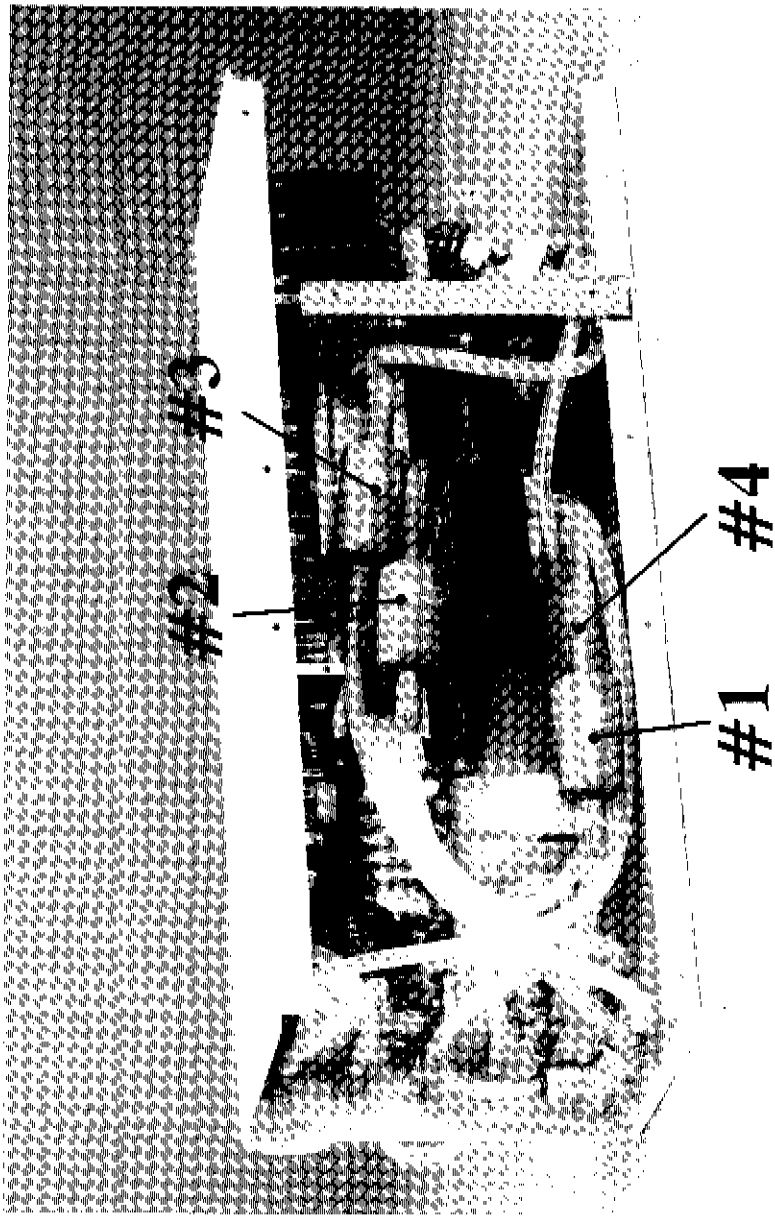
After you peel off the old material, you will probably want to clean up the adhesive from the outside of the tube before applying the new: *DO NOT USE ANY SOLVENTS TO DO THIS, AS IT WILL DAMAGE THE TUBE.* Clean the old adhesive off mechanically, or at the most, use soap and water or alcohol.

OPENING THE LI-6250

To get inside the LI-6250, remove the 4 phillips head screws in the corners on the top side of the box, and all screws on the bottom side of the case. The bottom shroud will now come free from the housing.

BE CAREFUL: The fan motor wires are connected to the fan switch wires by a white connector. Unplug this connector.

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INTERNAL AIR FILTERS

There are 4 internal air filters, and they are disposable. Extra filters are provided in the spare parts kit.

Filter #1 (see figure on page 8-5) protects the pump from external dirt, #2 protects the flowmeter from magnesium perchlorate, #3 protects the sample cell, and #4 protects the reference cell. The frequency with which these should be replaced depends upon how the LI-6250 is configured, and how dirty the environment is in which it has been working.

As configured for the LI-6200, filter #1 will become dirtiest the fastest, and filter #4 the slowest.

INTERNAL SODA LIME / DESICCANT

There is a small plastic bottle inside the LI-6250 that contains a mixture of soda lime and $Mg(ClO_4)_2$. This bottle is attached to the CO_2 analyzer's detector. Its purpose is to keep the detector free of CO_2 and its dewpoint below -12C.

If the CO_2 concentration in the detector rises, the linearity of the response will change. This means the factory supplied calibration function will be invalid. If the dewpoint in the detector rises to -12C, condensation will form, and there will be a large shift in the zero and/or span. The **READY** indicator will probably also fail to light.

