LI-6262
CO_2/H_2O Analyzer

INSTRUCTION MANUAL

LI-COR

LI-6262 CO$_2$/H$_2$O Analyzer Operating and Service Manual

Publication Number 9003-59
March, 1996
Software Version 2.02

U.S. and Foreign Patents Pending

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Printing History

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

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

1st Printing - April, 1990
2nd Printing - October, 1991
3rd Printing - March, 1996

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1 Unpacking & Inspection

1.1 What's What

This procedure should be followed if you have just taken delivery on your LI-6262. Check the packing list to verify that you have received everything that was ordered and that you have also received the following items:

● **Calibration Sheet** - This data sheet contains a copy of the calibration information entered into the analyzer at the factory. Keep it in a safe place for future reference, or in case calibration data must be re-entered.

● **Console Command Sheet** - A quick reference card for entering console commands via the LI-6262 keypad or from an external terminal.

● **Spare Parts Kit** - This kit contains replacement parts for your LI-6262. As you become familiar with the analyzer you will learn which items to keep close at hand and which items can be stored away.

● **External Scrubber and Desiccant Tube -** This tube is used during normal operation. Several spare gaskets and adhesive disks have been included for future use.

● **1000-90 Data Communications and Utility Software -** This software can be used to communicate with an IBM PC/XT/AT/PS2 or compatible. The software is provided on 3 1/2 inch diskettes.

● **RS-232C Cable** - (Part #392-02874) DTE to DCE, used to connect the LI-6262 (DCE) to a DTE device such as an RS-232C printer.

● **RS-232C Gender Changer** - (Part #392-02977) Female-to-female gender changer, used to connect the RS-232C cable to most computers.

There are several optional accessories available for use with the LI-6262, including:

6262-03 Pressure Transducer - measures pressure in the sample optical cell and its millivolt signal is used by the LI-6262 analyzer software to calculate pressure values. CO_2 and H_2O readings are then automatically corrected by the software for any detected pressure changes.

6262-04 Reference Pump - designed to purge the reference cell of H_2O during absolute mode operation. Air flow created by movement of the chopping shutter disc is sufficient to purge the reference cell of CO_2, but it is not sufficient to remove all the water vapor in the reference cell. For this reason, an auxiliary pump such as the 6262-04 or the LI-670 Flow Control Unit must be used when operating in absolute mode.

6000B Rechargeable Battery (provides 3.2 hours of battery life).

6200B Rechargeable Battery (provides 6.4 hours of battery life).

LI-6020 Battery Charger (92-138/184-276 VAC, 47 to 63 Hz).

1800-04 RS-232C Cable - Used to connect the LI-6262 (DCE) to a standard IBM AT-type 9-pin RS-232C communications port).

In addition, LI-COR manufactures a portable dew point generator (LI-610), and a flow control unit (LI-670), which are valuable accessories for calibrating and operating the LI-6262.

LI-610 Portable Dew Point Generator

The LI-610 is an ideal field-portable system for calibrating the LI-6262, and can also be used to provide a known water vapor source for use in environmentally controlled measurement chambers.

The LI-610 is a precision instrument that provides a controlled water vapor source of known dew point. The LI-610 has the ability to generate stable dew points from 0 to 50 °C with high accuracy ($\pm$ 0.2 °C). The water vapor source can be derived from any input air stream, including ambient air, eliminating the need for external tanks or mixing of gases.

The dew point temperature of the air stream can be viewed on the LI-610's 4 1/2 digit LCD display, or output to the LI-6262 directly, as an analog

signal. Analog output is linear, and the 0-50 °C dew point range is scaled over 0-5 volts (100mV/°C).

LI-670 Flow Control Unit

The LI-670 is a valuable accessory for use with the LI-6262, which can be used for a variety of calibration and gas exchange measurement functions. In its simplest form, the LI-670 is used as a constant source of air flow to the LI-6262. Independent pumps and rotameters allow variable flow rates through the LI-6262 sample and reference cells, if desired.

For calibration of the LI-6262, soda lime and desiccant tubes provide a zero gas source; a span gas can be swapped between cells to adjust for any zero offset present during calibration.

The LI-670 also can be used as a power source for the LI-6262; a built-in low battery detection circuit monitors battery life of the system. Mounting brackets are included for attaching the LI-670 and LI-6262, making the system completely portable.

1.2 Checking the Batteries (If purchased)

Batteries are tested and fully charged when they leave the factory, but they may discharge during shipping. It is a good idea to test each battery to see if it is charged. If the batteries are below 12V, they should be charged before use. Refer to Section 7.1 for charging instructions.

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

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2 Setup & Operation

This section will describe the steps necessary for you to set up the hardware and software in your LI-6262 to begin making measurements. Follow these steps to configure your analyzer; where noted, the steps are described in more detail in this and other sections.

2.1 Setup and Operation

1. Install Gelman filters.

The Gelman filters are used externally, and must be inserted in the Sample and Reference airstreams upstream from the analyzer. See Section 2.3, *Gelman Filter Installation* below.

2. Prepare a soda lime/desiccant tube, as described in Section 7.4, and attach to the **SCRUBBER** holder on the back panel.

3. Absolute or Differential mode operation?

The LI-6262 can be operated in absolute or differential mode. In *absolute* mode, the reference cell contains a zero concentration of CO_2 and H_2O. The sample cell is connected to the unknown gas to be measured. The signal from the sample cell is compared to the zero gas reference signal to provide absolute measurements of CO_2 and H_2O. In *differential* mode, the reference cell contains a non-zero gas of ***known concentration***. The difference between absorption in the sample cell and in the reference cell is measured. Configuring the LI-6262 for differential or absolute mode operation requires slightly different hose connections; see *Absolute vs Differential Mode Operation* below.

4. Turn the power ON.

The LI-6262 can be operated with AC or DC power. See Section 2.2, *Power On* below.

5. Calibrate the analyzer as described in Section 4.

6. Connect sample airstream to be measured.

7. Configure analyzer for data output.

Data can be obtained from the LI-6262 in several different ways; from the display, via RS-232C output, or from one of the analog output channels. See Section 6, *Interfacing*, for more information.

8. Configure the software.

All software commands are executed by pressing **FUNCTION** and then entering a two-digit function code. Some codes execute a function directly, while others access scrollable lists of options, or other functions. Items in lists can be selected by scrolling the list with the arrow keys and pressing **ENTER**.

● Enter the station barometric pressure. Press **FCT**, followed by **77**, and enter the barometric pressure, in kPa.

Pressure may also be input continuously using the 6262-03 Pressure Transducer from LI-COR, or through auxiliary channel 15 with an external pressure sensor, as described in section 6.4.

● Set the parameters for RS-232C output, if necessary. Press **FCT**, followed by **17**, and enter the data output parameters.

● Set the Print List (FCT 13).

Data from up to ten different channels may be sent to the RS-232C port at a specified interval. See Section 5, FCT 13.

● Set Auto Print (FCT 14).

Enter specified interval in seconds (0.1-3600) at which to transmit data (defined at FCT 13) to the RS-232C port. See Section 5, FCT 14.

● Set Auto Header (FCT 15).

The column header interval is the number of data lines which will be printed between column headers. See Section 5, FCT 15.

- Set the displays (FCT 91-99).

  The LCD display has two lines, and each line can be configured to show any channel code 21-29 (CO_2), 31-39 (H_2O), or 41-47 (MISC). As many as nine two-line display configurations can be defined by the Set Displays routine. Each display is identified by a number 1 through 9, and can be viewed by pressing the appropriate number *without* pressing **FCT**. See Section 5, FCT 04.

9. Begin making measurements.

2.2 Power On

1. If a LI-COR rechargeable battery is being used, connect it to the 10.5-16VDC battery connector on the rear panel. The 6000B Rechargeable Battery will provide power for approximately 3.2 hours at 25 °C, or 2.4 hours at 40 °C. The 6200B Rechargeable Battery has twice the capacity of the 6000B. Instructions for recharging these batteries are given in Section 7.1.

   One set of battery leads with a 3-pin plug is included in your spare parts kit for connection to a user-supplied battery (10.5 - 16VDC, 1.5 amp maximum current required) or other DC power supply.

   If AC line voltage is being used, make sure the AC VOLTAGE selector on the back panel is set correctly (choose the 115 setting for 100-130VAC, or the 220 setting for 200-260VAC), and plug the line cord into the receptacle on the back panel.

2. Turn the power switch on the front panel ON. The fan will run, and after a few seconds, the chopper motor will come up to speed. The READY light on the front panel will come on after 1-3 minutes. (The higher the ambient temperature, the longer it takes). Any one of the following conditions will prevent the READY light from illuminating:

   - Ambient temperature greater than about 55 °C.
   - Level of CO_2 is too high in the reference cell (greater than about 3000 ppm).
   - CO_2 or water vapor in the detector, caused by the internal soda lime/desiccant bottle being exhausted.
   - Span potentiometer on the front panel is defective (open).

Low Battery Voltage

> **IMPORTANT:** The LI-6262 has no built-in circuitry for monitoring battery voltage. When battery voltage drops below approximately 10.5 volts, the analyzer will shut down, and data transmission will stop. It is therefore suggested that battery voltage be monitored regularly to avoid system shutdown.

You may wish to monitor battery voltage with an external voltmeter, or use a timer with an alarm to alert the user to possible system shutdown. If you intend to operate the LI-6262 with battery power for more than 3 hours with the 6000B (6 hours with the 6200B), it is recommended that a user-supplied battery with a larger storage capacity be connected using the battery leads included with the LI-6262, or that several batteries be used in parallel for longer operation.

2.3 Gelman Filter Installation

> **IMPORTANT:** *Always install the external air filters before operating the LI-6262.* Insert filters into **both** the SAMPLE and REFERENCE airstreams before they enter the LI-6262. *Failure to do this will lead to contamination of the sample and reference optical paths, which can cause large zero offsets that may require expensive repairs.*

The Gelman polypropylene filters included use PTFE filter elements with a 1 µm pore size. They have excellent particle retention, very low water sorption, little flow restriction and small internal volumes. These filters will not fit inside the LI-6262 case, and must be used externally.

In *absolute mode*, insert a filter between the scrubber tube outlet (top) and the **REFERENCE IN** port (Figure 2-3). Use a jumper tube to connect the **REFERENCE OUT** port to the **TO CHOPPER** port. The scrubber tube inlet (bottom) is connected to the **FROM CHOPPER** port. Air supplied to the sample cell must also pass through a filter before it enters the LI-6262.

In *differential mode*, place a filter in the sample airstream before it enters the **SAMPLE IN** port on the LI-6262. Place a second filter in the reference airstream before it enters the **REFERENCE IN** port.

Replace the filters when flow rates drop due to particle retention, or when the apparent LI-6262 response to changes in humidity becomes slow due to filter retention of hygroscopic material.

When using the LI-6262 in high flow rate applications (e.g. eddy correlation) or where sample air is particularly dirty, you may consider stacking two filters in series. For maintenance, replace the filter furthest upstream from the analyzer with the filter closest to the analyzer and replace the filter closest to the analyzer with a new filter.
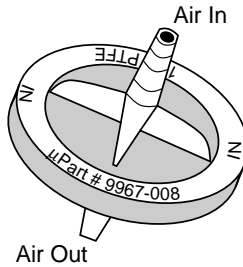
Install the new filter(s) with the blue lettering facing *away from* the **SAMPLE IN** or **REFERENCE IN** ports.

Instruments with serial numbers of IRG3-239 and below were shipped with internal Balston filters. Balston filters have good particle retention with low flow resistance, but they equilibrate slowly with changing humidities, thus degrading the apparent response time and performance of the LI-6262. Replace the Balston filters with external Gelman filters as described above.

We recommend that the **SAMPLE IN** and **REFERENCE IN** ports be covered with the dust caps provided or attached to an airline when the instrument is not in use. This will prevent dust from entering the instrument downstream from the filters where it can enter the optical paths.

Replacement Gelman Acro 50 filters can be obtained from LI-COR (part # 9967-008).

2.4 Absolute vs. Differential Mode Operation

The LI-6262 may be operated in either absolute or differential modes to simultaneously measure CO_2 and H_2O in any units. The following discussion will help you to set up the analyzer to measure these outputs.

Prepare a soda lime/desiccant tube, as described in Section 7.4, and attach to the **SCRUBBER** holder on the back panel.

Differential Mode Operation

● Orient the scrubber tube so that the soda lime is on the bottom and the magnesium perchlorate is on top.

● Attach the bottom hose (nearest the soda lime) to the **FROM CHOPPER** fitting.

● Attach the top hose (nearest the perchlorate) to the **TO CHOPPER** fitting (Figure 2-1).
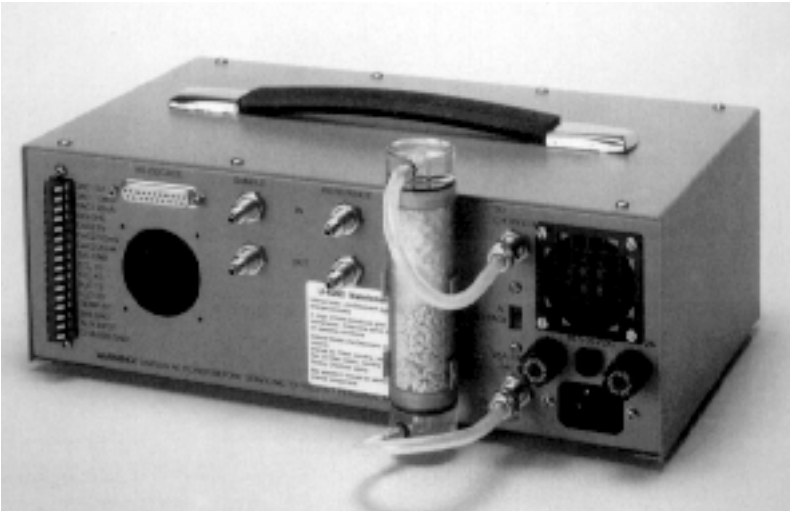
Figure 2-1. Hose connections for operation in differential mode.

IMPORTANT: Attach the hoses as shown in Figure 2-2. The hose nearest the soda lime is attached to the **FROM CHOPPER** fitting, and the hose near the magnesium perchlorate is attached to the **T O CHOPPER** fitting. This ensures that CO_2 is purged first, and then water vapor. If this sequence is reversed, the air will pick up water vapor from the soda lime before being returned to the chopper housing.
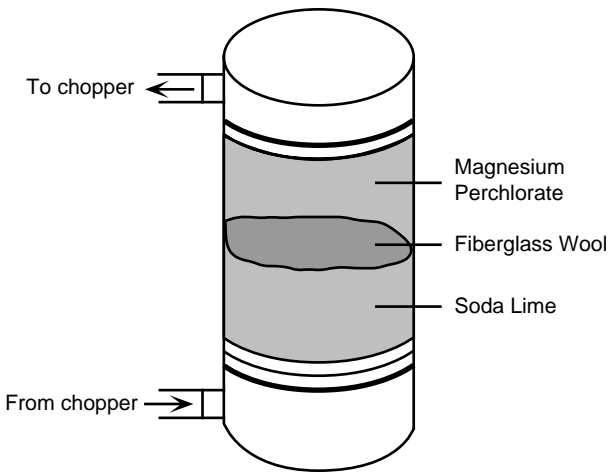
Figure 2-2. Hose attachments to external soda lime/desiccant tube assembly.

Absolute Mode Operation

IMPORTANT: Air flow created by movement of the chopping shutter disc is sufficient to purge the reference cell of CO_2, but is not sufficient to remove all of the water vapor in the reference cell. For this reason an auxiliary pump such as the 6262-04 must be used when operating in absolute mode. See Section 4.4 for more information.

● Orient the scrubber tube so that the soda lime is on the bottom and the magnesium perchlorate is on the top.

● Attach the bottom hose (nearest the soda lime) to the **FROM CHOPPER** fitting. An auxiliary pump should be placed between the **FROM CHOPPER** fitting and the bottom hose of the scrubber tube. *Make sure the pump is oriented to pump in the direction indicated in Figure 2-3*.

● Attach the top hose (nearest the perchlorate) to the **REFERENCE IN** fitting.

● Attach a jumper hose between the **REFERENCE OUT** and **TO CHOPPER** fittings.
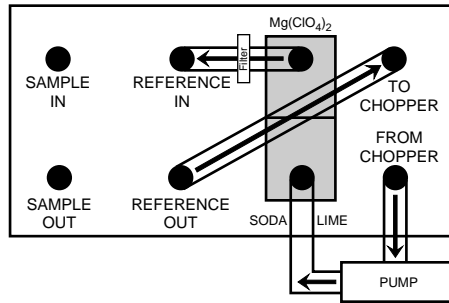
Figure 2-3. Hose connections for operation in absolute mode.

Theory of Operation

3.1 General Description

The LI-6262 is a differential, non-dispersive, infrared (NDIR) gas analyzer. The CO_2 and H_2O measurements are based on the difference in absorption of infrared (IR) radiation passing through two gas sampling cells. The **reference cell** is used for a gas of known CO_2 or H_2O concentration, and the **sample cell** is used for a gas of unknown concentration. Infrared radiation is transmitted through both cell paths, and the output of the analyzer is proportional to the difference in absorption between the two.
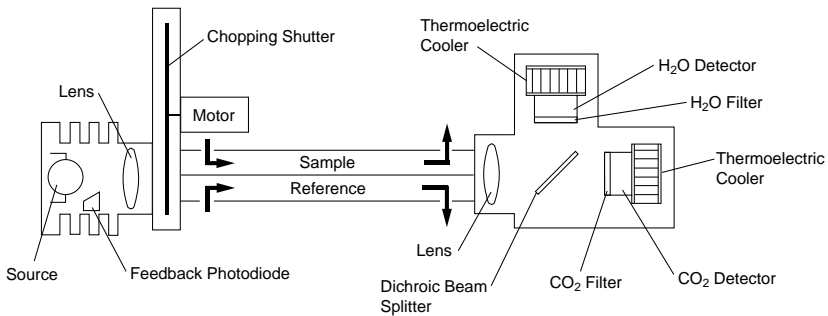
The infrared **source** is vacuum sealed for long life (> 10,000 hours) and high stability. A separate optical feedback circuit with a photodiode maintains the source at a constant color temperature (1250 °K). A gold reflector surrounding the IR source maximizes the radiation output from the source and decreases the power required.

The **chopping shutter** disc is spun by a motor, whose shaft turns on high precision bearings for long life and low noise. Rotation is precisely controlled at 500 hertz on a phase locked loop circuit. The optical path between the source and optical bench is sealed and continuously purged of CO_2 and H_2O by an attached tube containing soda lime and magnesium perchlorate. This eliminates interference due to ambient CO_2 or H_2O vapor.

The **sample cells** are gold-plated to enhance IR reflection and resist tarnishing over time. One set of sample cells is used for both H_2O and CO_2 measurements by using a **dichroic beam splitter** to provide radiation to two separate detectors.

A 150 nm bandpass **optical filter** is used to tune the CO_2 detector to the 4.26 micron absorption band for CO_2, and a 50 nm bandpass optical filter tunes the H_2O detector to the 2.59 micron absorption band. Both filters provide excellent rejection of IR radiation outside the desired band, allowing the analyzer to reject the response of other IR absorbing gases. The filters are mounted directly on the detectors for thermal stability.

Each **detector** is a lead selenide solid state device that is insensitive to vibration. The detectors are cooled and regulated to -5 °C by thermo-electric coolers, and electronic circuits continuously monitor and maintain a constant detector sensitivity. The result of this detector circuitry is a detector system that is very stable.

