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LI-6200
Technical Reference

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LI-6200
Technical Reference

March 1990

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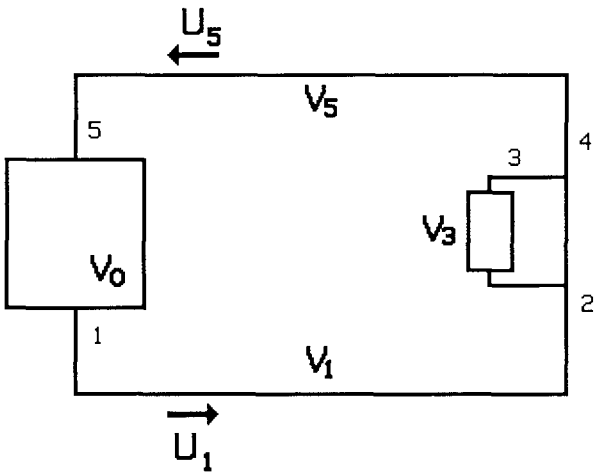
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System Equations

The derivation of the transpiration and photosynthesis equations is based on an analysis of the mass balance of water and CO_2 in the LI-6200 system. The LI-6200 can be represented schematically as a chamber with an external, closed loop. Part of the flow through the external loop has the potential of going through a secondary desiccant loop. Air exiting the chamber (location 1) is assumed to have the same properties as the air in the chamber, where temperature and humidity are measured. CO_2 is measured at location 4.



The following variables are used in the derivation:

E	mol m^{-2} s^{-1}	Transpiration rate of a leaf in the chamber.
A	μmol m^{-2} s^{-1}	Photosynthetic rate of a leaf in the chamber.
s	m^2	Leaf area in the chamber.
v_0	m^3	Chamber volume.
v_1	m^3	Volume from chamber to desiccant.
v_3	m^3	Desiccant volume.
v_5	m^3	Volume from desiccant to chamber.
u_1	mol s^{-1}	Flow rate leaving the chamber.
u_5	mol s^{-1}	Flow rate entering the chamber.
f		Fraction of flow that is diverted through desiccant.
w_n		Mole fraction of water vapor at location n (n = 1,3,5).
c_n		Mole fraction of CO_2 at location n (n = 1,3,5).
Δt_n	s	Time for air to move through volume v_n (n = 1,3,5).
ρ	mol m^{-3}	Density of air.

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Transpiration

The mass balance of water in the system is given by

$$s\ E = v_0\ \rho\ \frac{\partial w_1}{\partial t}\ K_{abs} + u_1\ w_1 - u_5\ w_5 \tag{1.1}$$

Equation (1.1) allows for non-steady state conditions with respect to water by including the $\partial w/\partial t$ term, although water absorption of the system will cause underestimates of the magnitude of $\partial w/\partial t$. (For simplicity, we assume density ρ is a constant). To account for this in conditions where it is not possible to hold w constant, the factor K_{abs} is included. K_{abs} is determined empirically with an empty chamber test, and typically has a value of about 1.1 for a clean chamber and fresh desiccant.

$$u_1 = u_5 + s\ E \tag{1.2}$$

$$w_4 = w_2\ (1 - f) \tag{1.3}$$

$$w_5 = w_4 - \frac{\partial w_4}{\partial t}\ \Delta t_5 \tag{1.4}$$

$$w_2 = w_1 - \frac{\partial w_1}{\partial t}\ \Delta t_1 \tag{1.5}$$

$$\Delta t_1 = \frac{v_1}{u_1}\ \rho \tag{1.6}$$

$$\Delta t_5 = \frac{v_5}{u_5}\ \rho \tag{1.7}$$

Assuming rates of change are constant, equations (1.1) thru (1.7) combine to form

$$E = \frac{f\ u_5\ w_1 + \rho \left[v_0 + (1 - f)(v_1 + v_5) \right] \frac{\partial w_1}{\partial t}\ K_{abs}}{s\ (1 - w_1)} \tag{1.8}$$

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In terms of quantities that the LI-6200 uses, we use the following relationships to rewrite Equation (1.8). The LI-6200 volume parameters V_t (total volume) and V_g (IRGA volume) are in cm^3 and leaf area is in cm^2, so

$$(v_0 + v_1 + v_3 + v_5)\ \{m^3\} = V_t\ \{cm^3\} \times 10^{-6} \tag{1.9}$$

$$(v_1 + v_3 + v_5)\ \{m^3\} = V_g\ \{cm^3\} \times 10^{-6} \tag{1.10}$$

$$s\ \{m^2\} = S\ \{cm^2\} \times 10^{-4} \tag{1.11}$$

Density of air is computed from the pressure parameter P {mb} and the measured air temperature {C}. The gas constant R is 8.314.

$$\rho \left\{ \frac{mol}{m^3} \right\} = \frac{P\ \{mb\}\ 100 \left\{ \frac{N/m^2}{mb} \right\}}{R \left\{ \frac{N\ m}{mol\ K} \right\} T\ \{K\}} \tag{1.12}$$

The mole fraction of water in the chamber is the ratio of the vapor pressure to the total pressure:

$$w_1 = \frac{e\ \{mb\}}{P\ \{mb\}} \tag{1.13}$$

The LI-6200 measures flow rate F_d $\{\mu mol\ s^{-1}\}$ going through the desiccant. The maximum flow rate parameter F_x $\{\mu mol\ s^{-1}\}$ is measured when all of the flow is diverted through the desiccant. Although f is the fraction of flow u_1 that is diverted through desiccant, we make the approximation that it is simply the ratio of F_d to F_x.

$$f \simeq \frac{F_d\ \{\mu mol\ s^{-1}\}}{F_x\ \{\mu mol\ s^{-1}\}} \tag{1.14}$$

The return flow rate u_5 is assumed to be close to the maximum flow rate F_x.

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$$u_5 \ \{mol\ s^{-1}\} \simeq F_x \ \{\mu mol\ s^{-1}\} \times 10^{-6} \qquad (1.15)$$

Substituting Equations (1.9) thru (1.15) into Equation (1.8) yields the equation used by the LI-6200 to calculate transpiration rate.

$$E = \frac{\dfrac{F_d\ e}{100\ P} + \left(\dfrac{K_{abs}}{8.314\ (T_a + 273)}\right)\left(V_t - \dfrac{F_d}{F_x} V_g\right)\dfrac{\partial e}{\partial t}}{S\left(1 - \dfrac{e}{P}\right)} \qquad (1.16)$$

Parameter	Units	System Reference	Description
T_a	C	12	Chamber air temp
F_d	μmol s^{-1}	16	Flow through desiccant
e	mb	18	Vapor pressure of air
$\partial e/\partial t$	mb s^{-1}	19	Rate of change of e
E	mol m^{-2} s^{-1}	25	Transpiration rate
P	mb	A0	Atmospheric pressure
S	cm^2	A1	Leaf area
V_t	cm^3	A2	Total volume
F_x	μmol s^{-1}	A5	Max flow rate
V_g	cm^3	A6	IRGA volume
K_{abs}		A7	Absorption coefficient

Note that the volume term in Equation (1.16) is not exactly equal to the volume term in Equation (1.8). At $F_d = F_x$ they are the same, but at $F_d = 0$, the Equation (1.16) volume will be greater by the desiccant volume. We rationalize this simplifying assumption by noting that the volume term is only important when $\partial e/\partial t$ is not near zero, and that the only time that this should be the case (except for user inattention) is when even maximum desiccant flow (F_d near F_x) is not sufficient for holding vapor pressure constant.

With no leaf in the chamber (E = 0), Equation (1.16) can be solved for K_{abs}.

$$K_{abs} = -\frac{F_d\ e\ (T_a + 273)\ .08314}{P\left(V_t - \dfrac{F_d}{F_x} V_g\right)\dfrac{\partial e}{\partial t}} \qquad (1.17)$$

K_{abs} can be determined from Equation (1.17) for data collected with no leaf in the chamber and some flow through the desiccant. Refer to the K Test section in the **Primer** for a discussion of the meaning of this value. Channel 23 in the LI-6200 is defined to calculate Equation (1.17); the value is meaningful only for an empty chamber test, however. *Also, the way channel 23 is defined, if leaf area is 0.0, then K_{abs} will be 0.0.*

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Stomatal Conductance

Total conductance to water g_{tw}, is the proportionality factor relating transpiration rate E to its driving force, the water mole fraction difference between the inside and outside of the leaf (w_i - w_a). The expression used (von Caemmerer and Farquhar (1981)) accounts for the convective effects at the stomatal pores caused by transpiration.

$$g_{tw} = \frac{E\left[1 - \frac{w_i + w_a}{2}\right]}{w_i - w_a} \tag{1.18}$$

Total conductance is considered to have two components: boundary layer conductance g_{bw} and stomatal conductance g_{sw}. The relationship is

$$\frac{1}{g_{tw}} = \frac{1}{g_{sw}} + \frac{1}{g_{bw}} \tag{1.19}$$

In order to calculate the stomatal conductance from the total conductance, the boundary layer conductance must be known. In leaf chambers that measure the sum of the conductances of both sides of the leaf (such as the LI-6200), it is important that the boundary layer conductance g_{bw} reflect the boundary layer of the equivalent transpiring leaf area. For example, suppose g_{bw} as determined by a piece of wet filter paper is 2 mol m^{-2} s^{-1}; each side of the paper having a conductance of 1. If a leaf is then measured that is transpiring from both sides, 2 would be the appropriate value of g_{bw}. If the leaf is transpiring from only one side, however, then 1 would be the correct boundary layer conductance.

The LI-6200 calculates the correct g_{bw} based upon two parameters: K, an *estimate* of the ratio of stomatal conductances of one side of the leaf to the other, and the boundary layer conductance (g_{bwo}) of *one side* of a leaf. The resulting approximation (Welles (1986)) is

$$\frac{1}{g_{tw}} = \frac{1}{g_{sw}} + \frac{1}{g_{bwo}}\left[\frac{K^2 + 1}{(K + 1)^2}\right] \tag{1.20}$$

In terms of LI-6200 parameters, the expression used for stomatal conductance to water vapor is

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$$g_{sw} = \frac{1}{\dfrac{e_s\langle T_\ell \rangle - e}{E\left[P - \dfrac{e_s\langle T_\ell \rangle + e}{2}\right]} - \dfrac{(K^2 + 1)}{g_{bwo}\,(K + 1)^2}} \qquad (1.21)$$

Parameter	Units	System Reference	Description
T_a	C	12	Chamber air temp
T_ℓ	C	13	Leaf temp
e	mb	18	Vapor pressure in chamber
E	mol m^2 s^{-1}	25	Transpiration rate of leaf
g_{sw}	mol m^2 s^{-1}	29,31	Stomatal conductance, water
$e_s\langle\rangle$	mb	74	Sat. vapor pressure function
g_{bwo}	mol m^{-2} s^{-1}	A3	One-sided b.l. conductance
K		A4	Stomatal ratio

Photosynthesis

The mass balance of CO_2 in the system is given by

$$-s\,A = v_0\,\rho\,\frac{\partial c_1}{\partial t} + c_1\,u_1 - c_5\,u_5 \qquad (1.22)$$

Equation (1.22) is analogous to the mass balance equation for water (Equation (1.1)), except for the sign difference by convention. In this case the transient term ($\partial c/\partial t$) is quite important, since the LI-6200 is a closed system and no attempt is made to maintain constant CO_2 concentrations. Also, the flow related terms in this situation represent a minor correction due to the time lag while air goes to the IRGA and back. If for example the CO_2 concentration is dropping in the chamber, the return air stream will always be at a higher concentration than the exiting air stream.

Equations (1.2), (1.6), and (1.7) also hold for CO_2, as well as the following additional relationships:

$$c_2 = c_1 - \frac{\partial c_1}{\partial t}\,\Delta t_1 \qquad (1.23)$$

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$$c_3 = \frac{c_2 - \frac{\partial c_2}{\partial t}\Delta t_3}{1 - w_2} \tag{1.24}$$

$$c_4 = c_2 (1 - f) + c_3 f \tag{1.25}$$

$$c_5 = c_4 - \frac{\partial c_4}{\partial t}\Delta t_5 \tag{1.26}$$

$$\Delta t_3 = \frac{v_3}{f u_1}\rho \quad \text{, for } f > 0 \tag{1.27}$$

Since the CO_2 measurement is made at location 4, we need expressions relating c_4 to c_1. Combining Equations (1.23) thru (1.25) and differentiating results in

$$\frac{\partial c_1}{\partial t} = G \frac{\partial c_4}{\partial t} \tag{1.28}$$

where

$$G = \frac{1 - w_2}{1 - w_2 + f w_2} \tag{1.29}$$

The assumption has been made that all rates of change are linear, so second derivatives are zero. Combining Equations (1.23) thru (1.29) leads to

$$c_1 = G c_4 + G^2 \left[(1 - f)\Delta t_1 + \frac{f}{1 - w_2}(\Delta t_1 + \Delta t_3)\right] \frac{\partial c_4}{\partial t} \tag{1.30}$$

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Equation (1.22) can now be written in terms of c_4:

$$-s\ A = X\ c_4 + Y \frac{\partial c_4}{\partial t}$$

where (1.31)

$$X = s\ E\ G + u_5\ (G - 1)$$

$$Y = \rho \left(G\ v_0 + G\ v_1 + \frac{G^2}{1 - w_2} v_3 + v_5 \right)$$

To simplify this expression, we make two approximations:

$$G \simeq 1 - f\ w_1 \quad (1.32)$$

$$Y \simeq \rho\ G\ (v_0 + v_1 + v_3 + v_5) \quad (1.33)$$

The error introduced by these approximations is negligible. The expression used by the LI-6200 in calculating photosynthesis is thus

$$A = \frac{F_d\ e\ C}{100\ S\ P} - \frac{P\ G\ V_t}{8.314\ (Ta + 273)\ S} \frac{\partial C}{\partial t} - C\ E\ G \quad (1.34)$$

Parameter	Units	System Reference	Description
T_a	C	12	Chamber air temp
C	$\mu\ell\ \ell^{-1}$	15	CO_2 concentration
F_d	μmol s^{-1}	16	Flow through desiccant
e	mb	18	Vapor pressure in chamber
$\partial C/\partial t$	$\mu\ell\ \ell^{-1}\ s^{-1}$	1A	Rate of CO_2 change
E	mol $m^{-2}\ s^{-1}$	25	Transpiration rate of leaf
A	μmol $m^{-2}\ s^{-1}$	28,30	Photosynthetic rate of leaf
P	mb	A0	Atmospheric pressure
S	cm^2	A1	Leaf area
V_t	cm^3	A2	Total volume

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Intercellular CO_2

The intercellular concentration C_i of CO_2 can be calculated from the measured assimilation rate and stomatal conductance (von Caemmerer and Farquhar (1981)).

$$C_i = \frac{\left(g_{tc} - \frac{E}{2}\right) C_a - A}{\left(g_{tc} + \frac{E}{2}\right)} \tag{1.35}$$

g_{tc} is the total conductance to CO_2, and is calculated from the conductances for water vapor by

$$\frac{1}{g_{tc}} = \frac{1.6}{g_{sw}} + \frac{1.37}{g_{bw}} \tag{1.36}$$

1.37 is the ratio of diffusivities of CO_2 and water vapor in the boundary layer, and 1.6 is the ratio of diffusivities of CO_2 and water vapor in air.

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Leaf Energy Balance

Through an analysis of the leaf's energy balance in the chamber, it is possible to obtain alternative determinations of quantities such as transpiration rate or leaf temperature. While the default configuration of the LI-6200 does not make use of any of this analysis, it is possible to modify the programming to include these sorts of calculations. This can be advantageous to do for two reasons:

- It can serve as a cross-check on the integrity of a data set. For example, if the energy balance predicts that the leaf should be 3 degrees colder than the air, but your direct measurement has the leaf 0.5 degrees warmer than the air, then something is probably wrong somewhere. One possibility would be that the desiccant is inadequate. The rationale: inadequate desiccant means too high a flow rate, which will yield a spuriously high transpiration rate, which, when plugged into the leaf energy balance, will yield a cold leaf.

- It can serve as a substitute for a direct measurement. For example, a pine shoot is not a convenient leaf on which to use the leaf temperature thermocouple, so determining the temperature indirectly may be helpful. Or suppose the flow meter fails; the leaf energy balance would provide a way to function without it.

Presented below is a fairly simple approach, geared toward use with the LI-6200. See Paw U and Daughtry (1984) for a discussion of an energy balance approach for non-chamber porometry.

The energy balance of a leaf has three major components; net radiation R_n (W m^{-2}) is balanced by fluxes of sensible heat Q (W m^{-2}) and latent heat L (W m^{-2}).

$$R_n = Q + L \tag{1.37}$$

Net radiation is the difference between incoming and outgoing radiation, including visible, near IR, and thermal.

$$R_n = R_{\text{in solar}} + R_{\text{in thermal}} - R_{\text{out solar}} - R_{\text{out thermal}} \tag{1.38}$$

To estimate the net radiation, we make the following assumptions:

- Solar radiation (W m^{-2}) $\simeq$ PAR reading R_q (μmol m^{-2} s^{-1}) $\times$ 0.5
- Chamber transmittance to solar radiation is 0.9
- Leaf absorptance in the near IR is 0.1
- Leaf absorptance in the visible is 0.9
- $\therefore$ Leaf absorptance in the solar is 0.5

We can then write the net solar term as

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$$R_{in\ solar} - R_{out\ solar} = R_q\ (.5)\ (.9)\ (.5) = R_q\ .22 \tag{1.39}$$

The net thermal term is the difference in black body radiation balance. Chamber walls are essentially opaque in the thermal, so the incoming radiation is proportional to the chamber wall temperature T_w.

$$R_{in\ thermal} - R_{out\ thermal} = 2\epsilon\sigma(T_w + 273)^4 - 2\epsilon\sigma(T_\ell + 273)^4 \tag{1.40}$$

ϵ is the thermal emissivity of the leaf, and σ is the Stefan-Boltzmann constant. The 2's in Equation (1.40) are from the assumption that incoming solar radiation strikes one side of the leaf, while both sides radiate and transfer sensible heat. Latent heat flux L is the transpiration rate E converted to W m^{-2}:

$$L = E\ 44100 \tag{1.41}$$

Sensible heat flux Q is related to the leaf - air temperature difference, the specific heat capacity of the air C_p (J mol^{-1} K^{-1}), and the boundary layer conductance of one side of the leaf, g_{bwo} (mol m^{-2} s^{-1}).

$$Q = 2\ C_p\ g_{bwo}\ (T_\ell - T_a) = 56\ g_{bwo}\ (T_\ell - T_a) \tag{1.42}$$

where we have taken C_p to be 28 J mol^{-1} K^{-1}. The 2 in Equation (1.42) is for both sides of the leaf. The leaf energy balance can now be written as

$$0.22\ R_q + 2\epsilon\sigma(T_w + 273)^4 - 2\epsilon\sigma(T_\ell + 273)^4 = 44100\ E + 56\ g_{bwo}\ (T_\ell - T_a) \tag{1.43}$$

If we let

$$\Delta T_\ell \equiv (T_\ell - T_a) \tag{1.44}$$

and note that

$$(T_\ell + 273)^4 \simeq (T_a + 273)^4 + 4(T_a + 273)^3\ \Delta T_\ell \tag{1.45}$$

then we can solve Equation (1.43) for ΔT:

$$\Delta T_\ell = \frac{.22\ R_q + 2\epsilon\sigma[(T_w + 273)^4 - (T_a + 273)^4] - 44100\ E}{56\ g_{bwo} + 8\epsilon\sigma(T_a + 273)^3} \tag{1.46}$$

Since ϵ is typically 0.95, and σ is 5.67×10^{-8} W m^{-2} K^{-1}, this becomes

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$$\Delta T_\ell = \frac{.22\ R_q + 1.077\times10^{-7}\ [(T_w + 273)^4 - (T_a + 273)^4] - 44100\ E}{56\ g_{bwo} + 4.309\times10^{-7}\ (T_a + 273)^3} \quad (1.47)$$

Equation (1.47) can be used to determine leaf temperature independent of the leaf temperature thermocouple.

Another approach is to solve the energy budget for transpiration rate:

$$E = \frac{.22\ R_q + 1.077\times10^{-7}\ [(T_w + 273)^4 - (T_\ell + 273)^4] - 56\ g_{bwo}\ (T_\ell - T_a)}{44100} \quad (1.48)$$

Equation (1.48) gives a transpiration rate estimate that is independent of the flow meter, the humidity sensor, and the desiccant.

Implementing Equations (1.47) and (1.48) in the LI-6200 is aided by using the built-in functions **7E** and **7F**. Refer to the example in Chapter 4.

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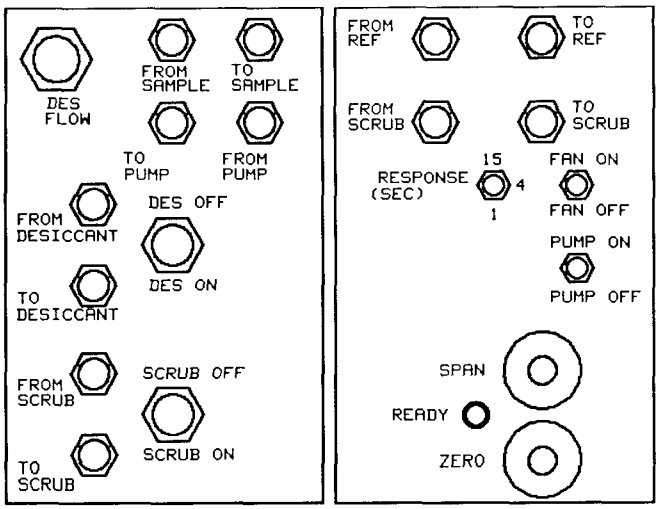
The LI-6250 CO_2 Analyzer

This section describes the theory of operation of the LI-6250 Gas Analyzer.

Description and Flow Diagrams

The LI-6250 contains an infrared gas analyzer, a mass flow meter, and a pump. It can be configured for either absolute or differential modes of operation simply by rearranging the external plumbing; no internal changes need be made.

The top panel of the LI-6250 is diagrammed below:



DES FLOW: Closing this valve (turning it clockwise) *increases* the flow of air though the external desiccant tube, provided the **DES** flow switch is on.

DES ON/OFF: Turning this switch off bypasses the external desiccant, needle valve, and flowmeter.

SCRUB ON/OFF: Turning this switch on diverts all of the air through the soda lime tube on the left side of the LI-6250.

RESPONSE (SEC): This switch selects the time response of the analyzer: 1, 4, or 15 seconds.

FAN ON/OFF: Controls the cooling fan mounted on the right end wall of the LI-6250.

PUMP ON/OFF: Controls the internal air flow pump.

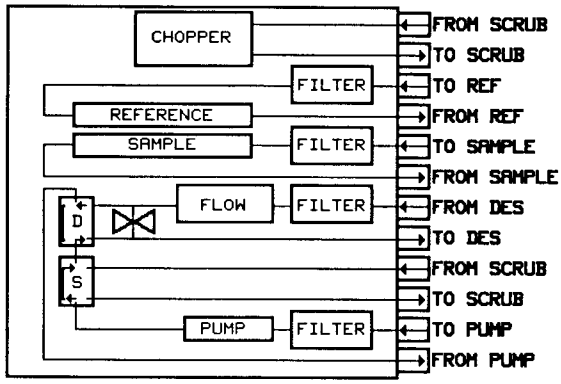
SPAN: A locking potentiometer for setting the span when calibrating the CO_2 analyzer.

ZERO: A locking potentiometer for setting the zero when calibrating the CO_2 analyzer.

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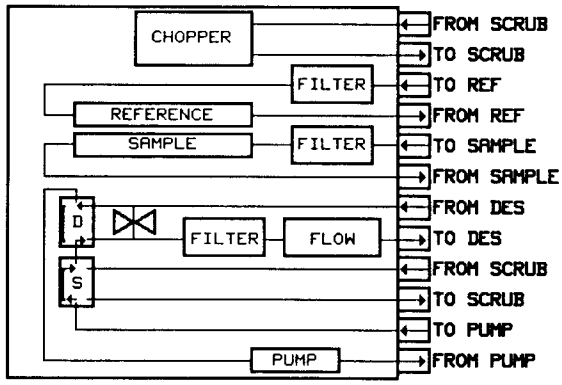
READY: This LED indicates if the CO_2 analyzer if functioning properly. It should illuminate within 1 to 3 minutes of powering up the LI-6250 (longer at high temperatures).

The internal plumbing of the LI-6250 is illustrated in the following schematic.



NOTE

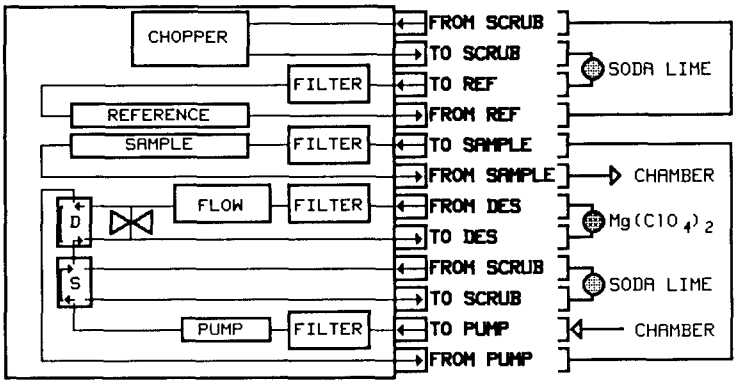
The above plumbing arrangement was implemented in late July, 1987 with serial number IRG-541. If your LI-6250 has a serial number below that, and it has never been returned to LI-COR since July, 1987, then it will have the following internal plumbing:



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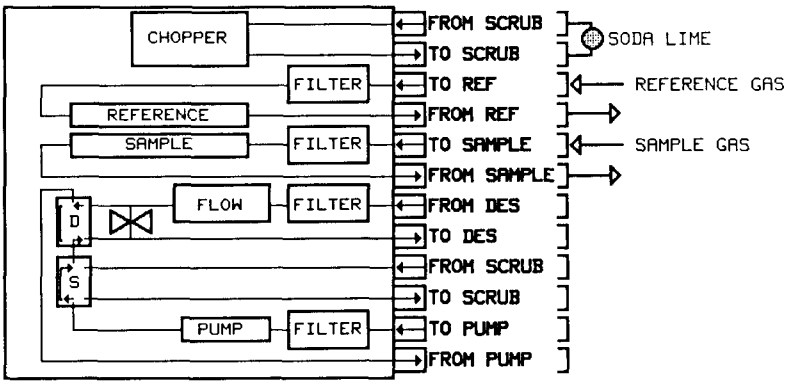
As used with the LI-6200, the LI-6250 should be configured for absolute measurements. This means the hose fittings should be connected as shown below.

ABSOLUTE MODE



In differential mode, the LI-6250 should be plumbed as follows:

DIFFERENTIAL MODE

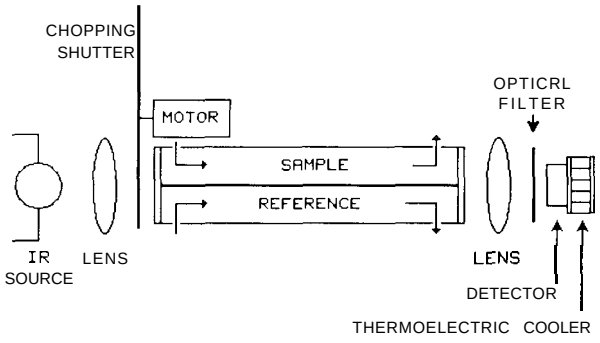


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CO_2 Analyzer

THEORY OF OPERATION

The CO_2 analyzer is a differential, non-dispersive infrared type. The CO_2 measurement is based on the difference in intensity of IR radiation passing through two gas sampling tubes: a ***reference*** tube contains a known amount of CO_2, and a *sample* tube contains an unknown amount. Infrared radiation is transmitted through both paths, and the output of the analyzer is proportional to the difference in absorption between the two.



The infrared **source** is vacuum sealed for long life and stability. **A** separate photodiode optical feedback circuit maintains **a** constant color temperature of the source (1000K).

The **chopping shutter** disc is spun by a phase locked loop controlled motor, whose shaft turns on high precision bearings for long life and low noise. An attached tube of soda lime keeps the shutter housing purged of CO_2. Rotational velocity is precisely controlled at 500 **hz.**

The **sample cells** are gold plated to enhance IR reflectance and provide long term stability.

The 150 nm bandpass optical **filter** tunes the analyzer to the **4.26** μm absorption band for CO_2. It provides excellent rejection of IR radiation outside the CO_2 band, allowing the analyzer to reject the response of other IR absorbing gasses, particularly water vapor.

The lead selenide **detector** is a solid state device that is inherently stable and insensitive to vibration. It is cooled and regulated to –12C by a thermoelectric cooler. To keep the detector housing free of water vapor and CO_2, there is a small bottle of magnesium perchlorate and soda lime that is attached to the detector. The contents of this bottle should be replaced annually.

These key elements combine to make an analyzer that is very stable and virtually insensitive to vibration and temperature changes.

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CALCULATING CO_2 CONCENTRATION

The analyzer's signal output V is proportional to the difference between the signals generated by the detector when it sees the sample cell (ν_s) and when it sees the reference cell (ν_r).

$$V = k\ (\nu_r - \nu_s) \tag{2.1}$$

The analyzer operates in such a way as to keep ν_r constant. If the CO_2 concentration in the reference cell increases, the gain of the detector increases automatically to hold ν_r constant. This has important implications for operation in differential mode, as will be seen shortly. Since ν_r is held constant, we can factor it out of the proportionality constant k and use a new constant $K = k\,\nu_r$.

$$V = K\left(1 - \frac{\nu_s}{\nu_r}\right) \tag{2.2}$$

As CO_2 concentration in the sample cell increases, ν_s will decrease due to increased absorption of radiation. The signal output V increases in proportion to the amount of decrease of ν_s (Equation 2.2). Figure 2-1 illustrates a typical relationship between CO_2 concentration, ν_s/ν_r, and signal output V.

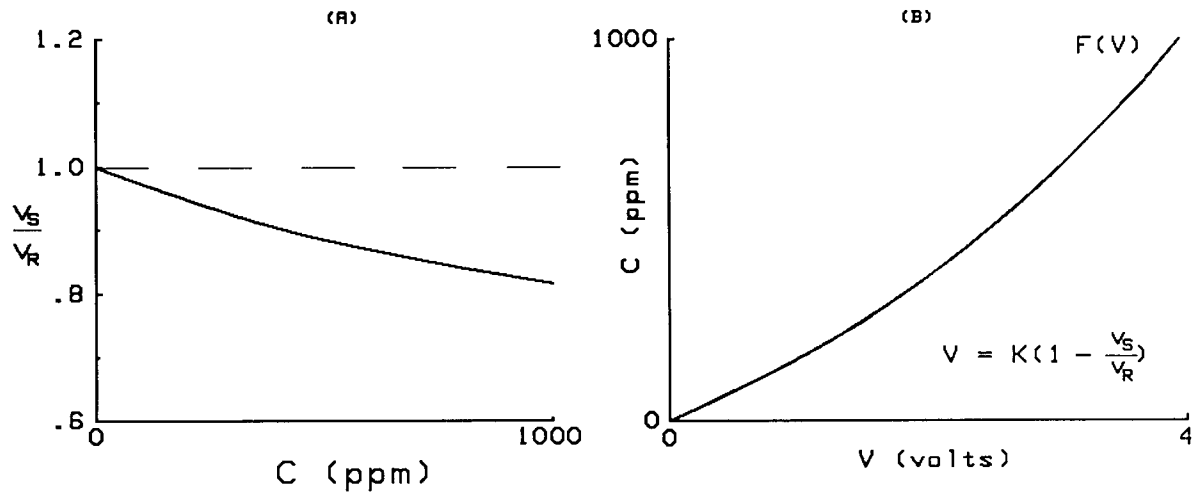


FIGURE 2-1. (A) The ratio of detector output while viewing the sample cell (ν_s) and the reference cell (ν_r) decreases with increasing CO_2. (B) The signal output V is related to the ratio of ν_s to ν_r by Equation (2.2). CO_2 in terms of V is the calibration function F(V).