The contents of the bottle should be changed on an annual basis. Note that the end cap stays attached to the detector. To change the contents, prepare a second bottle (in the spares kit, along with some instructions) by half filling with soda lime, then fill the remaining space with magnesium perchlorate. Unscrew the old bottle from the end cap, and screw the new bottle back on.

When the bottle is changed, allow some time period (1 hour to 1 day) for the detector to be come into equilibrium again. The time will depend, of course, on how much CO_2 had gotten into the detector.

Make sure that the rubber sealing washer in the lid of the bottle is intact, and the fibrous plug is in place to hold the chemicals so they

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don't fall into the detector housing.

HOSE CONNECTORS

Take a close look at one of the mating connectors (at the end of one of the air hoses from the desiccant tube, for example). Down inside you will see a small, black rubber O-ring. This O-ring must have a *tiny* amount of silicon grease (there's some in the spare parts kit) applied to it every few months. If the O-ring gets dry, the connector will be VERY difficult to screw onto the LI-6250 fitting; it will feel like the threads are cross threaded.

When you apply grease to this O-ring, the best method is to put the grease on the lip of one of the fittings on the LI-6250, and then screw the connector to be greased down onto it.

FAN FILTER

The external air filter should be cleaned or replaced as needed. Remove the 4 screws and the plastic grating in front of the filter to access the filter material.

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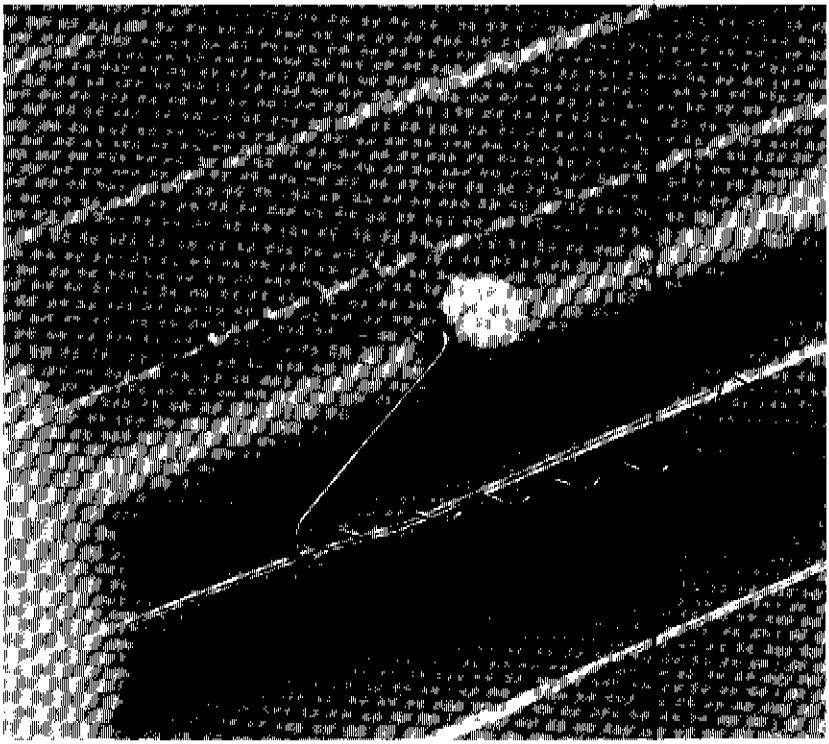
Leaf Chambers

CLEANING

The best way to clean a chamber is to remove it from the sensor housing, then wipe it with a damp cloth. *Do not use any solvents.*

REMOVING / REPLACING CHAMBERS

1. Unhook the leaf temperature sensor from the monofilament support lines. This is done one leg at a time by rotating the wire leg in the appropriate direction so that it comes free from the line, as shown below:



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2. Unplug the fans and quantum sensor, and remove the 4 knurled nuts from the back of the sensor housing.

3. Lift the sensor housing from the chamber, and carefully guide the thermocouple out of the chamber hole.

BE CAREFUL WITH THE SENSOR HOUSING AND THE EXPOSED SENSORS - ESPECIALLY THE HUMIDITY SENSOR. It is expensive, and if you touch it (the chip - not the white protective shield), it will probably have to be replaced.

To mount another chamber on the sensor housing, reverse the last three steps.