Infrared radiation from the source is focused through the gas cells and onto the detector by a **lens** at each end of the optical bench. Focusing the radiation maximizes the amount of radiation that reaches the detector in order to provide maximum signal sensitivity.

All of these features provide a CO_2 noise level that is typically 0.3 ppm peak-to-peak (at 350 ppm) when using 1 second signal averaging, and 1 ppm peak-to-peak with 0.1 second signal averaging; the H_2O noise level is approximately 0.002 kPa at 2.0 kPa when using 1 second signal averaging, and 0.006 kPa when using 0.1 second signal averaging. Signal averaging times are selectable (in software) between 1 and 30 seconds and are used to achieve even lower noise levels. For example, with 4 seconds of signal averaging, the noise levels typically decrease 50%.

3.2 Calculating Gas Concentration - General

LI-COR gas analyzers use a lead selenide detector that operates approximately as a linear quantum counter; that is, over much of its range the detector signal output ν is proportional to the number of photons reaching the detector. The output voltage V that is used to compute CO_2 mole fraction 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).

$$V = k(v_r - v_s) \qquad\qquad 3\text{-}1$$

The analyzer operates in such a way as to keep v_r constant, so we can factor v_r out of the quantity in parentheses, define $K = kv_r$, and obtain,

$$V = K\left(1 - \frac{v_s}{v_r}\right) \qquad\qquad 3\text{-}2a$$

In absolute mode, the instrument is operated with no CO_2 in the reference cell so v_r is proportional to maximum photon throughput. The sample cell normally contains CO_2, which reduces the photon flux reaching the detector through the sample cell and reduces v_s. Therefore, the ratio v_s/v_r gives the ratio of photon flux in the presence of CO_2 and in its absence, which is just the transmittance τ. Since absorptance A equals $1\text{-}\tau$, we can also write equation 3-2 as

$$V = K(1 - \tau) \qquad\qquad 3\text{-}2b$$
$$\text{and}$$
$$V = KA \qquad\qquad 3\text{-}2c$$

The constant K is given on the calibration sheet.

Equation 3-2c indicates that the analyzer output voltage is proportional to absorptance; however, absorptance is a non-linear function of CO_2 mole fraction. Absorptance and analyzer output voltage both increase with increasing CO_2 mole fraction in the sample cell. Figure 3-1 illustrates a typical relationship between gas concentration, transmittance (v_s/v_r) and analyzer output voltage.
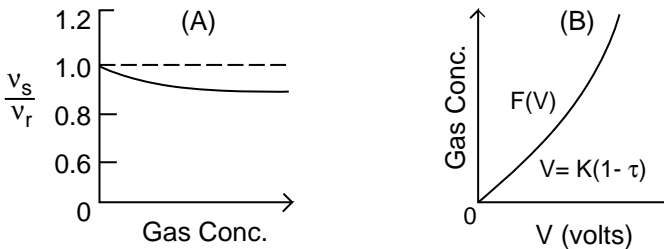
Figure 3-1. (A) The ratio of detector output while viewing the sample cell (v_s) and the reference cell (v_r) decreases with increasing gas concentration. (B) The output voltage V is related to the ratio of v_s to v_r by Equation (3-2a). Gas concentration in terms of V is the calibration function F(V).

The factory calibration of the analyzer consists of measuring the output V at several gas concentrations, and determining the coefficients for a fifth order polynomial (H_2O uses a third order polynomial) F(V) that relates V to gas concentration, with a zero gas concentration in the reference cell.

$$F(V) = a_1V + a_2V^2 + a_3V^3 + a_4V^4 + a_5V^5 \qquad \text{3-3}$$

Coefficients a_1 thru a_5 are factory-determined for the specific gas, and are unique to each analyzer. *The calibration function F(V) is only valid for the temperature and pressure at which it was determined, and a zero gas concentration in the reference cell.* It has been found empirically that (absolute) temperature affects the gas concentration in a linear fashion, while pressure affects the signal output V in a linear fashion. Therefore, the expression relating signal output to gas concentration with a zero gas concentration in the reference cell (absolute mode) is

$$C = F\left(V\frac{P_o}{P}\right)\frac{T}{T_o} \qquad \text{3-4}$$

where P is barometric pressure in the cell (kPa), P_o is standard barometric pressure (101.3 kPa), T is IRGA temperature (°C or °K), and T_o is IRGA calibration temperature (°C or °K).

The situation is a little more complicated in differential mode. If we place a nonzero CO_2 mole fraction in the reference cell, then infrared radiation will be absorbed, transmittance will decrease, and v_r should decline. This decline is prevented however, by an automatic gain control circuit that increases the detector gain by an amount necessary to hold v_r constant. This provides span stability over the long term, but the ouput voltage must now be corrected for the gain increase before the calibration polynomial can be applied.

How much is this gain increase? The detector output signal v_r is proportional to photon flux, so to hold v_r constant, the gain must be inversely proportional to the reduced photon flux that results when CO_2 is added to the reference cell. Transmittance is proportional to the photon flux, so *the gain increase is proportional to $1/\tau_r$,* where the subscript r refers to the transmittance of the reference cell. Therefore, to correct for the gain increase, we find the transmittance of the reference cell given the reference cell CO_2 mole fraction, and multiply the analyzer output voltage by τ_r.

To find τ_r, we assume that the sample and reference cells are optically identical when they contain the same absorbing gas concentrations. If the

two cells are identical, then for a given gas concentration, the transmittance will be the same whether it is computed against zero between the cells or within either cell.

Now, suppose the reference cell contains CO_2 mole fraction C_r. If we can compute what the transmittance would be if C_r were in the sample cell against zero in the reference cell, then we will know what the transmittance actually is in the reference cell when it contains C_r, and that will tell us how to correct for the gain change.

The strategy for accomplishing this is straightforward. First, we use C_r to solve equation 3-4 for V_r, giving

$$V_r = F^{-1}\left(C_r\left[\frac{T_o}{T}\right]\right)\left(\frac{P}{P_o}\right) \qquad\qquad 3\text{-}5$$

Then, rearrange equation 3-2b to find τ_r given V_r,

$$\tau_r = \left(1 - \frac{V_r}{K}\right) \qquad\qquad 3\text{-}6$$

Equations 3-5 and 3-6 ordinarily apply to the situation where C_r is in the sample cell and zero is in the reference cell; but if the cells are identical, τ_r also computes the transmittance in the reference cell when C_r is present. The gain correction G equals τ_r, as shown earlier, so

$$G = \left(1 - \frac{V_r}{K}\right) \qquad\qquad 3\text{-}7$$

After correcting the differential voltage V for the gain change we can write $GV = V_s - V_r$. Solving for V_s and substituting the result into equation 3-4 gives the general expression for computing the gas concentration C in the sample cell given concentration C_r in the reference cell,

$$C = F\left[(VG + V_r)\frac{P_o}{P}\right]\left[\frac{T}{T_o}\right] \qquad\qquad 3\text{-}8$$

The differential CO_2 mole fraction ΔC is simply $(C - C_r)$.

$$\Delta C = F\left[(VG + V_r)\frac{P_o}{P}\right]\left[\frac{T}{T_o}\right] - C_r \qquad\qquad 3\text{-}9$$

In this section we have assumed that the sample and reference cells are optically identical. Strictly speaking, of course, that is not true. This can be illustrated by setting zero with zero gases in both the sample and reference cells and then placing a single span gas in both cells. A small zero offset will usually be observed, illustrating any minor optical differences between the cells that may exist. Nevertheless, the treatment given here works very well in practice. Small optical anomalies of whatever origin can be corrected empirically by setting zero and span.

3.3 Calculating CO_2 Concentration

Mole fraction CO_2, C (μmol/mol, displayed using FCT 22) comes directly from equation 3-8. The reference concentration value C_r (μmol/mol), should be entered via FCT 59. If the reference air is not dry then c_r should be the actual CO_2 mole fraction in the presence of water vapor. See sections 3.5 and 3.6.

CO_2 differential ΔC, μmol/mol (FCT 23) is C - C_r.

CO_2 partial pressure p_c (Pa, displayed using FCT 24) is computed from C and total pressure P (kPa) by

$$p_c = \frac{cP}{1000} \qquad\qquad 3\text{-}10$$

The CO_2 weight fraction c_g (μg/g, displayed at FCT 26) is computed as

$$C_g = \frac{44c}{M} \qquad\qquad 3\text{-}11$$

where M = molecular weight of air (g/mol), weighted for water vapor.
      = 29(1 - w/1000) + 18w/1000
    w = mole fraction of water vapor (mmol/mol).

3.4 Calculating H_2O Concentration

The calculation of water vapor w (mmol/mol, displayed using FCT 32) is performed using an equation similar to equation 3-8. However, we have found that the pressure dependence is different from that used in equation 3-12. We have found empirically that $(P_o/P)^{0.9}$ gives more accurate pressure correction than P_o/P. Thus,

$$w = F_w \left[(VG + V_r) \left(\frac{P_o}{P} \right)^{0.9} \right] \left[\frac{T + 273}{T_o + 273} \right]$$
3-12

and

$$V_r = F_w^{-1} \left[w_r \left(\frac{T_o + 273}{T + 273} \right) \right] \left[\frac{P}{P_o} \right]^{-0.9}$$
3-13

For computational speed, we make the following approximation:

$$\left(\frac{P_o}{P} \right)^{0.9} \cong \left(\frac{P_o}{P} \right) 0.8845 + 0.1089$$
3-14

Vapor pressure e (kPa, FCT 38) is computed from the water vapor mole fraction w and total pressure P (kPa).

$$e = \frac{wP}{1000}$$
3-15

The dewpoint temperature T_d (°C, FCT 38) is computed from an equation that was fit to the data of Goff and Gratch (1946), as given by List (1966), giving saturation vapor pressure as a function of temperature over a range of -50 to 50 °C:

$$T_d = \frac{242.62z}{7.6448 - z}$$
3-16

where $z = \log_{10} \left(\frac{e}{.61083} \right)$

and e is vapor pressure in kPa.

The LI-6262 computes the water vapor weight fraction w_g (mg/g, FCT 36) as

$$w_g = \frac{18w}{M}$$
3-17

where M is given after equation 3-12.

3.5 Pressure Broadening Due to Water Vapor

Water vapor can influence infrared detection of CO_2 in three ways:
1) direct absorption in the CO_2 waveband of interest, 2) dilution, and 3)
pressure broadening. Direct infrared absorption by water vapor can be
virtually eliminated by judicious choice of wavebands and filters, and
methods to correct for dilution are well known (Section 3.6); however,
pressure broadening is more of a problem.

Gas phase absorption of infrared radiation is due to energy-induced changes
in vibrational and rotational energy states. Such energy states are altered by
intermolecular collisions which increase in number as pressure increases.
The kinetic theory of gases and quantum mechanics predicts that absorption
band widths increase with pressure, and it is observed that broad band
infrared absorption increases as pressure increases at constant absorber
concentration.

Not all gases are equally effective in causing pressure-induced line
broadening. Gases that are similar are more effective than dissimilar gases.
This effect is embodied in the concept of equivalent pressure, or effective
pressure, P_e. Total pressure P is equal to the sum of partial pressures of
component gases, while equivalent pressure is defined as

$$P_e = a_1 p_1 + a_2 p_2 + ...$$

where a_i are weighting factors representing the pressure broadening
effectiveness of each gas species relative to nitrogen ($a_{N_2} = 1$). For CO_2 in
nitrogen $P_e = p_{N_2} + 1.3\ p_{CO_2}$ (2).

Consider a simple atmosphere made up of H_2O vapor with pressure e, plus
dry gases with pressure P_d, so that

$$P = P_d + e,$$

or, in mole fraction units,

$$1 = X_d + X_w \qquad\qquad\qquad 3\text{-}18$$

where X_d is the mole fraction of all dry gases and X_w is the water vapor
mole fraction (e/P).

The equivalent pressure will be $P_e = \Sigma a_i p_i + a_w e$. In principle, P_e will vary
with CO_2 partial pressure, but the CO_2 partial pressure is so small that it can

be neglected. Thus, if other atmospheric components are constant, an equivalent pressure can be defined as

$$P_e = a_dP_d + a_we$$

$$= P(a_dX_d + a_wX_w) \qquad 3\text{-}19$$

where P_d is the total pressure of dry air, and a_d is a dry air weighting factor.

LI-COR calibrates all of its analyzers using CO_2 or water vapor in air, so $a_d = 1$ is taken as the standard condition. Substituting equation 3-18 into equation 3-19 gives

$$P_e = P[1 + (a_w - 1)X_w] \qquad 3\text{-}20$$

The value of a_w is not an intrinsic constant comparable to other such values in the literature because it uses dry air as a reference instead of nitrogen. Its value has been empirically determined to be about 1.5 against dry air. The value of a_w used in 3-20 is entered into the LI-6262 using FCT 78.

Equation 3-20 can be extended to include nitrogen as standard, and both water vapor and oxygen (or other gases) as variable components. P_e can be written in a more general form to anticipate that possibility:

$$P_e = P[1 + (a_w - 1)X_w + \Sigma(b_i - 1)X_i] \qquad 3\text{-}21$$

For the present, equation 3-20 is implemented in the LI-6262 software; equation 3-21 has not yet been tested. Equation 3-20 can be compactly rewritten as

$$P_e = P\chi(X_a) \qquad 3\text{-}22$$

where $\chi(X_a) = 1 + (a_w - 1)X_a$, and then incorporated into the CO_a calibration function.

The form of the CO_2 calibration function (equation 3-4) was derived empirically, but it can also be derived from a "scaling law" called the "non-overlapping line approximation" which holds when absorber concentrations are low or pathlengths are short (4). This "scaling law" allows absorption measured under one set of conditions to be scaled to other conditions (2),

$$\frac{A}{P} = g(u/P) \qquad 3\text{-}23$$

where A is total band absorption, P is total pressure (kPa), u is absorber amount (mol m^{-2}) = ρL; ρ is mol density (mol m^{-3}), and L is pathlength (m); g is a general unspecified function.

From the ideal gas law, the absorber mole density ρ can be expressed as

$$\rho = \frac{p}{RT}$$

$$= \frac{XP}{RT}$$

3-24

where ρ is absorber partial pressure and X is absorber mole fraction (mol absorber/mol air). Therefore,

$$\frac{u}{P} = \frac{XL}{RT}$$

3-25

Substituting equation 3-25 into 3-23 and incorporating the constants L and R into a new function h gives

$$\frac{A}{P} = h\left(\frac{X}{T}\right)$$

3-26

In principle, equation 3-26 can be solved for mole fraction, giving

$$X = h^{-1}\left(\frac{A}{P}\right)T$$

3-27

Since LI-COR gas analyzers produce an output voltage that is proportional to absorptance,

$$V = KA$$

3-28

substituting 3-28 into 3-27 yields

$$C = F\left(V\frac{P_o}{P}\right)\frac{T}{T_o}$$

3-29

where C is the CO_2 mole fraction in μmol mol^{-1}, and the constants K, P_o and T_o are included in the general function F; P_o = 101.3 kPa, and T_o is the calibration temperature in degrees Kelvin. Equation 3-29 is the fundamental

LI-COR gas analyzer calibration function, where $F(x)$ is a polynomial. By substituting equation 3-22 into 3-23 and following through the derivation, the calibration equations for CO_2 become:

$$V_r = \chi(w_r)F^{-1}\left(\frac{c_r}{\chi(w_r)}\left[\frac{T+273}{T_o+273}\right]\right)\frac{P}{P_o}$$

$$G = 1 - \frac{V_r}{K} \qquad\qquad 3\text{-}30$$

$$C = \chi(w_s)F\left(\frac{VG+V_r}{\chi(w_s)}\frac{P_o}{P}\right)\frac{T+273}{T_o+273}$$

$$\Delta C = C - C_r$$

The water correction is based upon a theoretically justifiable procedure which requires determination of a single physically meaningful constant, and can be applied to any LI-COR 6200 series infrared gas analyzer, and perhaps others, as well.

3.6 Dilution Corrections

A dilution correction can be applied in the LI-6262, if desired. When one component gas of multicomponent mixture is decreased at constant pressure, the partial pressures of all other components are increased accordingly. For example, if water vapor is removed at constant pressure, then the partial pressures of other components increase according to

$$P = \frac{\sum p_i{}^{wet}}{(1-w/1000)} \qquad\qquad 3\text{-}31$$

where w is the water vapor mole fraction (mmol/mol) and the $p_i{}^{wet}$ are partial pressures of other component gases before water vapor was removed. For individual components, Equation 3-31 becomes

$$p_i{}^{dry} = \frac{p_i{}^{wet}}{(1-w/1000)} \qquad\qquad 3\text{-}32$$

It is often necessary to correct the CO_2 mole fraction for differences in water vapor mole fraction in sample and reference cells when CO_2 and water vapor are measured together. An apparent CO_2 mole fraction difference will develop if water vapor is added to or removed from either air stream whether a net CO_2 flux is present or not. This dilution effect can be removed when the Vapor Flag (FCT 76) is set to **BndBrd, Dil → Ref**; the CO_2 mole fraction in the sample air stream is then corrected to the water vapor mole fraction that is in the reference air stream according to

$$C_s{}^{wr} = C_s{}^{ws} \frac{\left(1 - w_{ref}/1000\right)}{\left(1 - w/1000\right)}$$ 3-33

$C_s{}^{ws}$ is the actual CO_2 mole fraction in the sample cell diluted by w, and $c_s{}^{wr}$ is the equivalent sample cell CO_2 mole fraction if it were diluted by w_{ref}.

It is important to distinguish the different water corrections that can be applied in the LI-6262. The Vapor Flag (FCT 76) can be in one of three states:

0 - Corrections Off: No pressure broadening or dilution corrections are applied.

1 - Band Broadening: A pressure broadening correction is applied, but no dilution correction is performed. The actual CO_2 mole fraction in the sample cell or the actual CO_2 differential is displayed.

2 - BndBrd, Dil → Ref: Both a pressure broadening and a dilution correction are applied. The sample cell CO_2 mole fraction and the CO_2 differential are corrected for differences in sample and reference air stream water vapor contents. This is the appropriate setting for photosynthesis measurements. **NOTE**: This is the default setting when the system is configured at the factory, or when the system is reset (FCT 08).

3.7 C_r is Unknown. Measuring C_r against $C_s = 0$

Sometimes a CO_2 differential must be measured when the reference CO_2 mole fraction is not precisely known. For example, one might be measuring photosynthesis in the field with ambient air as the reference gas, the exact CO_2 mole fraction of which is not known. One could scrub the reference cell and measure the incoming CO_2 concentration in absolute mode. However, there will be a small zero shift when the reference gas is reduced from around 350 ppm to 0 ppm, so a zero adjustment must be made each

time the reference cell is scrubbed. The same is true when ambient air is returned to the reference cell.

It is easier to leave the reference gas alone and scrub the sample cell; this avoids zero shifts and gain changes. One can then measure the output voltage V and compute V_r and C_r according to equations 3-34 and 3-35.

$$V_r = \frac{-V}{1 - \dfrac{V}{K}}$$

3-34

$$C_r = F\left[V_r \frac{P_o}{P} \right]\left(\frac{T + 273}{T_o + 273} \right)$$

3-35

These values can be used as needed to compute C_s or ΔC over as long a time period as C_r and temperature are stable. **Note**: This is not implemented in the instrument, but is provided as an aid to those needing this trick.

