LI-820

CO_2 GAS ANALYZER

Instruction Manual

LI-COR®

Biosciences

LI-820

CO_2 Analyzer

Instruction Manual

LI-COR®

Federal Communications Commission
Radio Frequency Interference Statement

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

LI-COR®
Biosciences

LI-COR, inc.
Environmental
4647 Superior Street
P.O. Box 4425
Lincoln, Nebraska 68504 USA

Phone: 402-467-3576
FAX: 402-467-2819
Toll-free: 1-800-447-3576 (U.S. & Canada)
E-mail: envsales@licor.com

Declaration of Conformity

Manufacturer's Name: LI-COR Inc.

Manufacturer's Address: 4647 Superior Street
Lincoln, Nebraska USA 68504

declares that the product

Product Name: Infrared Gas Analyzer

Model Number(s): LI-820

Product Options: None

conforms to the following Product Specifications:

FCC 47 CFR Part 15.109 Radiated Emissions, Class A
FCC 47 CFR Part 15.107 Conducted Emissions, Class A

EN 55011 : 1998 Radiated Emissions, Class A
EN 55011 : 1998 Conducted Emissions, Class A
IEC 61000-4-2 : 1995 ESD, 4KV/8KV Contact/Air
IEC 61000-4-3 : 1995 Radiated RF Immunity, 10V/m
IEC 61000-4-4 : 1995 EFT/Burst
IEC 61000-4-5 : 1995 Surge
IEC 61000-4-6 : 1996 Conducted RF Immunity
IEC 61000-4-8 : 1993 H-Field Immunity, 30A/m
IEC 61000-4-11 : 1994 Voltage Dips

Supplementary Information:

The product herewith complies with the requirements of the EMC Directive 2004/108/EC (formerly 89/336/EEC).

David L. Dilley

Dave Dilley
Director of Engineering

Document #53-06935-A
February 1, 2002

LI-820						
	Hazardous Substances or Elements					
Component Name	Lead (Pb)	Mercury (Hg)	Cadmium (Cd)	Chromium VI Compounds (Cr^{6+})	Polybrominated Biphenyls (PBB)	Polybrominated Diphenyl Ethers (PBDE)
Optical Bench Assembly	X	O	O	O	O	O
Source Block Assembly	X	O	O	O	O	O
Detector Block Assembly	X	O	O	O	O	O
Ribbon Cable Assembly	X	O	O	O	O	O
Serial Cable Assembly	X	O	O	O	O	O
LED Circuit Board Assembly	X	O	O	O	O	O
RS-232 Cable Kit	X	O	O	O	O	O
Main Board V2 Circuit Board Assembly	X	O	O	O	O	O
Red Cap Plug	O	O	X	O	O	O
O: this component does not contain this hazardous substance above the maxiumum concentration values in homogeneous materials specified in the SJ/T 11363-2006 Industry Standard.						
X: this component does contain this hazardous substance above the maxiumum concentration values in homogeneous materials specified in the SJ/T 11363-2006 Industry Standard (Company can explain the technical reasons for the "X")						

LI-820 CO_2 分析仪						
	有毒有害物质或元素					
部件名称	铅 (Pb)	汞 (Hg)	镉 (Cd)	六价铬 (Cr^{6+})	多溴联苯 (PBB)	多溴二苯醚 (PBDE)
光路系统组件	X	O	O	O	O	O
红外光源组件	X	O	O	O	O	O
红外光检测器组件	X	O	O	O	O	O
带状电缆组件	X	O	O	O	O	O
串行电缆组件	X	O	O	O	O	O
发光二极管电路板组件	X	O	O	O	O	O
串行 RS-232 电缆	X	O	O	O	O	O
主机板 V2 电路板组件	X	O	O	O	O	O
红色帽塞	O	O	X	O	O	O
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。)						

Doc. #63-09206
March 1, 2007

Publication Number 984-06557
2nd Printing October, 2006
3rd Printing October, 2007
4th Printing June, 2009

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

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

LI-COR, Inc. ● 4647 Superior Street ● Lincoln, Nebraska 68504
Phone: 402-467-3576 ● FAX: 402-467-2819
Toll-free: 1-800-447-3576 (U.S. & Canada)
e-mail: envsales@licor.com ● envsupport@licor.com ● www.licor.com

Table of Contents

Section 1. General Description

Section 2. Power On

Section 3. Operation

Section 4. Theory of Operation

Section 5. Maintenance

1 General Description

What's What

This procedure should be followed if you have just taken delivery of your LI-820. Check the packing list to verify that you have received everything that was ordered and that you have also received the following items:

- **RS-232 Cable** - (Part #392-04993), used to connect the LI-820 to your computer. This cable is a null modem (cross-over) type cable; a straight through type cable will ***not*** work with the LI-820. Appendix B shows the pin assignments for the DB-9 connector on the LI-820 front panel.

- **820-500 Data Communications Software -** This Windows® XP/Vista compatible software is used to communicate with your computer. The software is provided on CD. A complete description of this software can be found in Section 3, *Operation*.

- **Standard Spare Parts Kit (9980-012)** - This kit contains replacement parts for your LI-820. As you become familiar with the analyzer you will learn which items to keep close at hand and which items can be stored away. Some of the items in the spare parts kit include:

Description	Qty.	LI-COR Part No.
Polyurethane Mounting Feet	4	234-02268
Mounting Screws	4	149-02610
Terminal Block	1	331-05273
Bev-a-line Tubing	12'	222-01824
Balston Air Filter	2	300-01961
Quick Connect Unions	2	300-03123
Rapid Tube Fitting Nut	2	9861-036
2A Fuse	2	439-03952
Cleaning Kit, includes:	1	9980-013
5" Cleaning Swabs	5	610-05315
O-Rings	4	192-00226
Pre-formed Optical Bench Tubing	4	6580-010

Features

The LI-820 is an economical high performance, non-dispersive infrared gas analyzer designed to be used for a wide variety of applications. Some of the LI-820's important features include:

- The 14 cm (5.5") optical bench is used to measure CO_2 concentrations over a range of 0-20000 ppm.
- The optical bench is fully serviceable by the user; cleaning the optical bench is a simple process, and does not affect the instrument calibration.
- Simple Windows® software provides for easy user calibration and data output.

Precautions

- The optical bench is maintained at a constant 50 °C. Avoid direct exposure to sunlight or extremely high temperatures that may elevate the temperature inside the LI-820 case.
- The optical source is sensitive to vibration, and can be damaged by strong vibrations or jarring. Do not drop the LI-820, or expose it to severe mechanical shock.
- Do not use abrasive cleansers when cleaning the optical bench, as damage to the gold plating may result. Instructions for cleaning the optical bench can be found in Section 5.

- Always filter air entering the LI-820. Two Balston filters (p/n 300-01961) are included in the spares kit.

Getting Started Tutorial

The following section briefly covers the basic steps you might follow to set up the LI-820 to collect and record data. Many of these steps are described in greater detail throughout this manual.

1 Install the 820-500 PC Communications Software.

This software is used to set the zero and span of the LI-820 and to set up data communication and data transfer parameters. Installation instructions can be found in Section 3, *Installing the Software on Your Computer*.

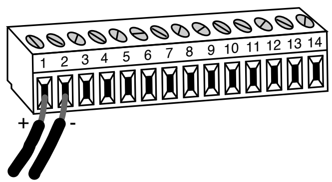
2 Determine your jumper settings for high and low alarm output, if required.

There are 2 jumpers inside the LI-820 case (on the main circuit board) which toggle the high and low alarm output between 0-5V (TTL levels) and an open drain condition (see Section 2, *Alarms*).

The default jumper positions are set for 0-5V output for both high and low alarms. This alarm configuration is suitable for logic devices such as dataloggers. To use the high and/or low alarms to operate a relay switch, the jumpers should be reconfigured for open drain output. See Section 2, *Alarms*, for a description of how to change the alarm jumper settings.

If the default jumper positions are suitable for your application, or if you do not intend to use the alarms, proceed to Step 3.

3 Connect a power source to the LI-820.



The LI-820 requires an input voltage of 12-30 VDC. The power supply must be able to source a maximum current drain of 1.2A (at 12 VDC). After the instrument has warmed up it will draw about 0.3A (at 12 VDC) with the heaters on. Bare wire leads are connected to the terminal strip at positions 1 and 2. Connect the positive lead to position #1 (12-30VDC), and the negative lead to position #2 (GND).

> **NOTE:** Pull straight out on the terminal strip to remove it; this can make it easier to connect the wires.

4 Connect the RS-232 cable.

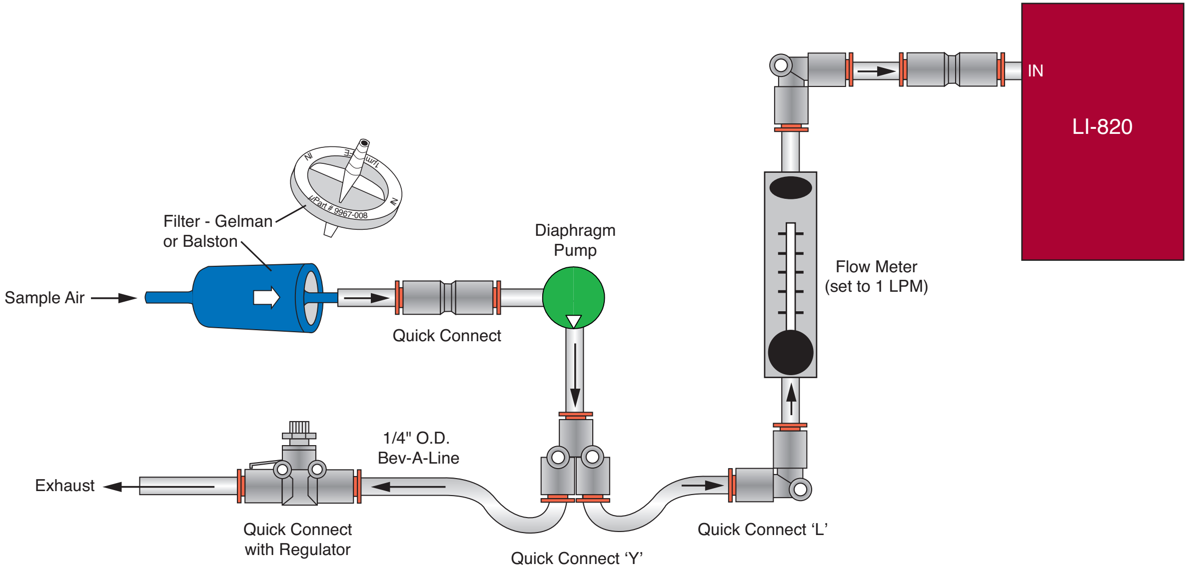
Connect one end of the serial cable to the 9-pin Serial I/O port on the LI-820 front panel, and the other end to a serial port on your computer. If you want to interface to a device with a 25-pin serial port, a 9-pin to 25-pin adapter must be used; a gender changer may also be required in some cases. Tighten the two screws on the ends of the serial cable. If your computer does not have a serial port, you can use the 6400-27 Serial-to-USB Adapter included to connect the serial cable to a USB port on your computer. The Adapter *does not* convert the RS-232 serial connection into a USB connection. It simply allows the USB port to receive data via a standard RS-232 serial connection.

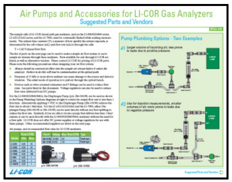
5 Connect other output device(s) if desired.

Output devices such as dataloggers and relay switches for high and low alarms are connected via the terminal strip. A complete description of the terminals can be found in Section 3, *Using the Terminal Strip*.

6 Connect an air pump and external power source.

The LI-820 sample cell must be continually flushed while making measurements, which requires an external air pump that supplies a flow rate of between 0.25 and 1.0 liters per minute. LI-COR offers a Diaphragm Pump under part number 286-04198 that is suitable for use with the LI-820. One pump plumbing option is shown below.




Air Pumps and Accessories for LI-COR Gas Analyzers
Suggested Parts and Vendors

NOTE: More information about plumbing options and parts available from LI-COR can be found in Application Note #IRG4-105, entitled 'Air Pumps and Accessories for LI-COR Gas Analyzers - Suggested Parts and Vendors', which can be downloaded at:

http://envsupport.licor.com/docs/Air_Flow_Kit_IRG4105.pdf

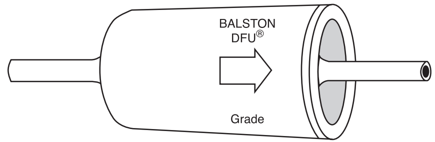
7 Hook up the input air stream and external filter.

