GasHound

Model LI-800

CO$_2$ Analyzer
Instruction Manual

LI-COR®
Environmental Division

GasHound
Model LI-800

CO$_2$ Analyzer

LI-COR®

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.

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General Description

What's What

This procedure should be followed if you have just taken delivery of your LI-800. 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-800 to your computer.

● **800-50 Data Communications Software -** This Windows® 95 and Windows® NT 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-800. As you become familiar with the analyzer you will learn which items to keep close at hand and which items can be stored away. The spare parts kit contains these items:

Description	Qty.	LI-COR Part No.
Polyurethane Mounting Feet	4	234-02268
Mounting Screws	4	149-02610
Bev-a-line Tubing	12'	222-01824
Disposable Air Filter	2	300-01961
Quick Connect Unions	2	300-03123
1.6A Fuse	2	439-04537
Cleaning Kit, includes:	1	9980-013
3" Cleaning Swabs	5	610-05314
5" Cleaning Swabs	5	610-05315
O-Rings	4	192-00226
Pre-formed Optical Bench Tubing	4	6580-010

Features

The LI-800 is an economical high performance, non-dispersive infrared gas analyzer designed to be used for a wide variety of applications. Some of the LI-800's important features include:
- Optional short (2") and standard long (5.5") interchangeable optical benches can be used to obtain resolutions of 0-20000 ppm and 0-2000 ppm, respectively. No changes in calibration polynomials or software need to be made when swapping optical benches.
- Optical benches are fully serviceable by the user; cleaning the optical benches 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-800 case.

- The optical source is sensitive to vibration, and can be damaged by strong vibrations or jarring. Do not drop the LI-800, 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-800. A Gelman polypropylene filter is included in the spares kit.

Getting Started Tutorial

The following section briefly covers the basic steps you might follow to set up the LI-800 to collect and record data. Many of these steps are described in greater detail throughout this manual.

1

Install the 800-50 PC Communications Software.

This software is required for setting the zero and span of the LI-800 and for setting 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 analog output (if desired) and high and low alarm output, if required.

There are 4 jumpers inside the LI-800 case (on the main circuit board), two of which determine the voltage output ranges on the terminal strip (position #9), and the other two, which toggle the high and low alarm output between 0-5V (TTL levels) and an open drain condition.

The default jumper positions are set for 0-5V analog output and 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; see Section 3, *Analog Output*, for a description of the voltage output jumpers.

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

3 Connect a power source to the LI-800.

Any power source that provides 12-30VDC can be used to operate the LI-800. 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).
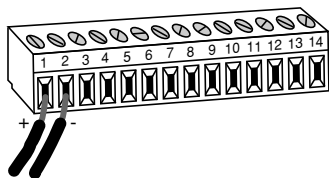
> **NOTE:** Pull straight out on the face of the terminal strip to remove it; this can make it easier to connect the wires.

4 Connect the RS-232 cable.

Connect one end of the serial cable to the 9-pin Serial I/O port on the LI-800 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 be required in some cases, also. Tighten the two screws on the ends of the serial cable.

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 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 the Balston filter (also in the spares kit) in the sample airstream before it enters the **FLOW IN** port on the LI-800.

IMPORTANT: *Always install the external air filter before operating the LI-800.* **Insert filter into the input airstream before it enters the LI-800.** *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-800 in 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.
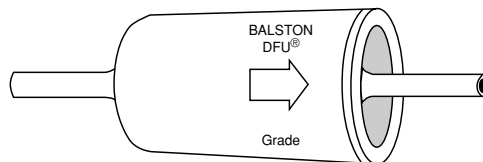
Install the new filter(s) with the arrow facing *toward* the **FLOW IN** port.

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 air filters can be obtained from LI-COR (part #300-01961).

7 Start the 800-50 PC Communications Software.

When you start the 800-50 program, you will be asked to choose the serial port to which the LI-800 is connected. The 800-50 Main window appears.

8 Configure the analyzer.

Click on the **Configure** button in the Main window. Select the CO_2 range (the 'Span' buttons) over which you will be measuring CO_2. Choose a value for signal averaging, 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. Make sure the Heater is enabled (checked), and click **OK**.

9 Set the analyzer zero.

Connect a dry, CO_2-free gas to the input air stream. Click on the **Calibrate** button in the Main window. Click on **Zero IRGA**. After a few minutes, a message will appear in the status bar at the bottom of the window that indicates when the IRGA is zeroed.

10 Set the analyzer span.

Connect your span gas to the input air stream. Click on **Span IRGA**. You will be prompted to enter the value of the span gas. After a few minutes, a message will appear in the status bar indicating that the span calibration is completed. Click **Quit**.

11

Set up the data collection parameters.

Click on the **Record** button in the Main window. Click on the Y-Axis, X-Axis, and Plot tabs to set up the parameters for displaying data on screen, if desired. Click on the Sampling tab and choose sampling and logging periods (see Section 3, *Record Window*, for a description of sampling and logging periods). Click on the Log File tab and choose the data points to be logged (Point, Mean, Max, Min). Click **Save To** and choose a data file name and destination. Click **Save**. Click **Start** to begin recording data. A graph with data will appear in the window and will be logged to the file designated.

12

Click *Stop* to close the data file and stop recording when you are done collecting data.
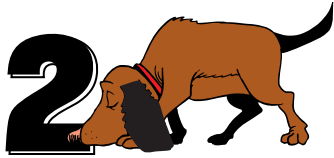
Power On

Power On

The LI-800 can be connected to a constant source of AC power by using a transformer that provides 12-30VDC (12W minimum) to the LI-800. If the LI-800 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-800 top panel will illuminate when the battery voltage drops below 10.5 volts. The LI-800 will continue to operate with a low battery; there will, however, be a corresponding reduction in performance.

Alarms

The LI-800 is equipped with high and low alarms, which can be configured as open collector or 0-5V output (TTL levels) using jumpers on the main PC board (Figure 2-1). The default configuration is 0-5V output. Figure 2-2 shows the position of the jumpers for each of the two alarm conditions.
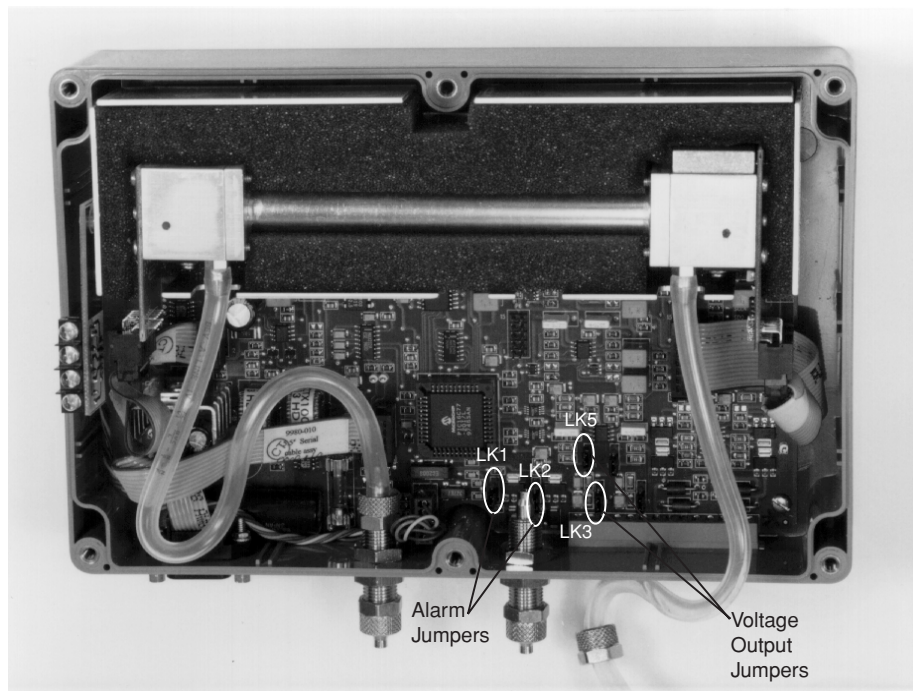
Figure 2-1. Location of alarm jumpers LK1 and LK2.