The factory calibration of the analyzer consists of measuring the output V at several different CO_2 concentrations, and determining the coefficients for a third order polynomial F(V) that relates V to CO_2 concentration, with 0 ppm in the reference cell.

$$F\left[\ V\ \right] \equiv a_1 V + a_2 V^2 + a_3 V^3 \tag{2.3}$$

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The calibration function F(V) is only valid for the temperature and pressure at which it was determined, and 0 ppm in the reference cell. It has been found empirically that (absolute) temperature affects the CO_2 concentration in a linear fashion, while pressure affects the signal output V in a linear fashion. Thus, the expression relating signal output to CO_2 concentration with 0 ppm of CO_2 in the reference cell (absolute mode) is

$$C = F\left(V \frac{P_0}{P} \right) \left[\frac{T + 273}{T_0 + 273} \right] \tag{2.4}$$

With some other concentration in the reference cell, the gain of the detector will be higher. Recall that the analyzer seeks to maintain ν_r at a constant level. The increased gain means that the function F(V) should now be steeper, since the analyzer is now more sensitive to CO_2. If we know the calibration function F(V), and that CO_2 concentration C_r is in the reference cell, we can predict the factor G by which the gain has changed. If ν_{sr} is what the detector's output would be with CO_2 concentration C_r in the sample cell and 0 ppm in the reference cell, then from Equation (2.2) we can write

$$G \equiv \frac{\nu_{sr}}{\nu_r} = (1 - \frac{V_r}{K}) \tag{2.5}$$

where V_r is the signal output that would exist if there were 0 ppm in the reference cell, and C_r in the sample cell. V_r is given by the inverse of F(V), corrected for temperature and pressure.

$$V_r = V' \frac{P}{P_0}$$

where (2.6)

$$V' = F^{-1}\left(C_r \left[\frac{T_0 + 273}{T + 273} \right] \right)$$

The general expression then for CO_2 concentration C in the sample cell given CO_2 concentration C_r in the reference cell and analyzer signal output V is thus

$$C = F\left(V H + V' \right) \left[\frac{T + 273}{T_0 + 273} \right]$$

where (2.7)

$$H = \left[\frac{P_0}{P} - \frac{V'}{K} \right]$$

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The CO_2 differential ΔC is simply $(C - C_r)$. For small ΔC values (less than 30 ppm), an approximation can be used that is based on the slope of F(V) at $V = V_r$:

$$\Delta C = V\ H\ S \qquad (2.8)$$

where

$$S = \frac{\partial F(V_r)}{\partial V} \left[\frac{T + 273}{T_0 + 273} \right]$$

LI-6200 SUPPORT

The LI-6200 software contains routines, built-in functions, and constants that can be used to support the LI-6250's CO_2 analyzer in either absolute or differential modes of operation.

The CO_2 output signal V is available on channel **05**, in units of mV.

FCT 45 accesses the CO_2 calibration list, in which the following values are contained: K, T_0, a_1, a_2, and a_3.

The built-in function **77** uses three parameters (C_r, T, P) and returns three parameters (C_r, V', H), based on the current values in the **45** list. P_0 is taken to be 1013 mb.

FCT 49 prompts for C_r and the system reference for T, then calculates V' and H, and stores C_r in **C9**, V' in **CA**, and H in **CB**. These Cx constants are included in the **E2** list. When **FCT 49** is performed, the value for pressure P is assumed to be **A0**, the pressure parameter. P_0 is taken to be 1013 mb.

Equation (2.7) is implemented in channel 15 in the default system configuration (E3 list), taking the form

```
05 CB 64 CA 62 14 71
```

05 corresponds to V, the CO_2 signal in mV.
CB is the value H, set the last time that **FCT 49** was performed.
64 multiplies V by H.
CA is the current value of V', set the last time **FCT 49** was performed.
62 adds V'.
14 is the temperature in the LI-6250.
71 is a built-in function that corresponds to Equation (2.8).

The built-in function **71** uses two parameters (V, T) and returns the value S as defined in Equation (2.8).

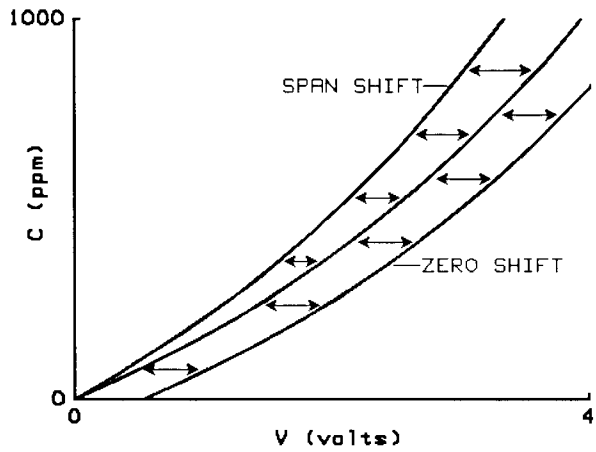
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CALIBRATION - GENERAL INFORMATION

The **factory** calibration of the LI-6250 CO_2 Analyzer consists of determining the coefficients for the function F(V). These coefficients should be quite stable over time, but we recommend they be checked annually.

The **user** calibration consists of adjusting the zero and span potentiometers so that the analyzer's output matches the function F(V). This should be done on a daily basis, after setting the pressure (FCT **41** or FCT **A0**) and the gain factor (FCT **49**) in that order.

The following diagram illustrates the effects of the zero and span adjustments.



CALIBRATION - ABSOLUTE MODE

1. Verify that the CO_2 calibration parameter list (FCT **45**) matches the one shown on the latest calibration sheet.

2. Set the pressure parameter and do FCT **49**.

3. Set the **zero**: flow zero ppm through the analyzer (can be achieved by having the pump on, and scrub flow switch on **SCRUB ON**), and adjust the zero potentiometer until the displayed reading is 0 ppm.

4. Set the **span**: flow a gas of known CO_2 concentration through the analyzer, and adjust the span potentiometer until the displayed reading is correct.

5. Recheck the zero.

6. Recheck the span.

7. (Optional): Check other CO_2 concentrations. If the concentration used to set the span reads correctly, and zero reads correctly, but intermediate concentrations are incorrect, then this would indicate that the linearity of the analyzer has shifted, and needs a factory recalibration.

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CALIBRATION - DIFFERENTIAL MODE

It is important to keep in mind that the pressures on the two sides of the analyzer be kept the same. For this reason, never connect the exit ports (**FROM SAMPLE** and **TO SAMPLE**) to anything - just vent them to the atmosphere, or to the same (short) lengths of tubing. If you wish to flow the same gas through both sides of the analyzer, NEVER do it by putting the sample and reference cells in series, as you will be guaranteed to have different pressures. Instead, split the flow upstream of the analyzer, and run separate hoses to the reference and sample cells. Also, be sure the flow rates through both sides are very similar.

The following procedure contains the phrase "... the reading is correct." What exactly "the reading" *is* depends on the programming of the LI-6200. If you have not changed the default definition of channel **15**, then reading will be the absolute value of what is in the sample cell. For example, if there is 300 ppm in both sample and reference cells, then channel **15** will show 300. If you've changed the definition to show a differential concentration, or pressure instead of concentration, then you have to decide what the correct reading is.

1. Verify that the CO_2 calibration parameter list (FCT **45**) matches the one shown on the latest calibration sheet.

2. Set the pressure parameter and do FCT **49**, entering the CO_2 concentration that is in the reference cell.

3. Set the **zero**: Flow the reference concentration through both sides of the analyzer, and adjust the zero potentiometer until the reading is correct.

4. Set the **span**: Flow a gas of known CO_2 concentration through the analyzer, and adjust the span potentiometer until the displayed reading is correct.

5. Recheck the zero.

6. Recheck the span.

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FLOW METER

THEORY OF OPERATION

The flow meter in the LI-6200 is commonly referred to as a thermal mass flow meter, and its output is proportional to number of molecules that are flowing. The flow meter has a thin wall capillary tube which is heated. When a gas is flowing through the tube, heat is transferred to the gas creating an asymmetrical temperature distribution along the tube. With a constant power input, the temperature differential is a function of the mass flow rate and the heat capacity of the gas.

The capillary tube can only operate with a limited amount of flow passing through it. Therefore, a laminar flow by-pass element within the flow meter divides the flow, sending a small portion through the capillary, and allowing the rest of the flow to by-pass it.

This type of measurement is said to be independent of pressure and temperature. In reality, there is a slight temperature dependence, but it is corrected in the software. Also, there is a fairly marked zero shift with temperature.

The flow meter is calibrated at three temperatures, and the data fitted to Equation (2.11), where F_{std} is flow in standard $cm^3\ s^{-1}$ and V_f is the flow meter signal output.

$$F_{std} = (b_1 + b_2\ T)V_f + (b_3 + b_4\ T)V_f^2 \qquad (2.9)$$

Conversion of F_{std} ($cm^3\ s^{-1}$ under standard conditions) to F_d ($\mu mol\ s^{-1}$) is done by

$$F_d = 44.64\ F_{std} \qquad (2.10)$$

where 44.64 is the density of air (Equation 1.12) in mol m^{-3} under standard conditions (P = 1013 mb and T = 273C).

LI-6200 SUPPORT

The coefficients b_1 thru b_4 are contained in the flow meter calibration list **FCT 46**, where they are labelled A thru D.

The **E2** list constant **CF** has the value 44.64.

FCT 48 determines the offset signal, and stores it in **C8**.

The flow meter signal output V_f is on channel **07** in units of mV.

Equations (2.9) and (2.10) are implemented in channel 15 in the default system configuration (E3 list), taking the form

```
07 C8 63 14 72 CF 64
```

07 corresponds to V_f, the flow meter signal in mV.

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C8 is the value of V_f with no flow, determined from **FCT 48**.
63 subtracts the offset from V_f
14 is the temperature in the LI-6250.
72 is a built-in function that corresponds to Equation (2.9).
CF is 44.64.
64 multiplies standard flow by 44.64.

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LI-6200 Software Topics

The purpose of this chapter is to acquaint the user with some of the capabilities of the LI-6200 which are not covered in the LI-6200 Primer. The information is presented in a building-block fashion, and useful examples are given at the end of each section.

Complete descriptions of the various functions provided in the software are given in the Software Reference section of this manual.

Files

The LI-6200 not only can store data pages in its memory, but also several other types of data as well. Essentially, any parameter list whose first entry is

```
LAB:
```

can be stored. It is not surprising that different types of lists are stored as different types of files. Below is a list of the different file types.

Code	Name	Size (Bytes)	Description	Accessed by FCT:
1	PAGE		Page parameters and scratch pad data	E7
2	SYSTM	1280	Channels 10-3F, Constants B0-BF	E3
3	I/O	69	I/O parameters	51
4	ASCII		ASCII file	56
5	PPARM	376	Page parameters	41
6	OPARM	42	Operational parameters	42
7	CO2	44	CO2 analyzer calibration	45
8	FLOW	41	Flowmeter calibration	46
9	RH	105	Humidity lookup table	47
10	SENSR	256	Channels 00-0F, Constants C0-CF	E2
11	SFORM	72	System format	D8
12	UFORM	425	User format	D9
13	KEYS	159	User defined keys	E1
14	KBUFF	153	Key buffer sequence	ED
15	VWSEQ	425	Mini view sequence	EC
16	PROG	45	Log key definition	E8

The GET and STORE keys are used to retrieve and store these files, but it depends on context. For example, while in VIEW MODE (FCT **E7**), GET and STORE operate on PAGE files, as demonstrated in the LI-6200 Primer. If you were to press STORE while in FCT **42** (the operating parameter list), you would store the operating parameter list in an OPARM file. And GET would allow you to load in any previously stored OPARM file.

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FILE COUNTERS

Each file type has associated with it a *file counter.* The file counter for data pages is shown in STATUS mode in the lower right hand corner of the display. A file counter is simply the highest number file of that particular type that has been stored. When a "new" file of that particular type is stored, the file counter will increment by one, and the file will be given that value as its number.

As a thought-experiment, suppose the memory is cleared; no files of any type are stored. You collect data, and store 10 data pages. The file counter for type 1 (PAGE) is now 10. Now, the I/O parameters are accessed (FCT **51**), and the list stored (file type 3). The memory now has 11 files total: ten pages, and one I/O list. The file counter for pages is still 10, and the file counter for I/O files is now 1.

To see the current status of all the file counters, use FCT **D4**. You will view a scrollable list (which is NOT storable, incidentally), with each entry showing the file code, name, and current value of the file counter.

FILE NUMBERS AND LABELS

Each file type is structured differently, but they all share something in common: every file, regardless of type, has a number and a label.

File numbers for each file type are independent and start at 1. In the example given above, the file number for the I/O file that was stored would be 1, even though there already existed a data page with that same number. The number is what you refer to when retrieving or accessing the file. Thus, you can retrieve data page 1 while in VIEW mode, or I/O parameter list 1 while looking at the I/O parameters (FCT **51**).

The file label is simply whatever followed the **LAB:** in the first line of the list. Thus, for example, if you edited the **LAB:** line in the I/O parameter list to say **LAB:IBM PC** prior to storing the list, then **IBM PC** would be the label for that file. File labels can be up to 12 characters in length.

The FILE INDEX routine (**D5**) is very useful for keeping track of stored files. This routine generates output that is sent to the I/O port, so a printer or terminal or some other device must be present to capture the data when you do this function. The output that it generates is a list of numbers and labels for all files that are stored, either for a particular file type, or for all file types.

For viewing file labels of stored files on the console display, use the VIEW LABEL routine (FCT **DA**). This routine prompts you for a file type, then shows you labels and file numbers for each file of that sort stored in RAM. This routine can also be invoked when you GET a file by entering a question mark (**SHIFT + W**) in response to the 'NUM:' prompt. You can then use the arrow keys to scroll through the list of file numbers and labels for that particular file type. Pressing **RTRN** selects the file number currently shown on the display.

DELETING FILES

Files of any type can be deleted using FCT **D1**. The file type must be specified by entering the code number (1 for PAGE, 2 for SYSTM, etc), then the range of file numbers to delete.

Deleting one or more files may or may not affect the file counter. If the files deleted include the highest numbered ones, then the file counter is adjusted. If the files deleted leave the highest numbered file of that type untouched, then the file counter is unchanged.

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When a file is deleted, the space in RAM that it occupied is available for use. The file number, however, will not be reused if the file counter is unchanged. The file renumber routine (FCT **D2**) can be used to eliminate "holes" in the file numbers due to deletions.

RENUMBERING FILES

The renumber routine (FCT **D2**) prompts for a file type code, then renumbers the files of that type so that they start at 1, and no numbers are skipped. After renumbering a particular file type, the file counter will be equivalent to the number of stored files of that type.

REQUIRED SPACE

The number of bytes required to store a file is given in the table at the beginning of this section.

PAGE files depend upon the number of samples and observations, as well as how many channels are defined:

	376	Overhead
+	**4 × N × S**	N = # 1x channels, S = # samples
+	**8 × N × B**	B = # observations
+	**4 × M × B**	M = # 2x channels
+	**4 × P × B**	P = # 3x channels
+	**16 × S**	If N>0
+	**32 × B**	If N>0
+	**16 × B**	If M>0
+	**16 × B**	If P>0

For the default configuration of the E3 list, N = 11, M = 8, and P = 5, and the equation for determining the required storage space reduces to

Bytes needed = 376 + (204 × B) + (60 × S)

Thus, a page having 10 samples and 2 observations would require 376 + 408 + 600 = 1384 bytes.

EXAMPLE

We will generate some files of a couple of different types, view the file counters, get an index of the labels, delete some, and see what the renumber function does.

1. Press FCT **D 4** to access the current values of the file counters. You will be viewing list that might look something like this:

```
 1:PAGE  =   21
 2:SYSTM =    0
 3:I/O   =    0
 4:ASCII =    0
 5:PPARM =    0
 6:OPARM =    0
 7:CO2   =    1
 8:FLOW  =    1
 9:RH    =    1
10:SENSR =    0
11:SFORM =    0
```


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```
12:UFORM =     0
13:KEYS  =     0
14:KBUFF =     0
15:VWSEQ =     0
16:PROG  =     0
```

2. Access the operating parameters: Press FCT **4 2**.

3. Press EDIT, and type **ABCDEF** for the label (LAB:), then press **RTRN**.

4. Now store this list. Press STORE.

At this point, one of two things will happen: If this is the first time that an operating parameter list has been stored, the display will simply say

```
OPARM:        1
STORED
```

If, however, someone has already stored one of these, you will be prompted

```
THIS FILE EXISTS
OVERWRITE(Y/N)_
```

If this has happened, press N, then **RTRN**, and you will get the storage message shown above, although with a different file number than 1. By answering this prompt with an 'N', you created a new file, rather than write over the existing file.

5. Now, change one of the operating parameters. Edit the CHANGE entry of the operating parameter list to be 99.

6. Edit the label to be 'UVWXYZ'.

7. Store the list again by pressing STORE. You will be asked if the file is to be overwritten because you just stored it once, so respond with a 'N'. The file will be stored as file 2 (or 1 plus whatever the number was from step 4).

8. Check the file counter for this file type. Press FCT **D4**, and scroll to the entry that says

```
6:OPARM = 2
```

It will say at least 2, or more if there were files of this type already stored.

9. Press FCT **4 2** to return to the operating parameters. The label shown should be the 'UVWXYZ' one, since this was the condition in which it was left.

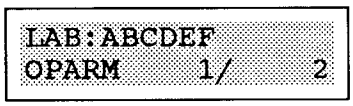
10. Retrieve the configuration of the 'ABCDEF' file by pressing GET. You will be prompted

```
GET OPARM
NUM:_
```

11. At this point you could simply enter the number of the file and press **RTRN**. But suppose you've

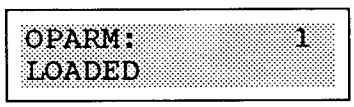
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forgotten the number. Enter **?** then **RTRN**. You will see



The label of OPARM file 1
File number 1. File counter is 2

By pressing ↑ or ↓, you will scroll through the OPARM files that are stored. When LAB:ABCDEF appears on the display, press **RTRN** to select that file. The display will indicate



momentarily when the file is retrieved.

12. Delete both of these files that you've created. Press FCT **D 1**. You will be prompted



13. The file type is OPARM, and the code is 6, so press **6**, then press **RTRN**.

14. You will then be prompted for the range of files to be deleted. Just delete the first of the two files, so enter 1 (or whatever the appropriate number is) in response to both the FROM and THRU prompts.

15. Examine the page counters (FCT **D4**) and see what happened to the OPARM value since we deleted one of these files. You'll find that it *didn't* change, since the highest numbered OPARM file was not deleted.

16. Now renumber the OPARM files. Press FCT **D 2**. You will be asked for a file code, so enter 6. If you check the page counter again, you will find that it reflects the number of OPARM files.

17. As a final exercise, delete the other OPARM file that you created. If that is the *only* other OPARM file, then the file counter will automatically reset to 0.

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Editing Stored Pages

Frequently, it is necessary to change one or more parts of a data page after it has been stored. For example, boundary layer conductance may have been incorrectly entered, or leaf areas perhaps were not available at the time of the measurement.

The brute force method of making changes to stored data is to:

1) Enter VIEW mode.
2) GET the page to be changed.
3) Make the necessary changes.
4) Do FCT **D6**, which causes recomputation and storage.

There is a much simpler method provided by the EDIT LOOP routine (**D7**). This routine prompts you for the following information:

- Starting page number
- Ending page number
- What parameter to change
- Change all pages alike, or use a different parameter value for each page?

The parameters are reference by code:

Code	Parameter	Code	Parameter
A0	Pressure (mb)	AA	Auxiliary Data 1
A1	Leaf Area (cm^2)	AB	Auxiliary Data 2
A2	Total Volume (cm^3)	AC	Auxiliary Data 3
A3	Boundary Layer Conductance (mol m^{-2} s^{-1})	AD	Auxiliary Data 4
A4	Stomatal Ratio	AE	Auxiliary Data 5
A5	Maximum Flow (μmol s^{-1})	AF	Auxiliary Data 6
A6	IRGA volume (cm^3)		
A7	K_{abs}		
A8	<unused>		
A9	<unused>		

NOTE

Be careful how the operational parameter KEEP SMP(Y/N) is set. If your stored pages include samples and KEEP SMP is set to N, then performing the EDIT LOOP routine will strip the samples from the pages. This may or may not be desirable to you.

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EXAMPLE: CHANGES EN MASSE

Let's assume that you wish to change the pressure parameter in pages 1 through 10 to 1000 mb.

1. Press FCT D 7. You will be prompted

```
EDIT
FROM:_
```

2. Enter the starting page number (1) of the group you wish to change. You'll then be prompted

```
FROM:1
THRU:_
```

3. Enter the ending page number (10) of the group you wish to change. You'll then be prompted

```
THRU:10
CODE:_
```

4. We want to change pressure, so enter A0. You will be prompted

```
CODE:A0
ASK EACH(Y/N)_
```

5. Since we want to change pressure in all of the pages to the same value, respond to this with N. You will then be prompted

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

6. The pressure value is to be 1000 mb, so enter that value.

The instrument will then retrieve each page, make the change, and re-store the page overwriting the old data. The display will keep you posted as to what page is currently being worked on.

EXAMPLE: PAGE-BY-PAGE CHANGES

Let's assume that you wish to change the leaf area parameter in pages 1 through 10. Each page is to have a different value for leaf area.

1. Press FCT D 7. You will be prompted

```
EDIT
FROM:_
```

2. Enter the starting page number (1) of the group you wish to change. You'll then be prompted

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```
FROM:1
THRU:_
```

3. Enter the ending page number (10) of the group you wish to change. You'll then be prompted

```
THRU:10
CODE:_
```

4. We want to change leaf area, so enter A1. You will be prompted

```
CODE:A1
ASK EACH(Y/N)_
```

5. Since we have different values for leaf area for each page, respond to this with a **Y**. You will then be prompted

```
   1 A(cm2)
NEW=_
```

Page number Parameter
Enter new value, or just press RTRN to keep old value

for pages 1 through 10 in succession. A null entry will leave the parameter unchanged; otherwise, enter the new value for the parameter for each page.

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Customizing the Output Format

When the scratch pad is printed (pressing PRINT while in view mode), or stored pages are printed (the DUMP PAGES routine **53**), the format in which the data is printed depends upon two format lists:

- The system format list (**D8**) if the operational parameter PRN FMT(U/S) is set to S.
- The user format list (**D9**) if PRN FMT(U/S) is set to U.

SYSTEM FORMAT

The system format list allows you to select what channels are printed, and in what order. The data portion of a printed page looks like this:

```
OB  TIME   QNTM   TAIR   TLEAF  CO2    FLOW   RH     EAIR   DE/DT  DC/DT
 1   1.800  1972.  35.71  35.07  323.0  179.3  46.04  26.93  26.93  323.0
 2   3.100  1979.  35.71  35.09  322.2  179.3  46.10  26.96  26.96  322.2
 :     :      :      :      :      :      :      :      :      :      :
11   23.60  1986.  36.02  36.02  310.4  180.2  46.57  27.71  27.71  310.4
12   25.20  1997.  36.05  36.05  309.5  181.1  46.63  27.79  27.79  309.5

 1M  6.233  1980.  35.75  35.15  320.4  179.9  46.18  27.07  .0359 -.5889
 2M  20.40  1992.  35.96  35.38  312.2  180.7  46.54  27.60  .0387 -.5694

 1R  9.799  17.06  .1317  .2094  5.815    1.8  .2857  .3641  .0029  .0045
 2R  9.599  11.23  .1790  .1304  5.395     .9  .1852  .3812  .0033  .0079

OB  PHOTO  COND   CINT   RS     CS
 1   33.64  .3117  127.8  1.224  .8166
 2   32.44  .3217  131.3  1.185  .8432
```

because the default state of the **D8** list is this:

```
LAB:
SAMP  COL  1:10        SYS  COL  1:FF        USER  COL  1:30
SAMP  COL  2:11        SYS  COL  2:FF        USER  COL  2:31
SAMP  COL  3:12        SYS  COL  3:FF        USER  COL  3:32
SAMP  COL  4:13        SYS  COL  4:FF        USER  COL  4:33
SAMP  COL  5:15        SYS  COL  5:FF        USER  COL  5:34
SAMP  COL  6:16        SYS  COL  6:FF        USER  COL  6:FF
SAMP  COL  7:17        SYS  COL  7:FF        USER  COL  7:FF
SAMP  COL  8:18        SYS  COL  8:FF        USER  COL  8:FF
SAMP  COL  9:19        SYS  COL  9:FF        USER  COL  9:FF
SAMP  COL 10:1A        SYS  COL 10:FF        USER  COL 10:FF
SAMP  COL 11:FF        SYS  COL 11:FF        USER  COL 11:FF
SAMP  COL 12:FF        SYS  COL 12:FF        USER  COL 12:FF
SAMP  COL 13:FF        SYS  COL 13:FF        USER  COL 13:FF
SAMP  COL 14:FF        SYS  COL 14:FF        USER  COL 14:FF
SAMP  COL 15:FF        SYS  COL 15:FF        USER  COL 15:FF
SAMP  COL 16:FF        SYS  COL 16:FF        USER  COL 16:FF
```

There are 48 possible output columns in system format. The channel to be used for each column is given by the channel code, or by FF if the column is to be skipped.

SAMP COL refers to sample columns, in which are printed the 1x channel samples (if present), and the Means and Ranges. For example: The first entry in the system format list is **SAMP COL 1: 10**. Channel

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10 is TIME, and TIME appears as the first column (after the OBS which always appear). Similarly, the rest of the printed columns correspond to the channel numbers listed in the system format (11 is QNTM, 12 is TAIR, etc.).

SYS COL refers to the system's intermediate calculations (2x channels). These are suppressed from the default format, so each entry is FF.

USER COL refers to the results in user determined units (3x channels). The default format requests channels 30 thru 34, and these appear in the printout accordingly: 30 is PHOTO, 31 is COND, etc.

NOTE

The system format list only affects what is printed. IT HAS NO AFFECT ON WHAT IS COMPUTED OR STORED. Removing or adding channels to the system format list does not remove them from or add them to the data page.

Requesting a channel number that is not present in the data page will result in 0.0 being printed in that column, with no label at the top of the column.

Holes in the format (that is, columns set to FF in between active columns) do not reflect themselves in the formatted output. FF columns are simply ignored.

EXAMPLE

Remove DE/DT from the sample columns, and print all system intermediates (2x channels).

1. Press FCT **D 8** to access the system format list. Scroll through the list, and make the indicated (♦) changes. (Note that **CTRL** +↑ and **CTRL** +↓ will jump up or down to the next group of column type entries).

```
SAMP  COL  1:10        SYS  COL  1:21♦       USER  COL  1:30
SAMP  COL  2:11        SYS  COL  2:22♦       USER  COL  2:31
SAMP  COL  3:12        SYS  COL  3:23♦       USER  COL  3:32
SAMP  COL  4:13        SYS  COL  4:24♦       USER  COL  4:33
SAMP  COL  5:15        SYS  COL  5:25♦       USER  COL  5:34
SAMP  COL  6:16        SYS  COL  6:26♦       USER  COL  6:FF
SAMP  COL  7:17        SYS  COL  7:27♦       USER  COL  7:FF
SAMP  COL  8:18        SYS  COL  8:28♦       USER  COL  8:FF
SAMP  COL  9:FF♦       SYS  COL  9:FF        USER  COL  9:FF
SAMP  COL 10:1A        SYS  COL 10:FF        USER  COL 10:FF
SAMP  COL 11:FF        SYS  COL 11:FF        USER  COL 11:FF
SAMP  COL 12:FF        SYS  COL 12:FF        USER  COL 12:FF
SAMP  COL 13:FF        SYS  COL 13:FF        USER  COL 13:FF
SAMP  COL 14:FF        SYS  COL 14:FF        USER  COL 14:FF
SAMP  COL 15:FF        SYS  COL 15:FF        USER  COL 15:FF
SAMP  COL 16:FF        SYS  COL 16:FF        USER  COL 16:FF
```


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2. Now print a data page or the scratch page. Make sure that the operating parameter PRN FMT(U/S) is set to S. The **2x** channels will now appear.

```
 PAGE  TIME              SYSTM
   21  17 JUL 16:50:52    0

 P(mb)  Vt(cc)  Vg(cc)  A(cm2) BC(mol)  STMRAT Fx(umol)    Kabs      A8      A9
 979.9   1140.   120.0   7.400   2.670   1.000    999.9   1.100     0.0     0.0

PLOT         PLANT         LEAF          REMARKS       pr5          pr6
5            10            3             TORN

OB  TIME   QNTM   TAIR   TLEAF  CO2    FLOW   RH     EAIR    DC/DT
 1   1.800  1972.  35.71  35.07  323.0  179.3  46.04  26.93   323.0
 2   3.100  1979.  35.71  35.09  322.2  179.3  46.10  26.96   322.2
 :     :      :      :      :      :      :      :      :       :
12   25.20  1997.  36.05  36.05  309.5  181.1  46.63  27.79   309.5

 1M  6.233  1980.  35.75  35.15  320.4  179.9  46.18  27.07  -.5889
 2M  20.40  1992.  35.96  35.38  312.2  180.7  46.54  27.60  -.5694

 1R  9.799  17.06  .1317  .2094  5.815    1.8  .2857  .3641   .0045
 2R  9.599  11.23  .1790  .1304  5.395     .9  .1852  .3812   .0079

OB  W      FRACT  FW/S   K      E      GS     DC     A
 1   .0276  .1799  .0067 -3.169  .0093  .3117 -31.65  33.64
 2   .0281  .1806  .0068 -3.017  .0096  .3217 -30.45  32.44

OB  PHOTO  COND   CINT   RS     CS
 1   33.64  .3117  127.8  1.224  .8166
 2   32.44  .3217  131.3  1.185  .8432
```

Transpiration (mol m^{-2} s_{-1}) is the E column, incidentally. For a discussion of the rest of the **2x** channels, refer to the Virtual Channel discussion in Chapter 4 of this manual.

USER FORMAT

When outputting a range of pages, frequently the system format provides "too much" data, especially if the results are to be used as input for a computer program. The user format list is simply a list of those quantities that you want selected from each data page to be printed.

For example, suppose from each page all you wished to have printed was page number, time of day, photosynthetic rate, and conductance, so that output from a range of pages would make a clean matrix:

```
 21  08:10:44  20.34  .3047
 22  08:12:30  22.28  .3344
 23  08:13:11  21.17  .3220
  :     :       :      :
```

This is accomplished with the user format, which is just a list of the items from each page that are to be printed. The desired items are referenced by codes and abbreviations, as shown in the following list.

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Code	Description	Code	Description
HDR	Page parameters in system format	EOL [n]	End of line(s).
PAG	Page number	SPA [n]	Space(s).
TIM	Time of day		
DAT	Date	LOOP	Loop over all observations.
DAY	Day of month	ENDLOOP	Used with LOOP.
HOU	Hour	OB.n	Observation number
MIN	Minute	1x.n	Nth sample of channel 1x
SEC	Second	1x.nM	Nth mean observation of channel 1x
NOB	Number of observations in the page	1x.nR	Nth range observation of channel 1x
SYS	System number	2x.n	Nth observation of channel 2x
APR.i	Auxiliary data prompt. i=1 thru 6.	3x.n	Nth observation of channel 3x
AXD.i	Auxiliary data string. i=1 thru 6.		
Ax	Page parameter, x=0 thru F.		

Note that the codes AA thru AF and the codes AXD.1 thru AXD.2 both refer to the 6 auxiliary data field responses. The difference is that AXD.n returns the actual string that was entered, and Ax returns a numeric value. If the string does not translate into a numeric value, then 0 is returned or Ax.

The LOOP..ENDLOOP structure allows output of multiple observations without having to specify them. An asterisk (*) is used within this structure as a wildcard (rather than the 'n' in the above codes) for specifying the observation number. Thus, for example, within a LOOP..ENDLOOP structure, the code `30.*` would reference all photosynthesis values, whereas the code `30.1` specifically means the first observation of photosynthesis.

1. The list entries between LOOP and END LOOP are cycled through once for each observation (not sample) in the page.

2. On each pass through the list, the * is interpreted as the current observation number.

3. There is an implied EOL after each pass through the loop, except for the last pass.

For example, the following are equivalent for a page with 2 observations:

With LOOP	Without LOOP
LOOP	15.1M
15.*M	30.1
30.*	EOL
ENDLOOP	15.2M
	30.2
	EOL

Multiple LOOP..ENDLOOP structures may be in the list. If they are nested, only the inner-most loop is seen. If the loops are overlapped, looping will be between the inner-most LOOP..END LOOP structure.

A LOOP with no ENDLOOP (or vice versa) is ignored.

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EXAMPLE 1

Suppose that you only wished to output the page number, time, quantum sensor readings, photosynthesis, and transpiration for each page.

1. Press FCT **D 9** to access the user format list.

```
LAB:
NUM:0_
```

A variable length list. Current length=0.

The number of entries shown depends on the value of NUM. NUM should be set to the desired length before editing. Since we are after 5 items, NUM should be set to that.