Remove the nut from the **FLOW IN** fitting and connect a short (12" or so) piece of Bev-a-line tubing (in the spares kit). Tighten the nut. Place a Balston filter (also in the spares kit) in the sample airstream before it enters the **FLOW IN** port on the LI-820.

> IMPORTANT: ***Always install the external air filter before operating the LI-820.*** **Insert filter into the input airstream before it enters the LI-820.** ***Failure to do this will lead to contamination of the optical path.***

There are some quick connect fittings in the spare parts kit that can be used on either side of the Balston filter to aid in changing the filter out. Press on the red part of the fitting to release the tubing.

When using the LI-820 for applications where sample air is particularly dirty, you may consider stacking two filters in series. For maintenance, replace the filter furthest upstream from the analyzer with the filter closest to the analyzer and replace the filter closest to the analyzer with a new filter.



Note that the maximum flow rate through the LI-820 is approximately 1 liter/minute.

*Figure 1-1. Install the new filter(s) with the arrow facing the **FLOW IN** port.*

The air inlet and outlet ports should be covered with the dust caps provided or attached to an air line when the instrument is not in use. This will prevent dust from entering the instrument downstream from the filters where it can enter the optical path. Replacement Balston filters can be obtained from LI-COR (part #300-01961).

8 Start the 820-500 PC Communications Software.

Click on the program icon to start the 820-500 program. The 820-500 Main window appears. Select **Connect** from the File menu. Choose the serial port to which the LI-820 is connected, and the data output interval. Select the COM port and the data output interval, if desired, and click the **Connect** button. If the analyzer is connected properly, data will appear in the main window.

9 Configure the analyzer.

Select **Settings** from the View menu. The Settings window appears. Choose a value for signal averaging (the Filter field), between 0 and 20 seconds. Set values for high and low alarms and corresponding dead bands, if desired. See Section 2 for a complete description of the alarms. If you are using an output device to collect data, choose the value to be output at DAC 1 and/or DAC 2. Make sure the Heater and Pressure Compensation buttons are enabled (checked), and click **OK**.

10 Set the analyzer zero.

Connect a dry, CO_2-free gas to the input air stream. Select **Calibration** from the View menu. Click on **Zero**. After about a minute, a message will appear that indicates the IRGA is zeroed.

11 Set the analyzer span.

Connect your span gas to the input air stream. Enter the value of the span gas. Click on **Span**. After a few minutes, a message will appear indicating the span calibration is completed. Click **Close**.

12 Set up the logging parameters.

Select **Options** from the Logging menu. Choose the File Headings to be output with the data, the values to be logged, the field delimiter, and log frequency. Click **OK**. Choose **Start** from the Logging menu. Enter a file name for the data file. Click **Save**.

13 Set up the charting parameters, if desired.

Select **Charting** from the View menu. Enter the Y-Axis min and max values, X-Axis max, and time units to be displayed on the plot. Click **Start** to begin recording data. A graph with data will appear in the window and data will be logged to the file designated in Step 12 above.

14 Choose *Stop* from the Logging menu to close the data file and stop recording when you are done collecting data.

2 Power On

Power On

The LI-820 can be connected to a constant source of AC power using a transformer that provides 12-30VDC (12W minimum) to the LI-820. If the LI-820 is powered On with a battery below 10.5 volts, the analyzer will not power up, and the Low Battery LED on the top panel will illuminate.

Low Battery Indicator

The low battery LED on the LI-820 top panel will illuminate when the battery voltage drops below 10.5 volts. The LI-820 will continue to operate with a low battery; there will, however, be a corresponding reduction in performance.

Alarms

The LI-820 is equipped with high and low alarms, which can be configured as open drain (open collector) or 0-5V output (TTL levels) using jumpers on the main PC board (Figure 2-1). Figure 2-2 shows the position of the jumpers for each of the two alarm conditions.

TTL stands for Transistor-transistor logic, which commonly refers to a signal level where the "on" voltage is near +5 volts. This is the default alarm jumper position in the LI-820, whereby whenever a high or low alarm is triggered, the LI-820 outputs a +5V signal.

The LI-820 alarms can also be configured as open drain (open collector), which is a circuit technique that allows multiple devices to communicate bi-directionally on a single wire.

Open drain/open collector devices sink (flow) current in their low voltage active (logic 0) state, or are high impedance (no current flows) in their high voltage non-active (logic 1) state. These devices usually operate with an external pull-up resistor that holds the signal line high until a device on the wire sinks enough current to pull the line low. Multiple devices can be attached to the signal wire. If all devices attached to the wire are in their non-active state, the pull-up will hold the wire at a high voltage. If one or more devices are in the active state, the signal wire voltage will be low.

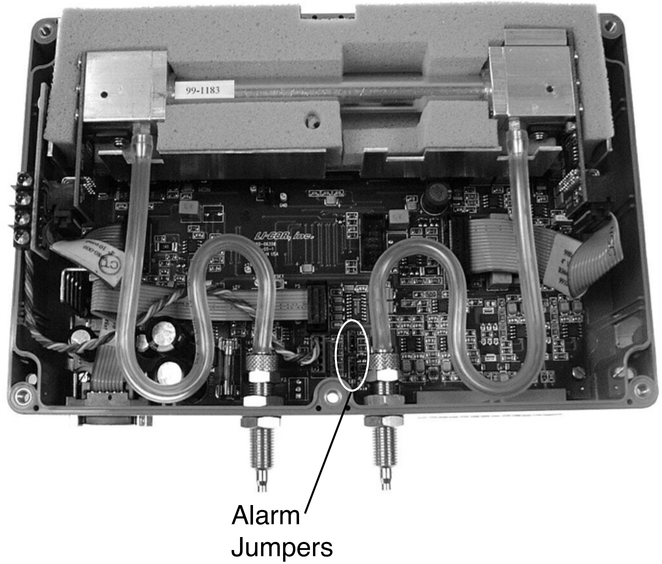


Figure 2-1. Location of alarm jumpers LK1 and LK2.

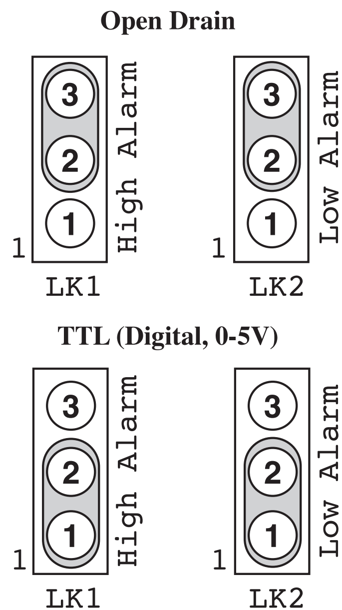
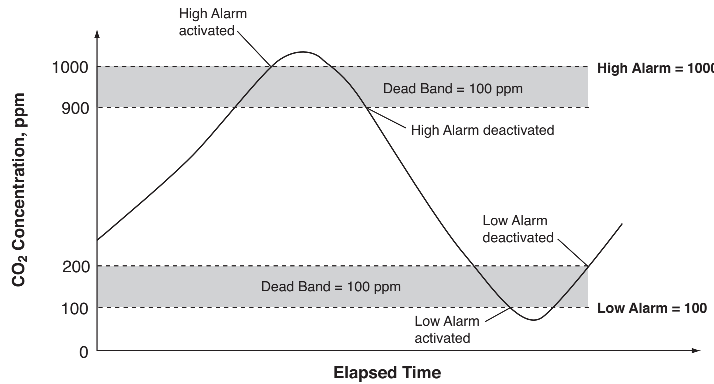


Figure 2-2. Position of jumpers for open drain and TTL (0-5V) output.

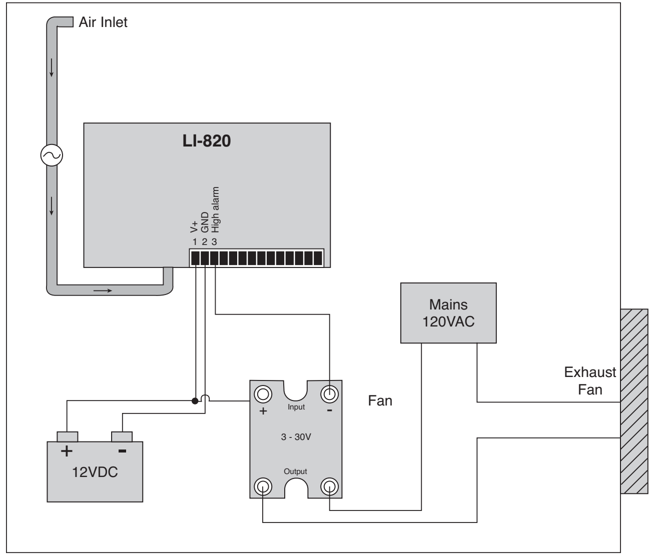
In addition, a "dead band" value can be set in software for both high and low alarms. To understand how the alarms and dead band values work, look at the diagram below.



In this chart, the low and high alarm values are set to 100 ppm and 1000 ppm, respectively. The dead band value in both alarms is set to 100 ppm. When the CO_2 concentration reaches 1000 ppm, the high alarm is activated, and remains active until the concentration drops below 900 ppm. When the CO_2 concentration falls below 100 ppm, the low alarm is activated, and remains active until the concentration rises above 200 ppm. Your choice for the dead band value(s) depends on your application, and the fluctuation in CO_2 concentrations over time.

Note: Increasing the signal average value in software (see *Settings Window; Options; Filter* in Section 3) can help reduce fluctuations in readings.

Alarm LEDs can be viewed on the top panel of the LI-820. Terminals 3 and 5 on the terminal strip are connected to the High and Low alarms, respectively. This is useful in cases where you want to connect an audible alarm, for example, or a relay switch to operate another device that will raise or lower the CO_2 concentration to the desired level. The schematic diagram below shows how the high alarm could be connected to a relay switch that triggers an exhaust fan in a greenhouse environment. These relays could also be used to trigger devices such as automatic dialers, alarms, pumps, and valves in industrial and other environments.



A list of suppliers of electronic relay switches can be found in Appendix C.

> **NOTE:** Consult your local electrical codes before wiring, and/or have a professional electrician wire your application.

3 Operation

Installing the PC Communications Software on Your Computer

The 820-500 software is shipped on CD. It requires that your computer have a USB or RS-232 serial (COM) interface, and Windows® XP/Vista.

An installation menu starts when you insert the CD into your CD-ROM drive. Select *Install Software* from the menu and follow the instructions. If installation does not start, select **Run** from the Windows *Start* menu, and select the `Setup.exe` file on the CD. When the software has finished the installation procedure, a 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 LI820 from the list of programs and click the Add/Remove button.

Setting the Communication Parameters

LI-820 communication parameters are set automatically when the program is run.

Cabling

The serial cable included has 9-pin connectors on both ends; either end plugs into the 9-pin connector (Serial I/O) on the front panel of the LI-820. Use this cable to interface with your computer's 9-pin serial port. If you want to interface to a computer with a 25-pin serial port, a 9-pin to 25-pin adapter must be used.

Using the RS-232-to-USB Adapter

A Serial-to-USB Adapter (p/n 6400-27) is included to facilitate data transfer between the LI-820 and computers lacking an RS-232 connector. Note that this **does not** convert the RS-232 serial connection into a USB connection. It simply allows the USB port to receive data via a standard RS-232 serial connection. Complete instructions for using the adapter are included with the 6400-27.

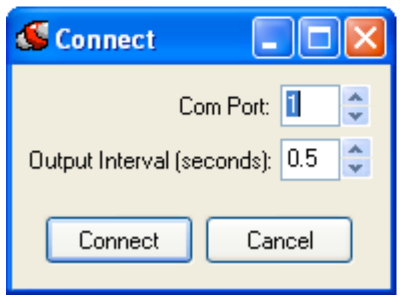
RS-232 Output

Data from the LI-820 can be transferred to a computer for analysis, printing or storage using the RS-232 interface. The LI-820 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-820.