Open Drain

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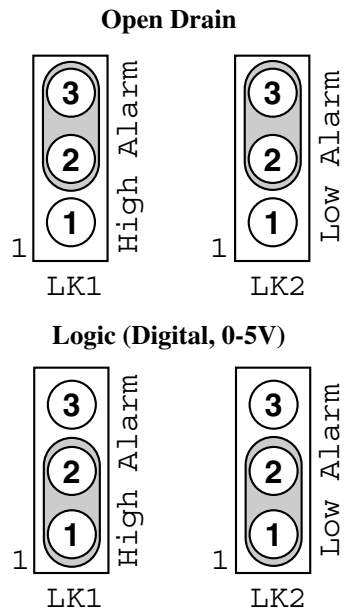
Figure 2-2. Position of jumpers for open drain and 0-5V output.

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.
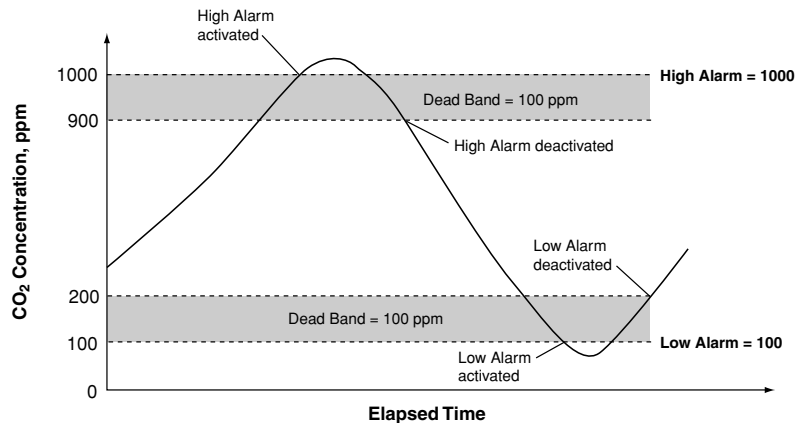
In this chart, the low and high alarm values are set to 100 ppm and 1000 ppm, respectively. The dead band value in both alarms is set to 100 ppm. When the CO_2 concentration reaches 1000 ppm, the high alarm is activated, and remains active until the concentration drops below 900 ppm. When the CO_2 concentration 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 can help reduce fluctuations in readings.

Alarm LEDs can be viewed on the top panel of the LI-800. Terminals 3 and 5 on the terminal strip are also 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.
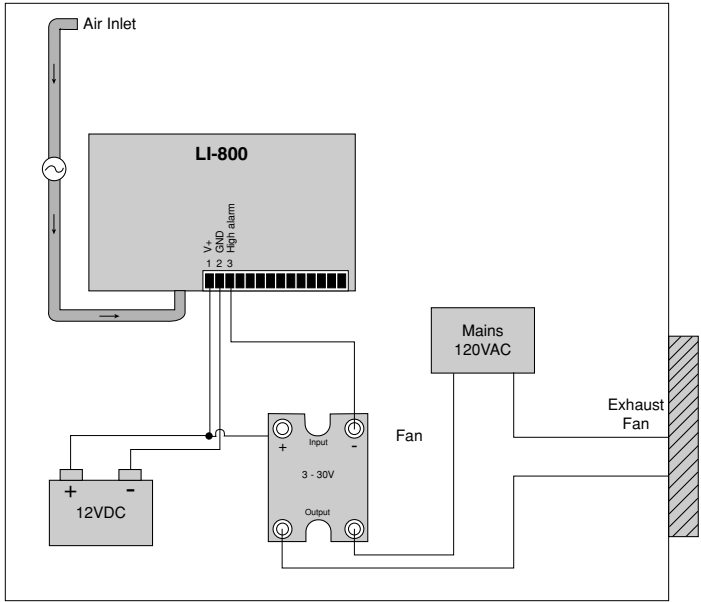
A list of suppliers of electronic relay switches can be found in Appendix C.

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 800-50 software is shipped on CD. It requires that your computer have an RS-232 serial (COM) interface, and Windows® 95/98 or Windows® NT. The program runs on any true PC-compatible computer.

Installation starts when you insert the CD into your CD-ROM drive. 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 LI800 from the list of programs and click the Add/Remove button.

Setting the Communication Parameters

LI-800 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-800. Use this cable to interface with devices such as computers, serial printers, 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 must be used.

RS-232 Output

Data from the LI-800 can be transferred to a computer for analysis, printing or storage using the RS-232 interface. The LI-800 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-800.

The 800-50 PC Communication Software that comes with the LI-800 is used to transfer data and setup files between the analyzer and the PC. Data are transferred in binary format (much faster than ASCII) and then converted and stored in ASCII format.

Initial Setup

LI-800
GasHound

Double-click on the LI-800 program icon to start the program. You will be asked to select the serial port to which the LI-800 is connected.

LI-800 GasHound ☒

Select the port where the
LI800 is connected

Port:
- ⦿ COM1
- ○ COM2
- ○ COM3
- ○ COM4

[OK]   [Cancel]
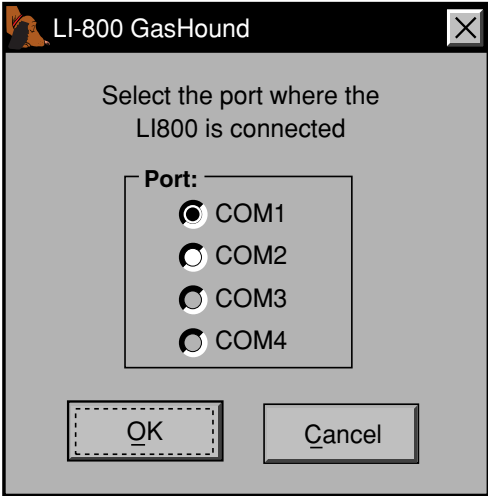
Choose a port and click **OK**. The following window will appear:

```
┌──────────────────────────────────────────────────────────┐
│ 🐾 LI-800 GasHound                              [_] [□] [✕] │
│ Concentration:                                             │
│ ┌────────────────────────────────────────────────────────┐ │
│ │                851.7 ppm                                │ │
│ └────────────────────────────────────────────────────────┘ │
│                    ┌─ Status: ──────────────────────────┐  │
│  ┌───────────┐     │ Parameter:          Value:         │  │
│  │ Configure │     │  Cell pressure       980 mBar      │  │
│  └───────────┘     │  Cell temperature    49.9C         │  │
│                    │  Heater              ON            │  │
│  ┌───────────┐     │  Filter              10 sec.       │  │
│  │ Calibrate │     │  Span                1000ppm       │  │
│  └───────────┘     │  Path length         5.5 in.       │  │
│                    │  Alarms              Disabled      │  │
│  ┌───────────┐     │  Alarm Status        H:    L:      │  │
│  │  Record   │     │  Input Voltage       14.7V         │  │
│  └───────────┘     └────────────────────────────────────┘  │
│  ┌───────────┐                                             │
│  ┊   Quit    ┊                                             │
│  └───────────┘                                             │
│ ┌──────────────────────────┬───────────┬─────────┐        │
│ │ IRGA ready.              │ 8/27/98   │ 5:03 PM │        │
│ └──────────────────────────┴───────────┴─────────┘        │
└──────────────────────────────────────────────────────────┘
```
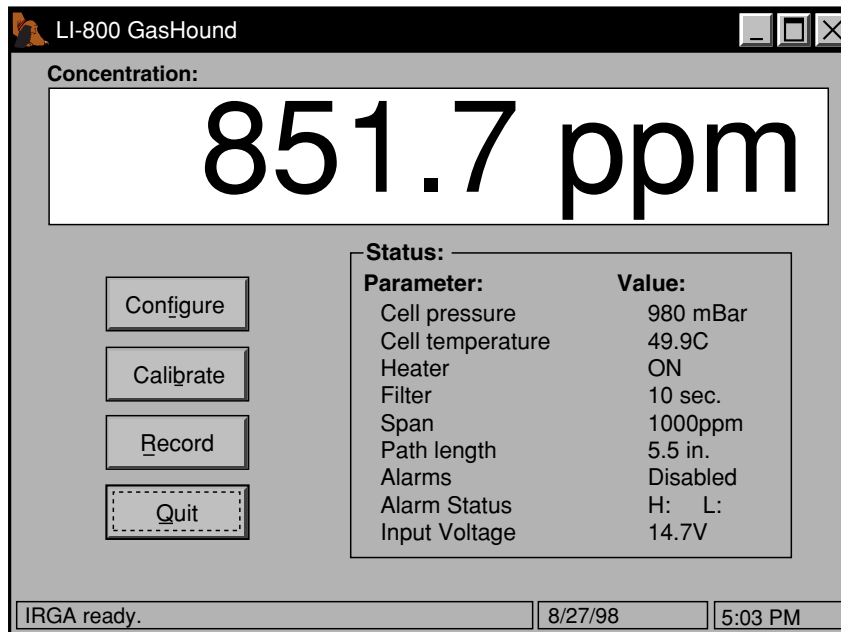
The Main window displays the CO_2 concentration (ppm), as well as the status of various LI-800 parameters. There are also three buttons that open additional windows used to configure the LI-800, perform zero and span calibrations, and set up the parameters for recording data. The status bar at the bottom of the window shows the current date and time