2. Change NUM to 5.

3. Edit the list so that it appears as below. Note that the 1:, 2:, etc. are supplied by the system and need not be entered.

```
LAB:EXAMPLE 1
NUM:5
1:PAG          Page number
2:TIM          Time of day
3:11.1M        Channel 11, 1st mean (QNTM)
4:30.1         Channel 30, 1st obs (PHOTO)
5:25.1         Channel 25, 1st obs (TRANSPIRATION)
```

4. Access the operating parameters (FCT **4 2**) and change the PRN FMT(U/S) to U, for user format.

5. Print a range of pages (FCT **5 3**). The output will appear something like this:

```
  1  11:19:00 1485.  45.65  .0041
  2  11:21:36 1502.  47.77  .0041
  3  11:22:57 1430.  46.72  .0042
  ↓     ↓      ↓     ↓      ↓
```


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EXAMPLE 2

To illustrate several features of the user format, compare the following sample output with the user format list that generated it:

```
1  11:19:00  PLANT      PLOT      LEAF
             10         5         3

1485.  332.6  45.66  .4058  117.7
1481.  325.3  42.00  .4146  130.1
1479.  317.8  44.43  .4162  113.1

2  11:21:04  PLANT      PLOT      LEAF
             10         5         4

1484.  333.6  44.44  .4058  120.7
1471.  326.3  43.60  .4146  115.1

3  11:23:48  PLANT      PLOT      LEAF
             11         5         2

1485.  332.6  45.66  .4058  117.7
1481.  325.3  42.00  .4146  130.1
1479.  317.8  44.43  .4162  113.1
1471.  310.3  43.60  .4146  115.1
```

Page 1 has 3 observations

Page 2 has 2 observations

Page 3 has 4 observations

```
LAB:EXAMPLE 2
NUM:18
1:EOL          Start out with blank line.
2:TIM          Time of day
3:APR.1        1st prompt
4:APR.2        2nd prompt
5:APR.3        3rd prompt
6:EOL          End of line
7:SPA.10       10 spaces
8:AXD.1        1st auxiliary data entry
9:AXD.2        2nd auxiliary data entry
10:AXD.3       3rd auxiliary data entry
11:EOL.2       Blank line
12:LOOP        Start of loop structure
13:11.*M       All obs of QNTM
14:15.*M       All obs of CO2
15:30.*        All obs of PHOTO
16:31.*        All obs of COND
17:32.*        All obs of Ci
18:ENDLOOP     End of loop structure
```


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Defining the User Keys

The definitions of the user keys (those keys outside of the black border on the LI-6200 console) are given in the list accessed by FCT E1. The default value of this list is shown below:

```
LAB:EXAMPLE 2
KEY:1 10          KEY:R FF
KEY:2 11          KEY:T 33
KEY:3 13          KEY:Y 34
KEY:4 12          KEY:A 4A
KEY:5 14          KEY:S E6
KEY:6 15          KEY:D 4B
KEY:7 16          KEY:F FF
KEY:8 17          KEY:G FF
KEY:9 FF          KEY:H E7
KEY:0 FF          KEY:Z 40
KEY:Q 30          KEY:X 50
KEY:W 31          KEY:C D0
KEY:E 32          KEY:V FF
```

The codes following the keys are the reference codes that you would enter if you were accessing the routine using the FCT key. FF is used to make a key undefined.

EXAMPLE

Define the V key to give direct access to the DUMP PAGE routine (**53**).

1. Press FCT E 1.
2. Press ↓, then EDIT.

```
KEY:V FF
NEW=_
```

3. Press **5**, then **3**, then **RTRN**.
4. Press **V**, and you will have accessed the DUMP PAGE routine.

```
DUMP PAGES
FROM:_
```

5. Press **RTRN** to abort it.

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Mini View Mode

MINI VIEW mode shows you a pre-determined sequence of values from the scratch pad. The user steps from one to the next by pressing any key (or the log button). The routine provides an alternative to VIEW mode that is useful if you are always looking at the same things in view mode, and want to do it without pressing so many keys.

MINI VIEW mode is defined using the SET MINI VIEW routine (**EC**). This routine accesses a variable length list whose elements indicate the channel and sample or observation to be shown. The protocol for specifying these is the same as for the user format list, including the LOOP..ENDLOOP structure. Only codes returning numeric values are used in mini view mode, however, so you can't include the prompts or the time and date codes.

When MINI VIEW is entered (**EB**), the display shows the first item, and the LI-6200 waits for a keystroke. It then displays the next item. **BRK** will abort, and is the only way to get out of MINI VIEW early.

EXAMPLE

1. Press FCT **E C** to access the MINI VIEW list.

```
LAB:
NUM:0
```

2. Press ↑, then **SHIFT** + EDIT.

```
NUM:0
NEW=_
```

3. We'll set NUM to 3, and make the 3 entries select the 1st observation of photosynthesis, the 2nd range observation of CO_2, and the 1st sample of air temperature. The list should look like this:

```
LAB:
NUM:3
1:30.1          1st obs of photosynthesis
2:15.2R         2nd range of CO2
3:12.1          1st sample of air temp
```

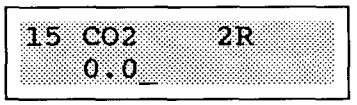
4. When done editing the list, press FCT **E B**. The display will show

```
30 PHOTO  1
   0.0_
```

If the scratch pad is empty, or if the requested data is missing, the value will be 0.0

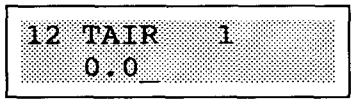
5. Press **RTRN** (or any other key). The display will show

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2nd range of channel 15, CO_2

6. Press **RTRN** (or any other key). The display will show



1st sample of channel 12, air temp

7. Press **RTRN** (or any other key), and MINI VIEW will be exited.

The LOG Program

The LOG key (and log button on the sensor head) initiate a user defined sequence of events. The list of these events is accessed by FCT **E 8**. This is a variable length list, whose default state is

```
LAB:
NUM:3
 1:E6          Clear pad
 2:E9          LOG mode
 3:E7          VIEW mode
```

Any entry permissible following FCT is permissible here.

The LOG program is terminated if any function greater than 3F is performed from the keyboard while the LOG program is active. This means, for example, if you added code D6 (to store the pad) after the E7 in the default list, and during VIEW mode (E7) you pressed the AREA key, (defined to do FCT 4A which is greater than 3F), then the D6 will never happen. Functions less than 3F are allowed, since that is how you select channels to view during logging.

It should also be pointed out that the LOG program does not need to have anything to do with logging data; it is named for its default use. In fact, LOG program lists are actually named PROG files (file type 16), not LOG files.

EXAMPLE 1: AUTO-PROMPTING

Suppose the sequence of events that you want to have happen when you press LOG are to clear the pad, log data, ask for leaf area, plot number, plant number, and leaf number, then compute the results and let you look at them in view mode.

1. Press FCT **4 1**, and define the first three auxiliary data prompts to be

```
pr1=PLOT #
pr2=PLANT #
pr3=LEAF #
```


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2. Press FCT E 8, and set the list to look like this:

```
LAB:
NUM:7
 1:E6          Clear pad
 2:E9          LOG mode
 3:4A          Ask leaf area
 4:AA          Prompt for PLOT #
 5:AB          Prompt for PLANT #
 6:AC          Prompt for LEAF #
 7:E7          VIEW mode
```

EXAMPLE 2: ONE-BUTTON OPERATION

Sometimes it is desirable to operate the LI-6200 without having to press any keys. This can be done using the LOG program, and making use of MINI VIEW mode. Set up the LOG program so that the following sequence of items is performed:

- Clear the pad
- LOG mode
- Display all observations of photosynthesis
- Display all observations of conductance
- Display all observations of intercellular CO_2.
- Store the page.

This program will allow data collection to be initiated with the log switch on the sensor head. When logging is over, the major results can be viewed in succession (pressing the log switch to change the display each time), and then the results are stored. If, while viewing the results, you decide NOT to store the data, you would have to press **BRK** on the keyboard.

1. Press FCT E C. Edit the variable length list so that it looks like this:

```
LAB:
NUM:5
 1:LOOP
 2:30.*        Photosynthesis, 1st obs
 3:31.*        Conductance, 1st obs
 4:32.*        Ci, 1st obs
 5:ENDLOOP
```

2. Press FCT E 8. Edit the variable length list so that it looks like this:

```
LAB:
NUM:4
 1:E6          Clear pad
 2:E9          LOG mode
 3:EB          MINI VIEW mode
 4:D6          Store pad
```


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The Key Buffer

When the LI-6200 receives keystrokes from the terminal (console), it buffers them until needed. For example, when you enter VIEW mode, the LI-6200 recomputes the scratch pad (unless it is empty). While the computing message is being displayed, if you pressed PHOTO, that keystroke (in this case, a Q) would be buffered until the LI-6200 finished computing, at which time it would look in the buffer, find the Q, and show you the photosynthesis channel. Pressing the **Q** key did not stop it from computing (only **BRK** would do that), but the LI-6200 did not ignore the key, either.

The key buffer used by the LI-6200 has room for 128 characters to be "typed ahead". There are two functions that allow use of the key buffer feature for purposes other than catering to speedy typists. FCT **ED** allows keystrokes to be entered in a special list known as a KBUFF file (file type 14). FCT **EE** clears the key buffer, and moves the contents of the current KBUFF file into the key buffer. Keep in mind that the KBUFF list (or file) is an entirely separate entity from the key buffer.

A SIMPLE EXAMPLE

To illustrate these two functions, here is a trivial yet entertaining example: We will make the LI-6200 enter the SETUP execute list, and scroll through it automatically.

1. Press FCT **E D**. You have accessed the KBUFF list. which consists of a 2 lines: the first is the familiar label line (LAB:), and the second a keystroke line (KEYS:).

2. Press **SHIFT** + EDIT.

3. For the label, enter nothing. Just press **RTRN**.

4. For the KEYS, enter the following keystrokes:

Z K K K K K K K K K P z.

Note that the last key is **SHIFT** + **Z**, which is used to terminal the entry.

5. Now execute the list by pressing FCT **E E**. The LI-6200 will enter the SETUP list, scroll up 10 times, then enter PAUSE mode.

A MORE USEFUL EXAMPLE

A more useful example involves automating a repetitive operation: Suppose that you are going to make alternating measurements, for which the required page parameters, operating parameters, and the LOG program are different. Suppose further that you have stored the PPARM, OPARM, and PROG files for both types of measurements. To make the first type of measurement, you need to get OPARM file 1, PPARM file 1, and PROG file 2; to make the second type of measurement, you need to get OPARM file 2, PPARM file 2, and PROG file 2.

The retrieval of these groups of files is easily done using KBUFF files. In this case, we would want two files: one to get the first group, and one to get the second. The first KBUFF file would look like this:

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```
LAB:GET 1
KEYS:L41B1↙L42B1↙LE8B1↙
```

and the second would look like this:

```
LAB:GET 2
KEYS:L41B2↙L42B2↙LE8B2↙
```

where the '↙' means that the **RTRN** key was pressed.

Once set up (and stored as KBUFF file 1 and 2), to retrieve the first set of files you would press

FCT E D GET 1 RTRN FCT EE

This loads KBUFF file 1 into the KBUFF list, and the **FCT EE** puts the keystrokes into the key buffer. The **L41B1↙** will make the LI-6200 think that you just pressed **FCT 41**, then **GET 1**, then **RTRN**, so the PPARM file 1 will be retrieved. Similarly, the rest of the KBUFF list will retrieve OPARM file 1, and PROG file 1.

To retrieve the second group of files, you would get the 2nd KBUFF file and execute it:

FCT E D GET 2 RTRN FCT EE

If you wanted to alternate between file sets one and two, you could make this operation even simpler. Change the two KBUFF files to look like this:

```
LAB:GET 1
KEYS:L41B1↙L42B1↙LE8B1↙LEDB2↙

LAB:GET 2
KEYS:L41B2↙L42B2↙LE8B2↙LEDB1↙
```

Now to swap file sets, all you need do is press **FCT EE**, since each time it executes, it leaves the other KBUFF file in the KBUFF list. Defining a spare key as **EE** would reduce the swapping operation to 1 keystroke.

RULES AND HINTS

• When editing the KEYS: line of the KBUFF list, all keystrokes go into the list, *including* **RTRN** and **DEL**. Thus, mistakes cannot be fixed without starting over.

• **SHIFT + Z** (which generates a lower case 'z' on the LI-6200 console) is reserved as the character to indicate the end of the KEYS: sequence. Thus, when you are done entering the key sequence, *don't* press **RTRN**. Press **SHIFT + Z** instead.

• A maximum of 125 characters can be entered into a KBUFF from the console.

• When the KEYS: line of the KBUFF list is displayed, all characters are interpreted normally. Thus, a **RTRN** keystroke (denoted '↙' in the above examples) will not appear as anything, but will cause a carriage return and line feed to occur on the display. It doesn't take a very big KBUFF list to make the display worthless in terms of viewing the entire KBUFF.

• Because of the above fact, a good policy when defining a KBUFF list is to ALWAYS do the following sequence:

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1. FCT ED
2. SHIFT + EDIT
3. Enter the label, press **RTRN**.
4. Enter the Keystrokes, followed by **SHIFT + Z**.

Otherwise, you won't know if the line you're entering is the LAB: line or the KEYS: line.

• Recursion is allowed. That is, a KBUFF list can contain the sequence **LEE**, which provides the potential to execute forever. Only **BRK** will regain control.

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LI-6200 Programming

This chapter introduces the LI-6200's programming structures: physical and virtual channels, system constants, and stack operators. Physical channels access millivolt signals at specific sensor input locations. Virtual channels allow mathematical operations using physical channels, other virtual channels, and system constants. Stack operators are the specific mathematical functions used by the virtual channels.

Physical Channels

System codes **00 - 0F** are channels that correspond to the physical inputs of the various sensors. Each has units of mV except **0E** which is battery voltage in volts. These channels can be viewed in MONITOR mode by pressing FCT, then entering the code. FCT **0E** will let you check battery voltage, for example, and FCT **05** will let you monitor the mV signal from the CO_2 analyzer.

Data from these channels is not stored with a data page. If you wish to store a mV value with a data page, a virtual channel should be defined to do this.

FCT **E2** accesses the SENSR list, which allows the user access to the definition of **0x** channels; these channels can be in one of three states: OFF, LOW, or HIGH (the latter two refer to 12 bit (2.44 mV) and 16 bit (.15 mV) resolution). Also, a 2 character ID can be specified for the channel.

The default 0x channels are set as follows:

Code	State	Label	Description	Connector	Pin # (Signal, Ground)
00	LOW	??	Reserved		
01	LOW	TA	Air temperature signal (mV)	Sensor Head	E,H
02	LOW	TL	Leaf temperature signal (mV)	Sensor Head	C,H
03	LOW	RH	RH sensor signal (mV)	Sensor Head	D,H
04	LOW	TC	IRGA temperature signal (mV)	Analyzer	9,8
05	HIGH	C2	CO_2 analyzer signal (mV)	Analyzer	2,8
06	LOW	QN	Quantum sensor signal (mV)	Sensor Head	A,H
07	LOW	FL	Flow meter signal (mV)	Analyzer	7,8
08	OFF		Spare channel #1	RS-232	9,10
09	OFF		Spare channel #2	RS-232	11,12
0A	OFF		Spare channel #3	RS-232	14,15
0B	OFF		Spare channel #4	RS-232	16,17
0C	OFF		Spare channel #5	RS-232	18,19
0D	OFF		Spare channel #6	RS-232	22,23
0E	LOW	BA	Battery (V)		
0F	LOW		Reserved		

There is a price to be paid for using the high resolution: it takes about 0.5 seconds to get a reading from a channel using high resolution. A low resolution readings takes about 0.15 seconds.

The signal inputs should be between -5.0 V and +5.0 V.

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System Constants

There are 48 system constants that can be referenced explicitly in the definition of a virtual channel. These are **A0 - AF** (the page parameters), **B0 - BF** (user parameters), and **C0 - CF** (sensor parameters). Although these groupings are completely arbitrary with respect to virtual channel definitions (that is, the system doesn't care if you reference **A5** or **CD** or **B9**), there are big differences with respect to how these values are stored and changed.

PAGE PARAMETERS A0 - AF

Values for **A0 - AF** are contained in the FCT **41** list and can be stored as a PPARM file. Also, these values are stored as part of PAGE files. The most important thing to remember about these constants is that *they are subject to change anytime a PPARM file or a PAGE file is retrieved.* The logical use for Ax constants is for values that potentially could change from one measurement to the next.

Code	Description
A0	P(mb) - Atmospheric pressure (mb)
A1	A(cm2) - Leaf area (cm^2)
A2	Vt(cc) - Total system volume (cm^3)
A3	BC(mol) - One sided boundary layer conductance (mol m^{-2} s^{-1})
A4	STMRAT - Ratio of stomatal conductances of one side of the leaf to the other
A5	Fx(umol) - Maximum flow rate though the desiccant (μmol s^{-1})
A6	Vg(cc) - IRGA volume (cm^3)
A7	Kabs - Water absorption factor for the system
A8	A8 - Unused
A9	A9 - Unused
AA	<pr1> - Numeric value of auxiliary data response field #1
AB	<pr2> - Numeric value of auxiliary data response field #2
AC	<pr3> - Numeric value of auxiliary data response field #3
AD	<pr4> - Numeric value of auxiliary data response field #4
AE	<pr5> - Numeric value of auxiliary data response field #5
AF	<pr6> - Numeric value of auxiliary data response field #6

USER CONSTANTS B0 - BF

System constants **B0 - BF** are available for the user to define and use. They are included in the SYSTM list (FCT **E3**) along with the virtual channel definitions. The constants **B0 - B3** are set up as multipliers on the channels you view when you press PHOTO , COND , Rs , and Cs respectively, to make changing units simple. For example, to make the PHOTO key (and channel **30**) yield photosynthesis in units of mg dm^{-2} hr^{-1}, you would simply have to press FCT **E3**, scroll to find the **B0** entry, and change it to a value of 1.584, which converts μmol m^{-2} s^{-1} to mg dm^{-2} hr^{-1}. (Or, press FCT **B0** and access it directly.)

Code	Default Value and Use	
B0	1.0	Units multiplier for photosynthesis
B1	1.0	Units multiplier for stomatal conductance (molar)
B2	1.0	Units multiplier for stomatal resistance (velocity)
B3	1.0	Units multiplier for stomatal conductance (velocity)
B4	0.0	Unused
B5	0.0	Unused
B6	0.0	Unused
B7	0.0	Unused
B8	0.0	Unused
B9	0.0	Unused
BA	0.0	Unused
BB	0.0	Unused
BC	0.0	Unused

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BC	0.0	Unused
BD	0.0	Unused
BE	0.0	Unused
BF	0.0	Unused

The logical use for **Bx** constants is for values that are used as part of your equation set that are not going to change from measurement to measurement. For example, values used in determining final units are a good candidate for **Bx** constants.

SENSOR CONSTANTS C0 - CF

System constants **C0 - CF** are primarily intended to be those constants needed to convert mV signals from the various sensors into more meaningful units. These constants are included in the SENSR list (accessed by FCT **E2**) along with the physical channel definitions.

Code	Default Value and Use	
C0	0.0	Unused.
C1	1.0	Used for the value 1.0.
C2	1.00	Used for the value 100.0.
C3	0.012207	Thermistor multiplier (50°C = 4096mV).
C4	.00226	Thermocouple multiplier (°C per mV).
C5	0.0	Unused.
C6	0.0	Quantum sensor cal constant.
C7	0.024414	Humidity sensor multiplier (4096 mV = 100%RH).
C8	0.0	Flow meter offset. Automatically set by FCT 48.
C9	0.0	CO_2 reference concentration (ppm). Automatically set by FCT 49.
CA	0.0	CO_2 reference signal (mV). Automatically set by FCT 49.
CB	1.0	CO_2 gain factor. Automatically set by FCT 49.
CC	0.179	Quantum circuit current to voltage conversion factor.
CD	0.0	Unused.
CE	0.0	Unused.
CF	44.64	Flow meter: converts standard $cm^{-3}\ s^{-1}$ to $\mu mol\ s^{-1}$.

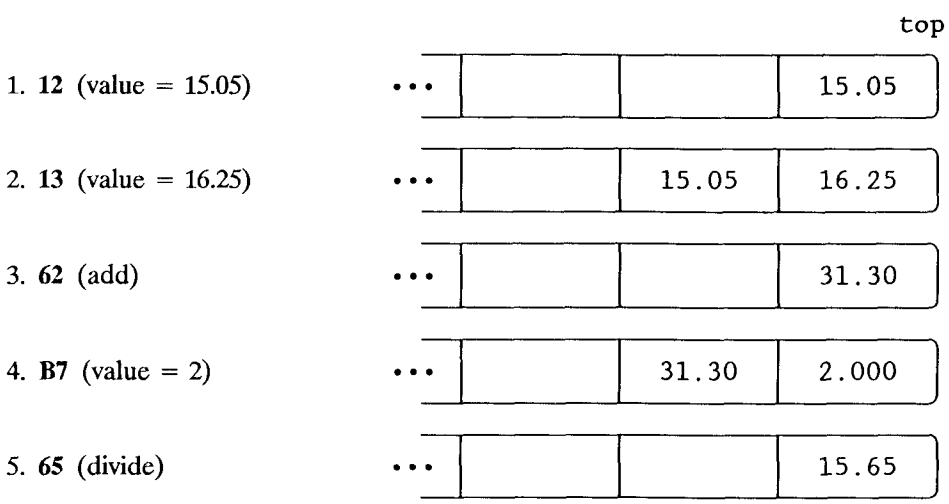
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Stack Operators

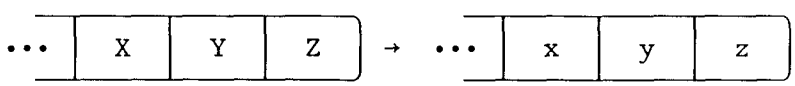
The calculation scheme uses a 10 level, last-in, first-out stack, and postfix notation (also known as reverse Polish notation, RPN). Thus, for example, adding two values is done by pushing one onto the stack, then the other, then specifying the add function. The add "consumes" two values from the stack, and the sum is pushed back onto the stack. System references **60 - 7F** are to built-in functions involving the stack.

The stack can be visualized as top-down or bottom-up, it doesn't matter. In the following discussions, the term "top of the stack" refers to the end at which values are pushed on or popped off. The accompanying diagrams use a horizontal representation, with the top on the right.

Suppose we want to average two channels, say **12** and **13** by adding them together and dividing by 2. If we had set up a constant somewhere with the value 2 (let's assume **B7** is so defined), and if we knew that the code for addition was **62** and the code for division was **65**, the sequence **12 13 62 B7 65** would accomplish this task. In terms of the stack, that sequence would cause the following events (assuming that channels **12** and **13** had values of 15.05 and 16.25 respectively):



The **60 - 6F** stack operators is shown below. Upper case Z,Y,X,... refer to the initial state of the stack, and lower case z,y,x... refer to the final state of the stack.



Code	Description	
60	SWAP	z = Y, y = Z
61	DROP	z = Y, y = X, ...
62	ADD	z = Z + Y
63	SUBTRACT	z = Z - Y
64	MULT	z = Z × Y
65	DIVIDE	z = Z ÷ Y
66	INVERT	z = 1/Z
67	CHNG SGN	z = −z
68	SQUARE	$z = z^2$
69	CUBE	$z = z^3$
6A	SQRT	$z = \sqrt{Z}$
6B	DUPE	z = Z, y = Z, x = Y, w = X, ...
6C	PREV xx	Returns previous 1x or 0x value.

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6D	**STORE xx**	Store top entry at location given by next code
6E	**RANGE 1x**	The next 1x reference is Range value, not Mean value.
6F	**SLOPE xx**	Compute Slope and Standard Error rather than Mean and Range

Codes **70 - 7F** are shown in the Software Reference Chapter of this manual.

FCT **60** (or **61, 62, ... 7F**) will access a calculator mode (see the Software reference section **60 - 7F** for details) which allows the user to operate the stack by entering numbers and codes from the keyboard.

Virtual Channels

The LI-6200 software makes available 48 virtual channels that can be defined as the user wishes. Unlike a physical channel which is literally tied to a specific input, a virtual channel is defined as sequence of mathematical operations whose "inputs" can be any other channel (virtual or physical) or constant. Thus, for example, to convert the mV signal from a linearized thermistor (such as would be found on channel **01**) to a value in degrees C, one would define a virtual channel to take the value found at **01** and multiply it by some constant.

Thus, the ingredients in LI-6200 programming are 1) the family of built-in mathematical operators and functions, 2) the set of constants that are available, and 3) the set of channels that are available.

Virtual channels are defined in the System Program (FCT **E3**). The definition of a virtual channel consists of a 5 character label, and up to 20 (although only 15 can be entered from the console) system codes. The 5 character label is optional, but a channel is "undefined" if the system code string is empty. The computation of virtual channels proceeds in order, so references to other virtual channels should be to lower ones. There are some legitimate exceptions to this rule, however, as is illustrated in the default **2x** channel definitions.

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10 - 1F

Channels **10 - 1F** are calculated once each second (approximately) during Monitor mode. During Log mode, they are calculated at the STEP parameter (in FCT **42**) frequency. At the end of each observation, Means and Ranges (or Slopes and Standard Errors of the Slopes) of each defined **1x** channel are calculated.

The logical use for **1x** channels is for only those quantities that need to be monitored in real time, or those that need rates of change calculated.

Code	Label	Sequence	Description
10	TIME	70	Time since clear pad
11	QNTM	06 C6 CC 64 65	Quantum sensor (μmol m^{-2} s^{-1})
12	TAIR	01 C3 64	Air temperature (C)
13	TLEAF	02 C4 64 12 62	Leaf temperature (C)
14	TCO2	04 C3 64	IRGA temperature (C)
15	CO2	05 CB 64 CA 62 14 71	CO_2 concentration (ppm)
16	FLOW	07 C8 63 14 72 CF 64	Flow rate (μmol s^{-1})
17	RH	03 C7 64 73	Relative humidity (%)
18	EAIR	12 74 C2 65 17 64	Vapor pressure (mb)
19	DE/DT	6F 18	Slope of vapor pressure
1A	DC/DT	6F 15	Slope of CO_2
1B			
1C			
1D			
1E			
1F			

20 - 2F

2x channels are calculated at the completion of observations during Log mode, upon entering View mode (FCT **E7**), and as part of the Store Pad routine (FCT **D6**). In the default configuration of the LI-6200, **2x** channels are used to calculate intermediate values:

Code	Label	Sequence
20		
21	W	12 75 A1 64 6D 2F 18 A0 65
22	FRACT	16 A5 65
23	FW/S	16 21 64 A1 65 C2 65
24	K	A2 A6 22 64 63 19 64 2F 65 6D 25 66 23 64 67
25	E	25 A7 64 23 62 C1 21 63 65
26	GS	13 74 18 25 A0 A4 A3 76 79
27	DC	A2 A0 64 1A 64 2F 65 15 25 64 62
28	A	23 15 64 27 C1 21 22 64 63 64 63
29		
2A		
2B		
2C		
2D		
2E		
2F	(RTS)	

Channel **21** calculates the molar fraction of water vapor (Equation (1.13)), but prior to doing that, it calculates the value of the product of the gas constant, the absolute temperature, and the leaf area, and stores it in channel **2F**. This is a space saving trick; since this value is used in several places, it is economical to calculate it once and store it away. It could have its own channel (such as **20**), of course, but each channel takes 4 bytes per observation when stored. Storing a value in an undefined channel saves this space, since **2F** is never stored because it is not defined (no code sequence).

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Channel **22** calculates the fraction of flow that is going though the desiccant (Equation (1.14)). This short definition could easily have been merged into another channel, of course, to save space. However, should the flow fraction need to be set to 1 (such as when using the LI-6050 analyzer - see Example 6 at the end of this chapter), it is convenient to have this on its own channel.

Channel **23** calculates flow rate times water mole fraction divided by leaf area.

Channel **24** calculates the water absorption term (Equation (1.17)). Along the way, however, it computes the volume-related term of transpiration rate (Equation (1.16)), at which point the value is stored ahead into channel **25**.

Channel **25** starts out by picking up the value passed ahead to it from channel **24**, then finishes the transpiration calculation.

Channel **26** calculates stomatal conductance (Equation (1.21)).

Channel **27** begins the photosynthesis calculation (Equation (1.34)).

Channel **28** finishes the photosynthesis calculation (Equation (1.34)).

Channel **2F** is not defined, since there is no code sequence. The value found in this channel comes from channel **21**, where it was passed ahead using the **6D** stack operator. Because this channel is not defined, the value is not stored in the page, so printing pages using FCT **53** will result in values of **2F** (if referenced in the system or user format list) being "trash". The value will be whatever is "left over" in the scratch pad at that location. The only time the **2F** value will be valid is following a computation, (when the display says "computing...").

30 - 3F

```
30      PHOTO     B0 28 64
31      COND      B1 26 64
32      CINT      26 A4 A3 76 7A 25 15 28 7B
33      RS        12 75 A0 65 26 64 6D 34 66 B2 64
34      CS        34 B3 64
35
36
37
38
39
3A
3B
3C
3D
3E
3F
```

Channel **30** takes the value of photosynthesis in units of μmol m^{-2} s^{-1} (channel **28**) and multiplies it by a user defined constant to put photosynthesis into the desired units.

Channel **31** takes the value of stomatal conductance in units of mol m^{-2} s^{-1} (channel **26**) and multiplies it by a user defined constant to put it into the desired units.

Channel **32** computes intercellular CO_2 concentration (Equations (1.35) and (1.36)).

Channel **33** takes the value of stomatal conductance in units of mol m^{-2} s^{-1} (channel **26**) and converts it to

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stomatal resistance in velocity units (default is s cm^{-1}) according to the user defined multiplier. Note that it passes the conductance value in units of cm s^{-1} ahead to channel **34**.

Computational Rules

Refer to the **E5** discussion in the Software Reference section (Chapter 7) for the Rules of Computing channels. That is, order of computation, etc.

The System Number

The System Number corresponds to the current SYSTM file number.

When the System Program list is accessed FCT **E3**, if it is stored, or if a previously stored file is retrieved, the current file number for SYSTM files will change, and so will the System Number. This value is displayed in Pause mode, along with the label of the current SYSTM file:

```
LI-6200.02.00
   5:MY PROG
```

When any file is stored, the System Number is included in the header information of that file. (For details, refer to the file structure discussion following **54 Binary Dump** in the Software Reference Section of this manual). The only file type for which the LI-6200 program is concerned about the System Number is page files, however.

Whenever a data page is retrieved (by a GET while in View mode, or by FCT **D7** (the EDIT loop)), the SYSTEM NUMBER of the retrieved page is compared with the current SYSTEM NUMBER. If they do not agree, then display will show

```
DIFFERENT SYSTM
Press Key ..._
```

and you must press a key for the retrieval process to continue.

The System Number starts out at 0. If you store the E3 list and thereby change the System Number, as well as (potentially) the program itself, there are three methods of recovering the default program.

1. Store the SYSTM list before any changes are made. Then, to recover the default program, simply GET the appropriate SYSTM file. The System Number will not be zero, however.

2. Do routine **E4**, which resets the E3 and E2 lists to default values, and resets the SYSTEM NUMBER.

3. Do routine **EA**, the system reset. This is somewhat drastic, however, as it results in ALL lists being reset to default values. Stored files are unaffected.

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EXAMPLE 1: EDITING THE SYSTEM PROGRAM

This example doesn't actually accomplish anything, but it does illustrate some things about editing the **E3** list.

1. Press FCT **E 3** to access the program list.

```
LAB:
10 TIME   70
```

2. Press ↑ a few times, to scroll into the **1x** channel definitions.