References

1. Goff, J.A., and S. Gratch, 1946. Trans. Amer. Soc. Heat. and Vent. Eng., Vol. 52, p. 95.

2. Jamieson, J.A., et.al. 1963. Infrared Physics and Engineering. McGraw-Hill, New York, N.Y. p. 65.

3. List, R.J. 1966. Smithsonian Meteorological Tables, 6th rev. ed. The Smithsonian Institution, 527 pp.

4. Wolfe, W.L., and G.J. Zissis. 1978. The Infrared Handbook. Office of Naval Research, Department of the Navy, Washington, D.C.

4 Calibration

4.1 Calibration - General Information

The factory calibration of the LI-6262 CO_2/H_2O Analyzer consists of determining the coefficients for the calibration polynomials for CO_2 and H_2O. These coefficients should be quite stable over time, but we recommend that they be checked every two years by returning the LI-6262 to LI-COR for recalibration.

The user calibration consists of adjusting the zero and span potentiometers so that the analyzer's output matches the linearization polynomial F(V). **This should be done on a daily basis (unless the 6262-03 Pressure Transducer is installed), as the span varies with barometric pressure, and the zero varies with temperature.**

Figure 4-1 illustrates the effects of the zero and span adjustments.
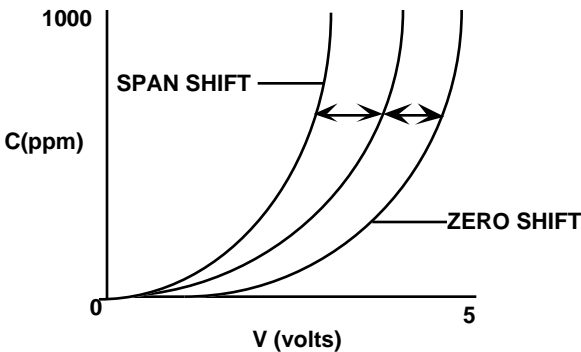
Figure 4-1. Effects of zero and span adjustments.

Procedures for zero and span calibrations are given in Section 4.2 for differential mode operation and in Section 4.3 for absolute mode operation.

4.2 Differential Mode Calibration

It is important to remember that in differential mode the pressures on the two sides of the analyzer must be kept the same. For this reason, never connect the exit ports (**SAMPLE OUT** and **REFERENCE OUT**) to anything - just vent them to the atmosphere, or to tubes of equal length. If you wish to flow the same gas through both sides of the analyzer, *try to avoid* doing it by putting the sample and reference cells in series, as you will likely 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 the same.

The concentrations used to set the zero and span should bracket the range of concentrations expected in subsequent measurements. For example, using 340 ppm for the zero and 300 ppm for the span might be the proper selections for flow-thru photosynthesis applications where drawdowns from ambient are expected.

There is generally a small zero shift when the reference concentration changes. Therefore, if operating in a mode in which there are significant changes in reference gas concentration, you should re-zero the analyzer following each change in concentration.

CO_2 Zero and Span Calibration

1. Set the CO_2 reference to zero (FCT 59). If you are not using the 6262-03 Pressure Transducer, enter the barometric pressure in FCT 77.

2. Display absolute CO_2 μmol/mol (FCT 22).

3. Flow a dry CO_2-free gas through both sides of the analyzer.

4. Unlock the CO_2 zero potentiometer and adjust until the absolute CO_2 concentration on the display reads zero.

5. With the CO_2-free gas on the reference side, flow a span gas through the sample cell. Set the span potentiometer to read the span gas mole fraction (μmol/mol).

6. Flow the span gas through both cells of the analyzer at the same flow rate. The flow rate should match that used in the reference cell. Set the CO_2 reference (FCT 59) to the span gas mole fraction (μmol/mol). Display differential CO_2 (FCT 23).

7. There will likely be a small zero offset. Adjust the zero potentiometer to read zero.

8. To check the span, flow a different gas through the sample cell. FCT 22 should show that value. If you don't have a second gas, you could scrub the sample cell, and see if FCT 22 reads zero. Adjust the span as needed.

9. Lock the potentiometers.

H$_2$O Zero and Span Calibration

It is likely that zero and reference gases containing known amounts of water vapor will be produced by a dewpoint generator, such as the LI-610, or measured with a dewpoint hygrometer. However, the LI-6262 requires that the reference cell water vapor mole fraction be entered as a parameter before differential measurements can be performed. Therefore, it will often be necessary to convert a dewpoint temperature into a vapor pressure, and then into mole fraction.

Vapor pressure can be obtained from dewpoint temperature by making reference to Appendix F, or by calculation. Note that Appendix F gives vapor pressure in millibars; these values must be divided by 10 to convert to kilopascals.

Vapor pressure e (kPa) can be calculated as

$$e = 0.61083 \times 10^{\frac{7.6448 T_d}{242.62 + T_d}}$$

where T_d is the dewpoint temperature. The reference water vapor mole fraction (mmol/mol) is

$$W_{ref} = 1000 \frac{e}{p}$$

where P is the local barometric pressure in kilopascals. See Section 3.4 for further information.

The H_2O zero and span calibration is identical to that for CO_2; however, allow adequate time for equilibration (several minutes after changing the humidity).

1. Set the H_2O reference to zero (FCT 68). If you are not using the 6262-03 Pressure Transducer, enter the barometric pressure in FCT 77.

2. Display absolute H_2O (FCT 32, 34, or 36).

3. Flow a dry gas through both sides of the analyzer.

4. Unlock the H_2O zero potentiometer and adjust until the absolute H_2O concentration on the display reads zero.

5. With a dry gas on the reference side, flow a span gas through the sample cell. Set the span potentiometer to read the value of the span gas in the appropriate units.

6. Flow the span gas through both cells of the analyzer, at the same flow rate. Set the H_2O reference (FCT 68) to the value of the span gas in the appropriate units. Display differential H_2O (FCT 33, 35, or 37).

7. There will likely be a small zero offset. Adjust the zero potentiometer to read zero.

8. To check the span, flow a different humidity through the sample cell. FCT 32 (or 34 or 36) should show that value. Adjust the span as needed.

9. Lock the potentiometers.

4.3 Absolute Mode Calibration

The procedure for setting the zero and span potentiometers in absolute mode is described in Steps 1 thru 5 above for differential mode calibration.

4.4 H_2O Absolute Mode Caution

When using the LI-6262 to measure water vapor in absolute mode, note the following:

When the LI-6262 is configured as described in Section 2.2 for absolute operation, air flow created by movement of the chopping shutter disc is sufficient to purge the reference cell of CO_2. This air flow is <u>not</u>, however, sufficient to remove all water vapor present in the reference cell.

An external pump, such as the 6262-04 Reference Pump from LI-COR (see *Using the 6262-04 Reference Pump* below), or the LI-670 Flow Control Unit, is necessary to provide an adequate flow of dry air through the desiccant circuit. A flow rate of approximately 500 ml per minute is sufficient to purge the reference cell.

The flow of dry air through the reference cell and scrubber tube assembly will also greatly affect the performance and maintenance requirements of the external soda lime/magnesium perchlorate mixture. An inherent property of soda lime is that a small amount of water vapor must be present for the chemical to scrub CO_2. Ordinarily, this water vapor is present in the soda lime due to normal diffusion through the air hoses; however, $Mg(ClO_4)_2$ reduces the airstream water vapor concentration to near zero. Prolonged exposure of the soda lime to dry air reduces its ability to scrub CO_2.

It is therefore recommended that the external soda lime/desiccant be replaced every 1-2 days when operating the LI-6262 for absolute H_2O measurements. If this is a problem, an alternative is to maintain a low flow of CO_2-free air from a compressed tank that goes through the chopper and reference cell and is then vented to the atmosphere.

Figure 4-2 shows one way in which the LI-6262 may be set up with an external pump providing air flow through the reference cell circuit. The arrows indicate the direction of air flow through the analyzer. It is recommended that the pump be placed inline between the **FROM CHOPPER** fitting and the scrubber tube assembly, rather than between the scrubber tube and the **REFERENCE IN** fitting. Pulling air from the scrubber tube assembly could cause damage to your pump and/or analyzer if, by chance, the paper filter disc in the scrubber tube was torn, causing magnesium perchlorate to be pulled into the system.
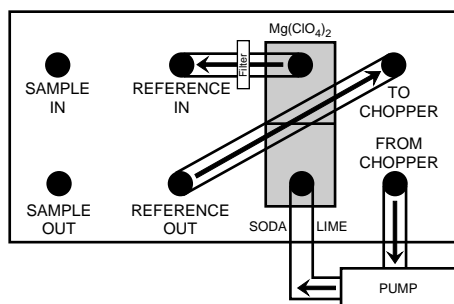
Figure 4-2. Configuration of LI-6262 with external pump for operation in H_2O absolute mode.

Using the 6262-04 Reference Pump

The 6262-04 pumps approximately 0.22 to 0.5 liters of air per minute, which is sufficient to purge the reference cell. The 6262-04 flow rate can be adjusted with the screwdriver included, by turning the **Flow Adjust** potentiometer clockwise to increase the flow, or counterclockwise to decrease the flow.

Please note also that there is no internal filter ahead of the reference cell. Make sure that the paper filter disk in the soda lime/desiccant tube is not torn, as magnesium perchlorate can be forced into the reference cell, damaging the analyzer. Alternatively, you can place an external filter between the soda lime/desiccant tube and the **Reference In** fitting.

■ A Phillips head screwdriver is required for installation. Follow these steps to install the 6262-04 Reference Pump:

1. Remove the soda lime/desiccant tube mounting clips from the back of the LI-6262.

2. Remove the 8 screws from the top and bottom of the 6262-04 cover.

3. Attach the 6262-04 cover to the analyzer using the 2 screws from the mounting clips. The screws are inserted into the holes where the mounting clips were previously attached.

4. Attach the 6262-04 to its cover by replacing the 8 screws.

5. Screw the soda lime/desiccant tube mounting clips into the rear face plate of the 6262-04. Attach the soda lime/desiccant tube.

6. Plug the battery cable from the 6262-04 into the battery jack on the analyzer.

7. Attach the hoses:

$Mg(ClO_4)_2 \rightarrow$ **REFERENCE IN** fitting (LI-6262)
Soda Lime $\rightarrow$ **TO SCRUB** fitting (6262-04)
TO CHOPPER fitting (LI-6262) $\rightarrow$ **REFERENCE OUT** fitting
(LI-6262). (This tube is threaded through the 6262-04).
FROM CHOPPER fitting (6262-04) $\rightarrow$ **FROM CHOPPER** fitting
(LI-6262)

The finished assembly will look similar to that shown in Figure 4-3 below.

8. Plug battery into the battery jack on the 6262-04, or connect a power cord to the LI-6262 if using AC power. **Important Note:** The 6262-04 Reference Pump must be turned off independently; it will not shut off when the LI-6262 is powered off.

9. Turn on the pump.
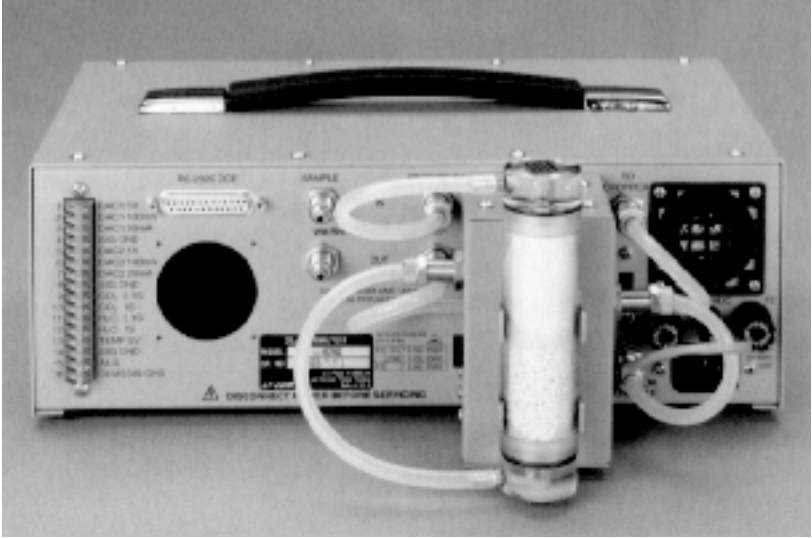
Figure 4-3. 6262-04 Reference Pump installed on LI-6262 back panel.

4.5 Pressure Corrections

NOTE: This section may be disregarded if the 6262-03 Pressure Transducer is installed.

The LI-6262 is sensitive to pressure differences between the sample and reference cells. The span of the analyzer should be set with a span gas flow rate equal to the flow rate at which it will be used. With the flow of the analyzer vented to the atmosphere the effect is minimal, but if the flow from the analyzer must pass through tubing, fittings, etc., the pressure increase must be taken into account.

If it is not convenient or possible to have the span gas flow rate equal to the flow rate used during measurement, the pressure effect can be characterized, and the span set at zero flow, after complete purging of the sample cell. The procedure for this is as follows:

1. Connect a stable source of air to the input of the analyzer, and adjust the flow rate to be equal to the flow rate at which measurements will be taken.

2. Monitor CO_2 or H_2O on the display, and record the concentration after the reading has stabilized.

3. Shut the flow off, leaving this same concentration in the sample cell.

4. Record the concentration from the display.

    Correction factor = Conc. (with flow)/ Conc. (without flow)

When setting the span, multiply the reading obtained without flow by the correction factor, and set the displayed concentration equal to the corrected value.

This flow/concentration relationship is linear over the entire measurement range of the LI-6262. If another flow rate is used, a new correction will have to be calculated.

4.6 Setting the Zero and Span in Software

FCT 08 (Test Menu) contains CO_2 and H_2O Zero/Span functions that provide a software method of setting the zero and span without manually adjusting the potentiometers. There are two advantages of allowing software zero and span adjustments; the zero and span can be set using a remote

command sequence, and the user can get the analyzer back "on scale" through software if the zero and/or span has gone beyond the range of the potentiometer.

The zero and span parameters initially default to these values:

H2 Zero = 0.0 (mV offset)
H2 Span = 1.0 (dimensionless)

C2 Zero = 0.0 (mV offset)
C2 Span = 1.0 (dimensionless)

When these default values are in effect, no software zero or span adjustments are performed.

When the H2 Zero and H2 Span values are changed, the mV signal normally used in the calculation of H_2O concentration (FCT 31) is transformed according to

H_2O mV$_{new}$ = (H2 Span) $\times$ (mV - [H2 Zero]).

When the C2 Zero and C2 Span values are changed, the mV signal normally used in the calculation of CO_2 concentration (FCT 21) is transformed according to

CO_2 mV$_{new}$ = (C2 Span) $\times$ (mV - [C2 Zero]).

The values of CO_2 mV$_{new}$ and H_2O mV$_{new}$ are used by the calibration polynomials to compute concentration, but do not change the raw CO_2 mV signal displayed at channel 21, or the raw H_2O mV signal displayed at channel 31, or the output (RS-232C) values of either.

The values of H2 Zero and H2 Span, and C2 Zero and C2 Span can be entered via the keypad at FCT 08, or by sending a remote command sequence. When sending a remote command, you have the option of entering the Zero and Span values, or allowing the analyzer software to calculate the values for you. The following examples demonstrate how you can calibrate your LI-6262 in software for both absolute and differential measurements.

Remote Commands

The remote command sequence for the CO_2 software zero and span is

```
*081,C2 Zero,C2 Span,CO2 concentration (μmol/mol).
```

The remote command sequence for the H_2O software zero and span is

```
*082,H2 Zero,H2 Span,H2O concentration (mmol/mol).
```

The last parameter (CO_2 or H_2O concentration) is optional, and is used only when you want the software to compute the zero or span value. If the concentration is set to zero, the software computes the zero offset and stores it as C2 Zero or H2 Zero. *When zero is entered, you must have the same gas concentration flowing to both the sample and reference cells of the analyzer.* If any value other than zero is entered, the software computes the dimensionless span value for that concentration as

$$\text{Span} = V_{calc} / V_{meas} = F^{-1} (\text{Span } T_o/T)/V_{meas}.$$

> **NOTE**: The LI-6262 will not accept remote commands while the Test Menu is active. Exit the Test Menu and enter display mode; the remote command will then be executed.

Absolute Mode Calibration

1. Set the CO_2 zero.
   - Flow CO_2-free air through the chopper housing, reference, and sample sides of the analyzer.
   - Send remote command *081,0,1,0 to set the zero.

2. Set the CO_2 span. Let's assume that we are using a 500 ppm span gas.
   - Flow CO_2-free air through the chopper housing and reference side of the analyzer.
   - Flow 500 ppm span gas through the sample side of the analyzer.
   - Send remote command *081,0,1,500 to set the span.

Differential Mode Calibration

Assume for this example that we are using precision span tanks of 300 and 500 ppm CO_2.
1. Set the CO_2 zero.
   - Flow CO_2-free air through the chopper housing, and the 300 ppm gas through the reference and sample sides of the analyzer.
   - Send remote command *081,0,1,0 to set the zero.

● Set FCT 59 (CO_2 reference) to 300.

2. Set the CO_2 span.
   ● Flow CO_2-free air through the chopper housing.
   ● Flow 300 ppm span gas through the reference side of the analyzer.
   ● Flow 500 ppm span gas through the sample side of the analyzer.
   ● Send remote command *081,0,1,500 to set the span.

The procedure for setting the H_2O zero and span is identical to the above steps, with the exception that the air must be completely dry to set the zero, and the span is set using an airstream containing a known water vapor concentration, as can be provided by the LI-610 Portable Dewpoint Generator, for example.

4.7 Using the LI-670 Flow Control Unit

The LI-670 Flow Control Unit can be a valuable accessory for operating and calibrating your LI-6262. The following discussion describes how you can calibrate your LI-6262 using the LI-670 and a single span gas.

Absolute and Differential Mode Calibration with One Span Gas.

Absolute mode. Set zero.
1. Connect the LI-6262 **Sample In** fitting to the LI-670 **Sample Out** fitting, and the LI-6262 **Reference In** fitting to the LI-670 **Reference Out** fitting.

2. Enter the station barometric pressure into the LI-6262 at FCT 77. Alternatively, you can use the 6262-03 Pressure Transducer, or an external sensor to input the barometric pressure.

3. Connect a span tank containing air (*not nitrogen*) with a known H_2O or CO_2 mole fraction to the LI-670 **Sample In** and **Reference In** fittings, and turn both the reference and sample **CO2/H2O Scrub** switches ON. Use tank pressure to provide flow at a nominal rate near that used during measurements. Final flow rate adjustments can be made with the LI-670 **SAMPLE** and **REFERENCE** vents.

4. When the reading is steady, adjust the zero potentiometer on the LI-6262 until the display reads zero.
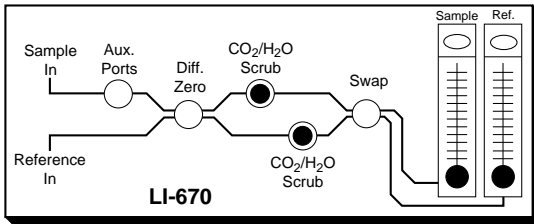
Scrub both cells.

Absolute mode. Set span.

5. Turn OFF the **SAMPLE C O_2/H_2O Scrub** switch. Leave the **REFERENCE CO_2/H_2O Scrub** switch ON. Adjust the flow as needed.

6. Set the LI-6262 span when the displayed reading is steady.
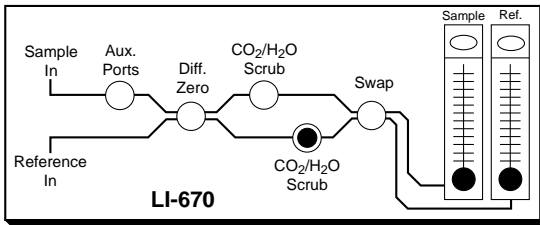
Scrub only the reference cell.