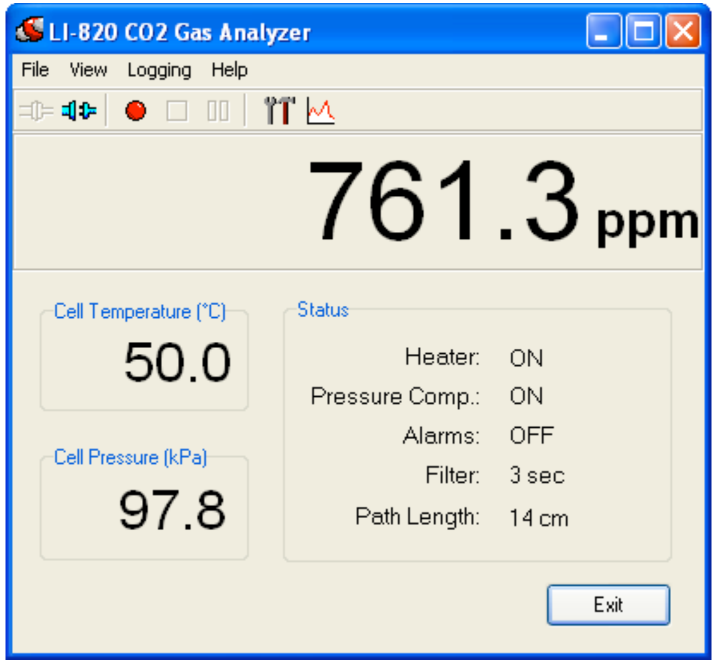
The 820-500 PC Communication Software that comes with the LI-820 is used to transfer data and setup files between the analyzer and the PC.

Initial Setup

Click on the LI-820 program icon to start the program. The LI-820 Main Window appears. Select **Connect** from the File menu. You are asked to select the serial port to which the LI-820 is connected, and the output interval at which data are output (0.5 to 20 seconds, in 0.5 second increments).



Choose a port and the output interval and click **Connect**. If the instrument is connected properly, data will begin to appear in the window:


LI-820 CO2 Gas Analyzer
File
View
Logging
Help
761.3 ppm
Cell Temperature (°C)
50.0
Cell Pressure (kPa)
97.8
Status
Heater: ON
Pressure Comp.: ON
Alarms: OFF
Filter: 3 sec
Path Length: 14 cm
Exit

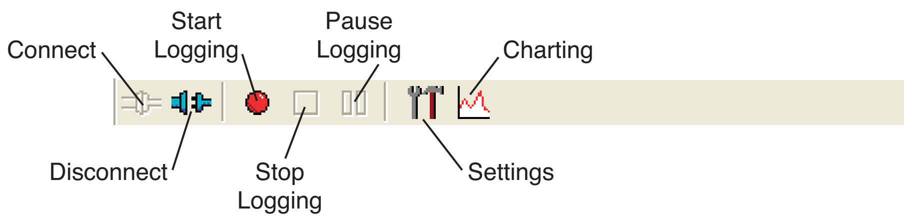
The Main window displays the CO_2 concentration (ppm), as well as the status of various LI-820 parameters. There are also three menus used to configure the LI-820, perform zero and span calibrations, and set up the parameters for recording data. The LI-820 parameters in this window are as follows:

Parameter	Description
Cell Temperature	Temperature (°C) in the LI-820 optical cell. This value should remain near 50 °C when the heater is turned ON.
Cell Pressure	Barometric pressure (kPa) measured in the LI-820 optical cell. This value can be used to correct CO_2 measurements for the effects of pressure fluctuations on gas density.
Heater	Shows status of heater (ON/OFF), which is used to maintain the optical cell at a constant 50 °C. The heater is turned ON/OFF in the Settings window.
Pressure Comp.	Shows whether pressure compensation is ON/OFF. When ON, CO_2 measurements are corrected for the effects of pressure fluctuations on gas density.
Alarms	Shows status of High and Low alarms, whose values are set in the Settings window. Alarms are enabled (ON), or disabled (OFF).

Parameter	Description
Filter	Shows the current value for software signal averaging, set in the Settings window. The filter can be set from 0 (no signal averaging) to 20 seconds.
Path Length	Shows the size of the optical bench installed in the LI-820, either 5.5 inches (14 cm), or 2 inches (5 cm). The 2 inch bench is no longer available, but may be present in older instruments.

Using the Toolbar

The toolbar in the Main window contains shortcuts for some of the commonly used menu items:



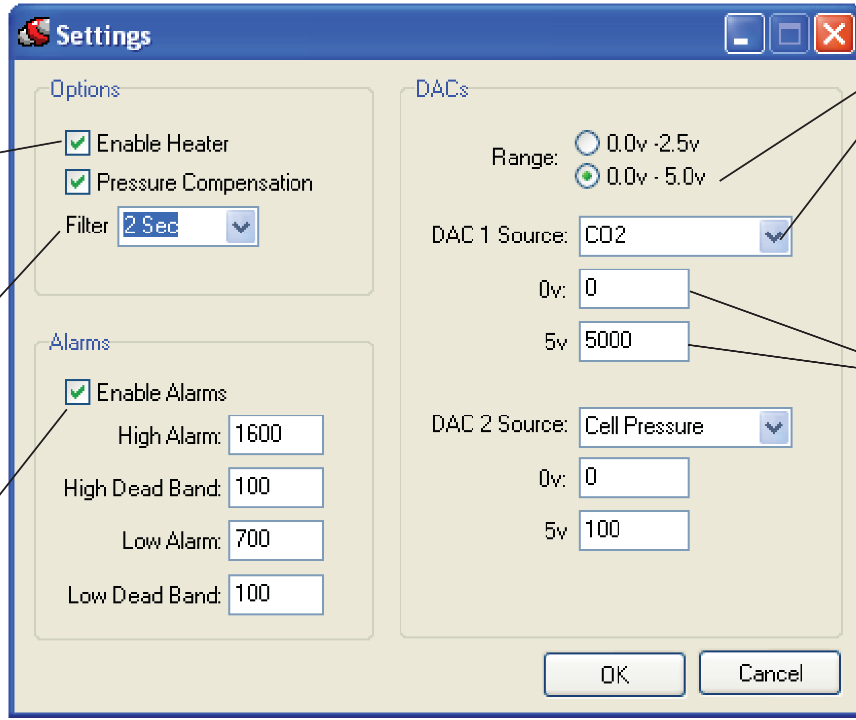
Settings Window - Setting Operational Parameters

The Settings window contains parameters related to initial setup of the LI-820, including signal filtering, high and low alarm setup, heater and pressure compensation options, and DAC output sources. Choose **Settings** from the View menu (or click on the toolbar icon) to open the Settings window:

The heater should be enabled to maintain the optical bench at a constant 50 °C. Pressure compensation is an optional parameter.

Software signal filtering is available from 0-20 seconds.

Disable the alarms here, or set high and low alarm values, and high and low dead band values.



DAC output range. Choose source to be output to DAC 1 (terminal strip connector #9), and/or DAC 2 (terminal strip connector #7).

0V and 5V scaling values. In this example, the CO_2 output will be scaled from 0-5000 ppm, over a range of 0-5V.

Options

Enable Heater

The Heater should be enabled to maintain the optical bench at a constant 50 °C.

Pressure Compensation

Enable the Pressure Compensation check box to automatically correct gas concentration values for changes in cell pressure. In most cases this should be turned on; disabling this feature means that no pressure correction is desired in the gas concentration calculations, which can lead to erroneous measurements.

Filter

Shows the current value for software signal averaging. The filter can be set from 0 (no signal averaging) to 20 seconds.

Alarms

Allows you to enable/disable the alarms, and enter high, low, and dead band values. A complete discussion can be found in *Section 2, Alarms*.

DACs

Analyzer output for up to 2 values (CO_2, Cell Temperature, or Cell Pressure) can be recorded by connecting a logging device to the terminal strip on the front of the analyzer. Output is linear, and is selectable at 0-5V or 0-2.5V. Choose the full scale voltage output range and the source for DAC 1 and/or DAC 2. Available output sources are CO_2, Cell Temperature, and

Cell Pressure. You can also choose a range over which to scale the output(s); you can achieve better resolution by scaling the output(s) over a narrower range, when appropriate.

The DACs in the LI-820 are bipolar, and will go slightly negative (~-0.100V). This can happen, for example, if the cell becomes contaminated or just from small random perturbations when the CO_2 concentration is near zero. See Section 5, *Cleaning the Optical Bench* for instructions on cleaning the cell should it become contaminated.

Voltage output is measured by attaching the positive lead from the logging device to terminal 9 (V Out 1), or terminal 7 (V Out 2) on the LI-820 terminal strip. Connect the negative lead to position 10, (GND), or position 8.

The CO_2 concentration can be calculated from the DAC output voltage as follows:

$$CO_2 = (X_F - X_Z)\frac{V}{V_{\max}} + X_Z \qquad \text{3-1}$$

where V is the measured voltage, X_F is the full scale value for CO_2 output (entered in the Settings Window as the 2.5 or 5V value, up to 20,000 ppm), X_Z is the zero value entered, and V_{max} is the full scale DAC output voltage selected (5V or 2.5V).

Example: The DAC output range selected is 0-5V (V_{max}), the zero CO_2 value entered is 0 ppm (X_Z), the full scale CO_2 value entered is 2000 ppm (X_F), and the measured output voltage (V) is 2.9V. To calculate the CO_2 concentration from Equation 3-1 above,

$$CO_2 = (2000)\frac{2.9}{5} + 0 \tag{3-2}$$

= **1160 ppm**.

Example 2: The DAC output range selected is 0-5V (V_{max}), the zero CO_2 value entered is 1000 ppm (X_Z), the full scale CO_2 value entered is 2000 ppm (X_F), and the measured output voltage (V) is 2.9V. To calculate the CO_2 concentration from Equation 3-1 above,

$$CO_2 = (2000 - 1000)\frac{2.9}{5} + 1000 \tag{3-3}$$

= **1580 ppm**.

Converting Voltage Output to Cell Temperature

Cell temperature can be calculated from the DAC output voltage as follows:

$$T(°C) = \left(X_F - X_z\right)\frac{V}{V_{\max}} + X_z \tag{3-4}$$

where V is the measured voltage, X_F is the full scale value for temperature output (entered in the Settings Window as the 2.5 or 5V value, up to 100 °C), X_Z is the zero value entered, and V_{max} is the full scale DAC output voltage selected (5V or 2.5V).

Converting Voltage Output to Cell Pressure

Cell pressure can be calculated from the DAC output voltage as follows:

$$\text{Pressure}\ (kPa) = \left(X_F - X_z\right)\frac{V}{V_{\max}} + X_z \qquad \text{3-5}$$

where V is the measured voltage, X_F is the full scale value for cell pressure output (entered in the Settings Window as the 2.5 or 5V value, up to 115 kPa), X_Z is the zero value entered, and V_{max} is the full scale DAC output voltage selected (5V or 2.5V).

Converting Current Output to ppm CO_2

Current output can be measured by connecting the positive input of the data logging device to positions 11 or 13 (4-20 mA 1 or 4-20 mA 2), and the negative input to position 12 or 14 (GND). The current output at positions 11 and 13 is non-isolated, and is rated to drive a 250 ohm load.

> Note that these channels mirror their respective voltage output channels; current output channel 1 uses the variable chosen for voltage output 1, and current output channel 2 uses the variable chosen for voltage output 2. Similarly, a voltage output of 0 volts corresponds to a current output of 4 mA, and when the voltage outputs are at full scale (2.5 or 5 V), the current output will be 20 mA.

To convert current output (I) to units of ppm CO_2 in your computer or other output device, the following equation can be used:

$$CO_2 = (X_F - X_Z)\left(\frac{I-4}{16}\right) + X_Z \qquad \text{3-6}$$

where I is the measured current, X_F is the full scale value for CO_2 output (entered in the Settings Window as the 2.5 or 5V full scale value, up to 20,000 ppm), and X_Z is the zero value entered.

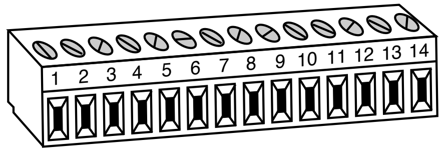
Example: The zero CO_2 value entered is 0 ppm (X_Z), the full scale CO_2 value entered is 2000 ppm (X_F), and the measured current output (I) is 16.25 mA. To convert to ppm CO_2:

$$CO_2 = (2000)\left(\frac{16.25-4}{16}\right) + 0 \qquad \text{3-7}$$

= **1531.25 ppm**.

Using the Terminal Strip

The terminal strip is located on the front panel of the LI-820. To connect the wires, insert the bare wire end into the appropriate terminal and tighten the screw above that terminal using the small flat head screwdriver in the spare parts kit. The terminal strip can be removed to aid in connecting the wires by pulling straight out on the face.