```
16 FLOW   07C863*
17 RH     03C764*
```

The * means there are more codes than the 3 shown.

3. Because this is a segmented list, **CTRL** ⇕ ↑ and **CTRL** ⇕ ↓ provide a quick means to jump to the next or previous segment. Press **CTRL** ⇕ ↑ and you will jump down to the start of the **2x** channels:

```
20
21 W      1275A1*
```

Channel 20 is undefined.

4. When editing a channel, you are first prompted for the label, then the code sequence. We'll edit channel **23** to illustrate. Press ↑ a few times until the display shows

```
23 FW/S   162164*
21 W      1275A1*
```

5. Press EDIT. You will be prompted for the label

```
FW/S
NEW=
```

The current channel label.
Press RTRN to leave unchanged.

Press **RTRN** to leave the label unchanged, and you will be prompted for the code sequence

```
162164A165C265
NEW=
```

Press RTRN to leave unchanged.

6. Press **RTRN** to leave it unchanged. If you wish to un-define a channel, enter a space, then **RTRN** for the code sequence. Code sequences should be entered in a continuous string - no spaces or other delimeters should separate any of the characters.

If a channel has a long code sequence, it is impossible to tell what it is using only the console display. For example, if you edit channel **24**, the display will show

```
656D2566236467
NEW=_
```

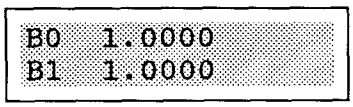
The end of channel 24 code sequence.

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when prompting for the code sequence, which is only the last half of it.

IT IS GOOD POLICY TO HAVE WRITTEN DOWN SOMEWHERE WHAT THE CODE SEQUENCES SHOULD BE, BECAUSE YOU CAN'T ALWAYS SEE THEM ON THE DISPLAY.

7. Press **CTRL** [↑] two more times, and you will get to the start of the last segment of the **E3** list, the **Bx** values. These are single value entries, and edit normally.



The B0 - BF part of the list.

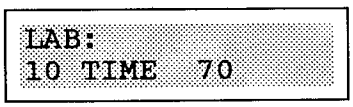
8. Press [PAUSE] to leave the **E3** list. If you think you messed something up while following this example, do [FCT] **E4** to reset the **E2** and **E3** lists.

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EXAMPLE 2: CHANGING UNITS

Suppose that you have 100 pages stored, and you have just discovered that you can make photosynthesis come out in units of mg dm^{-2} hr^{-1}, simply by changing B0 from 1 to 1.584.

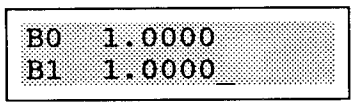
1. Press FCT **E 3** to access the program list.



The label.
Channel 10's single code definition.

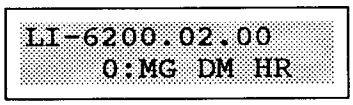
2. Let's identify the new system we are making by labelling it 'MG DM HR'. Press EDIT to edit the label for this list, and type **MG DM HR**, followed by **RTRN**.

3. Press **CTRL** + ↓ to jump to the B segment of the list.



4. Since B0 is the photosynthesis multiplier, to change units, we need to change B0 to 1.584. Press EDIT and enter **1.584** for the new value of B0.

5. Press PAUSE. Notice the PAUSE display reflects the new system program by the label, but the SYSTEM NUMBER hasn't changed because we did not store the SYSTM list:



At this point, you have not affected the stored pages - photosynthesis in those pages is still in units of μmol m^{-2} s^{-1}. You must recalculate those pages.

6. Press FCT **D 7** to access the EDIT loop function.

7. Enter the page range to be recomputed.

8. For the CODE, enter **A9**. This code is not used for anything, and serves as a good "dummy", since we don't really wish to change any other parameter.

9. In response to ASK EACH, enter N **RTRN**.

10. In response to A9, enter **0 RTRN**.

The pages will now be recalculated, and photosynthesis will be in mg dm^{-2} hr^{-1}. FCT **53** can then be used to output the results.

We did not store the system program for this example, because the Edit Loop program would not have run unattended (assuming that the stored pages had the same System Number as the current SYSTM file, that is).

If you wish to store the new program, re-enter the list, and press STORE.

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EXAMPLE 3: AVOIDING MOLAR FLOW RATES

If you would prefer to deal with flow rates in standard $cm^3\ s^{-1}$, then you will appreciate this example, as you will be shown how to have the displayed value of flow rate be in those units, as well as the maximum flow parameter Fx.

The default configuration of the LI-6200 version 2.0 software has flow rates in mass flow units of $\mu mol\ s^{-1}$. The calibration equation and coefficients convert the millivolt signal to standard $cm^3\ s^{-1}$, however. Notice that the final step of the channel **16** definition is to multiply the stack by the constant **CF**. This step converts $cm^3\ s^{-1}$ to $\mu mol\ s^{-1}$. The program could just as easily wait until it uses flow to calculate something to do this conversion, which is what we will make it so in this example.

Access the **E3** list, and make the following changes:

```
LAB:CM3 FLOW                              To identify this program.
16 FLOW  07 C8 63 14 72                   Keep flow in cm3 s-1 until...
23 FW/S  16 CF 64 21 64 A1 65 C2 65       ...it's used in the calculations.
```

The only other channel that used flow was channel 22, which computes the fraction of flow. As long as you enter the Fx(umol) parameter in units of $cm^3\ s^{-1}$ when using this program, you will be OK.

The purposes of comparison, the default (molar flow) sequences of channels **16** and **23** are (as was shown previously in this chapter):

```
16 FLOW  07 C8 63 14 72 CF 64
23 FW/S  16 21 64 A1 65 C2 65
```


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EXAMPLE 4: RECALCULATING VERSION 1.0x DATA PAGES

There are a number of reasons why you cannot simply load a data page collected under software revision 1.0x and recalculate it using the default system program:

1) The boundary layer parameter **A3** is resistance (s cm^{-1}) instead of molar conductance.
2) The flow rate and max flow parameter are volumetric (not standard) cm^3 s^{-1} instead of μmol s^{-1}.
3) The Vg(cc) parameter is undefined in version 1.0x.
4) The Kabs parameter is undefined in version 1.0x.
5) The slope function (**6F**) works differently in version 1.0x. This only will apply to collecting new data, or a big recompute (see **E5** is the Software Reference).

This example shows how to set up a system program specifically to be used with the EDIT LOOP function for recalculating version 1.0x data pages using version 2.0 equations. Specifically, it will do the following to each data page it computes:

- Set the Vg(cc) parameter to the appropriate value.
- Set the Kabs parameter to the appropriate value.
- Set the boundary layer conductance value.
- Convert the flow rate to molar units for purposes of the calculations. The channel **16** (flow) values will remain unchanged.
- Set a flag to indicate that this is a version 1 page, and that subsequent recomputations should convert the flow rate.

We will implement two system configurations: one to be used once with the EDIT LOOP routine to get the pages converted, and a second to be used subsequently for both new data and recomputing the converted pages. This second configuration will look for a flag to tell it if this is new data (molar flow rates) or an old data page (volumetric flow rates). We will use the unused page parameter **A9** as this flag.

1. Press FCT **E3** to access the system list. Make the following changes. Note that the code sequences shown below are spaced for clarity - do not enter them this way, however.

```
LAB:REDO 1.0X
20 X      B4 6D A6 B5 6D A7 B6 6D A3 C1 6D A9      Sets Vg(cc), Kabs, BC, and A9
23 FW/S   16 12 A0 7C 65 CF 64 21 64 A1 65 C2 65  Flow converted to molar
B4 = 120.                                         Desired value of Vg(cc)
B5 = 1.1                                          Desired value of Kabs
B6 = ???                                          Desired value of BC(mol)
```

Channel **20** sets the IRGA volume, absorption factor, and boundary layer conductance. It also sets the parameter A9 to 1. Channel **23** is similar to the default definition, except the flow rate has the density correction taken out (converts from volumetric to standard flow) and is multiplied by 44.64 (converts to molar flow).

The simplest way determine what to enter for **B6** is to take the old BLR parameter, multiply it by 2.5, and invert it. It is of course possible to set the program to do this automatically, but we will not. This will avoid the problem of what would happen if the page to be converted got recomputed more than once with this program.

2. Store this list away as a new SYSTM file by pressing STORE, and responding with N **RTRN** if asked if you wish to overwrite the file.

3. Now modify this list a second time, to set up the general purpose configuration. Make the following

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changes:

```
LAB:VER 1 OR 2
20 X      A9 12 A0 7C 64 CF 65 A9 63 C1 62 C2 64
23 FW/S   16 21 64 A1 65 20 65
B4 = 0.0
B5 = 0.0
B6 = 0.0
```

Channel **20** will come out being 100 if A9 is 0 (normal or new data pages). If A9 is 1, then channel **20** will be 100 times the factor necessary to convert the volumetric flow to standard flow. Channel **23** is just like the default definition, except that it divides by channel **20** at the end, rather than the constant **C2**.

4. Store this list away as a new SYSTM file by pressing STORE, and responding with N **RTRN** when if you wish to overwrite the file.

5. Retrieve the 'REDO 1.0X' system list by pressing GET and entering its file number.

6. Perform the EDIT LOOP function, looping over the version 1 pages that are stored in RAM. Do not do this to any version 2 pages, however.

```
FCT: D7
FROM: ??
THRU: ??
CODE: A8
ASK EACH(Y/N): N
A8: 0
```

Quite likely, when each page is loaded into the pad, the message

```
DIFFERENT SYSTEM
Press Key ..._
```

will be displayed. Just press a key, and the process will continue.

7. When the EDIT LOOP routine is finished, press FCT **E3** and load in the 'VER 1 OR 2' system list. You can now correctly recalculate old data of either version 1 or version 2, or take new data in the version 2 format.

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EXAMPLE 5: MAKING BOUNDARY LAYER A FUNCTION OF LEAF AREA

Theoretically, the boundary layer conductance is proportional to the square root the the ratio of wind speed to leaf size. As a practical matter, you may wish to measure boundary layer conductance for a range of leaf sizes, and fit a straight line to the result. Given a slope and intercept of BC(mol) as a function of leaf area, this example tells how to set up a system list so that the correct BC(mol) is used for any given leaf area.

Suppose you find that the function

Y = 1.5 - 0.05X

fits a graph of BC as a function of area. We'll use the normal BC parameter (**A3**) to store the intercept 1.5, and **A8** to store the slope -.05.

1. Press FCT **E3** to access the system list. Make the following changes. Note that the code sequences shown below are spaced for clarity - do not enter them this way, however.

```
LAB:BC=F(A)
20 BC     A4 A3 A1 A8 64 62 76      Adjust for area and the stomatal ratio parameter.
26 GS     13 74 18 25 A0 20 79      Replace the 'A4 A3 76' with '20'
32 CINT   26 20 7A 25 15 28 7B      Replace the 'A4 A3 76' with '20'
```

2. Store this list away as a new SYSTM file by pressing STORE, and responding with N **RTRN** if asked if you wish to overwrite the file.

3. To use this program, just remember that the BC(mol) page parameter is the intercept value now, and the previously unused **A8** parameter is the slope.

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EXAMPLE 6: LI-6200 VOLTMETER

A voltmeter adapter plug is in the spare parts kit. It is a 25 pin "D" connector with a red wire protruding from the top. You will also need the clip lead with the spring clips on either end.

To use the voltmeter, lists **E2** and **E3** need to be modified. The voltmeter plug is wired for spare channel #1 (channel **08**). Since full scale on the spare channels is ±5 V, the adapter has added circuitry so it can be used between ±50 V. The reading on channel 08 will be 1/10 the actual mV signal. We will configure the SYSTM list so that channel **1B** will divide channel **08** by 100, yielding a value in Volts. Constant **C2** is already 100, so we'll use that. The code for a divide is **65**.

1. Press FCT **E 2**.

2. Press EDIT, and enter **VOLTMETER** for the label, then press **RTRN**.

2. Scroll down until the display shows

```
08 OFF
09 OFF
```

Channel 08 is spare channel #1

3. Press EDIT. Press **L**, then **RTRN**. This sets channel 08 to LOW resolution. The display will now be prompting for a label. Press **V M** then **RTRN**. The display will show

```
08 LOW  VM
09 OFF
```

Channel 08 now voltmeter channel.

4. Store the E2 list away by pressing STORE.

5. Press FCT **E3** to access the system list. Make the following changes. Note that the code sequence shown below is spaced for clarity - do not enter it this way, however.

```
LAB:BC=F(A)
1B V     08 C2 65
```

6. Store this list away as a new SYSTM file by pressing STORE, and responding with **N RTRN** is asked if you wish to overwrite the file.

7. Press PAUSE. The display will indicate the new configuration:

```
LI-6200.02.00
   1:VOLTMETER
```

8. Press MONITOR, then FCT **1 B**. You are now monitoring the voltmeter channel on the top line of the display:

```
2230 1B V  ?????
   0 10 TI 2230.
```

Might read anything if not connected.

9. Plug the voltmeter adapter plug into the RS-232 connector on the console.

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10. The red wire protruding from the connector is the voltage side of the voltmeter. If you look down inside the connector housing, you will see a loop of block wire. This is the ground side.

When measuring the voltage of anything electrically connected to the LI-6200 console (attached battery, sensor housing, analyzer), you only need to connect the protruding wire, as the voltmeter connector ground is tied to the LI-6200 ground.

When measuring voltages from other sources, you will need to use the ground.

CAUTION

Measure DC voltages only, between +50 V and -50 V.

NOTE: The voltmeter as configured above is not purported to be of laboratory quality, but should function adequately for many diagnostic purposes. Improved performance can be achieved by the following procedure:

1. Set channel **08** to HIGH resolution.

2. Calibrate the voltmeter: Remove the shroud from the connector. Measure a known voltage source, and adjust the pot on the connector until the displayed reading is correct. Replace the shroud.

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EXAMPLE 7: LI-6050 ANALYZER

The fraction of flow on the LI-6050 is identically 1, since all flow goes through the desiccant. The following changes to the System Program will correctly reflect this configuration:

```
LAB:6050
22 FRACT C1
```

Since **C1** has a value of 1.0.

1. Press FCT **E3** to access the System Program.
2. Press EDIT to change the list label.
3. Enter **6050 RTRN** for the new label.
4. Press **CTRL** + ↑, followed by ↑ ↑ to access channel **22**.
5. Press EDIT to edit channel **22**.
6. Press **RTRN** to keep the label (FRACT) the same.
7. Type **C 1** and press **RTRN** for the new code sequence.
8. Press **STORE** to store the modified program in RAM.

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EXAMPLE 8: INTEGRATING

There are applications when it is desired to integrate raw samples, rather than compute means or slopes. Suppose, for example, that you wished to inject some CO_2 into an air stream that was eventually flowing though the CO_2 analyzer, and you wished to measure the total amount of CO_2 that went through. That is, for N samples, you wish to calculate total CO_2 T:

$$T = \sum_{i=2}^{N} \frac{C_i + C_{i-1}}{2} (t_i - t_{i-1})$$

This can be achieved by making these changes to the default System Program:

```
LAB:INTEGRATE
1B SUM   10 6C 10 63 15 6C 15 62 B4 65 64 1B 62
35 TOTAL 16 6E 1B 64 B5 64
B4 = 2.0
B5 = 1.0E-6
```

The first time through after a clear pad, channel **1B** will be zero. Notice that **1B** always adds the result to itself, so it is an accumulator. The **6C** operator fetches the previous value of its object channel. In the above case, it is used both for time and CO_2 concentration.

If logging is begun prior to the first CO_2 going though the analyzer, and completed after the last CO_2 has gone through, the range value of channel **1B** will be the total CO_2 in units of μmol mol^{-1} s. The total CO_2 in terms of μmol is obtained by multiplying the **1B** range by the mean flow rate in mol s^{-1}. Channel **35** accomplishes this, using the constant **B5** to convert flow from μmol s^{-1} to mol s^{-1}.

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EXAMPLE 9: TIME INTO EACH OBSERVATION

This example shows how to make the time column of the printed data page indicate the time since the start of each observation, rather than the time since the pad was cleared. That is,

this... rather than this.

OB	TIME	...
1	0.0	
2	1.600	
3	3.200	
4	5.600	
5	7.200	
6	9.600	
7	11.20	
8	0.0	
9	1.500	
10	3.900	
11	5.500	
12	7.900	
13	9.500	
14	11.90	
1M	5.485	
2M	5.742	
1R	11.20	
2R	11.90	

OB	TIME	...
1	2.100	
2	3.700	
3	5.300	
4	7.700	
5	9.299	
6	11.70	
7	13.30	
8	18.10	
9	19.60	
10	22.00	
11	23.60	
12	26.00	
13	27.60	
14	30.00	
1M	7.585	
2M	23.84	
1R	11.20	
2R	11.90	

This can be accomplished with the following change to the default system program:

```
LAB:OBS TIME
1B SUM   1F C1 6D 1F 61 10 6C 10 63 64 1B 62
```

The first time through (the first sample of an observation), channel **1F** will be 0. The `C1 6D 1F 61` sequence writes a 1 to channel **1F**, so that on all subsequent passes, **1F** will be 1. The 1 is then dropped off the stack. The `10 6C 10 63` computes the time difference between this sample and the last. This is then multiplied by a 0 or 1, depending upon whether or not it is the first sample, and accumulated in **1B**.

The system format list (**D8**) should also be changed so that **1B** is printed in the first column, rather than **10**.

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EXAMPLE 10: TRANSPIRATION

This example shows how to include transpiration (mmol m^{-2} s^{-1}) as a channel that can be viewed on the console, and printed in system or user format.

Transpiration is available on channel **25** in the default system program, but is in units of mol m^{-2} s^{-1}, and does not get included in the default system print format.

Make the following changes to the **E3** list:

```
LAB:TRANS
35 TRAN  25 B4 64
B4 = 1000
```

and the following changes to the **D8** list:

```
LAB:TRANS
USER COL  6:35
```

EXAMPLE 11: VAPOR PRESSURE DEFICIT

VPD, the difference in vapor pressure between the leaf and the air, is not available in the default system configuration. It is easily added, however, as either a real time quantity that you can watch in monitor mode, or else as a quantity that only gets computed after an observation.

This example will add VPD as a real-time channel.

Make the following changes to the **E3** list:

```
LAB:VPD
1B VPD   13 74 18 63
```

If you wish to add VPD to the system print format, make the following changes to the D8 list:

```
LAB:VPD
MEAS COL 11:1B
```


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EXAMPLE 12: LEAF ENERGY BALANCE

This example illustrates the use of an energy balance to determine leaf temperature. This temperature will be in channel **35**, and can NOT be monitored in real time, but can be viewed after an observation; it will be the mean leaf temperature during that observation. This value is then used to calculate a second conductance and intercellular CO_2 concentration in channels **36** and **37**.

Make the following changes to the **13** list:

```
LAB:LEAF EB
35 TEB   A3 12 6B BA 62 25 11 BB 64 7E 12 62      New leaf temp
36 GEB   35 74 18 25 A0 A4 A3 76 79               New conductance
37 CEB   36 A4 A3 76 7A 25 15 28 7B               New Cint
BA = 1.00                                         A guess at (Twall - Tair)
BB = 0.22                                         Converts PAR to net solar (Eq. 1.39)
```

and these changes to the **D8** list:

