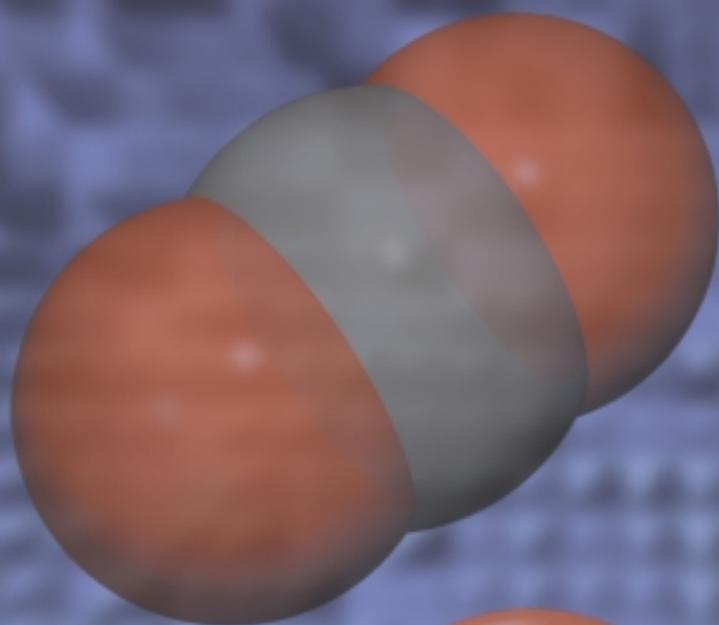
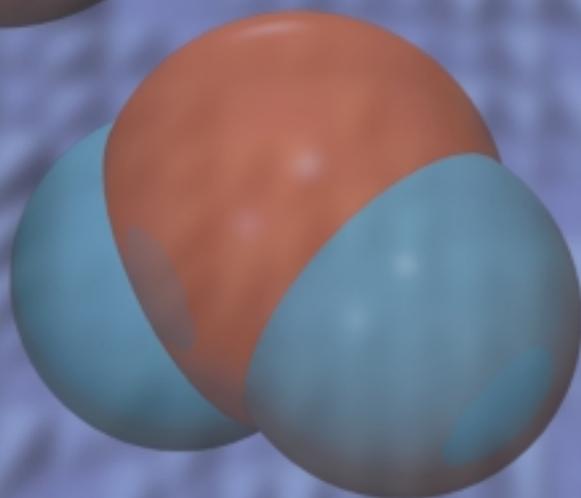


LI-7000

CO₂/H₂O Analyzer



Instruction
Manual

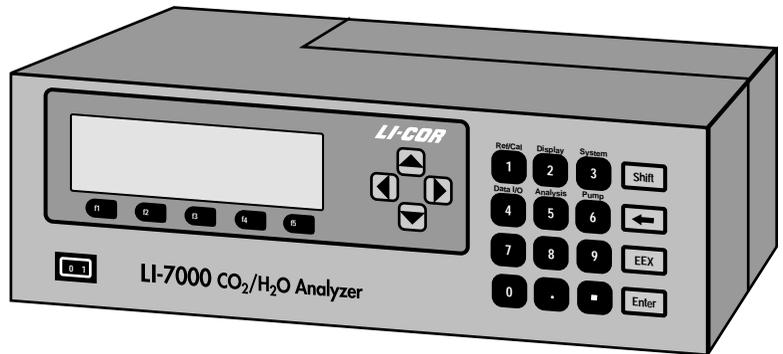


LI-COR

LI-7000

CO₂/H₂O Analyzer

Instruction Manual



LI-COR®

Biosciences

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This product is a CE-marked product. For conformity information, contact LI-COR Support at envsupport@licor.com. Outside of the U.S., contact your local sales office or distributor.

LI-7000						
Component Name	Hazardous Substances or Elements					
	Lead (Pb)	Mercury (Hg)	Cadmium (Cd)	Chromium VI Compounds (Cr ⁶⁺)	Polybrominated Biphenyls (PBB)	Polybrominated Diphenyl Ethers (PBDE)
Shielded Power Cord	X	0	0	0	0	0
Enclosure Covers and Panels	0	0	0	0	X	0
Optical Bench Assembly	X	0	0	X	0	0
Cabinet Assembly	X	0	0	0	0	0
Keypad	X	0	X	0	0	0
#4 Aluminum Spacer	0	0	0	X	0	0
Circular Fan	X	0	0	0	0	0
3 Pin Panel Mount Receptacle	X	0	0	0	0	0
Power Line Filter	X	0	0	0	0	0
LCD	X	0	0	0	0	0
Power Supply	X	0	0	0	0	0
Base Plate	0	0	0	X	0	0
Power Supply Circuit Board Assembly	X	0	0	0	0	0
Pump Assembly	X	0	0	0	0	0
Display Ribbon Cable Assembly	X	0	0	0	0	0
RS-232 Ribbon Cable Assembly	X	0	0	0	0	0
Pressure Transducer Assembly	X	0	0	X	0	0
Terminal Strip Circuit Board Assembly	X	0	0	0	0	0
Digital/Analog Circuit Board Assembly	X	0	0	0	0	0
#6 Aluminum Spacer	0	0	0	X	0	0

O: this component does not contain this hazardous substance above the maximum concentration values in homogeneous materials specified in the SJ/T 11363-2006 Industry Standard.

X: this component does contain this hazardous substance above the maximum concentration values in homogeneous materials specified in the SJ/T 11363-2006 Industry Standard (Company can explain the technical reasons for the "X")

LI-7000 闭路式CO2/H2O 分析仪						
部件名称	有毒有害物质或元素					
	铅 (Pb)	汞 (Hg)	镉 (Cd)	六价铬 (Cr ⁶⁺)	多溴联苯 (PBB)	多溴二苯醚 (PBDE)
屏蔽电缆线	X	0	0	0	0	0
仪器箱盖及箱板	0	0	0	X	0	0
光路系统组件	X	0	0	X	0	0
机箱组件	X	0	0	0	0	0
键盘	X	0	X	0	0	0
4号铝垫片	0	0	0	X	0	0
冷却风扇	X	0	0	0	0	0
3针板插座	X	0	0	0	0	0
电源线滤波器	X	0	0	0	0	0
液晶显示器	X	0	0	0	0	0
供电器	X	0	0	0	0	0
底板	0	0	0	X	0	0
供电器电路板组件	X	0	0	0	0	0
气泵组件	X	0	0	0	0	0
显示器的带状电缆组件	X	0	0	0	0	0
串行 RS-232 的带状电缆组件	X	0	0	0	0	0
气压力传感器组件	X	0	0	X	0	0
端子排电路板组件	X	0	0	0	0	0
数码及模拟信号电路板组件	X	0	0	0	0	0
6号铝垫片	0	0	0	X	0	0

O: 表示该有毒有害物质在该部件所有均质材料中的含量均在 SJ/T 11363-2006 标准规定的限量要求以下。

X: 表示该有毒有害物质至少在该部件的某一均质材料中的含量超出 SJ/T 11363-2006 标准规定的限量要求。(企业可在此处, 根据实际情况对上表中打 "X" 的技术原因进行进一步的说明。)

Note on Safety

LI-COR products have been designed to be safe when operated in the manner described in this manual. The safety of this product can not be guaranteed if the product is used in any other way than is specified in this manual.

Equipment markings:



The product is marked with this symbol when it is necessary for you to refer to the manual or accompanying documents in order to protect against damage to the product.



The product is marked with this symbol when a hazardous voltage may be present.



The product is marked with this symbol for a Chassis Ground connection.

WARNING **Warnings** must be followed carefully to avoid bodily injury.

CAUTION **Cautions** must be observed to avoid damage to your equipment.

Manual markings:

WARNING **Warnings** must be followed carefully to avoid bodily injury.

CAUTION **Cautions** must be observed to avoid damage to your equipment.

NOTE **Notes** contain important information and useful tips on the operation of your equipment.

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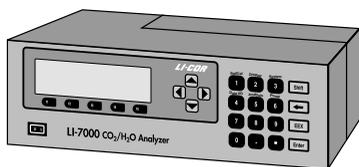
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1 Getting Acquainted

About the LI-7000

The LI-7000 is a high speed precision differential infrared gas analyzer designed for applications requiring high data output speeds. A unique, user-cleanable optical cell allows simultaneous measurements of CO₂ and H₂O concentrations in differential and absolute modes, even when the reference gas concentration is unknown. Data are output via fully linearized Digital-to-Analog-Converters (DACs) with an update rate of 600 Hz, with the RS-232 port at speeds up to 50 Hz, or with the USB port at up to 50 Hz.

Large diameter internal and external air fittings connected directly to the optical bench provide for greatly reduced resistance to air flow; a pressure transducer and internal pump are also built in. Windows[®] software for setup and operation is provided; all functions can also be accessed from the instrument front panel.

What's What

If you have just taken delivery of your LI-7000 check the packing list to verify that you received everything ordered, including the following items:

Calibration Sheet

This data sheet is a copy of the calibration information entered into the LI-7000 by LI-COR. Keep it in a safe place for future reference. LI-COR also retains copies of calibration information for your analyzer; contact us if yours is misplaced.

Spare Parts Kit

This box contains replacement parts for your LI-7000. As you become familiar with the system you will learn which items to keep close at hand and which items can be stored away.

Among others, the spares kit contains these commonly used items:

Description	Qty.	LI-COR Part No.
External Battery Leads	1	9960-120
Teflon Grease	1	210-05774
Bev-a-line Tubing	15'	222-01824
Quick Connect Union	2	300-03123
Swagelok Ferrule Set	10	300-05375
Terminal Strip 12-position Plug	1	331-05232
Terminal Strip 8-position Plug	1	331-05234
1 Amp Fuse (for 115V operation)	2	438-00844
1/2 Amp Fuse (for 230V operation)	2	438-00845
4 Amp Fuse	1	438-03399
Scrubber & Desiccant Tube Kit	1	9960-093
Filter Assembly	4	9967-008
Sock Tip Swab	4	610-05315
Standard RS-232 Cable Kit	1	9975-016
USB Cable, 6'	1	392-07872

6200B Rechargeable Batteries (optional)

(12VDC). The 6200B Rechargeable Batteries are tested and fully charged before they leave the factory, but may discharge during shipping. It is a good idea to test your batteries to make sure they are charged. See "*Recharging the 6200B Batteries*" in Section 7 for instructions about charging batteries. The 6200B requires the LI-6020 Battery Charger for recharging. One 6200B battery provides approximately 5 hours of battery life, with the pump off, at 25 °C.

7000-500 Data Communications and Utility Software

This Windows software is used to communicate with PC-compatible computers. The software is provided on a CD.

LI-COR Serial Cable (p/n 9975-016)

This is a null modem cable that is used to interface with devices such as computers or terminals with 9-pin serial ports. If you want to interface to a device with a 25-pin serial port, then a 9-pin to 25-pin adapter (in the spares kit) must be used.

USB Cable (p/n 392-07872)

The USB cable is used to interface with devices that have a USB 1.1 or 2.0 port. The USB cable is terminated with 5-pin A/Mini-B connectors; the Mini-B end connects to the LI-7000, and the 'A' end connects to the computer or other device. Note that connecting via a USB cable requires LI-7000 Windows interface software version 2.0 or greater; the software should be installed before connection, so that the proper USB drivers are installed.

Safety Considerations

Please be aware that there are certain safety precautions which should be followed when servicing the LI-7000.

Laser Safety

The Center for Devices and Radiological Health (CDRH) of the U.S. Food and Drug Administration has implemented regulations for laser products manufactured since August 1, 1976. Compliance is mandatory for products marketed in the United States. This analyzer is certified as a "Class I" laser product under the U.S. Department of Health and Human Services (DHHS) Radiation Performance Standard according to the Radiation Control for Health and Safety Act of 1968. Since radiation emitted inside this analyzer is confined within protective housings, laser radiation above Class I levels cannot escape during normal operation or maintenance.

WARNING! Never operate, maintain or service the analyzer with the protective cover removed. The protective cover has a label which states; **"DANGER, laser radiation when open. AVOID DIRECT EXPOSURE TO THE BEAM"**

1 Getting Acquainted

Is It Functioning Normally?

If you have just received your LI-7000, you may want to follow the steps below to verify that the instrument is functioning properly. This procedure takes only 5 or 10 minutes. It is helpful if you have access to a dry, CO₂-free source of air; a scrubber tube is provided in the spares kit which can be used to generate this air stream if a tank is not available.

1. Connect a battery or AC power, and turn the instrument on. You will see a series of messages indicating the instrument is warming up. After about 20 seconds, the display should look something like this:

1	CO2A μ m/m	CO2B μ m/m	CO2 Δ μ m/m	T °C
	1000.00	1483.98	483.98	25.97
	H2OAm/m	H2OBmm/m	H2O Δ mm/m	P kPa
	9.075	9.073	0.002	96.50
1	SetRef...		Calib...	Coeffs...

The 8 variables shown above constitute the default display definition #1. This (and the other 2 displays) can be edited later, if desired (see Section 5, *Defining the Displays*). Press 2 on the keypad to see default display definition #2. Press 3 on the keypad to see default display definition #3. Displays 2 and 3 contain the following variables:

2	Integral	Peak	Flow V	Aux1
	H2O $^{\circ}$ C	H2O B° C	H2O Δ mm/m	Aux2
3	CO2A abs	CO2B abs	CO2 AGC	Diag
	H2O A abs	H2O B abs	H2O AGC	RH %

2. Press **Shift** then **2** to access the Display function keys. Press **f3** several times and see if the display backlight changes. Leave the display at a comfortable viewing level.
3. Press **f4** and **f5** to verify that the display brightness and contrast change. Again, leave the display at a comfortable viewing level.
4. Press **Shift** then **6** to access the Pump control keys. Press **f1** thru **f4** to change the pump speed; you should notice audible changes between the speeds. If you do not hear any pump noise, press **f5** (Setup) and make sure that the Fast value is set to 255. Set it to 255, press **OK**, and press **f4** again to set the speed to Fast. The pump should be audible.
5. Press **Shift** then **3** to access the System function keys. Press **f3** to check/set the system time and date. Use the arrow keys to set the time and date, if necessary, and press **OK**.
6. Make sure Pressure and Temperature are reading OK. Sea-level pressure is 101 kPa, and a typical value at 300 m elevation is around 97 kPa.

Do this if you have access to dry, CO₂-free air:

7. Flow dry, CO₂-free air through Cell A. See Section 2, *Examples* for examples on setting the instrument up using the internal auxiliary pump to pull air through the included scrubber tube to provide the dry, CO₂-free air source.
8. Press **Shift** then **1**. Press **f1** (SetRef...).
9. Press **f1** (Edit) to change CO₂ to Exact:0, and H₂O to Exact:dry. Press **f5** (OK).
10. Insert a piece of tubing between the exhaust from Cell A and the inlet for Cell B.

11. The $\text{CO}_2\text{A}\mu\text{m/m}$ and $\text{H}_2\text{OAm/m}$ values on the display will read zero (from Step 8 above). The $\text{CO}_2\text{B}\mu\text{m/m}$ and $\text{H}_2\text{OBmm/m}$ values should stabilize at, or near zero.
12. Remove the tubing between the outlet of Cell A and the inlet of Cell B, and allow ambient air to flow through Cell B. Observe the readings and see if they look reasonable.

How It Works

The LI-7000 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. Cell A (normally the **reference cell**) is used for a gas of known CO_2 or H_2O concentration, and Cell B (normally the **sample cell**) is used for a gas of unknown concentration. Infrared radiation is transmitted through both cell paths, and the radiation at the detectors is measured in both cells and used to compute absorption.

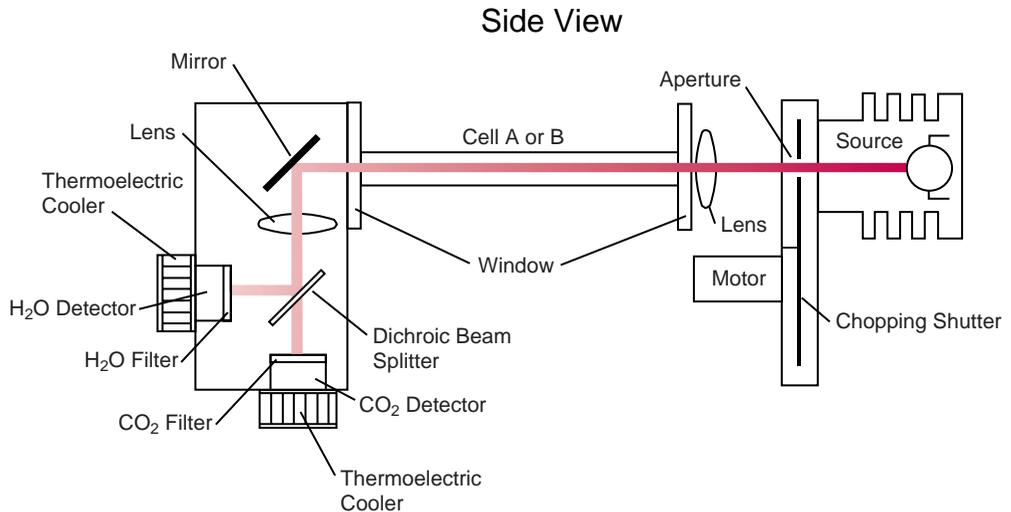


Figure 1-1. Schematic of LI-7000 optical path.

The infrared **source** contains a tungsten filament and is vacuum sealed for long life (> 20,000 hours) and high stability.

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 75 hertz on a phase locked loop circuit; 8 apertures on the chopping shutter disc provide an actual chopping rate of 600 Hz. The source and detector housings are sealed and continuously purged of CO₂ and H₂O by bottles containing Ascarite II and magnesium perchlorate. This eliminates interference due to ambient CO₂ or H₂O vapor.

The **optical cells** are nickel-plated to resist tarnishing over time. Optical cells are used for both H₂O and CO₂ measurements using a **dichroic beam splitter** to provide radiation to two separate detectors.

Bandpass **optical filters** are used to tune the CO₂ detector to the 4.255 micron absorption band for CO₂, and the H₂O detector to the 2.595 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 thermoelectric 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, and also prevents infrared radiation from touching and reflecting from the cell walls.

An on-board **pump** can be used to flow air into either Cell A or Cell B, or provide a reference gas to cell A. A built-in **pressure transducer** measures pressure in optical cell B continuously, allowing for corrections to be made for changes in barometric pressure.

Theory of Operation

Effective Pressure

Consider a mixture of gases, each with partial pressure p_i which sum to total pressure P .

$$P = \sum p_i \quad 1-1$$

The molar fraction x_i of each gas is $\frac{p_i}{P}$, so we can write

$$1 = \frac{\sum p_i}{P} = \sum x_i \quad 1-2$$

Now consider how this mixture absorbs radiation. Infrared absorption is due to energy-induced changes in vibrational and rotational 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. Therefore, how much radiation a particular gas will absorb depends not only on its mole fraction, but also on the mole fractions of all the other gases, especially those of similar structure.

A convenient way to quantify these ideas is with the notion of effective pressure, P_e . Effective pressure can be defined as a weighted sum of partial pressures, where each is weighted by an

appropriate pressure broadening coefficient a_i , which relates how that gas absorbs relative to Nitrogen.

$$P_e = \sum a_i p_i \quad 1-3$$

Note that we can re-write Equation (1-3) as

$$\begin{aligned} P_e &= P \sum a_i x_i \\ &= P(1 + \sum (a_i - 1)x_i) \end{aligned} \quad 1-4$$

For example, consider a mix of Nitrogen, Oxygen, water vapor, and CO₂. The effective pressure is

$$P_e = P(1 + (a_{N_2} - 1)x_{N_2} + (a_{O_2} - 1)x_{O_2} + (a_{H_2O} - 1)x_{H_2O} + (a_{CO_2} - 1)x_{CO_2}) \quad 1-5$$

If one sets out to measure the concentration of some gas in a mixture (e.g. CO₂ in air) by infrared absorption, then one must also know the effective pressure. But knowing effective pressure means knowing concentration, so there seems to be a problem.

We sidestep the dilemma by introducing the effective pressure of *foreign* gases (gases other than the one being measured at the moment). Thus, the effective pressure for the i^{th} gas in a mixture is

$$P_{ei} = P \left(1 + \sum_j (a_{ij} - 1)x_j \right) \quad 1-6$$

where j sums over the gases, and we denote the band broadening coefficients as a_{ij}

$$a_{ij} = \begin{cases} a_j & (i \neq j) \\ 1 & (i = j) \end{cases} \quad 1-7$$

which effectively takes concentration x_i out of the equation for P_{ei} . We also introduce the symbol ψ_i to represent the weighted sum of the foreign gases' interfering behavior.

$$\begin{aligned}
 P_{ei} &= P \left(1 + \sum_j (a_{ij} - 1)x_j \right) \\
 &= P\psi_i
 \end{aligned}
 \tag{1-8}$$

Bear in mind that ψ_i is a function of all the concentrations of the foreign (non- i) gases in the mixture.

Relating Absorptance to Concentration

The scaling law of Jaimeson et. al. (1963) shows the effect of pressure on infrared absorption. If the amount of absorber u_i (mol m⁻²) of some gas i and the absorptance α_i are related by function $h_i()$, then they both scale by effective pressure P_{ei} :

$$\frac{\alpha_i}{P_{ei}} = h_i \left(\frac{u_i}{P_{ei}} \right)
 \tag{1-9}$$

If we introduce path length L (m), then the mole density ρ_i (mol m⁻³) of the gas is given by

$$\rho_i = \frac{u_i}{L}
 \tag{1-10}$$

Since mole fraction x_i of gas i is $\frac{p_i}{P}$ and density ρ is given by the ideal gas law $\rho = \frac{P}{RT}$, we can write

$$x_i = \frac{p_i}{P}$$

$$\begin{aligned}
 &= \frac{\frac{P_{ei}}{L} h_i^{-1} \left(\frac{\alpha_i}{P_{ei}} \right)}{\frac{P}{RT}} \\
 &= T \frac{P_{ei}}{P} f_i \left(\frac{\alpha_i}{P_{ei}} \right) \\
 &= T \psi_i f_i \left(\frac{\alpha_i}{\psi_i P} \right)
 \end{aligned}
 \tag{1-11}$$

To determine the calibration function $f_i()$, one would plot $\frac{x_i}{\psi_i T}$ against $\frac{\alpha_i}{\psi_i P}$, and fit a curve. In practice, the ψ_i term can be set to

1 if interfering gases a) are not present during calibration (e.g. no water vapor in the CO₂ calibration gas), or b) are present in the same concentration as there will be for subsequent measurements (e.g. use “CO₂ in air” calibration tanks, so the O₂ concentration will be correct).

Measuring Absorptance

Given a source with radiant power Φ and a detector at distance L , in the absence of reflection, absorptance by gas i can be determined from

$$\begin{aligned}
 \alpha_i &= 1 - \tau_i \\
 &= 1 - \frac{\Phi_i}{\Phi_o}
 \end{aligned}
 \tag{1-12}$$

where τ_i is the transmittance through gas i , Φ_i is the transmitted radiant power in the absorption band with some concentration of gas i present, and Φ_o is the transmitted radiant power in the absorption band with zero concentration of i present.

The LI-7000 is a dual optical path analyzer, and can determine absorptance by comparing the received power through the measurement path with the received power through the reference path. Thus,

$$\alpha_i = 1 - \frac{W_i}{W_{io}} \quad 1-13$$

where W_i is the power received from the source through a cell with gas i present, and W_{io} is the power received through a cell containing no gas i . What if the pressures and temperatures of the two paths are different? And what if neither path actually has 0 concentration?

We designate the two cells of the LI-7000 as A and B, with cell A as the reference cell. The temperature and pressure of the cells is T_A , T_B , P_A , and P_B , and the measured power received through each cell for gas i is W_{iA} and W_{iB} . Adapting Equation (1-13) for each cell yields:

$$\alpha_{iA} = 1 - \frac{W_{iA}}{W_{io}} \quad 1-14$$

$$\alpha_{iB} = 1 - \frac{W_{iB}}{W_{io}} Z_i \quad 1-15$$

Note the presence of a zeroing term Z_i in the B cell absorptance equation. We can now write an equation for the cell A concentration, based on Equation (1-11):

$$x_{iA} = \psi_{iA} T_A f_i \left(\frac{\alpha_{iA}}{\psi_{iA} P_A} S_i \right) \quad 1-16$$

Note the presence of a span adjustment term S_i .

If we know the concentration in cell A (x_{iA}), we can solve Equation (1-16) for absorptance:

$$\alpha_{iA} = \frac{\psi_{iA} P_A}{S} f_i^{-1} \left(\frac{x_{iA}}{\psi_{iA} T_A} \right) \quad 1-17$$

which allows us to compute W_{iO} :

$$\begin{aligned} W_{iO} &= \frac{W_{iA}}{1 - \alpha_{iA}} \\ &= \frac{W_{iA}}{1 - \frac{\psi_{iA} P_A}{S_i} f_i^{-1} \left(\frac{x_{iA}}{\psi_{iA} T_A} \right)} \end{aligned} \quad 1-18$$

If the concentration is in fact 0, and because $f_i^{-1}(0) = 0$, then $W_{iO} = W_{iA}$. The concentration in cell B can then be computed from

$$\begin{aligned} x_{iB} &= \psi_{iB} T_B f_i \left(\frac{\alpha_{iB}}{\psi_{iB} P_B} \right) \\ &= \psi_{iB} T_B f_i \left(\frac{1 - \frac{W_{iB}}{W_{iO}} Z_i}{\psi_{iB} P_B} \right) \\ &= \psi_{iB} T_B f_i \left(\frac{1 - \left(\frac{W_{iB}}{W_{iA}} \left(1 - \frac{\psi_{iA} P_A}{S_i} f_i^{-1} \left(\frac{x_{iA}}{\psi_{iA} T_A} \right) \right) \right) Z_i}{\psi_{iB} P_B} S_i \right) \end{aligned} \quad 1-19$$

Equation (1-19) is written in three ways, first in terms of α_{iB} , then W_{io} , and then x_{iA} . In normal operation x_{iA} is known, so the final expression in Equation (1-19) is the useful one. Thus, determining the concentration of cell B requires knowing the concentration of cell A.

The middle expression in Equation (1-19) raises an interesting possibility, however; if the value of W_{io} could somehow be known, then not only could x_{iB} be determined, but also x_{iA} . Is it possible to determine W_{io} once using a known cell A concentration, then continue to use that W_{io} value when the concentrations in both cells are unknown? The answer is a qualified “yes”, and doing this is called **Reference Estimation Mode (REM)**.

Reference Estimation Mode

In its normal operating mode, W_{io} is updated at 600Hz based on a known cell A concentration. Alternatively, the LI-7000 can operate in a mode in which W_{io} is assumed not to change. This is called **Reference Estimation Mode**, and while operating in this manner, the LI-7000 will continually use the assumed value of W_{io} to compute reference (A) cell concentration x_{iA} using Equation (1-16), in addition to computing the cell B concentrations.

The theoretical advantage of REM is obvious; one gets a second IRGA for free. That is, one can (theoretically, at least) make independent measurements of gas concentration in both cells.

The reality of REM, however, is that the computations of concentrations x_{iA} and x_{iB} are only as good as the assumed value of W_{io} . So, just how stable is W_{io} ? What can make it change?

Anything that affects radiation transmission through the cell will affect W_{io} , and the list of such things includes dirt in the cell, time (source aging, detector aging), and temperature. While temperature changes will introduce errors slowly, dirt has the greatest potential to change things the fastest, since a speck of it can appear on or disappear from a cell window in an instant, and have a sizeable effect on what the value of W_{io} should be.

Therefore, with well-filtered air, REM should give good accuracy for the values of x_{iA} and x_{iB} at least for a few minutes at a time, but there's no guarantee; the first change in dirt, and there could be significant errors. There remains an advantage, however; as W_{io} becomes more and more erroneous, the difference between x_{iA} and x_{iB} is much more accurate than the absolute value of either quantity. Thus, the usefulness of REM is for times when one needs a good differential measurement when both air streams are changing, but an accurate measure of either stream is not needed.

At the start of REM, and periodically¹ thereafter, W_{io} should be updated. This is accomplished by the "Make Cell A Read..." calibration directive (see Section 6, *Overview*), which computes Equation (1-18) based on the target value specified.

Figures 1-2 and 1-3 illustrate the performance of Reference Estimation Mode. Figure 1-2 shows the results of running an LI-7000 in REM for 72 hrs with 0 ppm in one cell, and 330 ppm in the other. The IRGA was in a greenhouse, and subject to diurnal temperature swings. Note that the error in CO2A and CO2B varies directly with temperature, at a rate of about 1 ppm per °C in the experiment. Note too, that the error in CO2D (the differential) is about half the magnitude of the errors in either CO2A or CO2B, and is about 0.5 ppm per °C. Figure 1-3 shows a similar experiment, only this time there is 500 ppm in both cells. Now the error is about 2 ppm/°C in CO2A and CO2B, but the error in CO2D is < 0.01 ppm per °C.

REM performance summary:

- 1) Temperature changes are a significant source of error in the absolute concentrations of cell A or B.
- 2) The error in the differential measurement is less than the errors in cell A and B.
- 3) The error in the differential measurement is proportional to the differential.

Thus, REM is best suited to stable temperatures and small differentials.

1 Getting Acquainted

1. Minutes, or hours, or days, depending on the potential for dirt, temperature changes, and your error tolerance threshold.

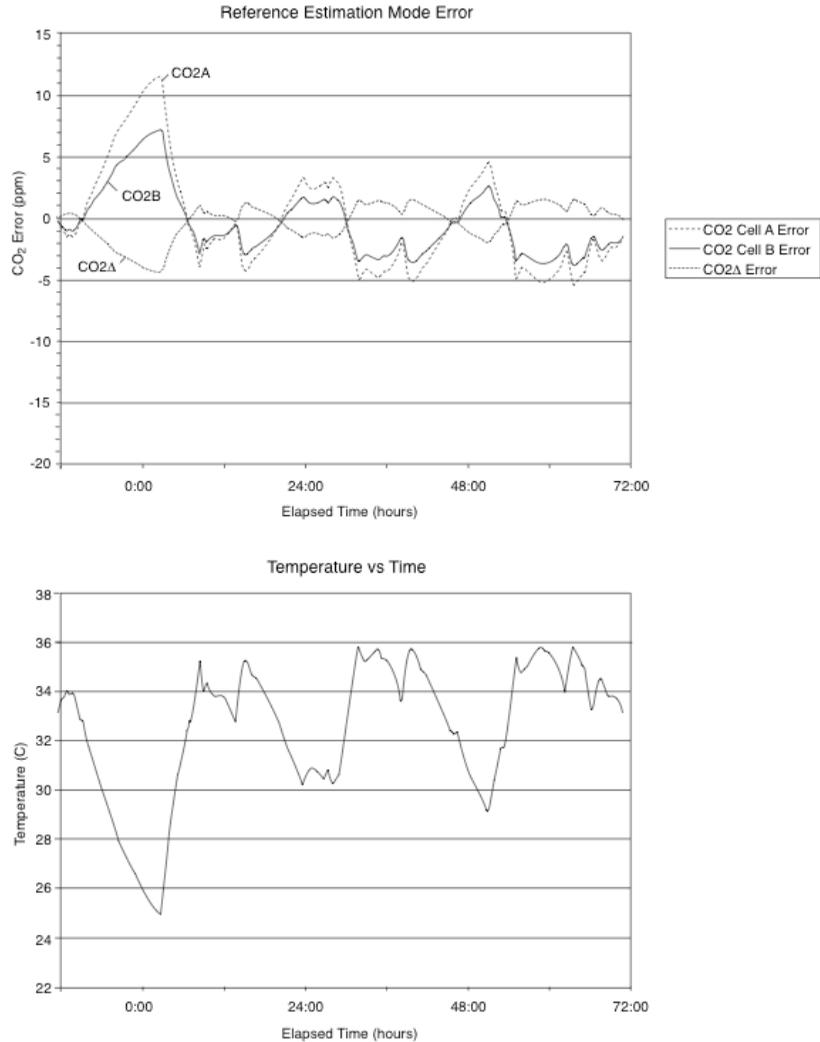


Figure 1-2. REM performance with 0 ppm in one cell and 330 ppm in the other cell.

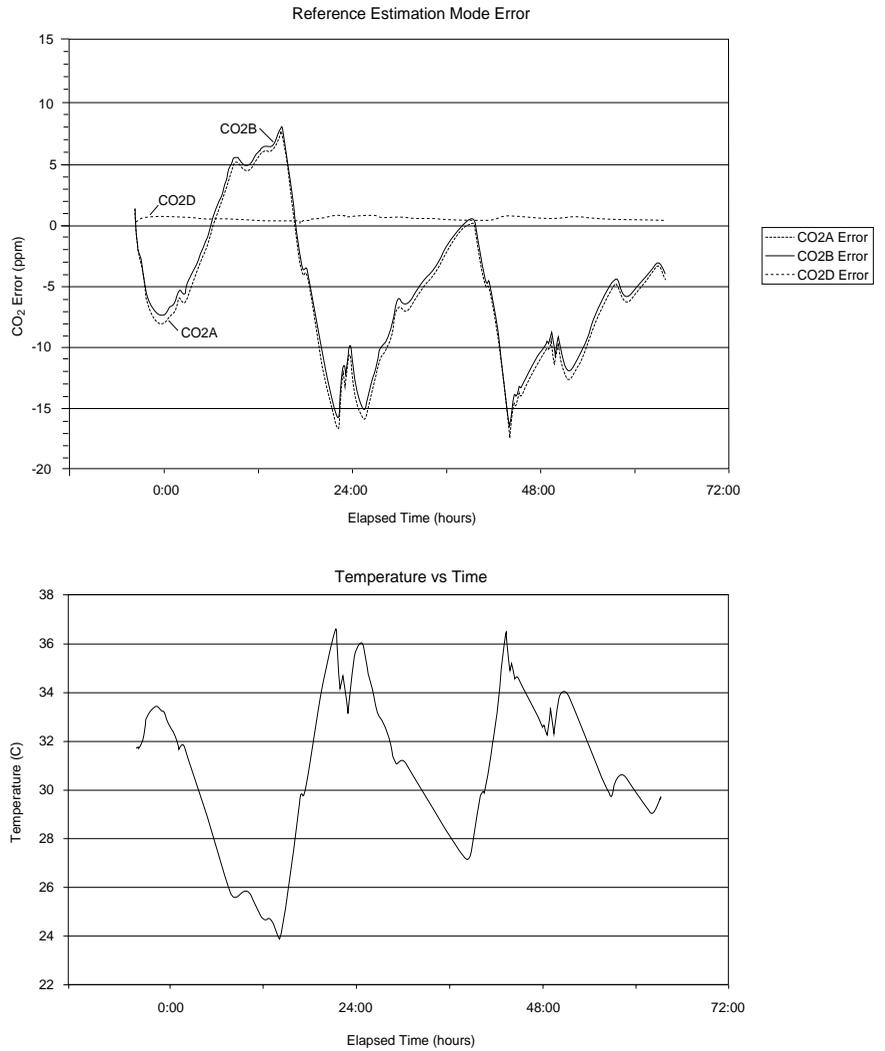


Figure 1-3. REM performance with 500 ppm in both cells.

The Zero Adjustment

Fundamentally, the zero (matching) adjustment term Z_i in Equation (1-15) is present to compensate for any differences in the two optical paths besides concentration differences. While variations in filters or window material, and inhomogeneities in source or detector contribute to such differences, the largest potential comes from dirt or foreign matter depositing on the cell windows. In addition there are two other factors that influence how the cells match; temperature and concentration.

Temperature

LI-7000s exhibit a slight zero shift with temperature, typically less than $\pm 0.3 \mu\text{mol mol}^{-1}$ per $^{\circ}\text{C}$ for CO_2 , and $\pm 0.02 \text{ mmol mol}^{-1}$ for H_2O . This drift is characterized during factory calibration, and compensated for in software, as shown below.

Concentration

The LI-7000 is matched by putting the same concentration in both cells. However, if this is done at one concentration, then checked at another, the match may have shifted. This is an individual IRGA characteristic; some are more sensitive than others. The LI-7000 has software compensation for this.

The zero adjustment term Z_i is implemented in the LI-7000 as

$$Z_i = z_i + z_{im}x_{iA} + z_{it}T \quad 1-20$$

where z_{it} accounts for zero drift with temperature, and z_{im} accounts for the concentration effect. z_{it} is measured during factory calibration, and is in essence a calibration coefficient. z_i and z_{im} are set by the user by performing the “Make Cell B Match Cell A” calibration directive. If the same air is in both cells,

$$x_{iA} = x_{iB}$$

$$x_{iA} = \psi_{iB} T_B f_i \left[\frac{1 - \left(\frac{W_{iB}}{W_{iA}} \left(1 - \frac{\psi_{iA} P_A}{S_i} f_i^{-1} \left(\frac{x_{iA}}{\psi_{iA} T_A} \right) \right) \right) Z_i}{\psi_{iB} P_B} S_i \right]$$

$$f_i^{-1} \left(\frac{x_{iA}}{\psi_{iB} T_B} \right) = \frac{1 - \left(\frac{W_{iB}}{W_{iA}} \left(1 - \frac{\psi_{iA} P_A}{S_i} f_i^{-1} \left(\frac{x_{iA}}{\psi_{iA} T_A} \right) \right) \right) Z_i}{\psi_{iB} P_B} S_i \quad 1-21$$

$$\frac{\psi_{iB} P_B}{S_i} f_i^{-1} \left(\frac{x_{iA}}{\psi_{iB} T_B} \right) = 1 - \left(\frac{W_{iB}}{W_{iA}} \left(1 - \frac{\psi_{iA} P_A}{S_i} f_i^{-1} \left(\frac{x_{iA}}{\psi_{iA} T_A} \right) \right) \right) Z_i$$

Solving this for Z_i yields

$$Z_i = \frac{W_{iA} \left(1 - \frac{\psi_{iB} P_B}{S_i} f_i^{-1} \left(\frac{x_{iA}}{\psi_{iB} T_B} \right) \right)}{W_{iB} \left(1 - \frac{\psi_{iA} P_A}{S_i} f_i^{-1} \left(\frac{x_{iA}}{\psi_{iA} T_A} \right) \right)} \quad 1-22$$

If the pressures, temperatures, and foreign gases are the same on both sides, then the expression simplifies considerably

$$Z_i = \frac{W_{iA}}{W_{iB}} \quad 1-23$$

and we can expand Z_i (Equation 1-20) and solve for z_i or z_{im} . (Note too, that without similar pressure, temperature, and foreign gases, Z_i would be a function of span S_i). As implemented in the LI-7000, either can be set using “Make Cell B match Cell A”. If the concentration in cell A is low ($<20 \mu\text{mol mol}^{-1}$ for CO_2 , or $<2 \text{mmol mol}^{-1}$ for H_2O), then z_i is computed:

$$z_i = \frac{W_{iA}}{W_{iB}} - z_{im}x_{iA} - z_{it}T \quad 1-24$$

If the concentration in cell A is above those thresholds, then z_{im} is computed:

$$z_{im} = \frac{\frac{W_{iA}}{W_{iB}} - z_i - z_{it}T}{x_{iA}} \quad 1-25$$

Thus, a 2-step match of the instrument is done by:

1. Putting 0 concentration in both cells, and doing “Make Cell B Match Cell A”.
2. Putting a higher concentration in both cells, and doing “Make Cell B Match Cell A” again.

Operational details are described in Section 6, *Calibration Instructions*.

The Span Adjustment

The span parameter S_i is set by putting a known concentration in cell B, and using the “Make Cell B Read...” calibration option. S_i is computed based on Equation (1-19). If the target concentration is x_{iT} , then

$$x_{iT} = \psi_{iB} T_B f_i \left(\frac{\alpha_{iB}}{\psi_{iB} P_B} S_i \right) \quad 1-26$$

Solving for S_i yields

$$S_i = \frac{\psi_{iB} P_B}{\alpha_{iB}} f_i^{-1} \left(\frac{x_{iT}}{\psi_{iB} T_B} \right)$$

$$\begin{aligned}
 &= \frac{\psi_{iB} P_B}{1 - \frac{W_{iB}}{W_{iO}} Z_i} f_i^{-1} \left(\frac{x_{iT}}{\psi_{iB} T_B} \right) \\
 &= \frac{\psi_{iB} P_B f_i^{-1} \left(\frac{x_{iT}}{\psi_{iB} T_B} \right)}{1 - \frac{W_{iB} \left(1 - \frac{\psi_{iA} P_A}{S_i} f_i^{-1} \left(\frac{x_{iA}}{\psi_{iA} T_A} \right) \right)}{W_{iA}} Z_i}
 \end{aligned} \tag{1-27}$$

Solving for S_i (it still appears on both sides of the Equation (1-27)) yields

$$S_i = \frac{\psi_{iB} P_B f_i^{-1} \left(\frac{x_{iT}}{\psi_{iB} T_B} \right) - \frac{W_{iB}}{W_{iA}} Z_i \psi_{iA} P_A f_i^{-1} \left(\frac{x_{iA}}{\psi_{iA} T_A} \right)}{1 - \frac{W_{iB}}{W_{iA}} Z_i} \tag{1-28}$$

Since S_i depends on Z_i , Z_i should be set first. Thus, “Make Cell B Match Cell A” should be performed before “Make Cell B Read...”.

Operational details are described in Section 6, *Calibration Instructions*.

H₂O Equation Summary

In a mixture of air, the gases that most affect how water vapor absorbs radiation are CO₂ and O₂. Since CO₂ concentrations are small (over the calibrated range of the LI-7000) compared to water vapor concentrations, we neglect them when determining effective pressure for water vapor. O₂ is neglected with the assumption that the O₂ concentration is the same when determining the calibration function as when operating. Thus,

$$\psi_w = 1 \quad 1-29$$

Also, we assume that both cells are at the same pressure and temperature

$$\begin{aligned} T_A &= T_B = T \\ P_A &= P_B = P \end{aligned} \quad 1-30$$

Table 1-1 summarizes the equations used by the LI-7000 for its computations of water vapor. The ID and Label columns identify the system values that are available for display or output.