(derived from the computer's system clock), and other relevant status messages. The LI-800 parameters in this window are as follows:

Parameter	Description
Cell Pressure	Barometric pressure (mBar) measured in the LI-800 optical cell. This value can be used to correct CO_2 measurements for the effects of pressure fluctuations on gas density and band broadening.
Cell Temperature	Temperature (°C) in the LI-800 optical cell. This value should remain near 50 °C when the heater is turned ON.
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 Configuration window.
Filter	Shows the current value for software signal averaging, set in the Configuration window. The filter can be set from 0 (no signal averaging) to 20 seconds.

Parameter	Description
Path Length	Shows the size of the optical bench installed in the LI-800, either 5.5 inches, or 2 inches.
Alarms	Shows status of High and Low alarms, whose values are set in the Configuration window. Alarms are either enabled (On), or disabled (Off).
Alarm Status	If the alarms are enabled, a red dot will be placed after the H: (high) or L: (low) when the alarms are activated.
Input Voltage	Shows DC input voltage in Volts.

Click on the Configure button to open the Configuration window (below).

Configuration Window - Setting Operational Parameters

The Configuration window contains parameters related to initial setup of the LI-800, including the resolution of the optical bench, signal filtering, high and low alarm setup, and controls.

The heater should be enabled to maintain the optical bench at a constant 50 °C. Pressure compensation and DAC offset are optional parameters.

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.

Range of optical bench. 5000 and 20000 ppm will be greyed out if 5.5" optical bench is installed. Similarly, 1000 and 2000 will be greyed out if 2" bench is installed.

LI-800 GasHound

Controls:
- ☑ Enable Heater
- ☐ Pressure Compensation
- ☐ DAC Offset Enable

Filter:
- 10 sec.

OK

Reset LI800

Cancel

Alarms:
- ☑ Enable Alarms
- High Alarm `1000`
- H. Dead Band `100`
- Low Alarm `300`
- L. Dead Band `100`

Span:
- ◉ 1000 ppm
- ○ 2000 ppm
- ○ 5000 ppm
- ○ 20000 ppm

IRGA ready. | 4/27/99 | 5:03 PM

Span

The span (range) buttons determine the maximum CO_2 range over which the LI-800 will make measurements. If the 5.5" optical bench is installed, 5000 ppm and 20000 ppm will be greyed out. Similarly, if the 2" optical bench is installed, 1000 ppm and 2000 ppm will be greyed out. Note that there are two benefits to selecting the 0-1000 ppm range if this range is adequate for your experiment. First, the narrower range provides better resolution in terms of the digital-to-analog converter (DAC). Each step of the DAC is now able to resolve twice as many data points as compared to the 0-2000 ppm range, which results in beter resolution. Secondly, the 0-1000 ppm range has a unique 4th order polynomial, which provides a better "curve fit", and ultimately improved accuracy over this range.

Controls

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.

DAC OffsetEnable

The DAC Offset Enable check box determines whether the analog output voltage includes a zero offset. The DAC in the LI-800 is unipolar, meaning that only positive analog values are output, even if the apparent CO_2 mole fraction as displayed by the Windows® software reads negative. This could happen, for example, if the cell becomes contaminated or just from small random perturbations when the CO_2 concentration is near zero. If the DAC offset is disabled, a voltage output of 0 volts would correspond to 0 ppm CO_2. If, however, the analyzer reading drops below 0 ppm (e.g. due to cell contamination), the analog output would continue to read 0 volts. This makes it difficult or impossible to tell from the data if negative zero offsets have occurred in the instrument. To accomodate this requirement, an offset can be introduced in the DAC output that allows you to identify a negative zero drift if it occurs. A negative 25 ppm offset is available for the 0-1000 and 0-2000 ppm ranges, and a negative 100 ppm offset is available for the 0-5000 and 0-20000 ppm ranges. Thus, when the DAC Offset Enable check box is selected, the actual concentration measurement ranges are -25 to 975 ppm and -25 to 1975 ppm for the 0 to 1000 ppm and 0 to 2000 ppm ranges, and -100 ppm to 4900 ppm and -100 ppm to 19900 ppm for the 0 to 5000 and 0 to 20000 ppm ranges. It follows then that an analog output of 0 volts will correspond to -25 ppm or -100 ppm, depending upon the CO_2 concentration range selected.

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

$$CO_2 = V\left(\frac{C_{range}}{V_{range}}\right) - C_{offset} \qquad\qquad 3\text{-}1$$

where V is the measured voltage, C_{range} is the maximum value of the CO_2 range selected (0 to 1000 ppm, 0 to 2000 ppm, etc.), V_{range} is the maximum DAC output for the selected range (0-5V, 0-2.5V, 0-1V, 0-0.5V), and C_{offset} is the CO_2 offset subtracted by the software for the range selected (25 ppm for the 0-1000 or 0-2000 ppm ranges, or 100 ppm for the 0-5000 or 0-20000 ppm ranges).

Example: The voltage output jumpers are set for 0-5V output (V_{range}), the maximum CO_2 range chosen is 2000 ppm (C_{range}), and the measured output voltage (V) is 2.9V. To calculate the CO_2 concentration (no offset) from Equation 3-1 above,

$$CO_2 = 2.9V\left(\frac{2000 \text{ ppm}}{5V}\right) - 0 \qquad\qquad 3\text{-}2$$

$$= \textbf{1160 ppm}.$$

To calculate the CO_2 concentration with the offset value subtracted,

$$CO_2 = 2.9V\left(\frac{2000 \text{ ppm}}{5V}\right) - 25 \qquad\qquad 3\text{-}3$$
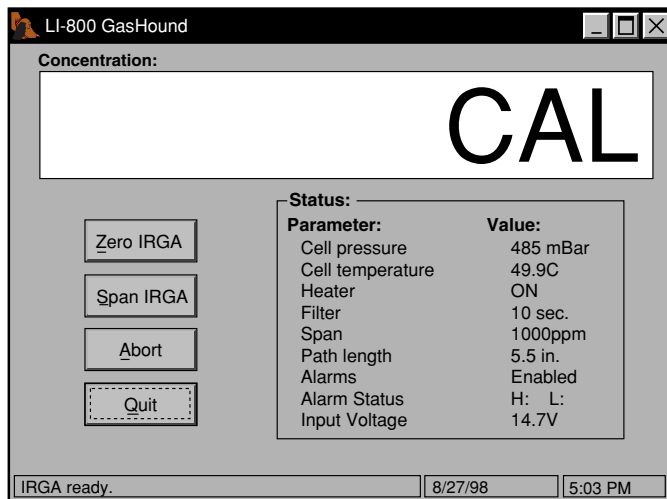
$$= \textbf{1135 ppm}.$$

Reset LI-800

The Reset button is used to set the LI-800 parameters back to the default values. Zero and span values are set to 1, alarms are set to Off, the heater is enabled, pressure compensation is disabled, and the DAC offset is reset to zero. In addition, the software signal filtering is set to 20 seconds, the span values are set to the maximum values, depending upon the size of the optical bench installed (2000 or 20,000 ppm), and the high and low alarm and dead band values are reset to the default values. Calibration polynomial coefficients are also loaded when Reset is pressed. *Always set the zero and span (see below) of the LI-800 after pressing Reset; if you do not, subsequent data will be erroneous*.