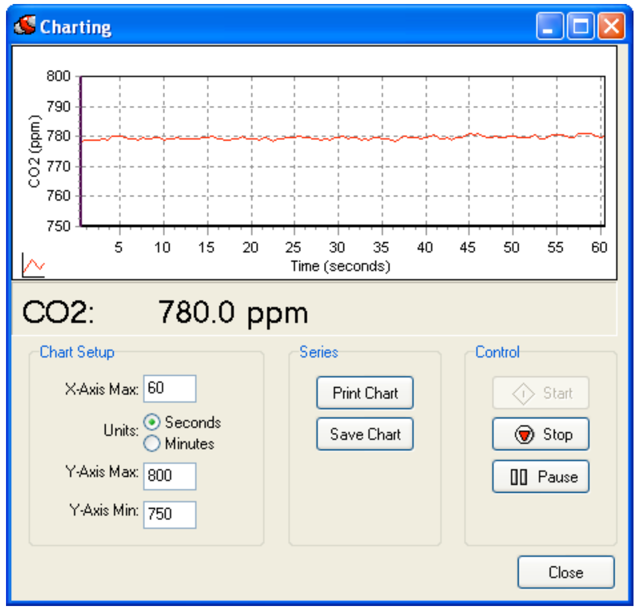


The terminal positions are as follows, reading left to right:

Terminal	Label	Description
1	12-30 VDC	Voltage In, 12-30 VDC
2	GND	Ground
3	High Alarm	High Alarm
4	GND	Ground
5	Low Alarm	Low Alarm
6	GND	Ground
7	V OUT 2	Voltage output channel 2
8	GND	Ground
9	V OUT 1	Voltage output channel 1
10	GND	Ground
11	4-20 mA 2	Current output channel 2
12	GND	Ground
13	4-20 mA 1	Current output channel 1
14	GND	Ground

Charting Window

Select **Charting** from the View menu to open the Charting window (below). This is the window in which you can set up the parameters for plotting your data.



X-Axis Max

Sets the maximum value for the X axis (Time). The units for the X axis can be seconds or minutes.

Y-Axis Max/Min

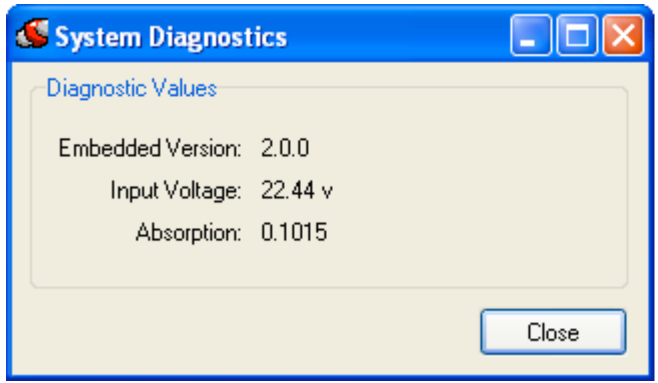
Sets the maximum and minimum values for the Y axis (CO_2).

Press **Print Chart** to send the current chart to your printer. Press **Save Chart** to save the chart as a bitmap (.bmp) file.

Press **Start** at any time to view the chart layout and begin displaying data. Note that you must press **Stop** to make changes to the chart parameters, and then press **Start** again to resume data display.

Diagnostics Window

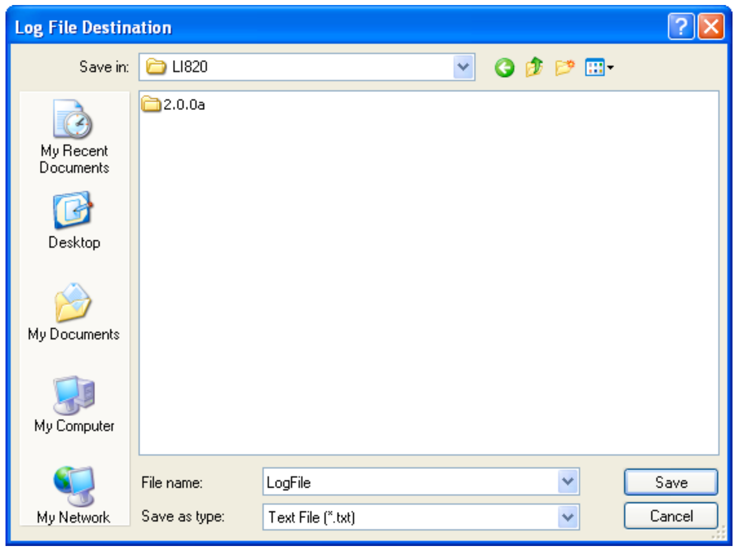
Select **Diagnostics** from the View menu to open the Diagnostics window (below). This window displays the current LI-820 internal software version number, the input voltage, and raw absorption value.



Logging Data

Start Logging

Opens the Log File Destination dialog, where you enter a file name for the data file. The file extension .txt is added automatically.



Stop Logging

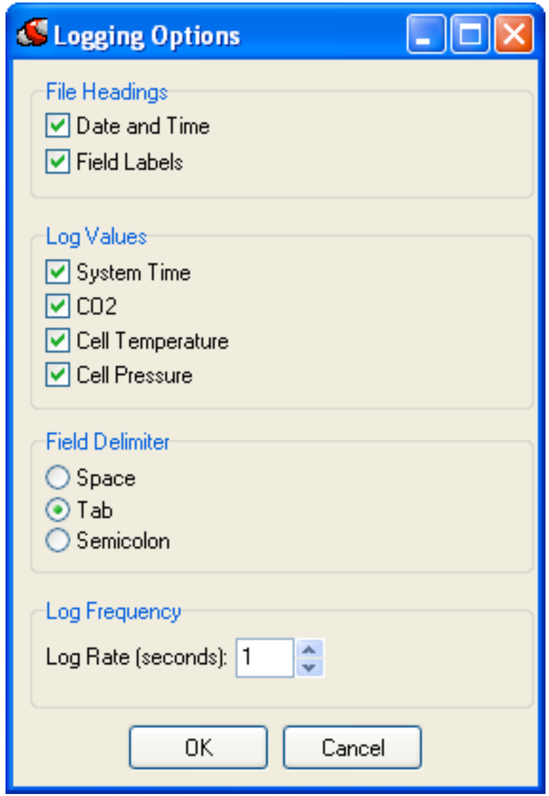
Stops data logging.

Pause Logging

Pauses logging of data until **Start** is chosen from the Logging menu again, or the Start button on the toolbar is pressed.

Options

Opens the Logging Options window, where you can configure the data output options.


Logging Options
File Headings
Date and Time
Field Labels
Log Values
System Time
CO2
Cell Temperature
Cell Pressure
Field Delimiter
Space
Tab
Semicolon
Log Frequency
Log Rate (seconds):
1
OK
Cancel

As configured above, the data output would appear similar to that shown below.

File Headings

```
"2001-12-19 at 14:41"
Time(H:M:S) CO2(ppm) CellTemp(c) CellPres(kPa)
```

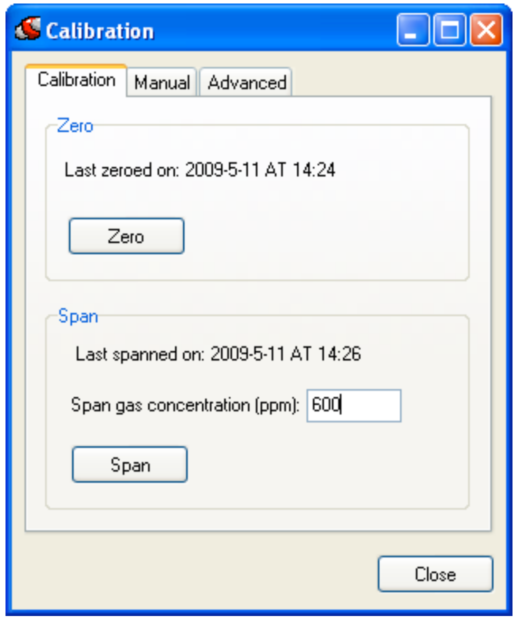
Log Values

```
14:41:45 502.71 51.65 97.62
14:41:46 502.60 51.65 97.62
14:41:47 502.39 51.65 97.62
14:41:48 502.48 51.65 97.62
14:41:49 502.68 51.65 97.62
14:41:50 502.57 51.65 97.62
14:41:51 502.79 51.65 97.62
14:41:52 502.92 51.65 97.62
14:41:53 503.00 51.65 97.62
14:41:54 502.88 51.65 97.62
```

System Time (1s log rate)	CO_2	Cell Temp.	Cell Pres.

Calibration Window - Setting the Zero and Span

Select **Calibration** from the View menu to open the Calibration window. This is the area in which you set the zero and span of the LI-820.



The calibration window shows the date and time at which the LI-820 was last zeroed and/or spanned. When spanning the instrument, you can enter the value of your span gas in the “Span gas concentration (ppm)” field. The Manual and Advanced tabs offer additional calibration options, discussed below under Two Point Span.

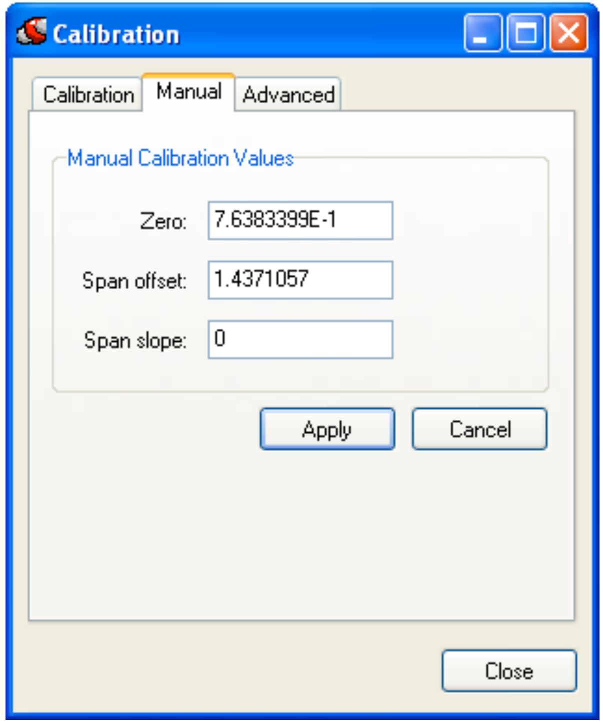
It is recommended that you perform the zero calibration first, followed by the span calibration. To zero, flow a dry, CO_2-free gas through the LI-820, and make sure the optical cell is completely purged. Press the **Zero** button. The display will show ZERO, and the text in the Calibration window is greyed out. The zero will be set electronically, and the current date will be entered in the "Last zeroed on" field when completed.

To span, connect your span gas to the input air stream. Make sure the cell is purged, enter the value of the span gas, and click on **Span**.

The display will show SPAN, and the text in the Calibration window is greyed out. The span will be set electronically, and the current date will be entered in the "Last spanned on" field when completed.

Advanced Calibration (Manual Tab)

The Manual tab in the Calibration window displays current calibration values for Zero, Span Offset, and Span Slope. The zero value is the parameter that is set when you zero the instrument. This value is typically between 0.8 and 1.2, and reflects the ratio of the two detectors’ output when there is CO_2-free air in the cell.

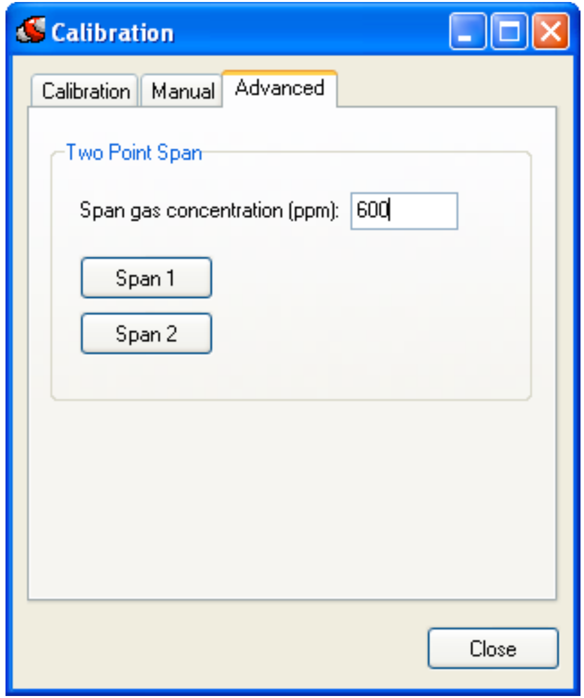

Calibration
Calibration
Manual
Advanced
Manual Calibration Values
Zero:
7.6383399E-1
Span offset:
1.4371057
Span slope:
0
Apply
Cancel
Close

The span offset is the parameter that is set when you span the instrument. The span offset value is usually close to 1.0. The actual span is a linear function of absorptance, so the span offset is the intercept term of that relationship, and the span slope is the slope of the relationship.