Table 1-1. LI-7000 H₂O Equation Implementation

Symbol/Equation	Description	ID	Label
W_{wA}	Raw value, cell A	52	H2OA W
W_{wB}	Raw value, cell B	53	H2OB W
$\alpha_{wA} = 1 - \frac{W_{wA}}{W_{wo}}$	A cell H ₂ O absorbance	56	H2OA abs
$\alpha_{wB} = 1 - \frac{W_{wB}}{W_{wo}} (z_{sw} + z_{swm} X_{wA} + z_{wl} T)$	B cell H ₂ O absorbance	57	H2OB abs
$W_{wo} = \frac{W_{wA}}{1 - \frac{P}{S_w} f_w^{-1} \left(\frac{X_{wA}}{T} \right)}$ (Known reference mode)	Raw value for zero absorption		(Not available. However, when $X_{wA} = 0$, then $W_{wo} = W_{wA}$)
$X_{wA} = Tf_i \left(\frac{\alpha_{wA}}{P} S_w \right)$ (Reference estimation mode)	H ₂ O in cell A, mmol mol ⁻¹	04	H2OAmn/m
$X_{wB} = Tf_w \left(\frac{\alpha_{wB}}{P} S_w \right)$	H ₂ O in cell B, mmol mol ⁻¹	05	H2OBmn/m
$X_{wB} - X_{wA}$	H ₂ O differential, mmol mol ⁻¹	06	H2OΔmn/m
$P_{wA} = X_{wA} \frac{P}{1000}$	H ₂ O in cell A, kPa	13	H2OA kPa
$P_{wB} = X_{wB} \frac{P}{1000}$	H ₂ O in cell B, kPa	14	H2OB kPa
$P_{wB} - P_{wA}$	H ₂ O differential, kPa	15	H2OΔ kPa
$T_{dA} = \frac{240.97 \ln \left(\frac{P_{wA}}{0.61365} \right)}{17.502 - \ln \left(\frac{P_{wA}}{0.61365} \right)}$	Dewpoint cell A, °C	16	H2OA °C

1 Getting Acquainted

Symbol/Equation	Description	ID	Label
$T_{dB} = \frac{240.97 \ln\left(\frac{P_{wB}}{0.61365}\right)}{17.502 - \ln\left(\frac{P_{wB}}{0.61365}\right)}$	Dewpoint cell B, °C	17	H2OB °C
$T_{dB} - T_{dA}$	Differential dewpoint, °C	18	H2OA °C

CO₂ Equation Summary

The dominant foreign gases are water vapor and oxygen. We neglect the latter by assuming the calibration function is determined with the same O₂ concentration as when it is used after initial calibration. Water vapor, however, must be accounted for. This is not a problem, since it is measured in the LI-7000.

$$\psi_c(x_w) = 1 + (a_w - 1)x_w \quad 1-31$$

The value of a_w (referenced against dry air) has been determined empirically to be 1.5. Pressure and temperature for both cells are assumed to be the same (Equation (1-30)).

Table 1-2 summarizes the equations used by the LI-7000 for its computations of CO₂. The ID and Label columns identify the system values that are available for display or output.

Table 1-2. LI-7000 CO₂ Equation Implementation

Symbol/Equation	Description	ID	Label
W_{cA}	Raw value, cell A	50	CO2A W
W_{cB}	Raw value, cell B	51	CO2B W
$\alpha_{cA} = 1 - \frac{W_{cA}}{W_{co}}$	A cell CO ₂ absorptance	54	CO2A abs
$\alpha_{cB} = 1 - \frac{W_{cB}}{W_{co}} (z_c + z_{cm} X_{cA} + z_{ct} T)$	B cell CO ₂ absorptance	55	CO2B abs
$W_{co} = \frac{W_{cA}}{1 - \frac{\psi_c(x_{wA})P}{S_c} f_c^{-1} \left(\frac{x_{cA}}{\psi_c(x_{wA})T} \right)}$ (Known reference mode)	Reference raw value	(Not available. However, when $X_{cA} = 0$, then $W_{co} = W_{cA}$)	
$X_{cA} = T \psi_c(x_{wA}) f_c \left(\frac{\alpha_{cA}}{\psi_c(x_{wA})P} S_c \right)$ (Reference estimation mode)	CO ₂ in cell A, $\mu\text{mol mol}^{-1}$	04	CO2A $\mu\text{m/m}$
$X_{cB} = T \psi_c(x_{wB}) f_c \left(\frac{\alpha_{cB}}{\psi_c(x_{wB})P} S_c \right)$	CO ₂ in cell B, $\mu\text{mol mol}^{-1}$	05	CO2B $\mu\text{m/m}$
$X_{cB} - X_{cA}$	CO ₂ differential, $\mu\text{mol mol}^{-1}$	06	CO2 Δ $\mu\text{m/m}$
$P_{cA} = X_{cA} \frac{P}{1000}$	CO ₂ in cell A, Pa	10	CO2A Pa
$P_{cB} = X_{cB} \frac{P}{1000}$	CO ₂ in cell B, Pa	11	CO2B Pa
$P_{wB} - P_{wA}$	CO ₂ differential, Pa	12	CO2 Δ Pa

Temperature and Pressure Equation Summary

The raw signal (V, measured in Cell B) from the pressure transducer can be converted to pressure in kPa using the offset (A_0) and slope (A_1) found on the Calibration coefficients sheet. Pressure is computed as

$$P \text{ (kPa)} = A_0 + A_1 \times (V/2) \quad 1-32$$

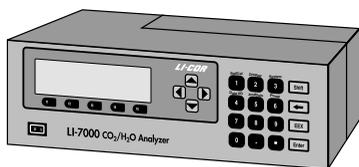
The LI-7000 uses a thermistor, and the Steinhart-Hart equation to determine cell temperature. Cell temperature T (degrees C, Sys ID#23) is computed from

$$T = 1/[A + B \ln(R) + C \ln(R)^3] - 273.15 \quad 1-33$$

where

$$R = 500,000/(V + 2.5) - 100,000$$

And V is the temperature signal (volts), Sys ID#67.



2 Setup & Operation

Power Connections

If a LI-COR rechargeable battery is being used, connect it to either of the 10.5-16.5VDC battery connectors on the rear panel.

One set of battery leads with a 3-pin plug is included in your spare parts kit for connection to a user-supplied, lead acid battery (10.5 - 16.5VDC, 4 amp maximum current required) or other DC power supply.

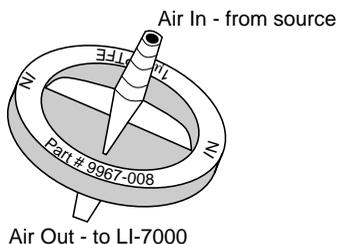
If AC line voltage (100-240VAC) is being used, plug the line cord into the receptacle on the back panel. Note that the LI-7000 will slow charge (~200 mA) connected batteries if AC power is being used.

If the LI-7000 is plugged in and fails to power up, check fuses F1, F2, and F3 to see if any have blown. There are extra fuses in the spare parts kit. Fuses F1 and F2 (1.0A and 0.5A slow blow, depending on voltage; 1.0A for 115V or 0.5A for 230V) protect the AC power input. Fuse F3 (4A fast blow) protects the DC power input.

Two batteries can be connected at one time. If one is charged and one not, however, disconnect the weaker one as soon as possible after connecting the charged one.

2 Setup & Operation

Air Connections



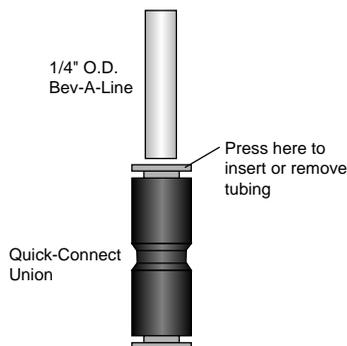
Filters

We recommend that all air should be filtered before it flows through the optical cells or the internal pump. LI-COR supplies filter assemblies designed for this purpose; Gelman filter assemblies (part #9967-008) are located in the spare parts kit.

The Gelman Acro 50 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. The filters are fitted with hose barbs at LI-COR for connection to 1/4" O.D. Bev-A-Line tubing or equivalent.

The frequency with which the filters need to be replaced will depend upon the operating environment. Change the filters if you notice the flow rate dropping.

Before installing a new filter, blow clean dry air through it in the normal direction of flow to remove any fibers or other debris that may be loose inside.



Some quick-connect unions are also included in the spares kit (part #300-03123) for simple connection to 1/4" O.D. Bev-A-Line tubing. Old filters can be removed by pressing the orange ring toward the center of the connector and pulling off the Bev-A-Line tubing. Attach the 1/4" (0.64 cm) O.D. Bev-A-Line tubing to the new filter(s) and insert the tubing into the coupling.

Install the new filter(s) with the blue lettering facing *away from* the **Cell A or B Inlet** port (Figures 2-1, 2-2, 2-3).

See *Example Operational Setups* below for some example configurations.

It is very important that incoming air be filtered. This is because any dirt in either cell will cause an immediate zero shift.

Pump

The auxiliary pump inside the LI-7000 case can provide approximately 1 liter per minute of air flow. The maximum allowable pressure through the LI-7000 optical cells is 115 kPa with the pressure sensor attached; with the sensor detached, flow rates are limited to 200 kPa.

In a typical configuration, the on-board auxiliary pump might be used to provide a dry, CO₂-free gas to Cell A, by flowing air through a desiccant/scrubber tube. A second, user-supplied pump might then be used to flow the sample gas through Cell B.

Tubing Recommendations

Bev-A-Line™ tubing (1/4" O.D.) is included in the spares kit for use with the LI-7000. Bev-A-Line is an ethylene vinyl acetate tubing, lined with polyethylene. CO₂ can diffuse through Bev-A-Line tubing; water, too, can absorb and desorb from the tubing walls. In general, this means that you should limit the length of tubing between the filter and the inlet ports on the LI-7000 whenever possible.

Other types of tubing can be used with the LI-7000, including flexible copper tubing for more permanent installations.

2 Setup & Operation

Gas Connections

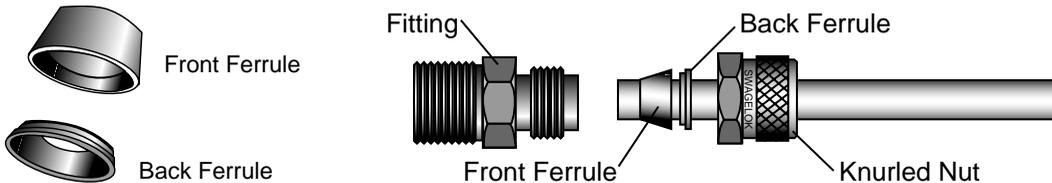
The internal pump is provided with rapid tube fittings for use with 1/4" O.D., 1/8" I.D. plastic tubing.

The sample cell ports are threaded female 1/8" NPT and will accept any fitting with 1/8" NPT male threads. These ports are also supplied with Swagelok® fittings. The Swagelok fittings are for use with 1/4" O.D. tubing. The plastic ferrules supplied with the Swagelok fittings are for use with plastic tubing, and for finger tightening.

Metal tubing can be used with the Swagelok fittings if metal ferrules are used (not supplied). See Swagelok literature for proper tightening of metal tube connections.

When using metal tubing, avoid transmitting mechanical stress forces to the analyzer. Coil loops can help in this regard.

Please note the orientation of the front and back ferrule, particularly the back.



Example Operational Setups

Any number of plumbing combinations are possible using the LI-7000; the following are simply a few examples of how you might configure the instrument. The first question that you should consider is what the reference gas consists of, and how it will be generated: for example, do you have a tank of compressed gas that will serve as the reference, or do you need to create a dry, CO₂-free gas using the scrubber tube included?

Next, consider the method that this gas will be pumped through the reference cell; do you want to use the auxiliary pump in the LI-7000, or do you have a separate pump outside the instrument that will be used? Lastly, consider how to provide the sample gas to cell B; again, the LI-7000 auxiliary pump, or a user-supplied pump can be used. Keep in mind, too, that air entering the auxiliary pump should always be filtered, as it is not protected with any internal filtering devices.

2 Setup & Operation

- **Example 1.** The LI-7000 auxiliary pump is used to provide the (filtered) sample gas to cell B. A compressed tank of nitrogen or other reference gas is input to cell A.

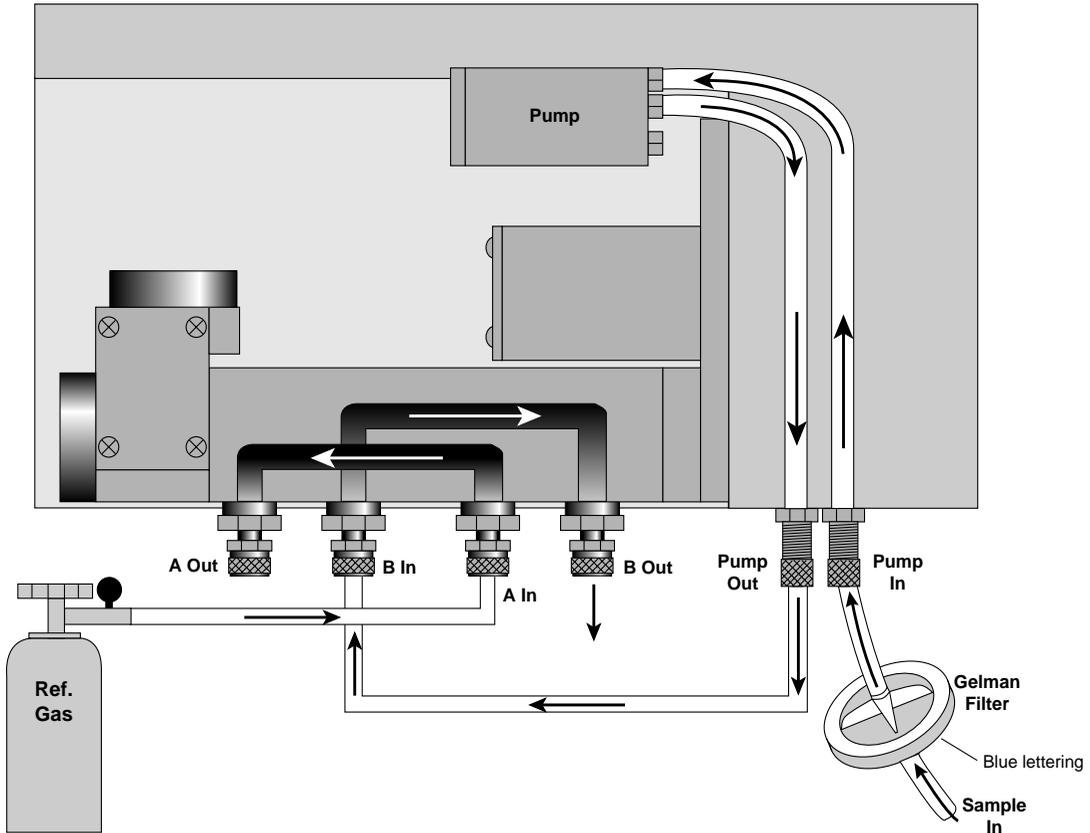


Figure 2-1. Plumbing configuration using reference gas tank and LI-7000 auxiliary pump.

- **Example 2.** A user-supplied pump is providing the sample gas to cell B. A tank of compressed nitrogen or other reference gas is sent to cell A. The LI-7000 auxiliary pump is not used.

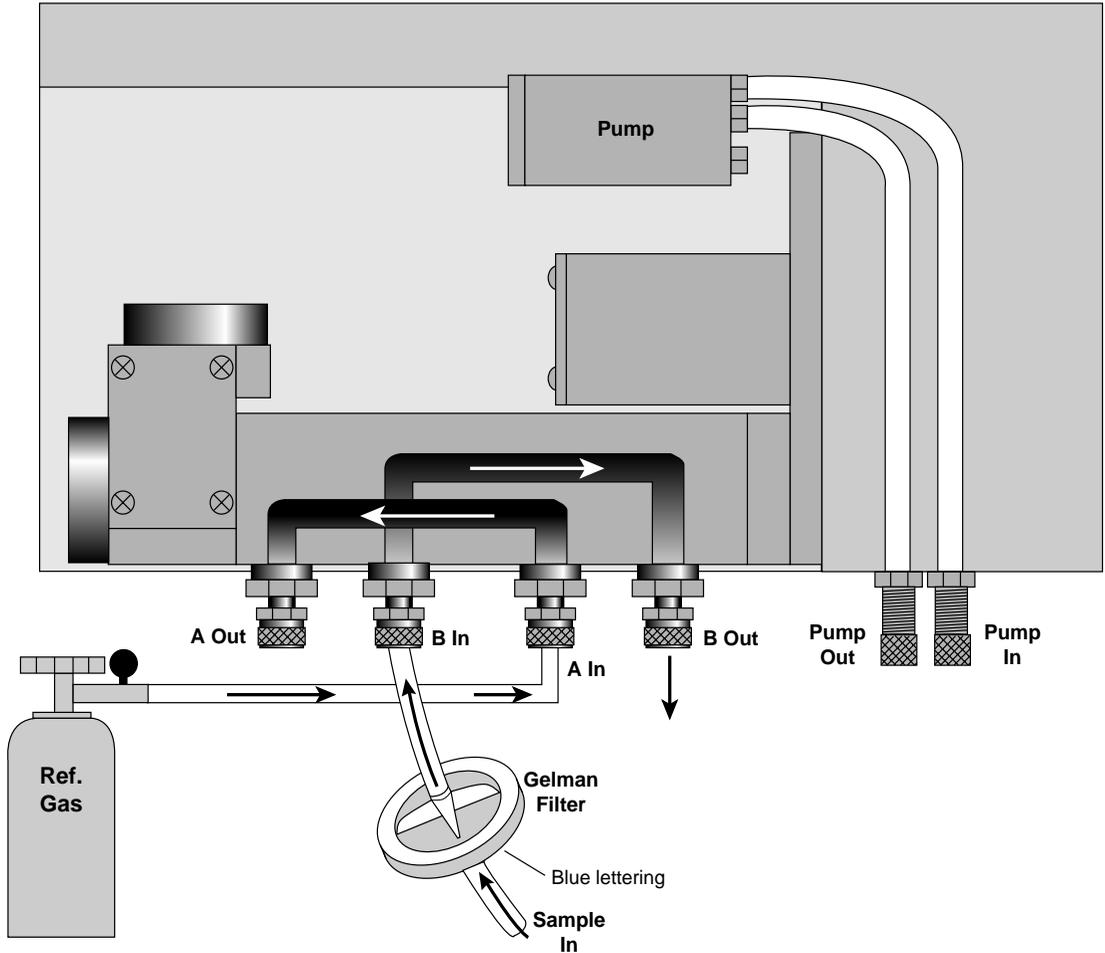


Figure 2-2. Plumbing configuration using reference gas tank and user-supplied pump for sample gas.

Using the External Scrubber Tube

The frequency with which the external chemicals must be replaced depends greatly on how much CO₂ and water vapor they are forced to remove.

There are several suitable CO₂ scrubbers (dry soda lime and Ascarite II), and H₂O scrubbers (Drierite and magnesium perchlorate); care should be taken in choosing which chemicals to use together for various applications. For the purposes of this discussion, we will use Ascarite II and magnesium perchlorate as the chemical scrubbing agents in the external scrubber column.

NOTE: LI-COR has written a publication that describes the use of chemical scrubbing agents with LI-COR gas analyzers. This publication, entitled "*Using CO₂ and H₂O Scrubbers with LI-COR Gas Analyzers*" is available free of charge from LI-COR. Ask for publication #IRG4-101.

When configured as shown in Figure 2-3 above, the chemicals will degrade rapidly, since they are purging CO₂ and water vapor from ambient air continuously. In this configuration, the chemicals may need to be changed every 24-48 hours of operation, or less.

IMPORTANT: Configure the tubing so that air first passes through the Ascarite II, followed by the magnesium perchlorate (or Drierite, in some cases¹).

Fill the tube about 1/2 to 2/3 full with magnesium perchlorate and from 1/3 to 1/2 full with Ascarite II, separated with a small piece of fiberglass wool, as shown in Figure 2-4 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).

1. Magnesium perchlorate does not interact with CO₂. Drierite does.

2

Setup & Operation

Magnesium perchlorate cannot be regenerated after use. Dispose of properly.

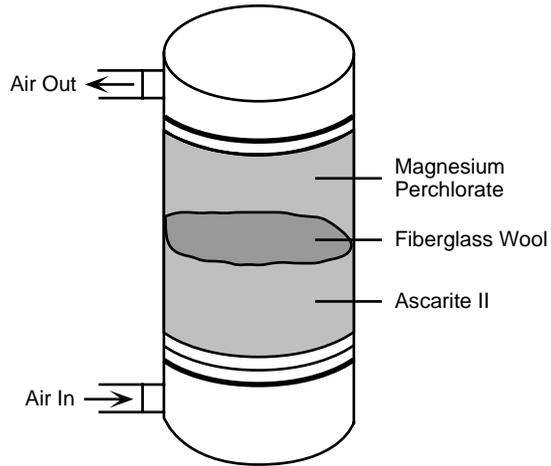
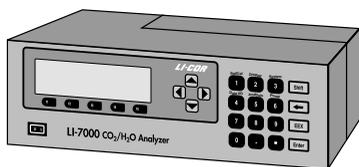


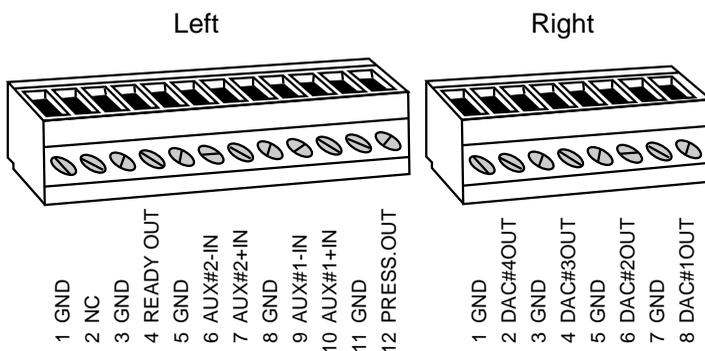
Figure 2-4. External scrubber tube assembly.



3 Interfacing

Using the Terminal Strips

The terminal strips are located on the back panel of the LI-7000. To connect the wires, insert the bare wire end into the appropriate terminal and tighten the screw above that terminal using a small flat blade screwdriver. The front plug of the terminal strips can be removed to aid in connecting the wires; pull straight out on the face to remove. There is an extra 12-pin (LI-COR part no. 331-05232; Phoenix Contact part no. 1827224) and 8-pin plug (LI-COR part no. 331-05234; Phoenix Contact part no. 1827185) in the spares kit should either become lost or damaged.



3 Interfacing

The terminal positions are as follows, reading left to right:

<u>Terminal</u>	<u>Label</u>	<u>Description</u>
L1	GND	Ground
L2	NC	No connect
L3	GND	Ground
L4	READY OUT	IRGA Ready indicator (0V OK, 5V not ready)
L5	GND	Ground
L6	AUX #2 - IN	Auxiliary Input #2 negative
L7	AUX #2 + IN	Auxiliary Input #2 positive
L8	GND	Ground
L9	AUX #1 - IN	Auxiliary Input #1 negative
L10	AUX #1 + IN	Auxiliary Input #1 positive
L11	GND	Ground
L12*	PRESS. OUT	Pressure output

<u>Terminal</u>	<u>Label</u>	<u>Description</u>
R1	GND	Ground
R2	DAC #4 OUT	DAC Channel 4 output
R3	GND	Ground
R4	DAC #3 OUT	DAC Channel 3 output
R5	GND	Ground
R6	DAC #2 OUT	DAC Channel 2 output
R7	GND	Ground
R8	DAC #1 OUT	DAC Channel 1 output

* This is the raw signal (V) from the pressure transducer in Cell B; *divide this value by 2 before calculating pressure according to the equation below.* The signal can be converted to pressure in kPa using the offset (A_0) and slope (A_1) found on the Calibration coefficients sheet. Pressure is computed as

$$P \text{ (kPa)} = A_0 + A_1 \times (V/2) \qquad 3-1$$

Using the Auxiliary Inputs

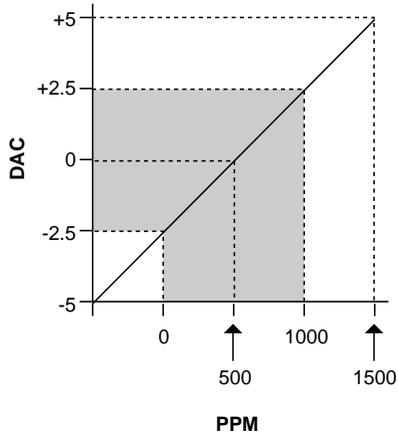
The LI-7000 has two auxiliary input channels (terminals L6-7 and L9-10) that can be used to input an analog signal from a user-supplied external sensor. CO₂ and H₂O references may be input through these channels. When using the auxiliary inputs, an LI-7000 GND terminal must be connected to the SIG GND or a common connection of the device providing the signal.

The auxiliary channels have an input voltage range of $\pm 2.5V$, and a bandwidth of 10 Hz.

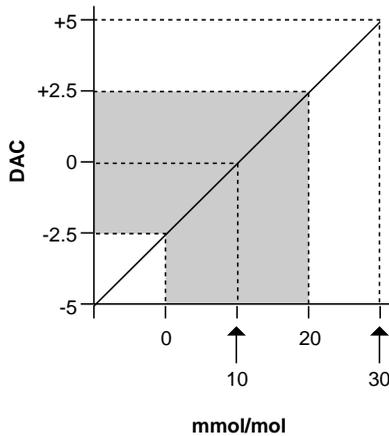
The following examples show how you can configure the LI-7000 to receive input signals from the LI-6262 CO₂/H₂O analyzer to provide CO₂ and/or H₂O reference values.

- **Example.** The LI-COR LI-6262 CO₂/H₂O analyzer is measuring CO₂ and H₂O concentrations of the reference air stream (0-1000 $\mu\text{mol/mol}$ CO₂, 0-20 mmol/mol H₂O) flowing to the LI-7000 and outputting the analog values to the LI-7000 terminal strip.

1. Connect the wires as shown in the diagram below.



- c. Use FCT 84 to designate channel code #32 (H₂O mmol/mol absolute) as the channel to output through analog output channel #2.
- d. For 0-20 mmol/mol to be output on the LI-6262 DAC as -2.5 to +2.5 volts, set FCT 85 and 86 to +10 mmol and 30 mmol, respectively.



3 Interfacing

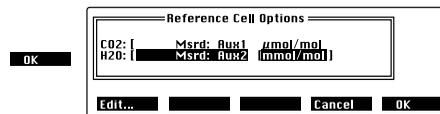
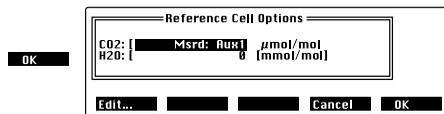
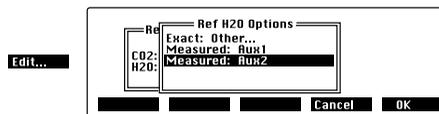
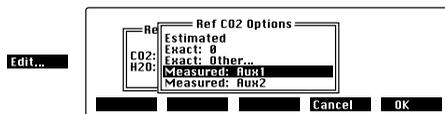
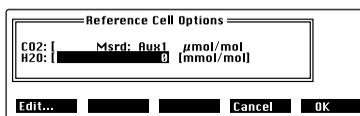
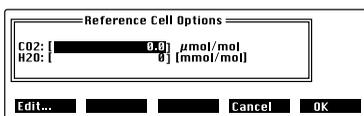
3. Configure the LI-7000 software:

Using the LI7000 PC Communications Software:

- Open the Configuration window and click on the Auxiliary tab.
- Under Auxiliary Input #1, set a0 = 500, a1 = 200, and a2 = 0. Note that a1 is the value of the multiplier, which in this case is 500 ppm/2.5V = 200.
- Under Auxiliary Input #2, set a0 = 10, a1 = 4, and a2 = 0.
- Click on the Reference tab and select Measured:Aux1 for CO2A, and Measured:Aux2 for H2OA. Click on mmol/mol under H2O Units.

Using the LI-7000 keypad:

- Press **Shift** then **1** to access the Ref/Cal menu (below).
- Press **f1** to access the Set Ref menu. Press **f1** (Edit) again and scroll to Measured:Aux1 to set the Reference CO₂ source. Press **f5** (OK).
- Highlight H₂O under Reference Cell Options and press **f1** (Edit).
- Scroll to Measured:Aux2 to set the Reference H₂O source. Press **f5** (OK). Press the right arrow button to move the highlight to the H₂O units and press **f1** (Edit) to toggle the units to mmol/mol, if necessary. Press **f5** (OK).



- Press **Shift** then **4** to access the Data I/O menu (below).

- f. Highlight the values under Aux1, press **f1** (Edit), and enter A=500, B=200, and C=0. Edit the values under Aux2 as A=10, B=4, and C=0. Press **f5** (OK).

Auxiliary Input			
Aux #1		Aux #2	
-----		-----	
A=[500]	A=[10]
B=[200]	B=[4]
C=[0]	C=[0]

Edit...

Cancel
OK

4. The LI-7000 is now configured to accept an analog signal from the LI-6262 and compute the CO₂ and H₂O reference cell concentrations. You can verify this by viewing source 01 (CO₂A μm/m), source 04 (H₂O A mm/m) on default display #1, or sources 20 and 21 (Aux1 and Aux2), which display the linearized signal at Aux1 and Aux2. The raw voltage signals at Aux1 and Aux2 can be viewed at sources 64 and 65, respectively, on default display #3.

3 Interfacing

Using the D/A Converters

There are four analog outputs labeled DAC1 through DAC4. Each of the DACs has an associated zero and full scale value, a data source, and a polarity. The polarity for DAC1 and DAC2 must be the same, while DAC3 and DAC4 have independent polarities. The polarity value is either unipolar (0 to +V_{max} output) or bipolar (-V_{max} to +V_{max} output). In addition, DAC3 and DAC4 also have a V_{max} parameter that can be 5V, 2.5V, 1.25V, or 0.625V. DAC1 and DAC2 have a V_{max} fixed at 5V.

	V _{max}	Unipolar Range	Bipolar Range
DAC 1	5V	0 to +5V	-5 to +5V
DAC 2	5V	0 to +5V	-5 to +5V
DAC 3	5V	0 to +5V	-5 to +5V
	2.5V	0 to +2.5V	-2.5 to +2.5V
	1.25V	0 to +1.25V	-1.25 to +1.25V
	0.625V	0 to +0.625V	-0.625 to +0.625V
DAC 4	5V	0 to +5V	-5 to +5V
	2.5V	0 to +2.5V	-2.5 to +2.5V
	1.25V	0 to +1.25V	-1.25 to +1.25V
	0.625V	0 to +0.625V	-0.625 to +0.625V

Scaling

To convert the output signal back into meaningful units, use

$$X = (X_F - X_Z) \frac{V}{V_{\max}} + X_Z \quad 3-1$$

where V is the output signal in volts, V_{max} is full scale (5, 2.5, 1.25, etc.), X_Z is zero value entered in DAC setup, and X_F is full scale value in DAC setup.

For example, if the variable of interest is CO_2 , $\mu\text{m/m}$, V_{max} is set for 0-2.5V output, $X_Z = 0$, $X_F = 3000$, and the measured voltage output is 1.5V, Equation 3-1 would take the form

$$CO_2 = (3000 - 0) \frac{1.5}{2.5} + 0 \quad 3-2$$

= 1800 ppm.

Resolution

The DACs are 14-bit bipolar devices, so the resolution can be calculated according to $(\text{voltage range } V_{\text{max}})/V_{\text{max}}^{14}$. Because the voltage ranges can go positive or negative, the resolution in *bipolar* mode is $\pm V_{\text{max}}/2^{14} = V_{\text{max}}/2^{13}$. This corresponds to 0.61 mV on the 5V range. In *unipolar* mode, the resolution is $V_{\text{max}}/2^{14}$, which corresponds to approximately 0.305 mV on the 5V range. The smallest difference that can be resolved for any variable X is given by

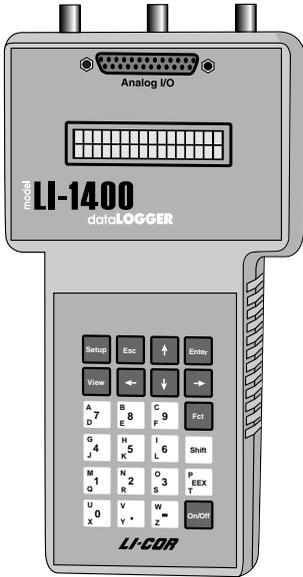
$$\Delta X = 2^{-13} (X_F - X_0) = 1.22 \times 10^{-4} (X_F - X_0) \quad [5V \text{ bipolar}]$$

or

$$\Delta X = 2^{-14} (X_F - X_0) = 0.61 \times 10^{-4} (X_F - X_0) \quad [5V \text{ unipolar}]$$

As an example, if $V_{\text{max}} = 5V$, $X_F = 1000$ ppm and $X_0 = 0$ ppm, the resolution will be 0.122 ppm (bipolar mode) or approximately 0.061 ppm (unipolar mode). Note that resolution in unipolar mode is approximate, because in this mode the DACs go very slightly negative.

3 Interfacing

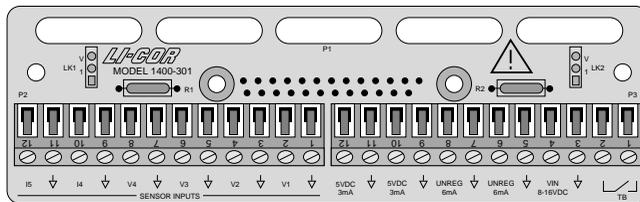


Connecting the LI-7000 to the LI-1400 Datalogger

The following example shows how you can connect the LI-7000 to a datalogging device such as the LI-COR Model LI-1400 DataLogger to collect analog data and convert to meaningful values for the variable of interest.

The LI-1400 can be used to monitor voltage signals up to ± 2.5 volts with 76 microvolt resolution (channels V1-V4) in real time and convert them into meaningful engineering units shown on the display. Alternatively, the LI-1400 can be configured to automatically log these data over extended periods of time and later transfer the results to a computer for further analysis.

Access to the voltage channels requires the 1400-301 Terminal block (below). Voltage channels are designated by the letter “V” and sequentially numbered V1-4. The lead from LI-7000 terminal #2, 4, 6, or 8 should be attached to one of the LI-1400 terminals labeled V1, V2, V3, or V4, while the lead from one of the GND terminals should be attached to one of the LI-1400 terminals labeled ↓.



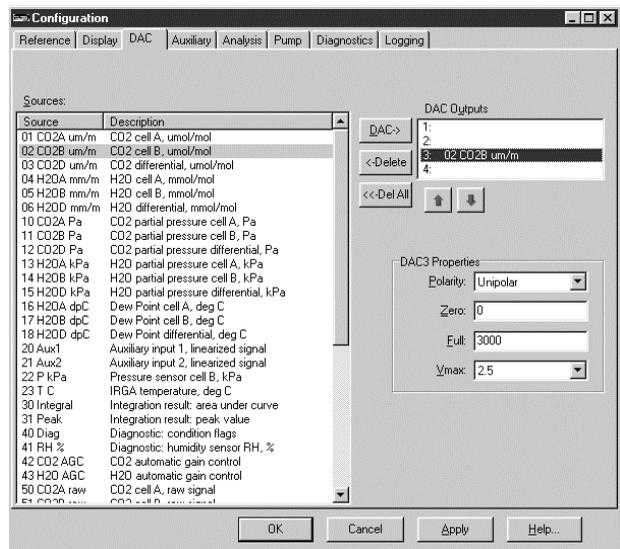
The following example shows how you can set up the LI-1400 Data Logger to collect raw voltage output from the LI-7000 and convert to meaningful values. We'll use variable 02, CO2B $\mu\text{m}/\text{m}$ for this example.

1. Connect LI-7000 terminal #4 on the small terminal strip labeled DAC #3 OUT to the terminal labeled V1 on the 1400-301 Terminal Block. Connect adjacent ground terminals.
2. On the LI-7000, configure DAC3. This can be done from the instrument's front panel, or remotely using a PC running the *LI7000* Windows software.

For more information on using the *LI7000* PC software, see Section 4.

Using a PC:

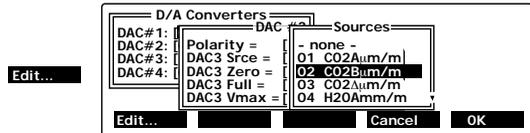
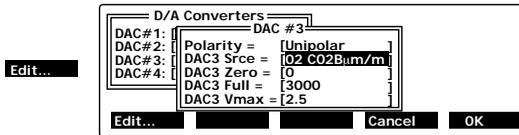
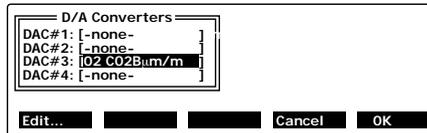
- a. Open the Configuration window and click on the DAC tab.
- b. Highlight 02 CO2B $\mu\text{m}/\text{m}$ in the Sources field.
- c. Highlight DAC Output #3 in the DAC Outputs list.
- d. Click on the DAC-> button to move source 02 into the DAC Outputs list at position 3.
- e. In the DAC3 Properties fields, set Polarity to Unipolar, Zero to 0, Full to 3000, and V_{max} to 2.5.
- f. Click **OK**.



3 Interfacing

On the LI-7000 keypad:

- Press **Shift** then **4** (Data I/O) to access the Data I/O setup menu.
- Press **f3** to access the D/A Converters menu.
- Scroll down to DAC#3. Press **f1** (Edit) to bring up the DAC3 setup menu. Set Polarity to Unipolar.
- Scroll down to DAC3 Srce = and press **f1** (Edit). Scroll to 02 CO2B μ m/m in the Sources list and press **f5** (OK).
- Set DAC3 Zero = 0.
- Set DAC3 Full = 3000.
- Set DAC3 V_{max} = 2.5.
- Press **f5** (OK). Press **OK** again to exit.



- In the LI-1400, configure V1 channel as *General* for CO₂.
- Enter a description, such as CO₂.
- Set Math = *Poly(nomial)* and press *Ent(er)*.
- Set description as desired, $a1 = 1200$, $a0, a2-a5 = 0$. When finished, press *Esc* to return to the main configuration list.
- Set *Oper(ator)* = *none*.
- Enter a *Label* such as *ppm* for the units.

9. Set *Average=1 sec* or as desired. CO₂ will now be displayed on channel V1.

To log CO₂ automatically, follow the remaining steps:

10. Set *Log Routine* to the desired log routine.
11. Set *Calc=Mean*.
12. To capture the minimum and maximum CO₂ values, set *MinMax* accordingly.
13. *TCoef* has no effect when *Calc=Mean*. It is used only when integrating.

Using the RS-232 Port

The LI-COR RS-232 Serial Cable (#9975-016) included with the LI-7000 is terminated on both ends with a 9-pin female connector. Connect either end to the RS-232 connector on the LI-7000 back panel, and the other end to a serial port on your computer. If you only have a 25-pin connector on your computer, use the 9 to 25 pin adapter that is included with the LI-COR serial cable.

The LI-7000 has a DTE serial port with default communication parameters of 9600 baud, 8 data bits, 1 stop bit, and no parity. XON/XOFF flow control is supported. The RS-232 port supports baud rates of 9600, 19200, 38400, 57600, and 115200.

Data output and/or instrument configuration from the LI-7000 can be initiated in any of three different ways; from the LI-7000 keypad, using the RS-232 Configuration menu (see *Data I/O Group*, Section 7); with the **LI7000** PC Communications Software for Windows (see *Operation - Using the LI7000 Software*, Section 4); or with a terminal program that sends control language commands to the LI-7000 (see *Language Reference*, Section 9).

3 Interfacing

RS-232 data transfer rates can be selected from 1 hr, 30 min, 10 min, 5 min, 2 min, 1 min, 30 s, 10 s, 5 s, 2 s, 1 s, 2 Hz, 5 Hz, 10 Hz, 20 Hz, 30 Hz, 40 Hz, or 50 Hz. Data transfer can also be polled, in which a data string is requested via a software command or through an external trigger input (see *Trigger Input* below).

As many as 55 different variables can be selected for output. Note, however, that the data transfer rate is also dependent upon the processing speed and memory availability of the computer to which the LI-7000 is connected. Table 3-1 shows the maximum log frequency for 10 and 20 variables at each of the available baud rates. The examples in Table 3-1 assume the following; 850MHz Pentium III processor, 256MB RAM, Windows® 2000/XP operating system, with no active graphs running.

Table 3-1. Estimated RS-232 data transfer rates for two log frequencies.

Baud Rate (bps)	Log Frequency	
	10 Variables	20 Variables
9600	5 Hz	2 Hz
19200	10 Hz	5 Hz
38400	20 Hz	10 Hz
57600	40 Hz	20 Hz
115200	50 Hz	40 Hz

Note that the table above gives *estimates* only; if you observe that output data are being missed, try reducing the processing demands on the computer (other programs running, etc.), reduce the number of output variables if possible, or turn off any active graphs in the *LI7000* program.

Trigger Input

A trigger input is provided on the RS-232 port that can be used to synchronize LI-7000 data output with other external sensors. It does this by receiving a logic input on pin 9 of the LI-7000 RS-232 port, and then generating an output back to the signaling system. The trigger event(s) can then be recorded and used as markers along with the other sensors' data. There is no effect on the LI-7000's timing; the signaling system simply monitors the triggered output from the LI-7000.

When the trigger is activated, the chosen data variables (see *Configuration; Logging Page* in Section 4) are output via both RS-232 and USB ports on the LI-7000. Note that the output frequency must be set to "polled" (see *RS-232* in Section 5) in order for the trigger to operate. Note too, that the LI-7000 processes data at 600 Hz; when triggered, the data set that is output will be from the nearest 1/600th second.

The trigger input occurs on the rising edge of the trigger signal. In other words, the trigger occurs when the trigger input goes from low to high. The signal is compatible with RS-232 input voltages and signal characteristics, but can also be driven by a pseudo-TTL level signal. The switching points (what the logic detects as high and low logic levels) are shown below. Because there is hysteresis between the switching points, the input is designed to accommodate slower transitions.

Absolute Maximum Input Voltage: -25V to +25 V.

For use as a pseudo-TTL level signal, the following should be observed:

VIT+, Positive going input threshold voltage: Maximum 2.4V.
VIT-, Negative going input threshold voltage: Minimum 0.6V.
V_{hys}, Input hysteresis (VIT+) - (VIT-): Typical 0.5V.