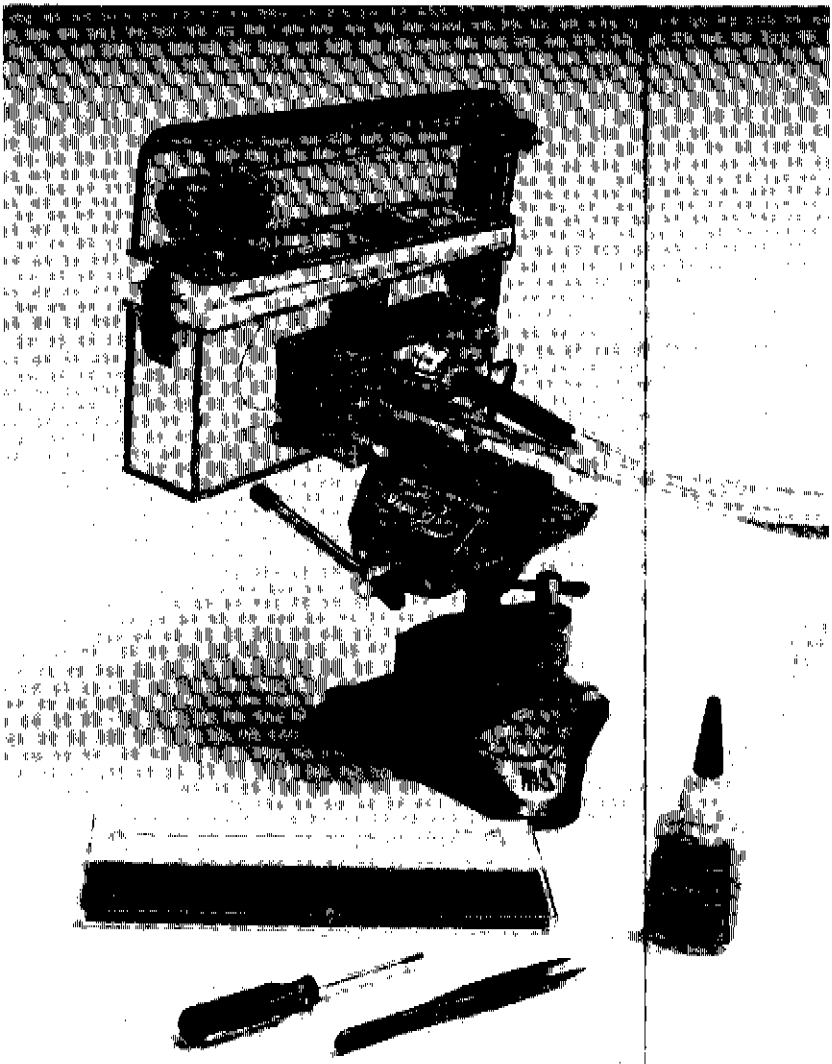
REPLACING THE THERMOCOUPLE

The leaf temperature thermocouple will last a long time *if you are careful with it.*

If the leaf temperature thermocouple is broken, the leaf temperature will read the same as air temperature. To replace a thermocouple, you will need a small pair of pointed tweezers, a small screwdriver, some adhesive, a means to hold the sensor housing while you work (a vise), and a spare thermocouple.

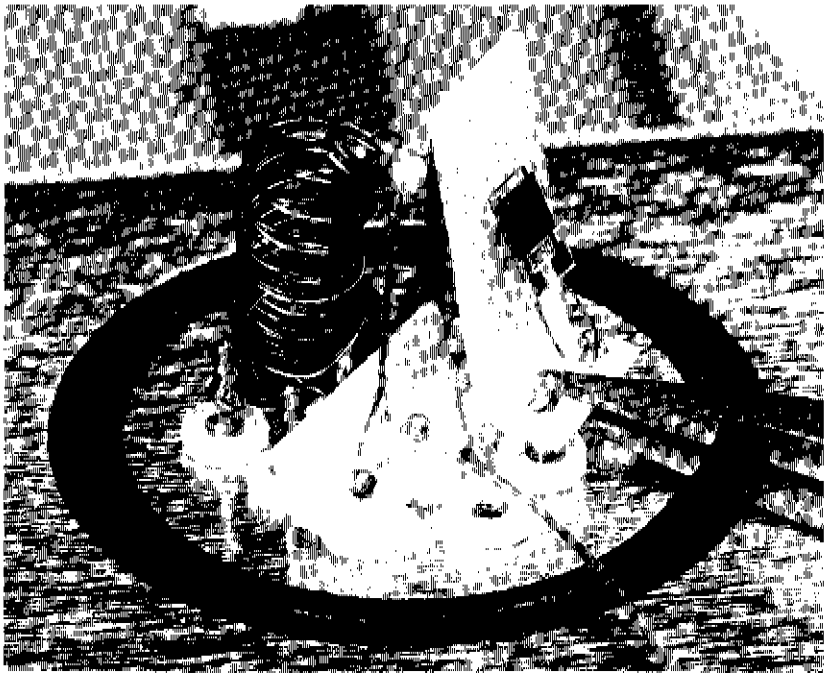
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1. Remove the chamber from the sensor housing, and mount the sensor housing firmly in a vise.