The LI-6262 is now ready for use in absolute mode. Differential mode operation requires three additional steps.

Differential mode. Set zero.

7. Perform steps 1 through 6, and then turn OFF the **REFERENCE CO_2/H_2O Scrub** switch. Adjust the flow to near that which will be used during measurements.

8. Adjust the LI-6262 to read zero when the displayed mole fraction is steady. Only a small adjustment should be necessary (about 5 ppm) when switching from zero to 350 ppm in the reference cell.

9. Enter the span gas CO_2 mole fraction in FCT 59, or the span gas H_2O mole fraction in FCT 68 in the LI-COR analyzer. Read differential H_2O or CO_2 on the analyzer display. Check the span by scrubbing the sample cell and looking for zero on FCT 22 or FCT 32.
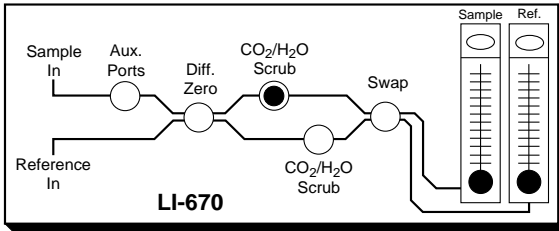
Scrub the sample cell.

The LI-6262 zero or span can be checked during measurements by turning ON the **Diff Zero** switch, and then using whichever scrubbers are needed.
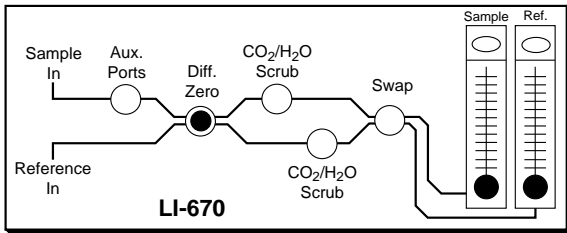
Flow the span gas through both cells of the analyzer.

Many other calibration variations are possible. For example, you may want to recirculate air in a closed reference loop for absolute mode operation.

$$5$$ **System Software**

5.1 Using the Keypad

The LI-6262 uses a 16-key keypad for entering all software function commands and calibration data. The keys are arranged as in Figure 5-1, and function as follows:
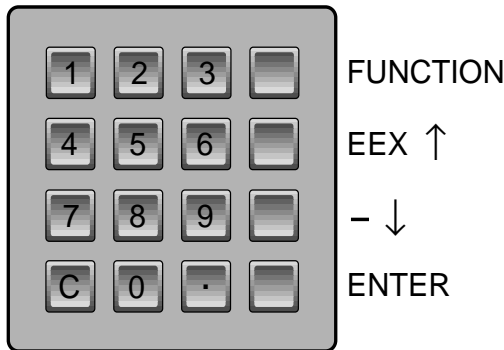
Figure 5-1. The LI-6262 Keypad.

Numeric keys (0-9) and decimal key - Used to enter software function codes and calibration numbers.

Function key - Function prompt is accessed, allows user to enter any software function command #00-99.

Exponent/Scroll Up key - Used to enter exponents (i.e, when entering CO_2 or H_2O calibration numbers), or to scroll upward through option lists.

Minus/Scroll Down key - Used to enter a negative number sign, or to scroll downward through lists.

Enter key - Used to terminate user input from the keypad after entering numbers, or to select list entries.

Clear key $\boxed{C}$ - Functions as a backspace key, deletes last character.

5.2 Software Overview

All software commands are executed by pressing **FUNCTION** and then entering a two-digit function code. Some codes execute a function directly, while others access scrollable lists of options, or other functions, any one of which can be selected by pressing **ENTER**.

All functions are contained in the main menu, by order of function code. Decade functions (00, 10, 20, ...90) merely serve as entry points to this menu. For example, pressing FCT 10 will access the menu at 10, from which point ↑ or ↓ can be used to scroll to neighboring functions. On the other hand, pressing FCT 11 does not access the menu, but executes function 11 directly. Rapid scrolling down through the menu is done by pressing **ENTER**, while viewing a decade function; you will jump to the next decade function (e.g. from 10 to 20) in the menu.

To illustrate the use of the **FUNCTION** key and the main menu, try this:

1. Press FCT 90. The display will show the main menu at 90 as **DISP**.

2. Press ↓ to move down one entry to function 91.

3. Press **ENTER**. This will select function 91, which shows the channel code that is currently defined for the top line of display #1, and prompts for a new value.

4. Press **ENTER** to retain the displayed value. You are prompted to enter a channel code for the bottom line of display #1. Press **Enter** again to retain the displayed value. Note that the display has returned to the menu.

5. Press ↑ to scroll up to function 90, **DISP**.

6. Press **ENTER**. Selecting a decade function jumps to the next decade function, so the display will show 00, **SETUP**.

7. Press **FUNCTION** to exit the menu.

8. Press FCT 91. This will directly execute the function described in step 3 above, which prompts for a new channel code for the top line of display #1.

9. Press **ENTER** to retain the displayed value of this constant, or press **FUNCTION** to cancel the operation.

Remote Commands

Certain function codes can be sent to the LI-6262 from a computer or terminal, as shown on the console command card.

Section 6.2 gives a complete explanation of how to connect your computer and LI-6262 for data transfer and for sending remote commands. Look for the icon at left in the following section for examples of how to format entries to be sent to the LI-6262.

5.3 Console Commands

This section discusses each function in detail. It may be helpful to reference the console command summary card while reading through the definitions of the following functions.

00 Setup

```
00** SETUP **
↑,↓,↵
```

Scroll ↑ (UP), ↓ (DOWN), or **ENTER.**

01 CO_2 Calibration

Function 01 is actually a group of functions; executing FCT 01 performs functions 51-59 and 76.

The LI-6262 is calibrated using a 5th order calibration polynomial of the form: $\mu mol/mol = A(mV) + B(mV)^2 + C(mV)^3 + D(mV)^4 + E(mV)^5$. The calibration coefficients (T,K,A,B,C,D,E) are entered into the LI-6262 at the factory, and are shown on the calibration sheet.

CO_2 reference mole fraction ($\mu mol/mol$) and the choice of water correction depend upon your system setup. See functions 59 and 76 for complete descriptions.

Check the calibration sheet to verify that the correct values are entered.

Prompt	Description	Related Function
C2 T=	Calibration Temperature	51
C2 K=	Calibration Constant K	52
C2 A=	Calibration Coefficient A	53
C2 B=	Calibration Coefficient B	54
C2 C=	Calibration Coefficient C	55
C2 D=	Calibration Coefficient D	56
C2 E=	Calibration Coefficient E	57
C2 R=	CO_2 Reference $\mu mol/mol$	59
BandBrd, Dil $\rightarrow$ REF	Water correction selection	76

```
*01T,K,A,B,C,D,E,REF,VAPOR FLAG
```

02 H_2O Calibration

Function 02 performs functions 61-65, and 68.

H_2O calibration coefficients (T,K,A,B,C) are factory-entered, and are on the calibration sheet. H_2O reference mole fraction is in units of millimoles/mole of water vapor in the reference cell.

Verify these values with the H_2O calibration sheet and change, if needed.

Prompt	Description	Related Function
H2 T=	Calibration Temperature	61
H2 K=	Calibration Constant K	62
H2 A=	Calibration Coefficient A	63
H2 B=	Calibration Coefficient B	64
H2 C=	Calibration Coefficient C	65
H2 R=	H_2O Reference mmol/mol	68

```
*02T,K,A,B,C,REF
```

03 Set Miscellaneous

Function 03 performs functions 71-75 and 77.

Prompt	Description	Function
P(kPa)=	Barometric Pressure	77
Avg(s)=	Signal Averaging Time	74
Aux A=	Auxiliary Input Coefficient A	71
Aux B=	Auxiliary Input Coefficient B	72
Aux C=	Auxiliary Input Coefficient C	75
Aux Dest=	Auxiliary Destination	73

There is no remote command for FCT 03, but all of the 7x functions can be accessed remotely.

04 Set Displays

Function 04 performs functions 91-99.

The LCD display has two lines, and each line can be configured to show any channel code 21-29 (CO_2), 31-39 (H_2O), or 41-47 (MISC). As many as nine two-line display configurations can be defined by the Set Displays routine. Each display is identified by a number 1 through 9, and can be viewed by pressing the appropriate number *without* pressing **FCT**.

> **NOTE:** Displays 1-6 (FCT 91-96) default to the configurations shown below at initial power-up or system reset.

Display	Function Codes (Top/Bottom Lines)	Description
1	21	CO_2 mV (non-linear)
	22	CO_2 μmol/mol absolute
2	23	CO_2 μmol/mol differential
	29	CO_2 μmol/mol reference
3	41	Temperature mV
	42	Temperature °C
4	31	H_2O mV (non-linear)
	32	H_2O mmol/mol absolute
5	33	H_2O mmol/mol differential
	39	H_2O mmol/mol reference
6	43	Barometric Pressure (kPa)
	44	Auxiliary mV

Set the displays as follows:

Press **FCT**, followed by 04. The display will show:

```
1 Top=21
NEW= __
```

Shows default channel code for top of display 1. Enter new code 21-29, 31-39, or 41-47.

```
1 Bottom=22
NEW= __
```

Default channel code for bottom of display 1.

Prompts to configure displays 2 through 9 follow. Press **FCT** to quit.

05 Set D/A Conversion #1

Function 05 performs functions 81, 82, and 83.

```
DAC 1 Code=
NEW= __
```

Digital to analog conversion code #1.

Digital to Analog Conversions may be performed on channel codes 22-27, 32-38, or 42. See function codes 80 - 83 for further details.

*05X,low,high (where x is channel code 22-27, 32-38, or 42).

06 Set D/A Conversion #2

Function 06 performs functions 84, 85, and 86.

```
DAC 2 Code=
NEW= __
```

D/A Conversion #2 (same as 05).

*06X,low,high (where x is channel code 22-27, 32-38, or 42).

07 Backlight ON/OFF

```
BACK LIGHT=NO
↑,↓,↵
```
YES or NO.

Press ↑ or ↓ to toggle the LCD display backlight on or off. Change if desired, depending on the lighting conditions in your work area. Continuous use of the backlight may slightly reduce battery operation time.

NOTE: If FCT 07 is executed from the main menu, the backlight condition does not change until you exit the menu.

*07Y (Yes) or ***07N** (No)**.**

08 Test Menu

```
DISPLAY Test
↑,↓,↵
```
Scrolls through display test menu.

While most of the items in the Test Menu are for technician use, there are a few items of interest to many users.

The KBD (Keyboard) Test prompts to press any key; each of the 16 keys should display correctly when pressed.

The D/A (Digital-to-Analog) Test is used to test the digital to analog conversion capabilities of the LI-6262. Enter a value (in volts), to be output to channel 1 or 2, which can be measured with a metering device.

```
DA1:            0.0
NEW= __
```
Prompt for digital to analog conversion value (in volts).

The A/D (Analog-to-Digital) Zero Test displays the analog count of output channels 1 and 2. If the A/D converter is functioning properly, these values should be nearly identical (approximately 32,700).

The A/D (Analog-to-Digital) Span Test displays the analog count of output channels 1 and 2, as well as the analog count and actual mV output of the CO_2, Temperature, and Auxiliary output channels.

The RAM (Random Access Memory) Test shows the amount of available system RAM. The LI-6252 has approximately 8K bytes of RAM.

The EEPROM (Electrically Erasable Programmable Read-Only Memory) Test shows the amount of available ROM memory. The system parameters entered by the user are stored in EEPROM. The LI-6262 has approximately 32K bytes of ROM program memory.

Geopotential - Displays the geopotential height in feet or meters, based on the current value of pressure at channel 43. This value can be provided by a sensor (FCT 73) or as a keyboard entered constant (FCT 77). Press the up or down arrow keys to toggle between units of feet and meters. Geopotential height is height above sea level in a standard atmosphere.

The I/O (Input/Output) Test checks the Input/Output capabilities of the RS-232C port. This test requires pins 2 and 3 to be shorted on the RS-232C connector.

CO2 Zero/Span - Provides a method to set the CO_2 zero and span in software, via the keypad or by sending a remote command sequence. See Section 4.5, *Setting the Zero and Span in Software*, for more information.

Reset System - The software used in the LI-6262 is also used in the LI-6252 CO_2 analyzer. By entering 1 for Yes you can change the configuration to that of a LI-6252 analyzer. This function is primarily for factory use only, so ordinarily this should not be changed. **Pressing 1 for Yes will remove all configuration parameters from the analyzer; they will then need to be re-entered.**

```
Reset System?
1=Yes, 0=No
```

YES or NO.

```
Clearing EEPROM...
```

```
SYSTEM TYPE
LI-62X2    (5/6)
```

Enter 6.

09 Integrate

This function allows the area under a peak to be computed. When you press FCT 09, you are prompted for the following parameters:

Prompt	Description
Source Ch=	Channel code of the quantity to be integrated.
Start = $\begin{cases} \text{On Exit} \\ \text{Thrsh} \end{cases}$	When to start the integration. 'On Exit' will start the integration immediately. 'Thrsh' will start the integration when the selected channel rises above the threshold value.
Thrsh= 0.0	If Start=Thrsh was selected above, you are prompted to enter the starting threshold value.
Stop = $\begin{cases} \text{Manual} \\ \text{Elaps tm} \\ \text{Thrsh} \end{cases}$	When to stop the integration. 'Manual' will cause the integration to continue until FCT is pressed, or until a * (asterisk) is received from the remote terminal. 'Elaps tm' (elapsed time) will cause the integration to run for the specified number of seconds. 'Thrsh' will cause the integration to continue until the target channel value drops below the threshold. **NOTE**: Pressing FCT, or receipt of a remote command (*) will always stop the integration. Pressing the display keys (1-9) will not stop the integration.
Elaps tm(s)=	If 'Stop=Elaps tm' was selected, you are prompted to enter the elapsed time, in seconds.
Thrsh=	If 'Stop=Thrsh' was selected, and 'Start=On Exit', you are prompted to enter the threshold value.

During the integration, channel 46 shows the accumulating total area A under the curve, as approximated by

$$A = \Sigma \, x \, \Delta t$$

where x is the quantity being integrated, and Δt is the time between readings. At the end of the integration, the non-peak area is subtracted according to

$$A = \Delta t\ \Sigma X_i - (t_e - t_s)[(X_e - X_s)/2]$$

where t_s and t_e are starting and ending times, and X_s and X_e are starting and ending values of x (Figure 5-2). Channel 46 displays this value, which will remain constant until the next integration is started.
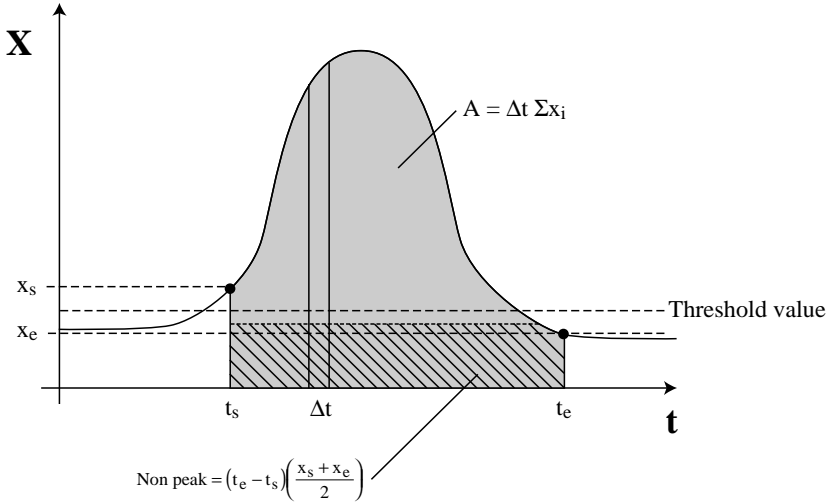
Figure 5-2. Accumulating total area A and non-peak area.

Channel 47 displays the peak value of the target channel during integration.

`*09x,start,[start value],stop,[stop value]` (x is channel code 22-29, or 32-39 to be integrated, and [ ] denotes optional start and stop values). The [start] value is required only if start = 2, and the [stop] value is required only if stop = 2 or 3.

Start	Description	Stop	Description
1	On Exit	1	Manual
2	Threshold	2	Threshold
		3	Elapsed Time

Examples:

`*0922,2,.5,2`	Integrate channel 22 (CO_2 μmol/mol absolute), starting when it goes above 0.5 μmol/mol, and ending when it falls below 0.5 μmol/mol.
`*0932,1,1`	Integrate channel 32 (H_2O mmol/mol absolute), starting immediately, and ending when the next * is received.
`*0922,2,100,3,30`	Integrate channel 22 (CO_2 μmol/mol absolute), starting when it goes above 100 μmol/mol, and ending 30 seconds later.

10 Print Commands

```
10 ** PRINT **
↑,↓,↵
```

Enters menu at command 10.

11 Print Header

Press FCT 11 to send a column header to the RS-232C port. The headers that are printed correspond to the channels specified by the Print List (FCT 13). Appendix D lists the labels for each channel code. Function 11 may be used at any time to output a single row of column headers.

`*11`

12 Print Data

Press FCT 12 to send a single line of data (as defined in the Print List, FCT 13), to the RS-232C port.

`*12`

13 Set Print List

```
Print Col 1=0
NEW= __
```

Scrolls through 10 print options.

Data from up to 10 channels may be sent to the RS-232C port at a specified interval (see FCT 14). Enter up to 10 channel codes #'s 21-29, 31-39, and 41-47. If all 10 print options are not needed, press **FCT** to exit at any time.

`*13x,x,x,x,x,x,x,x,x,x` (where x is channel code 21-29, 31-39, 41-47, and the last 9 x values are optional).

14 Auto Print

Print T(s)=0
NEW= __

Time interval between data transmissions through the RS-232C port.

Enter specified interval in seconds (0.2, 0.5, or 1-3600) at which to transmit data (defined at FCT 13) to the RS-232C port. The interval can be 0.2, 0.5, or any value from 1 to 3600.

*14x (where x is any number 0.2, 0.5, or 1 to 3600).

15 Auto Header

Auto Header=0
NEW= __

Number of data lines between headers (1-999).

The column header interval is the number of data lines which will be printed between column headers. For example, entering 5 will cause a column header to be printed after every 5 lines of data.

*15x (where x is any number from 1 to 999).

16 Print Calibration Data

Press **FCT 16** to send the current calibration stack for H_2O, CO_2, and Miscellaneous channel codes to the RS-232C port. The output includes the calibration constants, auxiliary channel equations, and zero and span parameters for H_2O and CO_2. The output should look similar to this:

```
CO2
   T: 3.5970E+01
   K: 1.7913E+04
   A: 1.4330E-01
   B: 9.5609E-06
   C: 7.8293E-09
   D:-1.1040E-12
   E: 7.5366E-17
Ref: 0.0000E+00
Zero: 0.0000E+00
Span: 1.0000E+00
VC:Corrections Off

H2O
   T: 4.1340E+01
   K: 1.5409E+04
   A: 6.3281E-03
   B: 3.1059E-06
   C: 1.1238E-12
Ref: 0.0000E+00
Zero: 0.0000E+00
Span: 1.0000E+00

MISC
 AUX DEST: 43
 AUX A: 5.9071E+01
 AUX B: 1.5360E-02
 AUX C: 0.0000E+00
 AVG TIME: 1
 PRESSURE: 9.6805E+01
 VP CORR A: 1.5000E+00
```

 *16

17 Set RS-232C Port

```
Baud=300
↑,↓,↵
```

Sets parameters for data output.