The trigger input is pulled low by a 5K Ohm resistor to electrical ground.

3 Interfacing

The VIT+ is the voltage level on the positive going signal at which the input is determined to be a logical high.

The VIT- is the voltage level on the negative going signal at which the input is determined to be a logical low.

The V_{hys} is the amount of "noise" or extraneous transitions that can occur on the input signal without being detected as an actual transition by the circuit.

It is best to drive the trigger signal such that ringing or noise does not occur in the voltage range between 0.6V and 2.4V, as measured at the trigger input to the LI-7000 with respect to the LI-7000's electrical ground. That is, as the measured signal transitions between 0.6V and 2.4V or vice-versa, the signal should be monotonic.

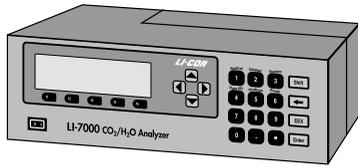
Using the USB Port

The USB cable (p/n 392-07872) is used to interface with devices that have a USB 1.1 or 2.0 port. The USB cable is terminated with 5-pin A/Mini-B connectors; the Mini-B end connects to the LI-7000 (the connection is located between the two terminal strips on the LI-7000 back panel), and the 'A' end connects to the computer or other device.

The **LI7000** program recognizes devices attached to the USB port according to the LI-7000 serial number; this number appears in the Connect dialog under the USB tab as IRG4-xxxx.

Data from the LI-7000 are output simultaneously via the RS-232 and USB ports. The LI-7000 can output all variables via the USB port at 50 Hz. Note that only one LI-7000 can be operational at a time through USB connections; you can, however, connect one instrument via USB and a second via the RS-232 port and operate them simultaneously.

When using the LI-7000 in an unattended mode, (typically associated with long-term data collection), we recommend using the RS-232 communication interface instead of the USB interface for data collection to the host computer. This recommendation is due to the potential for performance degradation of the USB interface in response to transients on the AC power input as well as electrostatic events (i.e., static discharge or ESD) that occur on the instrument. The potential performance degradation may include a loss of USB communications between the LI-7000 and the host computer. To re-establish communications when using a Windows computer, the USB cable must be physically disconnected and reconnected to the LI-7000. To re-establish communications when using a Linux computer, the user can either: A. utilize a custom software application that can perform this reconnection via software; or B. physically disconnect and reconnect the USB cable to the LI-7000. After the reconnection is made, data transfer resumes.



4 The *LI7000* Program

Interfacing with Windows™

Data from the LI-7000 can be transferred to a computer for analysis, printing or storage using the RS-232 and/or USB interface. The LI-7000 RS-232 port is configured as Data Terminal Equipment (DTE) with no hardware handshaking, and is bi-directional, meaning information can be transferred both into and out of the LI-7000.

The *LI7000* PC Communications Software that comes with the LI-7000 is used to transfer data and setup files between the analyzer and a PC.

LI-COR Serial Cable (p/n 9975-016)

This is a null modem cable that is used to interface with devices such as computers and terminals with 9-pin serial ports. If you want to interface to a device with a 25-pin serial port, then a 9-pin to 25-pin adapter (included with the cable) must be used.

USB Cable (p/n 392-07872)

The USB cable is used to interface with devices that have a USB 1.1 or 2.0 port. The USB cable is terminated with 5-pin A/Mini-B connectors; the Mini-B end connects to the LI-7000, and the 'A' end connects to the computer or other device.

Note on Windows NT/XP

If the LI-7000 is connected to a computer running Windows NT or XP (and possibly others) and the computer is powered on (or rebooted) while the LI-7000 is outputting data, the Windows operating system may interpret the data as coming from a mouse and attempt to load drivers for a serial mouse. This will prevent

4 Using the LI7000 Program

communication with the LI-7000. To prevent this problem, always disconnect the serial cable when booting the computer.

Installing the PC Communications Software on Your Computer



The *LI7000* software is shipped on CD. It requires that your computer have an RS-232 serial (COM) interface or Universal Serial Bus (USB), and Windows® 98SE/2000/XP.

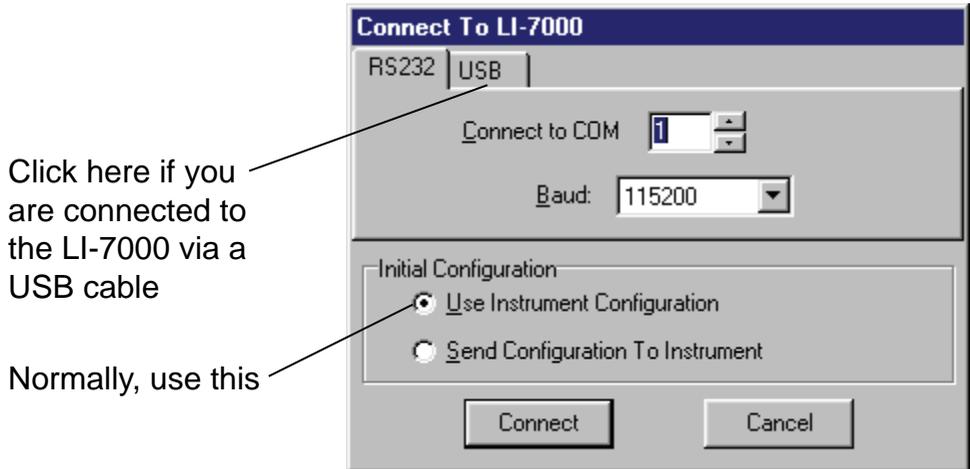
1. Insert the CD into your CD-ROM drive. If installation does not automatically start, select **Run** from the Windows *Start* menu, and select the *Setup.exe* file on the CD. Follow the instructions in the installation program. When the software has finished the installation procedure, the *LI7000* program icon will be placed in the Programs menu.

NOTE: To remove the software, go to the Control Panel and select *Add/Remove Programs*. Choose *LI7000* from the list of programs and click the *Add/Remove* button.

2. If you are going to connect to the LI-7000 using the RS-232 cable, connect the cable to the instrument and computer. Turn the LI-7000 on.
3. If you are going to connect to the LI-7000 using the USB cable, turn the LI-7000 on and wait for it to start up. Plug the Mini-B end into the back of the LI-7000, and the other end into your computer. The "Found New Hardware Wizard" will open. Follow the instructions in the installation windows to install the required USB drivers.
4. Start the *LI7000* program (e.g. *LI7000-2.0.0*) from the Windows *Start/Programs* menu.

Is the LI-7000 Connected Properly?

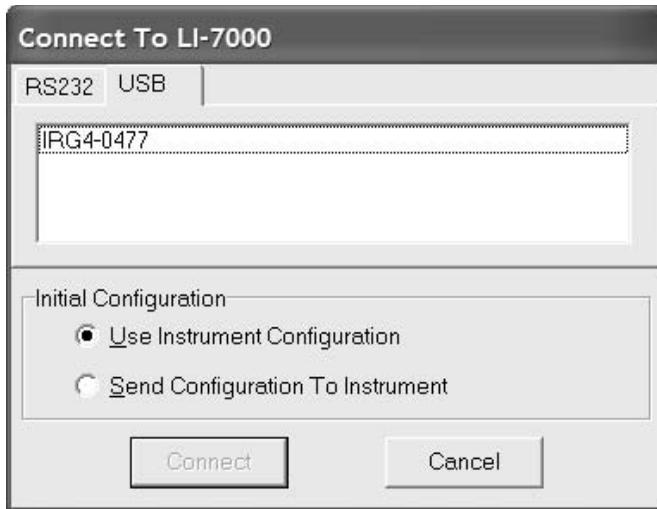
Select *Connect* from the Remote menu to verify that the LI-7000 is connected and communicating with the computer. The Connect to LI-7000 dialog appears:



Use the arrow buttons to select the serial port on your computer to which the LI-7000 RS-232 cable is connected. Valid numbers are from 1 to 99. Choose the baud rate at which you want to communicate with the LI-7000. Note that the baud rate selected here must match the baud rate on the LI-7000 front panel to connect (see *Data I/O Group; RS-232* in Section 5).

If you are connected to the LI-7000 via the USB cable, click on the USB tab and highlight the desired instrument to which the computer is connected (all LI-7000's connected via USB are identified by their serial numbers).

4 Using the LI7000 Program



Enable the "Use Instrument Configuration" button to use the LI-7000 analyzer's built in default configuration file at connection; enable the "Send Configuration To Instrument" button to send the configuration file *currently active in the LI7000 program window* to the instrument at connection. Click **Connect**.

After a few moments, data should start to appear in the window. Don't worry about the initial data output; the variables displayed are taken from a default configuration file (see *About Configuration Files* below), which you can reconfigure later, if desired. If data do not appear, check your cable connections, or try a different COM port number and retry. Also, check your logging frequency to be sure it is asking for data at a reasonable rate, and not once per hour, for example.

NOTE: The program requires Data Set Ready (DSR) to be high to connect via RS-232. If you are not using the 9975-016 cable, you may have to modify your cable for communications to work.

Operation - Using the *LI7000* Software



When the *LI7000* program is opened, the main window appears (data shown appear after communication is established with the analyzer):

The screenshot shows the LI7000 software interface with the following components labeled:

- Menu bar:** File, View, Configure, Remote, Logging, Help
- Tool bar:** Contains icons for file operations, a numeric keypad (1, 2, 3), and control buttons for 'Int', 'Off', and a power button.
- Text display:** Displays real-time data for eight parameters:

01 CO2A um/m	02 CO2B um/m	03 CO2D um/m	23 T C
350.00	383.17	33.17	27.33
04 H2OA mm/m	05 H2OB mm/m	06 H2OD mm/m	22 P kPa
20.000	20.696	0.696	97.59
- Graphs:** Two line graphs are shown:
 - 02 CO2B um/m:** Y-axis from 0 to 400, X-axis (Time in secs) from 13,980 to 14,020.
 - 05 H2OB mm/m:** Y-axis from 0 to 30, X-axis (Time in secs) from 13,980 to 14,020.
- Diagnostic indicators:** A row of seven status indicators: Integrating, Battery, CO2 Cooler, H2O Cooler, IR Source, and PLL Lock, each with a radio button.
- Status Bar:** Shows 'Connected' and 'Not Logging'.
- Logging Indicator:** A label pointing to the 'Not Logging' status.

The main window has five distinct areas: the **menu bar**, where you can select items from the six menus; the **tool bar**, which contains buttons that serve as shortcuts to some commonly used functions; the **data window**, where real-time data are displayed as text or as graphs; the **diagnostic area**, where buttons and messages are used to indicate whether the LI-7000 is functioning correctly, and the **status bar**, which displays connection and logging information.

4 Using the LI7000 Program

The menu items and associated functions are described below. See *"Toolbar Buttons"* later in this section for a description of the toolbar buttons. Diagnostic indicators are discussed in the *Troubleshooting* section.

Important Note on Initial Configuration

It is important to note here the difference between "Use Instrument Configuration" and "Send Configuration to Instrument" as shown in the Connect dialog on the previous page. When the "Use Instrument Configuration" button is selected, the **LI7000** PC communication software will *query* the instrument for its current settings during connection; the LI-7000 in turn sends its configuration for use in the **LI7000** program.

When the "Send Configuration to Instrument" button is selected, the **LI7000** program sends parts of the Li7000.170 configuration file *to* the instrument, which automatically overwrites the existing instrument configuration. Thus, care should be taken when using this option, to avoid accidentally overwriting configuration parameters that you have entered (via the keypad) into the LI-7000.

Note, too, that graphic and/or text displays defined in the **LI7000** Windows program are not mirrored on the LI-7000 display; they are configured independent of each other, and sending the configuration to the instrument will *not* overwrite any displays configured on the LI-7000 front panel.

If you use the "Send Configuration to Instrument" option the following instrument configurations are overwritten:

- Reference settings
- DAC outputs
- Auxiliary inputs
- Diagnostics
- Integral
- Pump
- Filtering
- RS-232 (restored on exit)

Upon exiting the **LI7000** program, the software configures the RS-232 port according to the settings on the Logging Page of the Configuration window (see *Logging Page* below). This ensures that data will continue to be output after the program is closed.

About Configuration Files

The **LI7000** program uses *configuration files* to store the software parameters used to set up the LI-7000 for data output. These configuration files store information such as how you want to view data in the main program window, DAC output channels, auxiliary input coefficients, data analysis parameters such as signal filtering and integrations, and the source channels that you want to log. Unique configuration files can be set up, saved, and then re-opened to change your setup information.

When the **LI7000** program is started, a default configuration file named Li7000.l70 is automatically loaded; this file contains a set of commonly used setup parameters that can be modified and saved, or saved as a new configuration file with a different name. During the initial software installation, the Li7000.l70 file is placed in the same folder as the **LI7000** program files. If this file gets lost the program will open with a blank configuration that you can re-configure as needed. The default Li7000.l70 file can be recovered from the program CD.

The LI-7000 analyzer also has a default configuration built in, which is used when the instrument is powered on. You can use the instrument software via the keypad to change setup and data output parameters, or you can open and/or define the configuration in the **LI7000** program before connecting, and then send the configuration to the analyzer for implementation. Configuration files can be sent to the LI-7000 during initial connection (see "Connect to LI-7000" dialog above), by enabling the "Send Configuration to Instrument" button. Alternatively, enabling the "Use Instrument Configuration" button in the "Connect to LI-7000" dialog causes the instrument's built-in configuration to be loaded during connection.

4 Using the LI7000 Program

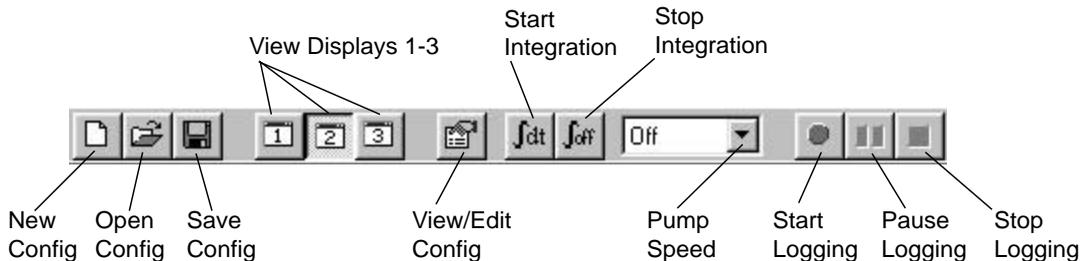
The LI-7000 stores its configuration so that it will power on configured just as it was when it was powered off. *To ensure that all configuration changes are saved automatically, wait five seconds after changing the configuration and disconnecting from the PC before rebooting or powering off the instrument.* A diamond (◆) symbol will appear in the upper righthand corner of the LI-7000 display for several seconds when a configuration change has been stored.

Toolbar Buttons

There are toolbar buttons that serve as shortcuts to some of the commonly used menu item functions. Move the mouse pointer over a button as shown below to view its function.



The buttons are as follows:



File Menu

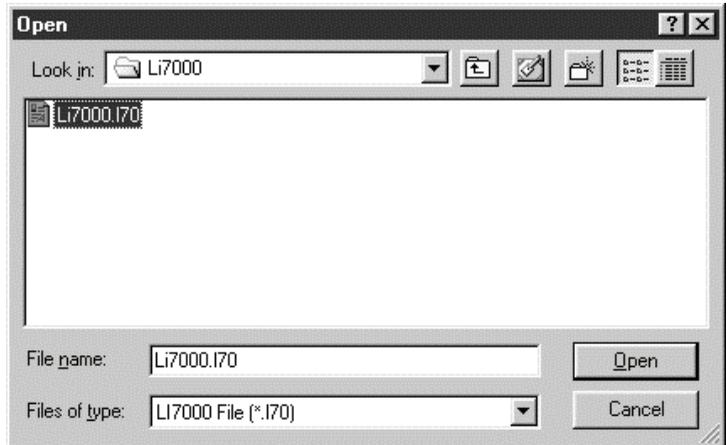


New Config

Select New Config to clear the main window of all parameters and create a new configuration. All displays and other setup information are cleared, providing a "blank slate" on which you can enter your own configuration parameters. After you have defined a new configuration, use Save Config or Save Config As (below) to save to a new file.

Open Config...

Opens a dialog where you can choose from existing LI-7000 configuration files (denoted by a .I70 file extension).



Use the scroll button in the 'Look in' field to change directories. Highlight the desired configuration file and click **Open**.

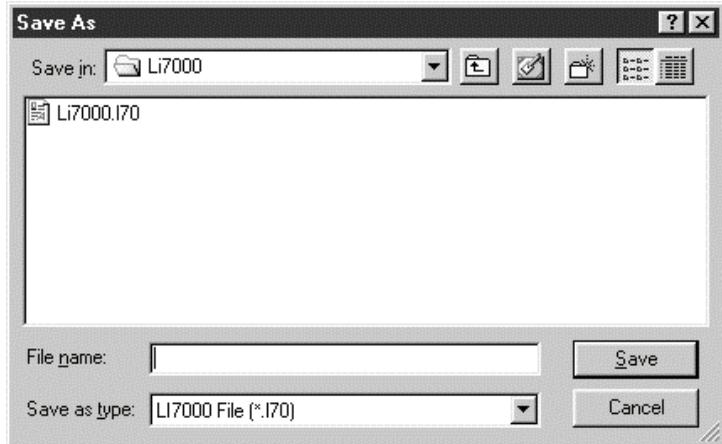
Save Config

Saves any changes made to the *active* configuration file.

Save Config As...

Saves the current configuration to a file with a different name.

4 Using the LI7000 Program

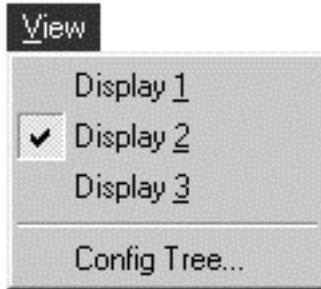


Enter the file name and click **Save**. File names are automatically appended with a .I70 file extension to denote an LI-7000 configuration file.

Exit

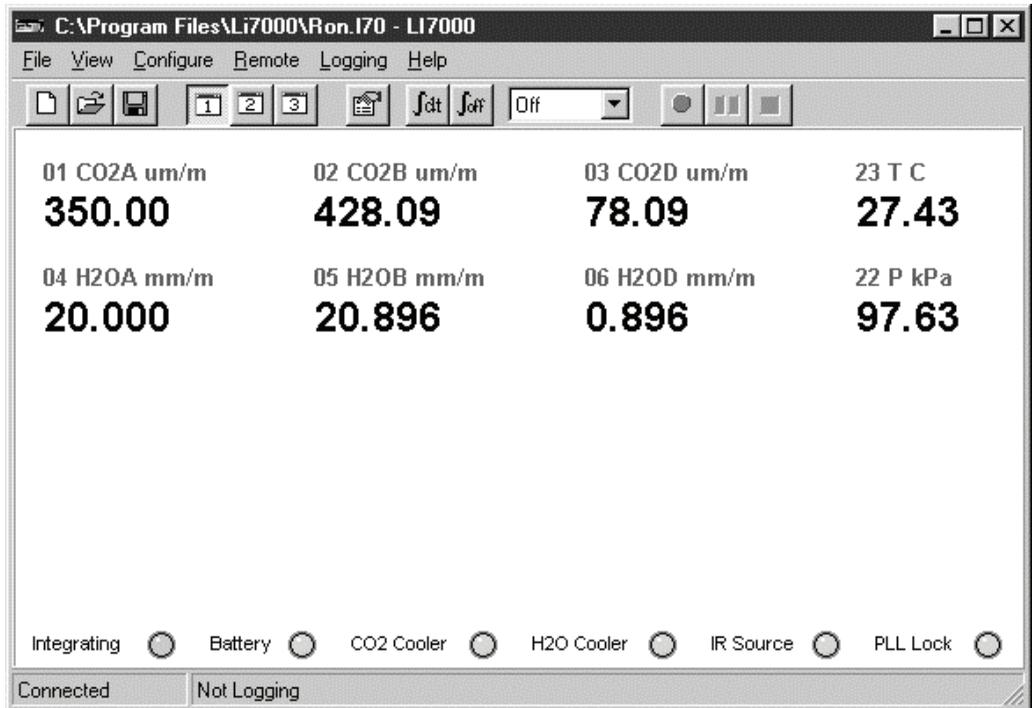
Closes the *LI7000* program and stops communications between the LI-7000 and the computer. Data will continue to be output by the LI-7000.

View Menu



Display 1-3

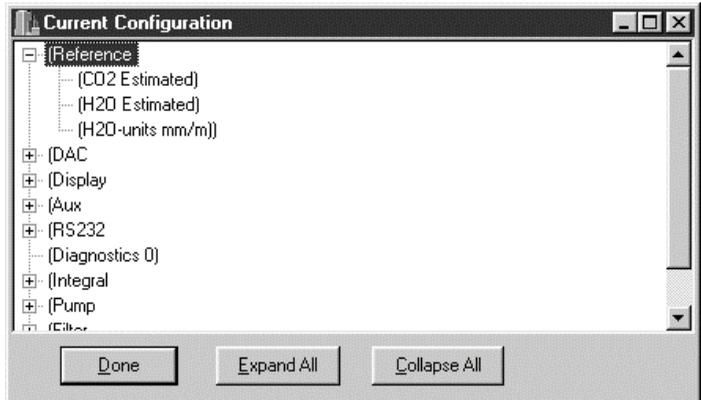
As many as three display definitions can be set up for viewing data in the data window, with as many as 8 source channels displayed as text, and as many as 3 source channels displayed as graphs. These definitions can then be recalled by selecting the associated menu item, or by clicking on the display buttons on the toolbar. This can be useful for viewing different sets of data; for example, you might define Display 1 to show only CO₂ data, and Display 2 to show only H₂O data. The display definitions are created in the Configuration window, Display page. The graphic below shows the factory default display definition #1.



4 Using the LI7000 Program

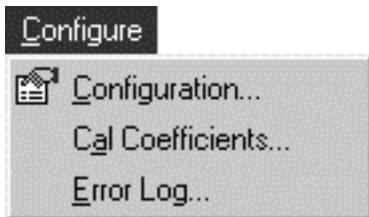
Config Tree...

Opens the Current Configuration dialog, where you can view all of the current configuration parameters in an expandable "tree" view.



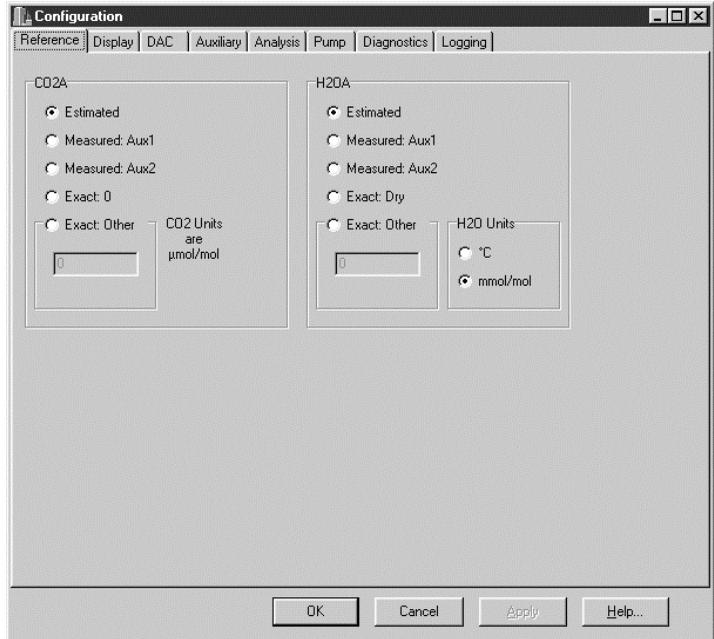
Click on the [+] sign to expand the tree, or click on the **Expand All** button to view the entire list. Click on the [-] sign to collapse a listing, or click on **Collapse All** to contract the list. Click **Done** to close the window. For more information about the items in this tree see Section 9, *Language Reference*.

Configure Menu



Configuration...

Opens the Configuration window (below). This is the area in which all of the setup and data output options for the LI-7000 are defined. The Configuration window has eight tabbed pages containing the configuration options; click on the tab to open the associated page.



The corresponding on-board functionality is discussed in Section 5, "Set Ref".

Reference Page

The Reference page (above) is the area where you choose the method by which the reference cell (A) CO₂ and H₂O concentrations are determined. The LI-7000 uses this information as a reference for the measurement of the gas in the sample cell (B). The choices are as follows:

Estimated - The concentration in the reference cell is unknown; the LI-7000 estimates the reference cell concentration, based on the most recent calibration (called REM in this manual; see Section 1, *Reference Estimation Mode*).

Measured:Aux 1 - The reference cell concentration is input as a voltage signal on the back panel terminal strip at Aux 1. The concentration is then calculated using the voltage signal and the user-entered coefficients for a second order

4 Using the LI7000 Program

polynomial (see *Auxiliary page* below). This allows you to use the output of one analyzer as the reference for another.

Measured:Aux 2 - The reference cell concentration is input as a voltage signal on the back panel terminal strip at Aux 2.

Exact:0 - The reference cell contains a zero gas (CO₂-free) or a dry gas (H₂O-free). Note that a dry gas is considered to be zero millimoles/mole, or -100 °C.

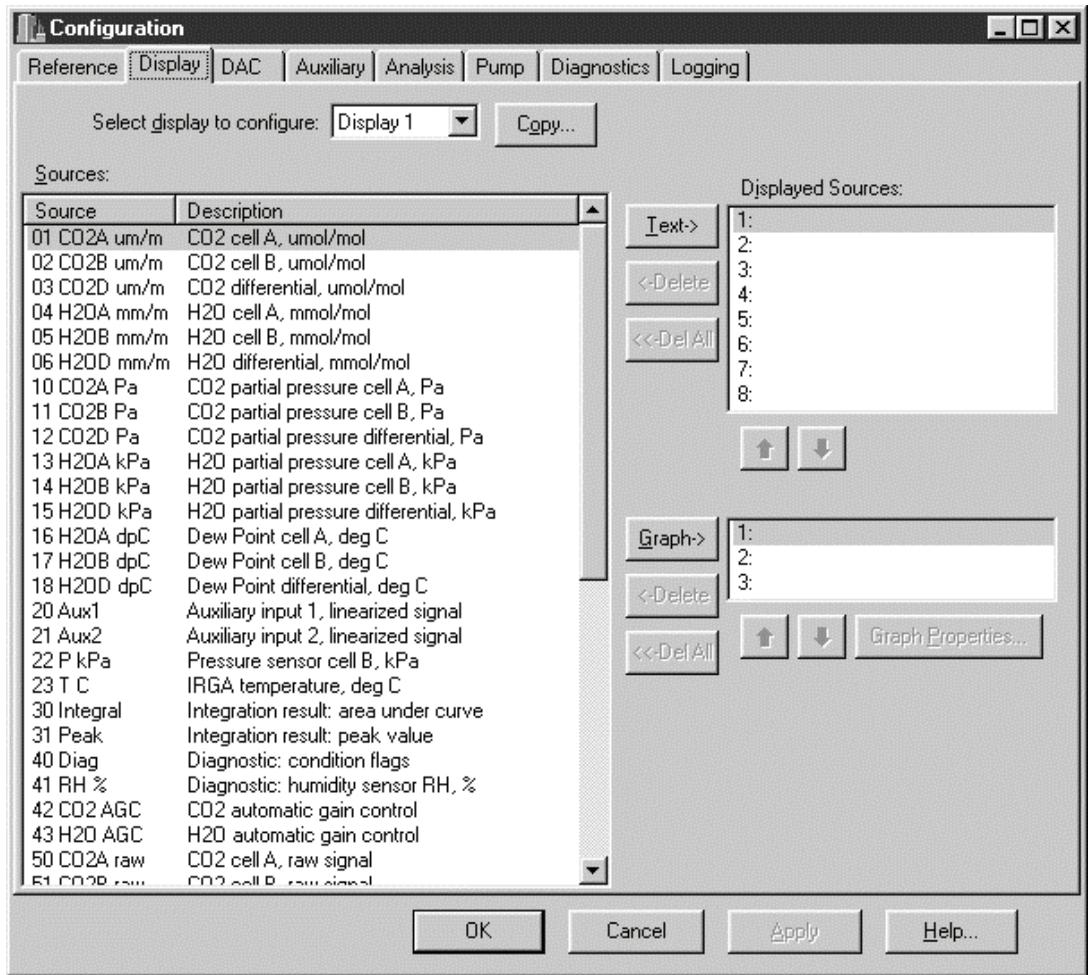
Exact:Other - The reference cell gas concentration is known. Enter the CO₂ concentration in units of $\mu\text{mol/mol}$; enter the H₂O concentration in °C dew point, or in units of mmol/mol.

The corresponding on-board functionality is discussed in Section 5, "Display Group".

Display Page

As many as three custom displays can be configured to show the source channels of interest in the main window. As many as eight source channels can be defined for each text display; three source channels can also be specified for graphing on XY plots. The Display page shows a list of available source channels which can be selected and moved into the display definition fields for either text or graphical displays.

NOTE: Defining displays on the *LI7000* PC Software does *not* affect the display definitions on the instrument, and vice-versa.



■ **To define a text display:**

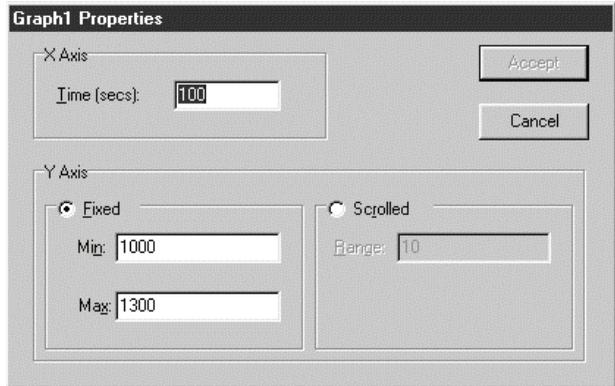
1. Select the display to be configured (1-3) from the "Select display to configure" pull-down menu. You can also click on **Copy** to load a pre-existing display definition (1 or 3 if on Display 2, or 1 or 2 if on Display 3) into the window for modification. This can save time re-defining

displays, if you only want to change a source channel or two.

2. Click on any of the source channels in the "Sources" field. Use the scroll bar to view more sources, if desired. When you have highlighted the desired source, click on the **Text** button to move that choice into the "Displayed Sources" field. Continue selecting up to eight sources in this manner. If you change your mind and want to remove a source channel, simply highlight it and click the **Delete** button. Click on **Del All** to remove all sources from the "Displayed Sources" field.
3. Configure Displays 2 and/or 3 in this manner, if desired. Click **OK** when you are finished with the display definitions. The active display in the main window will begin updating data based on the new display definition.

■ *To define a graph*

1. Select the display to be configured (1-3) from the "Select display to configure" pull-down menu.
2. Click on any of the source channels in the "Sources" field. Use the scroll bar to view more sources, if desired. When you have highlighted the desired source, click on the **Graph** button to move that choice into the "Displayed Sources" field. Continue selecting up to three sources in this manner. If you change your mind and want to remove a source channel, simply highlight it and click the **Delete** button. Click on **Del All** to remove all sources from the "Displayed Sources" field.
3. Highlight any of the three source channels chosen in Step 2 above and click on **Graph Properties**. The Graph Properties dialog opens (below), where you define the Time (in seconds) that will be displayed on the X axis, and the Y axis min/max values (or the range for a "floating" Y axis).



The Y axis can have fixed minimum and maximum values, as shown above. You can also enter a range about which the Y axis will "float"; this can be useful if data fluctuate widely, since the Y axis will move to keep the strip chart data on screen at all times.

The physical size of the strip chart will follow the window size, so for a bigger chart, enlarge or maximize the program's window.

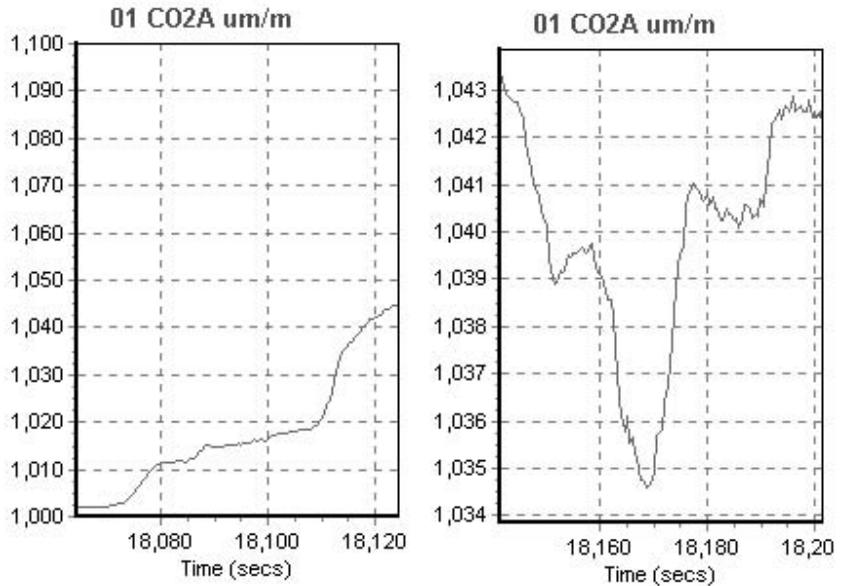
TIP: You can rescale the Y axis of an active strip chart "on the fly". Here's how:

- To change Max and Min together, a fixed amount: right click the mouse button on the chart, hold, and drag up or down.
- To change Max and Min differentially: left click the mouse button on the chart, hold, and drag to the top left (increase) or bottom right (decrease).

In the example below, the graph on the left uses a fixed Y axis with a minimum value of 1000 and a maximum value of 1100. Note that data points below 1000 or above 1100 will not be displayed. In the chart on the right, a scrolled

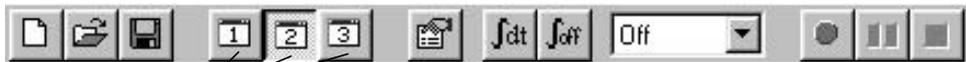
4 Using the LI7000 Program

Y axis has been chosen, with a range of 10. Values on the Y axis will change around a range of 10 $\mu\text{mol/mol}$ to keep the data on the chart.



4. Configure Displays 2 and/or 3 in this manner, if desired. Click **OK** or **Apply** when you are finished with the graphical display definitions. The active display in the main window will begin updating data based on the new display definition.

You can switch between Displays 1, 2, and 3 using the choices under the View menu, or by clicking on the associated button in the toolbar (below).



Choose Displays 1-3 here

■ ***To copy a display definition:***

If you have already defined one or more graph properties, you can copy these properties globally into the currently selected display definition. This can save time, as you do not have to re-define each graph individually.

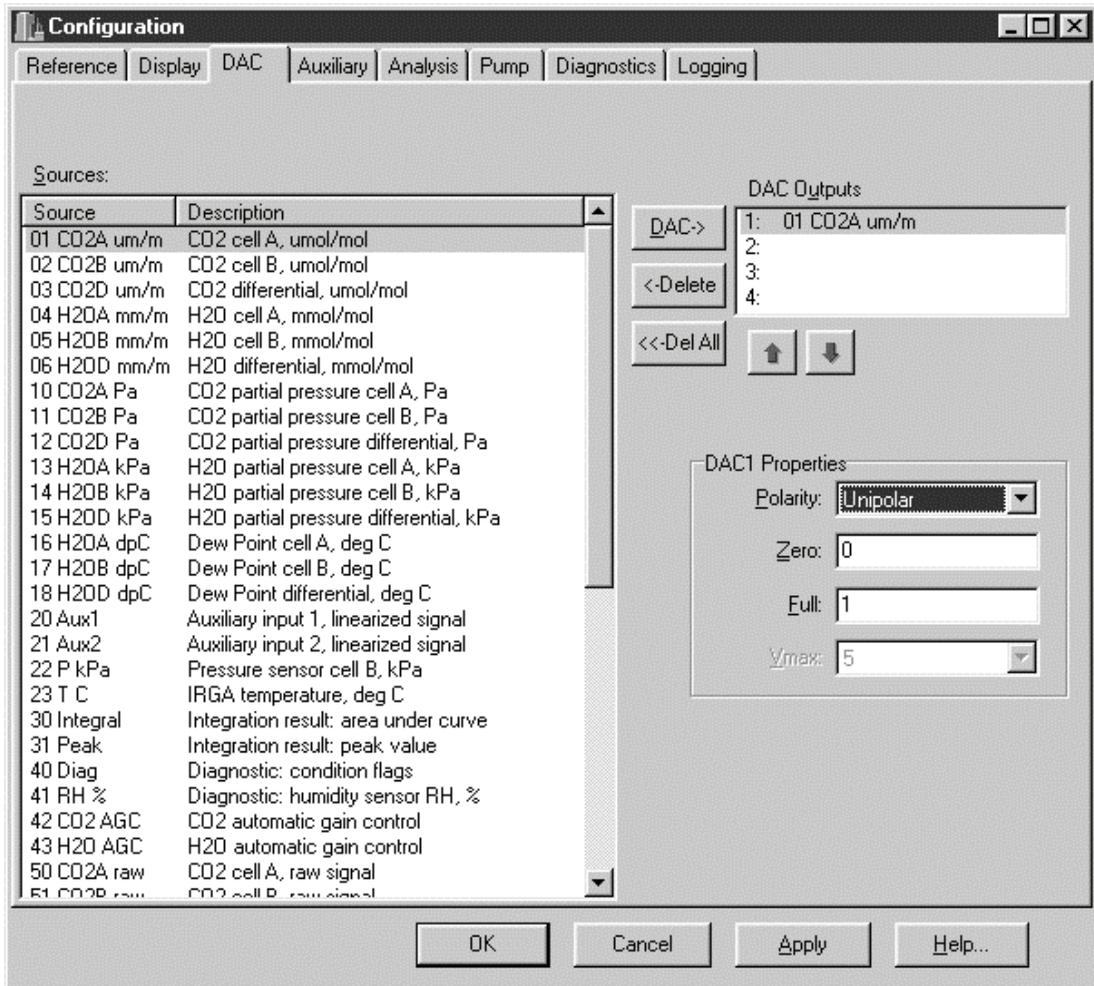
1. Click on the **Copy** button to open the Copy Display dialog.
2. Choose a display definition from the list whose parameters you want to copy to the current definition. These parameters can be edited later, if desired. Click **OK**.

DAC Page

The DAC page allows you to configure each of the four digital-to-analog converters (DACs) that are connected to the four DAC output ports on the back of the LI-7000. Each DAC can be set to have either a bipolar ($-V_{\max}$ to $+V_{\max}$) or unipolar (0 to $+V_{\max}$) output, although DAC1 and DAC2 must be set the same.

The corresponding on-board functionality is discussed in Section 5, "DACs".

4 Using the LI7000 Program



Each DAC is configured by specifying the source channel (e.g. CO₂ A $\mu\text{mol/mol}$) that drives the analog signal, the source channel value which corresponds to zero volts, the source channel value which corresponds to full scale voltage, and the maximum voltage range over which the source is measured.

For example, to configure DAC #1 to output a voltage signal proportional to CO₂ A $\mu\text{mol/mol}$, 2000 $\mu\text{mol/mol}$ full scale, select CO₂ $\mu\text{mol/mol}$ for the DAC1 Output, and set Zero = 0, and Full = 2000.

$$\begin{aligned} 0\text{V} &\rightarrow 0 && (X_0, \text{zero volts corresponds to } 0 \mu\text{mol/mol}) \\ 5\text{V} &\rightarrow 2000 && (X_F, \text{full scale corresponds to } 2000 \mu\text{mol/mol}) \end{aligned}$$

When a voltage range is selected, the DAC output voltage V resulting from a CO₂ molar value X is given by

$$V = V_{\max} \frac{X - X_0}{X_F - X_0}$$

DAC1 and DAC2 have a fixed V_{\max} of 5 volts. DAC3 and DAC4 can be set with a V_{\max} of 5, 2.5, 1.25, or 0.625 volts. The Zero and Full values map the value of the source to either the bipolar range ($-V_{\max}$ to $+V_{\max}$) or unipolar range (0 to $+V_{\max}$).

Note: the polarity settings for DAC1 and DAC2 must be identical, so changing one of them changes the other.

■ **To define the DAC outputs:**

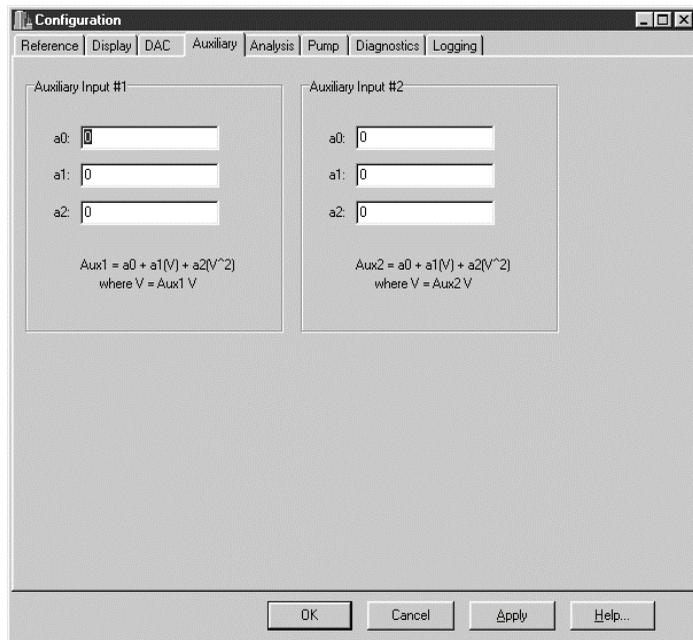
1. Select the DAC source channel to be output (1-4) from the "Sources" list. Highlight any of 1-4 under "DAC Outputs" and click the DAC button. The source is moved into the DAC Outputs list.
2. Choose the polarity under "DAC Properties", and enter the Zero and Full scale values. Select the V_{\max} value for DAC channels 3 and/or 4, if desired.

4 Using the LI7000 Program

The corresponding on-board functionality is discussed in Section 5, "Aux1 & 2".