# Calibration Window - Setting the Zero and Span

Click on the **Calibrate** button in the Main window to open the Calibration window. This is the area in which you set the zero and span of the LI-800.

LI-800 GasHound   [_] [□] [X]

Concentration:

CAL

Status:

Parameter:	Value:
Cell pressure	485 mBar
Cell temperature	49.9C
Heater	ON
Filter	10 sec.
Span	1000ppm
Path length	5.5 in.
Alarms	Enabled
Alarm Status	H: L:
Input Voltage	14.7V

[Zero IRGA]

[Span IRGA]

[Abort]

[Quit]

IRGA ready.   8/27/98   5:03 PM

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-800, and make sure the optical cell is completely purged. Press the **Zero IRGA** button. The display will show zero. The zero will be set electronically, and the message bar at the bottom of the window will display "IRGA zeroed" when finished.

To span, connect your span gas to the input air stream. Make sure the cell is purged, and click on **Span IRGA**. You will be prompted to connect the gas line, and then enter the value of the span gas:
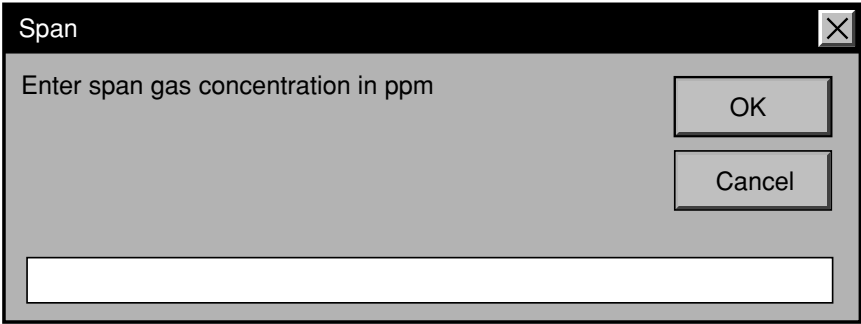
Span	✕
Enter span gas concentration in ppm	OK
	Cancel

After a few minutes, a message will appear in the status bar indicating that the span calibration is completed. Click **Quit**.

Record Window (Plotting Data)

Click on the **Record** button in the Main window to open the Record window (below). This is the window in which you can set up the parameters for plotting your data, and open and/or close a log file to which the data are saved.
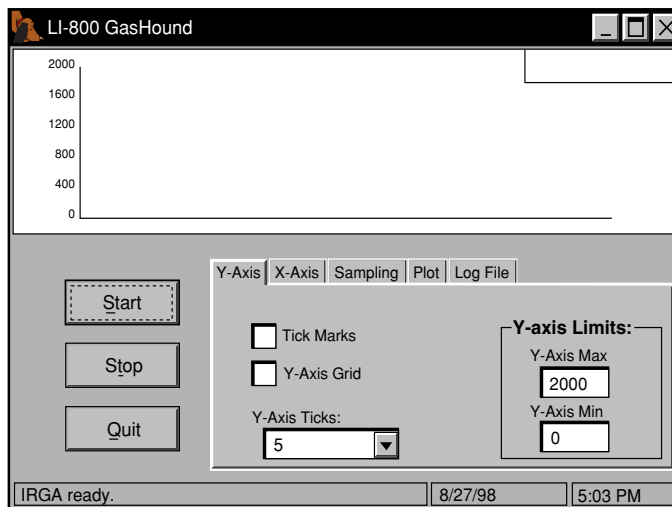
There are five tabs that open other pages that allow you to set up the parameters for collecting data. Each of these five pages is described below.

Y-Axis Page

Sets chart parameters for Y-axis. Tick marks can be placed on the Y-axis in increments from 1 to 10. The tick marks will be placed at equally spaced intervals along the Y-axis, depending upon the values chosen for the Max and Min. In the chart above, when a value of 5 is chosen for the Y-Axis Ticks, and the Y-Axis Max is set to 2000, the tick marks are placed every 400 ppm. Click on the 'Tick Marks' check box, and select the value from the 'Y-Axis Ticks' pull-down menu. Click on the 'Y-Axis Grid' check box to overlay the chart with a horizontal grid. Enter Y-Axis Max and Min values in the 'Y-axis Limits' field.

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

X-Axis Page

Sets chart parameters for X-axis. As with the Y-axis, you can place tick marks and/or a vertical grid on the chart by enabling the check boxes. You can also select the number of samples that are displayed on the chart before it scrolls to show more data.
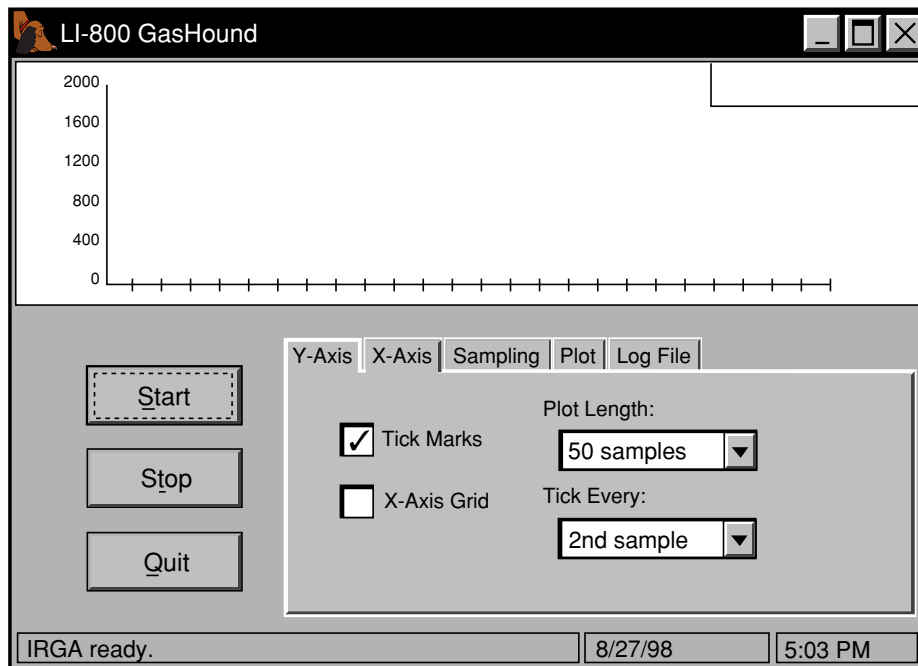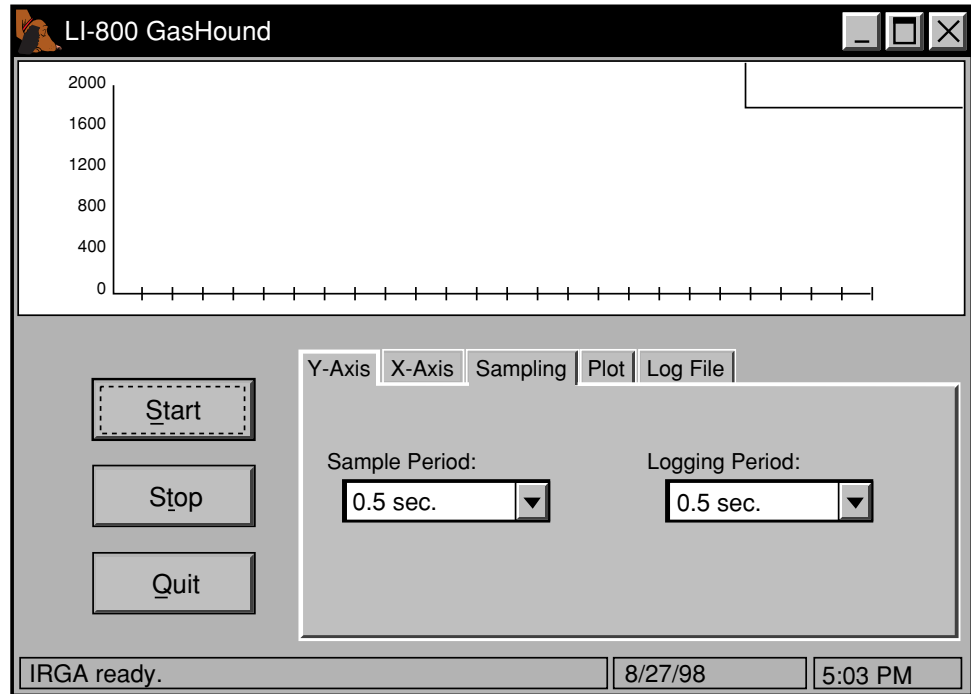
In the chart above, 50 samples will be displayed at one time; tick marks are placed every second sample. After the first 50 data points are displayed, the chart will scroll to show more