Scroll the options in the each parameter using the up and down arrow keys, and press **Enter** to select the value. The parameters for data output through the RS-232C port are as follows: (See Section 6 for further details on data communications).

Baud rate - 300, 600, 1200, 2400, 4800, or 9600.

Data bits - 7 or 8.

Stop bits - 1 or 2.

Parity - None, Even, or Odd.

Check DTR (Data Terminal Ready) - Yes or No. This is a hardware handshaking line. The LI-6262 looks for DTR on pin 20.

Check XON/OFF (Software Handshaking) - Yes or No. Controls the flow of data between transmitting and receiving devices. Receipt of Hex 13 halts transmission, receipt of Hex 11 resumes transmission.

18 Reset Timer

Press **FCT 18** to reset the Timer function. The Timer (FCT 45)will begin counting again at zero.

 *18

19 Full Status

Outputs the full status of the analyzer to the RS-232C port, in a format that can be read directly back into the analyzer, if desired. If you are accessing this function remotely, you can specify selected information to be sent by entering the optional parameter. For example, entering

   *191

would send only the *01 (CO_2 Cal) information, and

   *1913

would send only the *13 RS-232C print list. *19 will produce the entire list. The entire list will appear something like this:

```
*01  3.5970E+01, 1.7913E+04, 1.4330E-01, 9.5609E-06, 7.8293E-
09,-1.1040E-12, 7.5366E-17, 0.0000E+00,0
*02  4.1340E+01, 1.5409E+04, 6.3281E-03, 3.1059E-06, 1.1238E-
12, 0.0000E+00, 0.0000E+00, 1.0000E+00
*05 0, 0.0000E+00, 0.0000E+00
*06 0, 0.0000E+00, 0.0000E+00
*07 1
*08 1, 0.0000E+00, 1.0000E+00
*08 2, 0.0000E+00, 1.0000E+00
*09 0,1,1
*13
*15 0
*71 5.9071E+01
*72 1.5360E-02
*73 43
```

```
*74 1
*75 0.0000E+00
*76 0
*77 9.6805E+01
*78 1.5000E+00
*91 21,31
*92 23,29
*93 41,42
*94 31,32
*95 33,39
*96 43,44
*97 0,0
*98 0,0
*99 0,0
```

*19[n] (n is optional parameter for selecting just one output channel code).

20 CO_2

```
20 ** CO2 **
↑,↓,↵
```

Enters menu at function 20.

21-29 CO_2 Channel Codes

Press **FCT**, followed by the appropriate code, to view the CO_2 channel codes. These channels can only be viewed by pressing **FCT**; they are not executable from the main menu.

> **NOTE:** CO_2 reference value may be entered via the keyboard as a constant (FCT 59), or entered via analog signal. See Section 6.4.

Code	Description
21	CO_2 mV (non-linear)
22	CO_2 μmol/mol absolute
23	CO_2 μmol/mol differential
24	CO_2 Pa absolute
25	CO_2 Pa differential
26	CO_2 μg/g absolute
27	CO_2 μg/g differential
29	CO_2 μmol/mol reference

30 H$_2$O

```
30 ** H2O **
↑,↓,↵
```

Enters menu at function 30.

31-39 H$_2$O Channel Codes

Press **FCT**, followed by the appropriate code, to view the H$_2$O channel codes. These channels can only be viewed by pressing **FCT**; they are not executable from the main menu.

Code	Description
31	H$_2$O mV (non-linear)
32	H$_2$O mmol/mol absolute
33	H$_2$O mmol/mol differential
34	H$_2$O kPa absolute
35	H$_2$O kPa differential
36	H$_2$O mg/g absolute
37	H$_2$O mg/g differential
38	H$_2$O Dewpoint
39	H$_2$O mmol/mol reference

NOTE: H$_2$O reference value may be entered via the keyboard as a constant (FCT 68), or entered via analog signal (see Section 6.4).

40 Miscellaneous

```
40 ** MISC **
↑,↓,↵
```

Enters menu at function 40.

41-44 Temperature and Auxiliary

Press **FCT**, followed by the appropriate code, to view the temperature and auxiliary channel codes. These channels can only be viewed by pressing **FCT**; they are not executable from the main menu.

Code	Description
41	Temperature mV
42	Temperature °C
43	Pressure (kPa)
44	Auxiliary mV

NOTE: Pressure (kPa), FCT 43 is used for computations. This comes from FCT 77, or an analog signal at FCT 44 (see Section 6.4).

45 Timer

```
Timer              3.7
```

Displays accumulated time in seconds from instrument start-up.

The Timer acts as a counter which accumulates the number of seconds since instrument start-up (to 999,999), or since the Reset Timer function (FCT 18) was last executed.

The Timer can also be viewed by entering "45" into any of displays 1 to 9 (FCT 91-99). The Timer function can be output to a computer or printer by entering "45" into the Set Print List function (FCT 13).

46 Integration A

During the integration (FCT 09), channel 46 shows the total area A under the peak from the last integration, or the accumulating area during the present integration.

*46

47 Integration Peak Value

Displays the peak value of the target channel obtained during the last integration, or the largest value so far during the present integration.

*47

49 Software Revision I.D.

| Rev ID   2.02 |

Software revision number. Press FCT to escape.

*49

50 CO_2 Calibration

```
50 **CO2 CAL**
↑,↓,↵
```

Enters menu at function 50.

51-59 CO_2 Calibration Stack

The CO_2 calibration stack (FCT 51-57) contains individual CO_2 calibration coefficients, as well as the prompt to enter the CO_2 reference in μmol/mol (FCT 59).

```
C2 R=0
NEW= __
```

Enter CO2 reference in mmol/mol.

Code	Prompt	Description
51	C2 T=	Calibration Temperature
52	C2 K=	Calibration Constant K
53	C2 A=	Calibration Coefficient A
54	C2 B=	Calibration Coefficient B
55	C2 C=	Calibration Coefficient C
56	C2 D=	Calibration Coefficient D
57	C2 E=	Calibration Coefficient E
59	C2 R=	CO_2 Reference μmol/mol

The CO_2 reference value (FCT 59) should reflect the dilution by water vapor, if the reference is not dry. For example, if the reference gas contains 300 μmol/mol CO_2 when dry, and 0.5 kPa of water vapor is added before it enters the reference cell, then C2 R = 300(1 - 0.5/P), where P is the local barometric pressure.

60 H_2O Calibration

```
60 **H2O CAL**
↑,↓,↵
```

Enters menu at function 60.

61-68 H_2O Calibration Stack

The H_2O Calibration stack (FCT 61-68) contains individual H_2O calibration coefficients, as well as the prompt to enter the H_2O reference (FCT 68).

```
H2 R=0
NEW= __
```

Enter H2O reference in mmol/mol.

Code	Prompt	Description
61	H2 T=	Calibration Temperature
62	H2 K=	Calibration Constant K
63	H2 A=	Calibration Coefficient A
64	H2 B=	Calibration Coefficient B
65	H2 C=	Calibration Coefficient C
68	H2 R=	H_2O Reference mmol/mol

70 Set Miscellaneous

```
70 ** MISC **
↑,↓,↵
```

Enters the menu at function 70.

The 7x functions include those necessary for using the auxiliary input channel (#15 on the back panel terminal strip). The input signal is transformed by

$$Y = A + Bx + Cx^2$$

where x is the signal in mV, and the coefficients A, B, and C are entered in FCTs 71, 72, and 75. The value Y can be treated as pressure (FCT 43), reference CO_2 (FCT 29) or reference H_2O (FCT 39), according to FCT 73.

71 Auxiliary A (Offset)

```
Aux A=            0.0
NEW= __
```

Auxiliary A (Offset) value.

`*71<A>`

72 Auxiliary B

```
Aux B=              0.0
NEW= __
```

Auxiliary B value.

*72<B>

73 Auxiliary Destination

```
Aux Dest=0
NEW= __
```

Destination channel of auxiliary input signal.

The auxiliary channel input may be sent to channel codes 29 (CO_2 reference), 39 (H_2O reference), or 43 (pressure). Entering any other code at the NEW= prompt sets the destination to 0 and deactivates the input channel.

Setting this destination to 29, 39, or 43 causes the values of FCT 59, 68, or 77, respectively, to be ignored.

*73X (where x is the destination channel 29, 39, 43, or <null>).

75 Auxiliary C

```
Aux C=              0.0
NEW= __
```

Auxiliary C value.

*75<C>

74 Average Time

```
Avg(s)=0
NEW= __
```

Signal averaging time.

Sets the software signal averaging time, from 0 to 30 seconds. Increasing the average time decreases the noise level in any displayed channel.

The digital signal displayed is averaged over the entire time span set, after conversion from the analog signal. This results in a significant decrease in the apparent noise level, but slows the response time, as well.

This average time affects all computed values of CO_2 (FCTs 22 to 27), and H_2O (FCTs 32-38), whether displayed, or output to a DAC channel, or output by RS-232C. It does not affect the raw mV signals on the back terminal strip.

Setting Average Time to zero will turn off all digital averaging, and the displayed or output values of CO_2 and H_2O will reflect the hardware response time.

*74X (where x is any value from 0-30 seconds).

76 Vapor Flag

Water corrections may be selected in the LI-6262 using FCT 76. The Vapor Flag default setting is for both pressure broadening and dilution corrections to be applied if a System Reset (FCT 08) is performed. See Sections 3.4 and 3.5 for complete explanations of the vapor corrections.

Corrections Off ↑, ↓, ↵	No vapor corrections performed. State = "0"

Band Broadening ↑, ↓, ↵	Correct for band broadening. State = "1"

BandBrd, Dil → REF ↑,↓,↵	Band broadening & dilution corrections applied. State = "2"

*76X (where x is 0, 1, or 2 for no correction, correct for band broadening, or correct for band broadening and dilution, respectively).

77 Pressure

```
P(kPa)=          0.0
NEW= __
```

Barometric Pressure in kPa.

Barometric pressure *must* be entered correctly for CO_2 or H_2O concentrations to be calculated correctly.

> **NOTE:** Barometric pressure may also be input in Setup command 03. Pressure may also be input continuously using the 6262-03 Pressure Transducer from LI-COR, or through connector #15 on the back panel terminal strip, as described in section 6.4.

*77X (where x is the barometric pressure in kPa).

78 Vapor Correction a

```
VpCrr A= 1.5
NEW= __
```

Vapor correction value a.

Vapor correction coefficient a is factory-entered (a = ~ 1.5). See Section 3.5 for a description of the vapor correction. This value is only used when Vapor Correct (FCT 76) is in State 1 or 2.

*78a (where a is the value of vapor correction a).

80 D/A Conversions

```
80 ** DAC **
↑,↓,↵
```

Enters the menu at function 80.

The digital-to-analog converter (DAC) converts a digital value from channels 22-27, 32-38, or 42 into a calibrated analog voltage proportional to any units. There are two such channels (DAC 1, DAC 2) available on the instrument back panel.

Three output ranges are available for DAC 1 and DAC 2 on the LI-6262 back panel terminal strip; 0-5V, 0-100 mV, and 4 to 20mA.

To convert voltage output V to the value X that is driving it,

$$X = \left(\frac{X_F - X_o}{R} \right) V + X_o$$

where R = full scale voltage range (5V or 100mV),
X_F = the value of X corresponding to full scale voltage (set in FCT 83 or 86), and
X_o = the value of X corresponding to zero volts (set in FCT 82 or 85).

For current I,

$$X = \left(\frac{X_F - X_o}{16} \right) I + \frac{5X_o - X_F}{4}$$

where X_F is the value of X corresponding to 20mA and X_o is the value of X corresponding to 4mA, the minimum X value expected, because unlike the voltage outputs, the current output cannot go negative.

The output resolution of X will be

$$\Delta X = 4.88 \times 10^{-4} (X_F - X_o) \qquad \text{[voltage]}$$
$$\text{and}$$
$$\Delta X = 2.44 \times 10^{-4} (X_F - X_o) \qquad \text{[current]}.$$

If voltage is measured, the 0-5V range should be used whenever possible. The 0-100 mV range is provided for measuring or logging devices with a more limited voltage range; some resolution may be lost due to signal noise considerations when using the smaller output range.

The output impedance of the 0-100 mV range is 50-100Ω, so a measuring or logging device with a high input impedance should be used.

Note that resolution is maximized by minimizing the range to be covered. For example, if you are making CO_2 measurements that are always less than 400 ppm, set the DAC to cover only that range, rather than 0 to 1000 or 0 to 3000.

81 D/A Conversion Code #1

DAC 1 Code=
NEW= ___

Channel code for digital to
analog conversion #1.

Enter channel code # 22-27, 32-38, or 42 as the channel to output through
analog output channel #1.

82 D/A Conversion #1 Minimum

1   0V=
NEW= ___

Digital channel value which
corresponds to 0V or 4mA on
DAC #1.

83 D/A Conversion #1 Maximum

1   5V=
NEW= ___

Digital channel value which
corresponds to full scale (5V,
100mV, or 20mA) on DAC #1.

84 D/A Conversion Code #2

```
DAC 2 Code=
NEW= __
```

D/A Conversion #2 (same as 81).

85 D/A Conversion #2 Minimum

```
2  0V=
NEW= __
```

Digital channel value which corresponds to 0V or 4mA on DAC #2.

86 D/A Conversion #2 Maximum

```
2  5V=
NEW= __
```

Digital channel value which corresponds to full scale (5V, 100mV, or 20mA) on DAC #2.

90-99 Displays

```
90 ** DISP **
↑,↓,↵
```

Enters menu at function 90.

Nine two-line displays can be defined with functions 91-99. Function 91 defines display 1, accessed by pressing the "1" key, 92 defines display 2, etc. Displayable quantities are 21-29, 31-39, or 41-45.

All displays can be defined in one operation at FCT 04, or they can be defined individually using FCT 91-99, as shown below.

```
1 Top=
New= __
```

Channel code for top of display 1.

```
1 Bottom=
NEW= __
```

Channel code for bottom of display 1.

*91x,x, *92x,x, *93x,x etc. (where x is any channel code 21-27, 29, 31-39, and 41-47).

6 **Interfacing**

6.1 General Information

Data can be obtained from the LI-6262 in three ways: 1) from the display; 2) from the RS-232C port; or 3) from one of the analog output channels.

RS-232C Output

Up to 10 different channels can be output (in columnar form) at a user-specified time interval, or in response to a command (FCT 12). Data are transmitted as ASCII characters that can be captured with a computer or printed on a printer. The following communication parameters can be set in the LI-6262 software (FCT 17):

    Baud Rate: 300, 600, 1200, 2400, 4800, or 9600.
    Data Bits: 7 or 8
    Stop Bits: 1 or 2
    Parity: Odd, Even, or None.
    Check DTR: Yes, No
    Check XON/XOFF: Yes, No

Analog Output

Two linear voltage output channels are provided which have 0-100mV or 0-5V ranges. The signals for these channels can be scaled over any concentration range in any units (see Section 5.3, FCT 80). The linear channels are available after digital to analog conversions of any channel code 22-27, 32-38, or 42.

Two analog channels are also available for the raw CO_2 and H_2O analyzer outputs. Electronic filters provide both 0.1 second and 1 second response times for CO_2 and H_2O vapor. Units having serial numbers less than IRG3-422 had 1 and 4 second response times, unless modified by the 6262-01 or 6262-02 option(s).

6.2 RS-232C Data Transfer
Selecting a Cable

RS-232C ports on computers and printers often use 25-pin "D" connectors, but this is not always the case. The back panel of a typical IBM PC might have 2 such connectors; one male and one female. The female connector is usually the parallel interface and the male connector is usually the RS-232C port. However, an RS-232C port might use male or female connectors, so verify what is present before connecting anything to it. *It is possible to damage a serial interface by connecting it to another type of interface.*

The RS-232C port on the LI-6262 is the female 25-pin "D" connector on the back panel labeled "RS-232C DCE". The LI-6262 is configured as Data Communications Equipment (DCE), which means that it can communicate directly with computers, RS-232C printers, and other devices configured as Data Terminal Equipment (DTE) using only a cable that has pin-for-pin connections between the connectors on each end. The LI-COR 1000-04 RS-232C cable will work with most computers and printers with a 25-pin connector, and the 1800-04 RS-232C cable will work with most computers that have a 9-pin AT style RS-232C port. Most other cables that are manufactured for DCE to DTE RS-232C data communications will also work.

If your computer is configured as DCE (not normally the case), use the 1000-03 RS-232C cable or any other cable that can act as a null modem (DCE to DCE in this case).

Software Configuration

Functions 11-17 are used to set up RS-232C data transfer. They are accessed directly or via the PRINT stack (FCT 10). The following example illustrates how to configure the LI-6262 to transmit differential CO_2 (channel code 23), absolute H_2O (channel code 32), and analyzer temperature (channel code 42) through the RS-232C port. Data are captured with the 1000-90 COMM program, or any other general purpose ASCII capture program.

1. Set the communication parameters (FCT 17) as follows:

> Baud Rate: 4800
> Data Bits: 8
> Stop Bits: 2
> Parity: None

This configuration is appropriate for an IBM PC or compatible using the 1000-90 software described in the following section. Connect the appropriate cable.

2. To test the cable connections and make sure that the computer software is configured properly, press FCT 16, which will print a list of the current calibration data for the LI-6262. If nothing is sent, make sure that the cable connections are correct, and consult the software manual for the software you are using.

3. Press FCT 13 and designate 23, 32, and 42 as the channels to print.

4. Press FCT 15 to print a header after every 20 lines of data are output.

5. Press FCT 14 to set the print interval to 1 second.

6. The data should look similar to this:

```
   dC2mm/m           H2 mm/m          Temp C
   50.000            10.000           21.993
   50.000            10.000           21.998
      .                 .                .
      .                 .                .
      .                 .                .
```

Alternatively, to print a single header or one line of data, use functions 11 and/or 12 as needed, after setting the print interval (function 14) to zero.

Using an IBM PC Compatible Computer

The 1000-90 Communications and Utility Software included with the LI-6262 will enable the analyzer to interface with any PC-compatible computer with an RS-232C port.

Follow the instructions included with the 1000-90 to load the **COMM** program. The 1000-90 instructions describe how to run the **COMM** program using the softkeys F1 thru F9. Here are some tips for using the program with the LI-6262:

F1 - Accesses the configuration menu. Select the configuration labeled "General Purpose" by pressing **ENTER**.

F2 - Change COM. Notice that pressing F2 will toggle between COM1 and COM2 on the screen menu. Use this to select the communications port which is connected to the computer, if different than the default setting.

F3 - Local echo ON or OFF. Toggles between ON and OFF. Having the echo ON is useful to view the characters on the CRT which are typed if a computer is used to backload remote commands to the LI-6262.

F6 - File. Specifies the file into which incoming data will be copied (if desired). Specify both the filename and the path where you want to copy the data file. For example, typing C:\DATA will create an ASCII file named DATA on the root directory of drive C. Further manipulation of the data file can be accomplished with any software program that can read data from a generic text file.

There are several other inexpensive communication programs which may be used to interface the LI-6262 to a computer. Two such programs for IBM PC's and compatibles are PC TALK (Freeware, P.O. Box 862, Tiburon, CA 93920) and ProComm (Data Storm Technologies, Inc., P.O. Box 1471, Columbia, MO 65205). Either of these programs will allow ASCII data sent from the LI-6262 to be displayed on the computer terminal or stored in a disk file.