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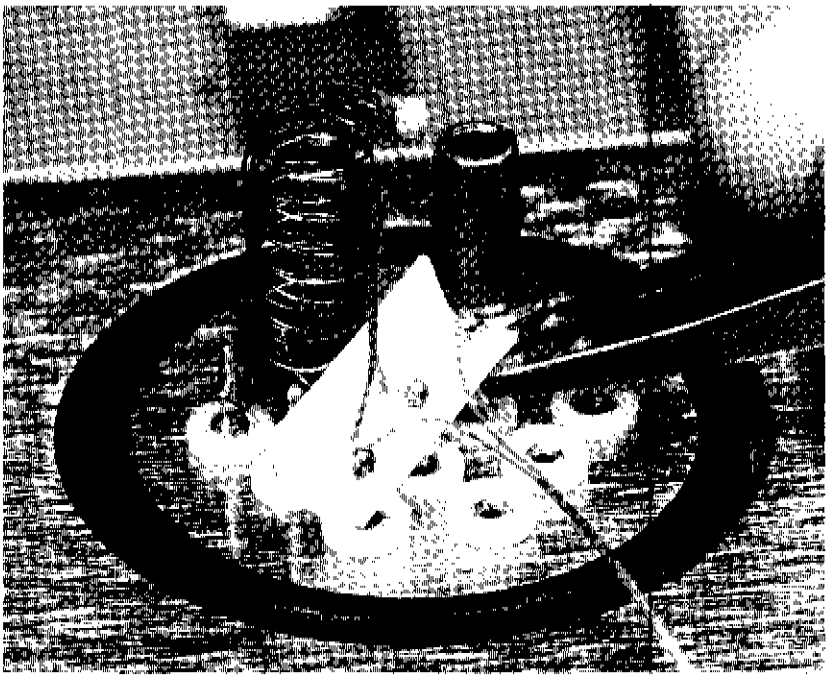
2. Use the tweezers to remove the humidity sensor. Grab onto the bottom of the white protective shield, and gently pry it out of the sockets. When removed, lay it down *in a very safe place* with the *white plastic side DOWN.*



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3. Notice that the short (reference) leads go to the thermistor bead. GENTLY try to pop the reference junction off the bead. If it won't pop off, cut the reference leads very close to the junction.

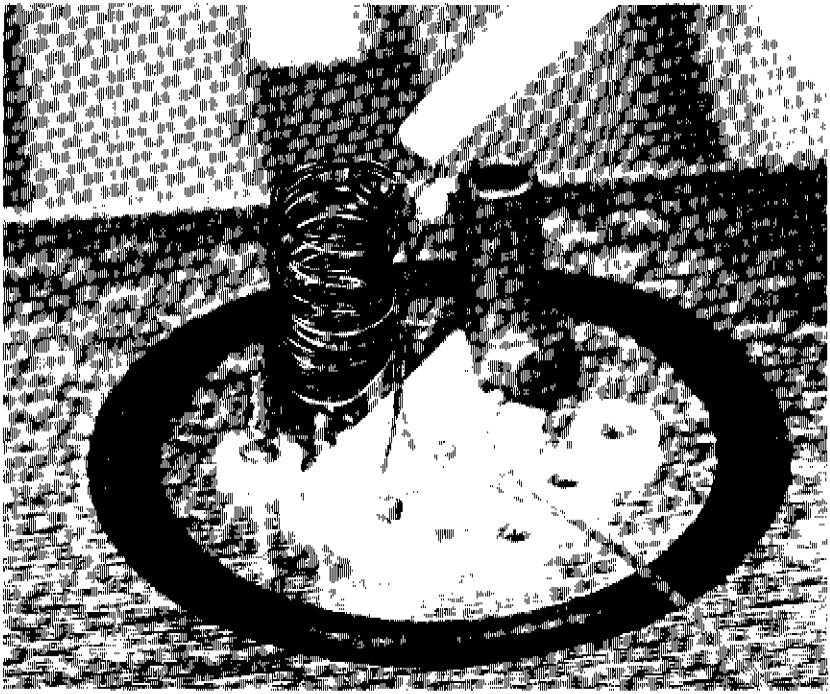
4. Use the tweezers to pry up the thermocouple, alternately working each leg up a little at a time.



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5. Install the replacement thermocouple, *making sure the pins are in the correct holes.*

6. Loop the reference junction (you will probably have to use the tweezers to *gently* widen the loop) over the thermistor bead, and glue the reference bead to the thermistor bead.



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7. Re-install the humidity sensor. Position it as shown in the prior photograph, so that the white plastic faces the nearest fan.

8. Put the leaf chamber back onto the sensor housing, and install the thermocouple onto the monofilament lines.

9. Adjust the thermocouple zero (instructions below).

LEAF TEMP ZERO ADJUSTMENT

The leaf temperature sensor should be set whenever a new thermocouple is installed, or whenever the leaf and air temperatures are not within 0.1 °C in a closed, shaded chamber with dry filter paper covering the thermocouple.