data. The Plot Length can be selected for 10, 20, 50, 100, 200, or 500 samples; note that at higher values, however, individual data points may be difficult to discern.

Sampling Page

The Sample Period is the time interval between samples within a Logging Period. The Logging Period is the time interval between data points logged to memory. The Sample Period and Logging Period can be set to 0.5, 1, 5, 15, 30, or 60 seconds. The Sample Period can not be set to a value that is greater than the Logging Period. As an example, if the Logging Period is set to 60 seconds, and the Sample Period is set to 15 seconds, 4 samples will be taken each minute, and one data point will be logged, based on the type of data chosen in the Log File page (see below).

LI-800 GasHound

```
2000
1600
1200
 800
 400
   0
```

| Y-Axis | X-Axis | Sampling | Plot | Log File |

Start

Stop

Quit

Sample Period:

0.5 sec.

Logging Period:

0.5 sec.

IRGA ready.   8/27/98   5:03 PM

Plot Page

Allows you to set a chart title and a Y-axis label, and select the type of chart that will be plotted. A line graph can be plotted (below), in which data points are connected with a continuous line, or a symbol graph can be selected, where each data point is represented with a symbol. The current data value is shown in the upper righthand corner of the plot window.
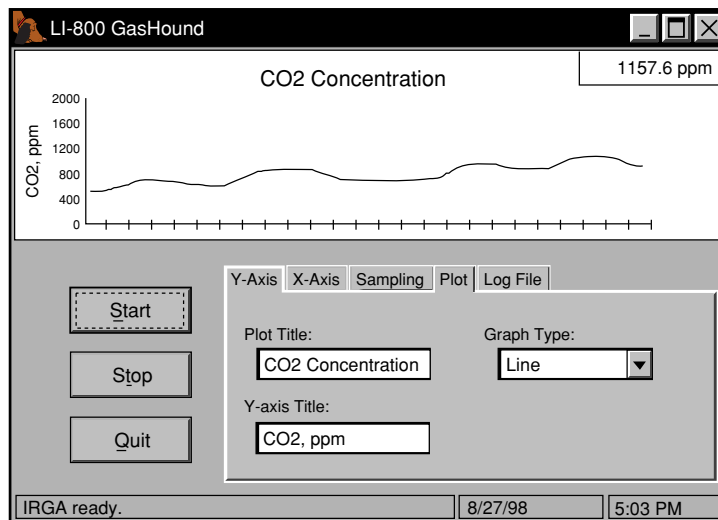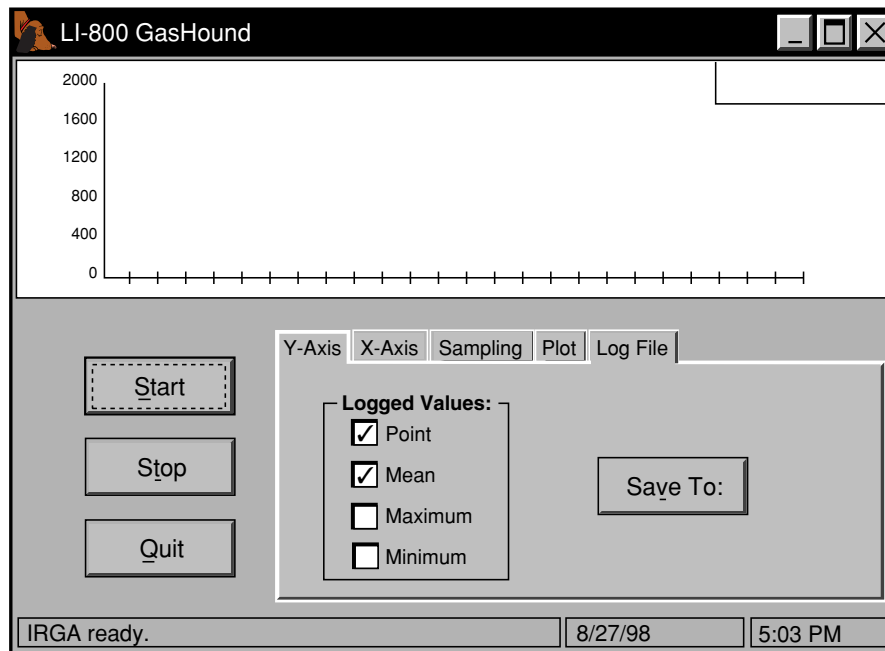
Log File Page

The Log File page allows you to choose the type of data point(s) that are collected at the end of each logging period (point, mean, maximum, minimum), and to choose a name and destination for the data file. Click on the **Save To** button to bring up the Open dialog box, where you can select a drive and folder for the file, and enter a name for the file. Click on the Point, Mean, Maximum, and/or Minimum check boxes to choose the type of data that are logged. Note that the temperature and pressure are also logged automatically at each data point.

Point - logs a single data point at the end of the chosen logging period.

Mean - logs an average value for the sample data points between each logging period.

Maximum - logs the maximum value collected during the chosen logging period.

Minimum - logs the minimum value collected during the chosen logging period.