Auxiliary Page

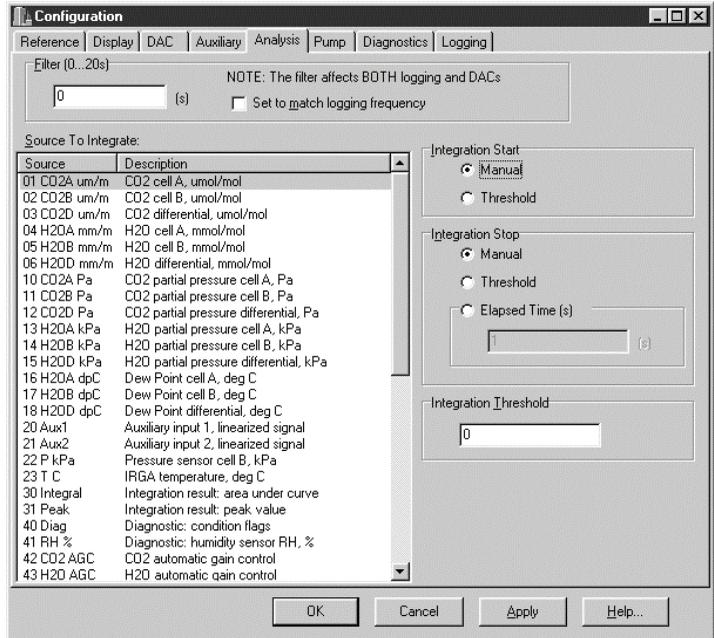
The Auxiliary Page is the area in which you can input the coefficients for a linear or second order polynomial for external devices connected to the Aux1 or Aux2 inputs on the back panel terminal strip. As an example, you could use a second analyzer's voltage output to input the reference cell concentration to the LI-7000.



The corresponding on-board functionality is discussed in Section 5, "Analysis".

Analysis Page

The Analysis page allows for the setup of an integration function using a selected source, and also contains a field for setting the signal averaging time.



Signal averaging can be set from 0 to 20 seconds, where 0 is no filtering. Note that the signal averaging affects data output via the RS-232 port *and* data output to any of the Digital-to-Analog converters (DACs).

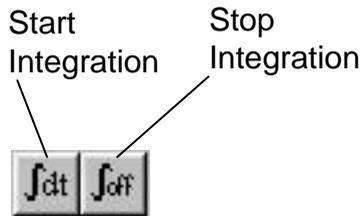
The signal averaging can be set to match the logging frequency by enabling the check box; the logging frequency is then chosen in the Logging Page (below). If this check box is enabled, the value in the Filter field is greyed out; the optimum signal averaging value will be set to correspond to the Log Frequency chosen in the Logging Page.

Integrating

1. Highlight a source to be integrated from the Source list.
2. Choose the method to start the integration; manually, or using a threshold value.

4 Using the LI7000 Program

3. Choose the method to stop the integration; manually, using a threshold value, or after a user-entered elapsed time has expired.
4. Enter a threshold value for the start or stop (or both) of the integration, if either was chosen in Steps 2 or 3 above.
5. Click on the Apply button to send the new configuration to the instrument for implementation.
6. If Manual was selected in Steps 2 or 3 above, the integration function is started and/or stopped manually, by pressing the Start or Stop Integrating button(s) on the toolbar (below).



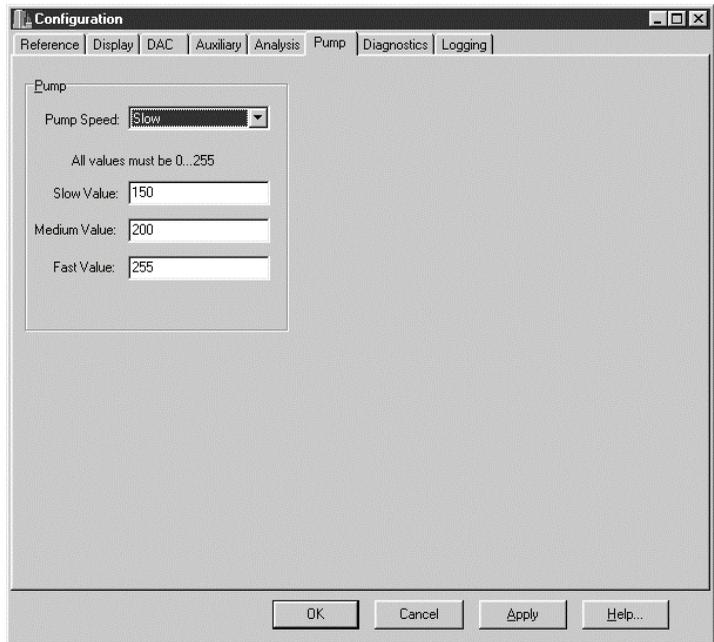
- **Example:** Start integrating CO₂A μm/m after it reaches a value of 500 μm/m, and continue integrating for 5 minutes.
1. Highlight source #01 (CO₂A μm/m) in the Source list.
 2. Choose the Threshold button at Integration Start.
 3. Choose the Elapsed Time button at Integration Stop, and enter 300 seconds.
 4. Click on the Apply button to send the new configuration to the instrument for implementation.

The integration result (the area under the curve) can be viewed at source #30; the integration peak value can be viewed at source #31.

The corresponding on-board functionality is discussed in Section 5, "Pump".

Pump Page

Allows you to select a pump speed from Off, Slow, Medium, and Fast, or edit the value of any of the speeds.



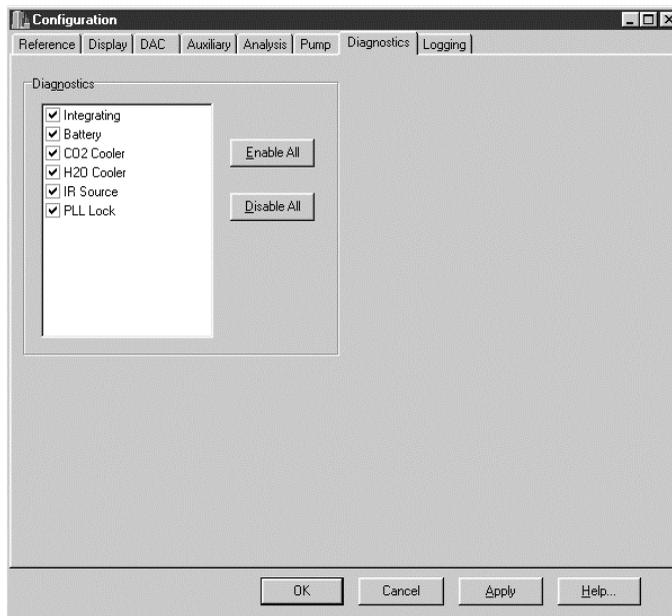
Values for Slow, Medium, or Fast speeds must be between 0 and 255, where 0 is off. Note that this value determines the *voltage* applied to the pump (approximately 0-10V); at values less than about 50, the pump may not turn on due to friction.

4 Using the LI7000 Program

The corresponding on-board functionality is discussed in Section 5, "Diag".

Diagnostics Page

The Diagnostics Page allows you to turn off individual or multiple system diagnostic indicators. These indicators are located at the bottom of the main window; red indicators show that there is a problem, while green indicators show that the instrument is functioning normally (with the exception of the Integrating button; it will remain gray until integration is turned on, at which point the indicator turns green). Diagnostic warnings also appear on the LI-7000 LCD display; turning the diagnostics off in the Configuration window also causes the warnings to be disabled on the instrument display.



Click on the check boxes to enable or disable the diagnostic warnings, or use the **Enable All** or **Disable All** buttons to check or uncheck all warnings. The Diagnostics are as follows (more information can be found in Section 8, *Troubleshooting*):

Integrating Battery CO2 Cooler H2O Cooler IR Source PLL Lock

Integrating - Green indicates that the integration function is currently active; gray indicates that integration is off.

Battery - Red indicates a low battery condition. Automatic shutdown will take place in approximately 10 minutes with a 6A/hr. battery.

CO₂ Cooler - Red indicates that the thermoelectric cooler for the CO₂ detector is out of normal operating range. Instrument readings will be erroneous until the cooler is within range. Note that it may take several minutes after instrument startup before the coolers reach normal operating range, especially if the instrument is being operated near the upper temperature limit (+50 °C). The RH sensor can also shut the cooler(s) off, indicating a need to change the internal chemicals.

H₂O Cooler - Same as above, for the H₂O detector.

IR Source - Red indicates a problem with the infrared source. Any data collected with a bad IR source will be erroneous.

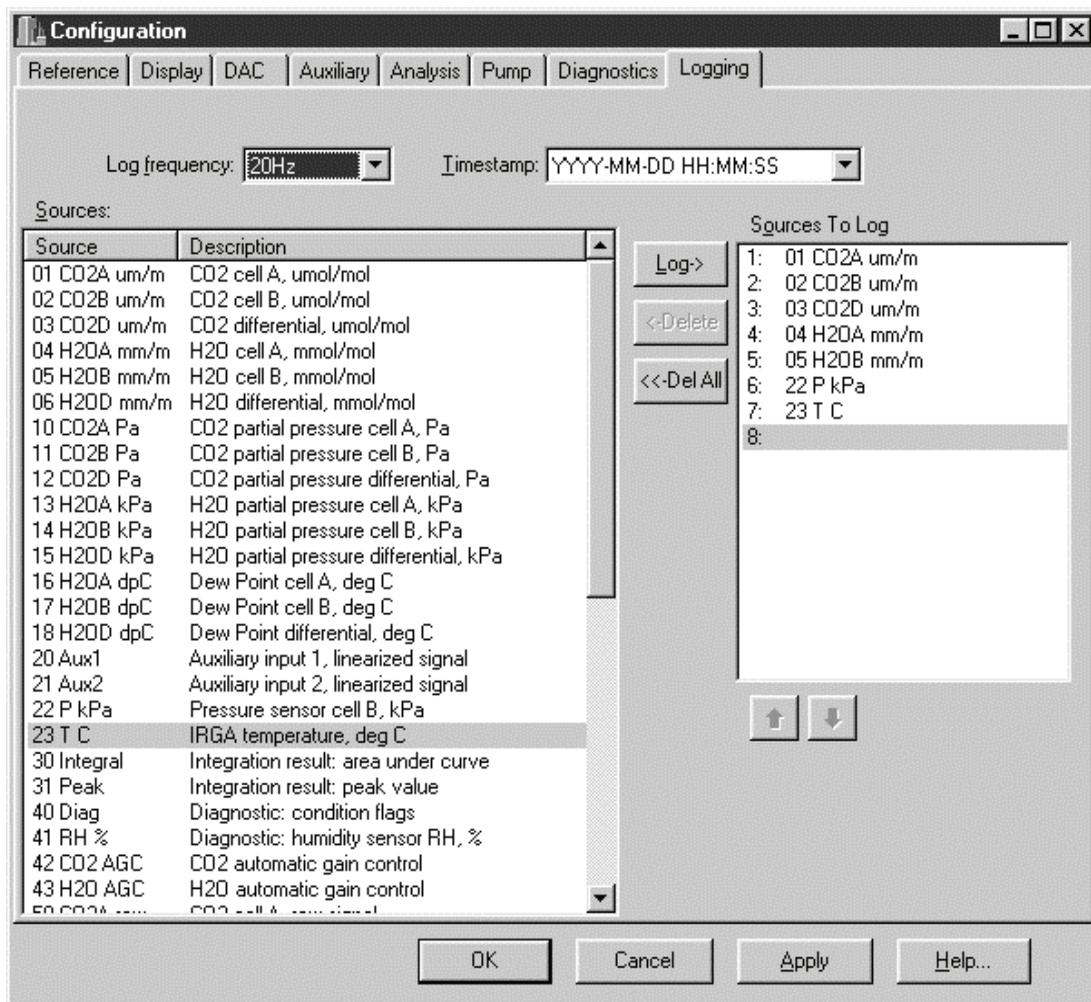
PLL Lock - Phase lock loop, red indicates the chopper motor is not operating at the proper speed. Note that it may take 10 seconds or so after instrument startup for the chopper motor to reach optimum speed. Intermittent PLL warnings can be caused by excessive vibration; more frequent warnings may indicate a failing chopper motor.

4 Using the LI7000 Program

The corresponding on-board functionality is discussed in Section 5, "RS-232".

Logging Page

The Logging page presents a list of data sources that will be recorded when logging is enabled. It also determines the frequency with which the main display updates.



Highlight the variables to be logged in the "Sources" list, and click on the Log button to move that variable into the "Sources To Log" list. Items can be removed from the list by highlighting them and clicking the **Delete** button (click **Del All** to clear the list). Continue to add additional variables to log and click **OK**.

Use the Log Frequency pull-down menu to set the data output frequency. The available rates are polled, 1 hour, 30 minutes, 10 minutes, 5 minutes, 2 minutes, 1 minute, 30 seconds, 10 seconds, 5 seconds, 2 seconds, 1 second, 1 Hz, 2 Hz, 5 Hz, 10 Hz, 20 Hz, 30 Hz, 40 Hz, and 50 Hz. **Important Note:** depending upon the number of sources selected for output, the actual output rate may be reduced so that all sources can be output without losing data (see Table 3-1). If 'Polled' is chosen, data will only be output upon a polling command sent to the RS-232 or USB port via the computer (see *Configuration Grammar* in Section 9), or via the Trigger Input (see *Trigger Input* in Section 3).

The time stamp and header information can be recorded in one of two forms; in year/month/day/hour/minute/second format (taken from the system clock), or as a cumulative number of milliseconds since the instrument was powered on. Choose none if you do not want to output a time stamp or header information.

Cal Coefficients...

The LI-7000 uses a fifth order polynomial for the CO₂ calibration, and a third order polynomial for H₂O calibration. The Calibration Coefficients dialog displays these factory-determined calibration coefficients, as well as those for the internal pressure, temperature, and RH sensors. Some of these coefficients are fixed at the factory (i.e., the a1-a5 CO₂ and a1-a3 H₂O polynomial coefficients); others change with user calibrations (i.e., Z, Zm, S, and W0'; see Table 6-1).

The calibration coefficients are unique to each instrument, and may be found on the calibration sheet shipped from the factory. In most cases you will not want to alter any of these values.

4 Using the LI7000 Program

Calibration Coefficients

WARNING: Changing these parameters will affect the performance of your instrument.

CO2 H2O Other

Curve Coefficients

a1 2393.24

a2 1188520

a3 1.75775E9

a4 -1.03416E12

a5 3.92185E14

View Curve...

Compute Adjustment...

User Calibration

Z 1 W0' 1500000

Zt 0 W0'_d 0

Zm 7.31953E-5 AGC 0.5

S 1 VpCrr 1.57

Load From File... Save To File... OK Cancel Refresh

The coefficients are not part of the normal .I70 configuration file; they can, however, be stored in a separate file (.c70). This happens when you choose **Save To File**. To load coefficients from an existing calibration file, click on **Load From File** and choose a valid calibration file (.c70). The **Refresh** button clears all coefficients from the dialog; if the LI-7000 is connected, the program will query the instrument for the most current coefficients, some of which may have changed during a user calibration. The **OK** button updates the instrument with the values shown in the dialog.

Compute Adjustment Function

The CO₂ and H₂O polynomial curves corresponding to the factory calibration coefficients can be viewed by clicking the **View Curve** button(s). The **Compute Adjustment** button can be used to

compute new calibration coefficients using a zero gas and two span gas standards. This function is discussed below, with examples.

WARNING: Changing the factory calibration coefficients will affect the performance of your instrument. The factory calibration is very stable and rarely requires adjustment. The calibration adjust function will compute a new 5th order CO₂ and/or 3rd order H₂O polynomial fit over the entire CO₂ and H₂O measurement range (0-3000 μmol/mol and 0-70 mmol/mol respectively) based on a zero gas and two span gas standards. The calibration adjust function will allow the calibration to fit perfectly at two gas concentration points at a specific temperature. The two gas concentration points are input to the program and are based on two tanks (or two dew point temperatures from the LI-610 in the case of the H₂O channel) of certified calibration gases as measured by the LI-7000 optical bench. It is very important that the user is confident in the accuracy of their span gases before using this "compute adjustment" function.

Once a new calibration polynomial fit is computed the user can choose to view the new curve (comparing it to the previous curve), upload the polynomial to the instrument or cancel out of the dialog. **Applying the new computed calibration polynomial to the instrument will affect the performance of your instrument. Saving the factory calibration polynomial to the computer prior to executing the calibration adjustment is highly recommended.** This will allow you to electronically re-load the factory calibration polynomial should any problems arise. The factory calibration polynomial coefficients can also be found on the calibration sheet that ships with each instrument. Please contact LI-COR for a replacement calibration document if you are unable to locate it.

A NOTE ABOUT THE LI-COR FACTORY CALIBRATION: LI-COR uses a series of thirteen CO₂ calibration gases ranging in concentration from zero to 3,000 μmol/mol. The thirteen working standards are verified against a set of primary WMO standards known to an absolute accuracy of ≤0.06%. Factory calibration

coefficients are obtained from a 5th order polynomial fit to the entire range of concentration from zero to 3,000 $\mu\text{mol/mol}$. The nominal accuracy of the polynomial fit across the entire range of concentrations is about 1%, but the absolute measurement accuracy obtained by the user depends primarily on the accuracy of the calibration gas used to set the analyzer span. This calibration is very stable.

The calibration procedure for water vapor is similar to that for CO_2 , except that water vapor mole fractions are generated using the LI-COR LI-610 Portable Dew Point Generator. Fifteen data points between 0 °C and 40 °C dewpoint are used during the calibration procedure, and a third order polynomial is fit to the data. The LI-610 is certified by the National Institute of Standards and Technology (NIST) to have an absolute accuracy of 0.2 °C. This calibration is very stable.

Linearity Adjustment

The gas analyzer's calibration polynomial relates absorbance to concentration. Ideally, this polynomial linearizes the instrument, so that if you zero and span, the instrument will then not only read correctly at zero and at the span value, but also at all other concentrations across the range.

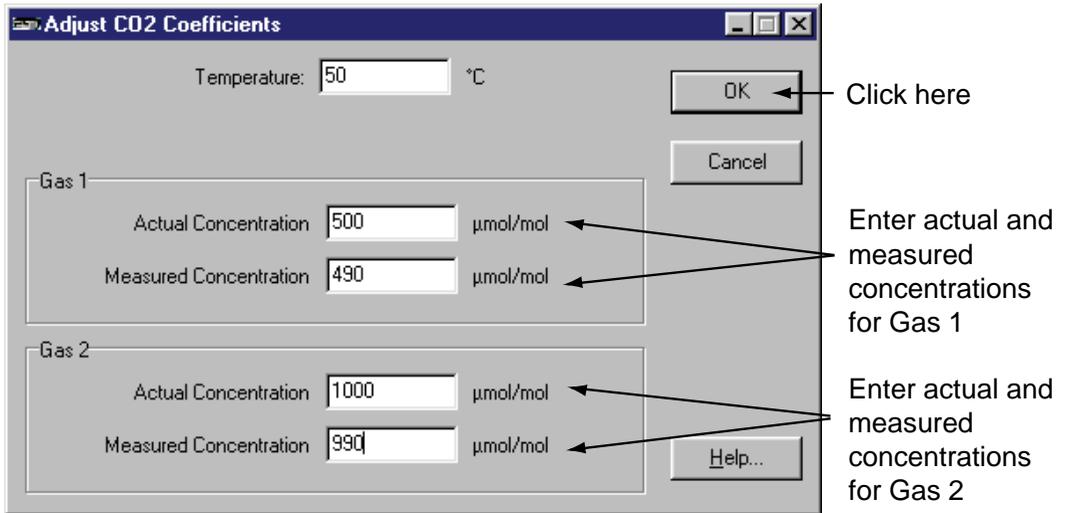
The linearity of the gas analyzer can be checked following zeroing and spanning by flowing another known concentration (for example, half of the value used for spanning) through the analyzer and seeing if it reads within the factory specification.

Factory calibrations, which determine the coefficients of the polynomial, are quite stable with time. However, if the analyzer's source or detector is replaced, or if significant dirt accumulates in the optical bench, then linearity errors that exceed specifications can result. If you determine that your gas analyzer's linearity error for CO_2 or H_2O is excessive, then you can make adjustments to the coefficients with this dialog. You will also need two span gases for CO_2 , and an LI-610 to generate two known dewpoints for H_2O .

1. Zero the instrument.
The instrument needs to be well zeroed for this correction.

SPAN OPTION: Before doing the next two steps, you may wish to manually set the span value to 1.00. This is especially true if you've noticed the span values getting progressively worse (0.9, 0.8, etc.). At any rate, whatever the span value is when you perform this calibration adjustment, that will be the new "normal" value. To adjust the span values in the LI-7000, view the current value (labeled "S"), and enter 1.00 if necessary.

2. Measure the first concentration (or dewpoint).
Make a note of the measured and true values, and also the bench temperature, and (if doing water) the bench pressure reading.



3. Measure the second concentration (or dewpoint).
Note the measured and true values. Presumably, the pressure and temperature will be essentially the same.

4

Using the LI7000 Program

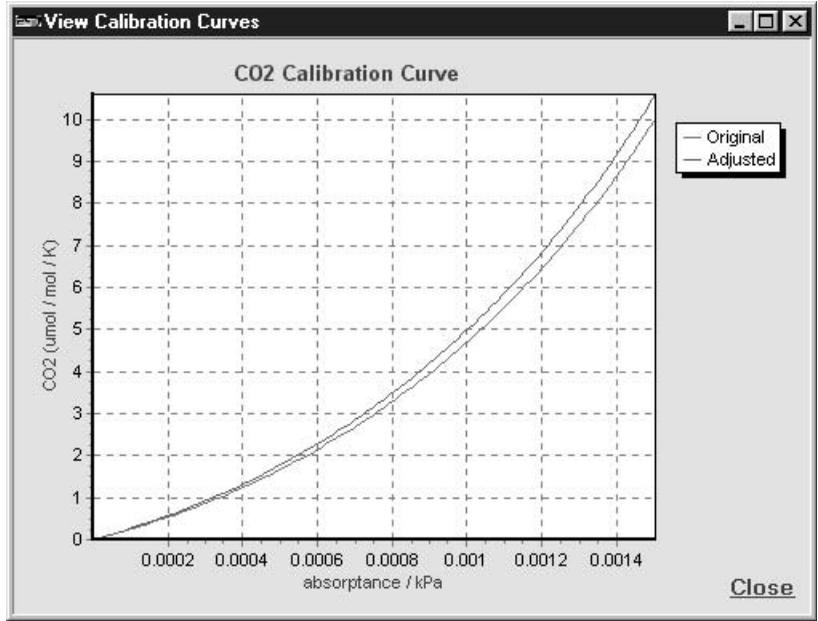
4. Enter the actual concentrations, and the measured data from Steps 2 and 3.

“Actual ” (concentration or dew point) is the true value. “Measured ” is what the analyzer indicated. Gas 1 can be either the higher or lower concentration, it doesn’t matter.

Note that if you want to perform the Calibration Adjustment procedure so that it covers the entire range of the instrument, and more closely mirrors the original factory calibration, you can choose CO₂ gases of 300 and 1500 $\mu\text{mol/mol}$, and H₂O values of 7 mmol/mol, and a second value slightly below ambient.

When done, click the **OK** button.

5. View the results.
Click the **View Curve** button. You will be shown the old and new curves and coefficients, based on the two points you entered.

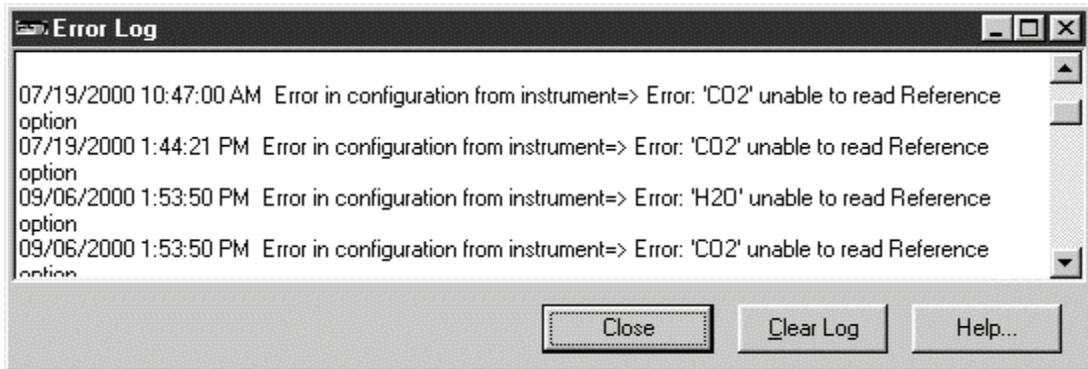


6. Apply the new coefficients, if desired.
Close the View Curves window. If you want to update the instrument with the new coefficients, click **OK**. Otherwise, **Cancel** will leave the instrument unchanged.

Error Log...

The Error Log dialog shows all items currently stored in the error log and allows for clearing the current text. When certain communication errors occur with the LI-7000, those errors are stored in the error log. The log is primarily a diagnostic tool for debugging communications problems.

4 Using the LI7000 Program



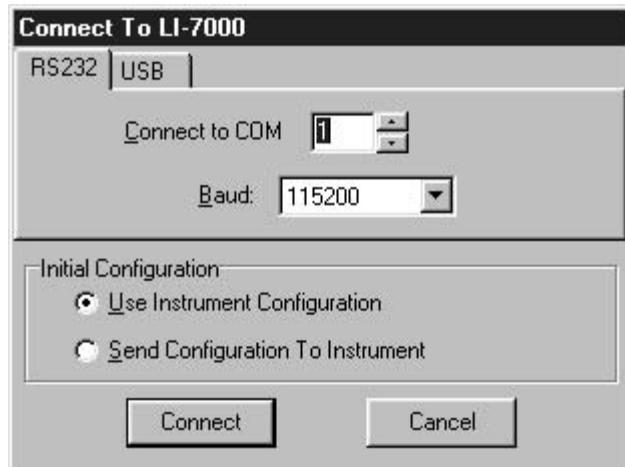
Click on **Clear Log** to clear the text in this dialog. The text in this dialog is saved in the same directory as the *LI7000* program file, and is named Li7000.log.

Remote Menu



Connect...

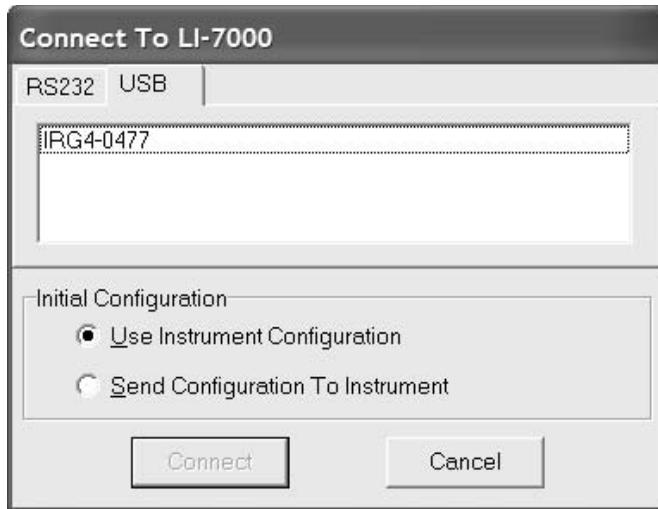
Opens the *Connect to LI-7000* dialog, where communications between the analyzer and your computer are established.



Use the arrow buttons to select the serial port on your computer to which the LI-7000 RS-232 cable is connected. Valid numbers are from 1 to 99. Choose the baud rate at which you want to communicate with the LI-7000. Note that the baud rate selected here must match the baud rate on the LI-7000 front panel to connect (see *Data I/O Group; RS-232* in Section 5).

If you are connected to the LI-7000 via the USB cable, click on the USB tab and highlight the desired instrument to which the computer is connected (all LI-7000's connected via USB are identified by their serial numbers).

4 Using the LI7000 Program



Enable the "Use Instrument Configuration" button to use the LI-7000 analyzer's built in default configuration file at connection; enable the "Send Configuration To Instrument" button to send the configuration file *currently active in the LI7000 program window* to the instrument at connection. Click **Connect**.

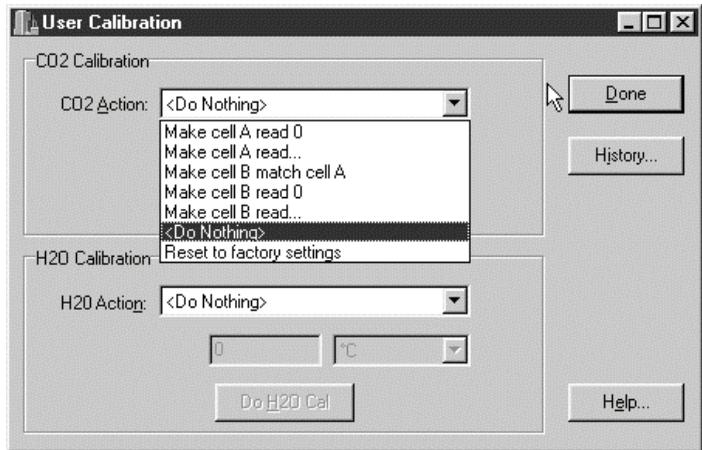
Disconnect

Terminates the RS-232 or USB connection between the LI-7000 and the computer.

NOTE: Section 6 contains complete calibration instructions. For the purposes of this discussion we will just refer to the options available in the User Calibration dialog.

User Calibration...

Opens the User Calibration dialog, where you can perform CO₂ and/or H₂O calibrations. Click on the History button to view a log of previous calibrations, including the action(s) performed, and the time at which the actions(s) were done.



Click on the arrow button in the "CO₂ Action" or "H₂O Action" fields to view the list of options available for the CO₂ or H₂O calibration. These options are:

Make cell A read 0 (Dry). Use this option when flowing a dry, or a dry, CO₂-free gas through cell A (the reference cell).

Make cell A read... This option allows you to specify the concentration of the gas flowing through cell A. When you select this option, the field below the CO₂ Action menu becomes active, and you can enter the CO₂ concentration, in $\mu\text{mol/mol}$.

Make cell B match cell A. Use this option to match the concentration of cell A and B. The same gas must be flowing through both optical cells.

Make cell B read 0 (Dry). Use this option when flowing a dry, or a dry, CO₂-free gas through cell B (the sample cell).

Make cell B read... This option allows you to specify the concentration of the gas flowing through cell B. When you select this option, the field below the CO₂ Action menu becomes active, and you can enter the CO₂ concentration, in $\mu\text{mol/mol}$.

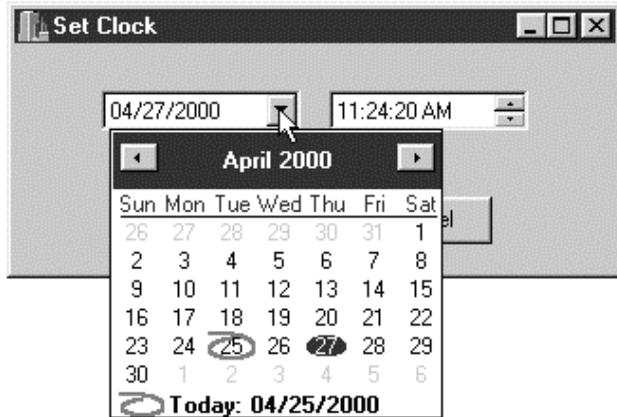
<Do Nothing>. Does not perform any calibrations. This setting allows you to perform either CO₂ or H₂O calibrations individually.

Reset to factory settings. Resets the user calibration coefficients back to the original factory settings.

The **DoCO2** and **DoH2O** buttons cause the calibration functions chosen in the 'CO2 Action' and 'H2O Action' menus to be performed. After the action has been performed, you can view the results in the Calibration Coefficients dialog box (see *Cal Coefficients* earlier in this section). For example, if you perform a CO₂ or H₂O calibration to match cells A and B, the zeroing term Z in the Calibration Coefficients dialog should read near 1. Note that you might need to click on the **Refresh** button in the dialog to view the latest coefficients derived from the calibration action.

Set Clock...

This dialog sets the real time clock on the LI-7000 analyzer.



Click on the down arrow button in the year and month field to open a calendar for the current month and year. Use the right or left arrow buttons at the top of the calendar to change months. Click on the current day of the month to select it. In the example above, clicking on the 27 changes the date to April 27, 2000.

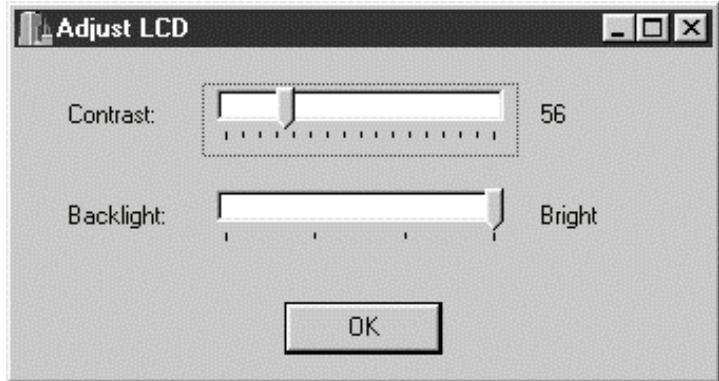
Click on the hour, minutes, or seconds field and use the up or down arrow buttons to adjust the time. If no fields are highlighted, clicking the up or down arrow button toggles between AM and PM.

Click **OK** to dismiss the dialog and accept the change(s).

Adjust LCD...

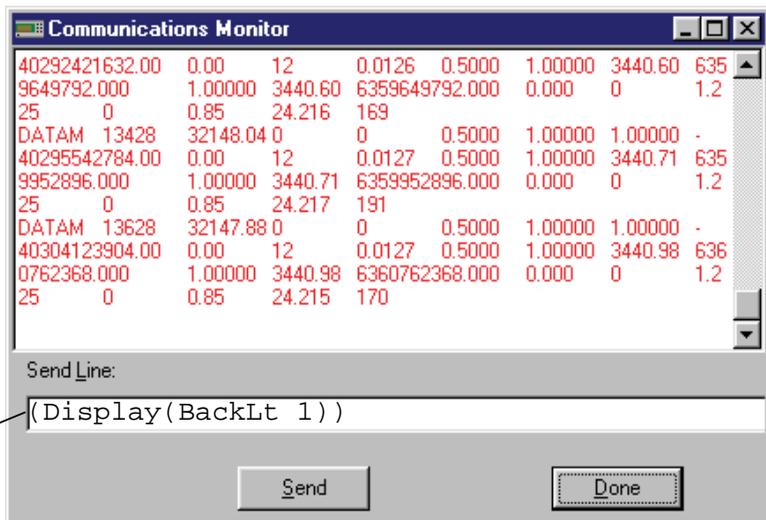
The LI-7000 LCD contrast and backlight can be adjusted to compensate for varying viewing conditions. The Adjust LCD dialog and the LI-7000 display interact in real time, meaning that as you move the Contrast and Backlight slider bars, the display will change immediately. Adjust as desired, and click **OK**.

4 Using the LI7000 Program



Monitor...

Opens a window that displays text strings of data being sent to the RS-232 or USB ports. This can be useful for viewing the variables that are being logged; this window can also be used for diagnostic purposes. Commands sent from the PC to the LI-7000 are displayed as blue text; data or other text strings sent from the LI-7000 to the PC are displayed as red text.



See Section 9,
Language Reference

The Communications Monitor window can also be used as a simple terminal emulator, by entering a command string in the "Send Line" field, and clicking the **Send** button. The text in the "Send Line" field in the graphic above shows an example of how you could enter a command to change the LCD display backlight to a value of 1.

Care should be taken when sending commands to the LI-7000, however; they can cause the *LI7000* program to lose synchronization with the instrument. See *Configuration Grammar* in Section 9 for more information on sending command line strings to the LI-7000.

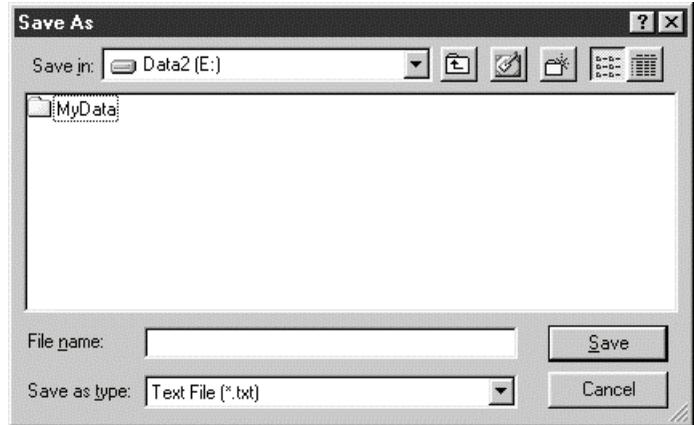
4 Using the LI7000 Program

Logging Menu



Start Logging

Starts logging data to a file, based on the parameters set up in the Configuration window, Logging page. When you start logging, you are prompted for a filename to which to save the data.



Enter a file name and choose the location to which the file will be saved. The file name will automatically be appended with a .txt extension. Note that existing log files can also be selected from the list; additional data are appended to the file, and no existing data are overwritten. Data are tab-delimited, and a new header string is sent each time logging is enabled, as shown below (example does not show all data labels).

```
"02/22/2000 2:58:30 PM"
```

```
"Time s"
```

```
"04/24/2000 3:23:10 PM"
```

```
"Time s"
```

```
"CO2A um/m"
```

```
2586.8 1116.65 1174.82 58.17
```

```
2587.8 1116.64 1174.75 58.12
```

```
2588.8 1116.46 1174.45 58.00
```

```
2589.8 1116.69 1174.44 57.76
```

```
2590.8 1117.02 1174.59 57.57
```

```
2591.8 1117.21 1174.77 57.56
```

```
2592.8 1116.97 1174.43 57.46
```

```
"04/24/2000 3:23:21 PM"
```

```
"Time s"
```

```
"CO2A um/m"
```

```
2598.8 1117.79 1174.70 56.91
```

```
2599.8 1117.53 1174.47 56.94
```

```
2600.8 1117.53 1174.41 56.87
```

```
2601.8 1117.72 1174.34 56.62
```

```
2602.8 1117.62 1174.31 56.69
```

```
2603.8 1117.96 1174.66 56.70
```

```
2604.8 1117.90 1174.51 56.62
```

```
"04/24/2000 3:23:37 PM"
```

```
"Time s"
```

```
"CO2A um/m"
```

```
2613.8 1118.62 1174.66 56.04
```

```
2614.8 1118.86 1174.95 56.09
```

```
2615.8 1118.91 1174.92 56.00
```

Stop Logging

Halts the logging of data.

Pause Logging

Pauses the logging of data, until either the Resume or Stop Logging menu items (or tool bar buttons) are selected. Note that when you resume logging, *a header string is not sent*; data are simply appended to the end of the file.

4 Using the LI7000 Program

Help Menu

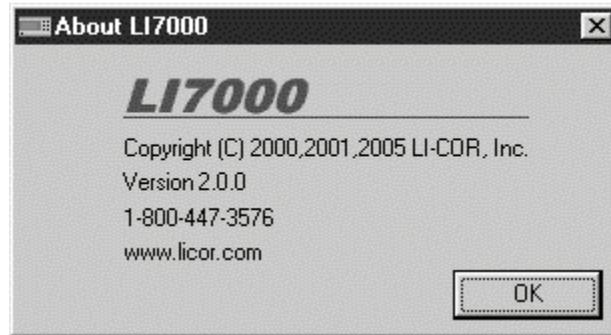


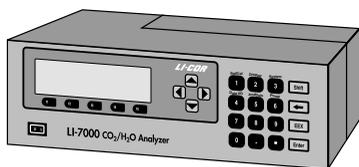
Help Topics

Opens an index of *LI7000* help topics.

About...

Displays the current *LI7000* program version number and LI-COR communication information.





5 The LI-7000 Software

This section provides an overview of the LI-7000 front panel interface. The LI-7000 front panel appears as shown below.

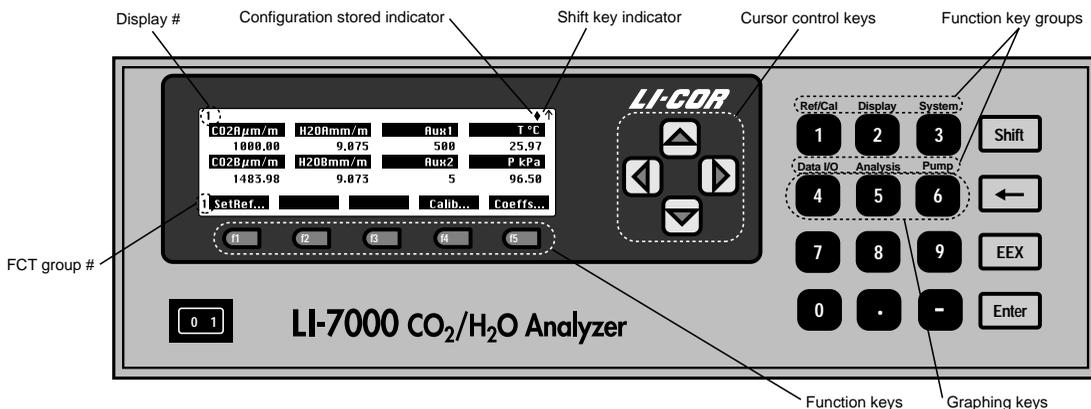


Figure 5-1. LI-7000 front panel and LCD display.

The Keypad

The keypad is used to enter numerical values, and to change the function key labels shown on the bottom line of the display. There are 6 function key groups (see *Function Keys* below), denoted with blue type on the keypad, that cause menus to be displayed at the bottom of the text display.

For example, in Figure 5-1 the labels are group #1, "Ref/Cal". If you press the Shift key, then 2 (not simultaneously), the keys change to the "Display" group:

2 Edit... BackLt3 Cntrst+ Cntrst-

5 Using the LI-7000 Instrument Software

The function group number is shown to the left of the row of function key labels (2 in the graphic above). A small arrow appears in the upper righthand corner of the display (Figure 5-1) after the **Shift** key is pressed, and remains there until the next key stroke.

The left arrow (←) key is used as a delete (backspace) key, **EEX** is used to enter exponential values, and **Enter** ends the function.