Sending Remote Commands to the LI-6262

The 1000-90 software program may also be used to send remote commands to the LI-6262. On the LI-6262 Console Command sheet there is a section entitled "remote commands". Most LI-6262 commands are duplicated by the remote commands, which may be typed on the terminal at any time during the execution of the COMM program, even while data are being transmitted. Typed characters can be viewed by toggling the F3 key to change to ECHO ON.

Type the remote commands exactly as they appear on the command sheet. For example, typing * (asterisk)1530 will change the Auto Header command to 30 seconds in the LI-6262. The first two digits identify the channel to be edited, followed by appropriate arguments for that channel. The arguments may be channel numbers, calibration values, or flags (e.g. Y,N), depending upon the channel edited. If more than one argument is required, the first follows the channel identifier without a space or comma, and subsequent arguments (if any) are separated by commas only. For example, typing *1321,32,33,38,41 will change the print list which is output to your terminal to channel codes 21, 32, 33, 38, and 41.

Uploading ASCII Files to the LI-6262

Remote commands can be written in an ASCII file and copied out the serial port. The LI-6262 will read and execute the commands sequentially as they are received. Any word processor or text editor that can write standard ASCII files is suitable for setting up the configuration file. It is important to to save the file in a "Text only", "ASCII only", or "Non-Document" mode. Here is a simple example of how a command file might be sent to the LI-6262:

Prepare the following ASCII file and name it DATA.

```
*744                  (Sets signal averaging time to 4
                      seconds)
*1321,23,25,31,38     (Sets print list)
*1430                 (Sets Auto Print to 30 seconds)
*1510                 (Sets Auto Header to 10 seconds)
*762                  (Turns Vapor Flag to State "2")
*9121,23              (Sets Display 1 to channel codes
                      21 and 23)
```

Upload the file from DOS by typing:

COPY filename COM1

This will copy the contents of the file to the serial port (use COM2 if that is the one to which the LI-6262 is connected). You may need to reset the communication parameters (Baud Rate, Parity, etc.) as well, using the DOS MODE command.

Note that you can create a complete configuration file for your LI-6262 by first capturing the data generated using remote command *19, and then editing the file (if desired). When this file is sent back to the LI-6262, it will configure all elements in its software.

Using an Apple Macintosh

Sending data to the Macintosh requires a Hayes compatible modem cable for the Macintosh. Most Hayes modem cables terminate with a male 25-pin "D" connector that will plug directly into the LI-6262. In the event that your cable has the wrong gender, use a female-to-female gender changer with pin-for-pin connections.

A number of data transfer software programs are commercially available. The 1000-91 Communication Software is available free of charge from LI-COR.

Using a Printer

The LI-6262 can communicate with virtually any printer having an RS-232C interface. One example is the 6000-03B printer from LI-COR, which is an Epson printer with an RS-232C interface installed. The LI-6262 is connected to the 6000-03B printer using the 1000-04 RS-232C cable.

Solving Communication Problems

A few common communication problems and possible causes are given below:

PROBLEM	WHAT TO CHECK
Nothing happens	Wrong cable. Connections tight? Handshake?
All characters are wrong	Baud rate set wrong.
Some characters are wrong	Data bits, stop bits, or parity wrong.

The most common problem in RS-232C communications is the use of the wrong cable. If you have communication problems that cannot be resolved, you may wish to purchase an RS-232C indicator card (Model #9960-031). This card indicates which lines in the cable are being used and generally indicates where the problem is.

If the output buffer (512 bytes) becomes full, the message "Too much Data or Baud Rate too low" will be displayed. This can happen at lower baud rates, or if the handshaking (XON/XOFF or DTR) is preventing the data from being sent.

6.3 Analog Output

Analyzer output can be recorded by connecting a logging device to the terminal strip on the back of the analyzer. Both linear outputs (scaled over any range and in any units) and non-linear outputs are available.

Measuring Linear Analyzer Output

The LI-6262 has two D/A Converters (DAC's), which can be used to convert calculated quantities (your choice of channels 22-27, 32-38, or 42) to an analog signal (-5V to +5V, -100mV to +100mV, or 4mA to 20mA ranges). The voltage and current ranges are selected by choosing the appropriate terminals on the back panel terminal strip.

DAC #1 is configured using FCT 05 (or FCTS 81-83), and DAC #2 is configured using FCT 06 (or FCTS 84-86).

A DAC is configured by specifying the source channel (e.g. 22, 23, etc.) which will drive the analog signal, the source channel value which

corresponds to zero volts (or 4mA), and the source channel value which corresponds to full scale voltage (or 20mA).

For example, to configure DAC #1 to output a voltage signal proportional to differential CO_2, 100 µmol/mol full scale, press FCT 05 and set

DAC 1 Code = 23   (Differential CO_2 channel)
1 0V → 0   (X_o, zero volts corresponds to 0 µmol/mole)
1 5V → 100   (X_F, full scale corresponds to 100 µmol/mole)

When a voltage range R is selected, the DAC output voltage V resulting from a CO_2 differential X is given by

$$V = R\frac{X - X_o}{X_F - X_o}$$

where R = 5V or 100mV. If the 4 to 20mA current loop is selected, the output current I (milliamps) is

$$I = 16\frac{X - X_o}{X_F - X_o}$$

To convert the DAC voltage output signal to µmol/mol (or other units),

$$X = \left(\frac{X_F - X_o}{R}\right)V + X_o$$

For the 4 to 20mA channel,

$$X = \left(\frac{X_F - X_o}{16}\right)(I - 4) + X_o$$

or, in terms of a slope and offset,

$$X = \left(\frac{X_F - X_o}{16}\right)I + \frac{5X_o - X_F}{4}$$

> **NOTE:** The 20 mA signal will not go negative. If you wish to use the 20mA option, configure the DAC so that the signal will always be positive. For example, to allow a range of -100 to +100 µmol/mol, set $X_0 = -100$, rather than 0. Then, -40 µmol/mol will generate an 8.8 mA signal on DAC 1 20 mA.

Resolution

The DAC's are 12-bit bipolar devices, so resolution is given by (total range)$/2^{12}$. The voltage ranges can go positive or negative, so resolution is $\pm R/2^{12} = R/2^{11}$. This corresponds to 2.44 mV on the 5V range, and 48.8 µV on the 100 mV range. The 4 to 20mA range does not go negative, so its resolution is $(20-4)/2^{12} = 3.91$ µA. The smallest difference that can be resolved for any variable is,

$$\Delta X = 2^{-11} (X_F - X_o) = 4.88 \times 10^{-4} (X_F - X_o) \qquad [\text{voltage}]$$
and
$$\Delta X = 2^{-12} (X_F - X_o) = 2.44 \times 10^{-4} (X_F - X_o) \qquad [\text{current}]$$

As an example, if $X_F = 1000$ and $X_o = 0$, the resolution will be about 0.5 µmol/mol on either voltage channel, and 0.25 µmol/mol on the current channel.

Timing

The DAC outputs change whenever the target channel changes. All of the CO_2 values (FCTs 22-27) are computed at 5 Hz. The H_2O values (FCTs 32-38), however, come at an *irregular* interval; they change at 5 Hz, but 2 of the 5 measurements each second are "missed" (while the temperature and auxiliary input channel are measured), so actually only 3 changes occur in 1 second. This irregularity makes outputting H_2O signals on the DAC inappropriate for high speed, regular sampling applications such as eddy correlation. Users needing high speed regular sampling should use the non-linear outputs for H_2O, and possibly CO_2, if >5 Hz is required.

Terminal Connections - Voltage

Figure 6-1 shows an example connection of a data acquisition device to the LI-6262 to measure the linear output of channel #1.

● Connect the positive input of the data logger to the terminal labeled **DAC1 5V** (or **DAC1 100mV**).
● The negative input should be connected to the terminal labeled **SIG GND**.
● Connect another input from the data logger to the terminal labeled **DAC2 5V** (or **DAC2 100mV**) to measure the linear output of channel #2.
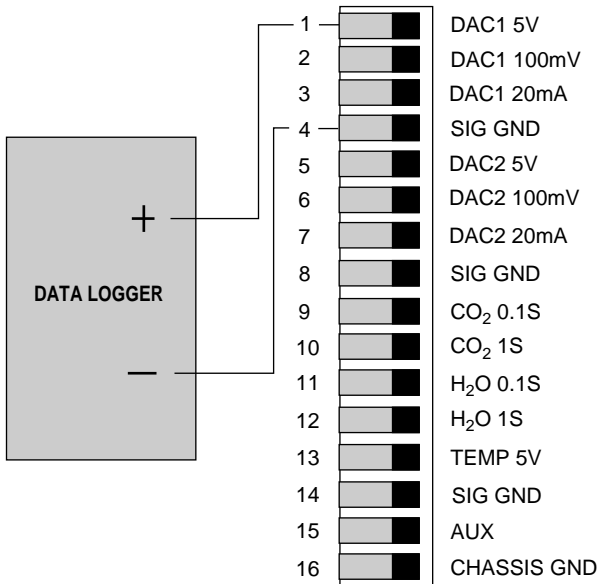
Figure 6-1. Connection of data logger for linear output.

Terminal Connections -Current

Figure 6-2 shows the proper connection of a data acquisition device to the LI-6262 terminal block.

● Connect the positive input of the data logger to the terminal labeled **DAC1 20mA** for channel one, or **DAC2 20mA** for channel two.
● Connect the negative input to one of the terminals labeled **SIG GND**.

1	DAC1 5V
2	DAC1 100mV
3	DAC1 20mA
4	SIG GND
5	DAC2 5V
6	DAC2 100mV
7	DAC2 20mA
8	SIG GND
9	CO_2 0.1S
10	CO_2 1S
11	H_2O 0.1S
12	H_2O 1S
13	TEMP 5V
14	SIG GND
15	AUX
16	CHASSIS GND

Figure 6-2. Connection of data logger for current loop output.

Measuring Raw (Non-Linear) Analyzer Output
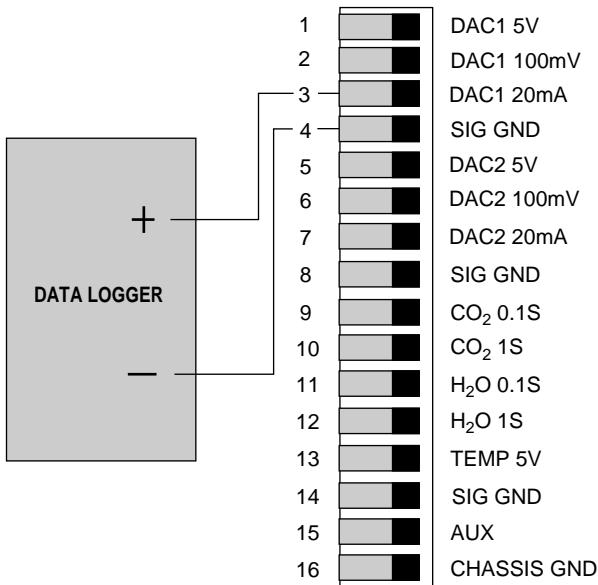
To measure the non-linearized voltage output of the CO_2 or H_2O analyzer (0.1 second response time) with a meter or data logger:

● Connect the positive input of the data logger to the terminal labeled **CO_2 0.1S** or **H_2O 0.1S** (see Figure 6-3).
● Connect the negative input to the terminal labeled **SIG GND**. If the cable from the data logger is shielded, the shield can be connected to the **CHASSIS GND** terminal.
● To measure analyzer temperature or the voltage output with a different response time, connect the appropriately labeled terminal to the positive input of another channel on the data logger.

The resolution which the data acquisition device should have is dependent upon the noise level of the analyzer (0.2 µmol/mol $C0_2$ typical, 0.4 µmol/mol maximum, or 0.05 mmol/mol H_2O typical, 0.2 mmol/mol maximum).

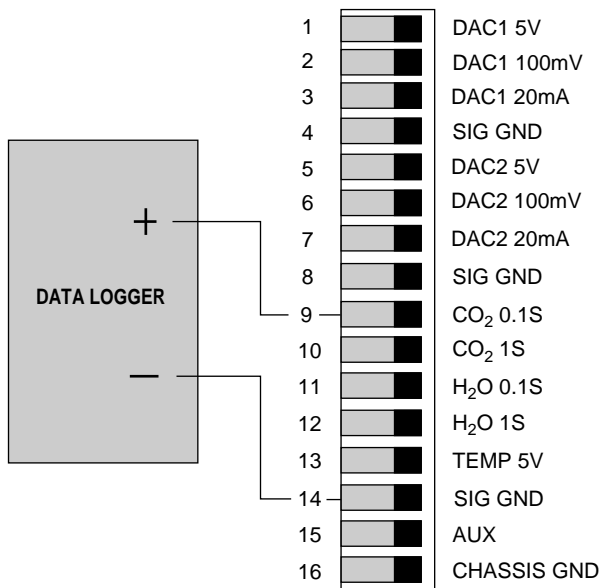|	
1	DAC1 5V
2	DAC1 100mV
3	DAC1 20mA
4	SIG GND
5	DAC2 5V
6	DAC2 100mV
7	DAC2 20mA
8	SIG GND
9	CO_2 0.1S
10	CO_2 1S
11	H_2O 0.1S
12	H_2O 1S
13	TEMP 5V
14	SIG GND
15	AUX
16	CHASSIS GND

Figure 6-3. Connection of data logger for non-linear output.

6.4 Auxiliary Channel Inputs

Terminal 15 is connected to the auxiliary channel which may be used to input an analog signal from a user-supplied external sensor. CO_2 and H_2O references may be input through this channel, as well as barometric pressure. Use FCT 73 to designate which channel (29, 39, or 43) the analog signal will be sent to. Figure 6-4 shows how to connect a sensor to the terminal strip on the back panel of the LI-6262.

NOTE: If the 6262-03 Pressure Transducer is installed in your analyzer, the auxiliary channel input is no longer available; the raw mV reading from the transducer can be *measured* at this terminal, however. Please see Section 6.6 for a complete discussion of the 6262-03.

● Connect the positive input from the sensor to the terminal labeled **AUX**.
● Connect the negative input to the terminal labeled **SIG GND**.

The auxiliary channel has an input voltage range of ± 4.096V.

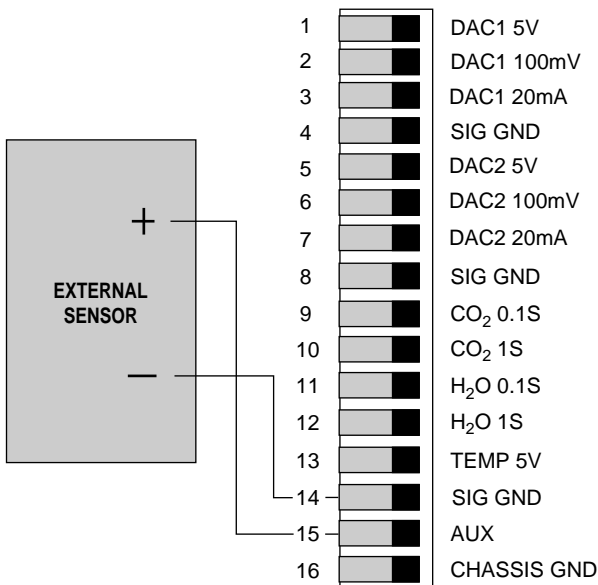Figure 6-4. Connection of an external sensor for analog signal input.

The calibration equation is of the form $Y = A + BX + CX^2$, where A, B, and C are FCTs 71, 72, and 75, and X is the actual mV output of the sensor. See Section 5.3, FCT 70.

6.5 Temperature Output

The analyzer temperature can be recorded by connecting a logging device to the terminal strip on the analyzer back panel. Connect the positive lead from the data logger to the terminal labeled **TEMP 5V**, and the negative lead to the terminal labeled **SIG GND** (Fig. 6-5).

Temperature output is linear, and can be computed according to

$$T(°C) = \left(\frac{50°C}{4096 \text{ mV}} \right) V$$

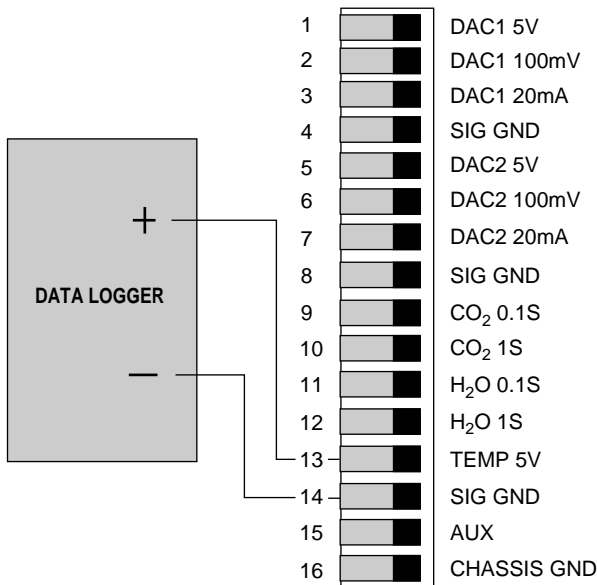where V = the analyzer output in millivolts, and 0V = 0 °C.

Figure 6-5. Connection of data logger for analyzer temperature output.

6.6 Using the 6262-03 Pressure Transducer

The 6262-03 is located inside the LI-6262 case, and senses pressure from a manifold on the optical cell. Because the calibration function used in LI-COR gas analyzers will correct for pressure changes if the pressure in the optical cell is known, the 6262-03 allows for automatic pressure corrections to be performed.

During installation, an adapter board is connected to the analyzer's digital board. The adapter board sends the transducer mV output to the Auxiliary terminal (#15) on the terminal strip (Figure 6-6). Because the mV *output* of the transducer is connected to the Auxiliary terminal on the terminal strip, the signal can be measured by connecting a voltmeter or datalogger to the **Aux** and **Sig Gnd** terminals. Pressure can then be calculated externally, if desired. Internal computations are performed provided FCTs 71, 72, 73, and 75 are set correctly (see *Software Considerations* below).

AUX INPUT terminal #15 = Pressure transducer mV output
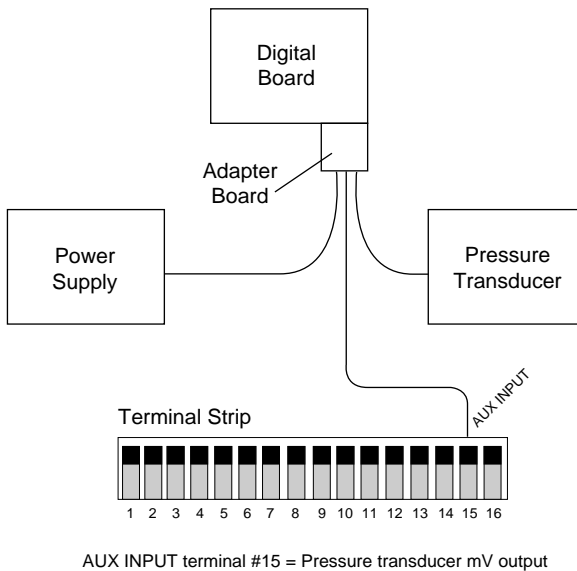
Figure 6-6. Block diagram of electrical connections.

Software Considerations

The pressure value (kPa) used in the calculation of CO_2 is stored at channel code 43. Pressure can be entered as a constant at FCT 77, or it can be calculated from the 6262-03 mV signal provided to the Aux Input. If you are using the 6262-03, the Auxiliary Destination (FCT 73) *must* be specified

as channel **43** (Pressure). Specifying the Auxiliary Destination as channel 43 causes any constant pressure entered in FCT 77 to be ignored.