```
LAB:TRANS
USER COL  6:35
USER COL 7:36
USER COL 8:37
```

The value of **BA** is an extimate of the wall - air temperature difference, but is not especially critical. An increase of BA by 1 (degree) will cause computed leaf temperature to increase by 0.15C when air is 25C, for example. The boundary layer conductance, on the other hand, has a strong impact on computed leaf temperature.

This approach gives reasonable estimates of leaf temperature, but has not been exhaustively tested, so use it carefully.

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Data Communications

This chapter deals with interfacing the LI-6200 using the RS-232 interface. It is assumed that the reader is familiar with the general operation of the instrument.

RS-232 Discussion

Since you are reading this, it may well be that you have discovered for yourself a fundamental truth about "standard RS-232" interfaces: If devices A and B both have RS-232 interfaces, connecting them together with a cable in no way guarantees that they will communicate.

The purpose of this discussion is to cover the basics of RS-232, so that when you are confronted with the "they just don't talk to each other" problem, you will have some things to try to remedy the situation.

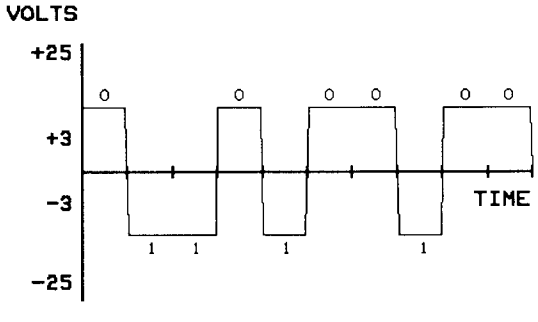
The discussion below is confined to asynchronous communications; the LI-6200 does not support synchronous.

BAUD RATE, DATA BITS, AND PARITY

In its simplest form, RS-232 communication can occur from device A to device B over two wires: one is a signal ground, and the other is the signal. Device A sends data by changing the voltage on the signal line between two voltage levels. The upper voltage is anything between +3V and +25V. This is known as the "space" condition. The other voltage level is between -3V and -25V, and is known as the "mark" condition.

Voltage Range	State	Name
+3V to +25V	0	Space
-3V to -25V	1	Mark

When the line is in the space condition for a certain length of time, it is interpreted as a 0; similarly the mark condition is a 1.



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Each 0 and 1 is referred to as a bit. A bit by itself is not very meaningful, but taken together in groups of 8, for example, they can codify a lot of information. Since there are 256 possible combinations of 1's and 0's in 8 bits, there are 256 possible characters that can be sent. Take a look at the ASCII table in the appendix. You will find the entire alphabet in upper and lower case, numbers, punctuation, and several other things all given unique binary codes. For example, an A is 0100001, a question mark (?) is 00111111, etc. This is the ASCII (USA Standard Code for Information Interchange) code, and is what the LI-6200 uses. Notice that the ASCII code contains only 128 (that is, 0 thru 127) characters, so it can be represented in 7 bits, rather than 8, since the left-most bit is always 0.

To successfully interpret the message that is sent, however, the sending device and the receiving device must agree on a number of things:

• What is the time associated with each bit? This is the **BAUD RATE**, which is the number of bits per second. This value is generally between 300 and 9600.

• How many bits are there in each character? This is the number of **DATA BITS**, and is usually 7 or 8.

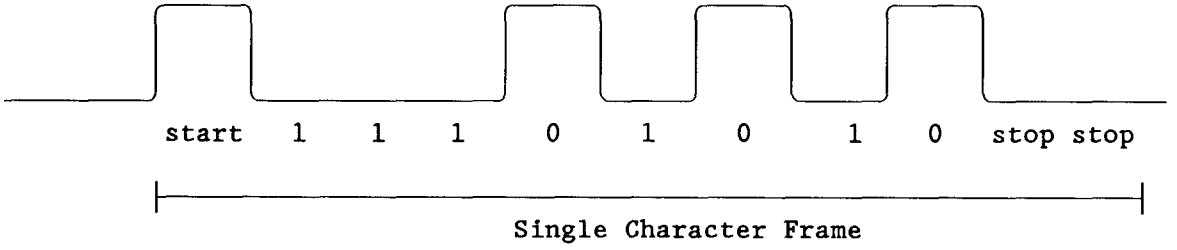
• What signals the end of a character? 1 or 2 **STOP BITS** follow each character.

There are a couple of things that both devices will automatically agree on:

• Between characters, when nothing is being sent, the line will be in the mark (1) state.

• The beginning of a character will always be signaled by a one bit shift to the 0 state. This is known as a start bit.

Suppose device A is to send the character W to device B. A W is represented in binary as 01010111. If it is agreed to send 8 bits per character and to end the character with 2 stop bits, the signal will look like this:



One other subtlety: the characters are sent "backwards", so least significant bits are sent first.

Since the ASCII code can be represented in 7 data bits, when sending ASCII data the 8th data bit can either be ignored, or used for something else. Frequently, this something else is **PARITY**.

Parity is sort of a built-in check to tell if a character was received properly. There are 5 possible methods of handling parity:

1. Do not use it.
2. Set the parity bit so that there are an **even** number of 1's in the character.
3. Set the parity bit so that there are an **odd** number of 1's in the character.
4. Always set the parity bit to a **1**.
5. Always set the parity bit to a **0**.

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Consider, for example, the characters X, Y, and Z, as represented using the 5 types of parity handling:

	W		X		Y	
Parity	8765	4321	8765	4321	8765	4321
None	101	0111	101	1000	101	1001
Even	1101	0111	1101	1000	0101	1001
Odd	0101	0111	0101	1000	1101	1001
1's	1101	0111	1101	1000	1101	1001
0's	0101	0111	0101	1000	0101	1001

When 8 data bits must be used (non-ASCII data, such the the binary transfer routines of the LI-6200), parity cannot be used.

DCE - DTE

Not all of the 25 pins in a standard RS-232 connector are used. In fact, for one way communication, only 2 lines are used: one for signal, one for ground. For 2-way communication, a third line is needed.

Pin 7 is ground, and pins 2 and 3 are the data lines.

Suppose device A is built to send data on pin 2, and receive data on pin 3. If device B is built the same way, they will not communicate. Obviously, device B needs to receive on 2, and send on 3.

Thus, there are 2 types of RS-232 devices in the world: Those that send data on pin 2, and those that receive data on pin 2. The former are known as Data Terminal Equipment (DTE) and the latter as Data Communications Equipment (DCE).

One of the most common reasons for not getting two devices to communicate is that they are BOTH DCE (or DTE), and thus CAN'T communicate on a pin-to-pin connection. They can be made to communicate, however, by connecting them with a cable that (at the very least) exchanges pins 2 and 3.

The LI-6200 is DTE. It sends data on pin 2, and receives data on pin 3.

CONTROL LINES

It can take more than three signal lines for reliable data communication. As an example, consider a receiving device that is "busy", and not ready to receive data. How can the sending device know that it should wait? The answer can involve control lines.

Control lines are distinct from the data lines (pins 2 and 3) in that rather than changing their voltage to signal data, they change their voltage to signal a change in state; for example, from "I'm ready" to "I'm not ready". Signal lines are ON when their voltage is greater than +3V, and OFF when less than -3V.

Each of the 25 pins have a standard definition associated with it. However, there is no guarantee that a particular RS-232 device will implement any of these, or implement them according to the standard. The LI-6200, for example, uses 12 of them for analog inputs to the spare channels. The important ones, and how they relate to the LI-6200 are indicated below:

Pin 1 - Protective Ground. The line is connected to the LI-6200's ground.

Pin 2 - Transmitted Data (TD). The LI-6200 sends data on this line.

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Pin 3 - Received Data (RD). The LI-6200 receives data on this line.

Pin 4 - Request to Send (RTS). The LI-6200 holds this line in an ON condition while it is powered up.

Pin 5 - Clear to Send (CTS). The LI-6200 must see this line ON before it will transmit any data. If the line goes OFF during data transmission, the LI-6200 will cease sending data and display CTS NOT HIGH.

Pin 6 - Data Set Ready (DSR). When the I/O parameter CHECK DSR is set to Y, then the LI-6200 must see this line ON before it will transmit any data. If the line goes OFF during data transmission, the LI-6200 will cease sending data and display DSR NOT HIGH.

Pin 7 - Signal Ground. Voltages are measured relative to this point.

Pin 8 - Received Line Signal Detect (Carrier Detect) (CD). When the I/O parameter CHECK CD is set to Y, then the LI-6200 must see this line ON before it will transmit any data. If the line goes OFF during data transmission, the LI-6200 will cease sending data and display CD NOT HIGH.

Pin 20 - Data Terminal Ready(DTR). The LI-6200 holds this line in an ON condition while it is powered up.

SOFTWARE PACING MECHANISMS

There are software methods of controlling transmission as well. There are a number of protocols in use today, but they all basically follow this pattern: one or two characters of the 128 or 256 possible characters are reserved to mean certain things, such as "I'm ready to receive data", or "Stop! Don't send any more until I tell you to".

The LI-6200 supports two of these protocols: ENQ/ACK ("enquire - acknowledge"), and XON/XOFF ("transmit on - transmit off", but more normally called "x-on - x-off")

XON/XOFF is the more widely used of the two, and it works like this: Device A is sending data to device B. If device B sends an XOFF character to device A, device A will cease transmission, until device B sends another character, the XON character, signalling that it is ready to receive data again. Generally, the XON character is a 00010001 (or more readily referred to as a decimal 17, or hex 11). The XOFF character is generally a decimal 19 (hex 13).

The LI-6200, if the I/O parameter XON/XFF (we abbreviated it to fit the display) is set to Y, will cease data transmission upon receipt of an XOFF, and resume upon receipt of an XON. Both characters can be redefined if needed.

ENQ/ACK is implemented on some mainframe computers. If the computer is sending data to a terminal, every so many characters (say 100), the computer will insert an ENQ character (decimal 5) into the data stream, and then stop and wait. Whenever the terminal finds an ENQ in the incoming data stream, it dutifully sends out an ACK character (decimal 6). This is the response that the computer is waiting for, and it then resumes it's data transmission.

The LI-6200, if the I/O parameter ENQ/ACK is set to Y, will send an ACK whenever it detects an ENQ in the incoming data stream.

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SO WHY DON'T THEY COMMUNICATE?

So, you've connected them together, and they won't communicate. What's wrong? As the preceding discussion shows, there may be a number of reasons. Below is a summary checklist, in the order that you should proceed to solve the problem.

The RS-232 Indicator board supplied in the LI-6200 spares kit is a valuable tool for solving these sorts of problems.

1. Is it really an RS-232 interface? - Sounds silly, but you'd be surprised. NOT EVERY 25 PIN "D" CONNECTOR YOU COME ACROSS IS CONNECTED TO AN RS-232 INTERFACE. A good example is found on the backplane of an IBM Personal Computer. If you find two 25 pin D connectors, one male and one female, odds are that the female one is a parallel interface - a totally different animal than an RS-232 interface. In fact, if you connect the right RS-232 device to the parallel interface, you could damage the parallel interface.

The RS-232 Indicator board can help here. When plugged into a parallel interface (it's safe by itself), none of the LEDs will light. When plugged into an RS-232 interface, DTR or DSR may or may not light.

2. Are both devices using ASYNCHRONOUS communications? - The LI-6200 does not support synchronous communications.

3. Are both devices listening and talking on the same lines? - If so, you need a null modem device between them. This is a fancy term for a cable that interchanges pins 2 and 3, and generally 6 and 20 as well. Remember, unless you use a null modem, DTE only communicates to DCE, not another DTE.

You can use the RS-232 Indicator Card to tell what's what, generally. When plugged into a DTE device, DTR will light (line 20), and perhaps RTS (line 4) as well. When plugged into a DCE device, DSR (line 6) will light, and perhaps lines 5 (CTS) and 8 (CD) as well.

One further note: Sometimes you are faced with the need for a "gender-changer"; that is, a short cable, or card, with back-to-back female or male connectors. BE CAREFUL HERE. Find out whether or not the gender-changer is also changing DTE to DCE or vice versa; is it pin-for-pin, or does it exchange pins 2 and 3?

Two different cables are shipped with the LI-6200: The Modem Cable (ribbon) has a male and female connector on each end, and can be used as a gender changer. The Printer Cable is in fact a null modem device.

4. Is data actually being sent? - If nothing else, use the RS-232 Indicator Card for this. You may have to shade the TD and RD LEDs to see if they are flickering or not. If they are, you know that data is being sent, and on what line.

If data is being sent, but ignored by the receiver, then there are a couple possibilities: Is the data on the correct line (step 3)? It may be that the receiving device, if it is DTE, needs to see pin 8 (CD) high.

If data is not being sent, then the sending device may need to see some pin high before it will send data. If the sender is the LI-6200, it will notify you if it is waiting for a line to go high *if that line has changed state since power up*. The LI-6200 must see pin 5 (CTS) high in order to transmit. Use the RS-232 indicator card to see if it is high.

5. Are the RS-232 interfaces configured the same? - Data bits, stop bits, parity, and baud rate all must match, although there are combinations of the first three that are compatible.

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Configuring the I/O Port

The LI-6200's RS-232 interface is configured in software. The configuration is accessed by FCT 5 1. This function accesses a list:

BAUD=4800	Baud rate
DATA BITS=8	Data bits
STOP BITS=2	Stop bits
PARITY=None	Parity
CHECK CD=N	Hardware pacing: DCD line
CHECK DSR=Y	Hardware pacing: DSR line
ENQ/ACK HSHK=N	ENQ/ACK handshake
XON/XFF HSHK=N	XON/XOFF handshake
XON CHAR=11	XON character (hex)
XOFF CHAR=13	XOFF character (hex)
FLAG PARITY=N	Display message if parity error detected
FLAG FRAME=N	Display message if framing error detected
LOCAL ECHO=N	Echo keystrokes back to the display in terminal mode
SOM=00	Start of message sequence (external console mode)
EOL=0D,0A	End of line sequence (hex)
EOL WAIT=0	End of line wait (milliseconds)
EOM=00	End of message sequence (external console mode)

NOTE

The configuration defined by this list is not actually implemented until the list is exited by pressing **RTRN**. Exit via **BRK**, or **FCT** may cause some changes to not be implemented.

BAUD can be any of the following: 50, 110, 150, 300, 600, 1200, 1800, 2400, 3600, 4800, 7200, 9600, 19200, 38400. When data is ready to be sent, it will be sent at the specified baud rate, but overall data transfer times will be slower when the LI-6200 has to search for and format the data first.

DATA BITS is the number of data bits per character, and can be 7 or 8.

STOP BITS is the number of stop bits per character, and can be 1 or 2.

PARITY can be None, Odd, Even, 1's or 0's. Only the first character need be entered (N, O, E, 1, or 0).

CHECK CD is a hardware handshake. When set to 'Y', the LI-6200 will only send data when it sees pin 8 (DCD) of the I/O port high (>3 V). If the voltage of this pin drops below this level, data transmission will cease until the voltage climbs above this level. While waiting for this to occur, the message 'CD NOT HIGH' is displayed on the console.

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CHECK DSR is a hardware handshake. When set to 'Y', the LI-6200 will only send data when it sees pin 6 (DSR) of the I/O port high (>3 V). If the the voltage climbs above this level. While waiting for this to occur, the message 'DSR NOT HIGH' is displayed on the console.

This method of pacing, or handshaking, is common with printers. The 6000-03 Epson printer as delivered by LI-COR has installed an RS-232 interface configured to handshake in this manner.

ENQ/ACK HSHK implements the enquire/acknowledge handshake. When this is set to 'Y', the LI-6200 will send a hex 06 (ASCII ACK) upon receipt of a hex 05 (ASCII ENQ). This feature will probably only be useful if using the LU-6200 as a terminal to a mainframe computer (such as an HP 3000) that uses this pacing mechanism.

XON/XFF HSHK is the XON/XOFF handshaking protocol. The LI-6200 will transmit data until an XOFF character (defined below) is received. Data transmission will resume upon receipt of an XON character (also defined below). This is a fairly common handshaking protocol.

XON CHAR defines the character to be considered the XON character if XON/XOFF handshaking is being used. This is normally a hex 11 (ASCII DC1).

XOFF CHAR defines the character to be considered the XOFF character if XON/XOFF handshaking is being used. This is normally a hex 13 (ASCII DC3).

FLAG PARITY, when set to 'Y', will cause the message 'PARITY ERROR' to be displayed when an error in parity in the incoming data is detected. This feature is probably only useful to aid in determining the correct I/O configuration to use in terminal mode.

FLAG FRAME, when set to 'Y', will cause the message 'FRAMING ERROR' to be displayed when a framing error in the incoming data is detected. The error will usually be generated by an incorrect number of data bits.

LOCAL ECHO pertains to terminal mode, and causes keystrokes to be echoed back to the display.

SOM and **EOM** only apply when the console has been redirected to the output port. SOM is a Start of message character, and EOM is an end of message character, and both are specified in hex. All data sent to the (redirected) console is preceded by SOM, and followed by EOM. EOM and SOM can be up to 5 characters each in length.

EOL is the end of line sequence in hex. Up to 5 characters may be defined. The default values of OD OA specify a CR and LF (carriage return and line feed).

EOL WAIT is the delay in milliseconds after each transmitted line of data.

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Using the RS-232 Interface

In addition to "normal" output, which is discussed throughout this manual, the RS-232 port can be used for some other tasks that might prove very useful to you.

TERMINAL MODE

In terminal mode (FCT **52**), all typed characters are sent to the RS-232 interface, and all characters received are displayed on the terminal's display. This mode is very useful for transferring data to a mainframe computer. The typical sequence of events might be

1. Configure the RS-232 interface to match the port used on the mainframe computer. You probably will need some sort of handshaking, such as XON/XOFF.

2. Replace your normal terminal with the LI-6200 console.

3. Put the LI-6200 into terminal mode, and log on to the host.

4. Open a file, or run a program, or do whatever you have to do to put the computer into a mode to receive data.

5. Exit terminal mode, and send the desired data to the host (for example, by FCT **53**).

6. Resume terminal mode, close and save the file, and log off from the host.

USING AN EXTERNAL TERMINAL

It is very simple to use another terminal device (such as an IBM PC running a communications package) to control the LI-6200. FCT **EF** (Swap Terminal) will cause the LI-6200 computer to redirect it's console communications to the I/O port, rather than the built-in terminal. The communications parameters are determined by the current setting of the I/O parameter list.

After FCT **EF** is performed, the built-in console will seem dead, and will remain that way until a FCT **EF** is performed by the alternate console (or until power off).

While the I/O port is serving as the terminal, any output function that would normally direct output to the RS-232 port will still function normally. Terminal mode and Capture mode (FCTs **52** and **56**) are not allowed, however.

One of the applications of this feature is that a small, hand-held terminal could be used with the LI-6200, eliminating the need for the operator to be right next to the main console (as long as you don't need to adjust flow rate, of course).

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BINARY TRANSFERS

Data files are stored in the memory of the LI-6200 in a structured, compressed manner. A floating point number, for example, whether it is 1.0 or 3.14159 always takes 4 bytes: the first 3 bytes are the mantissa of the number, where each bit represents 2 raised to some negative power, and the 4th byte is the exponent. (For details, refer to the Software Reference chapter, and the discussion following **54**, the binary dump).

FCT **54**, the Binary Dump routine, will send 1 or more files to the I/O port exactly in the form in which they are stored internally. This form is referred to as **binary format**. Dealing with files in binary format has some advantages to go along with its disadvantages:

ADVANTAGES

• Files are always in a consistent format. If you were going to program a computer to pick selected pieces of information out of a page file, for example, you would have to either ensure that the data were always in the same format, or else go crazy writing search routines to determine what in fact was present. (You would have to search for certain labels like CO2 or PHOTO, and if the data page were the result of a different system program, with different channel labels, you'd be stuck). In binary format, you could tell immediately what channels were and were not present, how many observations, samples, etc. Also, you could locate specific values (such as observation 5 of channel **22**) quite readily.

• Files are generally more compressed in binary format.

• Binary format files can be loaded back into the memory of the LI-6200. This feature is handy for storing configurations and data before loaning out the instrument for someone else to use. When you get it back, you can load its memory back into it.

DISDVANTAGE

• The main disadvantage is that you need a computer to interpret a file in binary format. And the computer needs custom programming, since there is absolutely nothing "standard" about the structure of these files.

LI-COR software packages 6200-25 and 6200-26 do support binary format, and serve as an alternative to doing your own programming, if you wish to interpret files in binary format.

CAPTURE MODE

Capture mode (FCT **56**) provides a method of using the LI-6200 as a general purpose RS-232 buffer/storage device. This routine creates an ASCII file, and then simply records whatever comes into the I/O port in this file. A certain keystroke on the console will terminate capture mode.

A separate routine **57** allows one or more ASCII files to be sent out the I/O port, byte-for-byte as they were received.

ASCII files cannot exceed 31K bytes. At the time of its creation, you can specify a label the file.

An example of using this capability in the field is with the LI-1600 Steady State Porometer, which has minimal on-board data storage, but does have RS-232 communications. If the LI-6200 and the LI-1600 were being used reasonably close to each other, the person with the LI-1600 could record about 15 or 20 readings, then walk over to the LI-6200 and dump them into another ASCII file. At then end of the day, the ASCII files could be dumped to a computer.

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Odds and Ends

Leaf Chambers

VOLUME CONSIDERATIONS

One way to think about the comparison between open and closed gas exchange systems is this: in an open system, the measurement of photosynthesis is proportional to the flow rate (volume per time) going through the system. In a closed system, such as the LI-6200, flow rate is replaced by the volume of the chamber and the length (time) of the measurement. In an open system, the range of leaf areas (for a given photosynthetic rate) that can be measured depends on the range of flow rates that can be used. In a closed system, leaf area depends on chamber volume and measurement time.

For example, with an open system, if 10 cm^2 of leaf area gives a certain differential CO_2 concentration using a flow rate of 0.5 ℓ min^{-1}, then to have the same CO_2 differential with 100 cm^2 of leaf area, a flow of 5 ℓ min^{-1} is needed. With a closed system, if 10 cm^2 leaf area yields a change in CO_2 concentration of 10 $\mu\ell$ ℓ^{-1} in 30 seconds using a 1000 cm^3 chamber, then to have the same result with 100 cm^2 of leaf area would require a chamber that is 10,000 cm^3 in volume.

One of the advantages of a closed system is that it is quite flexible in terms of the range of sample sizes and photosynthetic rates that can be accommodated. To measure 1 m^2 of crop, you simply need an adequately large chamber, and not a huge flow rate. To measure dark respiration rates on small leaves, you need a small chamber and/or a long measurement time, rather than a miniscule flow rate.

(One word of caution: these remarks apply to CO_2 measurements, not water vapor. Water adheres to everything, and a measurement system in which the rate of change of vapor pressure is the most important term is immediately suspect, unless the water adsorption (and absorption) effects are somehow "calibrated out". Such is the case with a transient porometer, for example.)

How best to determine what chamber volume to use? If we start with Equation (1.34), and ignore the first and third terms (which are generally an order of magnitude smaller than the middle term), we have the relationship:

$$A = -k \frac{V}{S} \frac{\partial C}{\partial t} \qquad (6.1)$$

where A is photosynthetic rate (μmol m^{-2} s^{-1}), V is total system volume (cm^3), S is leaf area (cm^2), and $\partial C/\partial t$ is the rate of change of CO_2 with time (ppm per second). k is a function of pressure and temperature, and has a value of 0.4 at 1000 mb pressure and 27C. For volume in m^3 and leaf area in m^2, use k = 40.0.

Suppose you wish to measure a square section of grass canopy, 0.5 m on a side. How big a volume (that is, how tall a chamber) do you need? First, determine total leaf area. If the LAI is 2, then the total leaf area in 0.25 m^2 is $2 \times 0.25 = 0.5$ m^2. Next, choose some typical canopy assimilation rate, such as 10 μmol m^{-2} s^{-1}. Then solve Equation (6.1) for V, assuming a rate of change of CO_2 of -0.5 ppm s^{-1}:

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$$V = \frac{A\ S}{-k \frac{\partial C}{\partial t}} = \frac{(0.5)\ (10)}{(40)\ (0.5)} = .25\ m^3, \text{ or } 1\ m \text{ tall.}$$

WATER ABSORPTION

Perhaps the better phrase would be "water uptake", since it is arguable whether the effects discussed here are absorption or adsorption. At any rate, we will use absorption, but mean it in a very loose sense.

Attempting a transpiration measurement by determining the rate of change of vapor pressure in a closed chamber will likely yield erroneous results. If vapor pressure in the chamber increases, the walls of the chamber will become drier than the surrounding air, and water molecules will move to (and perhaps into) the wall material, resulting in the perceived increase in vapor pressure being less than it "should" be. On the other hand, if vapor pressure drops during the measurement (too large a flow of dry air through the system, for example), the water molecules will move from the walls to the air, and the wall would thus become an additional source of water, besides the leaf.

As a general rule, the smaller the chamber, the greater the potential for serious errors due to water absorption. The volume to surface area ratio is the important item here: a small chamber has a lot of surface area and not much volume, while a large chamber has proportionally more volume to its surface area. (This ratio for a cube is length/6, a sphere is radius/3, etc.)

The K Test, described in the **Primer**, is a way to quantify the effects of water absorption (provided everything else is working correctly), but that works AFTER a chamber is already built, and serves as a sort of a dirty chamber indicator. The materials used in the chamber must be selected to minimize water uptake (Refer to Dixon and Grace (1982)).

Plexiglass (Pespex), nylon, and silicon rubber are materials to avoid, even in small quantities. Don't be tempted to use nylon line for leaf support lines, for example, because a few feet of that will have significant surface area, and a measureable effect on water uptake.

At the other extreme, glass is one of the best materials for not retaining water.

No matter what the chamber is made of, however, it will eventually get dirty. Dust, plant debris, pollen, etc. will turn any chamber into a veritable sponge.

MIXING THE AIR

Another consideration in chamber design is moving the air. In a large crop canopy type of chamber, mixing is important mainly to insure that the air subsampled is representative of what's in the chamber. For smaller, individual leaf chambers, mixing is also important for boundary layer considerations.

Usually, one wants a very low boundary layer resistance (high wind speed), so that its contribution to the total leaf resistance is small, allowing stomatal resistance to be deduced with a high degree of confidence. However, there is the potential that the low boundary layer resistance will in fact cause the stomata to react, thus changing what you wish to measure. (This is especially true of plants grown in artificial environments that have never experienced very much wind. Better results can be obtained if an oscillating fan is set up in the growth chamber to regularly and thoroughly agitate the plants throughout

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their life).

The fan speed is user-adjustable on the LI-6200 sensor head (see below).

LI-COR CHAMBER MATERIALS

The three LI-COR leaf chambers (6000-10, 6000-11, and 6000-12) are made of Lexan® and Margard,™ which is Lexan with a hard silicon coating that resists scratching. (Margard is used for things like rapid transit car windows, to reduce costs due to vandalism). These materials are measurably better than Plexiglass in terms of water absorption, but still not "good enough". Therefore, the interior of the chambers is coated with Teflon™ tape, as well as interior fan motor housings. Teflon is not as good at not taking up water as glass, but it is the best alternative we've found to date.

A 1/8 inch sample of Margard or Lexan will have a transmittance of about 90% in the visible and near IR. Below about 450 nm, however, it falls markedly to about 60% at 400 nm.

The top of the Four Liter chamber (6000-10) is cut out, and covered with Propafilm® C, a polypropylene sheet laminated on both sides with polyvinylidene chloride (saran). This thin film is widely used for food packaging, and has excellent gas barrier properties. Its water adsorption characteristics are not quite as good as Teflon. Originally, this material was put on top of the 6000-10 chamber in an effort to improve the heating characteristics of the chamber. The thin film (0.00135 inches) transmits about 70% in the 8 - 13 ℓm wave band, while the chamber walls are opaque to thermal radiation. The idea was that replacing the top surface (slightly above air temperature) with the relatively cold sky (with a radiative temperature perhaps 20C colder) would keep the leaf cooler. In practice, the effects have never been particularly measureable, but it does reduce the chamber weight.

The gasket material is a closed pore foam. In the past, we've used a number of different types, including Ensolite® PE 308S. Presently, we are using Volara®, Type A (4 pound density), a crosslinked polyethylene foam. It is important to use a closed cell foam for the gasket material, because open cell foam leaks like a sieve. The problem with closed cell foam is that it always has some degree of memory. That is, if you compress it for very long, it will stay compressed for awhile - perhaps forever. There are a lot of open cell foams that don't do that (we put one sample under a desk leg for a week, and it recovered immediately), but if used in a chamber, a leak test will reveal its inherent problem: air (and CO_2 and water vapor) goes right through it.

6000-10: REPLACING THE TOP FILM

The Propafilm top is quite tough. Should you need to replace it, however, there are spare sheets and double stick tape in the spares kit.

1. Remove the old film and all of the old tape.

2. Apply new tape to the top of the chamber, overlapping it at the corners. Trim excess tape with a razor blade.

3. Lay a sheet of Propafilm on a flat surface, and invert the chamber top onto it. Work out any air bubbles, and trim excess film with the razor.

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6000-11: IT MOUNTS UPSIDE DOWN

The Quarter Liter goes "upside down" on the sensor head. That is, the handle on the sensor head will be on the same side as the top of the chamber. Otherwise, the fan cable won't reach.

There is also radiation shield that clips onto the hose barbs. It should shield the humidity sensor and thermistor from direct sunlight.

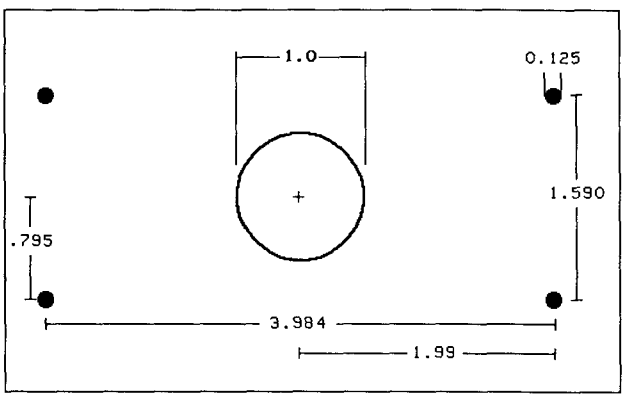
6000-12: CHAMBER INSERTS

The One Liter chamber has inserts that can be used or removed. When used correctly, they fix leaf area to a predetermined size, and allow faster measurements. The inserts snap into place, and can be slid back and forth as needed. As long as they don't get too close to the ends of the chambers, they do not affect the boundary layer conductance very much at all. They do take up some 25 cm^3 of volume, however; the V_t parameter should be adjusted accordingly.

BUILDING A CHAMBER

The 6000-15 Chamber Hardware assortment contains a variety of the hardware used on LI-COR leaf chambers. Consult LI-COR for a complete list of what is included. Chamber fans are also available, as part numbers 6000-16 (used in the Four Liter Chamber), and 6000-17 (used in the smaller chambers).

The diagram below (dimensions in inches) indicates the holes required in a chamber to mount the sensor head to it.



The only other advice that we can offer takes the form of a small list of where to get things:

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SUPPLIERS LIST

The company names, addresses and phone numbers are the most current we have at the time of this writing. In some cases, however, the information is several years old and likely out of date.

CHAMBER MATERIAL

Margard and Lexan are General Electric Company products, and widely available through a variety of suppliers. Otherwise, contact:

General Electric Company
Specialty Plastics Division
One Plastics Ave.
Pittsfield, MA 01201

Another approach is to use a fixed frame, and cover it with a material such as Propafilm:

ICI Americas, Inc
Films Division
Wilmington, DE 19897
302-575-8088

BONDING AGENT

Use Dichloroethane (also Ethylene Dichloride, Ethylene Chloride). This is a solvent of some types of plastics. It will not work with Margard unless the coating is first removed (abrasion) along the surfaces to be joined.

COATING MATERIAL

Teflon tape (adhesive backed) is available from LI-COR, part number 212-02314. The tape is 2.9 inches wide.

GASKET MATERIAL

Uniroyal Ensolite PE 308S closed cell foam. For a distributor list, contact

UNIROYAL, Inc.
Engineered Polymer Products
BOX 2000
Mishawaka, IN 46544
219-256-8108 / 8428

Volara Type A, (we use 4 lb ft^{-3} density) is made by

VOLTEK, Division of Sekisui America Corp
100 Shepard Street
Lawrence, MA 01843
617-685-2557

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TUBING

BEV-A-LINE 4, made by Ryan Herco Industrial Plastics

2509 N. Naomi St
Burbank, CA 91504
813-841-1141
714-522-1141

1819 Junction Ave
San Jose, CA 95131
408-286-1141
415-452-1140

1245 W. Geneva St.
Tempe, AZ 85282
602-968-1141

13200 Olympic Ave.
Seattle, WA 98188
206-575-1141

SODA LIME

Part # S-201, Mesh 6-12
Fisher Scientific
711 Forbes Avenue
Pittsburgh, PA 15219
201-379-1400

(LI-COR Part # 229-01828)

MAGNESIUM PERCHLORATE - ANHYDROUS

Part # M-54
Fisher Scientific
(Address above)

Part # C260M61 (P74935)
Thomas Scientific
Vine Street at Third
Box 779
Philadelphia, PA 19105
215-988-0533

Manufactured by
G. Frederick Smith Chemical Company
Columbus, OH
614-881-5501

CALIBRATION GAS

Regardless of how many certification papers it comes with, never believe a tank's concentration until you have independently verified it.

Air Products and Chemicals, Inc
Specialty Gas Dept.
Box 538
Allentown, PA 18105-0538
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Airco Industrial Gases
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International Office:
Riverton, NJ 08077
Phone: 609-829-7878
TWX: 710-941-0451

Ideal Gas Products, Inc.
977 New Durham Road
P.O.Box 709
Edison, NJ 08818
Phone: 800-225-1706 (Outside NJ)
Phone: 201-287-8766 (In NJ)
TWX: 710-986-3016
Telex: #13-6479

Liquid Carbonic
135 S. LaSalle St.
Chicago, IL 60603
Phone: 312-855-2500
Phone: 800-762-6412
Telex: 254-165-LIQUID INTL CGO

Matheson
Box 1587
Secaucus, NJ 07094
Phone: 201-867-4100

International Office:
932 Paterson Plank Road
Box 85
East Rutherford, NJ 07073
Phone: 201-933-2400
ITT: 424-456-MATSON

MG Industries
2640 Boulevard of the Generals
Valley Forge, PA 19482
Phone: 215-630-5492
Telex: 846482

International Office
175 Meister Ave
Box 5328
North Branch, NJ 08876
Phone: 201-231-9595
TWX: 846482

Scott Specialty Gases
Route 611
Plumsteadville, PA 18949
Phone: 215-766-8861
TWX: 510-665-9344
Telex: 205-766-0320

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Union Carbide
Linde Division
39 Old Ridgebury Road
Danbury, CT 06817-0001
Phone: 203-794-5599
Telex: 420542 UCC UI

Regulating Fan Speed

The fan voltage in the LI-6200 sensor head is regulated at 10 VDC. If you wish to lower this to slow the fan(s), do the following:

1. Remove the cover from the sensor head.

2. On the right side, down underneath the BNC connector for the quantum sensor, is a blue, 1-turn potentiometer.

3. Turn this pot clockwise to lower the fan voltage.

To reset the pot to 10 volts, use a voltmeter. If you set the pot too high, the fans will stop running before the low battery warning begins.

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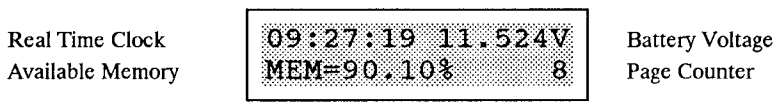
2.0 Software Reference

System Keys

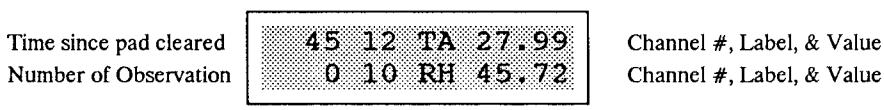
The system keys are those keys contained within the black border on the console overlay. The following is a complete description of each.

STATUS , MONITOR , PAUSE : These keys put the instrument into one of the three possible "home states", from which other routines may be initiated. When a routine is completed, execution will return to the last home state (Status, Monitor, or Pause) that the instrument was in.

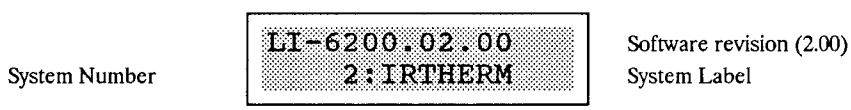
STATUS DISPLAY



MONITOR DISPLAY



PAUSE DISPLAY



BRK aborts processing, and returns to the last home state (Pause, Monitor, or Status).

LOG is a programmable key, defined in **E8**. The default definition is to clear the pad **E6**, initiate logging **E9**, and go to VIEW mode **E7**.

↑ ↓ in MONITOR mode will swap the order in which the two displayed channels are shown. In scrollable lists, the arrows cause a scroll up or down.

CTRL + ↑ or ↓ will causes a jump to the next logical break point in a list. For example, in VIEW mode when raw observations are present, **CTRL** + ↑ will jump to the next Mean and Range while viewing **1x** channels, skipping all the intermediate samples.

FCT followed by any valid hex code, will cause the selected routine to be executed.

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GET functions while viewing any storable list, and is used to retrieve any previously stored file of that list's type.

Entering a ? in response to the prompt for a file number will access a subset of the DA routine. This will allow you to use the ↑ and ↓ keys to scroll through the labels of the stored files of that particular type. Pressing **RTRN** will select the file currently shown on the display as the file to be loaded.

STORE functions only while viewing any storable list, and will cause the list to be stored as a file of the appropriate type. If the list already exists as a stored file, then you are given the opportunity to overwrite the file, or make a new file:



Y RTRN replaces the old file.
N RTRN (or just RTRN) makes a new file.

PRINT functions while viewing any list, and will cause the list to be sent to the I/O port. In VIEW mode, data is sent according to the PRNT FMT(U/S) operational parameter (FCT 42).

EDIT will allow the item of an editable list that is currently on the top line of the display to be changed by the user. Null responses to the prompt for a new value will leave the entry unchanged.

SHIFT + EDIT will cause all entries to be prompted for in turn, starting at the current entry (top line of display), and proceding to the end of the list. This automatic edit mode can be exited prematurely by pressing **CTRL** + **P**.

RTRN is used to exit a list. If the list is an execute list, it will cause the item on the top line of the display to be executed.

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00 - 0F Physical Channels

Code	State	Label	Description	Connector	Signal, Ground
00	**LOW**	**??**	Reserved		
01	**LOW**	**TA**	Air temperature signal (mV)	Sensor Head	E,H
02	**LOW**	**TL**	Leaf temperature signal (mV)	Sensor Head	C,H
03	**LOW**	**RH**	RH sensor signal (mV)	Sensor Head	D,H
04	**LOW**	**TC**	IRGA temperature signal (mV)	Analyzer	9,8
05	**HIGH**	**C2**	CO_2 analyzer signal (mV)	Analyzer	2,8
06	**LOW**	**QN**	Quantum sensor signal (mV)	Sensor Head	A,H
07	**LOW**	**FL**	Flow meter signal (mV)	Analyzer	7,8
08	**OFF**		Spare channel #1	RS-232	9,10
09	**OFF**		Spare channel #2	RS-232	11,12
0A	**OFF**		Spare channel #3	RS-232	14,15
0B	**OFF**		Spare channel #4	RS-232	16,17
0C	**OFF**		Spare channel #5	RS-232	18,19
0D	**OFF**		Spare channel #6	RS-232	22,23
0E	**LOW**	**BA**	Battery (V)		
0F	**LOW**		Reserved		

The signal inputs should be between -5.0 V and +5.0 V DC.

HIGH uses 16 bit (0.15mV) resolution, and takes 0.5 s to scan a channel. LOW uses 12 bit (2.44mV) resolution, and takes 0.15 s to scan a channel. OFF means the channel is not scanned.

Related References

E2 - Accesses the SENSR list which includes the **0x** definitions.

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10 - 1F Virtual Channels

Code	Label	Sequence	Description
10	TIME	70	Time since clear pad
11	QNTM	06 C6 CC 64 65	Quantum sensor (μmol m^{-2} s^{-1})
12	TAIR	01 C3 64	Air temperature (C)
13	TLEAF	02 C4 64 12 62	Leaf temperature (C)
14	TCO2	04 C3 64	IRGA temperature (C)
15	CO2	05 CB 64 CA 62 14 71	CO_2 concentration (ppm)
16	FLOW	07 C8 63 14 72 CF 64	Flow rate (μmol s^{-1})
17	RH	03 C7 64 73	Relative humidity (%)
18	EAIR	12 74 C2 65 17 64	Vapor pressure (mb)
19	DE/DT	6F 18	Slope of vapor pressure
1A	DC/DT	6F 15	Slope of CO_2
1B			
1C			
1D			
1E			
1F			

1x channels are calculated once each second (or as fast as possible) in Monitor mode.

In LOG mode, **1x** values become the samples that are recorded in the scratch pad. At the completion of an observation, Mean/Slope and Range/Error observations are computed, depending upon whether or not the function **6F** appears in the channel's definition.

During a little recompute (**E7**, **EB**, **D6**, or **E5** ("L" option)), **1x** values (whether means, ranges, or samples) are unaffected.

During a big recompute (**E5** ("B" option)), **1x** definitions are ignored, except that the presence of **6F** is checked to determine if Means or Slopes are to be computed. Samples must be present for a big recompute to occur. Mean/Slope and Range/Error observations are recomputed.

FCT **1x** selects the channel to be viewed in Monitor or Log mode.

Related References

E3 - Accesses the SYSTM list which includes the **1x** definitions.

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20 - 2F Virtual Channels

Code	Label	Sequence
20		
21	W	12 75 A1 64 6D 2F 18 A0 65
22	FRACT	16 A5 65
23	FW/S	16 21 64 A1 65 C2 65
24	K	A2 A6 22 64 63 19 64 2F 65 6D 25 66 23 64 67
25	E	25 A7 64 23 62 C1 21 63 65
26	GS	13 74 18 25 A0 A4 A3 76 79
27	DC	A2 A0 64 1A 64 2F 65 15 25 64 62
28	A	23 15 64 27 C1 21 22 64 63 64 63
29		
2A		
2B		
2C		
2D		
2E		
2F	(RTS)	

2x channels are computed following observations during LOG mode, and as part of both big and little computes (**E7, EB, D6, D7,** and **E5**).

FCT **2x** selects that channel in View mode. In Monitor or Log mode, the latest computed observation of that **2x** channel will be displayed.

Related References

E3 - Accesses the SYSTM list which includes the **2x** definitions.

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30 - 3F Virtual Channels

The default **3x** channels are defined as follows:

Code	Label	Sequence
30	**PHOTO**	**B0 28 64**
31	**COND**	**B1 26 64**
32	**CINT**	**26 A4 A3 76 7A 25 15 28 7B**
33	**RS**	**12 75 A0 65 26 64 6D 34 66 B2 64**
34	**CS**	**34 B3 64**
35		
36		
37		
38		
39		
3A		
3B		
3C		
3D		
3E		
3F		

3x channels are computed following observations during LOG mode, and as part of both big and little computes (**E7**, **EB**, **D6**, **D7**, and **E5**).

FCT **3x** selects that channel in View mode. In Monitor or Log mode, the latest computed observation of that **3x** channel will be displayed.

Related References

E3 - Accesses the SYSTM list which includes the **3x** definitions.

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40 Setup Execute List

40 ** SETUP **	
41 set pg parms	Page parameter list
42 set opr parm	Operating parameter list
43 set clock	Set month, day, hour, minute, second
44 set QU cal	Set quantum sensor cal constant
45 set CO2 cal	CO_2 analyzer calibration list
46 set FLOW cal	Flow meter calibration list
47 set RH cal	Humidity sensor calibration lookup table
48 zero FLOW	Determines flow meter offset voltage
49 CO2 ref	Setup a new reference gas for the CO_2 analyzer
4A leaf area	Enter a leaf area
4B aux data	Auxiliary data entry list
4C	
4D	
4E	
4F	

The default user key definitions allow this list to be accessed by the SETUP key.

When viewing this list, pressing **RTRN** will cause the routine on the top line of the display to be executed.

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41 Page Parameter List

LAB:EXAMPLE	File label. Type is 5 (PPARM). Also 1 (PAGE).
Vt(cc)=1140.	Total system volume in cm^3 (chamber, analyzer, hoses, etc.).
Vg(cc)=120.0	IRGA and hose volume in cm^3.
P(mb)=979.99	Atmospheric pressure in millibars.
BC(mol)=1.3000	One-sided boundary layer conductance in mol m^{-2} s^{-1}.
STMRAT=0.0000	Approx. ratio of stomatal conductances of either leaf side.
Fx(umol)=999.99	Maximum flow rate (μmol s^{-1}) with all flow diverted through desiccant.
Kabs=1.1	Absorption factor.
A8=0.0	Not used by default system list.
A9=0.0	Not used by default system list.
pr1=	Prompt for auxiliary data value #1.
pr2=	Prompt for auxiliary data value #2.
pr3=	Prompt for auxiliary data value #3.
pr4=	Prompt for auxiliary data value #4.
pr5=	Prompt for auxiliary data value #5.
pr6=	Prompt for auxiliary data value #6.

This is a storable list, so GET and STORE will function. The file type is 5 (PPARM).

LAB can be up to 12 characters in length, and is used as the file label if the parameter list is stored. This label is also used for the label in PAGE files.

Vt(cc) is the volume in cm^3 of the entire system (chamber + hoses + analyzer). Consult the calibration sheet for the correct value.

Vg(cc) is the volume in cm^3 of the IRGA and hoses.

P(mb) is atmospheric pressure in millibars. This is *station* pressure, not pressure corrected to sea level. If you have no better way of knowing what the pressure is on a particular day, you can estimate it from your elevation: Assume sea level pressure is 1013 mb, and that it decreases at a rate of 1 mb per 10 meters of elevation. Thus, if you are 1000 feet above sea level, 980 mb might be a reasonable guess for pressure.

BC(mol) is an estimate of the boundary layer conductance of *one side* of a leaf. For example, if you determine the conductance of 10 cm^2 of wet filter paper to be 2.8 mol m^{-2} s^{-1}, the one-sided value of conductance would be half that, or 1.4 mol m^{-2} s^{-1}. (Complete instructions for determining boundary layer conductance are given in the Pre-operation Tests section of **The LI-6200 Primer**.)

STOM RAT is an estimate of the ratio of stomatal conductances of one side of the leaf to the other side. This value is used with the BC parameter to compute the "true" boundary layer resistance for the leaf. If you are dealing with leaves with stomata on one side only, then STOM RAT should be 0. If the leaves have stomata on both sides in essentially equal amounts, then STOM RAT should be 1. If you know you are somewhere in between, but aren't sure where, then enter 0.5.

Fx(umol) is an estimate of the flow rate (μmol s^{-1}) when all of the air is being diverted through the

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system's desiccant tube on the LI-6250.

Kabs is a water absorption factor (Equation (1.1)). The K Test (**LI-6200 Primer**) is used to determine the value of this parameter.

A8, A9 are not used in the default configuration. They are accessible for user-modified configurations, however.

pr1 - pr6. These are the auxiliary data prompts, or labels. When a data page is printed using system format, these labels appear between the header and the data.