1. Close the chamber onto a piece of dry filter paper, so that the paper is in contact with the thermocouple.

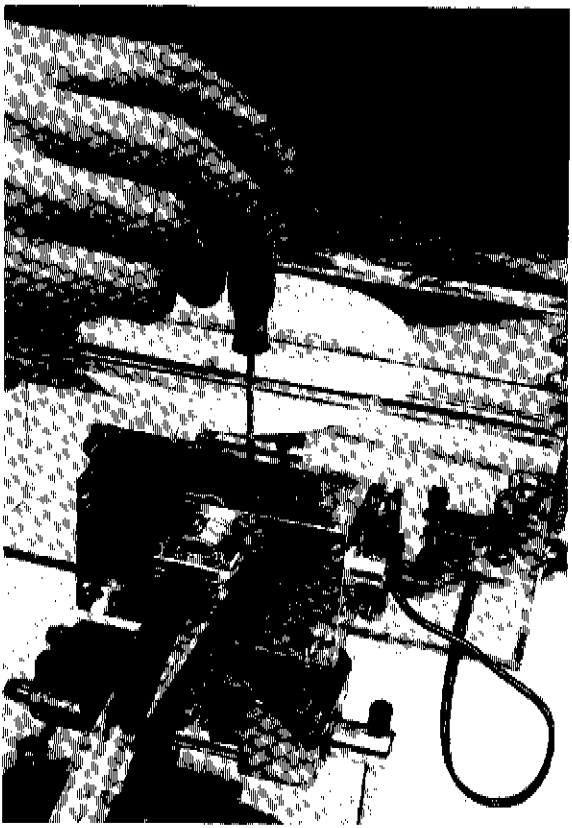
2. Monitor leaf and air temperature on the console display, and turn on the chamber fan(s).

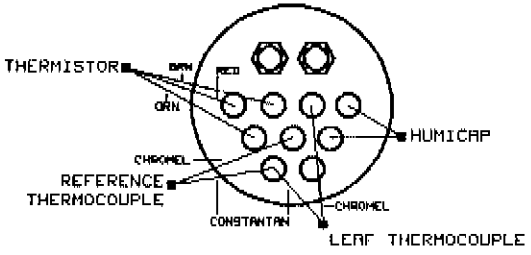
3. The two temperatures should be within 0.1 degrees of each other. If they are not, continue on.

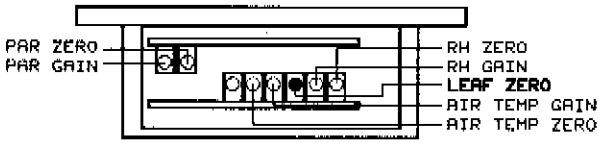
4. Remove the top plate from the sensor housing by removing the 4 screws in the corners.

5. After a minute or two, adjust the leaf temperature offset potentiometer with a small screwdriver. As shown in the photograph, this is the 3rd potentiometer from the right (fan switch side).

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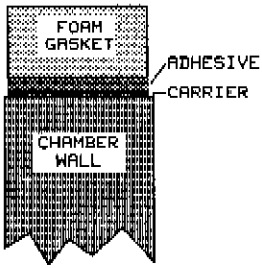




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REPLACING GASKETS

Replacement of the foam gaskets is a fairly simple task provided you peel up the old gasket correctly.



With a fingernail or knife, try to pry up a corner of the gasket, *getting the carrier*. If you only pry up the foam and adhesive, you'll have a real mess. If you get the carrier, it will all come off quite readily.

The replacement foam is ready to install after you peel off the backing. WORK CAREFULLY. Once it touches something, you won't be able to adjust it.

If you look at the adhesive on the foam once you've pulled the backing off, you may notice some indentations and channels. Notice too that these disappear if you bend the gasket in such a way as to stretch the adhesive surface slightly. The moral is this: *If you simply stick the gasket onto the chamber, those channels and indentations will become leaks.* The best technique is to start at one end or side of the chamber, curl the gasket up to stretch the adhesive, and apply to the chamber with sort of a rolling motion, so the adhesive is flat as it goes down.

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Batteries

RECHARGING

Batteries should be fully recharged as soon as possible after use. *STORING A BATTERY IN A DISCHARGED STATE CAN RUIN IT.*

Make sure the charger is set to the correct line voltage. There is a small 115V / 230V slide switch on the back panel.

The battery charger has 2 LEDs on the front panel. The AC light stays illuminated as long as the charger is plugged in to AC power. The CHARGE light will illuminate while a battery is being fast-charged; when the light is off, any connected battery is being trickle-charged.

For best results, charge batteries overnight. If charging 1 battery, it typically takes about 2 hours (4 hours for 6200B) for the fast-charge light to go off. At that point, the battery is probably 80 to 90% re-charged. The more batteries that are connected, the longer the recharge time will take.