LI-800 GasHound

2000
1600
1200
800
400
0

Y-Axis X-Axis Sampling Plot Log File

Start

Stop

Quit

Logged Values:
☑ Point
☑ Mean
☐ Maximum
☐ Minimum

Save To:

IRGA ready.   8/27/98   5:03 PM

Analog Output

Analyzer output 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, 0-2.5V, 0-1V, or 0-0.5V. Voltage output is selected using two jumpers on the main PC board, at locations LK3 and LK5, as shown in Figure 3-1 below. Table 3-1 shows the proper position of the jumpers for each voltage output.
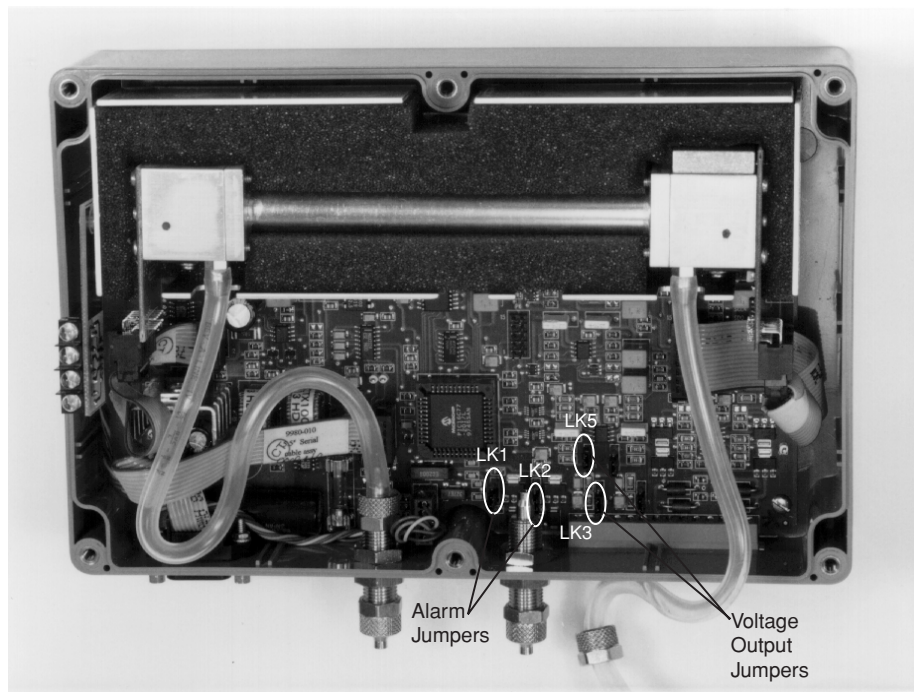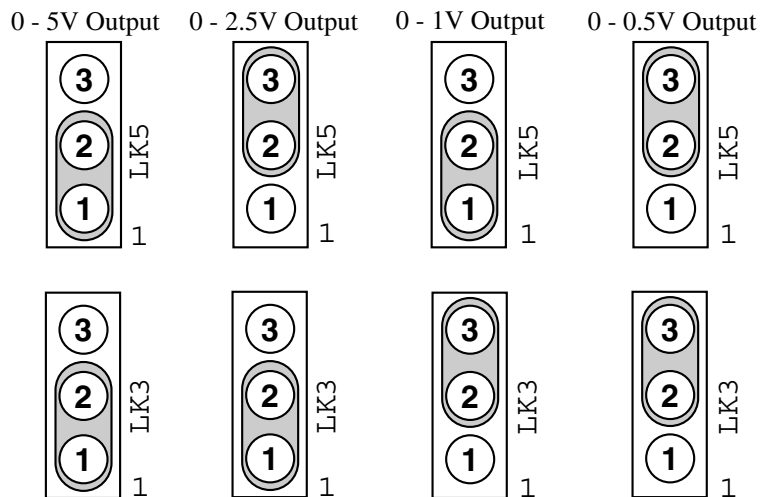
Figure 3-1. Location of voltage output jumpers LK3 and LK5.

Table 3-1. Jumper positions for changing voltage output.

0 - 5V Output   0 - 2.5V Output   0 - 1V Output   0 - 0.5V Output

To change jumper positions, power the LI-800 off, and remove the top cover. Carefully pull straight up on the jumper(s) to remove, and place in the desired position. Reassemble the case.

Voltage output is measured by attaching the positive lead from the logging device to terminal 9 (CO2 V Out) on the LI-800 terminal strip. Connect the negative lead to position 10, (GND).

Current output can be measured by connecting the positive input of the data logging device to position 13 (CO2 4-20 mA), and the negative input to position 14 (GND). The current output at position 13 is non-isolated, and is rated to drive a 250 ohm load.

Converting Current Output to ppm CO$_2$

To convert current output (I) to units of ppm CO$_2$ in your computer or other output device, the following equation can be used:

$$CO_2 = \frac{C_{range}}{16}(I-4) - C_{offset} \qquad\qquad 3\text{-}4$$

where C_{range} is the maximum available CO$_2$ resolution (1000, 2000, 5000, or 20000 ppm), I is the measured current output in mA, and C_{offset} is the CO$_2$ offset subtracted by the software for the range selected (25 ppm for the 0-1000 or 0-2000 ppm ranges, or 100 ppm for the 0-5000 or 0-20000 ppm ranges), when the DAC Offset is enabled.

Example: You have chosen 2000 for the range of the LI-800. The measured current output is 16.25 mA, and the DAC Offset is disabled. To convert to ppm CO_2:

$$CO_2 = \frac{2000}{16}(16.25 - 4) - 0 \qquad \qquad 3\text{-}5$$

= **1531.25 ppm**.

## Using the Terminal Strip

The terminal strip is located on the front panel of the LI-800. 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 front face of the terminal strip can be removed to aid in connecting the wires; pull straight out on the face to remove.
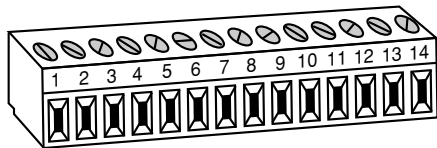
The terminal positions are as follows, reading left to right:

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	Reserved	No channel
8	GND	Ground
9	CO2 V Out	CO_2 Voltage output
10	GND	Ground
11	Reserved	No channel
12	GND	Ground
13	CO2 4-20 mA	CO_2 Current output
14	GND	Ground

Connecting the GasHound to the LI-1400 Datalogger
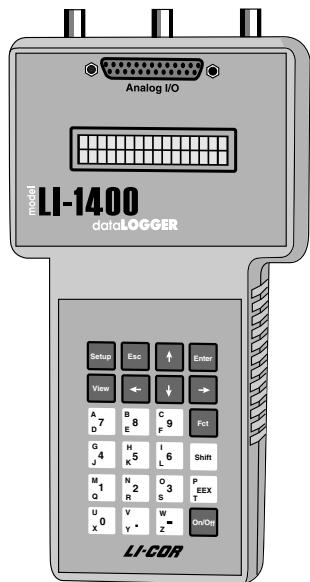
The following example shows how you can connect the LI-800 to a datalogging device such as the LI-COR Model LI-1400 DataLogger to collect analog data and convert to meaningful CO_2 values. As mentioned earlier, voltage output from the LI-800 is linear; converting analog data into ppm CO_2 simply requires multiplying the raw mV output by a conversion factor, which is dependent upon the selected voltage output range, and the maximum CO_2 resolution available (set in software at 0-1000 or 0-2000 ppm with the 5.5" optical bench, or 0-5000 or 0-20000 ppm with the 2" optical bench). In general, the conversion takes the form

$$CO_2 = V\left(\frac{C_{range}}{V_{range}}\right) - C_{offset} \qquad 3\text{-}6$$

where V is the measured voltage, C_{range} is the maximum value of the CO_2 range selected (0 to 1000 ppm, 0 to 2000 ppm, etc.), V_{range} is the maximum DAC output for the selected range (0-5V, 0-2.5V, 0-1V, 0-0.5V), and C_{offset} is the CO_2 offset subtracted by the software for the range selected (25 ppm for the 0-1000 or 0-2000 ppm ranges, or 100 ppm for the 0-5000 or 0-20000 ppm ranges).

For example, if the voltage output jumpers are set for 0-5V output, the maximum CO_2 range is 5000 ppm, the measured voltage output is 2.9V, and the DAC Offset is *disabled*, the equation would take the form

$$CO_2 = 2.9V\left(\frac{2000 \text{ ppm}}{5V}\right) - 0 \qquad\qquad 3\text{-}7$$

= **1160 ppm**.