```
 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
 968.2   4110.   120.0   55.47    0.800   1.000    1130.     1.1    0.0    0.0

PLOT          PLANT          TREATMENT      REMARKS          <- Aux. data labels
5             3              5 - 22 - 0     MITE DAMAGE      <- Auxiliary data
```

Each label can be up to 12 characters in length.

Related References

4B aux data - Enter/edit "responses" to the auxiliary data prompts.

D6 STORE PAD or STORE while in VIEW mode - Stores scratch pad and page parameters together as a page.

GET while in VIEW mode - Changes page parameters to those of the retrieved page.

53 dump pages - Leaves the page parameters consistent with the last page dumped.

D7 edit loop - Leaves the page parameters consistent with the last page edited.

FCT + Ax - Displays current value, prompts for new value. AA - AF are the auxiliary data entries (not the prompts pr1 - pr6).

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42 Operating Parameter List

LAB:EXAMPLE	File label (File type is 6 (OPARM))
CHANGE=5.0000	Criterion for an observation: the amount
CHANNEL=15	Criterion for an observation: the channel
OBS/PAGE=3	Number of observations per page
STEP(s)=1	Sample every ___ seconds
BEEP LOG(Y/N)=Y	Beep when a sample is completed
KEEP SMP(Y/N)=N	Keep raw observations with the data
PRN FMT(U/S)=S	Page print format: System or User
AREA MULT=1.0000	Area multiplier.

This is a storable list, so GET and STORE will function. The file type is 6 (OPARM).

LAB can be up to 12 characters in length, and is used as the file label if the parameter list is stored.

CHANGE is the amount that the selected channel (next parameter) must change to complete an observation. For normal operation, the channel is CO_2 concentration (15), so the CHANGE parameter should be a number like 10 ppm.

CHANNEL is the channel that is to be monitored for the CHANGE (previous parameter) to occur. The channel is specified using its hex code, and can be any 0x or 1x channel.

OBS/PAGE specifies the number of observations that must be in the scratch pad for logging to stop. This is *not* the maximum number of observations that the scratch pad can hold: Observations can be added by executing **E9**, which initiates logging without clearing the pad. Logging will always stop after each observation is added, as long as the number of observations in the pad exceeds the OBS/PAGE parameter.

What is the maximum number of observations that the scratch pad can hold? The pad is roughly 31,000 bytes in size. Each observation takes up 400 bytes, and each sample takes up 100 bytes. Neither of these figures depends on the number of channels you have defined. If samples are not being retained (the parameter KEEP SMP set to N), then the space occupied by the number of samples is recovered each time an observation is completed.

STEP is the minimum time in seconds between samples, and can range from 1 to 32767. The normal value to use is 1. When logging, the display will update once every STEP seconds.

NOTE: There is no guarantee that the LI-6200 will actually be able to collect data as fast as the STEP is set to. For example, if you enable some of the spare channels, or do a lot of calculations in the 1x channels, it may take the instrument longer than STEP seconds to get and compute all the readings. When this happens, it is simply a "missed" reading; the LI-6200 will take the next available set of readings.

BEEP LOG(Y/N) determines if the LI-6200 will beep upon the completion of each observation, and again when it stops logging.

KEEP SMP(Y/N) determines if the raw samples that make up a measurement are retained. When you

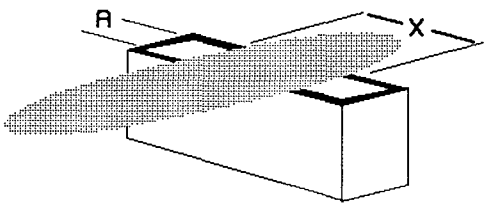
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are familiarizing yourself with the instrument, it is beneficial to do this. However, not retaining the samples will generally save tremendous amounts of memory, so in general, KEEP SMP should be set to N.

PRN FMT(U/S) select between System and User formats whenever a data page is printed, either by pressing PRINT while in VIEW mode, or by doing the DUMP PAGES routine **53**.

System format is defined by the list accessed by **D8**, and user format is defined by the list accessed by **D9**.

AREA MULT is the area multiplier. This parameter is useful when the chamber shape and leaf shape are such that the exposed leaf within the chamber approximates a rectangle:



If distance 'A' is entered for 'AREA MULT', then leaf area can be entered simply by entering distance X after pressing the AREA key (or FCT **4A**). Area entries are always multiplied by the current value of AREA MULT.

This parameter does NOT affect the EDIT LOOP routine **D7**; if you use EDIT LOOP to change areas, enter the real area, as it will not be multiplied. Nor does it affect the entry following FCT **A1**.

Related References

E9 log - CHANGE, CHANNEL, OBS/PAGE, STEP, BEEP LOG, KEEP SMP(Y/N).

D6 STORE PAD - KEEP SMP(Y/N)

4A leaf area - AREA MULT

53 dump pages or PRINT in VIEW mode - PNT FMT(U/S)

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43 Set Clock

```
04 JUL 11:22:48
NEW=_
```

Day Month Hour Minute Second
Enter a new date and time

A null entry will not change the time or date.

Each item must be separated by a delimeter (a period will work). Any of the following are valid entries:

`5.MAY.9.15`	Sets to 5 MAY 9:15
`7.OCT`	Changes only the day and month. The time remains as before.
`15`	Changes only the day. The month and time remain as before.

A month is specified by the first three characters of its name: JAN, FEB, MAR, APR, MAY, JUN, JUL, AUG, SEP, OCT, NOV, DEC. Any other entry will be ignored, as will any time entries that followed.

44 Quantum Sensor Cal Constant

```
QN CAL= 6.200
NEW=_
```

Current value
Enter a new value

The quantum sensor cal constant is the number of μA of output that the sensor will produce when exposed to 1000 μmol m^{-2} s^{-1} of photosynthetically active radiation. This information is provided with each LI-COR quantum sensor.

Related References

C6 - System reference for the quantum sensor cal constant.

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45 CO_2 Analyzer Calibration List

LAB: 395 5/5/86 File label. Type is 7 (CO2).
TEMP= 42.00C Information provided on the calibration sheet
K= 19800.
A= .14285
B= 1.9311E-05
C= 2.1453E-09

This is a storable list, so GET and STORE will function. The file type is 7 (CO2).

Related References

49 CO2 ref - Uses K.

71, 77, 78 - Use TEMP, A, B, and C.

46 Flow Meter Calibration List

LAB:223 5/5/86 File label. Type is 8 (FLOW).
A= .0081320 Information provided on the calibration sheet
B=-2.3199E-05
C= 1.0380E-07
D= 1.1240E-08

This is a storable list, so GET and STORE will function. The file type is 8 (FLOW).

Related References

72 - Uses A, B, C, and D.

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47 RH Calibration Table

LAB:	File label. Type is 9 (RH).
NPTS=5	Information provided on the calibration sheet
1: 0.0 -.5000	
2: 15.00 15.50	
3: 60.00 59.00	
4: 80.00 80.00	
5: 100.0 104.0	

This is a storable list, so GET and STORE will function. The file type is 9 (RH).

The purpose of the RH table is to correct for the slight non-linearity in the Vaisala Humicap® humidity sensor, and to provide a convenient means for the user to calibrate the sensor. Basically, the table is a variable length list of true humidity (1st) values and corresponding measured (2nd) humidity values. For example, according to the table above (which is the default table), when the true humidity is 60%, the sensor will read 59%.

If the table is applied to a value that exceeds the range of the right-hand (measured) numbers, the return value will be 99999. Thus, the table should always cover the complete measurement range.

Related References

69 Z=RH(H) - Uses this table.

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48 Flow Meter Zero

```
FLOW mV CHAN 07
NEW=_
```

Will use channel 07 as flow meter mV signal
Just press RTRN unless you've reconfigured the channels

```
FLOW=-34.603mV
<RTRN> TO ZERO_
```

Real time mV reading
Press RTRN when there is no flow

The flow meter is sensitive to temperature changes, so a method of zeroing the meter is provided. The object is to tell the computer what the flow meter's output is when there is no flow. The mV reading when you press **RTRN** (2nd display, shown above) is stored in **C8**, and used as the offset value.

The LI-6250 should be in a normal orientation when doing this function. Tilting the flowmeter affects its reading.

Related References

C8 - Location in which the offset value is stored

E3 set sys prog - Channel **16** defined to subtract **C8** from mV signal.

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49 Define CO_2 Reference

```
CO2 REF= 0.0
NEW=_
```

The CO_2 concentration in the reference cell
Press RTRN or enter the correct value (ppm)

```
GAS TEMP CHAN 14
NEW=
```

IRGA temperature is channel 14
Just press RTRN unless you've reconfigured the channels

This routine calculates the equivalent analyzer output (in mV) for the reference gas concentration in the analyzer, as well as the gain factor. To do this, it needs to know the reference gas being used (ppm), the value of pressure (entered in the page parameters), and the current temperature of the LI-6250. It does not care what the analyzer is actually reading at the moment. It assumes that the current value of system constant **A0** is the correct pressure reading.

The calculation uses an iterative technique on the analyzer calibration function. For this reason, the CO_2 calibration coefficients must be correctly entered.

If using the LI-6250 in absolute mode, this function need only be done once, after setting the pressure parameter.

If using the LI-6250 in differential mode, this function should be done whenever the reference gas concentration changes, or there is a change in temperature of more than a few degrees C.

Related References

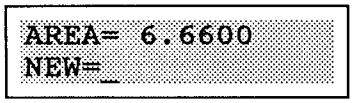
A0 - Assumed location for pressure.

C9, CA, CB - The reference ppm, signal, and gain factor. These three quantities represent the results of this routine.

45 set CO2 cal - Calibration coefficients.

77 - Programmable equivalent of **49**.

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Current value of leaf area (cm^2)
Enter new area, or just press RTRN to retain current value

This routine is also accessed by the AREA key unless the key has been redefined by the user.

If the user makes no entry (just presses **RTRN**), then the value of leaf area remains unchanged. If an entry is made, it is multiplied by the current value of the page parameter "AREA MULT", and the result is the new value of leaf area.

Related References

42 set opr parm - AREA MULT factor is in this list.

A1 - reference for current leaf area value.

FCT **A1** - Prompts for leaf area. Does not multiply by AREA MULT.

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4B AUXILIARY DATA

PLOT	pr1
5	aux data 1
PLANT	pr2
3	aux data 2
TREATMENT	pr3
5 - 22 - 0	aux data 3
REMARKS	pr4
MITE DAMAGE	aux data 4
pr5	pr5 (undefined)
	aux data 5
pr6	pr6 (undefined)
	aux data 6

This routine is also accessed by the AUX DATA key, unless that key has been redefined by the user.

The routine accesses a list of 6 pairs of items: the first of each pair is the auxiliary data label, as defined in the current page parameters, set by FCT **41**). The second item is the auxiliary data entry.

When an entry in the list is edited, the display shows the prompt and the current value, and you may enter a new value. For example,

```
PLOT=5
NEW=_
```

<label>=<current entry>
Enter new response, or just press RTRN

When a data page is printed in system format, auxiliary data and prompts appear as shown below:

```
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
968.2   4110.   120.0   55.47    0.800   1.000    1130.    1.1   0.0   0.0

PLOT          PLANT          TREATMENT     REMARKS          <- Aux. data labels
5             3              5 - 22 - 0    MITE DAMAGE      <- Auxiliary data
```

Related References

41 set pg parms - Determines the auxiliary data labels.

AA - AF - Following FCT, prompts for the auxiliary data directly.

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50 Comm Execute List

50 ** COMM **	
51 set I/O parms	Configuration of RS-232 I/O port
52 terminal	Terminal mode
53 dump pages	Output range of data pages
54 binary dump	General file output - binary format
55 binary load	General file input - binary format
56 ascii capture	Capture mode (ASCII file creation)
57 ascii dump	Output ASCII file
58 binary index	Dumps file headers in binary format
59	
5A	
5B	
5C	
5D	
5E	
5F	

The default user key definitions allow this list to be accessed by the COMM key.

When viewing this list, pressing **RTRN** will cause the routine on the top line of the display to be executed.

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51 I/O Configuration

LAB:	File label (File type is I/O)
BAUD=4800	Baud rate
DATA BITS=8	Data bits
STOP BITS=2	Stop bits
PARITY=None	Parity
CHECK CD=N	Hardware pacing: DCD line
CHECK DSR=Y	Hardware pacing: DSR line
ENQ/ACK HSHK=N	ENQ/ACK handshake
XON/XFF HSHK=N	XON/XOFF handshake
XON CHAR=11	XON character (hex)
XOFF CHAR=13	XOFF character (hex)
FLAG PARITY=N	Display message if parity error detected
FLAG FRAME=N	Display message if framing error detected
LOCAL ECHO=N	Echo keystrokes back to the display in terminal mode
SOM=00	Start of message sequence (external console mode)
EOL=0D,0A	End of line sequence (hex)
EOL WAIT=0	End of line wait (milliseconds)
EOM=00	End of message sequence (external console mode)

This is a storable list, so GET and STORE will function. The file type is I/O.

BAUD can be any of the following: 50, 110, 150, 300, 600, 1200, 1800, 2400, 3600, 4800, 7200, 9600, 19200, 38400. When data is ready to be sent, it will be sent at the specified baud rate, but overall data transfer times will be slower when the LI-6200 has to search for and format the data first.

DATA BITS is the number of data bits per character, and can be 7 or 8.

STOP BITS is the number of stop bits per character, and can be 1 or 2.

PARITY can be None, Odd, Even, 1's or 0's. Only the first character need be entered (N, O, E, 1, or 0).

CHECK CD is a hardware handshake. When set to 'Y', the LI-6200 will only send data when it sees pin 8 (DCD) of the I/O port high (>3 V). If the voltage of this pin drops below this level, data transmission will cease until the voltage climbs above this level. While waiting for this to occur, the message 'CD NOT HIGH' is displayed on the console.

CHECK DSR is a hardware handshake. When set to 'Y', the LI-6200 will only send data when it sees pin 6 (DSR) of the I/O port high (>3 V). If the the voltage climbs above this level. While waiting for this to occur, the message 'DSR NOT HIGH' is displayed on the console.

This method of pacing, or handshaking, is common with printers. The 6000-03 Epson printer as delivered by LI-COR has installed an RS-232 interface configured to handshake in this manner.

ENQ/ACK HSHK implements the enquire/acknowledge handshake. When this is set to 'Y', the LI-6200 will send a hex 06 (ASCII ACK) upon receipt of a hex 05 (ASCII ENQ). This feature will probably only be useful if using the LI-6200 as a terminal to a mainframe computer (such as an HP 3000) that uses this

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pacing mechanism.

XON/XFF HSHK is the XON/XOFF handshaking protocol. The LI-6200 will transmit data until an XOFF character (defined below) is received. Data transmission will resume upon receipt of an XON character (also defined below). This is a fairly common handshaking protocol.

XON CHAR defines the character to be considered the XON character if XON/XOFF handshaking is being used. This is normally a hex 11 (ASCII DC1).

XOFF CHAR defines the character to be considered the XOFF character if XON/XOFF handshaking is being used. This is normally a hex 13 (ASCII DC3).

FLAG PARITY, when set to 'Y', will cause the message 'PARITY ERROR' to be displayed when an error in parity in the incoming data is detected. This feature is probably only useful to aid in determining the correct I/O configuration to use in terminal mode.

FLAG FRAME, when set to 'Y', will cause the message 'FRAMING ERROR' to be displayed when a framing error in the incoming data is detected. The error will usually be generated by an incorrect number of data bits.

LOCAL ECHO pertains to terminal mode, and causes keystrokes to be echoed back to the display.

SOM and **EOM** only apply when the console has been redirected to the output port. SOM is a Start of message string, and EOM is an end of message string, both of which can be up to 5 characters in length, and are specified in hex. All data sent to the (redirected) console is preceded by SOM, and followed by EOM.

EOL is the end of line sequence in hex. Up to 5 characters may be defined. The default values of OD OA specify a CR and LF (carriage return and line feed).

EOL WAIT is the delay in milliseconds after each transmitted line of data.

Related References

5x - All COMM routines

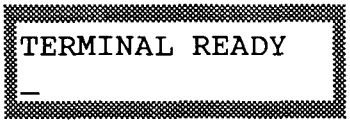
D5 - File index

EF - Swap terminal

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52 Terminal Mode

In terminal mode, the console can be used as a terminal. All data coming in through the RS-232 port is displayed on the 2 line display, and all keystrokes on the console are transmitted out the RS-232 port. When terminal mode is entered, the display will show:



While in terminal mode, remember that:

- **CTRL + P** sets a BREAK condition on the communications link.
- **SHIFT + L** (labelled **6200**) exits terminal mode.
- **SHIFT + P** (that is, **BRK**) will abort terminal mode.

So, if you want to "send a BREAK" to whatever you are communicating with, press **CTRL + P** (*not* **SHIFT + P**).

Related References

51 set I/O parms - Configures the I/O port.

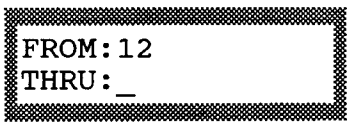
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53 Dump Pages

This routine outputs a group of data pages using the currently defined format (System or User, depending upon the operating parameter PRN FMT). The range of pages to be printed is selected by the user:



Enter the lowest page number to include



The low entry
Enter the highest page number to include

A null entry to either one of the prompts will abort the routine.

Related References

51 - Configures the I/O port.

42 - Accesses the PRN FMT parameter.

D8 - Determines system format.

D9 - Determines user format.

41 - Page parameters set to those of the last dumped page.

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54 Binary Dump

This routine allows a group of files to be output in binary format. Binary format is a byte-for-byte copy of how the file is stored in the memory of the LI-6200. The advantages of this format is that it is compressed; values are always in predetermined locations; the data can be loaded back into the LI-6200 console memory (Binary Load). The disadvantage of binary format is that it takes a computer to interpret the data. Floating point numbers, for example, are stored in a 4-byte representation. The 6200-25 (for IBM PC/AT/XT) and 6200-26 (HP Series 200/300) software packages do support binary format.

```
BINARY DUMP
ENTER FTYPE:_
```

Enter file type number

File type numbers are as follows:

FTYPE	NAME	FTYPE	NAME
1	PAGE	9	RH
2	SYSTM	10	SENSR
3	I/O	11	SFORM
4	ASCII	12	UFORM
5	PPARM	13	KEYS
6	OPARM	14	KBUFF
7	CO2	15	VWSEQ
8	FLOW	16	PROG

To dump ALL files of all types in memory, enter a *****.

If a specific file type is requested, the user is then prompted for the range of files to be output:

```
BIN DUMP RH
FROM:_
```

or PAGE, or SYSTM, or I/O, etc.
Enter lowest number to output