If your LI-820 is exhibiting erratic behavior such as no response to CO_2, or erratic readings, check the span offset and span slope values. As an example, if the span is inadvertently set at the wrong time (with CO_2-free air in the cell, for example), the span offset term can be near zero, or very large (10, 1000, etc.), in which case the instrument will not function correctly. The editable fields under the Manual tab allow you to manually set the two values to correct this. Set the Span offset value to 1.0, and the Span slope to zero and click **Apply** to return the instrument to a more “normal” state of operation. You should then perform a zero and span (or two point span) of the instrument.

Two Point Span (Advanced Tab)

The two point span function under the Advanced tab is used to set the span slope value using two non-zero gases. This is performed at the factory, and only needs to be repeated if the source and/or detector are replaced. To test the span slope after replacing the source and/or detector, zero the instrument, and then measure one of your two known gases, using it to set the span, if necessary. Measure your second known gas; if the reading exceeds the specification, you can use the two point span function to correct the span slope and bring the instrument back within factory specification.

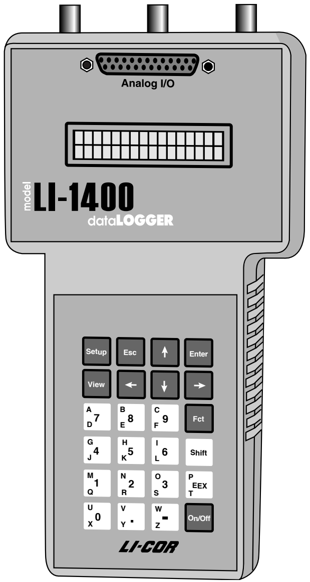


The two point span function sets the span zero and span slope parameters. The two gas concentrations used to do this should be fairly well separated. One gas concentration should be fairly low – 600 ppm or less. The second gas concentration should be fairly high, and ideally, close to the upper range of concentration that you are interested in (e.g. 1500, 3000, 10000, etc.). If you are interested in a narrow range of concentrations, such as 300 to 500 ppm, then we do not recommend using 300 and 500 for a two point span; simply use one or the other for a single span. Some suggested gas concentration pairs for various ranges of interest are shown below; these are not absolute limits, but simply recommendations.

Upper Range (μmol/mol)	Suggested Two Point Concentrations (μmol/mol)
2000	<400, >1500
5000	<600, >2000
>20,000	<600, >5000

To perform the two point span, first make sure the instrument is well zeroed. Flow the first span gas (either high or low, the order doesn't matter) through the cell, and enter the mole fraction in the "Span gas concentration" field. When the instrument's reading stabilizes, click the Span 1 button, After about 30 seconds the instrument should be reading the specified concentration. The span slope will be zero, and the span offset will reflect the span result. Repeat for the second gas concentration, clicking the Span 2 button. After about 30 seconds, the span slope value will change, as will the span offset, but only slightly. At this point, the instrument should read either of the two span values correctly.

Connecting the LI-820 to the LI-1400 Datalogger



The following example shows how you can connect the LI-820 to a datalogging device such as the LI-COR Model LI-1400 DataLogger to collect analog data and convert to meaningful CO_2 values. The CO_2 concentration is calculated from the DAC output voltage as follows:

$$CO_2 = (X_F - X_Z)\frac{V}{V_{\max}} + X_Z \qquad 3\text{-}8$$

where V is the measured voltage, X_F is the full scale value for CO_2 output (entered in the Settings Window as the 2.5 or 5V full scale value, up to 20,000 ppm), X_Z is the zero value entered, and V_{max} is the full scale DAC output voltage selected (5V or 2.5V).

For example, if the voltage range selected is 0-5V (V_{max}), the zero CO_2 value entered is 0 ppm (X_Z), the full scale CO_2 value entered is 2000 ppm (X_F), and the measured output voltage (V) is 2.9V, the equation would take the form

$$CO_2 = (2000)\frac{2.9}{5} + 0 \qquad 3\text{-}9$$

= 1160 ppm.

This general equation can be converted into simple multipliers, based on the two available voltage output ranges, and the CO_2 range (maximum 20,000, but can be any value, depending on what is chosen for the 0V and full scale 2.5V or 5V DAC output values). This multiplier can then be entered in the data logging device to convert raw voltage to CO_2 values. Table 3-1 lists some examples of values for this multiplier; simply choose the DAC output range in the second row, and then select the LI-820 CO_2 range in the first column (the full scale value minus the zero value); follow across to find the appropriate multiplier. Note that this table assumes that the zero value (X_Z) is zero; if it is not zero, the offset will need to be added onto the final result.

Table 3-1. Multipliers for Converting Voltage Output to CO_2 Readings (no offset)

	DAC Output Range	
	0-5V	0-2.5V
X_F - X_Z	**Multiplier (ppm/volt)**	
1000 ppm	200	400
2000 ppm	400	800
5000 ppm	1000	2000
20000 ppm	4000	8000

The LI-1400 can be used to monitor voltage signals up to 2.5 volts with 76 microvolt resolution 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 dump the results to a computer for further analysis.

Access to the voltage channels requires the 1400-301 Terminal block. Voltage channels are designated by the letter “V” and sequentially numbered V1-4. The lead from LI-820 terminal #7 or #9 should be attached to one of the LI-1400 terminals labeled V1, V2, V3, or V4, while the lead from terminal #8 or #10 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-820 and convert to CO_2 values.

1. Set the voltage output of the LI-820 for 2.5V output as described in Section 3, *Analog Output*.

2. In the LI-1400, configure V1 channel as *General* for CO_2.

3. Enter a description, such as *CO2*.

4. Set Math = *Poly(nomial)* and press *Ent(er)*.

5. Set description as desired, *a1 = multiplier from Table 3-2 above, a0, a2-a5 = 0*. When finished, press *Esc* to return to the main configuration list.

6. Set *Oper(ator) = none*.
7. Enter a *Label* such as *ppm* for the units.
8. Set *Average=1 sec* or as desired. CO_2 will now be displayed on channel V1.

   To log CO_2 automatically, follow the remaining steps:
9. Set *Log Routine* to the desired log routine.
10. Set *Calc=Mean*.
11. To capture the minimum and maximum CO_2 values, set *MinMax* accordingly.
12. *TCoef* has no effect when *Calc=Mean*. It is used only when integrating.

4 Theory of Operation

System Overview

The LI-820 CO_2 Gas Analyzer is an absolute, non-dispersive, infrared (NDIR) gas analyzer based upon a single path, dual wavelength, infrared detection system. The CO_2 measurement is a function of the absorption of IR energy as it travels through the optical path. Concentration measurements are based on the difference ratio in the IR absorption between a reference and sample signal. Reference and sample channels measure CO_2 in a single path through the use of narrow band optical filters with appropriately selected bands. The CO_2 sample channel uses an optical filter centered at 4.24 micrometers. This filter corresponds to the absorption band for CO_2. Concentrations of CO_2 present in the optical path will result in a reduction in IR energy as it traverses the optical path. The reference channel is established using a filter with a center wavelength at 3.95 micrometers. It follows that the out-of-band channel will experience no absorption due to CO_2 and thus serves as a reference since the detector receives the full energy of the source.

The instrument uses digital signal processing techniques to determine the temperature and pressure corrected CO_2 concentration based on the optical bench signals through the use of a ratio technique. The data are passed through a calibration function that performs linearization of the detector signal to a mole fraction mixing ratio of CO_2 in air given in μmol CO_2 per mole of air, or ppm (see *Computing CO_2 Mole Fraction below*).

Data output is provided in a digital format through an RS-232 interface that supports connection to an external computer. The instrument comes with a Windows® XP/Vista compatible application for instrument configuration, control, data collection and display. Analog signals are available through a terminal block for collection by a data logger or similar means.

Optical Bench System

The LI-820 CO_2 Gas Analyzer optical path is a thermostatically controlled IR detection system. The optical bench operation is based upon a broad band IR source and two pyroelectric detectors. The source is mounted in a parabolic reflector to collimate the light and increase energy through the optical path to the detectors. The reflector and optical path are gold plated to further increase energy transmission. The detectors are pyroelectric devices that operate based on thermal energy received. The narrow band optical filters allow only the two wavelengths of interest to illuminate a detector, allowing for the determination of CO_2 concentration in the presence of other infrared absorbing gases such as water vapor.

The detectors respond to thermal energy, so it is necessary to precisely regulate the detectors' temperature. This allows for differentiation of thermal gradient noise from the received signals from the optical path. The detection subsystem is shown in Figure 4-1.

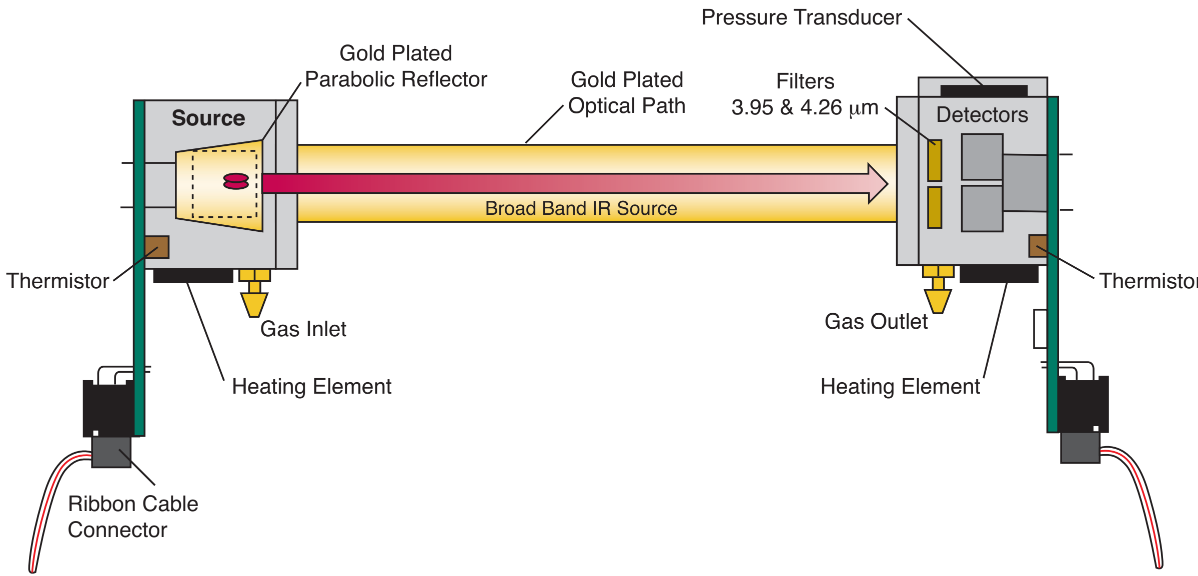


Figure 4-1. Schematic diagram of LI-820 optical bench.

The optical bench has a thermostat that maintains a constant operating temperature of 50 °C. A feedback loop is used to regulate the optical bench temperature. As shown in Figure 4-1, two thermistors, located in the source and detector housings, measure the present temperature. The thermistors are monitored as part of the control loop to determine corrections necessary in the thermal balance. Two heating elements are the sources of thermal energy into the source and detector housing. The optical path is in mechanical contact with the source and detector housing and thereby achieves thermal equilibrium.

The bench requires approximately 10 minutes to achieve the specified thermal temperature. A longer period of approximately 1.5 hours is required to bring the performance of the detection system to within 1 to 2% of reading. As shown in Figure 4-1, the detector housing has a pressure transducer integrated into the housing design. Part of the CO_2 concentration calculation depends on the pressure observed in the optical path, measured with an in-line pressure transducer. Many parameters can affect the pressure and thus the concentration reading. The processing center in the analyzer reads the pressure reading as part of its data collection task and uses this information in the concentration calculation. The gas flow enters the source housing, passes down the optical path and exits at the detector housing. **The maximum flow rate for the analyzer is approximately 1 liter/min**.