The response curve for the pressure sensor is given by the equation

$$Y = A + BX + CX^2$$

where Y is the sensor output (in kPa), X is the mV output of the sensor, A is the Y-axis intercept, and B is the calibration multiplier, which is equal to the slope of the line representing the sensor's response (Figure 6-7). On the 6262-03 calibration sheet the offset A is given as FCT 71, and the multiplier B is given as FCT 72. Enter these values into the software at FCT 71 (Aux A) and FCT 72 (Aux B). Make sure that FCT 75 (Aux C) is set to zero. These values convert the mV output of the pressure transducer to pressure in units of kPa.
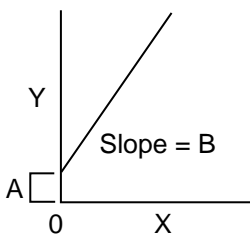
Figure 6-7. Response curve for pressure sensor.

Example:

On the 6262-03 calibration sheet the values listed are as follows:

FCT 71 = 58.239
FCT 72 = 0.01510
FCT 73 = 43
FCT 75 = 0

Enter the above values into software:

FCT 71

```
Aux A =        0.0
NEW = 58.239
```

FCT 72

```
Aux B =        0.0
NEW = 0.01510
```

FCT 73

```
Aux Dest       0.0
NEW = 43
```

FCT 75

```
Aux C =        0.0
NEW = 0
```

You can view the pressure value at FCT 43, and mV output at FCT 44. Both of these values can be viewed on a custom display, or sent via the RS-232C output to a printer and/or computer terminal.

7 Maintenance

7.1 Recharging the 6000B and 6200B Batteries

Batteries should be fully recharged as soon as possible after use. *Long term storage in a discharged state can reduce the battery's capacity, especially at high temperatures.*

Battery charging circuitry for the 6000B and 6200B batteries is built into the LI-6262, and requires only that the AC line cord be connected. If you are charging one 6000B battery, it will take 1 1/2 - 2 hours (3 - 4 hours for the 6200B) to recharge the battery to 80-90% of full capacity (with the LI-6262 power switch off). For best results, charge the batteries overnight.

Batteries may also be charged during operation of the LI-6262 with AC power. Charging times will be longer than those given above, however.

At room temperature the 6000B will run the LI-6262 for approximately 3.2 hours and the 6200B will last about 6.4 hours.

> **NOTE:** One set of external leads with a 3-pin plug connection is also included in the spare parts kit for installation with a user-supplied battery (10.5 - 16VDC, 1.5 amp maximum).

Storing The Batteries

Store the batteries fully charged, and in a cool place, if possible. For long-term storage, charge the batteries overnight every month.

7.2 Opening The LI-6262

Remove the 4 screws on the bottom of the LI-6262 housing that are closest to the ends of the housing, directly opposite the 4 rubber feet. There are 2 screws near each end.

Remove all 8 screws from the top of the housing, and slide the cover off.

7.3 Internal Soda Lime/Desiccant

> **NOTE:** Internal soda lime/desiccant *must* be changed annually.

CAUTION! The instrument should not be turned on for about 24 hours after changing the internal chemicals. The time needed will depend, of course, on how much CO_2 and/or water vapor gets into the detector housing during the exchange of bottles. Leaving the instrument off is done so that water vapor which may have entered the system during the time the chemicals were exchanged will not condense in the optical path when the Peltier coolers controlling the detector temperature are powered up.

There is a small plastic bottle inside the LI-6262 that contains a mixture of soda lime and anhydrous $Mg(ClO_4)_2$ (magnesium perchlorate). This bottle is attached to the CO_2/H_2O analyzers' detector housing. Its purpose is to keep the detectors free of CO_2 and water vapor, and their dewpoints below -5 °C.

If the CO_2/H_2O concentration in the detectors rises, the analyzer response curves will change, and the calibration polynomials will no longer match the response curves, and the factory-supplied calibration functions will be invalid. If the dewpoint in the detectors rises above -5 °C, condensation may form, resulting in a large shift in the zero and/or span. The READY light may also fail to light. **For these reasons, the internal soda lime/desiccant <u>must</u> be changed annually.**

The plastic bottle of soda lime/desiccant is located inside the nickel-plated desiccant bottle cover, which is connected perpendicularly to the detector housing (Figure 7-1). The bottle cover is attached with 2 Allen head screws, which may be removed with the hex key included in the LI-6262 spare parts kit. Be careful not to drop the screws onto the LI-6262 circuit boards, as damage may occur.

Follow these steps to replace the soda lime/desiccant bottle:

1. The spare soda lime/desiccant bottle (in the spare parts kit) is shipped without chemicals. You will need to procure chemicals locally. When handling chemicals, observe all manufacturer's safety warnings.

— Viton gasket in lid

— Polyester fiber in bottle

WARNING
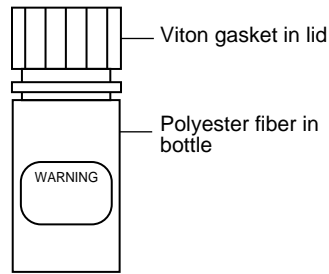
2. Fill the bottle slightly more than half full with soda lime. Fill to the neck with magnesium perchlorate. Tap the sides of the bottle to settle the chemicals. Insert a polyester fiber wad (provided), packing firmly. This helps keep dust from escaping. Make sure the filter disc in the lid is intact; replace if necessary.

Filter

$Mg(ClO_4)_2$
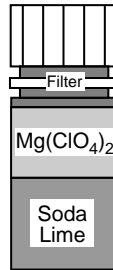
Soda Lime

3. Remove the old bottle; insert the new bottle into the bottle cover bottom first, and reattach the cover to the analyzer. Note that there is a small wad of polyester fiber in the bottom of the nickel-plated bottle cover, to prevent the soda lime/desiccant bottle from rattling.

Hole in cap

Nickel-plated bottle cover

New bottle

WARNING

Polyester fiber
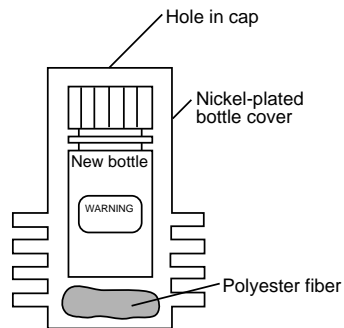
Magnesium perchlorate is the recommended desiccant since it does not interact with CO_2. **Do not use any other desiccant**. Several grades of magnesium perchlorate are available from commercial suppliers. In general, the more granular (as opposed to powdery) the grade the better. One type that works well is marketed under the name *Dehydrite*, and is available (catalog number C260-M61) from Thomas Scientific, P.O. Box 99, Swedesboro, NJ 08085-6099. (609) 467-2000. See List of Suppliers, Appendix B.

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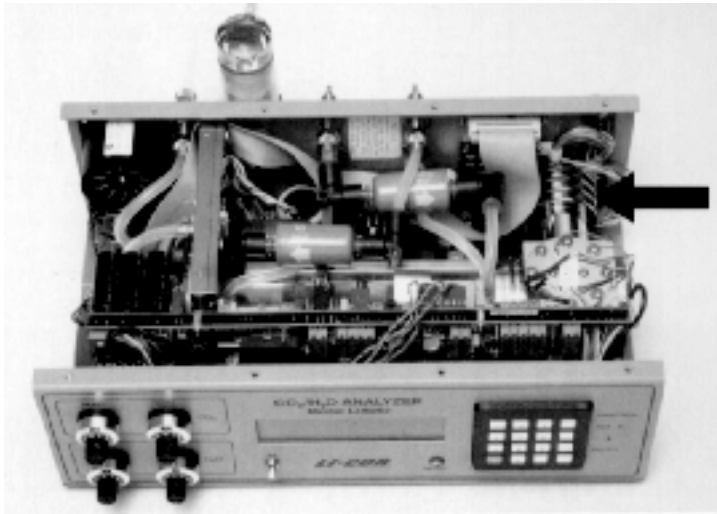

Figure 7-1. Location of internal soda lime/desiccant.

7.4 External Soda Lime/Desiccant

The frequency with which the external soda lime/desiccant must be replaced depends greatly on the mode in which the analyzer is operated, and how much CO_2 and water vapor it is forced to remove.

In differential mode, with the scrubber tube connected to the chopper ports, the soda lime/desiccant will need to be changed every 1-4 weeks, depending on usage. Once the scrubber tube removes the initial CO_2 and water vapor from the circuit, it will only need to remove the small amounts of CO_2 and water vapor resulting from tiny leaks and diffusion into the system.

In absolute mode, the soda lime/desiccant will degrade more rapidly, since it is purging CO_2 and water vapor from the reference cell continuously. When measuring H_2O in absolute mode, the external soda lime/desiccant will need to be changed every 24-48 hours of operation. For additional information on operating the LI-6262 in this mode, refer to Section 4.4, H_2O *Absolute Mode Caution*.

Fill the tube with equal parts soda lime and magnesium perchlorate, separated with a small piece of fiberglass wool, as shown in Figure 7-2 below. Make sure that the filter paper discs on either end cap are not clogged (reduces flow rate) or torn. Adhesive-ringed replacement discs are included in the spare parts kit (LI-COR part # 9960-040).

Magnesium perchlorate cannot be regenerated after use. Dispose of properly.
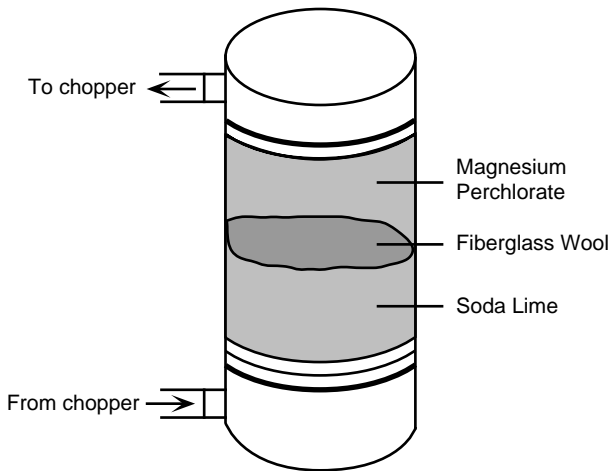
Figure 7-2. External soda lime/desiccant tube assembly.

7.5 Fan Filter

The external fan filter should be cleaned (rinsed out) or replaced as needed. The filter sits in a recessed cavity in the instrument case and can easily be pulled out with your fingers. Two additional external air filters are included in your spare parts kit (LI-COR part # 6560-159).

7.6 Fuses

There are two fuse holders on the back panel. The 1/2 amp slow blow fuse is for 110 VAC line voltage and the 1/4 amp slow blow fuse is for 220 VAC line voltage. The 2 amp fast blow fuse is for the external batteries. If the LI-6262 fails to turn on, check the fuse for the power source you are using (battery or AC). If the analyzer continually blows fuses it is in need of repair.

NOTE: At 50 Hz, 220 VAC, it may be necessary to use the 1/2 amp slow blow fuse due to near saturation of the power transformer core.

8 Trouble-shooting

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

Power ON Problems.

- **Nothing happens .**

Try another battery, or if using AC power, check the AC voltage switch on the back panel to make sure that it is set properly. Check the fuses to see if one has blown.

- **Display flickers, then goes out .**

The analyzer is probably shutting down because the battery voltage is too low (<10.5 V). Try another battery.

Ready Light Won't Illuminate.

The ready light may fail to illuminate for a number of reasons; some of these problems you can fix yourself.

- Ambient temperature is greater than about 55 °C.
- CO_2 level in the reference cell is greater than about 3000 ppm.
- CO_2 or water vapor in the detector, caused by internal soda lime/desiccant bottle leaking or if the internal soda lime/desiccant has been exhausted.
- Span potentiometer has an open circuit.

Zero and/or Span Adjustments Difficult to Set.

If the zero and/or span adjustments are difficult to set, check to see that the analyzer is configured correctly (jumper tubes, soda lime/desiccant, etc.). Also check to make sure that the flow through the analyzer is first entering the portion of the scrubber tube assembly containing the soda lime, not the magnesium perchlorate.

Make sure external soda lime/desiccant is fresh. Check for leaks on the desiccant tube (caps on tight). Check for internal leakage as follows:

Configure the analyzer for absolute mode measurement. Flow CO_2-free air through the sample cell, and breath into the cool-air intake filter (just below the RS-232C port) at the back of the analyzer. The displayed CO_2 should not rise by more than a few ppm. A sharp rise in the displayed CO_2 coinciding with your breathing indicates a leak. A slow increase of 2 to 3 ppm (depending on the flow rate of air through the sample cell) can be expected due to diffusion of CO_2 through the Bev-a-line tubing and does not indicate a leak.

Analyzer Displays CO_2, H_2O, and/or AUX instead of values.

This indicates an over range condition of the CO_2, H_2O, and auxiliary inputs, respectively.

Analyzer Displays Zero for CO_2 or H_2O Values.

- Check the calibration lists (FCT 01 and 02).
- Check pressure (FCT 43). If FCT 73 is set to 43 then pressure is computed from FCTS 71, 72, and 44. Otherwise, it comes from FCT 77.

Specifications

Type: Differential, non-dispersive infrared gas analyzer. H_2O or CO_2 channels can be independently configured for operation in either differential or absolute mode.

Detectors: Two solid state detectors; one each for CO_2 and H_2O, filtered at 4.26 and 2.59 microns, respectively.

Chopping Frequency: 500 hertz.

Source: Single source; lifetime >10,000 hours.

Optical Bench: One optical bench. Sample cell size: $0.6\ H \times 1.3\ D \times 15.2$ cm L $(0.25" \times 0.5" \times 6.0")$. Volume: $11.9\ cm^3$.

Resolution: High resolution and sensitivity provided via 16-bit analog-to-digital converter and user selectable signal averaging time (up to 30 seconds, set in 1 second increments). See individual specifications for CO_2 and H_2O.

Warm-up Time: 5 minutes.

Gas Temperature: Measured by a thermistor. Accuracy: ± 0.5 °C, 0-60 °C. Resolution: 0.01 °C.

Gas Pressure: Maximum allowable pressure is 17 kPa.

Maximum Flow through Analyzer: 10 liters/minute.

Software Features: Setup of parameters, scaling of analog outputs, signal averaging time, selection of RS-232C output parameters, selection of automatic output of data, external control of software via the RS-232C port.

Program Memory: 32K ROM. System parameters (user entered) stored in EEPROM. 8K bytes RAM.

Display: 2 line by 16 character backlit LCD with enlarged characters.

Back panel connections:

    Analog: Two channels, each having 100 mV, 5V, and 20 mA full scale, 12 bit D/A; The full range reading can be scaled within these output ranges (e.g. a full range of 350 ppm over 100 mV full scale).

    RS-232C: Software selectable parameters (baud rates up to 9600, stop bits, parity, check XON/XOFF).

    Non-linear: CO_2: 0-7500 mV for 0 to 3000 ppm, typical.
                    $\pm 15,000$ mV maximum.
                    H_2O: 0-4000 mV for 0 to 75 mmol/mol, typical
                    $\pm 15,000$ mV maximum.

    Auxiliary Input/Output Channel: 0-4096 mV.

Keypad: 16-key keypad for selecting software functions and entering numbers.

Hose Connections: Rapid connect hose fittings for 4 mm ID × 6 mm OD plastic tubing.

Temperature Range: 0-50 °C ambient, 0-50 °C optical bench temperature.

Power Requirements: 100-130 VAC or 200-260 VAC (47-65 hertz), or 10.5 - 16 VDC, 1.5 amp maximum.

Power Consumption: 8-12 Watts DC (dependent on temperature).

Size: 33.5 L × 13 W × 24 cm D (13" × 5" × 9.5").

Weight: 3.5 kg (7.7 lb).

H_2O Analyzer Specifications

Range: 0 to $\pm$ 7.5 kPa or 40 °C dewpoint. Optical bench and interconnecting hoses must be maintained above the dewpoint temperature by the user.

Accuracy: 1% of reading; at lower vapor pressures <1% of reading.

Zero Drift: <0.5 mB in 24 hours from 10-40 °C.

Span Drift: <1% in 24 hours from 10-40 °C, neglecting density changes.

Noise Level (kPa, peak-to-peak): Typical: 0.002 kPa (at 2 kPa with 1 second response time). 0.006 kPa at 2 kPa with 0.1 second response time.

Noise Level (dewpoint, peak-to-peak): Typical: 0.02 °C at 2 kPa with 1 second response time; 0.06 °C at 2 kPa with 0.1 second response time.

CO_2 Analyzer Specifications

Range: 0 ± 3000 ppm.

Accuracy: ± 1 ppm at 350 ppm (<3 ppm maximum). ± 2 ppm at 1000 ppm (<6 ppm maximum).

Zero Drift (over time):

  First Hour: <5 ppm at 25 °C.

  After first hour: <1 ppm per hour at 25 °C.

Zero Drift (with temperature): 0.12 ppm/°C typical, 0.45 ppm/°C maximum.

Span Drift: Typically <1 ppm in 24 hours at 25°C and 350 ppm (absolute mode).

Short Term Repeatability: ± 0.2 ppm at 350 ppm.

Water Sensitivity: <2 ppm from 0-4.0 kPa at 350 ppm. Software algorithm corrects for both band broadening and dilution effects.

Calibration: Factory linearization over 0-3000 ppm range using NIST-traceable standard gases.

Noise Level (ppm, peak-to-peak): Typical: 0.2 ppm, Maximum: 0.4 ppm at 350 ppm with 1 second response time; 0.6 ppm typical, 1 ppm maximum at 350 ppm with 0.1 second response time.

6262-03 Pressure Transducer Specifications

Pressure Range: 0 to 115 kPa absolute.
Accuracy (with software correction): ± 0.1% full scale.
Resolution: 0.002 kPa.
Signal noise (peak-to-peak): 0.002 kPa typical.
Power consumption: 50 mA (steady state).
Weight: 0.88 oz. (25 g).

B

Suppliers

The company names, addresses, and phone numbers are the most current we have at the time of this printing. In some cases the information may change without notice.

Soda Lime (6-12 mesh) and Magnesium Perchlorate (Anhydrous) $Mg(ClO_4)_2$

GFS Chemicals
P.O. Box 245
Powell, OH 43065
Phone: 614-881-5501
FAX: 614-881-5989
Toll free: 800-858-9682

Soda Lime: Part #66352

$Mg(ClO_4)_2$**:** Part #49001 (500g, <8% water)

Fisher Scientific
711 Forbes Avenue
Pittsburgh, PA 15219-4785
Phone: 201-467-6400
FAX: 201-379-7415
Toll free: 800-776-7000
Toll free FAX: 800-926-1166

Soda Lime: Part #S201-212
(LI-COR Part #9960-071)

$Mg(ClO_4)_2$**:** Part #M54-500 (500g)

Thomas Scientific
P.O. Box 99
Swedesboro, NJ 08085-6099
Phone: 609-467-2000
FAX: 609-467-3087
Toll free: 800-345-2100
Toll free FAX: 800-345-5232

Soda Lime: Part #C703-B76

$Mg(ClO_4)_2$**:** Part #C260-M61
(Dehydrite, 500g)

Function Code	Description	Page
00	**SETUP**	5-3
01	Set CO_2 Calibration	5-4
02	Set H_2O Calibration	5-5
03	Set Miscellaneous	5-5
04	Set Displays	5-6
05	Set D/A Conversion #1	5-7
06	Set D/A Conversion #2	5-7
07	Backlight ON/OFF	5-8
08	Test Menu	5-8
09	Integrate	5-11
10	**PRINT**	5-13
11	Print Header	5-14
12	Print Data	5-14
13	Set Print List	5-14
14	Auto Print	5-15
15	Auto Header	5-15
16	Print Calibration Data	5-16
17	Set RS-232C Port	5-17
18	Reset Timer	5-18
19	Full Status	5-18
20	**CO2**	5-20
21	CO_2 raw mV	5-20
22	CO_2 μmol/mol absolute	5-20
23	CO_2 μmol/mol differential	5-20
24	CO_2 Pa absolute	5-20
25	CO_2 Pa differential	5-20
26	CO_2 μg/g absolute	5-20
27	CO_2 μg/g differential	5-20
29	CO_2 μmol/mol reference	5-20

Function Code	Description	Page

D Channel Code Headers

The following table shows the way in which channel code headers will appear when sent from the LI-6262 to a terminal or printer through the RS-232C port.

