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LI-1800
Portable Spectroradiometer
Instruction Manual

Publication No. 8210-0030

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WA	Wait. Set end of line delay.		4-1
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Section I
Pre-Operation

1.1 General Information

If you have just taken delivery on your LI-1800 Portable Spectroradiometer, this section will provide you with a quick check to verify that it is working properly. If you had not planned on unpacking the LI-1800 for a while, read the battery charging and storage notes in this section before storing the LI-1800.

In addition to the items you ordered, please check to make sure that you have received the following items:

CALIBRATION DATA - This data relates the detector output of the LI-1800 to a standard lamp. The calibration data has been entered into the LI-1800 at the factory. Keep these calibration sheets in a safe place in case you need to re-enter the data.

SPARE PARTS KITS - There are two bags of spare and replacement items. The purpose of these items will become clear as you become familiar with the instrument.

DATA COMMUNICATION CABLES - There are two output cables included as standard equipment that are used to connect the LI-1800 to a printer or computer. The first is an RS-232C output cable (2232S) with a 25-pin connector at one end and a 9-pin connector on the other. The second cable (1000-04) is a flat ribbon communications cable with 25-pin male and female connectors on both ends. You may also have an optional cable; the 2233S-10 Terminal Extension Leads or the 1800-04 RS-232C Cable.

1.2 Cosine Receptor

The integral cosine receptor should be inspected for damage. The diffusing element is a spherical dome formed from a PTFE sheet. The top of the dome should be approximately flush with the top surface of the black metal body of the cosine collector. Do not apply pressure to the dome, it can easily be deformed. Use the red plastic cap to protect the cosine collector; remove the cap before making measurements.

1.3 The Internal Battery

The LI-1800 is shipped with the internal rechargeable battery (3000B) installed, fully charged, and ready for use. The battery is a sealed nickel cadmium type that can be used in any position (upside down, sideways, etc.). When discharged, overnight charging (16 hours) is sufficient to restore normal capacity. Recharging is accomplished by connecting the AC line cord to the LI-1800. An automatic timer in the LI-1800's circuitry reduces the charging rate after the battery is charged. The LI-1800 should not be used continuously on AC power (see Section 6.6).

When the battery is nearly discharged, a LOW BATT message and the current battery voltage is displayed on the user's terminal after each software command is performed. Exactly how much operating time remains before the instrument automatically switches itself off, is a function of the battery threshold level set by the parameter (PA) command (Section 4.1). The battery threshold level is the battery voltage at which the LOW BATT message is displayed. The LI-1800 automatically switches off at approximately 5.3 volts in order to prevent erratic operation or loss of stored data. Section 6.6 discusses recharging the battery.

Several of the portable terminals sold by LI-COR draw power directly from the LI-1800, but others have their own internal battery. For information on using or charging these terminals, consult Section V.

1.4 Using Line Voltage

Line voltage is supplied to the LI-1800 through the 3 prong receptacle located on the lower left corner of the recessed connector panel (Figure 1-1). Before connecting AC power, select the correct line voltage using the slide switch above the receptacle. Use "115" for 105 - 126 VAC, or "230" for 210 - 252 VAC (the frequency can vary from 48 - 66 Hz). Voltages lower than rated will reduce the charging rate, but cause no damage. Cover the voltage select switch with a piece of plastic tape if the instrument is subject to water splash (prevents switch corrosion).

CAUTION: Avoid using AC power in wet conditions.

1.5 Using an External Battery

An external 12 VDC battery can be used to power or recharge the LI-1800. The DC power connector is located to the left of the AC fuse holder in the recessed connector panel (Figure 1-1).

CAUTION: The external battery voltage must not exceed 15 volts.

When connecting the battery leads (included with the LI-1800) to the battery, connect the lead marked with red heat shrink to the positive (+) terminal. The positive lead is also identified by the square edge on the insulation; the negative lead is round. On the connector, the center post is connected to the positive lead and the negative lead is connected to the outer sleeve. A fuse has been included in the battery leads to protect the instrument. Use only 1 amp fast blow fuses.

1.6 Instrument Storage

The internal rechargeable nickel-cadmium battery (3000B) should be charged before the LI-1800 is stored. During long term storage, recharge the battery once a month (Section 6.6). The battery is used to maintain the memory of the LI-1800 during storage and the power drain (about 2 mA) will discharge the battery in approximately two months. If the battery completely discharges, the data stored in memory will be lost (including calibration data) and must be re-entered. Storing the LI-1800 with a discharged battery will make recharging difficult and could result in permanent damage to the battery.

CAUTION: Do not use the LI-1800 as a long-term data storage medium. Preserve important data by printing hard copies or transferring it to a computer.

1.7 Connecting a Terminal Device

All cables are connected to the LI-1800 through the recessed connector panel on the side of the instrument. The connectors are identified below.

CAUTION: With the exception of LI-COR portable terminals, no connector or device that makes use of either pin 9 or 10 should be connected to the terminal port.

CONNECTING THE 1800-01B

- Connect the 1800-01B to the **Terminal Port** of the LI-1800.