Another key parameter in the concentration calculation is the gas temperature in the optical path. It is assumed in the analyzer operation that the gas temperature will equilibrate to the optical bench temperature (50 °C) by the time it enters the optical path. Since the instrument performs temperature and pressure corrections as part of the concentration calculation, this assumption is very important. To cause the sample air to equilibrate to the optical bench temperature, an airflow pattern is created with sufficient eddy currents to cause thermal equilibration.

The optical bench is mounted in a foam enclosure to accomplish two purposes. The first is to assist in maintaining the controlled thermal environment required for the optical bench as described above. The second function of the foam enclosure is to protect the optical bench from mechanical shock and vibration that might damage the mechanically sensitive components. The foam enclosure is supported by a optical bench "tray" which is in turn attached to the main circuit board (PCB). The optical bench is mechanically de-coupled from the case by creating the s-bend in the Bev-a-line tubing from the external fittings to the optical bench gas inlet and outlet connectors. The electronic interface to the source and detectors is achieved through printed circuit boards mounted directly to the source and detector housings, respectively. The main PCB connects to the source and detector PCBs via a ribbon cable. This achieves the mechanical isolation desired for the optical bench.

Equation Summary

Measuring CO_2 Absorptance

CO_2 absorptance α_c is measured by the LI-820 by comparing the output of two detectors; one (W) filtered to a CO_2 absorption band, and the other (W_0) filtered to a non-absorption band.

$$\alpha_c = \left(1 - \frac{W}{W_o} Z\right) S \tag{4-1}$$

Z and S are zero and span parameters, where span is itself a linear function of absorptance,

$$S = S_o + \left(1 - \frac{W}{W_o} Z\right) S_1 \tag{4-2}$$

so,

$$\alpha_c = \left(1 - \frac{W}{W_o} Z\right) S_o + \left(1 - \frac{W}{W_o} Z\right)^2 S_1 \tag{4-3}$$

The absorptance α_{pc} that is reported by the LI-820 is pressure corrected.

$$\alpha_{pc} = \alpha_c g_c(\alpha_c, P) \tag{4-4}$$

Where $g_c(\alpha_c, P)$ is an empirically-determined pressure correction function (Figure 4-2).

$$g_c(\alpha_c, P) = \begin{pmatrix} X & \text{for P} < \text{P}_\text{o} \\ 1 & \text{for P} = \text{P}_\text{o} \\ \dfrac{1}{X} & \text{for P} > \text{P}_\text{o} \end{pmatrix} \tag{4-5}$$

Where P_o = 99.0 kPa,

$$X = \frac{1}{\dfrac{1}{b_1(p-1)} + \dfrac{\left(\dfrac{1}{b_5 - \alpha_c} - \dfrac{1}{b_5}\right)}{\dfrac{1}{b_2 + b_3 p} + b_4}} + 1 \qquad \text{4-6}$$

and $p = \dfrac{P_o}{P}$ or $\dfrac{P}{P_o}$, whichever is > 1. The remaining coefficients are

$b_1 = 1.10158$
$b_2 = -6.12178 \times 10^{-3}$,
$b_3 = -0.266278$,
$b_4 = 3.69895$,
$b_5 = 0.49609938$

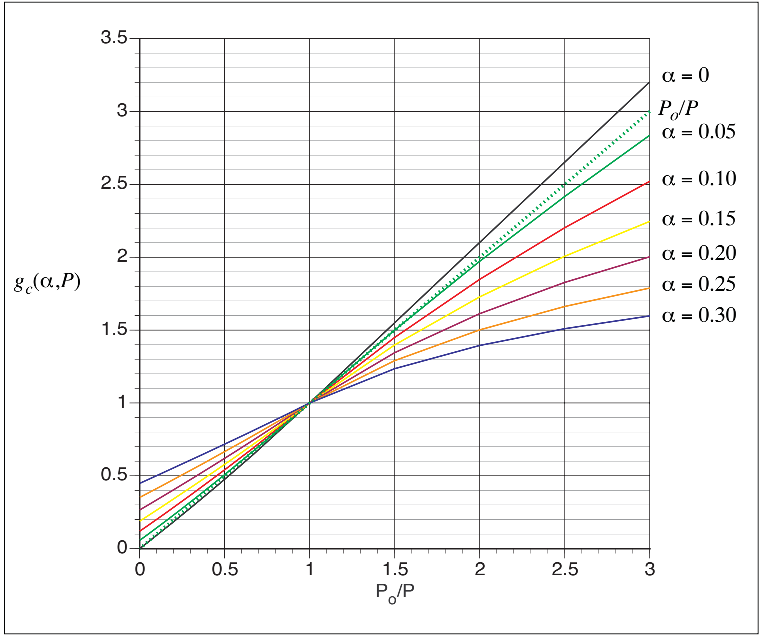


Figure 4-2. The pressure correction function for CO_2. For comparison, the typical correction method for focused-optics IRGAs, such as the LI-6262, is also shown (P_0/P line).

Computing CO_2 Mole Fraction

The relationship between pressure-corrected CO_2 absorptance α_{pc} and CO_2 mole fraction C is given by

$$C = f_c(\alpha_{pc})\left(\frac{T + 273.15}{T_o + 273.15}\right) \tag{4-7}$$

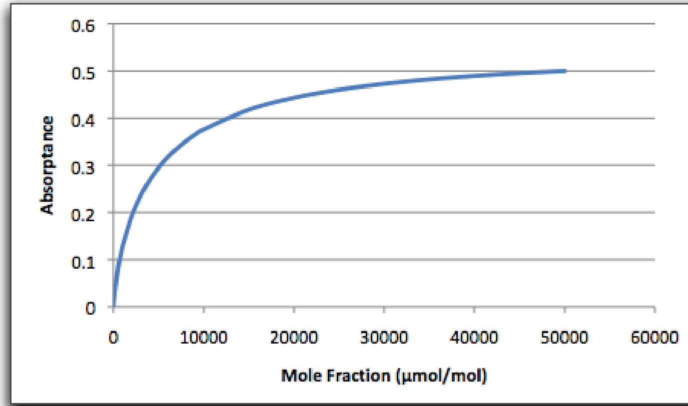
Where $f_c()$ is the CO_2 calibration function, and T is temperature (°C) of the gas in the cell, and T_o is 50 °C.

The *inverse* calibration function f_c^{-1} (C) (that is, the function that predicts pressure-corrected absorptance given a CO_2 mole fraction) is a double rectangular hyperbola:

$$\alpha_{pc} = f_c^{-1}(C) = \frac{a_1 C}{a_2 + C} + \frac{a_3 C}{a_4 + C} \tag{4-8}$$

This relation, suggested to LI-COR by Agu Laisk (Research Professor of Estonian Acad. Sci., University of Tartu, Estonia), fits measurements of mole fraction and absorptance very well over a wide range of CO_2 concentrations with only four parameters. In the LI-820, the coefficients are derived from data between 0 and 50,000 μmol/mol:

$a_1 = 0.3989974$
$a_2 = 5897.2804$
$a_3 = 0.097101982$
$a_4 = 596.49981$



The b_5 parameter in the pressure correction equation (Equation 6) comes from the asymptote of this relation,

$$b_5 = a_1 + a_3 \qquad\qquad 4\text{-}9$$
$$= 0.49609938$$

In practice, however, we need to predict mole fraction as a function of absorptance, so solving Equation 4-8 for C yields the calibration function:

$$C = f_c(\alpha_{pc}) = \frac{D - (a_2 + a_4)\alpha_{pc} - \sqrt{A^2\alpha^2{}_{pc} + B\alpha_{pc} + D^2}}{2\left(\alpha_{pc} - a_1 - a_3\right)} \tag{4-10}$$

where

$$\begin{aligned} A &= a_2 - a_4 \\ B &= 2A(a_1a_4 - a_2a_3) \\ D &= a_3a_2 + a_1a_4 \end{aligned} \tag{4-11}$$

Zeroing (Set Z)

Zeroing the LI-820 consists of flowing CO_2-free air through the cell, and sending the zero command to the instrument. When it receives this command, it averages readings of W and W_o for about 30 seconds, then computes Z such that

$$Z = \frac{\overline{W_o}}{\overline{W}} \tag{4-12}$$

which comes from rearranging Equation 1 when $\alpha_c = 0$.

Single Point Spanning (Set S_o)

To set the span, flow a known CO_2 concentration through the cell, and send the span command to the instrument. When it receives this command, it averages readings of W and W_o for 30 seconds, and computes

$$\bar{\alpha} = 1 - \frac{\overline{W}}{\overline{W_o}} Z \tag{4-13}$$

We rearrange Equation 4-7 to find the pressure-corrected target absorptance α_{pT} that would yield the target (span) concentration C_T.

$$\alpha_{pT} = f_c^{-1}\left(C_T\left(\frac{T_o + 273.15}{T + 273.15}\right)\right) \tag{4-14}$$

Next, we need to "undo" the pressure correction, and find the uncorrected target absorptance α_T.

$$\alpha_T = \frac{\alpha_{pT}}{g_c(\alpha_T, P)} \tag{4-15}$$

This is done by iterating Equation 4-15, starting with $\alpha_T = \alpha_{pT}$, until the value of α_T stops changing. (If the pressure correction is off, then no iteration is needed).

S_o is computed from

$$S_o = \frac{\alpha_T}{\overline{\alpha}} - S_1 \overline{\alpha} \qquad \text{4-16}$$

Two Point Spanning (Set S_o and S_1)

The two point span will not normally be required (after having been done initially at the factory), unless the source or detector has been changed. It requires two span gases, one fairly low (e.g. 300 to 600 ppm), and the other near the high end of the desired operating range (e.g. 20000 ppm). The procedure is to perform a SPAN 1 command for the first gas (high or low), and then a SPAN 2 command for the remaining gas.

Set Span 1

Readings are averaged for 30 seconds to compute

$$\overline{\alpha_1} = \overline{\alpha} = 1 - \frac{\overline{W}}{\overline{W_o}} Z \qquad \text{4-17}$$

Equations 4-14 and 4-15 are performed, and the α_T value retained as a_{T1}.

Set Span 2

Readings are averaged for 30 seconds to compute

$$\overline{\alpha_2} = \overline{\alpha} = 1 - \frac{\overline{W}}{\overline{W_o}} Z \qquad \text{4-18}$$

Equations 4-14 and 4-15 are performed, and the α_T value retained as a_{T2}. The S_1 comes from

$$S_1 = \frac{\dfrac{\alpha_{T2}}{\overline{\alpha_2}} - \dfrac{\alpha_{T1}}{\overline{\alpha_1}}}{\overline{\alpha_2} - \overline{\alpha_1}} \qquad \text{4-19}$$

The S_o parameter can then be computed from Equation 4-16.

5 Maintenance

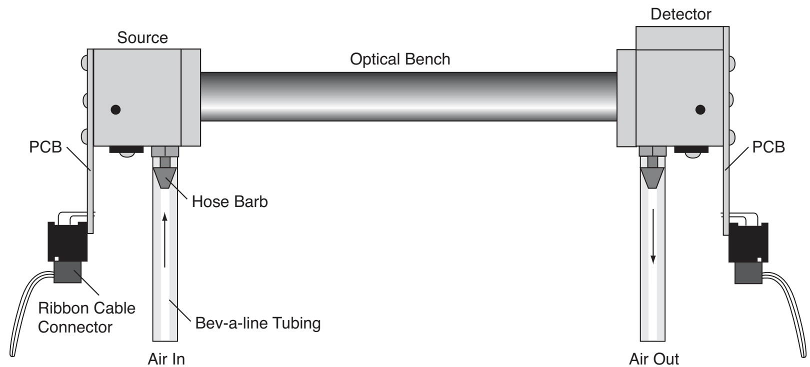
Cleaning the Optical Bench

The LI-820 optical bench can be removed and cleaned if necessary. If the optical path becomes dirty it may become difficult to span the analyzer. Excessive zero drift may also be observed if the optical path becomes dirty. Follow these steps to clean the optical bench:

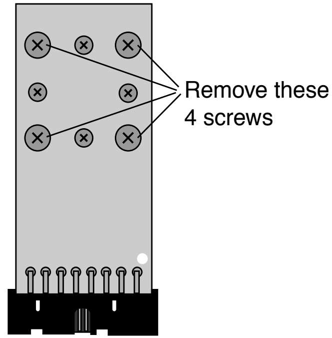
1. Turn the LI-820 off. Remove the six screws on the LI-820 top panel and remove the cover. Note that these screws are not molded into the case and may fall out.