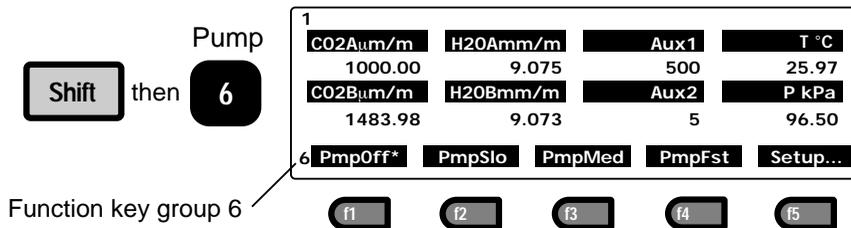
The Display

The display is 8 lines × 40 characters, for which 3 different user-defined display configurations can be set, using any combination of variables. Up to 8 variables can be displayed simultaneously, along with the function key options. The three displays are accessed by pressing any of 1 thru 3 on the keypad. The current display number is shown in the upper lefthand corner of the display as 1 thru 3.

In addition, as many as 3 graphical plotting screens with up to 3 graphs per screen can be defined; they are accessed by pressing any of 4, 5, or 6 on the keypad. When the graphing screens are displayed, pressing the up or down arrow key will switch between displays 4, 5, and 6. Press the Enter key to toggle between the graphing screen and a text screen that shows the real-time values of the variables defined for the corresponding plots.

Function Keys

There are 6 groups of function keys that are displayed at the bottom of the display. To show any particular group, press the **Shift** key, followed by the number. For example, press **Shift** then **6** to display function keys in the Pump group.



The function key groups are as follows:

5 Using the LI-7000 Instrument Software

Blue Label	Press	Fct Key Labels			
Ref/Cal	 then 1	1 SetRef...	Calib...	Coeffs...	
		Access the "Set Reference" dialog	Access the "User Calibration" dialog	View/Edit the factory calibration coefficients	
Display	 then 2	2 Edit...	BackLt3	Cntrst+	Cntrst-
		Edit the current display	Toggle display backlight	Increment display contrast	Decrement display contrast
System	 then 3	3 Diag...	Clock...	About...	
		Enable/disable diagnostics & warnings	Set time and date	Information box	
Data I/O	 then 4	4 Aux1&2	DACs...	RS-232...	
		Configure Aux1 and Aux2	Configure DAC1 thru DAC4	Configure RS-232 port and data output	
Analysis	 then 5	5 Filter...	SetInt...	StrtInt	StopInt
		Set running average time	Set up integration	Start integration	Stop integration (when running)
Pump	 then 6	6 PmpOff*	PmpSlo	PmpMed	PmpFst
		Pump off (* indicates current setting)	Slow speed	Medium speed	Fast speed
					Setup... Set pump speeds

Viewing Real Time Data

Real time data are displayed simultaneously on the LI-7000 LCD, regardless of what is happening with the RS-232 port (e.g. "talking" to a PC running the *LI7000* program).

The following quantities are available for display:

System ID #	LI-7000 Display	LI7000 Display	Description
01	CO2A $\mu\text{m}/\text{m}$	CO2A $\mu\text{m}/\text{m}$	CO ₂ cell A concentration, $\mu\text{mol}/\text{mol}$
02	CO2B $\mu\text{m}/\text{m}$	CO2B $\mu\text{m}/\text{m}$	CO ₂ cell B concentration, $\mu\text{mol}/\text{mol}$
03	CO2 Δ $\mu\text{m}/\text{m}$	CO2D $\mu\text{m}/\text{m}$	CO ₂ differential, $\mu\text{mol}/\text{mol}$
04	H2OAm mm/m	H2OA mm/m	H ₂ O cell A concentration, mmol/mol
05	H2OBm mm/m	H2OB mm/m	H ₂ O cell B concentration, mmol/mol
06	H2O Δ mm/m	H2OD mm/m	H ₂ O differential, mmol/mol
10	CO2A Pa	CO2A Pa	CO ₂ cell A partial pressure, Pa
11	CO2B Pa	CO2B Pa	CO ₂ cell B partial pressure, Pa
12	CO2 Δ Pa	CO2D Pa	CO ₂ partial pressure differential, Pa
13	H2OA kPa	H2OA kPa	H ₂ O cell A partial pressure, kPa
14	H2OB kPa	H2OB kPa	H ₂ O cell B partial pressure, kPa
15	H2O Δ kPa	H2OD kPa	H ₂ O partial pressure differential, kPa
16	H2OA °C	H2OA dpC	Dew point of cell A, degrees C
17	H2OB °C	H2OB dpC	Dew point of cell B, degrees C
18	H2O Δ °C	H2OD dpC	Dew point differential, degrees C
20	Aux1	Aux1	Auxiliary input channel 1, linearized signal
21	Aux2	Aux2	Auxiliary input channel 2, linearized signal
22	P kPa	PkPa	Pressure measured in cell B, kPa
23	T °C	T C	IRGA temperature, degrees C
30	Integral	Integral	Integration result, area under curve
31	Peak	Peak	Integration result, peak value
40	Diag	Diag	Diagnostic: condition flags
41	RH %	RH %	Diagnostic: humidity sensor RH %
42	CO2 AGC	CO2 AGC	CO ₂ automatic gain control
43	H2O AGC	H2O AGC	H ₂ O automatic gain control
50	CO2A W	CO2A W	CO ₂ cell A raw signal
51	CO2B W	CO2B W	CO ₂ cell B raw signal
52	H2OA W	H2OA W	H ₂ O cell A raw signal
53	H2OB W	H2OB W	H ₂ O cell B raw signal
54	CO2A abs	CO2A abs	CO ₂ cell A absorbance, unitless

5 Using the LI-7000 Instrument Software

System ID #	LI-7000 Display	LI7000 Display	Description
55	CO2B abs	CO2B abs	CO ₂ cell B absorptance, unitless
56	H2OA abs	H2OA abs	H ₂ O cell A absorptance, unitless
57	H2OB abs	H2OB abs	H ₂ O cell B absorptance, unitless
60	DAC1 V/2	DAC1V/2	Diagnostic: DAC1 output, volts/2
61	DAC2 V/2	DAC2V/2	Diagnostic: DAC1 output, volts/2
62	DAC3 V/2	DAC3V/2	Diagnostic: DAC1 output, volts/2
63	DAC4 V/2	DAC4V/2	Diagnostic: DAC1 output, volts/2
64	Aux1 V	Aux1V	Auxiliary input channel 1, volts
65	Aux2 V	Aux2V	Auxiliary input channel 2, volts
66	P V	PV	Pressure sensor cell B, volts
67	T V	TV	IRGA temperature, volts
68	RH V	RHV	Diagnostic: humidity sensor RH, volts
69	Flow V	FlowV	Flow rate estimate, volts
70	DAC1 cts	DAC1 cts	A/D DAC1 counts
71	DAC2 cts	DAC2 cts	A/D DAC2 counts
72	DAC3 cts	DAC3 cts	A/D DAC3 counts
73	DAC4 cts	DAC4 cts	A/D DAC4 counts
74	Aux1 cts	Aux1 cts	A/D Aux1 counts
75	Aux2 cts	Aux2 cts	A/D Aux2 counts
76	P cts	P cts	A/D Pressure counts
77	T cts	T cts	A/D Temperature counts
78	RH cts	RH cts	A/D Relative Humidity counts
79	Flow cts	Flow cts	A/D Flow counts
80	Adc0 cts	Adc0 cts	A/D Zero counts
81	AdcR cts	AdcR cts	A/D Reference counts

"Ref/Cal" Group

The "Ref/Cal" group of function keys allow you to set the concentration of CO₂ and/or H₂O in the reference cell, calibrate the analyzer, and view or edit the factory-entered calibration coefficients.

"SetRef"

The primary operational consideration when making measurements with the LI-7000 is knowing what is in the reference cell. There are three options for determining the reference cell concentration for CO₂ and H₂O:

1. The reference is known and stable (user-entered constant)

A known concentration of CO₂ and/or H₂O is flowing through the A (reference) cell. This option provides the best accuracy and long term stability.

2. The reference is measured externally

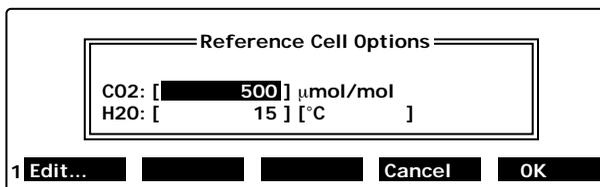
The LI-7000 measures an analog signal from an external (user-supplied) gas analyzer that is measuring the absolute concentration of the reference stream. For H₂O, the analog signal could be provided by a dew point generator such as the LI-COR LI-610, or by a LI-COR LI-6262 or another LI-7000. The LI-7000 has two auxiliary analog inputs that can be used by the LI-7000 to compute reference concentration(s) for CO₂ and/or H₂O.

3. The reference is estimated by the LI-7000

This measurement is based on the absorbance occurring in the reference cell. This option is the simplest, as you don't need to flow a gas through the reference cell, but this option does not have long term stability.

When you press **SetRef**, the "Reference Cell Options" dialog appears:

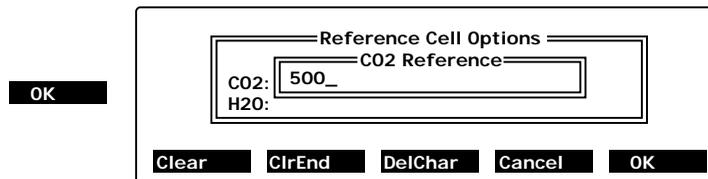
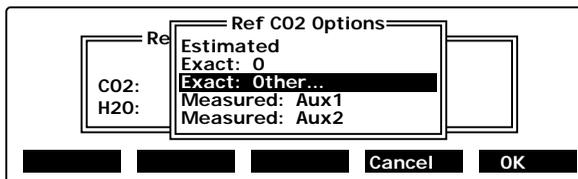
5 Using the LI-7000 Instrument Software



Note that there are 3 fields in this dialog; the editor for the CO₂ and H₂O concentration is a selection menu (below). Press **Edit** when the H₂O units are selected to toggle between °C and mmol/mol.

CO₂ Reference

The selection menu for the CO₂ reference concentration is shown below.



Choose **Estimated** to let the LI-7000 estimate the reference cell CO₂ concentration based on measured absorbance. Choose **Exact: 0** if you have a CO₂-free gas source flowing through the reference cell. Choose **Exact: Other** to enter the concentration of the CO₂ reference gas (in μmol/mol), if it is a non-zero gas. Choose **Measured: Aux1** or **Aux2** to measure an analog signal input at Auxiliary port 1 or 2.

H₂O Reference

The selection menu for the H₂O reference concentration is shown below.

*If units are mmol/mol,
"dry air" = 0. If units are
°C, "dry air" = -100 °C.*

Choose **Estimated** to let the LI-7000 estimate the reference cell H₂O concentration based on measured absorbance. Choose **Exact: 0** if you have a dry gas source flowing through the reference cell. Choose **Exact: Other** to enter the concentration of the H₂O reference gas (in mmol/mol or °C, depending on the units selected), if it is a non-zero gas.

NOTE: Make sure the H₂O units are set appropriately for the signal being measured. Use °C for a gas stream generated by a dew point generator or dew point hygrometer, or use either mmol mol⁻¹ or °C if the external device is a gas analyzer.

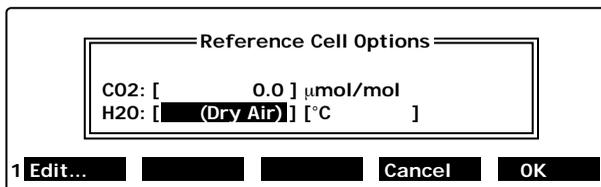
Choose **Measured: Aux1** or **Aux2** to measure an analog signal input at Auxiliary port 1 or 2.

■ Example 1: Operate with dry, CO₂-free air in the reference cell

1. Press **Shift** then **1** to access the "Ref/Cal" function key group.

5 Using the LI-7000 Instrument Software

2. Press **f1** (Set Ref...).
3. Highlight the CO₂ value and press **Edit**. Highlight **Exact: 0** in the menu, and press **OK**.
4. Highlight the H₂O value and press **Edit**. Highlight **Exact: Dry air** and press **OK**. The display should appear as



The screenshot shows a menu titled "Reference Cell Options" with two rows of settings. The first row is "CO2: [0.0] μmol/mol" and the second row is "H2O: [(Dry Air)] [°C]". Below the menu are four buttons: "1 Edit...", a blank button, a blank button, "Cancel", and "OK".

The H₂O value shown when **Exact: Dry air** was selected depends on which H₂O units are in effect. Dry air is taken to be 0 mmol mol⁻¹ or -100 °C.

5. Press **OK** to implement the new configuration, or **Cancel** to exit without making any changes. The following table lists some typical reference cell configuration examples.

Reference Source	How to Configure	Comments
Closed loop, with desiccant and CO ₂ scrubber.	CO2: [0] $\mu\text{mol/mol}$ H2O: [dry air] [°C] or mmol/mol	Easy to configure, excellent stability. Chemicals may need to be changed frequently.
Known concentration of air from a CO ₂ tank.	CO2: [410] $\mu\text{mol/mol}$ H2O: [dry air] [°C] or mmol/mol	Air from a compressed tank is usually pretty dry, but you may want to verify it, or let H ₂ O be in "Estimated" mode.
Ambient atmospheric air.	CO2: [Estimated] $\mu\text{mol/mol}$ H2O: [Estimated] [mmol/mol] or °C	Even if you know the approximate concentration, don't enter an "exact" reference value unless you know it exactly.
Ambient atmospheric air, pulled through a buffer volume, measured with an LI-6262 gas analyzer.	CO2: [Aux1] $\mu\text{mol/mol}$ H2O: [Aux2] [mmol/mol] or °C	The buffer volume is important here, to eliminate time delays between the LI-6262 measurement and the time that air is in the LI-7000 reference cell.
Air from an LI-610 Dew Point Generator	CO2: [Estimated] $\mu\text{mol/mol}$ H2O: [Aux1] [°C]	Estimate the CO ₂ value because of the potential for the water bath to change it. H ₂ O reference can be a constant (what the dew point generator is set to) or measured (the actual condenser block temperature).

"UserCal"

User calibration consists of putting a known concentration into one or both cells and making the LI-7000 read correctly. There are three different user calibration actions that can be performed:

1. Adjust the Reference Cell

With a known concentration in the reference cell, make the reference concentration read the expected value.

5 Using the LI-7000 Instrument Software

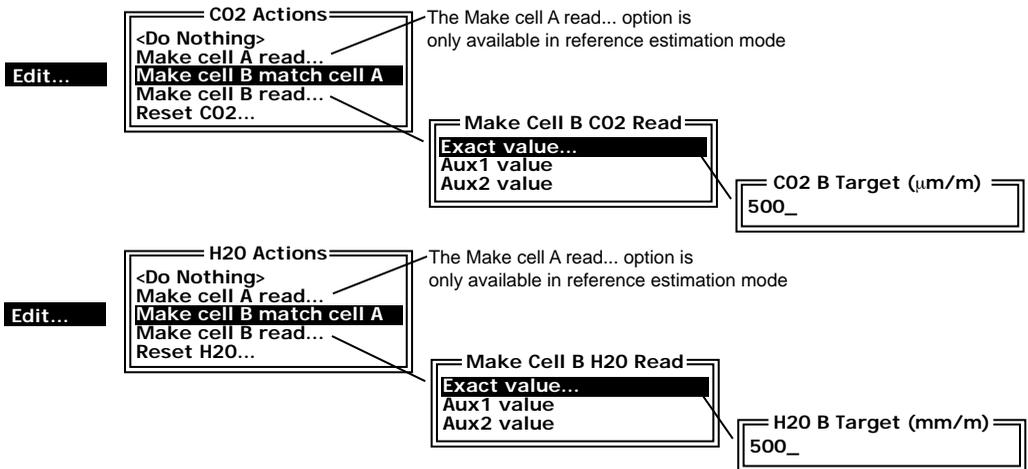
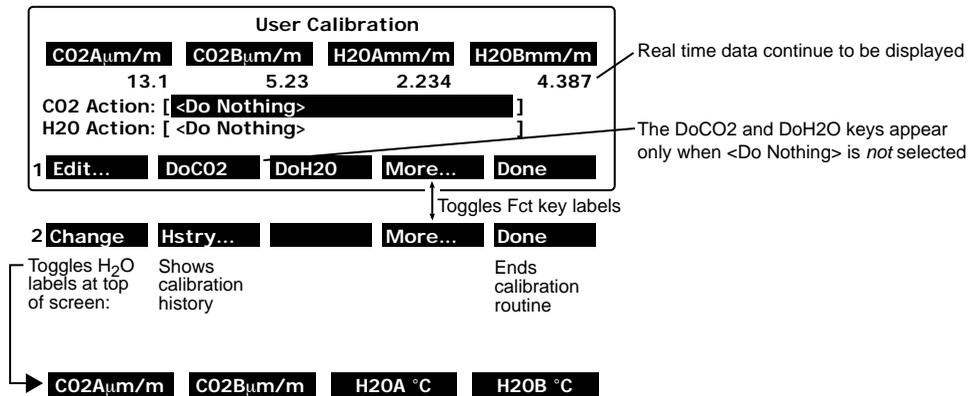
2. Match the Sample and Reference Cells

With the same (but not necessarily known) concentration in both cells, make the two cells agree. This is done by adjusting the sample cell. It does not change the reference cell.

3. Adjust the Sample Cell

This adjustment is to make the sample cell read correctly at some other concentration besides the one in the reference cell.

The user calibrations performed, and when they are done, depends heavily on how the reference cell is configured (see Section 6).



■ Example: Match Cell B to Cell A for CO₂ and H₂O with the User Calibration function.

1. Press **Shift** then **1** to access the "Ref/Cal" function key group.
2. Press **f4** (Calib...).
3. With CO2 Action highlighted, press **f1**(Edit...).

5 Using the LI-7000 Instrument Software

4. Move the highlight to 'Make cell B match cell A. Press **OK**.
5. Press **f2** (DoCO2). The highlight on the CO2 Action field will disappear while the analyzer performs the calibration; it will reappear when the calibration is finished.

For H₂O...

6. With H2O Action highlighted, press **f1**(Edit...).
7. Move the highlight to 'Make cell B match cell A. Press **OK**.
8. Press **f3** (DoH2O). The highlight on the H2O Action field will disappear while the analyzer performs the calibration; it will reappear when the calibration is finished.

"Coeffs"

The calibration coefficients can be viewed and/or edited with the Coefficients routine. In most cases you will not want to change any of these values manually. Usually the only reasons to view these coefficients are to troubleshoot problems, or to see the results of a calibration ("what did the span get set to?"). Highlight any coefficient and press **Edit** to change the value. Press **OK** when finished. You are prompted to verify that you want to make the changes.

```

----- Calibration Coefficients -----
--- CO2 values ---
a1 = 0.00239324
a2 = 1.18851
a3 = 1757.74
a4 = -1.03416e+06
a5 = 3.92185e+08
gamma = 1
Z = 1.01557
Zt = -1.32e-06
Zm = 0
S = 1.001
W0' = 1
W0'_d = 1
AGC = 0.5
VpCrr = 1.57
--- H2O values ---
a1 = 0.0821067
a2 = 21.923
a3 = 39286.8
gamma = 1
Z = 1.08406
Zt = 0
Zm = 0
S = 1.001
W0' = 1
W0'_d = 1
AGC = 0.5
---- Pressure ----
a0 = 58.481
a1 = 30.4
--- Temperature ---
A = 0.000828003
B = 0.000208687
C = 8.0874e-08
---- Humidity ----
a0 = 0
a1 = 1

```

Edit... PgUP PgDN Cancel OK

Attention!
OK to Make Changes?

No Yes

See Section 6, *Calibration* for details.

5 Using the LI-7000 Instrument Software

"Display" Group

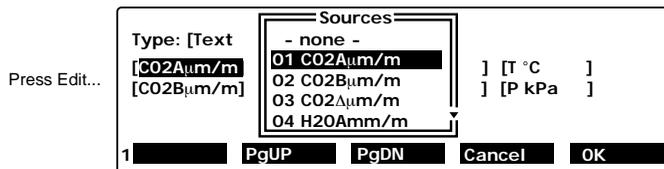
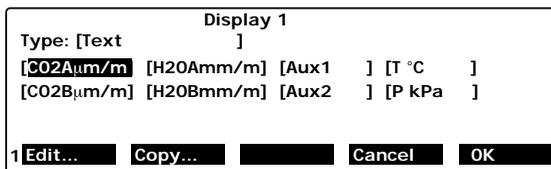
"Edit"

When **Edit** is pressed, a full screen dialog appears that allows the text or graphical definition of the display to be viewed and edited.

■ Defining the Text Displays

1. Press any of 1 thru 3 to access the associated text display definition to be modified.
2. Press **Shift** then **2** to access the set of Display function keys. The variables currently defined for the active display are shown. Press **f1 (Edit)**. Use the cursor control keys to move the highlight to the variable(s) to be changed. Press **f1** again. A menu of available variables pops up (below).

***HINT:** Shift, then ↑ will jump to the top of a menu, and Shift, then ↓ will jump to the bottom of a menu.*



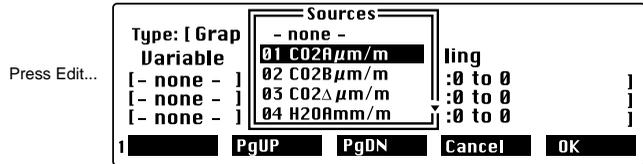
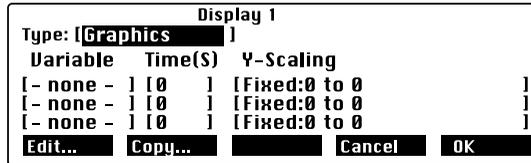
3. Use the PgUp, PgDN function keys, or the cursor control keys to scroll through the menu and highlight the desired variable, and press **f5 (OK)**. Continue to add or change the displayed variables in this manner. When finished, press **f5 (OK)**.

■ Defining the Graphical Displays

1. Press any of 4 thru 6 to access the associated graphical display definition to be modified.
2. Press **f1 (Edit)**. Press **f1 (Edit)** again, if necessary, to toggle between Text and Graphics. Use the cursor control keys to

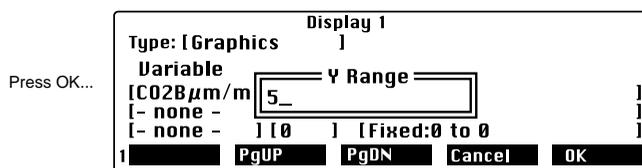
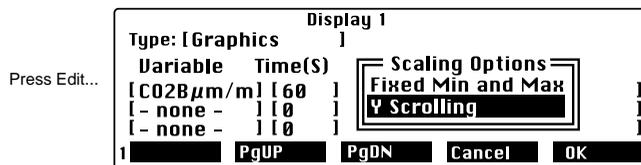
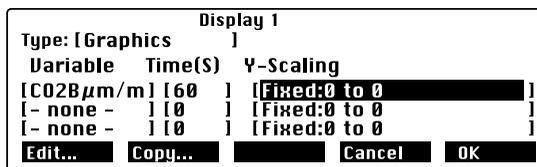
move the highlight to the first variable(s) to be plotted. Press **f1** again. A menu of available variables pops up (below).

HINT: Shift, then ↑ will jump to the top of a menu, and Shift, then ↓ will jump to the bottom of a menu.



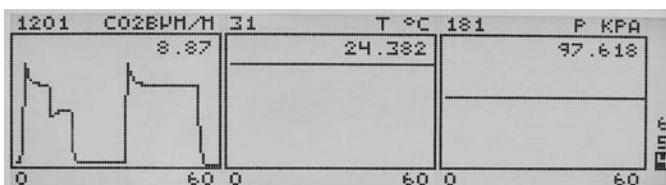
- Use the PgUp, PgDN function keys, or the cursor control keys to scroll through the menu and highlight the desired variable, and press **f5** (**OK**).
- Use the cursor control keys to move the highlight to the Time (S) field and press **f1** (**Edit**). Press the left arrow key (←) to move the cursor, and enter the number of seconds of data to be displayed along the X axis. Press **OK**. The X axis will automatically scroll to show the last x number of seconds of data, as defined here.
- Use the cursor control keys to move the highlight to the Y Scaling field and press **f1** (**Edit**). The Y axis can be set to display an axis with a fixed range between two user-defined points, or as a "floating" axis that will automatically keep the data on screen, with a range of x number of points above or below the current data points. For example, if you choose a Y Scaling axis value of 5, the axis will shift to remain 5 points above a rising plot, or 5 points below a falling plot. Press **OK** when you are finished defining the plot(s).

5 Using the LI-7000 Instrument Software



- As many as 3 graphical plotting screens with up to 3 graphs per screen can be defined; they are accessed by pressing any of 4, 5, or 6 on the keypad. When the graphing screens are displayed, pressing the up or down arrow key will switch between displays 4, 5, and 6. Press the **Enter** key to toggle between the graphing screen and a text screen that shows the real-time values of the variables defined for the corresponding plots.

The figure below shows display definition 4, which consists of 3 plots for CO2B μm/m, T °C, and P kPa. Each plot is displaying 60 seconds of data, with a fixed Y axis.



"BackLt<n>"

Toggles through the back light states (n=0, 1, 2, or 3), where 0 is no backlight, and 3 is maximum brightness.

"Cntrst+" and "Cntrst-"

Increments/decrements the display contrast setting.

■ Changing the Display Backlight and Contrast

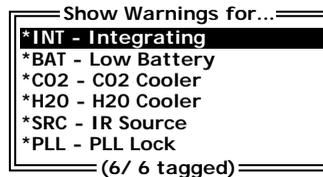
1. Press **Shift** then **2** to access the set of Display function keys. Press **f3** to toggle the backlight between values of 0 (lowest) and 3 (highest).
2. Press **f4** or **f5** to adjust the contrast of the display up or down.
TIP: Press Shift + ← at any time to reset the LCD contrast to the midrange value.

"System" Group

The System function keys access miscellaneous routines, including setting the clock, enabling/disabling diagnostic messages, and viewing instrument information.

"Diag"

The Diagnostics messages interface allows you to choose which conditions will generate a warning message on the display.



Press **Toggle** to enable/disable the selected warning(s). Press **TagAll** or **ClrAll** to enable/disable all warnings, respectively. Warning messages appear on the last line of the display, above the function key labels. See the *Troubleshooting* section in this

5 Using the LI-7000 Instrument Software

manual for a complete description of these and other warning messages.

"Clock"

The interface for setting the time and date shows the current values (updating each second). Use the right and left arrow keys to select the field to be changed, and the up and down arrow keys to change the value. Press **OK** when finished.

Set Date and Time
1 Jan 2000 00:15:52

Cancel

OK

"About"

Displays a scrollable window with the LI-7000 software version number and LI-COR communication information.

About this instrument
LI-COR LI-7000
Version 2.0.0
4421 Superior St. / P.O. Box 4425
Lincoln, NE 68504 USA
Phone: 402-467-3576
Toll-free: 800-447-3576 (US & Canada)
Fax: 402-467-2819
E-mail: enusales@licor.com
URL: <http://www.licor.com>

OK

"Data I/O" Group

"Aux1&2"

The auxiliary input channels 1 and 2 allow you to enter the coefficients of two second order polynomials used to convert the input signals (in volts) to other meaningful units. The conversion uses equations of the form

$$\text{Aux1} = A_1 + B_1V_1 + C_1V_1^2$$

$$\text{Aux2} = A_2 + B_2V_2 + C_2V_2^2$$

where A, B, and C are the user-entered coefficients, and V is the voltage input signal.

Auxiliary channels 1 and 2 are sampled at 50 Hz (± 1 Hz), without averaging. The filter on the analog input has a 10 Hz cutoff response.

Auxiliary Input	
Aux #1	Aux #2
A=[0]	A=[0]
B=[0]	B=[0]
C=[0]	C=[0]

Highlight the coefficient under Aux1 or Aux2 and press **Edit** to change the value. Press **OK** when finished editing.

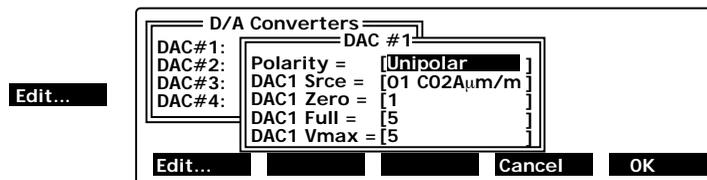
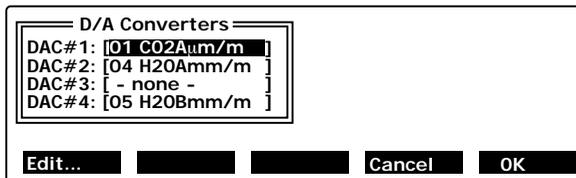
"DACs"

The DAC function allows you to configure each of the four digital-to-analog converters (DACs) that are connected to the four DAC output ports on the back of the LI-7000. Each DAC can be set to have either a bipolar ($-V_{\max}$ to $+V_{\max}$) or unipolar (0 to $+V_{\max}$) output, although DAC1 and DAC2 must be set the same.

Each DAC is configured by specifying the source channel (e.g. CO₂ A $\mu\text{mol/mol}$) that drives the analog signal, the source channel value which corresponds to zero volts, the source channel value

5 Using the LI-7000 Instrument Software

which corresponds to full scale voltage, and the maximum voltage range over which the source is measured.



■ To configure a DAC channel, follow these steps:

1. Press f3 in the Data I/O group to access the DAC function. Use the arrow keys to scroll to the DAC channel to be configured (1-4). Keep in mind that DAC1 and DAC2 have a *fixed* Vmax of 5 volts, and must be configured the same way.
2. Press **Edit** (f1). Press **Edit** (f1) again to toggle the polarity between bipolar and unipolar. Move the highlight to DAC1 Srce and press **Edit** (f1) to access a list of available source channels. Page up or down to select the source channel and press **OK** (f5).
3. Move the highlight to DAC1 Zero, Full, or Vmax and press **Edit** (f1) to enter the values for the source channel values that correspond to zero volts, full scale voltage (fixed at 5 volts for DAC1 and DAC2), and the maximum voltage range over which the source is measured. Press **OK** when finished. The specified source channel will now be sent to the respective output on the back panel terminal strip.

See Section 3, *Using the D/A Converters* for a more detailed discussion of the DAC channels.

"RS-232"

Sets the output options for data transfer via the RS-232 port.

RS-232 Configuration

Config: 9600, 8, 1, None
 Output freq: [2Hz]
 Time stamp: [ms since power on]
 Data list: [10 items]
 CheckSum: [off]

Baud Rate

Config

9600
19200
38400
57600
115200

Output frequency

Freqs

Polled
1hr
30min
10min
5min
2min
1min
30s
10s
5s
2s
1s
1Hz
2Hz
5Hz
10Hz
20Hz
30Hz
40Hz
50Hz

Time stamp

Options

none
 WWW-MM-DD HH:MM:SS
 ms since power on

Data list

Data List

01 C02A μm/m
 02 C02B μm/m
 03 C02 μm/m
 04 H20Amm/m
 05 H20Bmm/m

1

2

Variables

*01 C02A μm/m
 *02 C02B μm/m
 *03 C02 μm/m
 *04 H20Amm/m
 *05 H20Bmm/m

The RS-232 output parameters default to 9600 baud, 8 data bits, 1 stop bit, and no parity. The RS-232 port supports baud rates of 9600, 19200, 38400, 57600, and 115200. The other configuration parameters are edited by scrolling to the desired parameter and pressing **Edit** (f1). The options for each parameter are shown above.

Output Frequency - Determines the rate of data output. If 'Polled' is chosen, data will only be output upon a polling command sent to the RS-232 or USB port via the computer (see *Configuration Grammar* in Section 9), or via the Trigger Input (see *Trigger Input* in Section 3).

As many as 55 different variables can be selected for output. Note, however, that the data transfer rate is also dependent upon the processing speed and memory availability of the

5 Using the LI-7000 Instrument Software

computer to which the LI-7000 is connected. Table 5-1 shows the maximum log frequency for 10 and 20 variables at each of the available baud rates. The examples in Table 5-1 assume the following; 850MHz Pentium III processor, 256MB RAM, Windows® 2000/XP operating system, with no active graphs running.

Table 5-1. Estimated RS-232 data transfer rates for two log frequencies.

Baud Rate (bps)	Log Frequency	
	10 Variables	20 Variables
9600	5 Hz	2 Hz
19200	10 Hz	5 Hz
38400	20 Hz	10 Hz
57600	40 Hz	20 Hz
115200	50 Hz	40 Hz

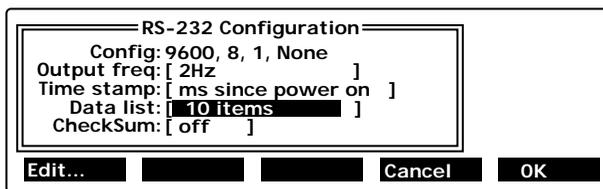
Note that the table above gives *estimates* only; if you observe that output data are being missed, try reducing the processing demands on the computer (other programs running, etc.), reduce the number of output variables if possible, or turn off any active graphs in the *LI7000* program.

Time Stamp - The time stamp and header information can be sent in one of two forms; in year/month/day/hour/minute/second format (taken from the system clock), or as a cumulative number of milliseconds since the instrument was powered on. Choose **None** if you do not want to output a time stamp or header information.

Data List - The list of source channels that are output to the RS-232 port. The number of items currently selected for output is displayed.

Using the LI-7000 Instrument Software **5**

To add or remove items from the list, press **Edit** (f1), press **More** (f1), and then press **Insert** (f2) or **Remove** (f3). When **Insert** (or **Remove**) is selected, a Variables list appears, where you can choose output sources to be added or removed from the Data List. A * symbol preceding the variable indicates that it is already selected for output. Move the highlight to the desired variable and press **OK**; it will be added to (or removed from) the Data list, and the RS-232 Configuration will update the number of items selected.



Edit... Press to Edit the Data List

More... **Insert** **Remove** **Cancel** **OK**

Insert Press to Insert or Remove items from the Data List

Remove



Sources from the Variables list will be inserted at the cursor location in the Data List. In the graphic above, any variable selected would be inserted before 01 CO₂A μ m/m, at the top of the Data List. To append a variable to the bottom of the list, move the cursor to the bottom of the list using the down arrow key, or the **MoveDN** function key. Select a variable from the Variables list and press **OK**.

Checksum - The checksum is a numeric value used to verify the integrity of a block of data. When data are transmitted

5 Using the LI-7000 Instrument Software

from point to point in a packet, the LI-7000 counts the bytes and adds a check digit at the end of the packet. The receiving computer calculates the bytes received and compares the sender's count with the receiver's count to determine if there is any change that might indicate that the data were corrupted in transit. Checksum can be toggled on or off.

"Analysis" Group

"Filter"

Sets the running signal average time. Values can be set between 0 seconds (no signal averaging) and 20 seconds. Note the relationship between the filter setting and the resulting frequency response time and signal delay in the table below.

Filter Setting (sec.)	Frequency Response (-3 db) Hz	Signal Delay
0	20	200 ms
0.05	10	225 ms
0.1	5	250 ms
0.2	2.5	300 ms
0.5	1.0	450 ms
1	0.5	700 ms
2	0.25	1.2 s
5	0.1	2.7 s
10	0.05	5.2 s
20	0.025	10.2 s

"SetInt..."

Sets the parameters for integration, including the threshold.

Integration Setup

Quantity: [H2OB kPa]

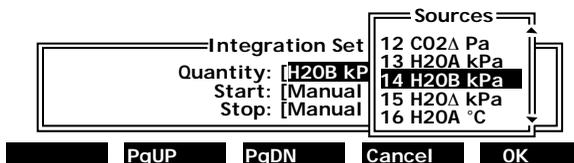
Start: [Manual]

Stop: [Manual]

Edit...
Cancel
OK

Highlight the Quantity field and press **Edit** to change the variable to be integrated. The Sources list appears, from which you can select a variable to integrate. Scroll to the desired variable and press **OK**.

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Integration can be started manually, by pressing the **StrtInt** button, and stopped manually, by pressing the **StopInt** button (which appears after integration is started). Integration can be started and stopped using a threshold value, also. Integration can be stopped using an elapsed time, also. Lastly, a combination of manual start/stop and threshold values can be used; for example, you can start integration manually, and let it progress until a threshold value is reached which stops the integration.



Edit the Start options by highlighting the Start field and pressing **Edit**. Highlight Manual or Threshold and press **OK**. If Threshold was selected, you are prompted to enter a value at which integration will start.



Edit the Stop options by highlighting the Stop field and pressing **Edit**. Highlight Manual, Threshold, or Elapsed Time and press **OK**. If either Threshold or Elapsed Time is selected, you are prompted to enter a threshold value at which integration will stop, or the elapsed time (in seconds) over which the integration will take place.

"StrtInt"

Starts the integration based on the parameters defined at "SetInt" above. This key appears only when an integration is *not* running.

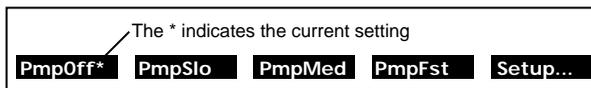
"StopInt"

Halts integration. This key appears only when an integration *is* running.

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"Pump" Group

Allows you to select a pump speed from Off, Slow, Medium, and Fast, or edit the value of any of the speeds.



"PmpOff"

Turns pump off.

"PmpSlo"

Sets pump to slow setting.

"PmpMed"

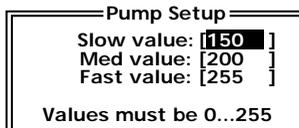
Sets pump to medium setting.

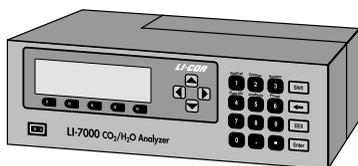
"PmpFst"

Sets pump to fast setting.

"Setup..."

Allows you to define values for slow, medium, and fast pump settings. Values must be between 0 and 255, where 0 is off. Note that this value determines the *voltage* applied to the pump (approximately 0-10V); at values less than about 50, the pump may not turn on due to friction.





6 Calibration

Introduction

Calibrating the LI-7000 is easy to do, but there are some basic concepts that must be understood. In fact, the term “calibration” should be clarified, because in its complete sense, it refers to a set of coefficients that allow each individual instrument to read correct concentrations under a range of conditions (temperature, pressure, dirtiness of the cells, etc.) All of these coefficients are determined initially at the factory; some of them you can ignore, as they will be stable for years, but others may need to be adjusted daily or even hourly. We’ll refer to this latter group as “user calibrations”, and they are the focus of this chapter.

As mentioned above, the factory calibrations which determine the coefficients of the polynomial are quite stable with time. However, if the analyzer’s source or detector is replaced, or if significant dirt accumulates in the optical bench, then linearity errors that exceed specifications can result. If you determine that your gas analyzer’s linearity error for CO₂ or H₂O is excessive, then you can make adjustments to the coefficients with the help of a utility in the Calibration Coefficients dialog in the **LI7000** Windows software. You will need two span gases for CO₂, or an LI-610 to generate two known dewpoints for H₂O. This calibration adjustment feature is described in Section 4, *Cal Coefficients*.

In this section we will first provide a brief overview of the types of user calibrations that are available. Then, we discuss what to use for CO₂ and H₂O standards. Finally, we provide some step-by-step guidance for actually doing user calibrations.

6 Calibration

Overview

The LI-7000 provides a convenient user interface for doing user calibrations (Figures 6-1 and 6-2).

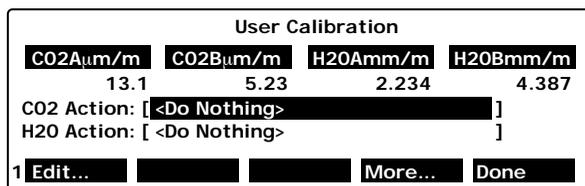


Figure 6-1. LI-7000 calibration function on instrument display.

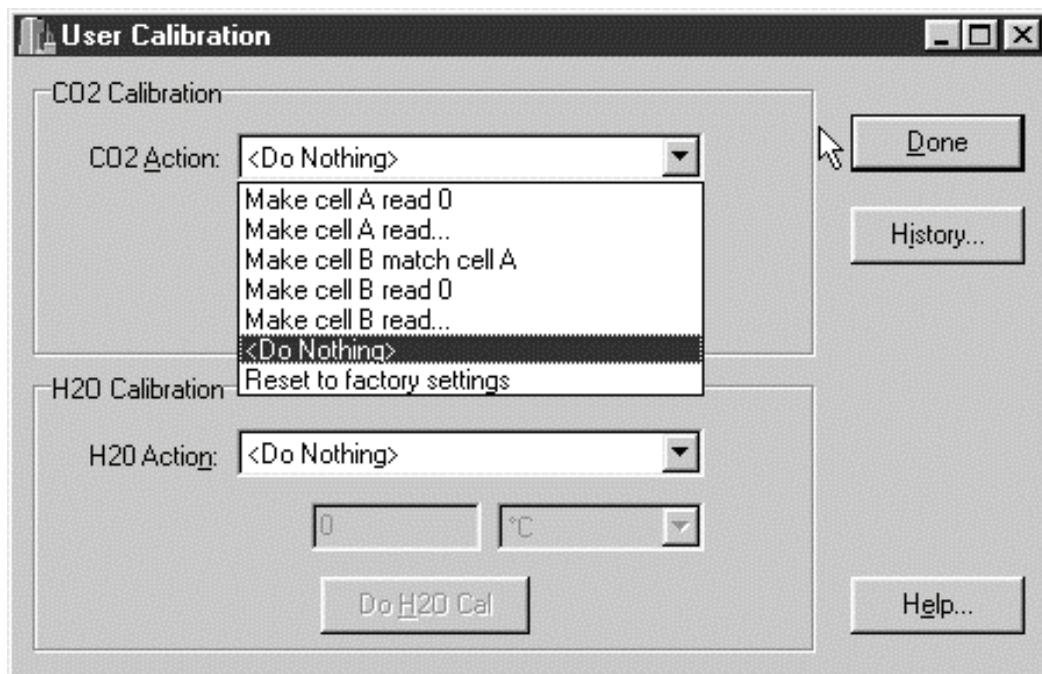


Figure 6-2. Calibration dialog box in PC communications software.