The LI-6200 will run (with everything on - pump, fans, etc.) for 2 hours on a fully charged, full capacity 6000B battery. As the battery ages, this life typically shortens. Deep cycling can help a battery recover lost capacity. To deep cycle a battery:

1. Use the battery until the instrument beeps (battery voltage at 10.5 V).

2. Recharge the battery until the fast-charge light goes out.

3. Connect another *discharged* battery to the charger. This will force the first battery to get another 2 hours of fast-charge mode.

Repeat steps 1 thru 3 until the battery life improves.

STORING

STORE BATTERIES FULLY CHARGED, and in a cool place, if

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possible.

For long term storage, place the batteries on the charger overnight every 3 months.

System Console

CLEANING AND DISASSEMBLY

The console exterior, including the keypad overlay and display window, can be cleaned with a damp, soft cloth.

The following disassembly procedure will not affect the instrument's memory as long as all boards remain fully seated.

1. With power OFF, disconnect the main battery, analyzer, and sensor housing from the console. Remove the battery from the console case.

2. Turn the console case bottom side up, and remove the four screws from the bottom. Keep the keyboard supported when you do this.

3. Carefully remove the card cage and keyboard from the blue box. There are cables on the top and right sides of the card cage, so be careful not to snag or pinch them.

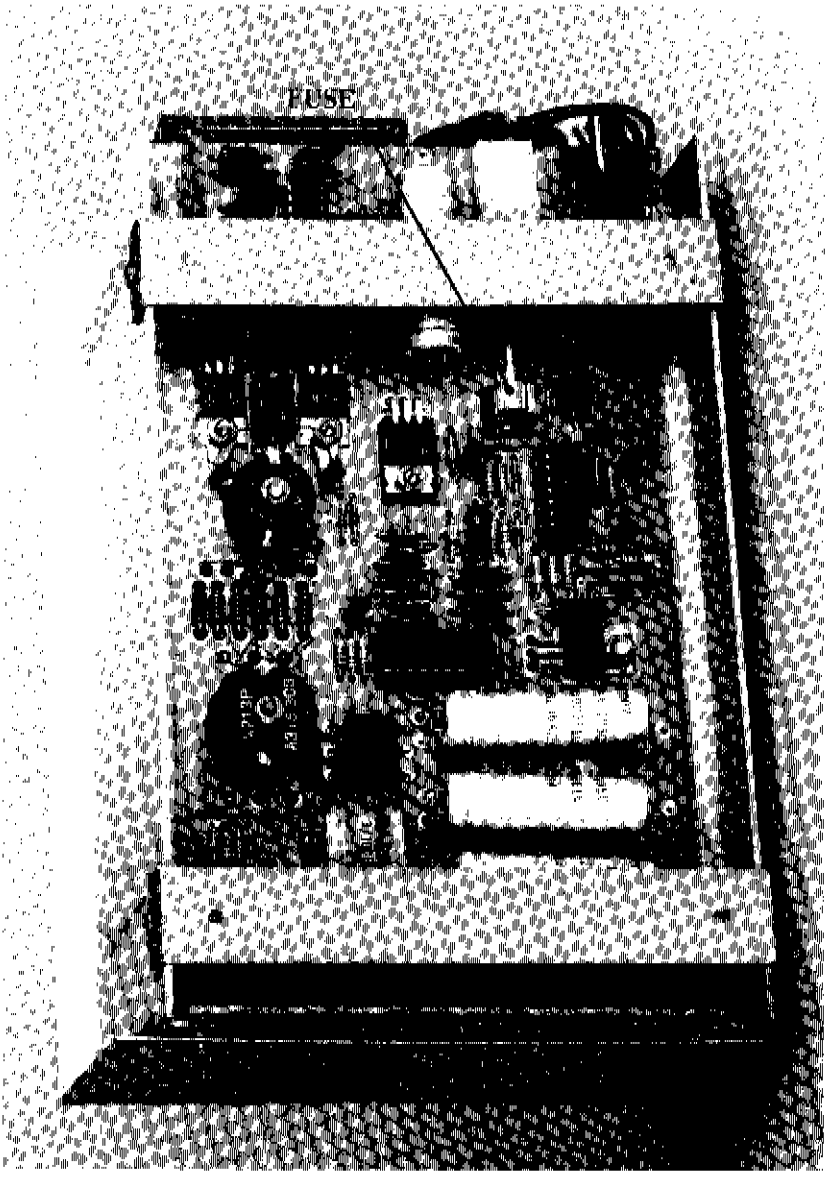
4. Wipe out any dust and debris from the blue box.

FUSE REPLACEMENT

Disassemble the console.

The fuse is indicated in the photograph. If it needs to be replaced, do so *without* removing the printed circuit board. The fuse is 250 V, 2 Amp fast blow, and there are some in the spare parts kit.