Header	Description	Channel Code
C2 mV	CO_2 raw mV	21
C2 μm/m	CO_2 μmol/mol absolute	22
ΔC2μm/m	CO_2 μmol/mol differential	23
C2 Pa	CO_2 Pa absolute	24
ΔC2 Pa	CO_2 Pa differential	25
C2 μg/g	CO_2 μg/g absolute	26
ΔC2μg/g	CO_2 μg/g differential	27
REFμm/m	CO_2 reference (μmol/mol)	29
H2 mV	H_2O raw mV	31
H2 mm/m	H_2O mmol/mol absolute	32
ΔH2mm/m	H_2O mmol/mol differential	33
H2 kPa	H_2O kPa absolute	34
ΔH2 kPa	H_2O kPa differential	35
H2 mg/g	H_2O mg/g absolute	36
ΔH2 mg/g	H_2O mg/g differential	37
DewPt C	H_2O Dewpoint °C	38
REFmm/m	H_2O reference (mmol/mol)	39
Temp mV	Temperature mV	41
Temp C	Temperature °C	42
P(kPa)	Pressure (kPa)	43
Aux mV	Auxiliary mV	44
Timer	Timer (s)	45

E

Console Commands

Setup Commands

00 **SETUP**	10 **PRINT**
01 Set CO_2 Calibration	11 Print Header
02 Set H_2O Calibration	12 Print Data
03 Set Miscellaneous	13 Set Print List
04 Set Displays	14 Auto Print
05 Set D/A Conversion #1	15 Auto Header
06 Set D/A Conversion #2	16 Print Calibration Data
07 Backlight ON/OFF	17 Set RS-232C Port
08 Test Menu	18 Reset Timer
09 Integrate	19 Full Status

Channel Codes

20 **CO2**	30 **H2O**	40 **MISC**
21 CO_2 raw mV	31 H_2O raw mV	41 Temperature mV
22 CO_2 μmol/mol abs.	32 H_2O mmol/mol abs.	42 Temperature °C
23 CO_2 μmol/mol diff.	33 H_2O mmol/mol diff.	43 Pressure kPa
24 CO_2 Pa abs.	34 H_2O kPa abs.	44 Auxiliary mV
25 CO_2 Pa diff.	35 H_2O kPa diff.	45 Timer
26 CO_2 μg/g abs.	36 H_2O mg/g abs.	46 Integration A
27 CO_2 μg/g diff.	37 H_2O mg/g diff.	47 Integration peak value
29 CO_2 μmol/mol ref.	38 H_2O Dewpoint	49 Software Revision ID
	39 H_2O mmol/mol ref.	

Calibration and Configuration Stacks	
50 **CO2 CAL**	60 **H2O CAL**
51 CO_2 Calibration T	61 H_2O Calibration T
52 CO_2 Calibration K	62 H_2O Calibration K
53 CO_2 Calibration A	63 H_2O Calibration A
54 CO_2 Calibration B	64 H_2O Calibration B
55 CO_2 Calibration C	65 H_2O Calibration C
56 CO_2 Calibration D	68 H_2O reference mmol/mol
57 CO_2 Calibration E	
59 CO_2 reference μmol/mol	

Calibration and Configuration Stacks		
70 **MISC**	80 **DAC**	90 **DISP**
71 Auxiliary A	81 D/A Conv. Code #1	91 Display 1
72 Auxiliary B	82 D/A Conv. #1 Min.	92 Display 2
73 Auxiliary Destination	83 D/A Conv. #1 Max.	93 Display 3
74 Average Time	84 D/A Conv. Code #2	94 Display 4
75 Auxiliary C	85 D/A Conve. #2 Min.	95 Display 5
76 Vapor Flag	86 D/A Conv. #2 Max.	96 Display 6
77 Pressure		97 Display 7
78 Vapor Correction a		98 Display 8
		99 Display 9

Remote Commands	
Function	Type the following on a computer or terminal (comments).
01 Set CO_2 Calibration 02 Set H_2O Calibration 05 Set D/A Conversion Code #1 06 Set D/A Conversion Code #2 07 Backlight 09 Integrate 11 Print Header 12 Print Data 13 Set Print List 14 Auto Print 15 Auto Header 16 Print Calibration Data 18 Reset Timer 19 Full Status 46 Integration A 47 Integration Peak Value 49 Software Revision I.D. 71 Auxiliary A 72 Auxiliary B 73 Auxiliary Destination 74 Set Average Time 75 Auxiliary C 76 Vapor Flag 77 Pressure 78 H_2O Cal. a 91 Display 1 │ 99 Display 9	***01T,K,A,B,C,D,E,REF,VAPOR FLAG** ***02T,K,A,B,C,REF** ***05x,low,high** (x is channel code 22-27, 32-38, 42) ***06x,low,high** (same as 05) ***07Y** (Yes) or ***07N** (No) to turn backlight ON/OFF ***09x,start,[start value],stop, [stop value]** (x is channel code 22-29, 32-39) ***11** (prints header) ***12** (prints data) ***13x,x,x,x,x,x,x,x,x** (x is any channel code 21-29, 31-39, 41-47) ***14x** (prints a line of data every x seconds where x is any number 0.2, 0.5, or 1 to 3600) ***15x** (prints a column header every x lines of data, from 1 to 999) ***16** (prints calibration stack for H_2O & CO_2) ***18** (resets the timer to zero) ***19x** (x is optional parameter to output) ***46** ***47** ***49** ***71<A>** (A is the auxiliary A value) ***72<B>** (B is the auxiliary B value) ***73x** (x is auxiliary destination channel <null>, 29, 39, or 43) ***74x** (x is any value from 0 to 30) ***75<C>** (C is auxiliary C value) ***76x** (x is 0, 1, or 2 to turn ON/OFF vapor/dilution corrections) ***77x** (x is barometric pressure in kPa) ***78x** (x is vapor correction a) ***91x,x** (x is channel code 21-27, 29, 31-39, 41-44, for top and bottom line) (***91 - *99** are all the same)

Temp.°C	.0	.1	.2	.3	.4	.5	.6	.7	.8	.9
0	6.11	6.12	6.20	6.24	6.29	6.34	6.38	6.43	6.48	6.52
1	6.57	6.62	6.66	6.71	6.76	6.81	6.86	6.91	6.96	7.01
2	7.06	7.11	7.16	7.21	7.26	7.31	7.37	7.42	7.47	7.53
3	7.58	7.63	7.69	7.74	7.80	7.85	7.91	7.96	8.02	8.08
4	8.14	8.19	8.25	8.31	8.37	8.42	8.48	8.54	8.60	8.67
5	8.72	8.79	8.85	8.91	8.97	9.03	9.10	9.16	9.22	9.29
6	9.35	9.42	9.48	9.55	9.61	9.68	9.75	9.82	9.88	9.95
7	10.02	10.09	10.16	10.23	10.30	10.37	10.44	10.51	10.58	10.65
8	10.73	10.80	10.88	10.95	11.03	11.10	11.18	11.25	11.33	11.41
9	11.48	11.56	11.64	11.72	11.80	11.88	11.96	12.04	12.12	12.20
10	12.28	12.37	12.45	12.53	12.62	12.70	12.79	12.87	12.96	13.04
11	13.13	13.22	13.31	13.39	13.49	13.57	13.67	13.75	13.85	13.93
12	14.03	14.13	14.21	14.31	14.40	14.50	14.60	14.70	14.79	14.88
13	14.99	15.09	15.18	15.28	15.38	15.48	15.58	15.69	15.79	15.88
14	16.00	16.09	16.21	16.30	16.42	16.51	16.63	16.74	16.84	16.95
15	17.06	17.17	17.29	17.40	17.50	17.62	17.74	17.85	17.96	18.08
16	18.19	18.32	18.43	18.54	18.67	18.78	18.91	19.02	19.15	19.26
17	19.39	19.52	19.63	19.76	19.89	20.01	20.14	20.27	20.40	20.52
18	20.65	20.78	20.91	21.05	21.18	21.31	21.45	21.58	21.72	21.85
19	21.99	22.13	22.26	22.41	22.55	22.69	22.83	22.98	23.12	23.26
20	23.41	23.55	23.69	23.84	23.99	24.14	24.28	24.44	24.58	24.74
21	24.90	25.04	25.20	25.36	25.52	25.67	25.83	25.99	26.15	26.31
22	26.47	26.63	26.78	26.96	27.12	27.29	27.45	27.62	27.78	27.96
23	28.13	28.30	28.46	28.64	28.81	28.98	29.16	29.35	29.52	29.69
24	29.87	30.06	30.23	30.42	30.60	30.78	30.97	31.15	31.34	31.53
25	31.72	31.91	32.10	32.29	32.49	32.68	32.87	33.06	33.26	33.46
26	33.66	33.86	34.07	34.26	34.47	34.67	34.88	35.08	35.29	35.49
27	35.77	35.92	36.12	36.34	36.55	36.77	36.99	37.20	37.42	37.64
28	37.86	38.08	38.30	38.52	38.76	38.98	39.20	39.44	39.66	39.90
29	40.13	40.36	40.59	40.83	41.07	41.30	41.54	41.78	42.02	42.27
30	42.50	42.76	42.99	43.25	43.50	43.75	43.99	44.24	44.50	44.75
31	45.02	45.27	45.52	45.79	46.05	46.31	46.57	46.84	47.11	47.37
32	47.64	47.91	48.18	48.47	48.74	49.01	49.29	49.25	49.84	50.13
33	50.41	50.70	50.98	51.29	51.55	51.84	52.14	52.43	52.73	53.01
34	53.31	53.62	53.92	54.22	54.52	54.82	55.12	55.42	55.74	56.04
35	56.36	56.68	57.00	57.31	57.63	57.95	58.27	58.58	58.90	59.24
36	59.57	59.89	60.22	60.55	60.89	61.22	61.56	61.89	62.23	62.28
37	62.92	63.26	63.61	63.96	64.31	64.65	65.01	65.36	65.71	66.06
38	66.43	66.80	67.16	67.51	67.88	68.25	68.62	69.00	69.37	69.73
39	70.12	70.50	70.88	71.26	71.63	72.03	72.42	72.80	73.18	73.58
40	73.98	74.38	74.77	75.17	75.57	75.98	76.38	76.78	77.20	77.60
41	78.03	78.45	78.86	79.28	79.70	80.12	80.53	80.97	81.40	81.82
42	82.27	82.70	83.13	83.57	84.00	84.45	84.88	85.33	85.78	86.23
43	86.68	87.14	87.60	88.05	88.52	88.97	89.44	89.90	90.37	90.84
44	91.32	91.80	92.27	92.76	93.24	93.71	94.19	94.69	95.18	95.66
45	96.18	96.66	97.16	97.66	98.16	98.68	99.18	99.68	100.20	100.72
46	101.24	101.75	102.27	102.80	103.32	103.86	104.38	104.91	105.45	105.98
47	106.53	107.08	107.62	108.15	108.72	109.27	109.81	110.36	110.93	111.50
48	112.07	112.62	113.20	113.77	114.34	114.91	115.48	116.07	116.66	117.27
49	117.84	118.43	119.03	119.62	120.22	120.83	121.43	122.03	122.64	123.26
50	123.88	124.50	125.12	125.74	126.36	126.98	127.62	128.25	128.88	129.52

This table gives the saturation vapor pressure of H_2O in millibars.

G Connector Descriptions

25 Pin RS-232C DCE Port

Pin #	Name
1	Frame ground
2	Received data
3	Transmitted data
4	Request to Send
5	Clear to Send
6	Data Set Ready
7	Signal Ground
8	Carrier Detect
9-19	Not connected
20	Data Terminal Ready
21-25	Not connected

1000-04 DTE To DCE Cable

The 1000-04 cable included is a pin-for-pin connection between the 25-pin connectors on either end. The 1000-04 is terminated with male connectors on both ends; a female-to-female gender changer may be required to connect the LI-6252 to some computers and/or printers.

H Sample Program

The following is a sample Borland's C program that could be used to calculate CO_2 and/or H_2O concentrations. The CO_2 calculations use the water correction equations described in Section 3.

```
/*

gascomp.c - Implements LI-COR IRGA equations

*/

#include <stdio.h>
#include <math.h>

static double ppm(double mV, double Cr, double Tirga, double vp_r, double vp_s, double kPa);
static double cal(double mv);
static double temp_correction(double t);
static double inverse_cal(double cppm);
static double cal_slope(double mv);
static double chi(double mfw);
static double p0_over_p(double kPa);


static double T_cal, K_cal, A_cal, B_cal, C_cal, D_cal, E_cal, Water_A;
static int water_flag;

/* ------------------------------------------------------------------------ */

static double ppm(double mV, double Cr, double Tirga, double vp_r, double vp_s, double kPa)
{
 /* This function implements Equations 6-6 (LI-6251manual), Equations 6-13 (LI-6252 manual)
    or Equations 3-29 (LI-6262 manual).

    mV - co2 signal in mV
    Cr - reference concentration (ppm)
    Tirga - Gas temp (C)
```

```
  vp_r - reference cell vapor pressure (kPa)
     vp_s - sample cell vapor pressure (kPa)
     kPa - total pressure (kPa)
  */

  double Vref, gain, chi_ws, chi_wr, eff_cr, tc, eff_mv, result, inv_cal;


  tc = temp_correction(Tirga);

  if (Cr == 0.0) {
   /* absolute mode
    */
   chi_ws = chi(vp_s/kPa);
   eff_mv = mV/chi_ws*p0_over_p(kPa);
   result = chi_ws * cal(eff_mv) * tc;
   return result;
  }

  /* differential mode
   */
  chi_wr = chi(vp_r/kPa);
  eff_cr = Cr / temp_correction(Tirga) / chi_wr;
  inv_cal = inverse_cal(eff_cr);
  Vref = chi_wr * inv_cal / p0_over_p(kPa);
  gain = (1.0 - Vref/K_cal);

  return ppm(Vref + mV*gain, 0, Tirga, 0, vp_s, kPa);
}

/* -------------------------------------------------------------------------- */

static double cal(double mv)
{
 /* The basic irga cal equation - polynomial
  */
 double rtn;

 rtn = (A_cal + (B_cal + (C_cal + (D_cal + E_cal*mv)*mv)*mv)*mv)*mv;
 return rtn;
}

/* -------------------------------------------------------------------------- */
```

H-2   *Sample Program*

```
static double temp_correction(double t)
{
 return (t + 273)/(T_cal + 273);
}

/* ------------------------------------------------------------------------- */

static double inverse_cal(double cppm)
{
 /* returns the mV that would be generated if in absolute mode with
   cppm in the sample cell
 */
 double mv_old = 0, mv, c;

 /* crude first guess
 */
 if (water_flag)
           mv = cppm/75 * 5000;
 else
  mv = cppm/3000 * 5000;

 while (fabs(mv - mv_old) > 0.5) {
  mv_old = mv;
  c = cal(mv_old);
  mv = mv_old - (c - cppm) / (cal_slope(mv_old));
 }
 return mv;
}

/* ------------------------------------------------------------------------- */

static double cal_slope(double mv)
{
 /* returns the slope of the cal function
 */
 return A_cal + (2*B_cal + (3*C_cal + (4*D_cal + 5*E_cal*mv)*mv)*mv)*mv;
}

/* ------------------------------------------------------------------------- */

static double chi(double mfw)
{
```

```
  /* Eqn 3-21 (LI-6262 manual) or 6-5 (LI-6251 or LI-6252 manual).
   */
  return 1 + (Water_A -1) * mfw;
}

/* -------------------------------------------------------------------------- */

static double p0_over_p(double kPa)
{
  if (water_flag)
    /* return (101.3 / kPa) * 0.88451 + 0.10889; */ /* The LI-6262 approx. */
    return pow(101.3 / kPa, 0.9);
  else
    return 101.3 / kPa;
}

/* -------------------------------------------------------------------------- */
/* -------------------------------------------------------------------------- */

double compute_co2(double Cal_temp, double Cal_k, double coeffs[],
                   double mv, double temp, double ref, double pressure,
                   double vap_ref, double vap_samp, double water_corr_a,
                   int vapor_correct_flag)
{
  /*
    Compute co2 concentration (umol/mol)
    Cal_temp - calibration temp (C)
    Cal_k    - calibration K factor
    coeffs[] - Calibration A, B, C, D, and E
    mv       - raw CO2 signal (mV)
    temp     - IRGA temp (C)
    ref      - Co2 reference concentration (umol/mol)
    vap_ref  - Vapor concentration (mmol/mol) of reference side
    vap_samp - Vapor concentration (umol/mol) of sample side
    water_corr_a - A value for water correction
    vapor_correct_flag - 0 no vapor corrections
                                     1 band broadening only
                                     2 band broadening, and dilution based on ref

    Returns CO2 concentration in umol/mol
   */

  double Cs;
```

```c
   water_flag = 0;
   T_cal = Cal_temp;
   K_cal = Cal_k;
   A_cal = coeffs[0];
   B_cal = coeffs[1];
   C_cal = coeffs[2];
   D_cal = coeffs[3];
   E_cal = coeffs[4];
   Water_A = water_corr_a;

   if (vapor_correct_flag == 0) {
    vap_ref = 0;
    vap_samp = 0;
   }

   Cs = ppm(mv, ref, temp, vap_ref/1000.0*pressure,
                               vap_samp/1000.0*pressure, pressure);

   /* The dilution correction is hypothetical.  It says what the concentration
      in the sample cell would be if the water vapor concentration there
      were the same as in the reference cell.
   */
   if (vapor_correct_flag == 2)
    Cs *= (1.0 - vap_ref/1000.0) / (1.0 - vap_samp/1000.0);

   return Cs;
}

/* ------------------------------------------------------------------------- */

double compute_h2o(double Cal_temp, double Cal_k, double coeffs[],
                        double mv, double temp, double ref, double pressure)
{
 /*
    Compute co2 concentration (umol/mol)
    Cal_temp - calibration temp (C)
    Cal_k    - calibration K factor
    coeffs[] - Calibration A, B, C
    mv       - raw H2O signal (mV)
    temp     - IRGA temp (C)
    ref      - H2O reference concentration (umol/mol)
```

Returns water vapor concentration in mmol/mol
*/

 double Ws;

 water_flag = 1;
 T_cal = Cal_temp;
 K_cal = Cal_k;
 A_cal = coeffs[0];
 B_cal = coeffs[1];
 C_cal = coeffs[2];
 D_cal = 0;
 E_cal = 0;

 Ws = ppm(mv, ref, temp, 0, 0, pressure);

 return Ws;
}

/* -- */

double dewpoint(double vp_kPa)
{
           double z;

           z = log10(vp_kPa / .61083);
           return 242.62 * z / (7.6448 - z);
}

/* -- */