2. Unscrew the tube retaining nuts on the inner air port fittings. Remove the tubing from both air ports. Leave the tubing connected to the source and detector housings.

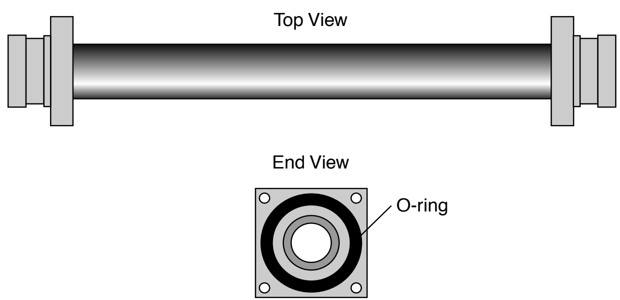
3. There are ribbon cables (Figure 5-1 below) connected to the circuit boards on the source and detector housings. Pull straight out on the connector that is attached to each ribbon cable. The optical bench can now be removed from the foam casing.

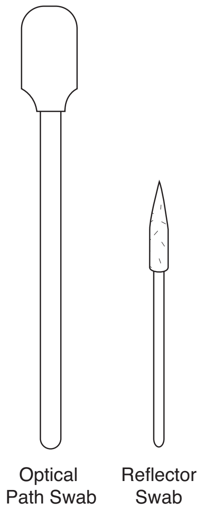


4. There are four screws on the source and detector circuit boards that must be removed. Remove the four screws in the corners of the boards, as shown below (they are slightly larger than the other four screws). Do not remove the remaining four screws.



5. The source and detector housings (with attached circuit boards) can now be removed. The bench will appear as shown below. It is a good practice to replace the O-rings when cleaning or replacing the optical path.





6. There are a number of swabs in the spare parts kit (see at left). Dip one end of the swab into a 50:50 ethanol/water solution and carefully swab both ends of the optical bench, until there is no more visible residue. A mild solution of dish washing type soap and water will also work. ***Do not use abrasive cleansers, as they can irreparably damage the gold plating on the optical bench.***

7. Use a reflector swab and carefully swab the gold-plated concave surface of the source housing, if necessary.

8. If you need to clean out the hose barbs and/or replace the tubing connected to the source and detector housings, use a small pair of diagonal cutters to remove the tubing from the hose barbs. Use the cutters to pinch the tubing parallel to the hose barb axis, and then pivot the cutters over the hose barb tip; the tubing will pull off of the hose barb. *Be very careful not to cut the tubing or scratch the hose barb with the cutters, as subsequent tubing connections may leak.*

9. Let the optical bench dry. Re-assemble the bench, making sure the O-rings are in place on both ends of the bench. Note that the orientation of the cylinder is not important; either end can be inserted into the source or detector housing.

10. Re-assemble the LI-820 case. Make sure that the foam insulation on the inside top cover is positioned over the optical bench; it is required for thermal stability.

11. Perform zero and span calibrations as described in Section 3, *Calibration Window*.

Changing the Fuse

The LI-820 power supply is protected by a 2A 250V, 5 × 20 mm fast-blow type fuse located inside the case. If the battery fails to power the LI-820, and will not light the Power LED on the top panel, check to see if the fuse has blown.

To check the fuse, remove the six screws on the top of the LI-820. The fuse is located on the main circuit board, near the Flow In port, as shown in Figure 5-1. Replacement fuses (part #439-03952, in the spares kit) plug into the fuse holder; no soldering is required. Replace the fuse and reassemble the LI-820 case.

A Specifications*

Measurement Range: 0 – 20000 ppm

Measurement Principle: Non-Dispersive Infrared

Accuracy:
Measurement range 0 - 20000 ppm: <3% of reading

Zero Drift: < .15 ppm/°C

Span Drift at 370 ppm: <0.03%/°C

Total Drift at 370 ppm: <0.4 ppm/°C

RMS Noise at 370 ppm with 1 second signal filtering: < 1 ppm

Span Drift: < 3 ppm in 24 hrs at 350 ppm

Pressure Compensation Range: 15 - 115 kPa

Maximum Gas Flow Rate: 1 liter/minute

Internal Optical Bench Volume: 14.5 mL.

Signal Averaging: 0-20 seconds (user-selectable)

Source Life: Approximately 18,000 hours.

Output Signals: 0 – 5V, 0 – 2.5V, 4 – 20 mA

DAC Resolution: 14-bits across specified range

Power Requirements: Input Voltage 12-30 VDC (low power light comes on at approximately 10 VDC)
1.2A @ 12V (14W) maximum during warm-up with heaters on.
0.3A @ 12V (3.6W) average after warm-up with heaters on.

Warm-Up Time: 1.5 hours

Operating Temp Range: -25 °C to +45 °C

Relative Humidity Range: -25 to 45 °C, 0 to 95% RH, Non-Condensing

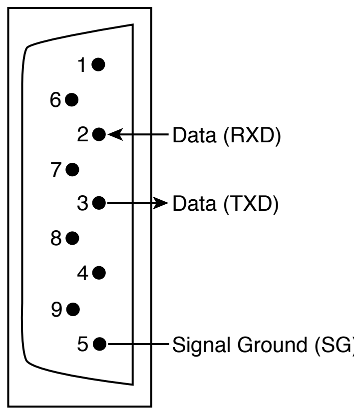
Dimensions: 8.75” × 6” × 3” (22.23 × 15.25 × 7.62 cm)

Weight: 2.2 lbs. (1.0 kg)

* Specifications subject to change without notice.

B Pin Assignments

DB-9 Connector



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.

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

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

Soda Lime: Part #66352

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

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

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

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

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

Soda Lime: Part #C703-B76

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

Electronic Relay Switches

Crydom Inc.
9525 Chesapeake Dr.
San Diego, CA 92123
800-827-9366
FAX: 619-715-7280

Potter & Brumfield Products Div.
Siemens Electromechanical
Components, Inc.
200 S. Richland Creek Dr.
Princeton, IN 47671-0001
info@ae.sec.siemens.com

D Configuration Grammar

Introduction

The LI-820 communicates exclusively through a serial interface. The following discussion describes how to implement a synchronized communication protocol.

LI-820 Communications and XML

The configuration grammar used to communicate with the LI-820 is based upon a subset of the e**X**tensible **M**arkup **L**anguage (XML). XML relies on the use of tags to "Markup", or give structural rules to a set of data.

A *tag* is a descriptive identifier, enclosed between a less than (<) and a greater than (>) symbol, used in part to describe a piece of data. For example, <NAME> is a tag that describes a person's name. Each tag must have a corresponding end tag, denoted by '/'. Extending the example above, the end tag of `<NAME>` is `</NAME>`.

Elements are the basic unit of XML content. An element consists of a start tag and an end tag, and everything in between. For example, consider the following element:

```
<NAME>George</NAME>.
```

In this example, `<NAME>` (start tag) and `</NAME>` (end tag) comprise the markup, and "George" comprises the data. Because XML is extensible, tags can be defined specifically for the data they are meant to describe.

Elements can also contain other elements other than data.

```
<NAME>
        <FIRST>George</FIRST>
        <LAST>Smith</LAST>
</NAME>
```

In this example, the outermost element `<NAME>` emcompasses two other elements that contain data. All elements combined make up the XML document.

Connecting and Configuring Data Output

The LI-820 communicates through a serial port on the front of the instrument. This port is configured as follows:

Baud Rate: 9600 bps
Data Bits: 8
Parity: None
Stop Bits: 1
Flow Control: None

After a serial connection is established, the LI-820 will immediately send data out the serial port in the manner in which it was configured previously. In order to reconfigure the LI-820 to output specific data values, you must send the RS-232 portion of the XML grammar to the instrument with the desired values "turned on". To "turn on" the data value, set the value of the element to TRUE. As an example, the following string is sent to the instrument after a connection has been made between the computer (using the Windows® application software) and the LI-820:

```
<LI820>
      <CFG>
            <OUTRATE>{1}</OUTRATE>
      </CFG>
      <RS232>
            <STRIP>FALSE</STRIP>
            <ECHO>FALSE</ECHO>
```

```
                <CELL TEMP>TRUE</CELL TEMP>
                <CO2>TRUE</CO2>
                <CO2ABS>FALSE</CO2ABS>
                <CELLPRES>TRUE</CELLPRES>
                <IVOLT>TRUE</IVOLT>
                <RAW>FALSE</RAW>
        </RS232>
</LI820>
```

Sending Data to the LI-820

To send data to the LI-820, each string must end with a '\n' to ensure that the LI-820 can parse consecutive commands.

After data have been sent to the LI-820, the instrument replies with:

```
<LI820><ACK>TRUE</ACK></LI820>
```

if the XML was received and parsed correctly. If there was an error in the XML, the following is sent:

```
<LI820><ACK>FALSE</ACK></LI820>.
```

For example, suppose that you would like to reconfigure the LI-820 to stop outputting cell temperature. Here is the command to send to the LI-820:

```
<LI820><RS232><CELLTEMP>FALSE</CELLTEMP></RS232></LI820>
```

If the command was received correctly, the LI-820 replies with

```
<LI820><ACK>TRUE</ACK></LI820>.
```

Reading Data From the LI-820

The LI-820 can send data continuously. To determine where one message ends and the next begins, each XML document sent from the LI-820 is delimited with a '\n' (0x10) character.

Polling the Current State of the LI-820

The LI-820 can be polled for individual sets of data by sending an XML document with a '?' in place of the set of elements requested. The element sets that can be requested include the data set, the current configuration, and the entire state of the instrument.

Sending this command:

```
<LI820><DATA>?</DATA></LI820>
```

instructs the LI-820 to send the most recent set of data values (as configured) as an XML document.

Sending this command:

```
<LI820><CFG>?</CFG></LI820>
```

instructs the LI-820 to send an XML document containing all of the configuration information, including heater status, filter settings, DACs, and alarms.

To receive the entire state of the instrument as an XML document, send this command:

```
<LI820>?</LI820>.
```

Calibration

The LI-820 calibration (zero and span) can be performed using XML grammar. This is accomplished in three steps:

1. Send the calibration command to the LI-820.

```
<LI820>
      <CAL>
            <DATE>{iso date}</DATE>
            <CO2ZERO>{bool}</CO2ZERO>
            <CO2SPAN>{int}</CO2SPAN>
            <CO2SPAN_A>{int}</CO2SPAN_A>
            <CO2SPAN_B>{int}</CO2SPAN_B>
      </CAL>
</LI820>
```

2. An acknowledgement is returned from the LI-820 if the command was accepted.

```
<LI820><ACK>TRUE</ACK></LI820>
```

3. After about a minute, all of the calibration information is returned from the LI-820, indicating that it has finished the zero and/or span.

```
<LI820>
      <CAL>
            <CO2LASTSPAN>{iso date}</CO2LASTSPAN>
            <CO2LASTZERO>{iso date}</CO2LASTZERO>
            <CO2KZERO>{float}</CO2KZERO>
            <CO2KSPAN>{float}</CO2KSPAN>
            <CO2KSPAN1>{float}</CO2KSPAN1>
      </CAL>
</LI820>
```

If the calibration can not be performed, an ERROR is sent:

```
<LI820><ERROR>{Error Text}</ERROR></LI820>.
```

To Zero the LI-820

1. Send the XML command to initiate the zero.

```
<LI820>
```

```
        <CAL>
                <DATE>YYYY-MM-DD</DATE>
                <CO2ZERO>TRUE</CO2ZERO>
        </CAL>
</LI820>
```

2. Wait for the acknowledgement.

3. Wait for the date to be returned to verify the zero operation succeeded. If the operation fails an <ERROR> will be sent.

To Span the LI-820

1. Send the XML command to initiate the span.

```
<LI820>
        <CAL>
                <DATE>YYYY-MM-DD</DATE>
                <CO2SPAN>Gas Concentration</CO2SPAN>
        </CAL>
</LI820>
```

2. Wait for the acknowledgement.

3. Wait for the date to be returned to verify the span operation succeeded. If the operation fails an <ERROR> will be sent.

To Perform a Two Point Span

1. Send the XML command to initiate the first span.

```
<LI820>
      <CAL>
            <DATE>YYYY-MM-DD</DATE>
            <CO2SPAN_A>Gas Concentration</CO2SPAN_A>
      </CAL>
</LI820>
```

2. Wait for the acknowledgement.

3. Wait for the date to be returned to verify the span operation succeeded. If the operation fails an <ERROR> will be sent.