```
FROM:15
THRU:_
```

The low entry
Enter highest number to output

A null entry for any of the three prompts will abort this routine.

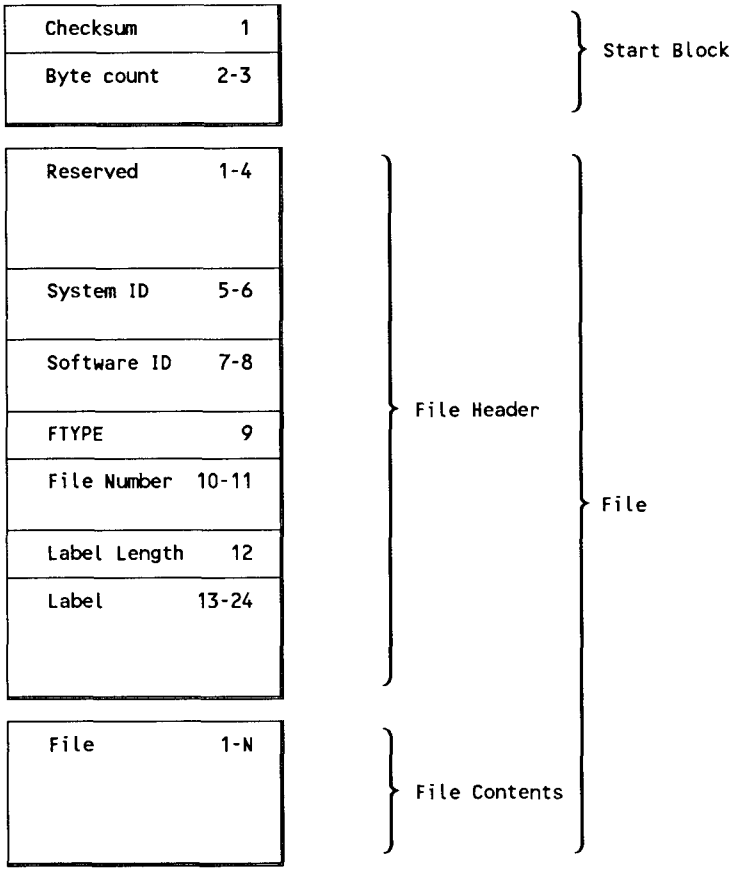
Related References

51 - Configures the I/O port.

55 - Loads binary files back into the instrument.

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When the LI-6200 outputs a file in binary format, the file itself it preceded by a three-byte start block.



Checksum - Can be used for error checking (it is used by the LI-6200 when binary loading data). It is the sum of all the bytes in the file, MOD 256.

Byte count - 2 byte integer indicating the total file length (NOT including the start block).

System ID (integer) is the SYSTM file number in effect when the file was stored.

Software ID (integer) is the code identifying which software was in the LI-6200 when the file was stored. 0 is revision 1.0x, and 2 is revision 2.0.

FTYPE (byte) identifies the type of file:

File Number (integer) is the file number of the file.

Label Length (byte) indicates how many bytes (up to 12) are in the file label.

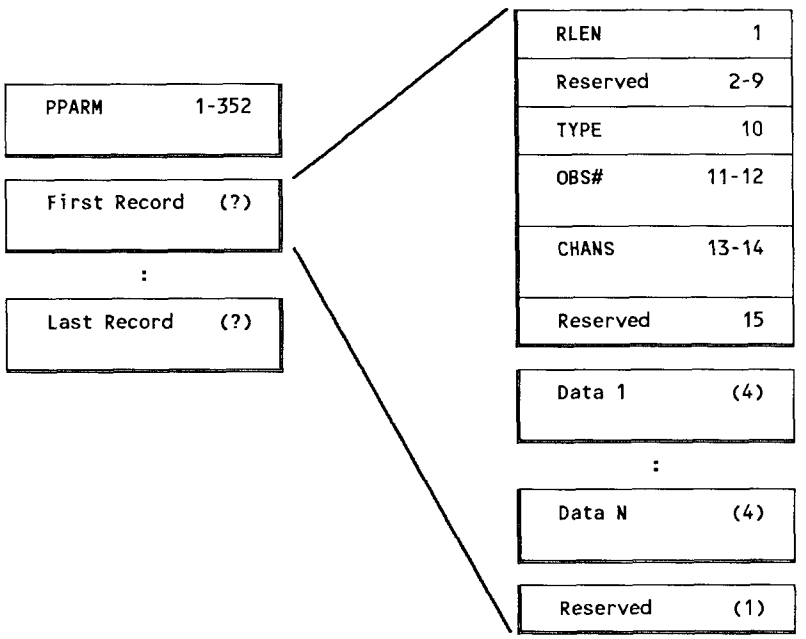
Label (string) is the file label.

The meaning of the bytes in the file itself depends on the file type. The 16 file types are decoded on the next several pages.

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File Type: 1 PAGE
Length: Variable

Page files consist of 352 bytes of parameter information (see PPARM files for how to decode this), followed by a series of variable length records.



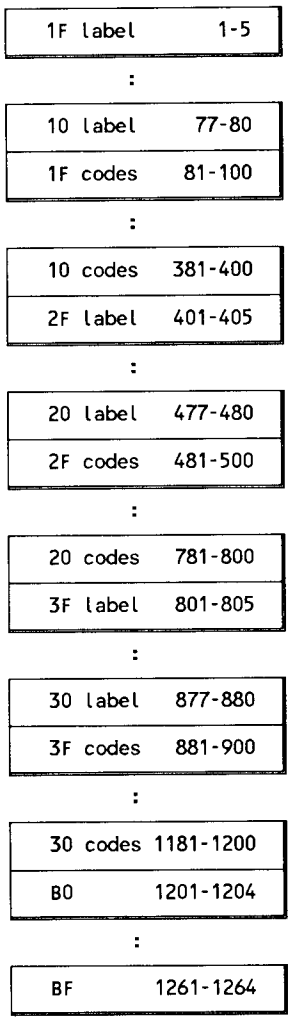
The length of the record is given by the **RLEN** byte. What type of record it is can be determined from the **TYPE** byte:

HEX(TYPE)	Record Type
10	Sample
11	Mean/Slope of 1x channels
12	Range/Error of 1x channels
20	2x channels
30	3x channels

The observation number that the record represents is given by the 2 byte integer **OBS#**. All 16 channels (that is, 10 - 1F if TYPE is 10, 11, or 12; or channels 20 - 2F is TYPE is 20; or channels 30 - 3F is type is 30) will not necessarily be represented in the record. The 16 bits of **CHANS** is a packed boolean array that indicates what channels are present; bit Y will be set if channel xY is present. For every bit set in **CHANS**, there will be a 4 byte real number corresponding to it in the record.

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Channel labels take 5 bytes each, and channel code sequences take 20 bytes. Code sequences are terminated with a 00 byte.



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File Type: 3 I/O
Length: 45

Reserved	1-2
FMT	3
CTL	4
Reserved	5-6
HSK	7
IOE	8
Reserved	9-12
SOM Length	13
SOM	14-20
EOM Length	21
EOM	22-28
EOL Length	29
EOL	30-36
EOL Wait	37-38
XON Char	39
XOFF Char	40
Reserved	41-45

CTL, FMT, HSK, and **IOE** bytes are decoded on the next page.

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CTL

Byte 4

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Not Used		Stop Bits 0 = 1 1 = 2	Not Used	Baud Rate 0 0 0 0 = 50 0 0 0 1 = 110 0 0 1 0 = 135 0 0 1 1 = 150 0 1 0 0 = 300 0 1 0 1 = 600 0 1 1 0 = 1200 0 1 1 1 = 1800 1 0 0 0 = 2400 1 0 0 1 = 3600 1 0 1 0 = 4800 1 0 1 1 = 7200 1 1 0 0 = 9600 1 1 0 1 = 19200 1 1 1 0 = 38400			
Value=128	Value=64	Value=32	Value=16	Value= 8	Value= 4	Value = 2	Value = 1

FMT

Byte 3

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Not Used	Data Bits 0 0 = 5 0 1 = 6 1 0 = 7 1 1 = 8		Parity 0 0 = ODD 0 1 = EVEN 1 0 = 1's 1 1 = 0's		Parity 1 = ON 0 = OFF	Not Used	
Value=128	Value=64	Value=32	Value=16	Value= 8	Value= 4	Value = 2	Value = 1

HSK

Byte 7

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Local Echo 0 = OFF 1 = ON	ENQ/ACK 0 = OFF 1 = ON	XON/XOFF 0 = OFF 1 = ON	Check DSR 0 = OFF 1 = ON	Not Used			
Value=128	Value=64	Value=32	Value=16	Value= 8	Value= 4	Value = 2	Value = 1

IOE

Byte 8

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Flag Frame 0 = OFF 1 = ON	Flag Parity 0 = OFF 1 = ON	Check CD 0 = OFF 1 = ON	Not Used				
Value=128	Value=64	Value=32	Value=16	Value= 8	Value= 4	Value = 2	Value = 1

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File Type: 5 PPARM
Length: 352

# Obs	1-2
# Samples	3-4
Reserved	5
A1 (area)	6-9
Timestamp	10-15
A2 (Vt)	16-19
A3 (BC)	20-23
Reserved	24-27
A5 (Fx)	28-31
A4 (STMRAT)	32-35
A0 (P)	36-39
A6 (Vg)	40-43
A7 (K)	44-47
A8	48-51
A9	52-55
Reserved	56-64
Aux Data 1	65-112
Aux Data 2	113-160
Aux Data 3	161-208
Aux Data 4	209-256
Aux Data 5	257-304
Aux Data 6	305-352

Aux Data (48 Bytes)

Prompt Length	1
Prompt String	2-20
Data Length	21
Data String	21-44
Data Value	44-48

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STEP	1-2
OBS/PAGE	3-4
LENMULT	5-8
CHANGE	9-12
Reserved	13-16
CHANNEL	17
FLAGS	18

FLAGS **Byte 18**

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Not Used	Format 0 = USER 1 = SYS	Not Used		Beep 0 = NO 1 = YES	Keep Samples 0 = NO 1 = YES	Not Used	
Value=128	Value=64	Value=32	Value=16	Value= 8	Value= 4	Value = 2	Value = 1

STEP and **OBS/PAGE** are 2 byte integers. **LENMULT** and **CHANGE** are floating point numbers. The hex value of **CHANNEL** corresponds to the CHANNEL parameter.

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File Type: 7 CO2
Length: 20

All values are floating point numbers.

TEMP	1-4
K	5-8
A	9-12
B	13-16
C	17-20

File Type: 8 FLOW
Length: 17

All values are floating point numbers.

Reserved	1
A	2-5
B	6-9
C	10-13
D	14-17

File Type: 9 RH
Length: 81

TRUE and **MSRD** values are floating point.

NUMPTS	1
TRUE #1	2-5
:	
TRUE #10	38-41
MSRD #1	42-45
:	
MSRD #10	78-81

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Reserved	1-24
DEF 0E	25-28
DEF 01	29-32
DEF 06	33-36
DEF 03	37-40
DEF 02	41-44
DEF 07	45-48
DEF 05	49-52
DEF 04	53-56
DEF 08	57-60
DEF 09	61-64
DEF 0A	65-68
DEF 0B	69-72
DEF 0C	73-76
DEF 0D	77-80
DEF 00	81-84
DEF 0F	85-88
0F Label	89-93
0E Label	94-98
:	
01 Label	159-163
00 Label	164-168
C0	169-172
C1	173-176
:	
CF	229-232

The **DEF** bytes are decoded on the next page.

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DEF byte 1

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved	Channel 0 = ON 1 = OFF	Reserved					
Value=128	Value=64	Value=32	Value=16	Value= 8	Value= 4	Value = 2	Value = 1

DEF byte 2

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Reserved			Resolution 0 = HIGH 1 = LOW	Reserved			
Value=128	Value=64	Value=32	Value=16	Value= 8	Value= 4	Value = 2	Value = 1

DEF bytes 3 and 4 are reserved.

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File Type: 11 SFORM
Length: 48

1x COL 1	1
1x COL 2	2
:	
1x COL 16	16
2x COL 1	17
2x COL 2	18
:	
2x COL 16	32
3x COL 1	33
3x COL 2	34
:	
3x COL 16	48

Each 1 byte entry corresponds to a channel code.

File Type: 12 UFORM
Length: 401

NUMPTS	1
LEN 1	2
STRING 1	3-11
LEN 2	12
STRING 2	13-21
:	
LEN 40	392
STRING 40	393-401

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File Type: 13 KEYS
Length: 135

KEY 1 ASCII	1
reserved	2-4
KEY 1 CODE	5
KEY 2 ASCII	6
reserved	7-9
KEY 2 CODE	10

:

KEY 26 ASCII	126
reserved	127-129
KEY 26 CODE	130
reserved	131-135

File Type: 14 KBUFF
Length: 129

Length	1
KEYS	2-129

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File Type: 15 VWSEQ
Length: 401

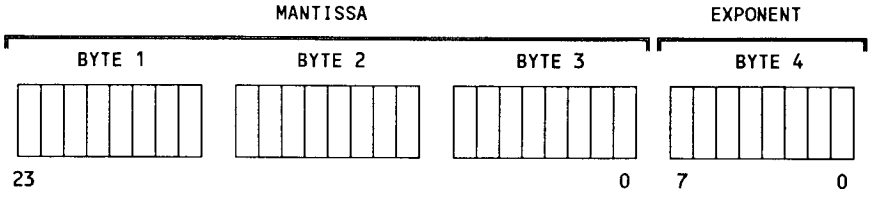
Same format as a **UFORM** file.

File Type: 16 PROG
Length: 21

NUMPTS	1
CODE 1	2
:	
CODE 20	21

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DECODING 4 BYTE FLOATING POINT VALUES



1. The value E of the exponent is calculated by summing the values of set bits 0 thru 6. If bit 7 is set, subtract 256.

2. If bit 23 of the mantissa is set, take the binary complement of the mantissa, and add a binary 1 (00000000 00000000 00000001) to the mantissa.

3. Sum the values of the set bits in the mantissa. The value of the ith bit is given by

$$\frac{1}{2^{(23 - i)}}$$

4. The value of the number is $M \times 2^E$, where M is the mantissa sum. If step 2 was performed (bit 23 originally 1), then the value is negative.

EXAMPLES

BINARY	HEX	Decimal
01000000 00000000 00000000 00000001	40 00 00 01	1.00
00110001 11111111 11111111 00001000	31 FF FF 08	100.0
01001010 00001110 01000001 11111000	4A 0E 41 F8	0.00226
10101011 11001101 11101111 11110001	AB CD EF F1	-2.007×10^{-5}

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55 Binary Load

This routine puts the LI-6200 into a mode in which binary files can be received and stored in memory. The display will show:



When the binary load is initiated, a 3 byte code is sent out the RS-232 interface. This three byte **RETURN CODE** is explained below.

The first three bytes that the LI-6200 expects to receive is the checksum and byte count of the file to be loaded. (This is identical to the three byte start block with which the LI-6200 precedes each binary dumped page).

The LI-6200 examines the received byte count when it arrives, and determines if in fact there is room in RAM for this file. Another **RETURN CODE** sequence is sent. If there is room for the file, the LI-6200 will await the receipt of the number of bytes that it was told to expect. If there is no room for the file, the binary load will be aborted.

After the file bytes are received, the LI-6200 computes the file checksum, and compares it with the byte initially sent with the byte count information. If the checksums match, the file is stored. If not, the binary load is aborted. Either way, another RETURN CODE is sent out indicating what happened. If the file was stored, the last two bytes of the return code will tell what the file's new number is.

RETURN CODE

Byte 1:
- 0 (hex 30) = OK
- 1 (hex 31) = Checksum Error
- 2 (hex 32) = Insufficient Memory
- 3 (hex 33) = Other Error

Bytes 2,3: Integer value corresponding to the file number of the last stored file.

A received break, framing error, or parity error will abort this mode. Also, if an incoming file has a checksum error, it will abort.

Files are numbered according to the current value of the particular file counter. Thus, the number that a file had when it was output has nothing to do with the number it will have when loaded back into the instrument.

Related References

51 set I/O parms - Configures the I/O port.

54 binary dump - Outputs files in binary format.

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56 Ascii Capture

In capture mode, all incoming data is stored in an ASCII file byte for byte. When entering this routine, the user is prompted for the file label and size in Kbytes.

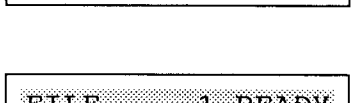


Enter file label

followed by



Enter size of ASCII file in kbytes (1 to 31)



The actual file size of the ASCII file is not what you specify, but is determined by the data received. If you specify a 5K file size, but only send 30 bytes, then the file is 30 bytes in size (plus the file header).

Capture mode is terminated by pressing **BRK**.

Baud rates above 9600 are not recommended for ASCII capture mode.

Related References

51 set I/O parms - Configures the I/O port.

57 ASCII dump - Outputs ASCII files.

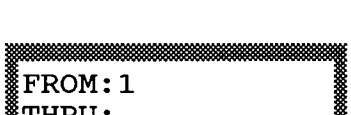
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57 ASCII Dump

The ASCII DUMP routine outputs a range of ASCII files to the I/O port.



Enter lowest number to output



The low entry
Enter highest number to output

A null entry to either one of the prompts will abort this routine.

Related References

51 set I/O parms - Configures the I/O port.

56 capture mode - Creates ASCII files.

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58 Binary Index

This routine allows for rapid determination of what is in the LI-6200's memory using an external computer. The binary index is just like the binary dump routine (**54**), except that only file headers are sent, not the entire file. Files of a selected type may be indexed, or all files in RAM. In the latter case, file information is sent in the order in which the file occurs in RAM.



Enter file type number

File type numbers are as follows:

FTYPE	NAME	FTYPE	NAME
1	PAGE	9	RH
2	SYSTM	10	SENSR
3	I/O	11	SFORM
4	ASCII	12	UFORM
5	PPARM	13	KEYS
6	OPARM	14	KBUFF
7	CO2	15	VWSEQ
8	FLOW	16	PROG

To dump ALL files of all types in memory, enter a *.

Related References

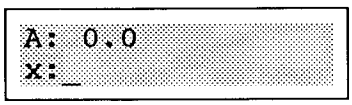
51 - Configures the I/O port.

54 - Binary dump.

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60 - 7F Calculator Mode

Entering any code between **60** and **7F** following FCT will cause entry into Calculator Mode.



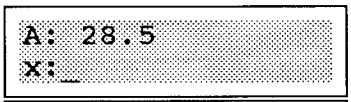
Top of the stack
Entry line

Numeric values may be pushed onto the stack by entering them, followed by a **RTRN**. Stack operators, system constants, and channel values (latest) may be performed by entering the code preceded by an **H**. Multiple codes may follow the **H**. The only illegal stack operators in calculator mode are **6C** and **6F**.

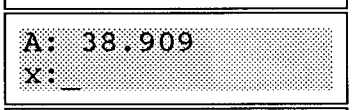
The **A:** line always shows the value on the top of the stack.

Calculator mode is exited by pressing **RTRN** when the **x:** line is empty.

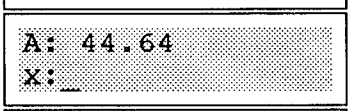
EXAMPLE: Find the saturation vapor pressure of 28.5, then divide that value by the system constant **CF**.



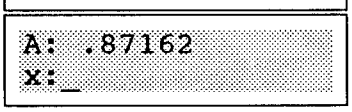
Enter 28.5, and press RTRN.



Type H74 and press RTRN. This result is the saturation vapor pressure of 28.5 degrees C.

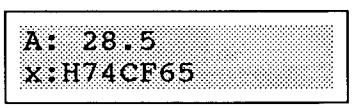


Fetch system constant CF by typing HCF RTRN.



Divide 38.909 by 44.64 by typing H65 RTRN.

Note that the last 3 steps could have been combined into 1 entry:



Do 74, fetch CF, and Divide

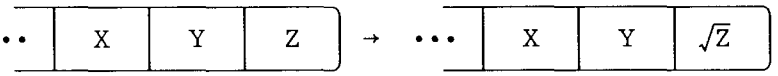
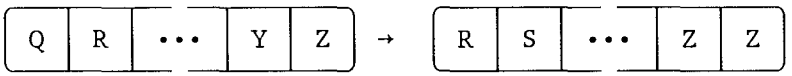
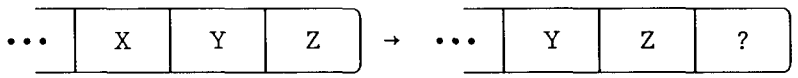
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60 - 7F Stack Operators

Calculations use a 10 level, circular, last-in first-out stack and postfix notation (RPN).

CODE	NAME	INITIAL STACK	FINAL STACK
60	SWAP	... X Y Z (top)	... X Z Y (top)
61	DROP	Q R ... Y Z	Z Q ... X Y
62	ADD	... X Y Z	... W X Y+Z
63	SUBTRACT	... X Y Z	... W X Y−Z
64	MULTIPLY	... X Y Z	... W X Y×Z
65	DIVIDE	... X Y Z	... W X Y÷Z
66	INVERT	... X Y Z	... X Y 1/Z
67	CHANGE SIGN	... X Y Z	... X Y −Z
68	SQUARE	... X Y Z	... X Y Z^2
69	CUBE	... X Y Z	... X Y Z^3

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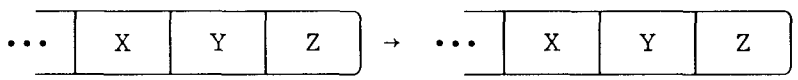
CODE	NAME	INITIAL STACK	FINAL STACK
6A	**SQUARE ROOT**		
6B	**DUPLICATE**		
6C	**PREVIOUS**		

The code immediately following a **6C** must be a **0x** or **1x** channel. The **6C** indicates that the value to be returned is previous value, not the current value. In Monitor mode, the previous value is the value of that channel at the end of the last scan. In Log mode, the previous value is the value of the channel for the last sample. **0x** values are not retained in the pad, of course, but 2 sets (the present and the previous) are kept just for this purpose.

Note that referencing a higher **1x** channel will always get the previous value, since the present value has not yet been determined. Thus, **6C** is really only necessary when you wish to fetch the previous value of a lower channel.

For the first sample in an observation, and the first scan after the pad is cleared, previous **1x** channels are set to 0. This does not mean that the previous *samples* are zeroed, of course, but rather the internal array that holds the previous values for **1x** channels is zeroed.

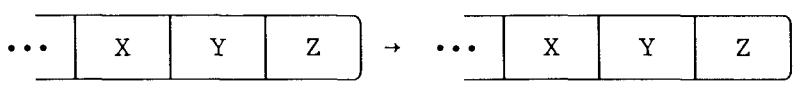
6D **STORE**



The code immediately following the **6D** is taken as an address, and the value Z on the top of the stack is copied to that address. The stack is left unchanged.

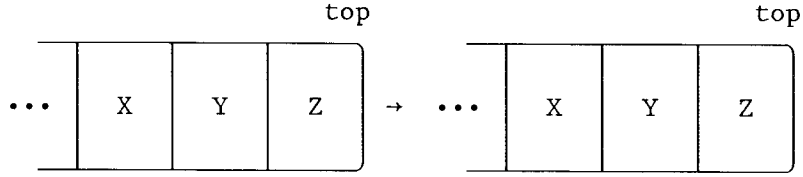
If a **2x** or **3x** channel attempts to store into a **1x** channel, it will have no affect on the **1x** channel. Other than that, any channel can store to any other channel, or any system constant. Bear in mind, however, the order of calculation. Storing ahead to a defined channel will not be permanent, since that channel has yet to be computed. Storing behind to an already computed channel works for **2x** and **3x** channels, but not for **1x** channels.

6E **RANGE**



The code immediately following the **6E** should be a **1x** code. The **6E** simply sets a flag indicating that the next **1x** code should fetch the Range/Error observation. If no **6E** precedes the **1x** code, then the **1x** will fetch the Mean/Slope observation. The stack is left unchanged. The **6E** code is not allowed as part of the object of the store function **6D**.

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CODE	NAME	INITIAL STACK	FINAL STACK
6F	SLOPE		

The **6F** is essentially a flag that indicates that this channel is to have Slope and Error (rather than Mean and Range) computed. The **6F** can occur anywhere in the code sequence, and does not affect the stack.

In Log mode, while samples for an observation are being collected, channels containing a **6F** accumulate several sums; at the end of the observation, these sums are used to compute the slope and standard error of the slope, using the following formulae: Note that Y_i represent the second value left on the stack each time (the dependent variable), and the independent variable t_i is always time. N is the number of samples.

$$\frac{\partial Y}{\partial t} \equiv m = \frac{N \sum(Y_i\ t_i) - \sum Y_i \sum t_i}{N \sum(t_i\ t_i) - \sum t_i \sum t_i}$$

The intercept (Y at t=0) is

$$b = \frac{\sum Y_i - m \sum t_i}{N}$$

The variance of the slope m is

$$s^2 = \frac{\sum(m\ t_i + b - Y_i)^2}{(N - 2)\left[\sum(t_i\ t_i) - \frac{\sum t_i \sum t_i}{N}\right]}$$

and the standard error of the slope is

$$s = \sqrt{s^2}$$

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70 TIME

Initial Stack (top)

...	Y	Z

Final Stack (top)

...	Z	Time since pad cleared {s}

71 CO_2 Calibration function

Initial Stack (top)

...	X	Y = Signal {mV}	Z = Temp {C}

Final Stack (top)

...	W	X	f(Y,Z) {ppm}

$$f(Y,Z) = (AY + BY^2 + CY^3)\frac{Z + 273}{T + 273}$$

where A, B, C, and T are from the FCT **45** list.

72 FLOW Calibration Function

Initial Stack (top)

...	X	Y = Signal {mV}	Z = Temp {C}

Final Stack (top)

...	W	X	f(Y,Z) {cc/s}

$$f(Y,Z) = (A + BZ)Y + (C + DZ)Y^2$$

where A, B, C, and D are from the FCT **46** list.

73 RH Lookup Table

Initial Stack (top)

...	Y	Z = Measured RH (%)

Final Stack (top)

...	Y	True RH (%)

This table is found in FCT **47**.

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74 Saturation Vapor Pressure

Initial Stack (top)

•••	Y	Z = temp {C}

Final Stack (top)

•••	Y	f(Z) {mb}

$$f(Z) = a + bZ + cZ^2 + dZ^3 + eZ^4 + fZ^5 + gZ^6$$

$a = 6.1078$
$b = 4.4365 \times 10^{-1}$
$c = 1.4289 \times 10^{-2}$
$d = 2.6505 \times 10^{-4}$
$e = 3.0312 \times 10^{-6}$
$f = 2.0341 \times 10^{-8}$
$g = 6.1368 \times 10^{-11}$

This equation from Lowe (1976)

75 Gas Constant Times Absolute Temp

Initial Stack (top)

•••	Y	Z = temp (C)

Final Stack (top)

•••	Y	f(Z)

$$f(Z) = 8.314\ (Z + 273)$$

76 Adjustment for Stomatal Ratio

Initial Stack (top)

•••	X	Y = Stomatal Ratio	Z = B. L. Conductance

Final Stack (top)

•••	W	X	f(Y,Z)

$$f(Y,Z) = Z \frac{(Y + 1)^2}{Y^2 + 1}$$

77 CO_2 Reference Function

Initial Stack (top)

•••	W	X = Ref {ppm}	Y = Temp {C}	Z = Pressure {mb}

Final Stack (top)

•••	W	Ref {ppm}	Ref {mV}	Gain Factor

This is the stack operation equivalent of FCT **49**, only the results are left on the stack, rather than being stored into **C9, CA,** and **CB**.

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78 Slope of CO_2 Calibration Function

Initial Stack (top)

...	X	Y = Signal {mV}	Z = temp {C}

Final Stack (top)

...	W	X	f(Y,Z)

$$f(Y,Z) = (A + 2BY + 3CY^2)\,\frac{Z + 273}{T + 273}$$

where A, B, C, and T are from the FCT **45** list.

79 Stomatal Conductance

Initial Stack (top)

...	V = Sat. Vap. Press of Leaf {mb}	W = Vapor Press of Air {mb}	X = Transp. {mol/ m^2/s}	Y = Press. {mb}	Z = B.L. Cond. {$mol/m^2/s$}

Final Stack (top)

...	R	S	T	U	f(V..Z)

$$f(V,W,X,Y,Z) = \frac{1}{\dfrac{V - W}{X\left(Y - \dfrac{V + W}{2}\right)} - \dfrac{1}{Z}}$$

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7A Conductance to CO_2

Initial Stack (top)

...	X	Y = Stom. Cond. Water {mol/m²/s}	Z = B.L. Cond. {mol/m²/s}

Final Stack (top)

...	W	X	f(Y,Z)

$$f(Y,Z) = \frac{1}{\frac{1.6}{Y} + \frac{1.37}{Z}}$$

7B Intercellular CO_2

Initial Stack (top)

...	V	W = Cond. CO_2 {mol/m²/s}	X = Transp. {mol/m²/s}	Y = Ambient CO_2	Z = Assim.Rate {μmol/m²/s}

Final Stack (top)

...	S	T	U	V	f(W..Z)

$$f(W,X,Y,Z) = \frac{(W - \frac{X}{2})\ Y - Z}{W + \frac{X}{2}}$$

7C Density

Initial Stack (top)

...	X	Y = temp {C}	Z = press {mb}

Final Stack (top)

...	W	X	f(Y,Z)

$$f(Y,Z) = \frac{(Y + 273)}{273}\ \frac{1013}{P}$$

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7D 5th Order Polynomial

...	T	U	V	W	X	Y	Z

...	X	Y	Z	Q	R	S	f(T..Z)

$$f(T,U,V,W,X,Y,Z) = T + UZ + VZ^2 + WZ^3 + XZ^4 + YZ^5$$

7E Delta T (Leaf Energy Balance)

Initial Stack (top)

...	V = BLCond {mol/m²/s}	W = Air Temp {C}	X = Wall Temp {C}	Y = Transp. {mol/m²/s}	Z = Net Rad. {W/m²}

Final Stack (top)

...	R	S	T	U	f(V..Z)

Leaf - Air temperature difference (C).

$$f(V,W,X,Y,Z) = \frac{Z - 44100\,Y + 1.077\times10^{-7}\,[(X+273)^4 - (W+273)^4]}{56\,V + 4.309\times10^{-7}\,(W+273)^3}$$

7F Transpiration (Leaf Energy Balance)

Initial Stack (top)

...	V = BLCond {mol/m²/s}	W = Air Temp {C}	X = Leaf Temp {C}	Y = Wall Temp {C}	Z = Net Rad. {W/m²}

Final Stack (top)

...	R	S	T	U	f(V..Z)

Transpiration rate (mol m^{-2} s^{-1}).

$$f(V,W,X,Y,Z) = \frac{Z + 1.077\times10^{-7}\,[(Y+273)^4 - (X+273)^4] - 56\,V\,(X-W)}{44100}$$

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A0 - AF Page Constants

CODE	LABEL	DESCRIPTION
A0	**P(mb)**	Atmospheric pressure (mb)
A1	**A(cm2)**	Leaf area (cm^2)
A2	**Vt(cc)**	Total system volume (cm^3)
A3	**BC(mol)**	One sided boundary layer conductance (mol m^{-2} s^{-1})
A4	**STMRAT**	Ratio of stomatal conductances of leaf surfaces
A5	**Fx(umol)**	Max flow rate through desiccant (μmol s^{-1})
A6	**Vg(cc)**	System volume excluding chamber enclosure (cm^3)
A7	**Kabs**	Water absorption factor.
A8	**A8**	Unused
A9	**A9**	Unused
AA		Auxiliary data #1
AB		Auxiliary data #2
AC		Auxiliary data #3
AD		Auxiliary data #4
AE		Auxiliary data #5
AF		Auxiliary data #6

The Ax constants are references to the page parameters. They can be used in the definitions of virtual channels, the system and user format lists, and calculator mode.

The auxiliary data references return a numeric value; if the auxiliary data string can not be interpreted as a numeric value, a 0 will be returned.

Ax following FCT will prompt for a new value for that constant. For example, FCT **A0** will cause

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

Present value
Enter new value

Remember that FCT **A1** will NOT multiply the entry by the LEN MULT parameter.

FCT AA through FCT **AF** will prompt for new auxiliary data strings using the auxiliary data labels for the prompt.

Related References

41 set pg parms - View/edit page parameter values A0 - A9, and aux data prompts.
4B aux data - View/edit aux data entries AA - AF.
E3 set sys prog - Defines virtual channels.
D8 set sys fmt - Defines system format.
D9 set user fmt - Defines user format.

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B0 - BF User Constants

CODE	VALUE	DESCRIPTION
B0	**1.00**	Multiplier for **30** photosynthesis (1 = μmol m^{-2} s^{-1})
B1	**1.00**	Multiplier for **31** stomatal conductance (1 = mol m^{-2} s^{-1})
B2	**1.00**	Multiplier for **33** stomatal resistance (1 = s cm^{-1})
B3	**1.00**	Multiplier for **34** stomatal conductance (1 = cm s^{-1})
B4	**0.00**	Not used
B5	**0.00**	Not used
B6	**0.00**	Not Used
B7	**0.00**	Not used
B8	**0.00**	Not used
B9	**0.00**	Not used
BA	**0.00**	Not used
BB	**0.00**	Not used
BC	**0.00**	Not used
BD	**0.00**	Not used
BE	**0.00**	Not used
BF	**0.00**	Not used

The **Bx** constants can be used in the definitions of virtual channels, the system and user format lists, and calculator mode.

These constants are included in the **E3** list.

Bx following FCT will prompt for a new value for that constant. For example, FCT **B2** will cause

```
B2 = 0.00
NEW=_
```

Present value
Enter new value

Related References

E3 set sys prog - Contains **Bx** constants.

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C0 - CF Sensor Constants

CODE	VALUE	DESCRIPTION
C0	**0.00**	Not used
C1	**1.00**	Used for the value 1.00
C2	**100.0**	Used for the value 100.
C3	**0.012207**	Thermistor multiplier
C4	**0.00226**	Thermocouple multiplier
C5	**0.00**	Not used
C6	**0.00**	Quantum sensor cal constant
C7	**0.024414**	Humidity sensor multiplier
C8	**0.00**	Flow meter offset, set by FCT **48**
C9	**0.00**	CO_2 reference concentration (ppm), set by FCT **49**
CA	**0.00**	CO_2 reference signal (mV), set by FCT **49**
CB	**1.00**	CO_2 gain factor, set by FCT **49**
CC	**0.179**	Used in quantum sensor calculation
CD	**0.00**	Not used
CE	**0.00**	Not used
CF	**44.64**	Flow meter units conversion factor to μmol s^{-1}.

The Cx constants can be used in the definitions of virtual channels, the system and user format lists, and calculator mode.

These constants are included in the **E2** list.

Cx following FCT will prompt for a new value for that constant. For example, FCT C5 will cause

```
C5 = 0.00
NEW=_
```

Present value
Enter new value

Related References

E2 set sys prog - Contains Cx constants.

44 set QNTM cal - Sets C6.

48 zero FLOW - Sets C8.

49 CO2 ref - Sets C9, CA, and CB.

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D0 Memory Execute List

D0 * MEM *****	
D1 delete files	Delete a range of files, specified type
D2 renum files	Renumber files of a specified type
D3 mem status	Status of each 32K block of RAM
D4 file status	File counters of each file type
D5 file index	Outputs a list of file numbers and labels for a file type
D6 STORE PAD	Store the PAD as a data page
D7 edit loop	Edit a group of data pages
D8 set sys fmt	The system format list
D9 set user fmt	The user format list
DA view labels	Scroll through labels of files in RAM
DB	
DC	
DD	
DE	
DF clear mem	Clear all files

The default user key definitions allow this execute list to be accessed by the MEMORY key.

When viewing this list, pressing **RTRN** will cause the routine on the top line of the display to be executed.

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D1 Delete Files

This routine allows a group of like files to be deleted from memory, and their space recovered. The user is prompted for the type of file to delete:

```
DELETE FILES
ENTER FTYPE:_
```

Enter file type number

File types are:

FTYPE	NAME	FTYPE	NAME
1	PAGE	9	RH
2	SYSTM	10	SENSR
3	I/O	11	SFORM
4	ASCII	12	UFORM
5	PPARM	13	KEYS
6	OPARM	14	KBUFF
7	CO2	15	VWSEQ
8	FLOW	16	PROG

The user is then prompted for the range of files to be deleted:

```
DELETE PAGE
FROM:_
```

```
FROM:15
THRU:_
```

Do not interrupt this routine once you have entered the 'THRU' value, as you would stand to lose potentially all of your stored files.

When files are deleted, the file counter remains unchanged unless the file deletion includes the highest numbered files.

A null entry to any of the three prompts will abort this routine.

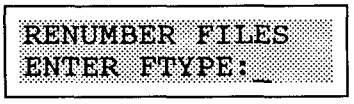
Related References

D2 renum files - Recover file numbers

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D2 Renumber Files

This routine allows a group of like files to be renumbered, recovering "holes" in the file numbers. The user is prompted for the type of file to delete:



Enter file type number

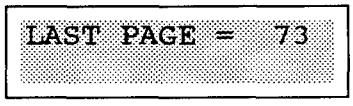
File types are:

FTYPE	NAME	FTYPE	NAME
1	PAGE	9	RH
2	SYSTM	10	SENSR
3	I/O	11	SFORM
4	ASCII	12	UFORM
5	PPARM	13	KEYS
6	OPARM	14	KBUFF
7	CO2	15	VWSEQ
8	FLOW	16	PROG

When a valid file type code is entered, the display will show



then the updated value of the file counter.



Related References

D1 delete files

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D3 Memory Status

The memory status routine checks each 32K bank of memory, and generates a scrollable list (printable, not storable) that tells the selectcode of each bank, the amount of available memory, and the computed checksum.

```
MEMORY STATUS
COMPUTING...
```

Followed by a scrollable list:

```
80,6B,System          1st 32K, 128K board #1
81,50,   92           32K board #1
82,51,11553           32K board #2
84,NONE               32K board #3
88,D3,32719           2nd 32K, 128K board #1
90,98,32719           3rd 32K, 128K board #1
98,F2,32719           4th 32K, 128K board #1
A0,NONE               1st 32K, 128K board #2
A8,NONE               2nd 32K, 128K board #2
B0,NONE               3rd 32K, 128K board #2
B8,NONE               4th 32K, 128K board #2
C0,NONE               1st 32K, 128K board #3
C8,NONE               2nd 32K, 128K board #3
D0,NONE               3rd 32K, 128K board #3
D8,NONE               4th 32K, 128K board #3
E0,NONE               1st 32K, 128K board #4
E8,NONE               2nd 32K, 128K board #4
F0,NONE               3rd 32K, 128K board #4
F8,NONE               4th 32K, 128K board #4
```

The first 2 characters displayed on each line is the selectcode for the 32K bank. There are 19 possible selectcodes, and the unused ones are followed with the work NONE. If memory is found at a selectcode, it is followed by a checksum computed for the bank, and the number of bytes remaining. If no files are in a bank, there will be 32719 bytes available.

One of the banks will be labelled 'System', which means it is the bank used for the scratch pad.

Codes 81, 82, and 84 are used for 32K boards. All other codes indicate the presence of a 128K board. In the example above, there are two 32K boards, and one 128K board present in the instrument.

Board selectcodes are determined by a jumper on the memory board.

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D4 File Status

This routine shows the current value of the file counters for each type of file. Note that this corresponds to the number of stored files of any given type *only* if no intermediate files have been deleted without renumbering.

The resulting list is scrollable and printable, but not storable.

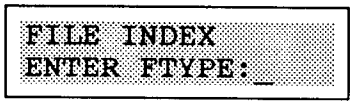
```
 1:PAGE  =   27
 2:SYSTM =    7

 3:I/O   =    0
 4:ASCII =    0
 5:PPARM =    1
 6:OPARM =    2
 7:CO2   =    1
 8:FLOW  =    1
 9:RH    =    0
10:SENSR =    0
11:SFORM =    1
12:UFORM =    0
13:KEYS  =    0
14:KBUFF =    0
15:VWSEQ =    0
16:PROG  =    0
```


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D5 File Index

The file index outputs a list of the numbers and labels of a specified file type, or of all types.



Enter the file type code, or a '*' to do all files

To get an index of ALL file types, enter an asterisk (**SHIFT** + **G**) for the file type code.

For each file type, the output which is sent to the I/O port will look something like this:

```
INDEX OF 3:I/O
FILE  LABEL
===== ============
    1 IBM PC
    2 THINKJET
    3 RALPH TEST
```

Related References

51 set I/O parms - Configures the I/O port

58 binary index - Outputs file headers in binary format

DA view labels - Allows labels of stored files to be viewed on the display

D6 Store Pad

This function will compute the scratch pad (if an Ax value has changed since the pad was last computed) and store it as a page file. It accomplishes the same thing as entering View mode and pressing STORE.

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D7 Edit Loop

The EDIT LOOP routine changes any Ax parameter in a group of stored PAGE files, and recomputes the file using the new value.

When EDIT LOOP is entered, you are asked a sequence of questions:

```
EDIT
FROM:_
```

```
FROM:1
THRU:_
```

```
THRU:10
CODE:_
```

The CODE is any Ax reference, as indicated below:

Code	Parameter	Code	Parameter
A0	Pressure	A8	A8
A1	Area	A9	A9
A2	Total volume	AA	Auxiliary Data 1
A3	Boundary layer conductance	AB	Auxiliary Data 2
A4	Stomatal ratio	AC	Auxiliary Data 3
A5	Maximum Flow	AD	Auxiliary Data 4
A6	IRGA volume	AE	Auxiliary Data 5
A7	Kabs factor	AF	Auxiliary Data 6

After entering a code (A0 thru AF), you will be prompted:

```
CODE:A0
ASK EACH(Y/N)_
```

If you respond with N, you will be asked the value to use for all the pages. For example, if you had entered A0 for the CODE, you will be prompted:

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

Pressure
Enter the correct pressure

Each page will then be loaded, the pressure (or whatever you're changing) value changed, and then re-stored. During this time, the display will indicate the current page number being operated on, and what is being done to it ("FOUND", "computing...", and "STORED"). If the page is missing, a message to that effect will be displayed.

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If you respond to the ASK EACH prompt with a Y, you will be prompted for a new value for pressure (or whatever) for each page:



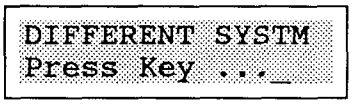
Page Number Parameter
Enter the correct value

After you make the entry (a null entry will leave the value unchanged), the page is re-computed and stored.

IMPORTANT

Pages are stored in accordance with the current setting of the KEEP SMP(Y/N) operating parameter. If this is set to 'N', and pages having samples are edited using EDIT LOOP, the samples will be lost.

If a page is retrieved having a different system number than the current system number, you will be prompted



If you press any key besides **BRK**, execution of the edit loop will continue, and the page will be stored with a new system number, in addition to whatever change due to the EDIT loop occurred.

Related References

42 set opr parm - To check the KEEP SAMP parameter.

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D8 Set System Format

The scratch pad and stored pages are output using either the system format or a user defined format. This routine lets you define what the system format is. You may specify which channels are to be printed from the 1x, 2x, and 3x groups. The default format is shown below:

```
LAB:
MEAS COL  1:10        SYS COL  1:FF        USER COL  1:30
MEAS COL  2:11        SYS COL  2:FF        USER COL  2:31
MEAS COL  3:12        SYS COL  3:FF        USER COL  3:32
MEAS COL  4:13        SYS COL  4:FF        USER COL  4:33
MEAS COL  5:15        SYS COL  5:FF        USER COL  5:34
MEAS COL  6:16        SYS COL  6:FF        USER COL  6:FF
MEAS COL  7:17        SYS COL  7:FF        USER COL  7:FF
MEAS COL  8:18        SYS COL  8:FF        USER COL  8:FF
MEAS COL  9:19        SYS COL  9:FF        USER COL  9:FF
MEAS COL 10:1A        SYS COL 10:FF        USER COL 10:FF
MEAS COL 11:FF        SYS COL 11:FF        USER COL 11:FF
MEAS COL 12:FF        SYS COL 12:FF        USER COL 12:FF
MEAS COL 13:FF        SYS COL 13:FF        USER COL 13:FF
MEAS COL 14:FF        SYS COL 14:FF        USER COL 14:FF
MEAS COL 15:FF        SYS COL 15:FF        USER COL 15:FF
MEAS COL 16:FF        SYS COL 16:FF        USER COL 16:FF
```

This is a storable list, so GET and STORE will function. The file type is 11 (SFORM).

The **MEAS COL** entries dictate what channels, and in which order, are printed when the samples (if any), mean observations, and range observations are printed.

The **SYS COL** entries determine which 2x channels are printed.

The **USER COL** entries determine which 3x channels are printed.

The code **FF** means that the no channel is printed.

This is a composite list, so **CTRL** + ↑ or ↓ will jump up or down to the next logical break point.

Related References

41 set op parm - Accesses the PRN FMT(U/S) operational parameter.

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D9 Set User Format

The user format list is a list of items to be extracted from each page to be printed. It is used as an alternative to system format.

To generate output in user format, you need to:

1) Define the format using the USER FORMAT routine.

2) Implement the format by setting the PRN FMT(U/S) operating parameter to 'U'.

The user format is a variable length list. The maximum number of entries is 40. The codes for picking off the various numbers in the data page are:

Code	Description	Examples	
HDR	Page parameters in system format		
PAG	Page number		
TIM	Time of day		
DAT	Date		
DAY	Day of month		
HOU	Hour		
MIN	Minute		
SEC	Second		
NOB	Number of observations in the page		
SYS	System number		
APR.i	Auxiliary data prompt. i=1 thru 6.	APR.1	
AXD.i	Auxiliary data string. i=1 thru 6.	AXD.4	
Ax	Page parameter (numeric value), x=0 through F.	A0	
EOL[.n]	End of line(s).	EOL	EOL.2
SPA[.n]	Space(s).	SPA	SPA.18
LOOP	Used with the observation wildcard *. See below.		
ENDLOOP	Used with LOOP.		
OB.n	Nth observation number	OB.1	OB.*
1x.s	Sth sample of channel 1x	11.1	
1x.nM	Nth mean observation of channel 1x	12.1M	19.*M
1x.nR	Nth range observation of channel 1x	12.1R	1A.*R
2x.n	Nth observation of channel 2x	20.1	20.*
3x.n	Nth observation of channel 3x	33.3	32.*

The LOOP..ENDLOOP structure allows output of multiple observations without having to specify them. An asterisk (*) is used within this structure as a wildcard for specifying the observation number.

- The list entries between LOOP and END LOOP are cycled through once for each observation (not sample) in the page.

- On each pass through the list, the * is interpreted as the current observation number.

- There is an implied EOL after each pass through the loop, except for the last pass.

Multiple LOOP..ENDLOOP structures may be in the list. If they are nested, only the inner-most loop is seen. If the loops are overlapped, looping will be between the inner-most LOOP..END LOOP structure.

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A LOOP with no ENDLOOP (or vice versa) is ignored.

LAB:EXAMPLE	File label (File type is UFORM)
NUM:9	Number of items in the format
1:PAG	Page number
2:TIM	Time
3:NOB	Number of observations
4:EOL	New line
5:LOOP	Start of loop structure
6:11.*M	nth mean of channel 11.
7:30.*	nth obs of channel 30
8:ENDLOOP	End of loop structure
9:EOL	End of line

If page 1 has 3 observations, and page 2 has 1, then when printed with this format, they would appear as