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TROUBLESHOOTING

This section summarizes some things that might go wrong, and suggests what to do about them should they happen to you.

Console

POWER ON PROBLEMS

Nothing Happens.

Try another battery. Try a battery and the charger together. Disconnect the analyzer and sensor housing, and try it. Check the fuse.

Display flickers, then goes out.

The instrument is probably shutting itself down because it sees the battery voltage as too low (<10 V). Try another battery, or pair of batteries, or the charger together with a battery. Disconnect the sensor housing and analyzer, in case one of those has a problem and is putting too much of a load on the system.

CLOCK LOSES TIME

If this happens with no battery plugged into the console, then it may be the first indication of a problem with the internal backup battery. This battery also holds the RAM, so be sure to check all tables for proper values, and avoid leaving the console with no batteries plugged into it. (The backup battery is charged from the main battery. A healthy backup battery should hold the RAM for months, but if there is data in the console you don't wish to lose, it's a good policy never to leave it without a battery plugged in.)

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ERROR AND WARNING MESSAGES

"COMMO ERROR - PRESS ANY KEY"

This message will occur at power up if the terminal and the 6200 computers failed to establish communications. Press **RTRN** several times, and they should start communicating. If that fails, there are 2 other possibilities: the LI-6200 computer is not functioning, or the cable connecting the two boards is disconnected. You can check the latter by taking the card cage out of the blue box, and making sure all connectors are fully seated. The cable in question here is a 4 wire ribbon cable that connects the CPU board to the display board.

"ERROR PROM n"

At power up, the LI-6200 does a checksum test on its Erasable Programmable Read Only Memory. If an EPROM fails the test, it is indicated with this message. Contact LI-COR. It can also occur if one of the pins on an EPROM is bent under, instead of being in the socket, and making intermittant contact.

"RESETTING RAM"

If this message occurs on power up, then it means the system RAM was found to be unconfigured. If the console had been disconnected from a battery, then perhaps the internal backup battery has failed. The following will need to be set by you:

Clock (**FCT** **43**)
Quantum Calconstant (**FCT** **44**)
CO_2 Calibration (**FCT** **45**)
Flow Calibration (**FCT** **46**)
RH Calibration (**FCT** **47**)

If the user RAM is still intact, then the calibration files can be retrieved from there, since the factory lists are stored as file 1 for CO_2, flow, and RH. (That is, do the following: **FCT** **45** **GET** **1** **RTRN** **FCT** **46** **GET** **1** **RTRN** **FCT** **47** **GET** **1** **RTRN** to retrieve the three calibration lists).

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"RESETTING BANK xx"

At power up, if the LI-6200 detects a 32K bank of user RAM that is unconfigured, it will clear and reset it. "xx" in the message is the hex address of the bank, such as 80. This occurs at the factory when a RAM board is first installed. Should this happen to you, it probably means the console was left disconnected from any batteries, and the internal backup battery has failed.

"RAM CLOBBERED"

If during a file access (GET, STORE, etc.) a file's address is determined to be out of the range of memory, it is assumed that something bad has happened to some or all of the memory, and this message is displayed as a warning to you. Should this ever happen, do the following:

1) Get a printout (if you wish) of whatever files you can still retrieve.
2) Perform FCT DF to clear and reset the user RAM.

"PAD FULL - PRESS ANY KEY"

If the scratch pad becomes full during logging, this message is displayed. This can happen accidentally if you connect or disconnect the sensor head while the console is powered up (this triggers a log), and then not notice that the console is logging. If this happens while you are trying to log data, then the obvious solution is to shorten the logging period, or increase the STEP parameter so not as many samples are collected. If you are collecting multiple observations during the measurement, then this problem can be avoided by setting STORE SMP to N, so the samples are flushed from the pad after each observation is completed.

"CTS NOT HIGH"
"DSR NOT HIGH"
"CD NOT HIGH"

See page 7-5.

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"DIFFERENT SYSTM - Press Key..."

This message will occur when a page is retrieved that has been stored under a system different than the present one. The system number (SYS in the page header when printed) is defined as the file number of the current E3 list. This number appears on the bottom line of the display in PAUSE mode, followed by the E3 list label. If you never access, edit, and store the E3 list, then this message will never appear. Consult the **Technical Reference** for further details.

Sensor Housing

FANS DON'T RUN

Is the switch on (switch positioned toward the outside of the sensor housing)? Wiggle the fan connector with the switch in the on position. Look for a broken fan wire on the chamber.

To determine if the problem is the sensor head or the fan motor, try plugging the fan from another chamber (if you have one) into the sensor head. If you have no other chamber, then unplug the fan, and apply 12V DC to the fan plug.

BLOWS FUSE WHEN FANS TURNED ON

Unplug the fan and and turn on the fan switch. If this blows the fuse, then the problem is in the sensor head. If this doesn't blow the fuse, then look for a short in the fan jack, or in the fan wires or motor.