The calibration dialog box allows you to define a calibration action to be performed for CO₂ and/or H₂O. You then flow the

appropriate gas(es) through the appropriate cell(s), wait for the readings to stabilize, and then press DoCO₂ (f2) or DoH₂O (f3) to execute the calibration action. For the next few seconds, the LI-7000 will average the readings it is taking, then perform the requested action.

There are three major choices for calibration actions:

1. Make cell A read...
2. Make cell B match cell A
3. Make cell B read...

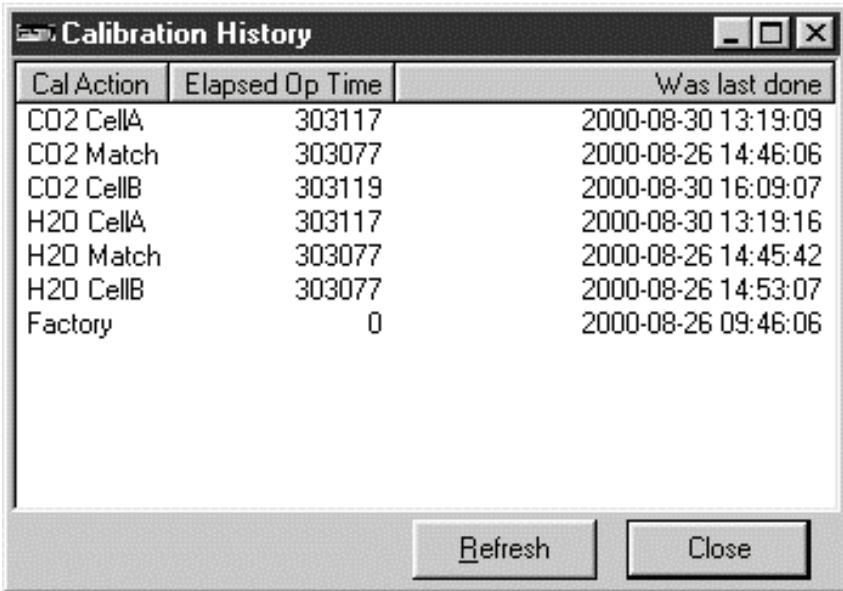
The “Make cell A read...” option is designed to correct the drift with time that occurs while in Reference Estimation Mode (REM). (This action is not available from the front panel unless you are in REM.) You perform this procedure while temporarily flowing a known concentration through cell A. Any concentration will work, even 0.

The “Make cell B match cell A” option is the most common procedure. You flow the same air through both cells and execute this procedure to remove the effects of dirt and other sources of error. You don’t need to know the actual concentration of this gas, but it should be stable. There is a subtlety here: if you match the cells at one concentration, you may find that the cells are no longer matched at a different concentration. The LI-7000 can adjust for this common mode drift: match first with a (near) zero concentration, then match again at the higher concentration, and the IRGA should then be reasonably well matched between those two concentrations.

The “Make cell B read...” adjusts the span parameter for the calibration polynomial, and should only be used when the cell A concentration is known (that is, don’t do this while in REM). **NOTE:** You can use any concentration in the B cell to do this - even 0; just make sure that there is a significant difference between the cell A and B concentrations.

6 Calibration

Click on the History button to view a log of previous calibrations, including the action(s) performed, and the time at which the actions(s) were done.



Cal Action	Elapsed Op Time	Was last done
CO2 CellA	303117	2000-08-30 13:19:09
CO2 Match	303077	2000-08-26 14:46:06
CO2 CellB	303119	2000-08-30 16:09:07
H2O CellA	303117	2000-08-30 13:19:16
H2O Match	303077	2000-08-26 14:45:42
H2O CellB	303077	2000-08-26 14:53:07
Factory	0	2000-08-26 09:46:06

CO₂ and H₂O Standards

A suitable source of air free of CO₂ and water for calibrating can be generated with chemical scrubbers (such as Ascarite II or dry soda lime for removing CO₂ and magnesium perchlorate or Drierite[®] for removing water), or obtained from a cylinder of zero grade gas. When using chemical scrubbers, it is important to make sure that the chemicals are fresh, and that air goes through the chemicals in the right order: Ascarite II or soda lime first, desiccant last (if the desiccant is Drierite[®], allow time for the CO₂ to "wash out" of it). When using a cylinder, it is important to verify that the air in the cylinder really is CO₂-free since a typical cylinder of standard grade nitrogen might have as much as 20 $\mu\text{mol mol}^{-1}$ of CO₂ in it. Compressed cylinders may be at

pressures of several thousand pounds per square inch; before using them for calibration, they should be fitted with a regulator to reduce the pressure down to a range of around fifteen pounds per square inch. When setting known CO₂ concentrations, a cylinder of CO₂ in air which has been verified to be accurate to within at least 1% would be a suitable choice for many applications. Be cautious, as the stated value of the calibration cylinder may be significantly different from the actual gas concentration.

For known water vapor concentrations, a convenient standard to use is a dew point generator such as the LI-COR LI-610. To avoid condensation problems choose a dew point temperature that is about 3 to 5 °C below the ambient temperature. Also, since water vapor sorbs and desorbs from surfaces, allow plenty of time for the reading to stabilize, and minimize the surface area it has to absorb on (minimize tubing lengths). It is important not to rush through water vapor calibrations; give the surfaces plenty of time to equilibrate to large changes.

Calibration Instructions

The type of user calibrations that are appropriate depend on what operating mode you are using, and there are basically three:

I. Reference (Cell A) Is Known and Constant

A constant, known concentration is continually flowing through cell A. The source may be scrubbed air, or air from a tank, or air from a dew point generator.

II. Reference (Cell A) Is Known, but not Constant

The cell A air stream is being measured by an external analyzer, which is communicating the concentration to the LI-7000 through an auxiliary input. The concentration changes with time, but it is always being measured.

III. Reference (Cell A) is Estimated

This is Reference Estimation Mode (REM). The LI-7000 is continually providing its best estimate of the cell A concentration. The cell B concentration will have the same error as the cell A concentration, so the differential value will be more accurate than either individual cell's accuracy.

The calibration instructions for these three operating modes are described next.

I. Reference (Cell A) Is Known and Constant

If you will be flowing a known, constant concentration gas through the A cell, there are two user calibrations that you may want to do.

- **1 Point Match (periodically)**

Put the cell A gas through cell B to match the cells (Box 1, below). This counteracts drift and dirt effects.

- **Span (optional)**

Put a known concentration (and different from cell A) in cell B, and calibrate (Box 3, below).

II. Reference (Cell A) Is Known, but not Constant

If during operation, cell A will have a range of known concentrations, a potential problem with common mode drift arises. This can be minimized by adding a 2 Point Match to the list of calibrations. (Note that during any calibration, the cell A and B concentrations must be stable.)

- **2 Point Match (initially)**

Match first with scrubbed air in both cells, then again with a typical cell A concentration in both cells (Box 2, below). This will characterize the common mode drift in order to minimize the effect on matching of a changing reference concentration.

- **1 Point Match (periodically)**

Put the current cell A gas through cell B to match the IRGA (Box 1, below). This counteracts drift and dirt effects.

- **Span (optional)**

Put a known concentration (different from cell A) in cell B, and calibrate (Box 3, below).

III. Calibrating for REM Operations

If you are going to be operating with an unknown concentration of gas flowing through the A cell, there are two calibrations that you will need to do periodically.

- **Calibrate Cell A (initially, and periodically thereafter)**

The cell A calibration (Box 4, below) is critical to how REM works. After that, experience will tell you how often it needs to be redone; the period might range from hours to days, depending on conditions, such as temperature.

- **1 Point Match (periodically)**

Put the cell A gas through cell B to match the cells (Box 1, below). This counteracts drift and dirt effects.

6 Calibration

Box 1

One Point Match

This procedure will match the cells at a single concentration.

1. Flow the target gas through cells A and B simultaneously.

Pressures, temperatures, and water concentrations should be the same.

2. Set both H₂O and CO₂ actions to "Make cell B match cell A."

3. When stable, press "DoH₂O".

After about 5 seconds, the H₂O readings for A and B should match. (Always do H₂O first, since the CO₂ calculations depend on H₂O being correct).

4. Press "DoCO₂".

After about 5 seconds, the CO₂ readings for A and B should match.

Box 2

Two Point Match

The two point match will match the cells at a low and a high concentration. The low concentration should be <20 $\mu\text{mol/mol}$ for CO₂ (<3 mmol/mol for H₂O); the high concentration should be near the upper end of where you are planning to operate cell A.

1. Set reference to 0.

Temporarily set the operating mode to 0 (or dry) air in the reference cell (A). (If reference is being measured externally, you won't have to do this).

2. Do a "1 Point Match" with 0 (dry) air.

This matches the cells at a low concentration.

3. Change reference to the high concentration.

If reference is being measured externally, you won't have to do this.

4. Do a "1 Point Match" at the high concentration.

This matches the cells at a high concentration. The match should be reasonably good between the two.

Box 3

Setting the Span

Make sure you have done a one or two point match first.

- 1. Flow reference gas through A, and the span gas through B.**
The concentrations must be different.
- 2. Set CO₂ (or H₂O) action to "Make cell B read..."**
You'll be prompted for the cell B target value.
- 3. Wait for stability, then press "DoCO2" (or "DoH2O").**
After about 5 seconds, the cell B reading should be on target.

Box 4

Calibrate Cell A

This procedure is necessary periodically while in REM (Reference Estimation Mode) operations.

- 1. Flow a known gas through cell A.**
Any concentration (including 0) is fine.
- 2. Pick "Make cell A read..." for CO₂ (or H₂O).**
You will be prompted for the concentration.
- 3. Press "DoCO2" (or "DoH2O").**
After 5 or 6 seconds, cell A should be reading the target value.

User Calibration Examples

Example 1. An application requires measurements of absolute ambient atmospheric CO₂ concentrations. The mode of operation is to flow a known gas in the reference cell (A); for this example we'll use a zero gas (i.e., dry, CO₂-free air). The periodic calibration procedure is given below.

1. Flow a zero gas through both cells of the LI-7000 optical bench.
2. Press **Shift + 1** to display the calibration group labels.
3. Press the **SetRef** key (f1). The Reference Cell Options are displayed. Press **Edit** (f1) to edit the CO₂ options. Choose **Exact: 0**. Repeat for H₂O, and choose **Exact: 0**. Press **OK**.
4. Press the **Calib** key (f4). Edit both the CO₂ and H₂O Action boxes and set to **Make cell B match cell A**.
5. Press **DoH2O** (f3) wait for about 5 seconds. Press **DoCO2** (f2) and wait for about 5 seconds again. Cells A and B will be matched and will read 0. Note that the DoH2O key must be pressed before the DoCO2 key, because of the effect of the water vapor reading on CO₂.

For best results, the one-point match sequence above should be followed by spanning cell B using a gas of different concentration. For monitoring typical ambient atmospheric CO₂ concentrations, a suitable CO₂ span gas should be within a range of 350 - 400 $\mu\text{mol/mol}$. The procedure for setting the span in cell B is given below.

6. Flow the CO₂ span gas through cell B. As an example, use 400 $\mu\text{mol/mol}$.

7. Press the **Calib** key (f4). Press **Edit** (f1). Set the CO₂ action to '**Make cell B read...**'. Press **OK**. Choose **Exact value**, press **OK**, and enter 400 for the **CO2 B Target**.
8. Press the **DoCO2** key (f2). After about 5 seconds the cell B reading will be adjusted by the instrument software to 400 $\mu\text{mol/mol}$.
9. Press **Done** (f5).

Example 2. Reference Estimation Mode (REM) for both CO₂ and H₂O. REM is used when precise differential concentrations are required and where absolute accuracies are less important. In this example a tank of gas of 370 $\mu\text{mol/mol}$ CO₂ in dry air is used for calibration. A periodic user calibration procedure for operating the LI-7000 in REM is given below.

1. Flow the calibration gas through both cells of the LI-7000 optical bench.
2. Press **Shift + 1** to display the calibration group labels.
3. Press the **SetRef** key (f1). The Reference Cell Options are displayed. Press **Edit** (f1) to edit the CO₂ options. Choose **Estimated**. Press **OK**. Repeat for H₂O, and edit the H₂O units box to display the desired units (mole fraction or °C).
4. Press the **Calib** key (f4). In the H₂O Actions box, highlight '**Make cell A read...**' and press **OK**.
5. Highlight '**Exact value**' and press **OK** (f5). Enter a value of 0 for mole fraction, or a dew point of -100 °C (depending on the units displayed), and press **OK** (f5).
6. Press the **DoH2O** key (f3) and wait for about 5 seconds. Cell A will now read the H₂O value entered above.

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7. Press the **Calib** key (f4). In the H₂O Actions box, highlight **'Make cell B match cell A'** and press **OK**.
8. Press the **DoH2O** key (f3) and wait for about 5 seconds. The cell B reading will be matched to the H₂O value of cell A.
9. Press the **Calib** key (f4). In the CO₂ Actions box, highlight **'Make cell A read...'** and press **OK**.
10. Highlight **'Exact value'** and press **OK**. Enter a target value of 370 and press **OK**.
11. Press the **DoCO2** key (f2) and wait for about 5 seconds. Cell A will now read 370 $\mu\text{mol/mol}$.
12. Press the **Calib** key (f4). In the CO₂ Actions box, highlight **'Make cell B match cell A'** and press **OK**.
11. Press the **DoCO2** key (f2) and wait for about 5 seconds. Cells A and B will now read 370 $\mu\text{mol/mol}$.
12. Press **Done** (f5).

Calibration Coefficients - Reference

The values of all the calibration coefficients can be viewed by pressing the "Coeffs" function key in level 1 (Figure 6-3). They are presented in a large list, with interspersed headings:

Calibration Coefficients

```

--- CO2 values ---
a1 = 0.00239324
a2 = 1.18851
a3 = 1757.74
a4 = -1.03416e+06
a5 = 3.92185e+08
gamma = 1
Z = 1.01557
Zt = -1.32e-06
Zm = 0
S = 1.001
WO' = 1
WO'_d = 1
AGC = 0.5
VpCrr = 1.57
--- H2O values ---
a1 = 0.0821067
a2 = 21.923
a3 = 39286.8
gamma = 1
Z = 1.08406
Zt = 0
Zm = 0
S = 1.001
WO' = 1
WO'_d = 1
AGC = 0.5
---- Pressure ----
a0 = 58.481
a1 = 30.4
--- Temperature ---
A = 0.000828003
B = 0.000208687
C = 8.0874e-08
---- Humidity ----
a0 = 0
a1 = 1
    
```

CO₂ calibration coefficients

H₂O calibration coefficients

For on-board pressure sensor

For thermistor attached to optical bench

RH sensor in detector (for diagnostic warnings)

Figure 6-3. Calibration coefficients list.

Tables 6-1 through 6-3 describe these coefficients.

6 Calibration

Table 6-1. CO₂ Calibration Coefficients

Label in list	Symbol ^a and Description	How to Change
a1	Coefficients of CO ₂ polynomial f_c which relates absorbance to concentration.	Factory calibration
a2		
a3		
a4		
a5		
gamma	Not used	
Z	Zeroing term z_c	"Make cell B match cell A" with <20 $\mu\text{mol/mol}$ in cell A
Zm	Zeroing term z_{cm} (common mode response)	"Make cell B match cell A" with >20 $\mu\text{mol/mol}$ in cell A
Zt	Zeroing term z_{ct} (temperature drift)	Factory calibration
S	Span factor S	"Make cell B read..."
Wo'	REM calibration factor W_{co}	"Make cell A read..."
Wo'_d	Default (after reset) value of W_{co}	
AGC	AGC value for use in REM	Factory calibration
VpCrr	Band broadening coefficient	Use 1.57

a. See Table 1-2 in Section 1 for the CO₂ Equation Implementation.

Table 6-2. H₂O Calibration Coefficients

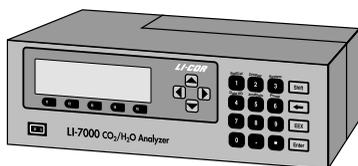
Label in list	Symbol ^b and Description	How to Change
a1	Coefficients of H ₂ O polynomial f_w which relates absorbance to concentration.	Factory calibration
a2		
a3		
gamma	Not used	
Z	Zeroing term z_w	"Make cell B match cell A" with <3 mmol/mol in cell A
Zm	Zeroing term z_{wm} (common mode response)	"Make cell B match cell A" with >3 mmol/mol in cell A
Zt	Zeroing term z_{wt} (temperature drift)	Factory calibration
S	Span factor S	"Make cell B read..."
Wo'	REM calibration factor W_{wo}	"Make cell A read..."
Wo'_d	Default (after reset) value of W_{wo}	
AGC	AGC value for use in REM	Factory calibration

b. See Table 1-1 in Section 1 for the H₂O Equation Implementation.

6 Calibration

Table 6-3. Other Calibration Coefficients

Label in list	Symbol and Description	How to Change
a0	Pressure sensor polynomial	Factory calibration
a1	Pressure sensor polynomial	Factory calibration
A	Temperature thermistor polynomial	Factory calibration, default value = 0.000828003
B	Temperature thermistor polynomial	Factory calibration, default value = 0.000208687
C	Temperature thermistor polynomial	Factory calibration, default value = 8.0874E-8
a0	RH sensor polynomial	Factory calibration, default value = 0
a1	RH sensor polynomial	Factory calibration, default value = 1



7 Maintenance

Recharging the 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.*

At room temperature the 6000B will run the LI-7000 for approximately 2 hours and the 6200B will last about 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 - 16.5VDC, 4 amp maximum).

Although it is not practical to charge batteries in this manner, the LI-7000 *will* trickle charge connected batteries (approximately 200 mA/hr). Batteries can be left connected during AC operation; they will not overcharge.

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.

Opening the LI-7000

The LI-7000 has a panel on the top rear of the instrument that can be removed to clean the optical cell and change the internal chemicals. Make sure that the instrument is powered off and the power cord is disconnected before removing this panel.

There are 6 Philips head screws that secure the removeable panel; 2 on the top, 2 on the right side, and 2 on the rear panel, as shown below.

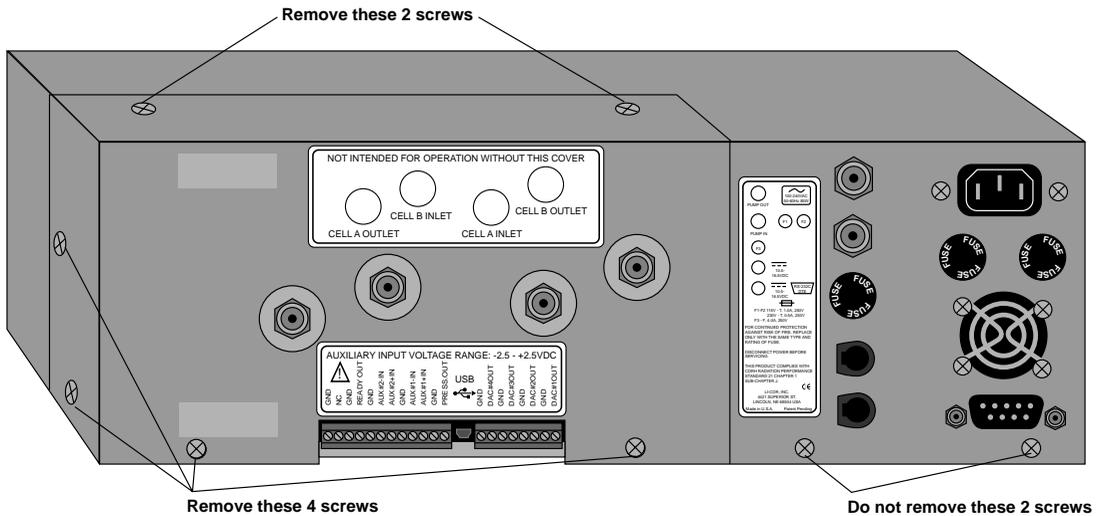


Figure 7-1. Remove the 6 screws shown and take off the removeable panel.

Remove the 6 screws and slide the panel straight back over the air fittings to expose the optical bench.

Cleaning the Optical Cell

The LI-7000 optical bench can be removed and cleaned should the need arise.

Follow these steps to remove and clean the optical bench:

1. Remove the 6 screws on the LI-7000 case that secure the removeable panel, as shown in Figure 7-1. Slide the panel off over the air fittings. The interior of the LI-7000 will appear as shown below.

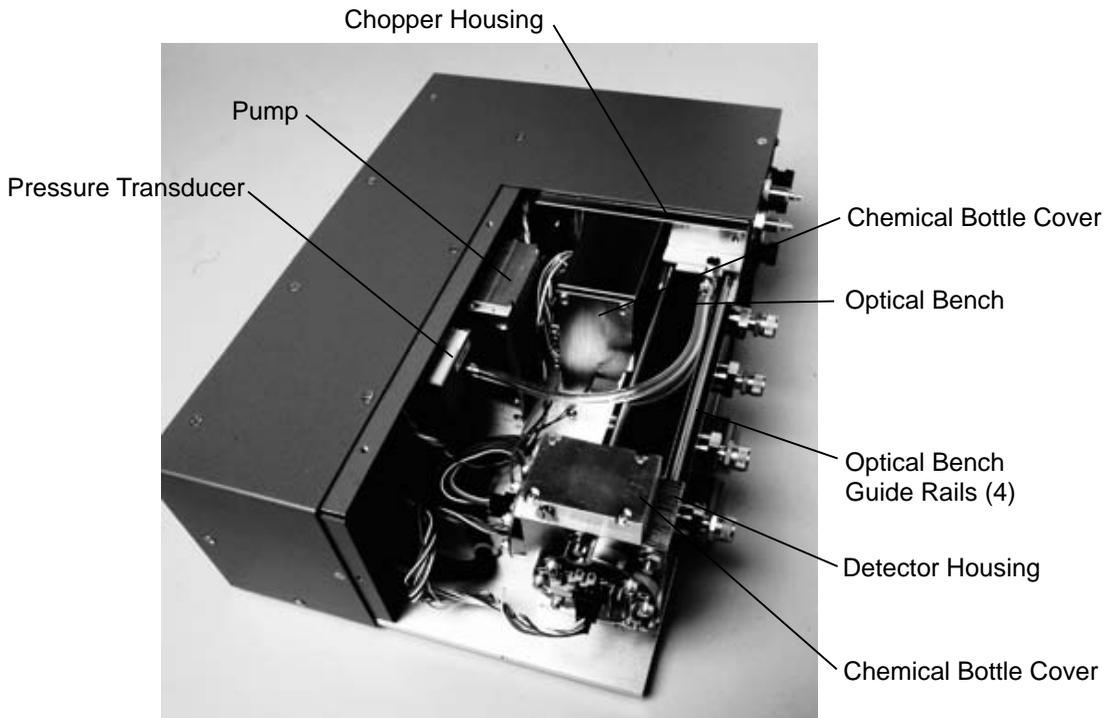


Figure 7-2. LI-7000 interior.

2. There are 3 connectors that must be removed before removing the optical bench; one on each of the CO₂ and H₂O detectors,

and the third on the rear of the optical bench, as shown below. Pull straight out on the connectors to remove.

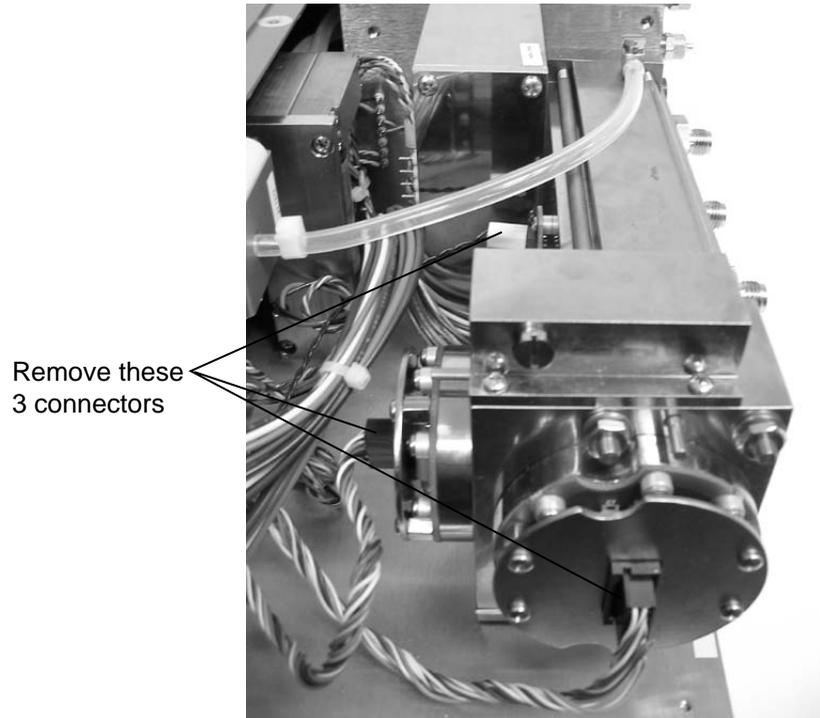


Figure 7-3. Remove the 3 connectors indicated.

3. Remove the 4 nuts on the face of the detector housing that secure the housing to the optical bench guide rails, as shown below. There is a 3/8" nut driver in the spares kit that is used to remove the nuts.

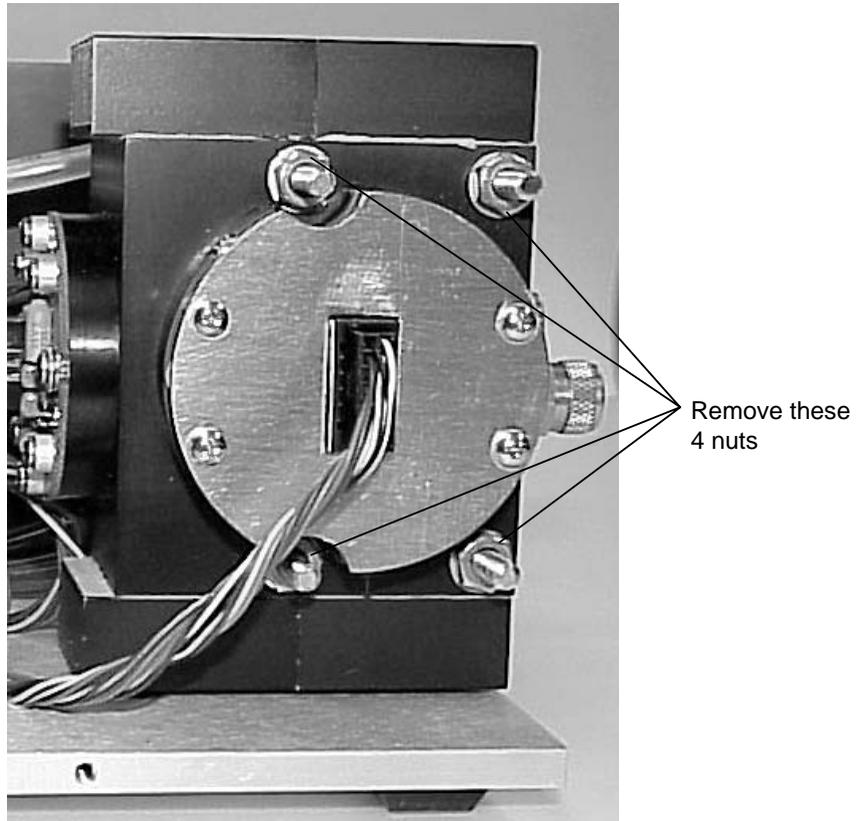


Figure 7-4. Remove the 4 nuts from the guide rails.

4. Remove the detector housing by pulling straight out so that it slides off the guide rails.
5. Remove the bev-a-line tubing at the pressure transducer by pulling straight out on the white connecting clamp. You can now slide the optical bench off the guide rails, as well. Be careful when handling the optical bench; it is heavy and can cause injury if dropped, particularly when the electrical connector pins are exposed.

7 Maintenance

6. The optical bench will appear as shown below. Avoid making nicks or dents to the end corners of the optical bench; careful handling is required.

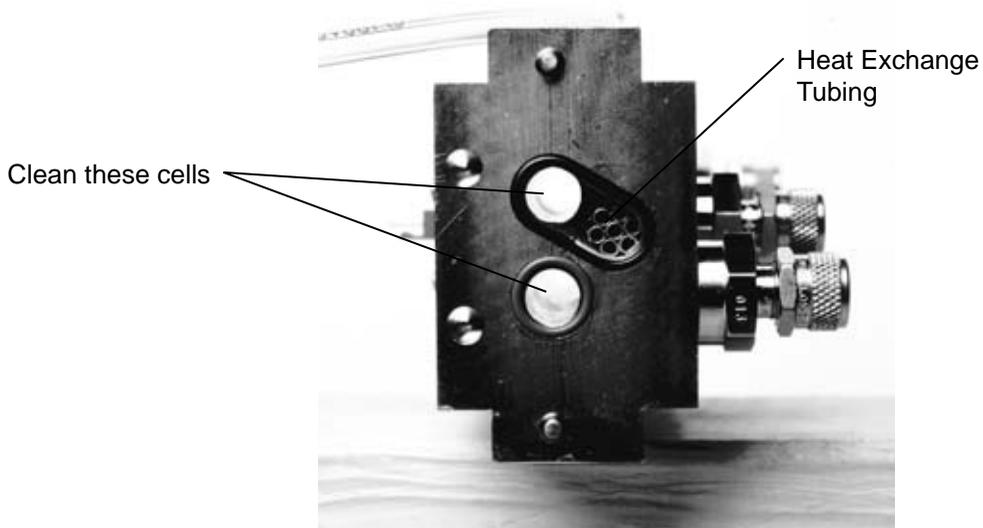


Figure 7-5. Clean the cells indicated.



Optical
Path Swab

7. There are a number of swabs in the spare parts kit (left). Dip one end of the swab into a 50:50 alcohol/water solution and carefully swab both ends of the optical bench cells, until there is no more visible residue. A mild solution of dish washing type soap and water will also work.

Note that there are a number of small copper tubes pressed into the cell, which serve as heat exchangers between the optical bench and the air in the cell. If these tubes become clogged they can be cleared by blowing compressed air through the inlet or outlet fittings, or by running tap water through the cell.

Use a dry swab to absorb any moisture that may remain in the cells, or allow to air dry.

The air fittings can also be removed and cleaned if needed; turn the fittings counterclockwise to loosen.

8. Make sure that the optical windows on the face of the chopper housing (shown below) and the detector housing (not shown) are clean and free of any dust or debris. The windows are sapphire, and are extremely durable and resistant to scratches; clean the windows with any mild detergent or glass cleaner. Dry thoroughly.

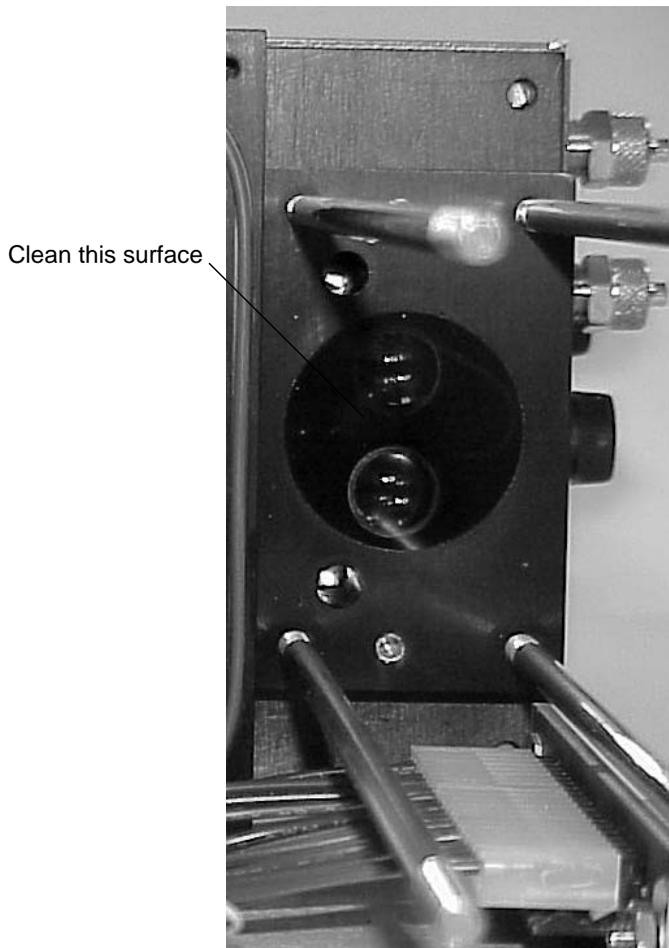


Figure 7-6. Clean the windows on chopper and detector housings.

9. With the LI-7000 case open, you may want to check or replace the internal chemical bottles present in the chopper and detector housings (see *Changing the Internal Chemicals* below). Reassemble the optical bench assembly, making sure that the O-ring seals are in place. These O-rings do *not* need to be greased; they can simply be pressed into place.

Make sure that the surfaces of the detector and chopper housings are flush with the ends of the optical bench, and tighten the 4 nuts to the guide rails securely. Re-attach the 3 connectors and replace the removeable cover.

Changing the Internal Chemicals

There are two small plastic bottles, each containing Ascarite II and magnesium perchlorate, inserted on top of and below the detector housing that keep the detectors free of CO₂ and water vapor. There are also two larger bottles that are located near the chopper housing. These bottles should be recharged with fresh chemicals on an annual basis. These bottles can be obtained from LI-COR in pre-charged kits that are ready to use. Part #7000-950 from LI-COR contains 2 large and 2 small bottles for the chopper and detector housings. If you want to change the chemicals yourself, refer to *Appendix C, Suppliers*, for a list of suppliers of Ascarite II and magnesium perchlorate.

NOTE: Calibration shifts will occur if CO₂ or H₂O are not kept out of the detector housing. Changing detector bottles quickly is desirable to minimize moisture getting into the detector housing.

■ To change the detector housing scrubber/desiccant bottles:

1. Remove the six screws on the removeable panel as shown in Figure 7-1, and slide the panel off.
2. Remove the 4 nuts on the face of the detector housing that secure the housing to the optical bench guide rails, as shown in Figure 7-4. There is a 3/8" nut driver in the spares kit that is used to remove the nuts.
3. Remove the detector housing. Remove the two chemical bottle covers from the top and bottom of the detector housing. Note the orientation of the bottle covers (below); the cap of

the chemical bottles lies over the large hole in the detector housing.

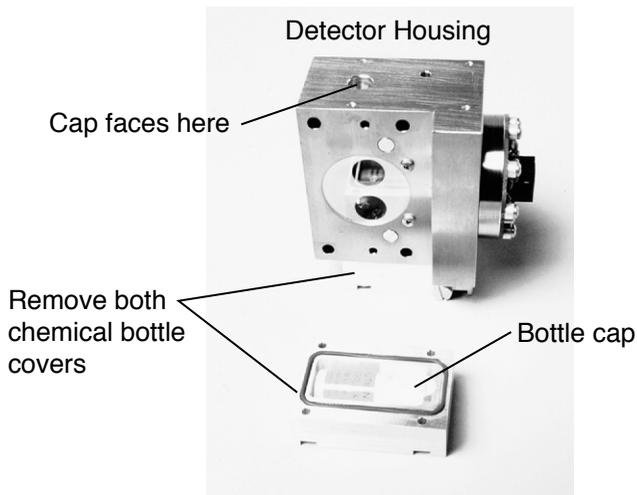


Figure 7-7. Remove bottle covers; note orientation when replacing.

4. If you are preparing your own chemical bottles, dispose of the exhausted chemicals and prepare the new bottles by filling them with equal parts Ascarite II and magnesium perchlorate (Figure 7-8). Fill the bottles 1/2 full with Ascarite II first, followed by the magnesium perchlorate. Place a filter paper disk in the lid to keep the chemicals from spilling into the detector housing.

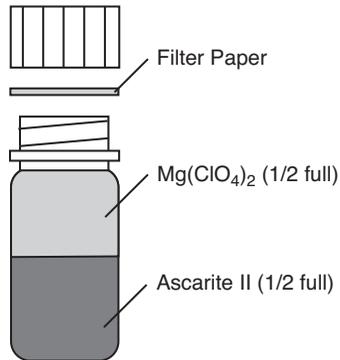


Figure 7-8. Fill the bottles ½ full with Ascarite II, followed by magnesium perchlorate.

5. If you are using pre-charged bottles from LI-COR, be sure to change the bottle caps before inserting; use the caps with a hole in the top to allow air exchange. Insert the recharged (or pre-charged) bottles and replace the chemical bottle covers.

When the bottle covers are properly placed, the cover is flush with the edge of the housing; if improperly placed, the cover will hang over the edge of the housing slightly.

6. Remove the optical bench if necessary to access the chopper housing chemical bottle cover. Remove the 4 screws on the bottle cover. Remove the two chemical bottles and recharge as shown in Figure 7-8.

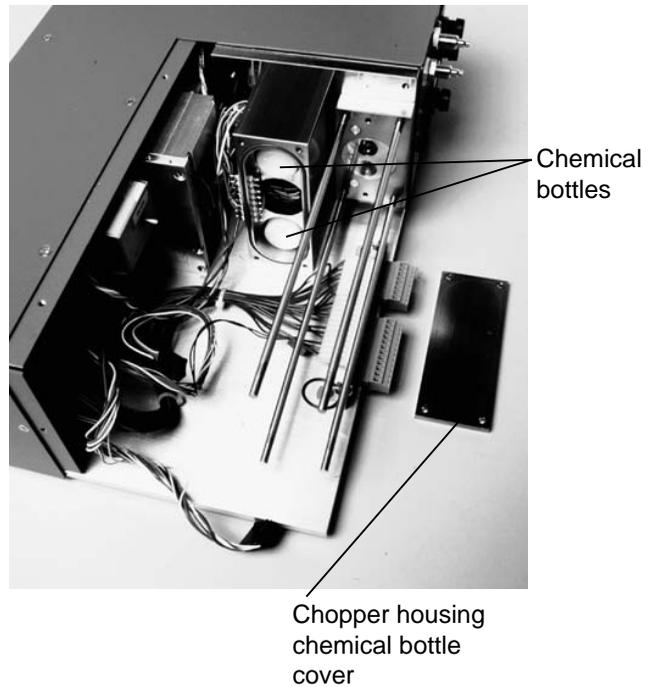
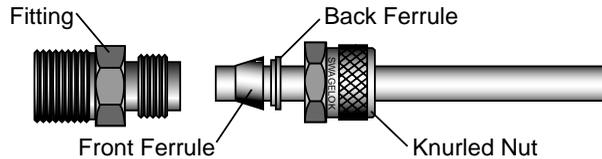


Figure 7-9. Remove the chopper housing bottle cover and replace the 2 chemical bottles.

7. Insert the recharged bottles into the chopper housing *cap first*. Make sure the O-ring is clean and lubricated with the supplied Teflon grease. Replace the bottle cover. Re-assemble the optical bench and replace the instrument cover.
8. After installing, **allow at least 24 hours** to scrub the housing. This should be followed by setting the CO₂ and H₂O zeros. Check the zero again, if possible, after one or two days.

Ferrules

The large air inlet and outlet ports for cells A and B contain plastic ferrules that facilitate tightening of the fittings over the inlet tubing. Spare ferrules are included in the spares kit (part #300-05375) should they get lost or damaged. Please note the proper orientation of the ferrules; the fittings will not work correctly if the ferrules are inserted backwards. Note, too, that there are two parts to each ferrule; the front and back. Insert the back ferrule into the knurled nut, followed by the front ferrule; the narrow portion of the front ferrule faces the instrument fitting.



Fuses

If the LI-7000 is plugged in and fails to power up, check fuses F1, F2, and F3 to see if any have blown (below). There are extra fuses in the spare parts kit. Fuses F1 and F2 have the same rating (1.0A or 0.5A slow blow, depending on voltage; 1.0A for 115V or 0.5A for 230V) and protect the AC power input. Fuse F3 (4A fast blow) protects the DC power input.

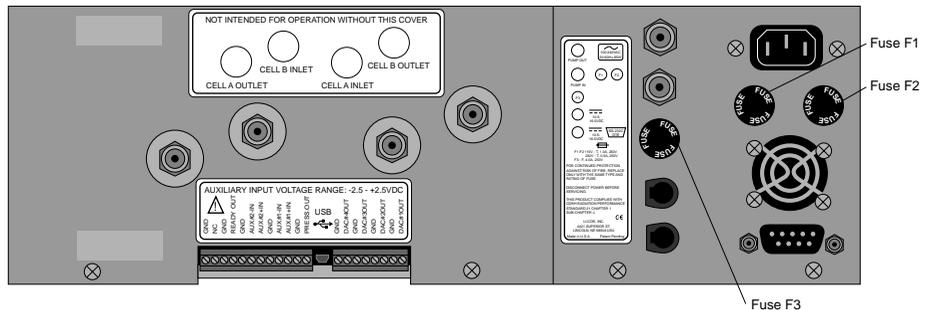


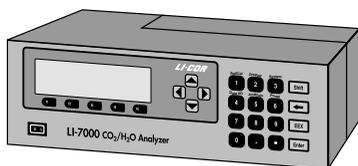
Figure 7-10. Location of fuses F1, F2, and F3.

Note on Salt Water Contamination

LI-COR has periodically received gas analyzers returned for servicing due to the introduction of salt water into the optical cell, during use in oceanographic research applications. This can happen if, for example, an inlet tube becomes accidentally immersed, drawing water into the instrument. This is a serious problem, and generally requires expensive repairs.

The LI-7000 can greatly reduce the need for factory service if this occurs, due to the ability of the user to remove and clean the optical bench. *It is important to note, however, that if salt water is accidentally introduced into an optical cell, it should be disassembled and cleaned immediately.* The optical cells are nickel plated, and are very durable; during the plating process, however, there can be microscopic areas at which the plating does not completely adhere to the surface of the cell. Salt water is very invasive, and can quickly erode the plating and irreparably damage the optical cell.

For this reason, salt water should not be left in the optical cell(s) after accidental introduction. Remove the bench as described earlier in this section and flush with tap water; dry completely and re-assemble.



8 Troubleshooting

Power On Problems

If operating with batteries, the instrument requires between 10.5 and 16 VDC, at 4 Amps, to operate (a LI-COR LI-6020 battery charger, for example, will *not* by itself power the LI-7000).

Nothing happens

- Plugged in?
- Check fuses to see if one has blown. See Section 7, *Maintenance*, for fuse location and replacement type.
- Inadequate power supply.