This general equation can be converted into simple multipliers, based on the four known voltage output ranges, and the four values for maximum CO_2 resolution (1000, 2000, 5000 and 20000). This multiplier can then be entered in the data logging device to convert raw voltage to CO_2 values. Table 3-2 lists the appropriate values for this multiplier; simply choose your DAC output range (see Section 3, *Analog Output*), in the second row, and then select the LI-800 maximum CO_2 range in the first column; follow across to find the appropriate multiplier.

Table 3-2. Multipliers for Converting Voltage Output to CO_2 Readings

C_{range}	DAC Output Range			
	0-5V	0-2.5V	0-1V	0-0.5V
	Multiplier (ppm/volt)			
0-1000 ppm	200	400	1000	2000
0-2000 ppm	400	800	2000	4000
0-5000 ppm	1000	2000	5000	10000
0-20000 ppm	4000	8000	20000	40000

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 require the 1400-301 Terminal block. Voltage channels are designated by the letter "V" and sequentially numbered V1-4. The lead from LI-800 terminal #9 should be attached to one of the LI-1400 terminals labeled V1, V2, V3, or V4, while the lead from terminal #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-800 and convert to CO_2 values (DAC Offset disabled).

1. Set the voltage output jumpers 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.

This example could be modified to subtract a DAC Offset value of 25 ppm or 100 ppm using a math channel to store the value of the CO_2 calculation, and then subtracting the offset. See the LI-1400 DataLogger instruction manual for instructions on using math channels.
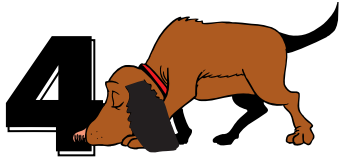
4 Theory of Operation

System Overview

The LI-800 CO_2 Gas Analyzer is an absolute, non-dispersive, infrared (NDIR) gas analyzer based upon a single path, dual wavelength, infrared detection subsystem. 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 is passed through a 6th order polynomial 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.

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® 95 and Windows® NT 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. The instrument has an interchangeable optical path that allows for different concentration ranges as required by a particular application.

Optical Bench System

The LI-800 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 a pyroelectric detector. The source is mounted in a parabolic reflector to collimate the light and increase energy throughput down the optical path to the detector. The reflector and optical path are gold plated to further increase energy transmission. The detector is a pyroelectric device that operates based on thermal energy received. The narrow band optical filters allow only the two wavelengths of interest to illuminate the detector, allowing for the determination of CO_2 concentration in the presence of other infrared absorbing gases such as water vapor.

The detector operates responds to thermal energy so it is necessary to precisely regulate the detector 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.
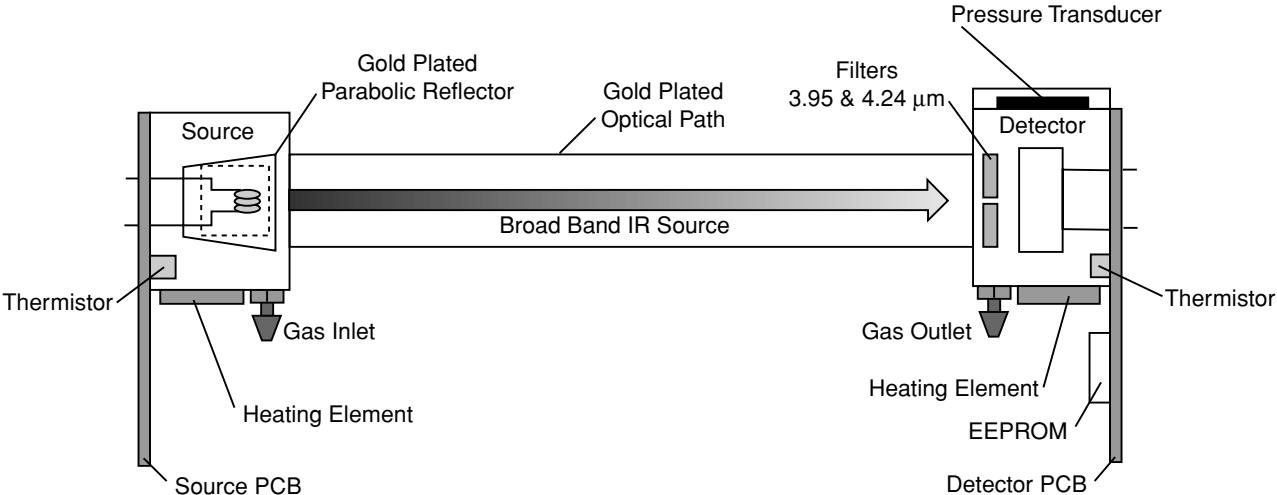
Figure 4-1. Schematic diagram of LI-800 optical bench.

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 for 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 detector is achieved through printed circuit boards mounted directly to the source and detector housings respectively. The PCBs connect the main PCB to the source and detector PCBs via a ribbon cable. This achieves the mechanical isolation desired for the optical bench.

Two optical bench variations are available depending on the concentration range necessary for the particular application. The benches vary in length resulting in different concentration ranges:
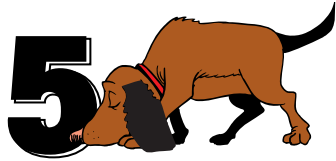
14 cm (5.5") Optical Bench
0 – 1000 ppm
0 – 2000 ppm

5 cm (2") Optical Bench
0 – 5000 ppm
0 – 20000 ppm

The ease of interchangeability for the optical bench options was a consideration from the beginning of the analyzer design. The foam enclosure is designed to accept either length bench while maintaining the two-fold purpose stated earlier. The electrical connections also support easy optical bench exchange as well as providing safe interconnection for proper operation. The main PCB contains two source headers and one detector header for connection to the source and detector PCBs via the ribbon cable. Combining the physical location of the two source headers with different ribbon cable lengths, the user can easily swap the optical benches and will be able to select the correct source header on the main PCB.

5 Maintenance

Cleaning the Optical Bench

The LI-800 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-800 off. Remove the six screws on the LI-800 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.
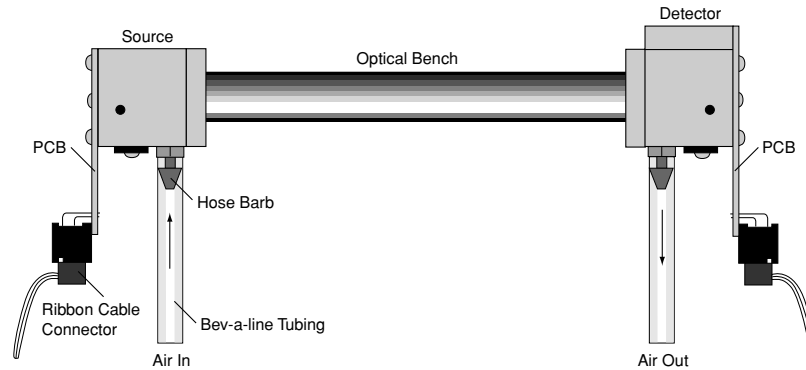
4. There are four screws on the source and detector circuit boards that must be removed. Remove the four screws in the corners of the boards, as shown below (they are slightly larger than the other four screws). Do not remove the remaining four screws.

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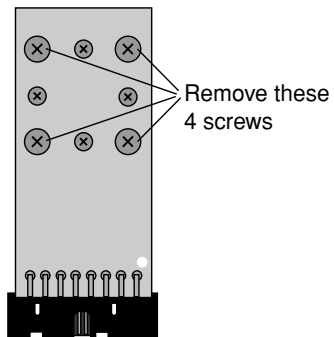
5. The source and detector housings (with attached circuit boards) can now be removed. The bench will appear as shown below. It is a good practice to replace the O-rings when cleaning or replacing the optical path.