PAR READINGS

Is the quantum sensor connected? Do FCT **44** and set the calibration constant.

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LEAF TEMPERATURE READINGS

If leaf and air temperature are always identical, then replace the leaf temperature thermocouple. It is broken.

RELATIVE HUMIDITY READINGS

Either the humidity sensor is broken, or else there is a problem with the software transformations done on the signal. Channel 03 is the millivolt signal from the humidity sensor. 0mV is 0% RH, and 4096mV is 100% RH. If channel 03 behaves (viewed by FCT **03** in MONITOR mode), but channel 17 doesn't, then the problem is either with the humidity lookup table, accessed by FCT **47**, or the multiplier value (system constant C7) has been changed.

The humidity lookup table should match the table on the factory calibration sheet. This table has 5 data points, and spans the range 0 to 100% RH. If the measured humidity is beyond the range of the table, the table will return a value of 99999.

To check the multiplier value, press FCT **C7**. The display should indicate that C7 is 0.024414. If it is, then press **RTRN**. If it isn't, then enter this value and press **RTRN**.

If channel 03 seems pegged at 5000mV, then the RH sensor is broken.

LI-6250 Gas Analyzer

READY LIGHT WON'T ILLUMINATE

The ready light will go out for a number of reasons; some of them you can fix yourself.

- Ambient temperature greater than about 55° C.
- Too high CO_2 in the reference cell. Is there a leak in the chopper scrubber soda lime tube? Is that soda lime any good?
- The internal soda lime / desiccant bottle could be leaking, or the soda lime no good.

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Otherwise, contact LI-COR.

CO_2 READINGS

FCT 05 while in MONITOR mode will allow you to monitor the mV signal from the analyzer. The range will be between -5 and +5 volts, and 0 volts will should be 0 ppm. If the mV reading seems to respond OK, but the calculated gas concentration seems in error, then the problem may software related. Verify that the following are set correctly:

- CO_2 calibration list (FCT 45).
- CO_2 reference routine (FCT 49).

If the mV reading seems abnormal (doesn't change, for example), check the following:

- The electrical connector between the console and the analyzer.
- Is the READY indicator lit?
- Is the analyzer configured correctly (jumpers, soda lime, etc.)?
- Is there flow through the analyzer? Set DES ON, and see what the flowmeter indicates.

CO_2 ANALYZER DIFFICULT TO ZERO

Make sure both soda lime tubes contain fresh soda lime. Check for leaks on the desiccant tube (caps on tight) and soda lime tubes. Check for internal leaks.

FLOW READINGS

FCT 07 while in MONITOR mode will allow you to monitor the mV signal from the flowmeter. The range will be between -5 and +5 volts, and 0 volts will should be 0 flow. If the mV reading seems to respond OK, but the calculated flowrate seems in error, then the problem may be software related. Verify that the following are set correctly:

- Flow calibration list (FCT 46).
- Flow software zero (FCT 48).

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If the mV reading seems abnormal (doesn't change, for example), check the following:

- The electrical connector between the console and the analyzer.
- How do the other channels from the LI-6250 behave (CO_2 and IRGA gas temperature, FCT 05 and FCT 04, respectively)?

Strange Results

If you have modified the LI-6200's programming (after studying the **Technical Reference**), then the first place to look if you are getting strange results is at your modified program.

Are the page parameters (leaf area, system volume, etc) set correctly? Correct units?

CONDUCTANCE TOO LOW

- Humidity reading too low.
- Flowmeter reading too low.
- Leaf area too high.
- Volume too high (if not steady state conditions).
- Bad contact between leaf thermocouple and leaf, with $T_{leaf} > T_{air}$.
- DE/DT too large (>0), especially if K_{abs} is set to too small a number.
- DE/DT too large (<0), especially if K_{abs} is set to too large a number.

CONDUCTANCE TOO HIGH OR NEGATIVE

- Humidity reading too high.
- Flowmeter reading too high.
- Desiccant not adequate.
- Volume too low (if not steady state conditions).
- Leaf area too low. If it is low enough to make the leaf resistance come out smaller than the boundary layer resistance, then the stomatal resistance (and conductance) will be negative.
- Bad contact between leaf thermocouple and leaf, with $T_{leaf} < T_{air}$.

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- DE/DT too large (>0), especially if K_{abs} is set to too large a number.
- DE/DT too large (<0), especially if K_{abs} is set to too small a number.

PHOTOSYNTHESIS TOO LOW (HIGH)

- CO_2 analyzer calibrated correctly? Are you sure of your span gas?
- Volume too low (high).
- Leaf area too high (low).
- Pressure parameter too low (high).

INTERCELLULAR CO_2 TOO LOW (HIGH)

- Photosynthesis too high (low).
- Stomatal conductance too low (high).

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