Display blank (or black)

- Check LCD contrast; too low? See Section 5, *Changing the Display Contrast*.
- Instrument failed to power up.
- Displays are not defined. See Section 5, *Display Group*.
- LCD has failed. Contact LI-COR.

Blown Fuses

- Fuses are improper amperage; check and replace, if necessary.
- Erratic power supply providing power "spikes".
- Contact LI-COR if problem persists.

8 Troubleshooting

Warning Messages

Make sure the diagnostic indicators are enabled. See Section 4, *Diagnostics Page*, or Section 5, "*System Group*" for information on enabling the diagnostics.

"PLL Lock" (Instrument displays PLL)

Phase lock loop, indicates if the chopper motor is not operating at the proper speed. Note that it may take 10 seconds or so after instrument startup for the chopper motor to reach optimum speed. Intermittent PLL warnings can be caused by excessive vibration; more frequent warnings may indicate a failing chopper motor.

"CO₂ Cooler" (Instrument displays CO₂)

Indicates that the thermoelectric cooler for the CO₂ detector is not within normal operating range. Instrument readings will be erroneous until the cooler is within range. Note that it may take several minutes after instrument startup before the coolers reach normal operating range, especially if the instrument is being operated near the upper temperature limit (+50 °C).

"CO₂ Cooler" or "H₂O Cooler" will appear if the detector housing is not dry enough. Internal chemicals may need to be changed. See Section 7, *Changing the Internal Chemicals*.

"H₂O Cooler" (Instrument displays H₂O)

Same as above for CO₂ detector.

"IR Source" (Instrument displays SRC)

Indicates a problem with the infrared source. Any data collected with a bad IR source will be erroneous.

"Low Battery" (Instrument displays BAT)

Indicates a low battery condition. Automatic shutdown will take place in approximately 10 minutes with a 6A/hr. battery.

"Integration" (Instrument displays INT)

This is *not* a warning like those listed above; it simply indicates that the integration function is active.

Erroneous Readings

Erroneous readings can be caused by a number of factors; however, most arise from the manner in which the instrument is configured with respect to the concentration of gas in the reference cell. For example, if you are in Reference Estimation Mode, but have not "told" the instrument (by setting the reference to "estimated"), readings will be erroneous. Similarly, you do not want to use the option "Make cell B read..." when in REM mode; this should only be used when the concentration of cell A is known.

Other sources of error can include the calibration standards used, especially when mixed, or generated with chemicals that may not be fresh. Section 6 contains thorough calibration information; a review of this section may be in order if you encounter difficulty obtaining expected readings.

- Check calibration. Has operational mode changed (i.e., REM vs. normal operation)?
- Check calibration standards. Check chemicals, if using to generate zero and/or dry gases.
- Check calibration coefficients (compare with factory calibration sheet). Check Vapor Correction value.
- Check Diagnostic warnings. Are any flagged?
- If optical bench has been disassembled, check to make sure bench is secure against source and detector housings, and that o-ring seals are in place.

8 Troubleshooting

CO₂A reads 0

- CO₂A reads zero because it was told that a zero concentration gas was flowing through it. If CO₂ reference is set to zero, the CO₂A reading will always display zero, even if a non-zero gas is flowed through the cell. Check CO₂ reference setup.

H₂O reads 0

- H₂O reads zero because it was told that a zero concentration (dry) gas was flowing through it. If H₂O reference is set to dry, the H₂O reading will always display zero, even if a non-zero gas is flowed through the cell. Check H₂O reference setup.

CO₂ or H₂O noisy

If density or mole fraction values are noisy, watch the temperature and pressure values to see if they are the source of the noise. Check the calibration coefficients and band broadening value (if the problem is with CO₂) to make sure they are correct.

Calibration Problems

Matching Cell B to Cell A for CO₂ Doesn't Work

Matching will fail if T, P, or H₂O are different for the two cells. Be sure and match H₂O first, before CO₂.

Communication Problems

RS-232 Connection

- Check cable. Using cable included with instrument? Is it loose?
- Serial port incorrectly identified. Go to Connect dialog and choose a different serial port. Make sure the proper RS-232 port is chosen in the Connect dialog.
- If using an adapter or gender changer with the LI-COR serial cable, check to make sure that no pins are swapped.
- Serial port is in use by another device.
- PC indicates LI-7000 is not connected, even though it is connected. Make sure you are using the correct serial port, and make sure you are using the LI-COR cable; the **LI7000** program requires DSR to be high, and if it doesn't see that, it assumes the LI-7000 is not connected.

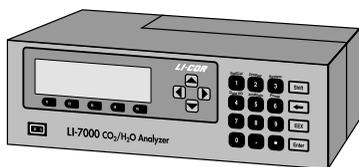
USB Connection

- Check cable. Using cable included with instrument? Is it loose?
- USB connection requires version 2.0 or greater LI-7000 Windows software. Connecting via USB requires the installation of proper USB drivers that are automatically installed with version 2.0 or greater Windows interface software.

8 Troubleshooting

D/A Output Problems

- Check wire gauge. If traveling long distances, voltage drop across small gauge wire may cause problems. Increase wire gauge.
- Connections at terminal strip tight?
- Proper connections at terminal strip? Positive/negative reversed? Properly grounded?
- Software setup incorrect. Note that DAC1 and DAC2 always use the same polarity, and have a V_{\max} of 5 volts. See Section 4, DAC Page for more information. Check source(s) to be output.
- Output device not configured correctly. Overranging?
- Proper polarity selected (bipolar vs. unipolar)? Zero and full scale values correct?



9 Language Reference

Introduction

This section describes the protocol used by the LI-7000 to communicate via its RS-232 and USB ports, for both configuration and data output purposes.

During normal operations, the serial interface on the LI-7000 RS-232 connector defaults to 9600 baud, 8 Data Bits, No Parity and 1 Stop Bit (9600 N 8 1). The serial port is configured as a bi-directional Data Terminal Equipment (DTE) device. Additional baud rates available are 19200, 38400, 57600, and 115200 baud. The instrument typically does not use *hardware* flow control, but it does hold the DTR and RTS lines high for use with other communication devices (e.g. spread spectrum radios). The LI-7000 will use *software* flow control when its incoming buffer gets full (~1kb). The LI-7000 will send out an XOFF (0x13) when the input buffer is full and XON (0x11) when there's room again. The USB interface is 2.0 compliant and runs at Full Speed (12Mbps).

Commands transmitted to the LI-7000 have a certain structure that must be followed, and data sent by the LI-7000 comes packaged in a particular way. Commands sent to the LI-7000 ***are*** case sensitive.

Each command transmitted to the LI-7000 begins with a left parenthesis '(' and ends with a right parenthesis ')'. The parentheses typically mark the start and stop of the command. A line feed character (decimal 10, <lf>) must follow commands transmitted to the analyzer. The LI-7000 does not try parsing a command until a line feed is received. Responses to commands

coming from the LI-7000 are also terminated with a line feed and no carriage return.

Successful commands sent with open and closed parentheses “()” will return the word “OK” from the LI-7000 Analyzer. If the right only parenthesis “)” is transmitted, “OK” will also be returned. Unrecognizable commands will return multiple “Error:” messages followed by each character of the command that was not recognized.

Multiple parentheses may be used within a command. A simple rule of thumb is that for each left “(“ parenthesis you typically have a corresponding right parenthesis “)” to close the command. When the right parenthesis is not sent it infers you are navigating within a command to a specific point. However; you must have enough of the command syntax in your command string without the right parentheses to avoid an “Error:” message.

The general hierarchy of the LI-7000 command structure is

(Command(sub-command *element*))

Where:

Command is one of the 18 commands (e.g. **Display**). Commands are listed on page 9-12. The **sub-command** does an operation related to the Command (e.g. setting the display back lighting) and the ***element*** is a value associated with the sub-command (e.g. setting the intensity of the display back lighting (0-3)).

Element Summary

In the rest of this section, the type of an element is described from the table below:

Type	Description	Examples
<i>float</i>	A real number	-1.234e-23 34 65.265
<i>integer</i>	An integer or floating point value	-24 752
<i>boolean</i>	Values of zero or one (or On/Off, True/False, etc.)	On True
<i>string</i>	Anything contained by double quotes. Quotes are only required if there are embedded spaces; otherwise they are optional	"Hey, you!"
<i>item</i>	Means you must include at least one of the items in the list	item1 item2 item3
<i>source</i>	The name of a data source	Aux1 "Aux1 V"
<i>source_list</i>	A list of sources grouped with parentheses	(Aux1 "Aux1 V" Aux2 "Aux2 V")
<i>time_date</i>	The date formatted as yyyy-mm-dd followed by a space and the time formatted as hh:mm:ss and enclosed in quotation marks	"1999-08-28 15:42:56"

Examples:

```
(Reference(H2O-units [mm/m|C]))
```

 Command

```
(H2O [Estimated|Dry|Aux1|Aux2|float])<lf>
```

 Sub-command

This indicates that the user may set the element H2O-units to 'mm/m' or 'C'. The H₂O element may be set to either 'Estimated', 'Dry', 'Aux1', 'Aux2', or a number of type *float*.

Example to set the display back light to level 3:

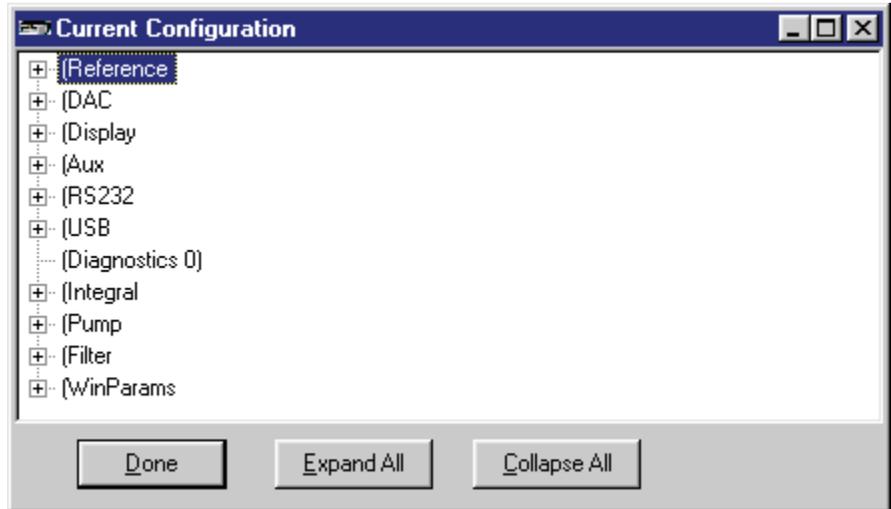
```
(Display(BackLt 3))<lf>
```

This command sets the LI-7000 display back light to its brightest level. Note the use of two parentheses and line feed (<lf>) at the end of the command.

To get a better feel for the command structure and syntax used to communicate with the LI-7000, a review of the command and response is illustrated below using the **LI7000** PC Software (on 7000-500 CD).

- Choose Connect from the Remote menu. Enable the “Send Configuration to Instrument” radio button, and click Connect.
- View the active configuration by selecting “Config Tree” under the View Menu. The Current Configuration Tree also demonstrates the general command syntax. Click **Done**.
- Select Monitor from the Remote menu to open the Communications Monitor window.

Current Configuration Dialog:

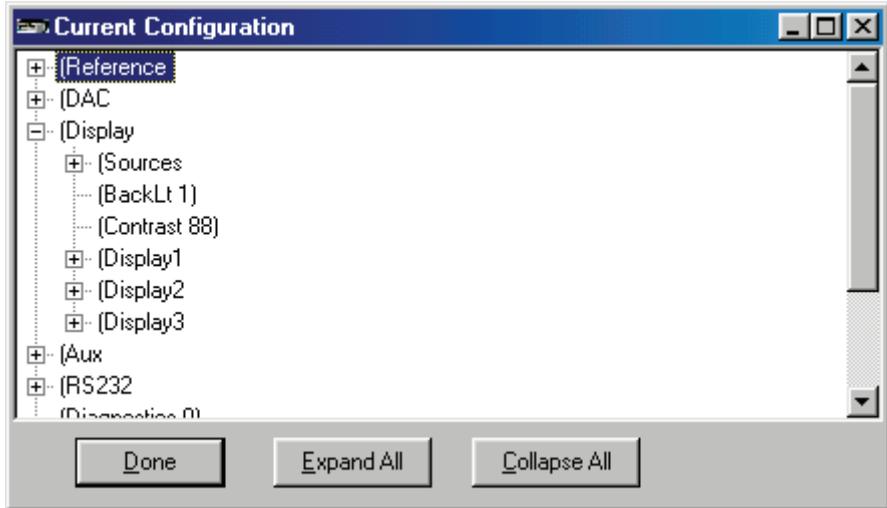


Let's do a few examples using the Communications Monitor window, with the Config Tree as a reference. Note that the Current Configuration window and the Communications Monitor windows cannot be open at the same time; the examples below are for reference only.

Example 1. Setting Display Backlighting.

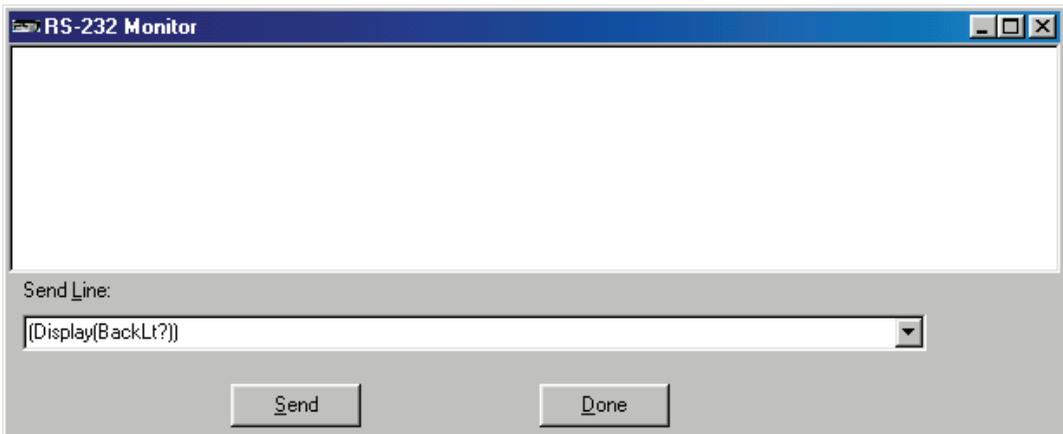
Expand the **Display** Tree Structure by pressing the (+) symbol. This command allows you to configure the (3) numerical displays on your analyzer and set the back lighting level and contrast.

9 Language Reference

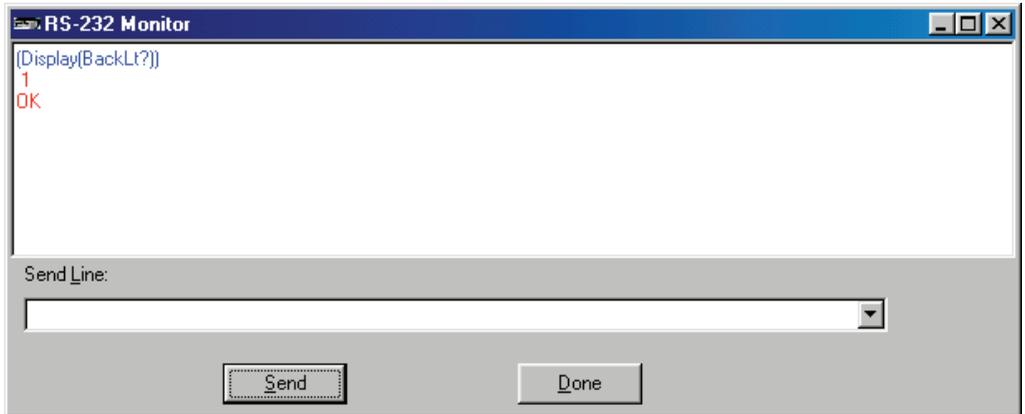


First query the analyzer for its current display setting using the command **(Display(BackLt?))<lf>**. Simply enter this command on the send line and press the Send button. The *LI7000* Software will automatically append a <lf> character to the command sent.

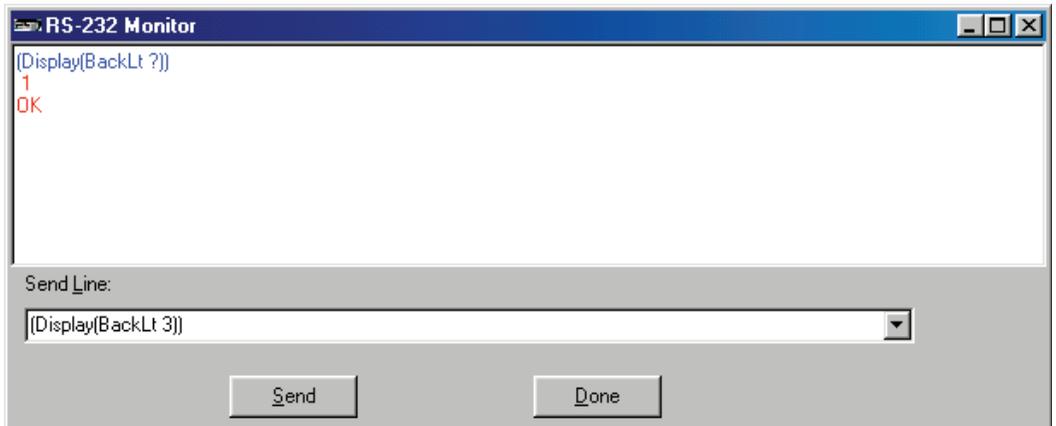
1. Enter the command as shown below



2. Click **Send**.

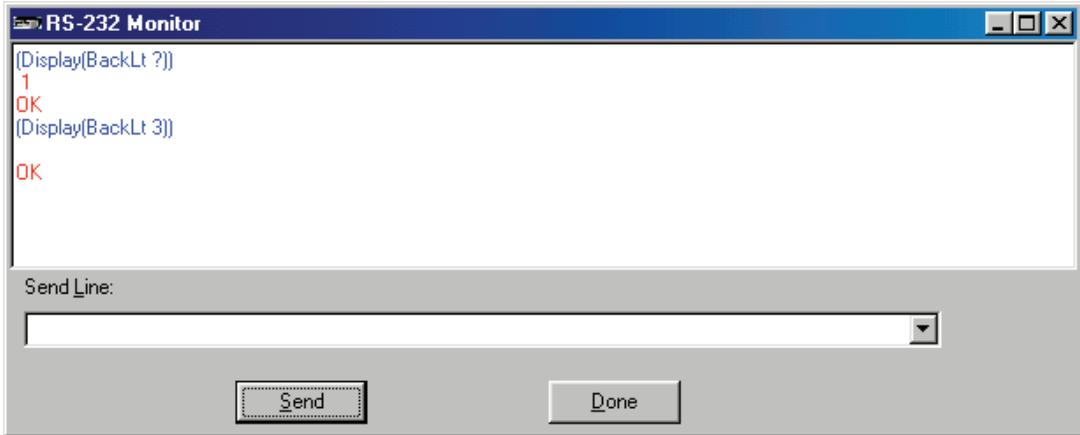


The text in the dialog above shows the Display Backlight set to a low light level (1). Let's change it. Valid entries are 0 to 3. For example, to set the back light to 3 (the highest level), enter the command **(Display(BackLt 3))<lf>**.



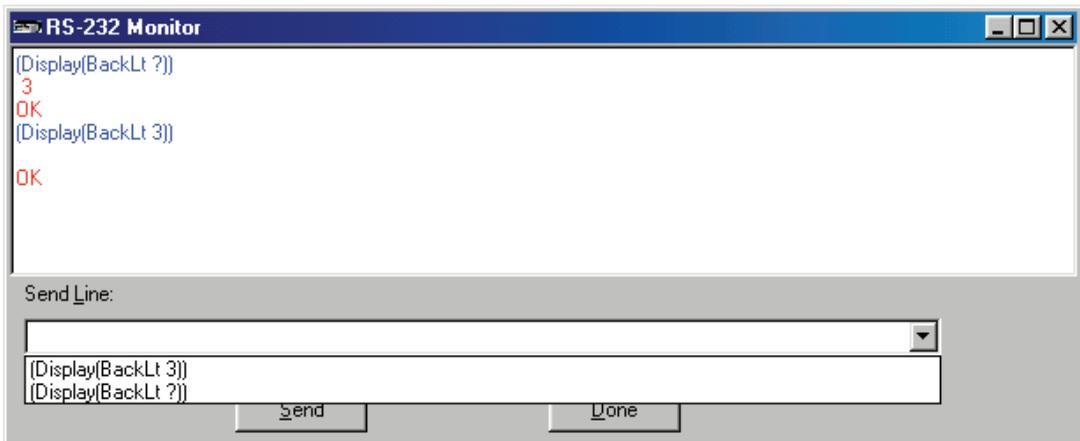
- Click **Send**.

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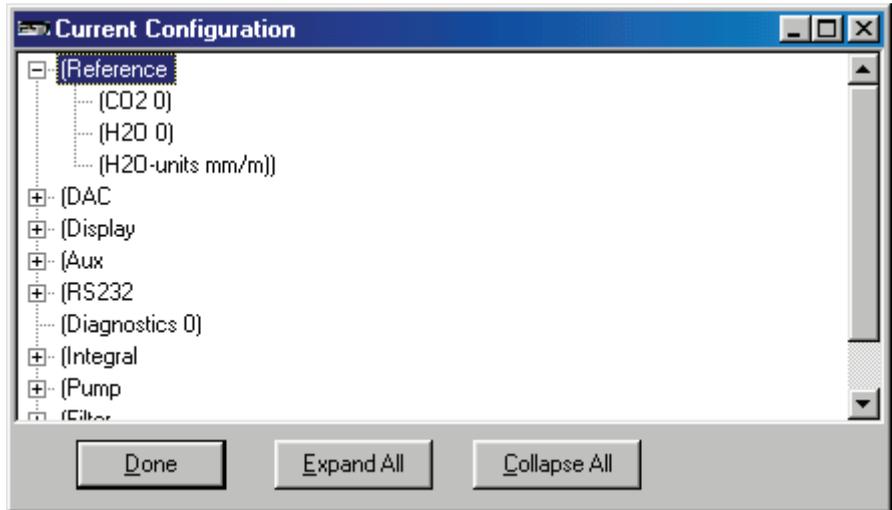
The backlight on the instrument display should now be at its brightest setting.

In the Communications Monitor window, note that the down arrow to the right of the Send Line field allows you to recall previously used commands without retyping them.

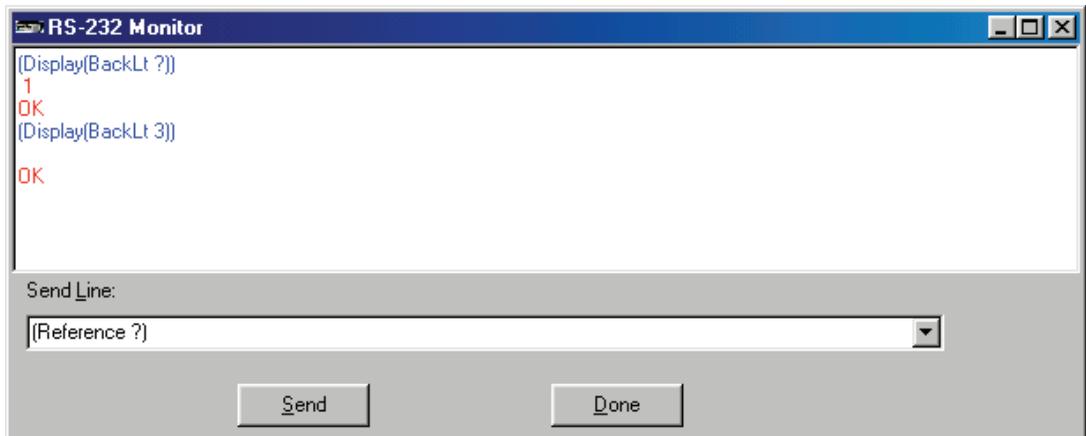


Example 2. Setting CO₂ Reference

First review the configuration tree to see the current state of **Reference**. Click **Done**.

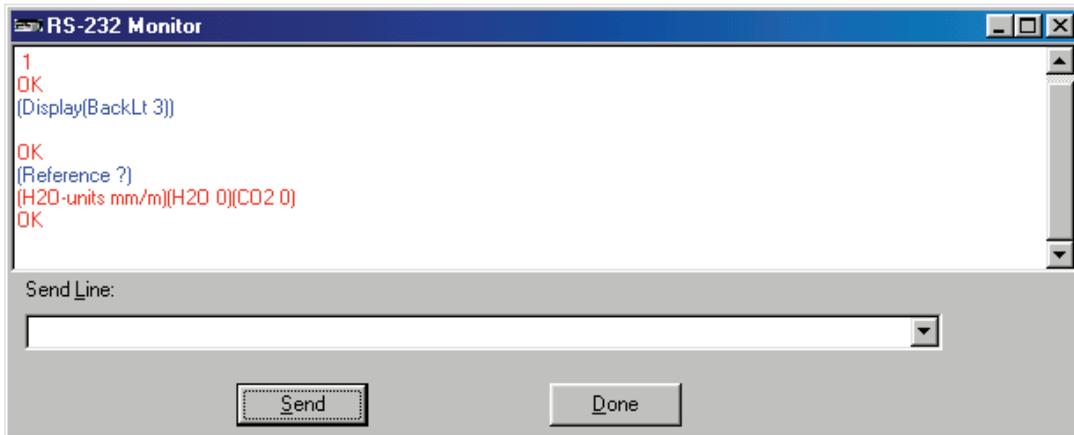


To verify these settings using **Reference** configuration, enter the command **(Reference ?)<lf>** in the Send Line field.

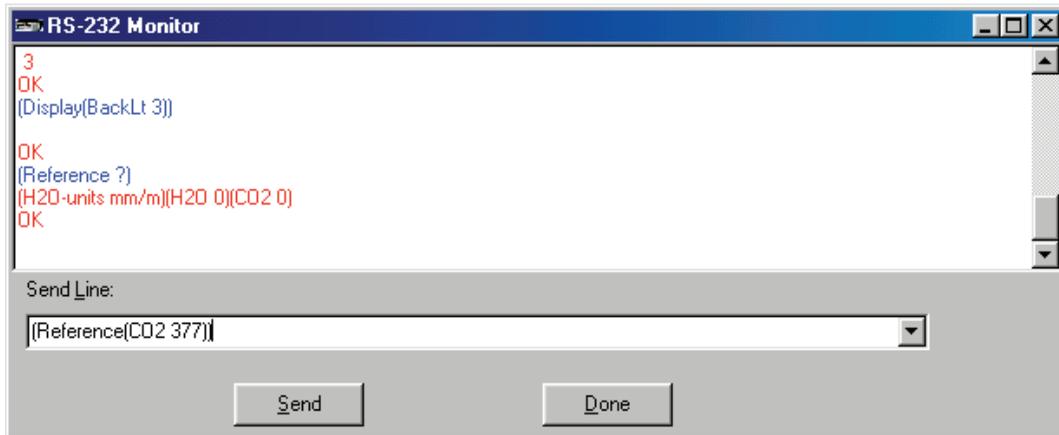


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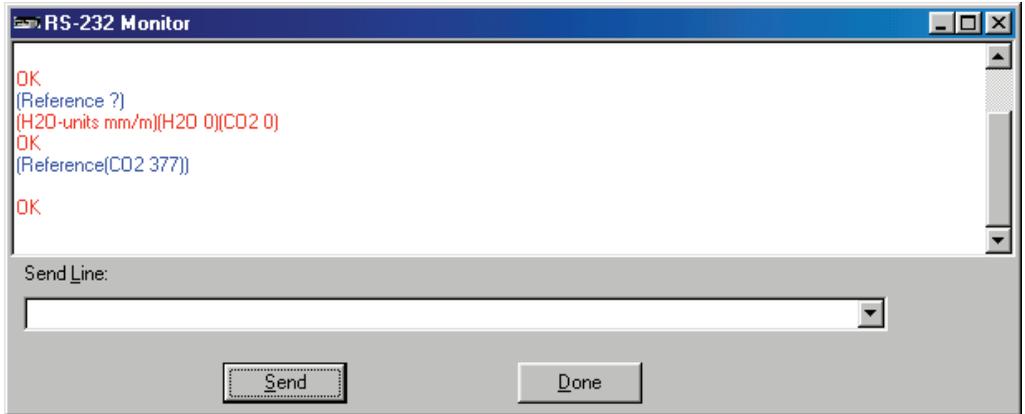
Press **Send**.



The response from the LI-7000 indicates the CO₂ reference is set to zero. If you are flowing a known concentration through the analyzer, say 377 ppm, then enter **command (Reference (CO2 377))<lf>** in the Send Line.



Click **Send**.



The instrument is now configured for a Cell A concentration of 377 ppm.

Command Overview

There are a total of 18 commands. In general, a core set of 9 commands are commonly used to configure the LI-7000 Analyzer. These commands are mirror images of the tabs as seen in the configuration menu of the *LI7000* program. Other less commonly used commands are also described below.

Core Commands	Description	LI7000 Software Configuration Tab
Reference	Gas Reference used for Cell A	Reference
DAC	Digital to Analog Converter Scaling	DAC
Aux	Auxillary Input Linearization	Auxillary
RS232	Data sources used	Logging
USB	Data sources used	Logging
Diagnostic	Diagnostics On/Off	Diagnostics
Integral	Integral Configuration	Analysis
Pump	Pump On/Off, Speed	Pump
Filter	Signal Averaging	Analysis

Other Commands	Description	LI-7000 Software Menu
Sources	LI-7000 Data Sources	
UserCal	User Calibration	Remote UserCalibration
History	Calibration History	Remote UserCalibration
Clock	View/Set Time	Remote SetClock
About	Instrument/Contact Information	
Reboot	Restarts LI-7000	
Cal	Calibration Coefficients	Configure CalCoefficients
Serial Number	Sets the instrument serial number	Configure CalCoefficients
Display	Configures LI-7000 Display	Remote Adjust LCD

There are four special characters that are used *with* the Commands listed above. They are ?, !, # and). The first three are used for querying status information and the last command “)” is used for navigating. Each character has a unique operation.

<u>Character</u>	<u>Operation</u>
#	Query a command showing its complete path and options
?	Query a command for output that can "safely" be reloaded into instrument
!	Query a command for immediate output
)	Back up one level in the command structure

Any of the first 3 command characters transmitted above at the root level will return the configuration tree. The ! and # commands will return the same file information at the root level. The response to the ? command is intended to retrieve an instrument profile that can be safely re-loaded back into the LI-7000.

For example,

Transmitted to LI-7000 ?<lf>

Response from LI-7000:

```
(About)(Aux(Aux1(a0 0)(a1 0)(a2 0))(Aux2(a0 0)(a1 0)(a2 0)))(Cal("P kPa"(a0
58.49)(a1 30.56))("T C"(A 0.000828003)(B 0.000208687)(C 8.0874e-08))("RH
%"(a0 0)(a1 1))(H2O(a1 38.6432)(a2 28983.7)(a3 650377)(gamma 1)(Z
1.11883)(Zt 5.57e-05)(Zm -0.00773063)(S 1.02312)(W0' 1.48099e+06)(W0'_d
1.49252e+06)(AGC 0.579834))(CO2(a1 825.646)(a2 73657.8)(a3 1.37334e+08)(a4
-2.90925e+10)(a5 3.13966e+12)(gamma 1)(Z 1.1361)(Zt -1.61e-05)(Zm -
0.000794452)(S 1.00287)(W0' 1.49978e+06)(W0'_d 1.50931e+06)(AGC
0.589844)(VpCrr 1.57)))(DAC(DAC1(Source ""(Zero 0)(Full 1)(Polarity
Unipolar))(DAC2(Source ""(Zero 0)(Full 1)(Polarity Unipolar))(DAC3(Source
""(Zero 0)(Full 1)(Polarity Unipolar)(Vmax 5))(DAC4(Source ""(Zero 0)(Full
1)(Polarity Unipolar)(Vmax 5))(Diagnostics 0)(Display(Sources ("CO2A um/m"
"CO2B um/m" "H2OA mm/m" "H2OB mm/m" "H2OA dpC" "H2OB dpC" Integral
Peak Diag))(BackLt 1)(Contrast 80)(Display1(Type Text)(Text(Source1 "CO2B
um/m")(Source2 Integral)(Source3 Peak)(Source4 ""(Source5 ""(Source6
""(Source7 ""(Source8 ""))(Graphs(Graph1(Source ""(Time 0)(Y-Scale
Fixed)(Min 0)(Max 0)(Delta 0))(Graph2(Source ""(Time 0)(Y-Scale Fixed)(Min
0)(Max 0)(Delta 0))(Graph3(Source ""(Time 0)(Y-Scale Fixed)(Min 0)(Max
0)(Delta 0))))(Display2(Type Text)(Text(Source1 ""(Source2 ""(Source3
""(Source4 ""(Source5 ""(Source6 ""(Source7 ""(Source8
```

```

"")))(Graphs(Graph1(Source "")(Time 0)(Y-Scale Fixed)(Min 0)(Max 0)(Delta
0))(Graph2(Source "")(Time 0)(Y-Scale Fixed)(Min 0)(Max 0)(Delta
0))(Graph3(Source "")(Time 0)(Y-Scale Fixed)(Min 0)(Max 0)(Delta
0)))(Display3(Type Text)(Text(Source1 "")(Source2 "")(Source3 "")(Source4
"")(Source5 "")(Source6 "")(Source7 "")(Source8 "")))(Graphs(Graph1(Source
"")(Time 0)(Y-Scale Fixed)(Min 0)(Max 0)(Delta 0))(Graph2(Source "")(Time
0)(Y-Scale Fixed)(Min 0)(Max 0)(Delta 0))(Graph3(Source "")(Time 0)(Y-Scale
Fixed)(Min 0)(Max 0)(Delta 0)))(Filter(Time 0))(History(H2O(Cella(Time
"1989-01-01 00:00:00")(Hours 0))(Match(Time "2005-04-27 17:04:09")(Hours
95))(CellB(Time "1989-01-01 00:00:00")(Hours 0))(CO2(Cella(Time "1989-01-
01 00:00:00")(Hours 0))(Match(Time "2005-04-26 17:04:14")(Hours
95))(CellB(Time "1989-01-01 00:00:00")(Hours 0))(Factory(Time "1989-01-01
00:00:00")(Hours 0))(Now))(Integral(Start Manual)(Stop Manual)(Threshold
0)(Time 1)(Source "CO2B um/m")(State Off))(RS232(Baud 57600)(Poll
)(Checksum Off)(Rate 10Hz)(Timestamp None)(Sources ("CO2A um/m" "CO2B
um/m" "H2OA mm/m" "H2OB mm/m" Aux1 Aux2 "P kPa" "T C" Diag "RH %"
"CO2A W" "CO2B W" "CO2A abs" "CO2B abs" "P V" "T V" "Adc0 cts" "AdcR
cts")))(USB(Poll)(Checksum On)(Rate 2min)(Timestamp Short)(Sources ("Adc0
cts" "AdcR cts" Aux1 Aux2 "CO2A W" "CO2A abs" "CO2A um/m" "CO2B W"
"CO2B abs" "CO2B um/m" Diag "H2OA mm/m" "H2OB mm/m" "P V" "P kPa"
"RH %" "T C" "T V")))(Pump(Installed True)(FlowRate Off)(Slow 150)(Medium
200)(Fast 255))(Reference(H2O-units mm/m)(H2O 30)(CO2 300))(Reboot
)(Sources)(UserCal)(SerialNumber ENGR-5014)<lf>
OK<lf>

```

Example using the ? and # Commands

The “?” command will retrieve *constants* and command option responses (e.g. scaling for Auxilliary inputs) that can be loaded back into the instrument. The # character will return a complete command response that would normally require several queries with the “?” command. The “?” command however will not return responses to the commands listed below other than an “OK” response:

- **About**
- **Sources**
- **UserCal**
- Commands with a **Now** response.

If you are using the keyboard to interact with the equipment the “?” command might be used to view specific command options. If you are writing a software program to interact with the instrument the “#” command will give you a packaged command response with only one query.

Examples:

Transmitted	Response
(Aux(Aux1(a0 ?)))	350<lf>OK
(Aux #)	(Aux(Aux1(a0 350)(a1 1200)(a2 0))(Aux2(a0 0)(a1 16)(a2 0)))<lf>OK

Example using the “)” character

When the right parentheses are not sent it infers you are navigating within a command to a specific point. However; you must have enough of the command syntax in your command string without the right parentheses to avoid an “Error:” message. Unrecognizable commands will return multiple “Error:” messages followed by each character of the command that was not recognized.

Examples of navigating within the Auxiliary command are shown below.

If you were interested in knowing what the offset values (a0) was for your auxiliary input you would send the Aux command without any right parenthesis. Note that “OK” is not returned while in this mode.

```
Transmitted to LI-7000      (Aux(Aux1(a0<lf>
Response from LI-7000      nothing
```

You are now at a specific point (parameter a0) in this command. Note there is not a response from the command at this point since no right parenthesis is transmitted. Specifically the value of the offset at this point can be found with the command character “?”.

```
Transmit to LI-7000        ? <lf>
Response from LI-7000     25<lf>
```

The value at this point can be changed and queried as well. For example, if you wanted to change the value from 25 to 10, simply transmit 10 and the “?” command at this point:

```
Transmit to LI-7000        10<lf>
Transmit to LI-7000        ? <lf>
Response from LI-7000     10<lf>
```

To back up one level with this command, transmit the right parenthesis “)”:

```
Transmit to LI-7000      )<lf>
Transmit to LI-7000      ? <lf>
Response from LI-7000     (a0 10)(a1 1200)(a2 0)
```

Note that the responses to the command “?” are the sub-commands associated with the Aux Command. To see the full path you can also transmit the Command, #.

```
Transmit to LI-7000      #<lf>
Response from LI-7000     (Aux(Aux1(a0 5)(a1 1200)(a2 0)))
```

NOTE: If you are unsure where you are within a command, simply transmit several right parentheses to move down the tree to its root level. The instrument will return OK's for each level you have moved.

```
Transmitted to LI-7000      ))))) <lf>
Response from LI-7000     OK
                           OK
                           OK
                           OK
                           OK
```

The “!” Command

The “!” command will return immediate responses to commands that either have a **Now** in the command response or where you would normally use a “?” command. The “!” command returns a similar response to the “?” command but contains information that you would not want to transmit back to the instrument unintentionally (i.e., user calibration).

Commands sent with “! “ that have a **Now** response (e.g. History) will return information as requested. Note that no additional information after the **Now** response is returned with the **History ?** command.

```
Transmitted to LI-7000:      (History !)<lf>
Response from LI-7000:
```

```
(H2O(CellA(Time "1989-01-01 00:00:00")(Hours 3720))(Match(Time "1989-01-01 00:00:00")(Hours 3720))(CellB(Time "1989-01-01 00:00:00")(Hours 0)))(CO2(CellA(Time "1989-01-01 00:00:00")(Hours 3720))(Match(Time "1989-01-01 00:00:00")(Hours 3728))(CellB(Time "1989-01-01 00:00:00")(Hours 3720)))(Factory(Time "1989-01-01 00:00:00")(Hours 0))(Now(Time "1989-01-01 00:00:00")(Hours 4011))
OK<lf>
```

```
Transmitted to LI-7000:      (History ?)<lf>
Response from LI-7000:
```

```
(H2O(CellA(Time "1989-01-01 00:00:00")(Hours 3720))(Match(Time "1989-01-01
00:00:00")(Hours 3720))(CellB(Time "1989-01-01 00:00:00")(Hours
0)))(CO2(CellA(Time "1989-01-01 00:00:00")(Hours 3720))(Match(Time "1989-
01-01 00:00:00")(Hours 3728))(CellB(Time "1989-01-01 00:00:00")(Hours
3720)))(Factory(Time "1989-01-01 00:00:00")(Hours 0))(Now)
OK<lf>
```

Application Example

In a typical field application it may be desirable to configure the LI-7000 for initial setup, serial output and periodic zero and span.

- The zero and span example assumes that Cell A has a known constant concentration (see Section 6, *Calibration* for more information).
- Periodically reading data through the **Poll Now** command could give the program an idea when the readings are stable. Retrieving calibration information for future reference is illustrated below.

What is not described in detail below are:

- The timing constraints required for a proper user calibration sequence.
- Setting water vapor span can take 15-20 minutes for readings to stabilize as water adsorbs and desorbs from surfaces of the tubing and analyzer cells.
- Timing for getting updated calibration parameters after setting zero and span (this can take up 5-10 seconds after the procedure has been initiated).
- Switching solenoids would be required if this were an automated procedure.

A general outline for setting up the instrument would consist of the following sequence:

Initial setup	Commands Used
Configure Reference for CO ₂ /H ₂ O	(Reference (CO2 0)(H2O 0)(H2O-units mm/m))<lf>
Set Digital Filter	(Filter (Time 1)) <lf>
Configure Diagnostics	(Diagnostics 1) <lf>
Configure RS-232 variables and timing	(RS232 (Rate 1s)(Sources ("CO2B um/m" "H2OB mm/m" "P kPa" "Diag"))(Timestamp Long)) <lf>
Periodic calibration check	Commands Used
Set RS-232 Output for polling only	(RS232(Poll)(Rate Polled)(Timestamp Long)(Sources ("CO2B um/m" "H2OB mm/m" "P kPa" Diag))) <lf>
Flow dry gas through both cells and periodically query instrument measurement for H ₂ O stability.	(RS232(Poll Now)) <lf>

Note you will have to initially poll the instrument twice the first time to get the data header (DATAD). Sample dialog is below:

```
(RS232(Poll Now)) <lf>
OK
DATAH "CO2B um/m" "H2OB mm/m" "P kPa" Diag
(RS232(Poll Now)) <lf>
OK
DATAD "2000-09-13 15:22:47" 55.30 7.472 95.56 0 <lf>
```

Once readings have stabilized, zero H₂O (UserCal (H2O (CellA-mm/m 0))) <lf>

Match A and B Cells (UserCal (H2O (Match Now))) <lf>

Get Results of Cal (Cal(H2O(#)))<lf>

Flow H₂O span gas through analyzer and periodically query instrument measurement for stability. Note for span gas units are °C. (RS232(Poll Now)) <lf>

Span H₂O when stable (UserCal (H2O (CellB-C 15))) <lf>

Flow CO₂-Free gas through analyzer and (RS232(Poll Now)) <lf>
periodically query instrument measurement
for stability.