```
    1 10:12:45     3
1197.1   23.872
1180.3   21.983
892.24   16.224

    2 10:14:54     1
1007.2   22.106
```

Page number Time Number Obs.
1st obs mean of channel 11, 1st obs of channel 30
2nd obs mean of channel 11, 2nd obs of channel 30
3rd obs mean of channel 11, 3rd obs of channel 30
Blank line
Page number Time
1st obs mean of channel 11, 1st obs of channel 30
Blank line

Related References

41 set op parm - Accesses the PRN FMT(U/S) operational parameter.

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DA View Labels

The View Labels routine allows the labels of the files stored in RAM to be viewed on the display. Files of one type may be selected, or all files in RAM.

When initiated, the user is prompted for a file type:



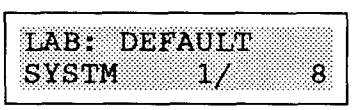
Enter the file type code, or a '*' to do all files

File type numbers are as follows:

FTYPE	NAME	FTYPE	NAME
1	PAGE	9	RH
2	SYSTM	10	SENSR
3	I/O	11	SFORM
4	ASCII	12	UFORM
5	PPARM	13	KEYS
6	OPARM	14	KBUFF
7	CO2	15	VWSEQ
8	FLOW	16	PROG

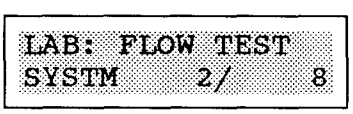
An entry of * will access all files in the order in which they occur in RAM.

The display will indicate



SYSTM file #1 label.
File type (SYSTM), Number (1), and File Counter (8)

[↓] will go to the next highest file number of the selected type, such as



SYSTM file #2 label.
File type (SYSTM), Number (2), and File Counter (8)

[↑] will go to the next lowest file number of the selected type.

CTL +[↑] or [↓] will jump to the lowest file number.

If * were entered as the file type, the files are taken in order of occurrence. Pressing **CTL** +[↓] jump to the first file in memory.

RTRN exits the View Label routine.

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Entering **R A M** then **RTRN** will cause the all files stored in memory to be lost, and all file counters to be set to 0. This has no effect on system RAM.

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E0 System Configuration Execute List

E0 ** CONFIG **	
E1 set keys	User key definitions
E2 set sensors	0x definitions and Cx values
E3 set sys prog	1x,2x,3x definitions and Bx values
E4 E2,E3 reset	Reset lists E2, E3
E5 recompute	Recompute pad
E6 CLEAR PAD	Clears scratch pad
E7 view	Enter VIEW mode
E8 program	Definition of LOG key and button
E9 log	Start/stop data collection
EA sys reset	System reset
EB mini view	View selected values of pad
EC set mini view	Determine values for mini view
ED set kbuff	Setup key buffer file
EE EXEC KBUFF	Execute key buffer file
EF SWAP TERMINAL	Redirect console I/O to output port

This list is access by **FCT** **E0**.

When viewing this list, pressing **RTRN** will cause the routine on the top line of the display to be executed.

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E1 User Key Definitions

LAB:
KEY:1 10
KEY:2 11
KEY:3 13
KEY:4 12
KEY:5 14
KEY:6 15
KEY:7 16
KEY:8 17
KEY:9 FF
KEY:0 FF
KEY:Q 30
KEY:W 31
KEY:E 32
KEY:R FF
KEY:T 33
KEY:Y 34
KEY:A 4A
KEY:S 4B
KEY:D FF
KEY:F E6
KEY:G FF
KEY:H E7
KEY:Z 40
KEY:X 50
KEY:C D0
KEY:V FF

This is a storable list, so GET and STORE will function. The file type is 13 (KEYS).

The definition of each user key consists of a code; pressing that key is equivalent to pressing FCT, followed by the code.

FF indicates the key is undefined.

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E2 Sensor List

LAB:

00	**LOW**	**??**	Reserved
01	**LOW**	**TA**	Air temperature signal (mV)
02	**LOW**	**TL**	Leaf temperature signal (mV)
03	**LOW**	**RH**	RH sensor signal (mV)
04	**LOW**	**TC**	IRGA temperature signal (mV)
05	**HIGH**	**C2**	CO_2 analyzer signal (mV)
06	**LOW**	**QN**	Quantum sensor signal (mV)
07	**LOW**	**FL**	Flow meter signal (mV)
08	**OFF**		Spare channel #1
09	**OFF**		Spare channel #2
0A	**OFF**		Spare channel #3
0B	**OFF**		Spare channel #4
0C	**OFF**		Spare channel #5
0D	**OFF**		Spare channel #6
0E	**LOW**	**BA**	Battery (V)
0F	**LOW**		Reserved
C0	**0.00**		Not used
C1	**1.00**		Used for the value 1.00
C2	**100.0**		Used for the value 100.
C3	**0.012207**		Thermistor multiplier
C4	**0.00226**		Thermocouple multiplier
C5	**0.00**		Not used
C6	**0.00**		Quantum sensor cal constant
C7	**0.024414**		Humidity sensor multiplier
C8	**0.00**		Flow meter offset
C9	**0.00**		CO_2 reference concentration (ppm)
CA	**0.00**		CO_2 reference signal (mV)
CB	**1.00**		CO_2 gain factor
CC	**0.179**		Used in quantum sensor calculation
CD	**0.00**		Not used
CE	**0.00**		Not used
CF	**44.64**		Flow meter units conversion factor to μmol s^{-1}.

This is a composite list, containing the 0x channel definitions, and the Cx system constants. This is a storable list, so GET and STORE will function. The file type is 10 (SENSR).

Refer to sections **00 - 0F** and **C0 - CF** for further details.

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```
LAB:
10    TIME      70
11    QNTM      06 C6 CC 64 65
12    TAIR      01 C3 64
13    TLEAF     02 C4 64 12 62
14    TCO2      04 C3 64
15    CO2       05 CB 64 CA 62 14 71
16    FLOW      07 C8 63 14 72 CF 64
17    RH        03 C7 64 73
18    EAIR      12 74 C2 65 17 64
19    DE/DT     6F 18
1A    DC/DT     6F 15
1B
:
1E
1F
20
21    W         12 75 A1 64 6D 2F 18 A0 65
22    FRACT     16 A5 65
23    FW/S      16 21 64 A1 65 C2 65
24    K         A2 A6 22 64 63 19 64 2F 65 6D 25 66 23 64 67
25    E         25 A7 64 23 62 C1 21 63 65
26    GS        13 74 18 25 A0 A4 A3 76 79
27    DC        A2 A0 64 1A 64 2F 65 15 25 64 62
28    A         23 15 64 27 C1 21 22 64 63 64 63
29
:
2E
2F    (RTS)
30    PHOTO     B0 28 64
31    COND      B1 26 64
32    CINT      26 A4 A3 76 7A 25 15 28 7B
33    RS        12 75 A0 65 26 64 6D 34 66 B2 64
34    CS        34 B3 64
35
:
3E
3F
B0    1.00
```


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B1 1.00
B2 1.00
B3 1.00
B4 0.00
:
BE 0.00
BF 0.00

This is a composite list, containing **1x**, **2x**, and **3x** channel definitions, and the **Bx** user constants. GET and STORE will function. The file type is 2 (SYSTM).

For further details, consult the **10 - 1F**, or **20 - 2F**, or **30 - 3F**, or **B0 - BF** sections.

E4 Reset E2,E3

The user is prompted

```
E2,E3 RESET
Enter 'E23':_
```

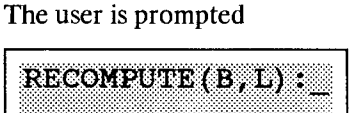
Entering **E 2 3** then **RTRN** will cause the E2 and E3 lists to be reset to default values, and reset the system number to 0.

Related References

EA sys reset

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The user is prompted



Big or Little recompute.

Big Recompute: If samples are present in the scratch pad, this option will compute the Mean/Slope and Range/Error **1x** observations, then do a little compute.

Little Recompute: **2x** and **3x** channels are computed based on the current **1x** Mean/Slope and Range/Error observations, and the system constants.

There is probably no need to use FCT **E5** for little recomputes, since they are done automatically:

- When entering View mode (**E7**) and Miniview mode (**EB**).
- Prior to page storage (if needed) as part of the store pad (**D6**) function.
- As part of the Edit Loop routine (**D7**).

The only reason a big recompute would be needed is if the samples were edited in View mode.

RULES OF COMPUTATION

♦ Computations occur in ascending order of channel number. Thus, a channel should not generally reference a higher channel for purposes of retrieving a value, since the higher channel's value has not yet been computed. There are times when exceptions to this rule prove helpful, however.

♦ A channel is undefined (and not computed) if its code sequence (in the **E3** list) is a null string.

♦ After the pad is cleared, all **1x** channels are zeroed. Thus, if a **1x** channel references itself, that reference will return a zero on the first computation after the clear pad; subsequently, the previous value will be returned.

♦ In real time (Monitor mode), only the **1x** channels are computed.

♦ In LOG mode, **1x** channels are computed at as close to the STEP frequency as is possible. **2x** and **3x** channels are computed after each observation is completed.

♦ A little recompute will never change any **1x** channel samples, means, or ranges, even if there is a **2x** or **3x** channel defined to store a value into a **1x** channel.

♦ A big recompute considers only whether a **1x** channel has a **6F** as part of its definition. If it does, it will use that channel's stored samples to compute the slope and standard error of the slope as a function of time. If no **6F** is present, then it will compute the mean and range of the samples.

One of the ramifications of this rule is that it is not possible to "add" or modify (changing units, for example) a **1x** channel after a data page has been collected.

♦ The time used by the slope channels (**6F** in their definition) is NOT channel **10**, although if channel **10**'s

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definition is simply **70**, then channel **10**'s value will be the same as the time used in the slope calculation. If channel **10** is defined differently, it will not affect any slope calculation.

♦ The **6D** code can be used to pass values ahead or to change a prior channel's present value. Any channel between **20** and **3F** can send values to any other channel in that range. Defining a **2x** or **3x** channel to send a value back to a **1x** channel will NOT change that **1x** channel's mean, range, or sample value. If a **1x** channel uses the **6D** function to affect the value of another **1x** channel, this will work successfully, but only in Monitor mode or in Log mode. It will have no effect during a big or little recompute.

♦ The code sequence **6D 6E 1x** will result in an argument error. It is not legal to attempt to store into a range value.

♦ Previous values (accessed by the **6C** code) are retained for **0x** and **1x** channels. **6C** cannot be used on higher channels. Previous values for **1x** channels are zeroed at clear pad and at the start of each observation. Previous values for **0x** channels are always measured. At clear pad, two sets of data are taken while the **Pad cleared** message is displayed. The first is used for the **0x** previous values, and the second becomes is used for the pass through the **1x** channels.

E6 Clear Pad

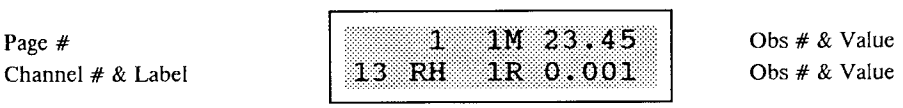
Clear pad performs the following sequence of events:

1. Message displayed on console
2. Pad is reset.
3. 2 sets of **0x** readings are taken.
4. The statistical intermediates for the Mean/Slope and Range/Error are initialized.

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E7 View Mode

View mode allows the user to view the contents of the scratch pad on the display. The format is



Entering view mode will cause the pad to be recomputed using the current values of **Ax, Bx,** and **Cx** constants and using the current system program (**E3**).

Observations are scrolled by pressing [↑] or [↓]. Different channels are viewed by pressing [FCT] followed by the channel number.

Scratch pad values can be edited by pressing [EDIT] or **SHIFT** + [EDIT].

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E8 Log Program

LAB:
NUM:3

1:E6	Clear pad
2:E9	LOG
3:E7	View mode

The Log program list is a sequence of events that will occur when the LOG key (or the log switch on the sensor head) is pressed.

This is a storable list, so GET and STORE will function. The file type is 16 (PROG).

Permissible entries are any hex reference code that is permissible following FCT.

The maximum number of entries in the list is 20.

Once initiated, the LOG program will continue until one of the following things happens:

- The end of the list is reached.

- A function code greater than **3F** is initiated *from the console*. For example, if one of the routines in the LOG program were **4B** (the auxiliary data list), and while viewing this list you pressed AREA to change the leaf area, then that would effectively terminate the Log program, since the AREA key does a FCT **4A**, and **4A** is greater than **3F**. The "proper" way to exit **4B** and continue the Log program would be to press **RTRN**.

- If Log mode (**E9**) is included in the Log program, terminating the Log mode (by pressing the LOG key) will also terminate the Log program sequence.

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LOG mode is the way in which virtual channel values are recorded in the scratch pad. The display in LOG mode is very much like in MONITOR, except for the presence of an asterisk on the bottom line of the display:

```
 123 11 QN 1234.
   0*15 CO 321.4
```

Time since pad cleared Chan # Label Value
Number completed obs Chan # Label Value

In log mode, the following are true:

• [LOG] (or the log switch) - will cause logging to stop. If there are 2 or more samples recorded for an as yet incompleted observation, the observation is completed. If the Log program (**E8**) is in effect, it is cancelled.

• [FCT] **1x** or **2x** or **3x** - Causes the specified channel to be shown on the display. Logging continues. Note that logging is SUSPENDED while awaiting the code entry.

• All other keystrokes or FCT sequences will cause logging to cease, and samples associated with the present uncompleted observation are discarded.

• While in LOG mode, the display updates with the frequency specified by the operating parameter STEP(s).

LOG mode is exited when any of the following occurs:

1. Upon completion of an observation the total number of observations in the pad equals or exceeds the OBS/PAGE operational parameter.

2. A non-channel function (greater than **3F**) is performed.

3. The scratch pad fills, and the following is displayed:

```
PAD FULL
Press a key ...
```

The scratch pad is approximately 31 Kbytes in size. Each sample requires 100 bytes, and each observation 400 bytes. Thus, the pad can hold roughly 310 samples (with no observations). If the operating parameter KEEP SMP is set to N, then sample space is recovered after each observation is completed.

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EA System Reset

```
SYSTEM RESET
Enter 'SYS':_
```

Entering **S Y S** then **RTRN** will cause the following lists to be reset to default values or zeroed:

41 Page Parameters
42 Operating Parameters
44 Quantum Sensor Cal Constant
45 CO_2 Calibration Data
46 Flowmeter calibration Data
47 RH calibration table
51 I/O Parameters
D8 System print format
D9 User print format
E1 User key definitions
E2 Sensor list (**0x** channel settings and **Cx** constants)
E3 System program list (**1x, 2x, 3x** definitions and **Bx** constants)
E7 Scratch Pad
E8 LOG program
EC Mini view definition
ED Key buffer list

SYSTEM RESET does not affect user memory (stored files).

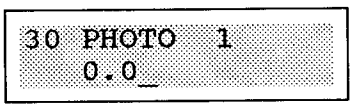
Related References

E4 reset E2,E3

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EB Mini View

MINI VIEW mode displays preselected locations of the scratch pad in a sequence. The user moves through the sequence by pressing any key (or the log switch). The display format is



Channel # Label Obs #
Value

Related References

EC set mini view - Determine the sequence of locations to view.

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EC Set Mini View

This routine determines which data are to be viewed in MINI VIEW mode. Permissible entries in this list are a subset of those for the user format list (**D9**). The LOOP...END LOOP structure is valid.

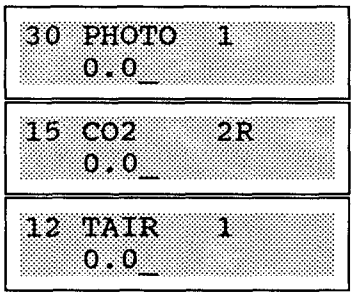
The mini view list is a variable length list (max entries is 40).

Code	Description
LOOP	Used with the observation wildcard. See below.
ENDLOOP	Used with LOOP.
1x.n	Nth sample of channel 1x
1x.nM	Nth mean observation of channel 1x
1x.nR	Nth range observation of channel 1x
2x.n	Nth observation of channel 2x
3x.n	Nth observation of channel 3x

Refer to the **D9** discussion for details.

A sample list and the resulting sequence on the display are shown below:

```
LAB:
NUM:3
1:30.1          1st obs of photosynthesis
2:15.2R         2nd range of CO2
3:12.1          1st sample of air temp
```



If the scratch pad is empty, or if the requested data is missing, the value will be 0.0

2nd range of channel 15, CO_2

1st sample of channel 12, air temp

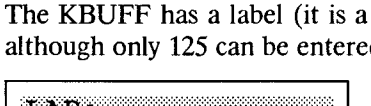
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ED Set Kbuff

The LI-6200 has a 128 byte buffer into which keystrokes typed on the console are put until the program reaches a point in which user input is needed. Thus, there is a 128 byte type-ahead buffer.

There is also another part of the system RAM known as the KBUFF list. The KBUFF is a list that can be loaded with keystrokes by the user - generally to perform some specific task. The function described here (**ED**) accesses the KBUFF, and lets the user define it, either by typing in keystrokes, or else by loading a previously stored list (KBUFF file) into the KBUFF. A separate function (**4E**) will move the contents of the KBUFF into the 128 byte key buffer area all at once, causing the LI-6200 to perform whatever tasks are called for.

The KBUFF has a label (it is a storable list - type 12 (KBUFF)) and can contain up to 128 characters, although only 125 can be entered from the console.



Up to 12 characters for a label.
Up to 128 characters for the KBUFF.

Only a very short KBUFF will actually fit on the display, of course, and it is good to remember that all keystrokes entered when defining the KEYS portion of the KBUFF are put into the KBUFF, including **DEL** and **RTRN**. Further, these bytes are also interpreted normally by the display (**RTRN**s cause a carriage return and line feed on the display for example), so it is difficult or impossible to actually see all but the smallest KBUFFs on the display.

When editing the KEYS: portion of the KBUFF, there is a special character used to terminate the entry. (**RTRN** will not work - if pressed, it goes into the KBUFF file as another byte). This character is a lower case Z, generated by pressing **SHIFT + Z**. Thus, it is by definition not possible to make a lower case z part of the KEYS portion of a KBUFF.

The best procedure to follow when entering a KBUFF list from the console is the following:

1. FCT **ED**
2. **SHIFT +** EDIT
3. Enter LABEL, press **RTRN**
4. Enter KEYS, followed by **SHIFT + Z**

Otherwise, it can be confusing trying to figure out if in fact you are editing the LAB: or the KEYS:.

Besides a lower case z, the only other "key" that cannot be built into a KBUFF is a **BRK**.

Related References

EE exec kbuff - Moves the KEYS: portion of the KBUFF into the key buffer.

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EE Exec Kbuff

This function copies the KEYS portion of the KBUFF list into the LI-6200 key buffer. Refer to the **ED** discussion.

The only method of prematurely terminating the resulting action is to press **BRK**, which flushes the key buffer.

Related References

ED set kbuff - Allows definition of the KBUFF.

EF Swap Terminal

This function causes all console activity to cease, and the LI-6200 considers the I/O port as the terminal. This allows external devices to be used as the terminal by connecting them to the I/O port, rather than wiring them directly to the LI-6200's controller board.

While the terminal is re-directed to the I/O port, the following routines are invalid:

52 Terminal Mode
56 Capture Mode

The SOM and EOM entries in the I/O parameters are used by the LI-6200 while in this mode. All messages sent to the terminal are preceded by the SOM sequence, and the EOM sequence is added to the end.

The built-in values of EOM and SOM that the LI-6200 uses with its normal terminal are 0C and 11 respectively (form feed and DC1).

Related References

51 set I/O - Configures I/O port.

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F8 Tech Checkout

This routine is used in the technician checkout of the instrument.

```
Test:_
```

1st Key	2nd Key	Description
T		Time and date displayed each second.
	T	Change time and date. Enter `6.JUN.15.33` for 6 June 3:33 pm.
C		Counter tests (A/D converter).
	Z	ZERO High resolution zero. Should be near 32768.
	z	zero Low resolution zero. Should be near 2048.
	R	REF High resolution reference. Should be near 58982.
	| (shift + R)	ref Low resolution reference. Should be near 3686.
	1	CHAM Chamber air temp
	2	PAR Quantum sensor
	3	RH Relative humidity
	4	LEAF Leaf temp thermocouple
	5	FLOW Flowmeter
	6	CO2 CO_2 analyzer
	7	GAS IRGA temperature
	8	US1 Spare channel 1
	9	US2 Spare channel 2
	A	US3 Spare channel 3
	B	US4 Spare channel 4
	C	US5 Spare channel 5
	D	US6 Spare channel 6
	E	BATT Battery voltage
R		RAM test. All banks. If not present, says "ERROR".
P		PROM test. Tests 12 blocks of EPROM.
E		RS-232 communications test. Ports A and B talk to each other.
M		MUX test. Same keys as counter test. Displays MUX code for each channel.
ESC		Exit the **F8** mode.

Pressing **BRK** at any time returns to the `Test:` prompt.

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References

Saturation Vapor Presure Equation

Lowe, P. R. (1976). An approximating polynomial for the computation of saturation vapor pressure. *J. Appl. Meteor., 16*:100 - 103.

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von Caemmerer, S. and G. D. Farquhar (1981). Some relationships between the biochemistry of photosynthesis and the gas exchange of leaves. *Planta 153*:376-387.

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Leuning, R. and P. S. Sands (1989). Theory and practice of a portable photosynthesis instrument. *Plant, Cell & Environment, 12*:669-678.

Leaf Energy Balance

Paw U, K. T. and C. S. T. Daughtry (1984). A new method for the estimation of diffusive resistance of leaves. *Agric. For. Meteorol., 33*:141-155.

Boundary Layer Correction for Stomatal Ratio

Welles, J (1986). A portable photosynthesis system. In: *Advanced Agricultural instrumentation*, Gensler, W. G. ed., Martinus Nijhoff Publishers, Boston.

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Summary of Codes

CHANNELS

00		10	TIME	70	20			30	PHOTO	B02864	
01	TA mv	11	QNTM	06C6CC6465	21	W	1275A1646D2F18A065	31	COND	B12664	
02	TL mV	12	TAIR	01C364	22	FRACT	16A565	32	CINT	26A4A3767A2515287B	
03	RH mV	13	TLEAF	02C4641262	23	FW/S	162164A165C265	33	RS	1275A06526646D3466B264	
04	TC mV	14	TCO2	04C364	24	K	A2A622646319642F656D2566236467	34	CS	34B364	
05	C2 mV	15	CO2	05CB64CA621471	25	E	25A7642362C1216365	35			
06	QN mV	16	FLOW	07C8631472CF64	26	GS	13741825A0A4A37679	36			
07	FL mV	17	RH	03C76473	27	DC	A2A0641A642F6515256462	37			
08	mV	18	EAIR	1274C2651764	28	A	23156427C1212264636463	38			
09	mV	19	DE/DT	6F18	29			39			
0A	mV	1A	DC/DT	6F15	2A			3A			
0B	mV	1B			2B			3B			
0C	mV	1C			2C			3C			
0D	mV	1D			2D			3D			
0E	BA V	1E			2E			3E			
0F		1F			2F	(RTS)		3F			

ROUTINES

40	** SETUP **	50	** COMM **	D0	*** MEM ***	E0	** CONFIG **
41	set pg parms	51	set I/O parms	D1	delete files	E1	set keys
42	set opr parm	52	terminal	D2	renum files	E2	set sensors
43	set clock	53	dump pages	D3	mem status	E3	set sys prog
44	set QNTM cal	54	binary dump	D4	file status	E4	E2,E3 reset
45	set CO2 cal	55	binary load	D5	file index	E5	recompute
46	set FLOW cal	56	ascii capture	D6	STORE PAD	E6	CLEAR PAD
47	set RH cal	57	ascii dump	D7	edit loop	E7	view
48	zero FLOW	58	binary index	D8	set sys fmt	E8	set program
49	CO2 ref	59		D9	set user fmt	E9	log
4A	leaf area	5A		DA	view labels	EA	sys reset
4B	aux data	5B		DB		EB	mini view
4C		5C		DC		EC	set mini view
4D		5D		DD		ED	set kbuff
4E		5E		DE		EE	EXEC KBUFF
4F		5F		DF	clear mem	EF	SWAP TERMINAL

CONSTANTS

A0	P(mb)	B0	PHOTO MULT	C0	0
A1	A(cm2)	B1	COND MULT	C1	1
A2	Vt(cc)	B2	RS MULT	C2	100
A3	BC(mol)	B3	CS MULT	C3	.012207 (thermistor)
A4	STMRAT	B4		C4	.00226 (thermocouple)
A5	Fx(umol)	B5		C5	0
A6	Vg(cc)	B6		C6	0 (QNTM cal constant)
A7	Kabs	B7		C7	.024414 (RH multiplier)
A8		B8		C8	0 (Flow offset)
A9		B9		C9	0 (CO2 ref ppm)
AA	AUX DATA 1	BA		CA	0 (CO2 ref mV)
AB	AUX DATA 2	BB		CB	1 (CO2 gain factor)
AC	AUX DATA 3	BC		CC	0.179 (Quantum gain)
AD	AUX DATA 4	BD		CD	0
AE	AUX DATA 5	BE		CE	0
AF	AUX DATA 6	BF		CF	44.64 (Flow units)

PROGRAMS

60	Swap	70	Time Since Pad cleared
61	Drop	71	CO2 Calibration(mV,T)
62	Add	72	Flow Calibration(mV,T)
63	Subtract	73	RH Table(rh)
64	Multiply	74	Saturation Vapor Pressure(T)
65	Divide	75	8.314×(T+273)
66	Invert	76	Boundary Layer Adjust(Ratio,BC)
67	Change Sign	77	CO2 Reference(ppm,T,P)
68	Square	78	CO2 Slope(mV,T)
69	Cube	79	Conductance(es,e,E,P,bc)
6A	Square Root	7A	CO2 Conductance(g,bc)
6B	Duplicate	7B	Ci(g,E,C,A)
6C	Previous	7C	Density(T,P)
6D	Store	7D	5th Order Poly(a,b,c,d,e,f,X)
6E	Range	7E	Energy Bal DeltaT(bc,Ta,Tw,E,Rn)
6F	Slope	7F	Energy Bal Transpiration(bc,Ta,Tℓ,Tw,Rn)

FILES

1	PAGE
2	SYSTM
3	I/O
4	ASCII
5	PPARM
6	OPARM
7	CO2
8	FLOW
9	RH
10	SENSR
11	SFORM
12	UFORM
13	KEYS
14	KBUFF
15	VWSEQ
16	PROG

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Conversion of Units

Assimilation Rate

From	To	Multiply by
$\left\{\frac{\mu mol}{m^2\ s}\right\}$	$\left\{\frac{mg}{m^2\ s}\right\}$	$\frac{44\ \left\{\frac{g}{mol}\right\}\ \ 10^3\ \left\{\frac{mg}{g}\right\}}{10^6\ \left\{\frac{\mu mol}{mol}\right\}} = 0.044$
$\left\{\frac{mg}{m^2\ s}\right\}$	$\left\{\frac{mg}{dm^2\ hr}\right\}$	$\frac{3600\ \left\{\frac{s}{hr}\right\}}{100\ \left\{\frac{dm^2}{m^2}\right\}} = 36$
$\left\{\frac{\mu mol}{m^2\ s}\right\}$	$\left\{\frac{mg}{dm^2\ hr}\right\}$	$= 0.044 \times 36 = 1.584$

Transpiration

From	To	Multiply by
$\left\{\frac{mol}{m^2\ s}\right\}$	$\left\{\frac{mg}{m^2\ s}\right\}$	$18\ \left\{\frac{g}{mol}\right\}\ 1000\ \left\{\frac{mg}{g}\right\} = 18000.$
$\left\{\frac{mol}{m^2\ s}\right\}$	$\left\{\frac{W}{m^2}\right\}$	$18\ \left\{\frac{g}{mol}\right\}\ 2450\ \left\{\frac{J}{g}\right\} = 44100.$

Conductance

From	To	Multiply by
$\left\{\frac{mol}{m^2\ s}\right\}$	$\left\{\frac{cm}{s}\right\}$	$\frac{8.314\ \left\{\frac{N\ m}{mol\ K}\right\}\ \ T\ \{K\}}{P\ \{mb\}\ 100\ \left\{\frac{N/m^2}{mb}\right\}}\ 100\ \{cm/m\} = \frac{8.314\ (T_a + 273)}{P}$

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Connector Descriptions

25 PIN RS-232 DTE PORT

Pin #	Name	Color	Internal 14 Pin I/O	Internal 26 Pin Spare
1	Frame ground	brown	3	
2	Transmitted Data	red	14	
3	Received Data	orange	9	
4	Request to Send	yellow	11	
5	Clear to Send	green	4	
6	Data Set Ready	blue	13	
7	Signal Ground	purple	2	
8	Carrier Detect	gray	12	
9	Spare Channel 1	white		15
10	Spare Channel 1 Ground	yellow		16
11	Spare Channel 2	red		17
12	Spare Channel 2 Ground	white		18
13	<not connected>			
14	Spare Channel 3	yellow		19
15	Spare Channel 3 Ground	gray		20
16	Spare Channel 4	purple		21
17	Spare Channel 4 Ground	red/white		22
18	Spare Channel 5	orange		23
19	Spare Channel 5 Ground	black		24
20	Data Terminal Ready	red	1	
21	<not connected>			
22	Spare Channel 6	blue		25
23	Spare Channel 6 Ground	green		26
24	No signal	brown	10	
25	No signal	black	5	

SENSOR HEAD CONNECTOR

Pin #	Name
A	Quantum sensor signal
B	unused
C	Leaf temp signal
D	RH signal
E	Air temp signal
F	+15.5V
G	Log switch
H	Signal ground
J	+5 V
K	Fan ground
L	Battery
M	unused
N	unused
P	Power ground

9 PIN ANALYZER CONNECTOR

Pin #	Name
1	Signal Ground
2	CO_2 analyzer signal
3	Battery Ground
4	-15.5 V
5	+15.5 V
6	12 V battery
7	Flowmeter
8	Ground
9	Air temperature

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9960-023 RS-232 DCE/DTE CABLE

Pin #	Color	Pin #
1	shield	1
2	red	3
3	yellow	2
5,6,8	green	20
20	blue	5,6,8
7	black	7

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ASCII Table

Ascii Char	Binary	Hex	Dec
null	00000000	00	0
soh	00000001	01	1
stx	00000010	02	2
etx	00000011	03	3
eot	00000100	04	4
enq	00000101	05	5
ack	00000110	06	6
bell	00000111	07	7
bs	00001000	08	8
ht	00001001	09	9
lf	00001010	0A	10
vt	00001011	0B	11
ff	00001100	0C	12
cr	00001101	0D	13
so	00001110	0E	14
si	00001111	0F	15
dle	00010000	10	16
dc1	00010001	11	17
dc2	00010010	12	18
dc3	00010011	13	19
dc4	00010100	14	20
nak	00010101	15	21
sync	00010110	16	22
etb	00010111	17	23
can	00011000	18	24
em	00011001	19	25
sub	00011010	1A	26
esc	00011011	1B	27
fs	00011100	1C	28
gs	00011101	1D	29
rs	00011110	1E	30
us	00011111	1F	31

Ascii Char	Binary	Hex	Dec
	00100000	20	32
!	00100001	21	33
"	00100010	22	34
#	00100011	23	35
$	00100100	24	36
%	00100101	25	37
&	00100110	26	38
'	00100111	27	39
(	00101000	28	40
)	00101001	29	41
*	00101010	2A	42
+	00101011	2B	43
,	00101100	2C	44
-	00101101	2D	45
.	00101110	2E	46
/	00101111	2F	47
0	00110000	30	48
1	00110001	31	49
2	00110010	32	50
3	00110011	33	51
4	00110100	34	52
5	00110101	35	53
6	00110110	36	54
7	00110111	37	55
8	00111000	38	56
9	00111001	39	57
:	00111010	3A	58
;	00111011	3B	59
<	00111100	3C	60
=	00111101	3D	61
>	00111110	3E	62
?	00111111	3F	63

Ascii Char	Binary	Hex	Dec
@	01000000	40	64
A	01000001	41	65
B	01000010	42	66
C	01000011	43	67
D	01000100	44	68
E	01000101	45	69
F	01000110	46	70
G	01000111	47	71
H	01001000	48	72
I	01001001	49	73
J	01001010	4A	74
K	01001011	4B	75
L	01001100	4C	76
M	01001101	4D	77
N	01001110	4E	78
O	01001111	4F	79
P	01010000	50	80
Q	01010001	51	81
R	01010010	52	82
S	01010011	53	83
T	01010100	54	84
U	01010101	55	85
V	01010110	56	86
W	01010111	57	87
X	01011000	58	88
Y	01011001	59	89
Z	01011010	5A	90
[	01011011	5B	91
\	01011100	5C	92
]	01011101	5D	93
^	01011110	5E	94
_	01011111	5F	95

Ascii Char	Binary	Hex	Dec
`	01100000	60	96
a	01100001	61	97
b	01100010	62	98
c	01100011	63	99
d	01100100	64	100
e	01100101	65	101
f	01100110	66	102
g	01100111	67	103
h	01101000	68	104
i	01101001	69	105
j	01101010	6A	106
k	01101011	6B	107
l	01101100	6C	108
m	01101101	6D	109
n	01101110	6E	110
o	01101111	6F	111
p	01110000	70	112
q	01110001	71	113
r	01110010	72	114
s	01110011	73	115
t	01110100	74	116
u	01110101	75	117
v	01110110	76	118
w	01110111	77	119
x	01111000	78	120
y	01111001	79	121
z	01111010	7A	122
{	01111011	7B	123
|	01111100	7C	124
}	01111101	7D	125
~	01111110	7E	126
del	01111111	7F	127

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