Top View

End View

O-ring

Optical
Path Swab

Reflector
Swab
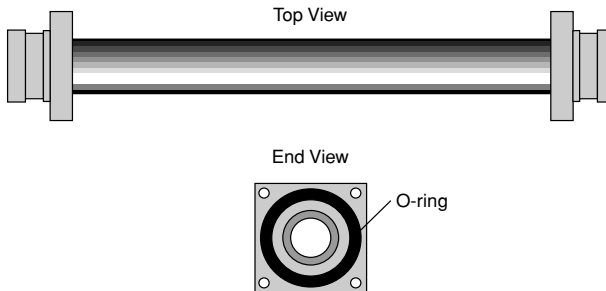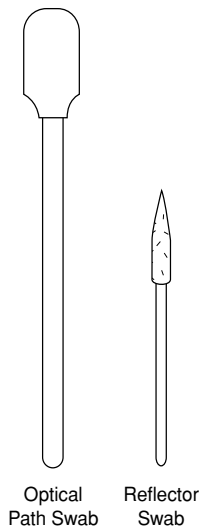
6. There are a number of swabs in the spare parts kit (see at left). Dip one end of the swab into a 50:50 ethanol/water solution and carefully swab both ends of the optical bench, until there is no more visible residue. A mild solution of dish washing type soap and water will also work. ***Do not use 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-800 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 Optical Bench

The 14 cm (5.5") and 5 cm (2") optical benches of the LI-800 can be interchanged to provide CO_2 measurements of 0-2000 and 0-20000 ppm, respectively. The LI-800 will automatically sense which optical bench is installed; no further software or hardware switches are required. To change the optical bench, follow these steps:

1. Follow Steps 1-5 above at *Cleaning the Optical Bench* to remove the existing bench and the source and detector housings.

2. Install the source and detector housings on the gold-plated optical path cylinder. Make sure that both source and detector housings have an O-ring installed, as shown in Step 5 above. The orientation of the cylinder is not important; either end can be inserted into the source or detector housing. **Note**: There is no need to grease the O-ring; simply press into place.

3. Carefully remove the 10-pin connector that was attached to the source housing circuit board from the main circuit board. Reattach the 10-pin connector to one of the connectors shown below, depending on which optical bench is being installed.
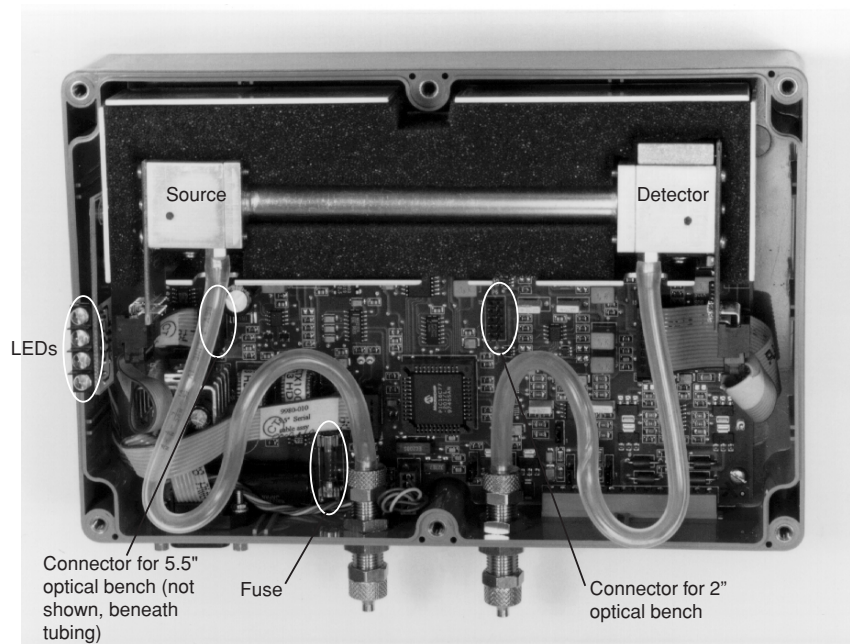
Figure 5-1. Location of 10-pin connectors for 5.5" and 2" optical benches.

4. Install the new bench in the same orientation as the existing bench, with the source side on the left as you face the front of the instrument.

5. Reattach the 10-pin connectors to the source and detector housing circuit boards. Reattach the Bev-a-line tubing to the hose barbs on the source and detector housings, and to the flow in and out ports, if necessary. Reassemble the case.

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

Changing the Fuse

The LI-800 power supply is protected by a 1.6A 250V, 5×20 mm fast-blow type fuse located inside the case. If the battery fails to power the LI-800, 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-800. The fuse is located on the main circuit board, near the Flow In port, as shown in Figure 5-1. Replacement fuses (part #439-04537, in the spares kit) plug into the fuse holder; no soldering is required. Replace the fuse and reassemble the LI-800 case.

A Specifications*

Measurement Range: 0 – 1000 ppm, 0 – 2000 ppm
0 – 5000 ppm, 0 – 20000 ppm

Measurement Principle: Non-Dispersive Infrared

Accuracy:
    5 cm (2") Optical Bench (measurement range 0 - 20000 ppm):
    P = 95 to 102 kPa   0 - 1000 ppm; ± 4% of reading ± 10 ppm
                          1000 - 20,000 ppm; ± 4% of reading
    P = 50 to 113 kPa   0 - 1000 ppm; ± 6% of reading ± 10 ppm
                          1000 - 20,000 ppm; ± 6% of reading
    14 cm (5.5") Optical Bench (measurement range 0 - 2000 ppm):
    P = 95 to 102 kPa   0 - 200 ppm; ± 3% of reading ± 5 ppm
                          200 - 2,000 ppm; ± 3% of reading
    P = 50 to 113 kPa   0 - 200 ppm; ± 5% of reading ± 5 ppm
                          200 - 2,000 ppm; ± 5% of reading

Zero Drift: < 1 ppm in 24 hrs at 350 ppm

* Specifications subject to change without notice.

Appendix A

Signal Noise: 3.0 ppm pk-pk noise @ 350 ppm (1 sec signal averaging)
1.0 ppm pk-pk noise @ 350 ppm (20 sec signal averaging)

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

Pressure Compensation Range: 150 mbars - 1150 mbars

Maximum Gas Flow Rate: 1 liter/minute maximum

Output Signals: 0 – 5V, 0 – 2.5V, 0 – 1.0V, 0 – 0.5V
                   4 – 20 mA

DAC Resolution: 13-bits across specified range

Power Consumption: 1A @ 12V (12W) maximum during warm-up with heaters on.
                    0.3A @ 12V (3.6W) average after warm-up with heaters on.

Supply Operating Range: 12 – 30V

Warm-Up Time: 1.5 hours

Operating Temp Range: -25 $^{\circ}$C to +45 $^{\circ}$C
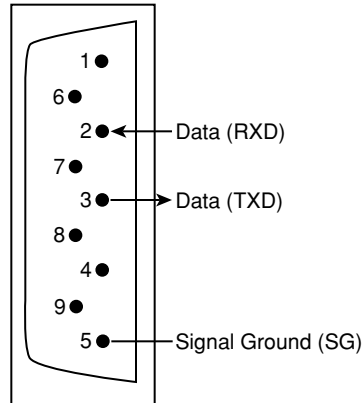
Relative Humidity Range: -25 to 45 °C, 0 to 95% RH, Non-Condensing

Dimensions: 8.75" $\times$ 6" $\times$ 3" (22.23 $\times$ 15.25 $\times$ 7.62 cm)

Weight: 2.2 lbs. (4.84 kg)

B Pin Assignments

DB-9 Connector

```
1 ●
6 ●
   2 ● ◄──── Data (RXD)
7 ●
   3 ● ────► Data (TXD)
8 ●
   4 ●
9 ●
   5 ● ───── Signal Ground (SG)
```
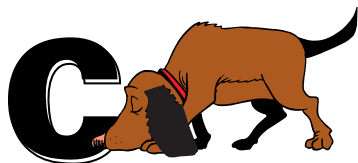
Suppliers

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)

Appendix C

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

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®

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