Zero CO₂ when stable (UserCal (CO2 (CellA-um/m 0))) <lf>
Match A and B Cells (UserCal (CO2 (Match Now))) <lf>

Flow CO₂ span gas through analyzer and (RS232(Poll Now)) <lf>
for stability.

Span CO₂ (UserCal (CO2 (CellB-um/m 350))) <lf>

Get last zero and span (Cal(CO2(#)))<lf>

Resume Normal RS-232 Output (RS232 (Rate 1s)(Sources ("CO2B
um/m" "H2OB mm/m" "P kPa"
"Diag"))(Timestamp Long)) <lf>

If you have a lot of commands to send it is better to chain them together and put 1 line feed character at the end rather than individual commands. An example of scaling the auxiliary inputs is illustrated below. Both methods will work but the second method will take longer in addition to returning the OK response multiple times and also run the risk not working unless your are responding to XON/XOFF flow control.

Single Command with (1) line feed:

```
(Aux(Aux1(a0 350)(a1 1200)(a2 0))(Aux2(a0 0)(a1 16)(a2 0)))<lf>
```

Multiple commands with multiple line feeds:

```
(Aux(Aux1(a0 350)))<lf>
(Aux(Aux1(a1 1200)))<lf>
(Aux(Aux1(a2 0)))<lf>
(Aux(Aux2(a0 0)))<lf>
(Aux(Aux2(a1 350)))<lf>
(Aux(Aux2(a2 0)))<lf>
```

Measurement data are also output to the RS-232 port. Data begin with headers 'DATAH', 'DATA', 'DATAM' or 'DATAD' and end with a newline. Values between the header and newline are delimited by tabs. The 'DATAH' header is sent followed by the names of the sources that will be output whenever the configuration of the data to be output changes. The 'DATA' header is followed by the values of each source that the LI-7000 is configured to output. The 'DATAM' and 'DATAD' records are the same as 'DATA' records except that between the header and the source values a timestamp is inserted. For 'DATAM' records, the timestamp is the number of milliseconds since the LI-7000 was powered on. For 'DATAD' records, the timestamp is a full date and time.

When checksums are turned on

(RS232(CheckSum On))

or

(USB(CheckSum On))

the DATAH record will have the 3 letters CHK appended to the end, and the decimal 8-bit checksum will be appended to each DATA, DATAM, or DATAD record.

DATAH "CO2B um/m" Diag "H2OB mm/m" CHK

DATAM 420005831 321.89 0 30.525 237

DATAM 420015831 321.72 0 30.506 229

DATAM 420025831 322.31 0 30.554 229

The checksum is computed using an 8-bit unsigned integer, initialized to zero, adding all the characters on the line starting with the 'D' in DATA and ending with the tab character before the first digit of the checksum. The checksum is always printed as a decimal number between 0 and 255 inclusive and will always be the last three characters before the <lf> at the end of the line. So for example, if the checksum is 63, it will be printed as the three digits 063.

A difficulty with writing software that works with the LI-7000 RS-232 interface is the fact that responses to queries and measurement data are intermingled in the same stream of characters. For example:

```
DATAM 8724600 7.65 4.23
(History(Now(Time!)))
"1999-08-25DATAM 8724700 7.65 4.23
5 14:32:12"
OK
DATAM 8724800 7.65 4.23
```

The response to the query for the time was interrupted by the data with timestamp 8724700. Measurement data are never interrupted by query results. By removing the measurement data from the stream (all characters from DATA to the following newline), the response to the query for the time can be found:

```
"1999-08-25 14:32:12"
```

The (About!) Command

The About command lists the instrument model and software version numbers, as well as contact information for LI-COR, inc.

Grammar

```
(About !)
```

The (Aux...) Command

The Aux command allows the user to configure the coefficients of the linearization polynomials for each of the two auxiliary ports located on the back panel terminal strip of the LI-7000. The raw auxiliary ports are provided as sources "Aux1 V" and "Aux2 V". Each of these has a polynomial applied to transform the linearized sources "Aux1" and "Aux2". The polynomials are each of the form:

$$y = a_0 + a_1x + a_2x^2$$

Grammar

```
(Aux(Aux1(a0 float)
      (a1 float)
      (a2 float))
  (Aux2(a0 float)
      (a1 float)
      (a2 float)))
```

The (Cal...) Command

The Cal command contains calibration coefficients that are either not often changed or are changed automatically due to action in other sections (e.g. the UserCal section may change Z_i and S_i parameters for H₂O or CO₂).

Grammar

```
(Cal("P kPa"(a0 float)
      (a1 float))
  ("T C"(A float)
      (B float)
      (C float))
  ("RH %" (a0 float)
      (a1 float))
  (H2O(a1 float))
```

(a2 *float*)

(a3 *float*)

(gamma *float*)

(Z *float*)

(Zt *float*)

(Zm *float*)

(S *float*)

(W0' *float*)

(W0'_d *float*)

(AGC *float*)

(CO2(a1 *float*))

(a2 *float*)

(a3 *float*)

(a4 *float*)

(a5 *float*)

(gamma *float*)

(Z *float*)

(Zt *float*)

(Zm *float*)

```
(S float)

(W0' float)

(W0'_d float)

(AGC float)

(VpCrr float))
```

The (Serial Number...) Command

The `SerialNumber` command is for getting/setting the serial number of the instrument. The serial number can be any string of characters that uniquely identifies the instrument. It is used to identify the instrument in the USB connection dialog when multiple instruments are connected to one computer. The `SerialNumber` is set at the factory and normally should not need adjustment.

Grammar

```
(SerialNumber serial_number)
```

The (Clock...) Command

The `Clock` command allows the user to view or set the date and time. This information is used for setting the time stamp for data output.

The `Clock` command is available as a subset of the `History` section (see above).

Grammar

```
(History(Now(Time time_date)))
```

The (DAC...) Command

The DAC command allows the user to configure each of the four digital-to-analog converters that are connected to the four DAC output ports on the back of the LI-7000. Each DAC can be set to have either a bipolar ($-V_{\max}$ to $+V_{\max}$) or unipolar (0 to $+V_{\max}$) output, although DAC1 and DAC2 must be set the same. DAC1 and DAC2 have a fixed V_{\max} of 5 volts. DAC3 and DAC4 can be set with a V_{\max} of 5, 2.5, 1.25, or 0.625 volts. Each DAC must also be set to output the desired source.

Each DAC has a Zero and Full value also, which are floating point numbers that map the value of the source to either the range ($-V_{\max}$ to $+V_{\max}$) or (0 to $+V_{\max}$) depending on the polarity setting. The Zero value is the value of the source that maps to 0 volts on the output. The Full value is the value of the source that maps to V_{\max} volts, whatever it may be. Zero - Full maps to $-V_{\max}$ volts. The output volts are given by

$$\text{volts} = V_{\max} * (\text{Source} - \text{Zero}) / (\text{Full} - \text{Zero})$$

where Source is the value of the source channel. To return the value of the source from the voltage, use

$$\text{Source} = \text{Zero} + (\text{Full} - \text{Zero}) * \text{Volts} / V_{\max}$$

Note that the polarity settings for DAC1 and DAC2 must be identical, so changing one of them changes the other.

Grammar

```
(DAC(DAC1(Polarity [Unipolar|Bipolar])
```

```
  (Zero float)
```

```
  (Full float)
```

```
  (Source source))
```

```
(DAC2(Polarity [Unipolar|Bipolar])
```

```
  (Zero float)
```

```
  (Full float)
```

```
  (Source source))
```

```
(DAC3(Polarity [Unipolar|Bipolar])
```

```
  (Vmax [5|2.5|1.25|0.625])
```

```
  (Zero float)
```

```
  (Full float)
```

```
  (Source source))
```

```
(DAC4(Polarity [Unipolar|Bipolar])
```

```
  (Vmax [5|2.5|1.25|0.625])
```

```
  (Zero float)
```

```
  (Full float)
```

```
  (Source source))
```

The (Diagnostics...) Command

The Diagnostics command allows the user to turn off individual system diagnostics. The Diagnostics command uses an integer that corresponds to the mask number of each active warning that is turned off. The following table summarizes the warnings.

Warning	Description	Mask Number
INT	Integrating	1
BAT	Low Battery	2
CO2	CO ₂ Cooler	4
H2O	H ₂ O Cooler	8
SRC	Infrared Source	16
PLL	Phase Lock Loop	32

Grammar

(Diagnostics *integer*)

Example:

(Diagnostics 63) turns **off** all Diagnostics

(Diagnostics 0) turns **on** all Diagnostics

(Diagnostics 3) turns off INT and BAT

The (Display...) Command

The Display command is used to configure the three logical text displays using the selected sources. Each text display can show from zero to eight sources. This command is also used for adjusting the backlight and contrast of the front panel LCD.

Grammar

```
(Display(Sources !)  
  
    (BackLt [0-3])  
  
    (Contrast [0-255])  
  
    (Display1(Type [Text|Graphs])  
  
        (Text(Source1 source)  
  
            (Source2 source)  
  
            (Source3 source)  
  
            (Source4 source)  
  
            (Source5 source)  
  
            (Source6 source)  
  
            (Source7 source)  
  
            (Source8 source))  
  
        (Graphs(Graph1(Source source)  
  
            (Time float)  
  
            (Y-Scale  
[Fixed|Scrolled])  
  
            (Min float)  
  
            (Max float)  
  
            (Delta float))  
  
        .  
        .
```

```

    .
    (Graph3(Source source)
        (Time float)
        (Y-Scale
            [Fixed|Scrolled]
            (Min float)
            (Max float)
            (Delta float)))
    .
    .
    .
    (Display3(Type [Text|Graphs])
        (Text(Source1 source)
            (Source2 source)
            (Source3 source)
            (Source4 source)
            (Source5 source)
            (Source6 source)
            (Source7 source)
            (Source8 source))
        (Graphs(Graph1(Source source)
            (Time float)

```

```

[Fixed|Scrolled]
    (Y-Scale
    (Min float)
    (Max float)
    (Delta float))
.
.
.
(Graph3(Source source)
    (Time float)
    (Y-Scale
    [Fixed|Scrolled]
    (Min float)
    (Max float)
    (Delta float))))

```

The (Filter...) Command

The Filter command specifies the amount of signal averaging (in seconds) to use. Signal averages from 0 to 20 seconds are valid. The following channels are filtered:

- CO₂A $\mu\text{m}/\text{m}$
- CO₂B $\mu\text{m}/\text{m}$
- CO₂D $\mu\text{m}/\text{m}$
- H₂OA mm/m
- H₂OB mm/m
- H₂OD mm/m
- CO₂A Pa
- CO₂B Pa
- CO₂D Pa
- H₂OA kPa
- H₂OB kPa
- H₂OD kPa
- H₂OA dpC
- H₂OB dpC
- H₂OD dpC
- CO₂A abs
- CO₂B abs
- H₂OA abs
- H₂OB abs
- Aux1
- Aux2
- Aux1 V
- Aux2 V
- Aux1 cts
- Aux2 cts

The following channels are filtered, but the minimum averaging time is constrained to 0.62 seconds:

- P kPa
- T C

- RH
- P V
- T V
- RH V
- Flow V
- P cts
- T cts
- RH cts
- Flow cts

Grammar

```
(Filter(Time float))
```

The (History...) Command

The History command allows the calibration history of the LI-7000 as well as the current time to be set or queried. Each event is recorded both as a date and time and as the cumulative hours of operation when the event occurred.

Grammar

```
(History(H2O(CellA(Time time_date)
           (Hours integer))
         (Match(Time time_date)
           (Hours integer))
         (CellB(Time time_date)
           (Hours integer)))
         (CO2(CellA(Time time_date)
           (Hours integer))
         (Match(Time time_date)
```

(Hours *integer*)

(CellB(Time time_date)

(Hours *integer*))

(Factory(Time time_date)

(Hours *integer*)

(Now(Time time_date)

(Hours *integer*))

The (Integral...) Command

The integral command allows configuration of and control over the integrator and peak detection functions in the LI-7000. The input to the two functions is selected with the Source parameter. The output of these two functions is available as the Integral and Peak source (see the Sources section.)

When the functions are started, the Integral and Peak values are reset. The two values will then be updated until the functions are stopped. After being stopped, they will hold their values until being started again. The functions are started either by manually changing the State parameter to Off, or when the value of the input source crosses the threshold from below, depending on the Start parameter. The functions are stopped either when the State parameter is manually changed to Off, when the value of the input source crosses the threshold from above, or when an elapsed time expires since the integration was started, depending on the setting of the Stop parameter.

It should be noted that The Manual setting of the Start and Stop parameters should be interpreted as "Manual Only"; the State can always be changed manually no matter what the setting of the Start and Stop parameters. The Threshold parameter is a floating point value expressed in the same units as those of the input source. The Time parameter is the integer number of seconds to integrate when Stop is set for elapsed time.

Please note that there is only one threshold value that is used for both threshold start and stop.

Grammar

```
(Integral(Start [Manual|Threshold])
```

```
(Stop [Manual|Threshold|ElapsedTime])
```

```
(Threshold float)
```

```
(Time integer)
```

```
(Source source)
```

```
(State [Off|On]))
```

The (Pump...) Command

The Pump command allows the pump to be configured. Each of three speeds (Slow, Medium, and Fast) can be configured with a value from 0 to 255. The speed value relates directly to the voltage applied to the pump, *not* to flow rate. The flow rate can then be set to Off, Slow, Medium, or Fast.

Grammar

```
(Pump(Slow [0-255])
```

```
      (Medium [0-255])
```

```
      (Fast [0-255])
```

```
      (FlowRate [Off|Slow|Medium|Fast]))
```

The (Reboot) Command

Restarts the LI-7000.

Grammar

```
(Reboot Now)
```

The (Reference...) Command

The Reference command allows the user to specify what is known about the gas flowing through Cell A. This information is required for the LI-7000 to operate correctly. The LI-7000 uses this information as a reference for the measurement of the gas in Cell B.

The user selects what is known about the H₂O and CO₂ concentrations in Cell A. For H₂O, the information can be entered as a mole fraction in units of millimoles per mole or as a dewpoint temperature in units of degrees celcius. For CO₂, the information must be entered as a mole fraction in units of micromole per mole.

For each of the two gas components, the user can choose Estimated, Aux1, Aux2, or enter a floating point number. Estimated means that the user may not know what the concentration is and that the LI-7000 should use information from previous calibrations (See UserCal) to estimate its concentration. Aux1 or Aux2 means that the user has provided the concentration to the LI-7000 as a voltage on the back panel. See the Aux section for information on converting the voltage to the units that you want. By entering a floating point value, the user can specify that the gas is known and has a fixed concentration. For H₂O, Dry can also be chosen to mean either zero millimoles per mole or -100 degrees celcius depending on the units selected. For CO₂, Zero means zero micromoles per mole.

Grammar

```
(Reference(H2O-units [mm/m|C])
```

```
(H2O [Estimated|Dry|Aux1|Aux2|float])
```

```
(CO2 [Estimated|Zero|Aux1|Aux2|float]))
```

The (RS232...) Command

The RS232 command allows the user to choose the list of sources whose values are sent out the serial port, the rate at which they should be sent, and what time stamp will be included. The time stamp options include none, a short format with the number of milliseconds since being powered on, and a long format with the full date and time to the nearest second. The Poll command is provided so that a user can request that the data be output instead of the data being output at a fixed rate. Only when the rate is set to Polled does the poll command cause the data to be output; otherwise the command has no effect. The trigger input is enabled when the Rate for RS-232 is set to Polled. When enabled, the rising edge of the Ring Indicator (RI) pin on the serial port will trigger a reading that will then be output on the RS-232 and/or USB. The trigger is accurate to within 1/600th of a second.

Grammar

```
(RS232 (Baud [9600|19200|38400|57600|115200])
```

```
(Poll Now)
```

```
(Checksum [Off|On])
```

```
(Sources source_list)
```

```
(Rate[Polled|1hr|30min|10min|5min|2min|1min  
|30s|10s|5s|2s|1s|1Hz|2Hz|5Hz|10Hz|20Hz|30H  
z|40Hz|50Hz])
```

```
(Timestamp [None|Short|Long])
```

The (USB...) Command

The USB command allows the user to choose the list of sources whose values are sent out the USB port, and what time stamp will be included. The time stamp options include none, a short format with the number of milliseconds since being powered on, and a long format with the full date and time to the nearest second. The Poll command is provided so that a user can request that the data be output instead of the data being output at a fixed rate. Only when the rate is set to Polled does the poll command cause the data to be output; otherwise the command has no effect. The trigger input is enabled when the Rate for USB is set to Polled. When enabled, the rising edge of the RI pin on the serial port will trigger a reading that will then be output on the RS-232 and/or USB. The trigger is accurate to within 1/600th of a second.

Grammar

```
(USB (Poll Now)
```

```
    (Checksum [Off|On])
```

```
    (Sources source_list)
```

```
    (Rate[Polled|1hr|30min|10min|5min|2min|1min  
|30s|10s|5s|2s|1s|1Hz|2Hz|5Hz|10Hz|20Hz|30H  
z|40Hz|50Hz])
```

```
    (Timestamp [None|Short|Long]))
```

The (Sources!) Command

This command lists data sources that the LI-7000 provides. These sources can be displayed on the front panel LCD, output through the DAC channels on the back panel, output to the RS-232 or USB port, or used as the integrand of an integral. See the Display, DAC, RS-232, USB, and Integral sections for more information about these uses. Each source is primarily identified by name, but a number is also provided for convenience. The following table lists the number, name and description of all data sources available on the LI-7000.

Number	Name	Description
01	CO2A um/m	CO ₂ cell A concentration, $\mu\text{mol/mol}$
02	CO2B um/m	CO ₂ cell B concentration, $\mu\text{mol/mol}$
03	CO2D um/m	CO ₂ differential, $\mu\text{mol/mol}$
04	H2OA mm/m	H ₂ O cell A concentration, mmol/mol
05	H2OB mm/m	H ₂ O cell B concentration, mmol/mol
06	H2OD mm/m	H ₂ O differential, mmol/mol
10	CO2A Pa	CO ₂ cell A partial pressure, Pa
11	CO2B Pa	CO ₂ cell B partial pressure, Pa
12	CO2D Pa	CO ₂ partial pressure differential, Pa
13	H2OA kPa	H ₂ O cell A partial pressure, kPa
14	H2OB kPa	H ₂ O cell B partial pressure, kPa
15	H2OD kPa	H ₂ O partial pressure differential, kPa
16	H2OA dpC	Dew point of cell A, degrees C
17	H2OB dpC	Dew point of cell B, degrees C
18	H2OD dpC	Dew point differential, degrees C
20	Aux1	Auxiliary input channel 1, linearized signal
21	Aux2	Auxiliary input channel 2, linearized signal
22	PkPa	Pressure measured in cell B, kPa
23	T C	IRGA temperature, degrees C
30	Integral	Integration result, area under curve
31	Peak	Integration result, peak value
40	Diag	Diagnostic: condition flags

Number	Name	Description
41	RH %	Diagnostic: humidity sensor RH %
42	CO2 AGC	CO ₂ automatic gain control
43	H2O AGC	H ₂ O automatic gain control
50	CO2A W	CO ₂ cell A raw signal
51	CO2B W	CO ₂ cell B raw signal
52	H2OA W	H ₂ O cell A raw signal
53	H2OB W	H ₂ O cell B raw signal
54	CO2A abs	CO ₂ cell A absorptance, unitless
55	CO2B abs	CO ₂ cell B absorptance, unitless
56	H2OA abs	H ₂ O cell A absorptance, unitless
57	H2OB abs	H ₂ O cell B absorptance, unitless
60	DAC1V/2	Diagnostic: DAC1 output, volts
61	DAC2V/2	Diagnostic: DAC1 output, volts
62	DAC3V/2	Diagnostic: DAC1 output, volts
63	DAC4V/2	Diagnostic: DAC1 output, volts
64	Aux1V	Auxiliary input channel 1, volts
65	Aux2V	Auxiliary input channel 2, volts
66	PV	Pressure sensor cell B, volts
67	TV	IRGA temperature, volts
68	RHV	Diagnostic: humidity sensor RH, volts
69	Flow V	Flow rate estimate, volts
70	DAC1 cts	A/D DAC1 counts
71	DAC2 cts	A/D DAC2 counts
72	DAC3 cts	A/D DAC3 counts
73	DAC4 cts	A/D DAC4 counts
74	Aux1 cts	A/D Aux1 counts
75	Aux2 cts	A/D Aux2 counts
76	P cts	A/D Pressure counts
77	T cts	A/D Temperature counts
78	RH cts	RA/D Relative Humidity counts
79	Flow cts	A/D Flow counts
80	Adc0 cts	A/D Zero counts
81	AdcR cts	A/D Reference counts

The following indicates how the complete list of data sources may be obtained from the RS-232 port.

Grammar

(Sources !)

The (UserCal...) Command

The UserCal command allows the user to calibrate the LI-7000 using known gases.

Three types of calibrations can be done for each gas component (CO₂ and/or H₂O):

- A known gas is flowed through Cell A to set W_{i0} '. This parameter is useful only when operating with an estimated reference. See the Reference section above.
- A single gas (with possibly unknown concentration) is flowed through the two cells and the two cells are made to match. This also sets the Z_i parameter. This is the most frequently performed calibration.
- A known gas is flowed through Cell B to set the S_i parameter. A different gas must also be flowed through Cell A and the Reference section must be configured for it.

For cases when a known gas concentration needs to be entered, the user can choose Dry, Zero, Aux1, Aux2, or enter a floating point value as was done in the Reference section. The user has the option of entering information about H₂O as either a mole fraction in units of millimoles per mole or as a dewpoint in units of degrees Celsius. Information for CO₂ must be entered as a mole fraction in units of micromoles per mole.

Grammar

```
(UserCal (H2O (CellA-mm/m
[ Dry | Zero | Aux1 | Aux2 | float ] )
```

```
( CellA-C [ Dry | Aux1 | Aux2 | float ] )
```

```

(Match Now)

(CellB-mm/m
[ Dry|Zero|Aux1|Aux2|float])

(CellB-C [Dry|Aux1|Aux2|float])

(Reset Now))

(CO2(CellA-um/m [Zero|Aux1|Aux2|float])

(Match Now)

(CellB-um/m [Zero|Aux1|Aux2|float])

(Reset Now)))

```

Example Configuration Conversation

The following is an example of how you might configure a series of commands used to set up data output on the LI-7000 using the configuration grammar described earlier in this section.

A fixed width font is used to indicate text sent from one of the user interfaces to the mill. A bold fixed width font is used to indicate responses.

Double slashes (//) are used to indicate a comment in this section.

A ? is used to query the LI-7000 for a response.

A ! can be used like ? but will also query those items that you wouldn't normally want to save (e.g. the time).

9 Language Reference

```
( Reference ( H2O-units mm/m ) // Sets H2O units to mm/m. Choices: C, or mm/m
  ( H2O Dry ) // Sets H2O ref. to 0 mm/m. Choices: Estimated, Dry,
    Aux1, Aux2, or float
  ( CO2 [Zero ] ) // Choices: Estimated, Zero, Aux1, Aux2, or float
( UserCal ( H2O ( CellA-mm/m 300 ) // Set Wo
  ( CellA-C -100 ) // Set Wo
  ( Match Now ) // Set Z - Now is a write only value
  ( CellB-mm/m 400 ) // Set S
  ( CellB-C 20 ) // Set S
  ( Reset Now ) // Reset to factory values
  ( CO2 ( CellA-um/m 0 )
    ( Match Now )
    ( CellB-um/m 300 )
    ( Reset Now )))
( History ( H2O ( CellA ( Time "1999-05-24 13:45:45" )// Settable and Gettable
  ( Hours 123456 ) // Settable and Gettable
  ( Match ( Time "1999-05-25 13:45:45" )// Settable and Gettable
    ( Hours 123456 ) // Settable and Gettable
  ( CellB ( Time "1999-05-25 13:45:45" )// Settable and Gettable
    ( Hours 123456 ) ) // Settable and Gettable
  ( CO2 ( CellA ( Time "1999-05-24 13:45:45" )// Settable and Gettable
    ( Hours 123456 ) // Settable and Gettable
  ( Match ( Time "1999-05-25 13:45:45" )// Settable and Gettable
    ( Hours 123456 ) // Settable and Gettable
  ( CellB ( Time "1999-05-25 13:45:45" )// Settable and Gettable
    ( Hours 123456 ) ) // Settable and Gettable
  ( Factory ( Time "1998-09-03 13:45:45" ) // Settable and Gettable
    ( Hours 123456 ) // Settable and Gettable
  ( Now ( Time "1998-09-03 13:45:45" ) // Settable and Gettable
    ( Hours 123456 ) ) // Note: (Now will not display
      parameters to the "?" query, but will to the "!" query)

( Display ( Sources ( "CO2 um/m" "H2O mm/m" ) )
  ( BackLt 3 )
  ( Contrast 40 )
  ( Display1 ( Text ( Source1 "H2OA mm/m" )
    ( Source2 "H2OB mm/m" )
    ( Source3 "H2OD mm/m" )
    ( Source4 "H2OA dpC" )
```

```

        ( Source5 "H2OB dpC" )
        ( Source6 "H2OD dpC" )
        ( Source7 "TC" )
        ( Source8 "Aux1" )
    .
    .
    .
    ( Display3 ( Text ( Source1 "CO2A um/m" )
                    ( Source2 "CO2B um/m" )
                    ( Source3 "CO2D um/m" )
                    ( Source4 "CO2A Pa" )
                    ( Source5 "CO2B Pa" )
                    ( Source6 "CO2D Pa" )
                    ( Source7 "Integral" )
                    ( Source8 "Peak" )
    ( Diagnostics 63 ) // Mask indicating which diagnostics to shut off
    ( Cal ( "P kPa" ( a0 123456.78 ) // Pressure Sensor Linearization Polynomial
          ( a1 123456.78 ) )
    ( "T C" ( A 123456.78 ) // Steinhart-Hart Coefficients
          ( B 123456.78 )
          ( C 123456.78 ) )
    ( "RH %" ( a0 123456.78 )
          ( a1 123456.78 ) ) // Relative Humidity Linearization Polynomial
    ( H2O ( a1 123456.67 ) // Linearization Polynomial
          ( a2 123456.67 )
          ( a3 123456.67 )
          ( gamma 123456.67 ) // Power with which to raise pressure ratio
          ( Z 123456.67 ) // User calibration values
          ( Zt 123456.67 )
          ( Zm 123456.67 )
          ( S 123456.67 )
          ( W0' 123456.67 )
          ( W0'_d 123456.67 ) // Factory defaults for user calibration values
          ( AGC 123456.67 ) // Fixed values for REM mode
    ( CO2 ( a1 123456.67 ) // CO2 Linearization Polynomial
          ( a2 123456.67 )
          ( a3 123456.67 )
          ( a4 123456.67 )
          ( a5 123456.67 )

```

```

( gamma 123456.67 )
( Z 123456.67 )
( Zt 123456.67 )
( Zm 123456.67 )
( S 123456.67 )
( W0' 123456.67 )
( W0'_d 123456.67 )
( AGC 123456.67 )
( VpCrr 1.5 ) ) // The vapor correction coefficient
( SerialNumber IRG4-0123 )
( Pump ( Installed True ) // Gettable only
  ( Slow 45 ) // 0 - 255
  ( Medium 120 ) // 0 - 255
  ( Fast 255 ) // 0 - 255
  ( FlowRate Off ) // Can be Off, Slow, Medium, or Fast
( About ! ) // Gettable only
" LI-COR LI-7000 Version 2.0.0
4421 Superior Street / P.O. Box 4425
Lincoln, NE 68504 USA
Phone: 402-467-3576
Toll-free: 800-447-3576 (U.S. & Canada)
FAX: 402-467-2819
E-mail: envsales@licor.com
URL: http://www.licor.com"
OK
( Aux ( Aux1 ( a0 0 )
  ( a1 1 )
  ( a2 2.5 ) )
  ( Aux2 ( a0 -3.2 )
  ( a1 1 )
  ( a2 2.5 ) ) )
( DAC ( DAC1 ( Polarity Bipolar ) // Unipolar or Bipolar
  ( Zero 190 )
  ( Full 200 )
  ( Source "CO2A um/m" ) )
  ( DAC2 ( Polarity Bipolar ) // Uses the polarity of DAC1
  ( Zero 190 )
  ( Full 200 )
  ( Source "CO2A um/m" ) )

```

```

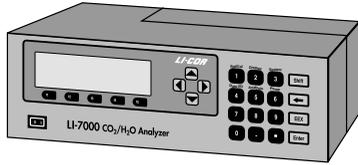
( DAC3 ( Polarity Unipolar )
  ( Vmax 1.25 ) // 5, 2.5, 1.25, 0.625 (Note: the 5 must be "5", 5.0
    won't work)
  ( Zero 300 )
  ( Full 310 )
  ( Source "CO2B um/m" ) )
( DAC4 ( Polarity Bipolar )
  ( Vmax 2.5 )
  ( Zero 300 )
  ( Full 310 )
  ( Source "CO2A um/m" ) ) )
( RS232 ( Sources ( "CO2A um/m" "CO2B um/m" "H2OA mm/m" "H2OB mm/m" ) )
  ( Poll Now )
  ( Rate 10Hz )
  ( Timestamp None ) ) // Choices: None, Short, Long
  ( CheckSum On ) // Choices: Off, On
  ( Baud 9600 ) ) // Choices: 9600, 19200, 38400, 57600, 115200
( USB ( Sources ( "CO2A um/m" "CO2B um/m" "H2OA mm/m" "H2OB mm/m" ) )
  ( Poll Now )
  ( Rate 50Hz )
  ( Timestamp None ) ) // Choices: None, Short, Long
  ( CheckSum On ) // Choices: Off, On
( Filter ( Time 5 ) )
( Integral ( Start Threshold ) // Manual, Threshold
  ( Stop ElapsedTime ) // Manual, Threshold, ElapsedTime
  ( Threshold 200 )
  ( Time 60 )
  ( Source "CO2A um/m" )
  ( State Off ) ) // On, Off
( Reboot Now )
( Sources ! ) // Gettable Only
( "H2OA W" "H2OB W" "CO2A W" "CO2B W" "H2O AGC" "CO2 AGC" "H2OA mm/m"
"H2OB mm/m" "CO2A um/m" "CO2B um/m" "H2OA abs" "H2OB abs" "CO2A abs"
"CO2B abs" "Flow V" "T V" "P V" "RH V" "Aux1 V" "Aux2 V" "DAC1 V/2"
"DAC2 V/2" "DAC3 V/2" "DAC4 V/2" "Adc0 cts" "AdcR cts" "Flow cts" "T
cts" "P cts" "RH cts" "Aux1 cts" "Aux2 cts" "DAC1 cts" "DAC2 cts"
"DAC3 cts" "DAC4 cts" "H2OD mm/m" "CO2D um/m" Aux1 Aux2 "P kPa" "T C"
"RH %" Peak Integral Diag "H2OA kPa" "H2OB kPa" "CO2A Pa" "CO2B Pa"
"H2OD kPa" "CO2D Pa" "H2OA dpC" "H2OB dpC" "H2OD dpC" Idle Overhead

```

9 Language Reference

Working FHeapFree FHeapUsed NHeapFree NHeapUsed)

```
"RH %      RH %      Diagnostic: humidity sensor RH, %"      //
(Diagnostic: Shouldn't operate coolers if above 30%)
"PLL      PLL      Diagnostic: Phase lock loop locked, bool"      //
(Diagnostic: May take 10s on startup, after that indicates vibs or failing motor)
"CO2 Cool CO2 Cool Diagnostic: CO2 cooler in control, bool"      //
(Diagnostic: Indicates the CO2 Cooler is controlling to -5C)
"H2O Cool H2O Cool Diagnostic: H2O cooler in control, bool"      //
(Diagnostic: Indicates the H2O Cooler is controlling to -5C)
"IR Source IR Source Diagnostic: Infrared source fuctioning, bool" //
(Diagnostic: 10s warmup, after that indicates a bad source)
"Battery Battery Diagnostic: Battery life > 10 min, bool"      //
(Diagnostic: about 10min of life left)
"Zero Corr Zero Corr Diagnostic: Zero correction in range, bool" //
(Diagnostic: Indicates a larger amount of dirt in one cell than the other)
"Span Corr Span Corr Diagnostic: Span correction in range, bool" //
(Diagnostic: Indicates wrong gas, poor job of zeroing, or a bad pressure sensor)
"AGC Gain AGC Gain Diagnostic: AGC gain in range, bool"      //
(Diagnostic: Indicates a problem if it is at its max or min)
"Flow Err Flow Err Diagnostic: Flow error OK, bool"      //
(Diagnostic: May indicate an obstruction or bad pump, but only if the pump is on)
```



A Specifications

Type: Differential, non-dispersive infrared gas analyzer.

Detectors: Two solid state detectors; one each for CO₂ and H₂O, filtered at 4.255 and 2.595 microns, respectively.

Chopping Frequency: 600 hertz.

Source: Single source, lifetime > 20000 hours.

Optical Bench: One optical bench. Sample cell size: 9.53 mm Dia. × 152.4 mm L (3/8" × 6"). Volume: 10.86 cm³.

Warm-up Time: Approximately 2 minutes to operation; 2 hours to temperature equilibration.

Gas Pressure: Maximum allowable pressure is 115 kPa (17 psi) with pressure sensor connected. 200 kPa (29 psi) max. w/o pressure sensor connected.

Maximum Flow through Analyzer: >50 liters/min.

Internal Pump: Yes

Display: 40 character × 8 line backlit LCD. Three numeric screens available.

Graphing: Three graphing screens available with 1-3 graphs per screen.

Back Panel Connections:

Analog: 4 user-scalable 14 bit DACs, 600 Hz update frequency.

RS-232: 9600, 19200, 38400, 57600, 115200 baud, 8, N, 1. Supports XON/XOFF and trigger input.

USB: 2.0 compliant. PC must be running Windows® 2000 or XP to support USB connectivity.

Auxiliary Input Channels: 2, -2.5 to +2.5V. Common mode input voltage range ±2.5V.

Tubing Connections: Swagelok.

Power Requirements: 100-240 VAC, 50-60 Hz, or 10.5-16 VDC, 4 amp max.

Power Consumption: 15-40Watts DC (dependent on temperature and pump usage).

Temperature Range: 0-50 °C ambient, 0-55 °C bench.

Size: 5" H × 9.875" D × 14.5" L (12.7 × 25 × 36.8 cm).

Weight: 19.4 lbs. (8.8 kg).

CO₂ Analyzer Specifications

Range: 0-3000 μmol/mol.

Accuracy: 1% nominal.

A Specifications

Zero Drift (with temperature): $\pm 0.3 \mu\text{mol/mol}/^\circ\text{C}$.

Span Drift: $\pm 0.2\%$ of reading/ $^\circ\text{C}$.

Water Sensitivity: $< 0.1 \mu\text{mol/mol CO}_2/\text{mmol/mol H}_2\text{O}$ (Software algorithm corrects for band broadening effects).

Calibration: Factory linearization over 0-3000 $\mu\text{mol/mol}$ range using NIST-traceable standard gases.

Pressure Range: 0 to 115 kPa absolute.

Accuracy: 1% nominal. $\pm 0.1\%$ of full scale.

Display Resolution: 0.01 $\mu\text{mol/mol}$.

Signal Noise: See Table A-1.

H₂O Analyzer Specifications

Range: 0-60 mmol/mol. Optical bench and interconnecting hoses must be maintained above the dewpoint temperature by the user.

Accuracy: 1%.

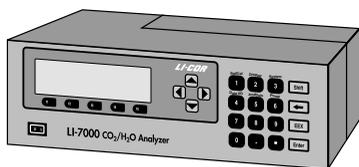
Zero Drift: $\pm 0.02 \text{ mmol/mol}/^\circ\text{C}$.

Span Drift: $\pm 0.4\%$ of reading/ $^\circ\text{C}$.

Signal Noise: See Table A-1.

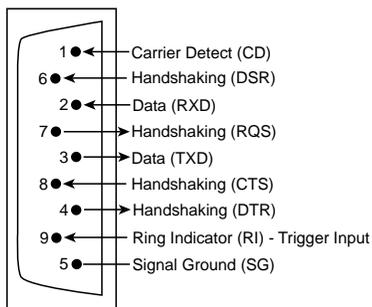
Table A-1. Noise Specifications.

Noise Specifications (Typical)					
		CO ₂ (370 $\mu\text{mol/mol}$)		H ₂ O (10 mmol/mol)	
Average Time (s)	Bandwidth (Hz)	RMS Noise (ppb)	Peak-to-Peak (ppb)	RMS Noise (ppm)	Peak-to-Peak (ppm)
20	0.025	6	39	0.4	3
1	0.5	25	173	2	12
0.5	1	35	245	2	17
0	20	157	1096	11	75



B Pin Assignments

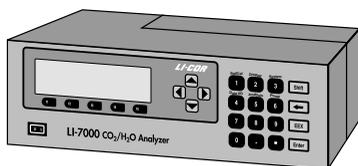
DB-9 Connector



The DB-9 connector is located on the LI-7000 back panel, and is used for RS-232 output. The diagram at left shows the pin-out connections on this connector; note that not all pins are used for communication between the LI-7000 and a computer. If you want to make a custom cable for use with the LI-7000, follow the diagram and the list in Table B-1 for the proper connections.

Table B-1. RS-232 Pin Description and Usage.

Pin Number	Pin Description	LI-7000 Usage	Wiring
1	Carrier Detect (CD)	Unused	Not wired
2	Receive Data (RXD)	Data	To TXD
3	Transmit Data (TXD)	Data	To RXD
4	Handshaking (DTR)	Always high	To DSR
5	Signal Ground (SG)	Ground	To ground
6	Handshaking (DSR)	Unused	To DTR
7	Handshaking (RQS)	Always high	To CTS
8	Handshaking (CTS)	Unused	To RQS
9	Ring Indicator (RI)	Trigger input	To host



C 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.

Chemical Sources

CO ₂ Scrubber	H ₂ O Scrubber
Ascarite II	Drierite
	Magnesium Perchlorate

Fisher Scientific www.fishersci.com 800-766-7000 770-871-4500	VWR Scientific Products www.vwrsp.com 800-932-5000 908-757-4045
Thomas Scientific www.thomassci.com 800-345-2100 856-467-2000	GFS Chemicals, Inc. www.gfschemicals.com 800-394-5501 740-881-5501
P.W. Perkins Co., Inc. www.pwperkins.com 856-769-3525	LI-COR Biosciences 4421 Superior Street Lincoln, NE 68504 USA 800-447-3576 402-467-3576 www.licor.com

Internal Chemical Bottle Kit

The internal scrubbing bottles on the LI-7000 gas analyzer can be purchased in a pre-charged kit that is ready to use. The bottles contain magnesium perchlorate and Ascarite II. The LI-7000 kit can be ordered under part number **7000-950**, and contains two large and two small bottles.

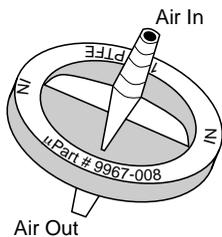
Gelman Filters

LI-COR Part #9967-008

Also available at:

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
www.fishersci.com



Warranty

Each LI-COR, inc. instrument is warranted by LI-COR, inc. to be free from defects in material and workmanship; however, LI-COR, inc.'s sole obligation under this warranty shall be to repair or replace any part of the instrument which LI-COR, inc.'s examination discloses to have been defective in material or workmanship without charge and only under the following conditions, which are:

1. The defects are called to the attention of LI-COR, inc. in Lincoln, Nebraska, in writing within one year after the shipping date of the instrument.
2. The instrument has not been maintained, repaired, or altered by anyone who was not approved by LI-COR, inc.
3. The instrument was used in the normal, proper, and ordinary manner and has not been abused, altered, misused, neglected, involved in an accident or damaged by act of God or other casualty.
4. The purchaser, whether it is a DISTRIBUTOR or direct customer of LI-COR or a DISTRIBUTOR'S customer, packs and ships or delivers the instrument to LI-COR, inc. at LI-COR inc.'s factory in Lincoln, Nebraska, U.S.A. within 30 days after LI-COR, inc. has received written notice of the defect. Unless other arrangements have been made in writing, transportation to LI-COR, inc. (by air unless otherwise authorized by LI-COR, inc.) is at customer expense.
5. No-charge repair parts may be sent at LI-COR, inc.'s sole discretion to the purchaser for installation by purchaser.
6. LI-COR, inc.'s liability is limited to repair or replace any part of the instrument without charge if LI-COR, inc.'s examination disclosed that part to have been defective in material or workmanship.

There are no warranties, express or implied, including but not limited to any implied warranty of merchantability or fitness for a particular purpose on underwater cables or on expendables such as batteries, lamps, thermocouples and calibrations.

Other than the obligation of LI-COR, inc. expressly set forth herein, LI-COR, inc. disclaims all warranties of merchantability or fitness for a particular purpose. The foregoing constitutes LI-COR, inc.'s sole obligation and liability with respect to damages resulting from the use or performance of the instrument and in no event shall LI-COR, inc. or its representatives be liable for damages beyond the price paid for the instrument, or for direct, incidental or consequential damages.

The laws of some locations may not allow the exclusion or limitation on implied warranties or on incidental or consequential damages, so the limitations herein may not apply directly. This warranty gives you specific legal rights, and you may already have other rights which vary from location to location. All warranties that apply, whether included by this contract or by law, are limited to the time period of this warranty which is a twelve-

month period commencing from the date the instrument is shipped to a user who is a customer or eighteen months from the date of shipment to LI-COR, inc.'s authorized distributor, whichever is earlier.

This warranty supersedes all warranties for products purchased prior to June 1, 1984, unless this warranty is later superseded.

DISTRIBUTOR or the DISTRIBUTOR'S customers may ship the instruments directly to LI-COR if they are unable to repair the instrument themselves even though the DISTRIBUTOR has been approved for making such repairs and has agreed with the customer to make such repairs as covered by this limited warranty.

Further information concerning this warranty may be obtained by writing or telephoning Warranty manager at LI-COR, inc.

IMPORTANT: Please return the User Registration Card enclosed with your shipment so that we have an accurate record of your address. Thank you.

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