4. Send the XML command to initiate second the span.

```
<LI820>
      <CAL>
            <DATE>YYYY-MM-DD</DATE>
            <CO2SPAN_B>Gas Concentration</CO2SPAN_B>
      </CAL>
</LI820>
```

5. Wait for the acknowledgement.

6. Wait for the date to be returned to verify the span operation succeeded. If the operation fails an <ERROR> will be sent.

LI-820 XML Grammar and Element Description

Data Types in the XML Grammar

{val | val |...}

The value will be a member of the specified set. | = or.

{bool}

Boolean values, TRUE | FALSE.

{float}

Floating point values in decimal or exponential notation.

{int}

Integers.

{iso date}

A date in the ISO format. 4 digit year - 2 digit month - 2 digit day.
Example: 2002-04-27.

XML Grammar

```
<LI820>
        <ACK>{bool}</ACK>
        <VER>{string}</VER>
        <DATA>
                <CO2>{float}</CO2>
                <CO2ABS>{float}</CO2ABS>
```

```
        <CELLTEMP>{float}</CELLTEMP>
        <CELLPRES>{float}</CELLPRES>
        <IVOLT>{float}</IVOLT>
        <RAW>{integer}</RAW>
</DATA>
<RS232>
        <CO2>{bool}</CO2>
        <CO2ABS>{bool}</CO2ABS>
        <CELLTEMP>{bool}</CELLTEMP>
        <CELLPRES>{bool}</CELLPRES>
        <IVOLT>{bool}</IVOLT>
        <STRIP>{bool}</STRIP>
        <ECHO>{bool}</ECHO>
        <RAW>{bool}</RAW>
</RS232>
<CFG>
        <OUTRATE>{float}</OUTRATE>
        <HEATER>{bool}</HEATER>
        <PCOMP>{bool}</PCOMP>
        <FILTER>{int}</FILTER>
        <ALARMS>
                <ENABLED>{bool}</ENABLED>
                <HIGH>{int}</HIGH>
                <HDEAD>{int}</HDEAD>
                <LOW>{int}</LOW>
                <LDEAD>{int}</LDEAD>
        </ALARMS>
        <BENCH>{5|14}</BENCH>
        <DACS>
```

```
                <RANGE>{2.5 | 5.0}</RANGE>
                <D1>{NONE | CO2 | CELLTEMP | CELLPRES}</D1>
                <D1_0>{float}</D1_0>
                <D1_F>{float}</D1_F>
                <D2>{NONE | CO2 | CELLTEMP | CELLPRES}</D2>
                <D2_0>{float}</D2_0>
                <D2_F>{float}</D2_F>
            </DACS>
        </CFG>
        <CAL>
            <DATE>{iso date}</DATE>
            <CO2ZERO>{bool}</CO2ZERO>
            <CO2SPAN>{int}</CO2SPAN>
            <CO2SPAN_A>{int}</CO2SPAN_A>
            <CO2SPAN_B>{int}</CO2SPAN_B>
            <CO2LASTZERO>{iso date}</CO2LASTZERO>
            <CO2LASTSPAN>{iso date}</CO2LASTSPAN>
        </CAL>
        <ERROR>{string}</ERROR>
    </LI820>
```

Element Description

Tag	Parent	Value(s)	R/W	Comments
<LI820>	N/A (root)	<DATA> <RS232> <CFG> <CAL> <ACK> <VER> <ERROR> ?		<LI820> is the root tag for all XML statements. LI-820 outputs entire configuration.
Examples: <LI820>?</LI820> <LI820><ACK>TRUE</ACK></LI820>				

Tag	Parent	Value(s)	R/W	Comments
<DATA>	<LI820>	<CO2ABS> <CELLTEMP> <CELLPRES> <IVOLT> <RAW> ?		<DATA> contains all data values sent from the LI-820. All of the elements within the DATA tag are readable only. A ? requests all data values to be output.
Examples: <LI820><DATA><CO2>2.34e2</CO2><IVOLT>1.5e2</IVOLT></DATA></LI820> <LI820><DATA>?</DATA></LI820>				

Tag	Parent	Value(s)	R/W	Comments
<CO2>	<DATA>	Float	R	CO2 in ppm
<CO2ABS>	<DATA>	Float	R	CO2 absorption
<CELLTEMP>	<DATA>	Float	R	Cell temperature
<CELLPRES>	<DATA>	Float	R	Cell pressure
<IVOLT>	<DATA>	Float	R	Input voltage
<RAW>	<DATA>	Text	R	Raw detector readings
Examples: <LI820><DATA><CELLTEMP>5.16E1</CELLTEMP><CELLPRES>9.742E1 </CELLPRES><CO2>6.17E2</CO2><CO2ABS>8.94E2</CO2ABS>DATA></LI820>				

Tag	Parent	Value(s)	R/W	Comments
<RS232>	<LI820>	<CO2> <CO2ABS> <CELLTEMP> <CELLPRES> <IVOLT> <RAW> <ECHO>		Setting <RS232> values will determine what values are output in <DATA>

<table>
<tr><th>Tag</th><th>Parent</th><th>Value(s)</th><th>R/W</th><th>Comments</th></tr>
<tr><td><CO2></td><td><RS232></td><td>TRUE | FALSE</td><td>R/W</td><td>CO_2 in ppm</td></tr>
<tr><td><CO2ABS></td><td><RS232></td><td>TRUE | FALSE</td><td>R/W</td><td>CO_2 absorption</td></tr>
<tr><td><CELLTEMP></td><td><RS232></td><td>TRUE | FALSE</td><td>R/W</td><td>Cell temperature</td></tr>
<tr><td><CELLPRES></td><td><RS232></td><td>TRUE | FALSE</td><td>R/W</td><td>Cell pressure</td></tr>
<tr><td><IVOLT></td><td><RS232></td><td>TRUE | FALSE</td><td>R/W</td><td>Input voltage</td></tr>
<tr><td><RAW></td><td><RS232></td><td>TRUE | FALSE</td><td>R/W</td><td>Raw detector readings</td></tr>
<tr><td><ECHO></td><td><RS232></td><td>TRUE | FALSE</td><td>R/W</td><td>Echo commands sent to LI-820</td></tr>
<tr><td><STRIP></td><td><RS232></td><td>TRUE | FALSE</td><td>R/W</td><td>Strip XML from all data sent</td></tr>
<tr><td colspan="5">Example:
<LI820><CFG><OUTRATE>0.5</OUTRATE></CFG><RS232><STRIP>FALSE </STRIP><ECHO>FALSE</ECHO><CELLTEMP>TRUE</CELLTEMP><CO2ABS> TRUE</CO2ABS><CO2>TRUE</CO2><CELLPRES>TRUE</CELLPRES><IVOLT> TRUE</IVOLT><RAW>TRUE</RAW></RS232></LI820></td></tr>
</table>

Tag	Parent	Value(s)	R/W	Comments
<CFG>	<LI820>	<OUTRATE> <HEATER> <PCOMP> <FILTER> <ALARMS> <DACS> <BENCH> ?		Elements within the <CFG> tag control system settings.
Example: <LI820><CFG><HEATER>TRUE</HEATER><PCOMP>TRUE</PCOMP></CFG> </LI820>				

Tag	Parent	Value(s)	R/W	Comments
<OUTRATE>	<CFG>	0 to 20	R/W	Output data every N seconds (0.5 s increments).
<HEATER>	<CFG>	TRUE | FALSE	R/W	Turn heater on/off.
<PCOMP>	<CFG>	TRUE | FALSE	R/W	Pressure compensation on/off.
<FILTER>	<CFG>	0 to 20	R/W	Set a 0 to 20 second filter.
<ALARMS>	<CFG>	<ENABLED> <HIGH> <HDEAD> <LOW> <LDEAD>		High and low alarm settings.
<DACS>	<CFG>	<RANGE> <D1> <D2> <D1_0> <D1_F> <D2_0> <D2_F>		DAC outputs.
<BENCH>	<CFG>	5.5 | 14	R	Optical bench length.

Tag	Parent	Value(s)	R/W	Comments
<ENABLED>	<ALARMS>	TRUE I FALSE	R/W	Enable alarms.
<HIGH>	<ALARMS>	Integer	R/W	High alarm on at this value.
<HDEAD>	<ALARMS>	Integer	R/W	High alarm off at this value.
<LOW>	<ALARMS>	Integer	R/W	Low alarm on at this value.
<LDEAD>	<ALARMS>	Integer	R/W	Low alarm off at this value.

Example:
<LI820<LI820><CFG><ALARMS><ENABLED>TRUE</ENABLED><HIGH>1600</HIGH><HDEAD>1500</HDEAD><LOW>200</LOW><LDEAD>300</LDEAD></ALARMS></CFG></LI820>

Tag	Parent	Value(s)	R/W	Comments
<RANGE>	<DACS>	2.5 | 5.0	R/W	Output voltage. 2.5V or 5.0V.
<D1>	<DACS>	CO2 | CELLPRES | CELLTEMP	R/W	DAC1
<D1_0>	<DACS>	Float	R/W	Value where DAC1 outputs 0V
<D1_F>	<DACS>	Float	R/W	Value where DAC1 outputs full scale
<D2>	<DACS>	CO2 | CELLPRES | CELLTEMP	R/W	DAC2.
<D2_0>	<DACS>	Float	R/W	Value where DAC2 outputs 0V
<D2_F>	<DACS>	Float	R/W	Value where DAC2 outputs full scale
Example: <LI820><CFG><DACS><RANGE>2.5</RANGE><D1>CO2</D1><D2>CELLTEMP </D2></DACS></CFG></LI820>				

Tag	Parent	Value(s)	R/W	Comments
<CAL>	<LI820>	<DATE> <CO2ZERO> <CO2SPAN> <CO2SPAN_A> <CO2SPAN_B> <CO2LASTZERO> <CO2LASTSPAN> <CO2KZERO> <CO2KSPAN> <CO2KSPAN1>		Calibrating parameters. When calibrating, <DATE> must be paired with a <CO2ZERO> or a <CO2SPAN>.

Tag	Parent	Value(s)	R/W	Comments
<DATE>	<CAL>	20 character date	W	The date the calibration is taking place.
<CO2ZERO>	<CAL>	TRUE | FALSE	W	Start a CO_2 zero.
<CO2SPAN>	<CAL>	Integer (CO2 ppm)	W	Start a CO_2 span.

<CO2SPAN_A>	<CAL>	Integer (CO2 ppm)	W	Start part 1 of a dual CO_2 span.
<CO2SPAN_B>	<CAL>	Integer (CO2 ppm)	W	Start part 2 of a dual CO_2 span.
<CO2LASTZERO>	<CAL>	20 character date	R	The date the LI-820 was last zeroed.
<CO2LASTSPAN>	<CAL>	20 character date	R	The date the LI-820 was last spanned.
<CO2KZERO>	<CAL>	Float	R/W	Calibration zero constant.
<CO2KSPAN>	<CAL>	Float	R/W	Calibration span constant.
<CO2KSPAN1>	<CAL>	Float	R/W	Calibration span slope constant.

Examples:
To Zero:
<LI820><CAL><DATE>2001-02-07</DATE><CO2ZERO>TRUE</CO2ZERO></CAL></LI820>
To Span:
<LI820><CAL><DATE>2001-02-07</DATE><CO2SPAN>1000</CO2SPAN></CAL></LI820>
Possible LI-820 Replies
<LI820><ACK>TRUE</ACK></LI820>
<LI820><ERROR>{ErrorText}</ERROR></LI820>
<LI820><CAL><CO2LASTSPAN>
{isodate}</CO2LASTSPAN><CO2LASTZERO>{isodate}</CO2LASTZERO><CO2KZERO>{float}
</CO2KZERO> <CO2KSPAN>{float}</CO2KSPAN> </CAL></LI820>

Tag	Parent	Value(s)	R/W	Comments

<ACK>	<LI820>	TRUE | FALSE	R	Acknowledgement to a send command.
<VER>	<LI820>	Text	R	Embedded software version.
<ERROR>	<LI820>	Text	R	Error. Includes a message.

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 and 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 of 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 state to state. 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.

LI-COR Biosciences

LI-COR, inc. ● Environmental ● 4421 Superior Street ● P.O. Box 4425 ● Lincoln, Nebraska 68504 USA
Phone: 402-467-3576 ● FAX: 402-467-2819
Toll-free 1-800-447-3576 (U.S. & Canada)
E-mail: envsales@licor.com
Internet: http://www.licor.com