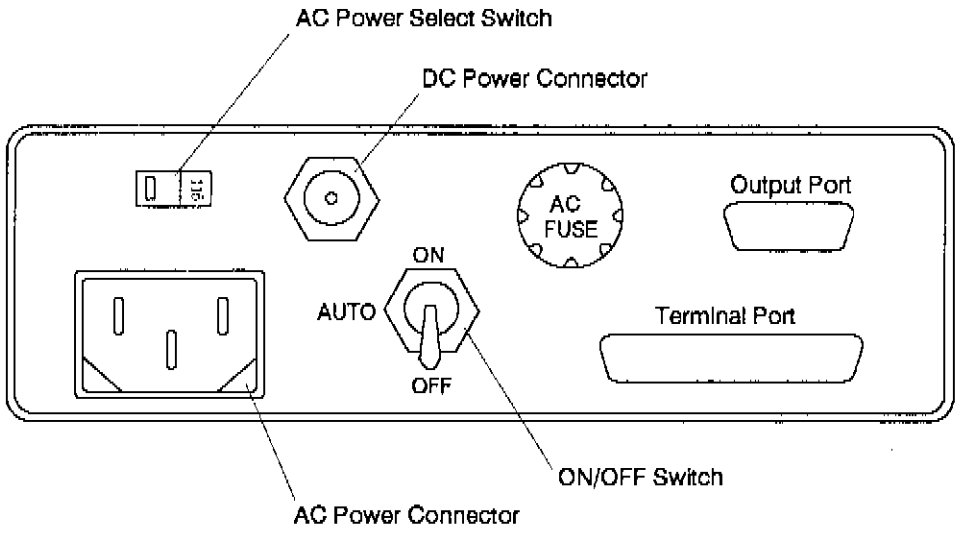


Figure 1-1. LI-1800 Connector Panel.

The communication parameters (baud rate, parity, etc.) of the 1800-01B have been properly configured at the factory. It should not be necessary to make changes to these parameters. The 1800-01B is powered by the LI-1800 and will beep when the LI-1800 is turned on.

Section V contains information on connecting and using earlier models of the portable terminal, and other computer or terminal devices.

INITIATING COMMUNICATION

The LI-1800 power switch is a three position switch. The up position is ON, the down position is OFF, and the center position (AUTO) is a standby mode used with the AL (Alarm) and PR (Program) commands.

- Move the LI-1800 power switch to the ON position.
- After about 4 seconds, press the RETURN key on the terminal to send the LI-1800 a carriage return <cr>. The LI-1800 uses this character to determine the baud rate being used. The LI-1800 will respond with

```
LI-1800.xxx.yyy
aa/bb  cc:dd
FCT:
```

where xxx.yyy is the version of software that is resident in the instrument, aa/bb is the month and day, and cc:dd is the hour and minute according to the internal clock. FCT: is the system prompt for a command.

If the terminal does not respond when RETURN is pressed, check the cable connections and then the communication parameters of the terminal you are using (see Section V).

TERMINAL COMMUNICATION PROCEDURES

The LI-1800 functions in response to commands issued from the terminal. Section IV discusses these commands in detail. There are some operating procedures that should be discussed first, however.

"FCT:" - The function prompt is sent to the terminal by the LI-1800 to signal the completion of a task and to request the user to enter the next desired command. A proper response to this prompt consists of a two character entry, followed by pressing RETURN (sending a <cr>). Since all LI-1800 commands are two character commands, any extra characters after the first two are ignored. Thus, "PLOT" is equivalent to "PL".

Pressing RETURN in response to "FCT:" will cause the LI-1800 to send a list of all software commands to the terminal.

```
AL   AN   BA   BD   BL
BS   CA   CC   CL   CO
CR   CS   DO   D1   DC
DE   DI   DU   ED   X
H0   H1   IL   IT   LA
LI   ME   MU   PA   PL
PP   PR   PT   QA   QD
QI   QP   QR   QS   RA
RE   RU   SC   SH   SP
SY   TI   WA   XF   *B
*D   *L   *Q   !!
```

Each of these 2 letter abbreviations are commands that will initiate routines. Page vi lists these mnemonics with their descriptions.

ALL COMMANDS MUST BE SENT IN UPPER CASE, not lower case.

An improper entry to the FCT: prompt (entering a command that the LI-1800 does not recognize - ZZ or sc, for example) will cause the FCT: prompt to be repeated.

CLEAR - Pressing CLEAR (sending a <break>) on the terminal will abort whatever the LI-1800 is doing and cause "FCT:" to be sent to the terminal. Some routines, such as PT (single wavelength monitoring), require the use of CLEAR for termination.

On the 1800-01B, the break function has been assigned to the CLEAR key, so the CLEAR key does not function as the TransTerm instruction manual indicates. On the earlier model 1800-01A, the break key is located on the upper right side of the keyboard (press the FUNCTION key, and then the BREAK key to execute the break command). The earlier model 1800-01 Portable Terminal has a push-button on the right side of the terminal which functions as the break key.

<break> is not a character, but rather the simulation of a physical break in the transmit line (transmit line goes high, logic 0). During some operations, particularly those involving scanning, the LI-1800 does not check the transmit line as often as it normally does. To abort these operations it may be necessary to hold down the CLEAR key for several seconds.

DEV(Y/N) - If there is an RS-232C connector plugged into the OUTPUT port of the LI-1800, the (Y/N) prompt is given on several functions . A "Y" response will cause the output for that particular function to be directed to the OUTPUT port instead of to the TERMINAL port.

(Y/N) - Any time (Y/N) appears at the end of a prompt from the LI-1800, a yes or no response is required. In every case, the default answer (e.g., just press RETURN) is NO. Thus, the user must make one of 4 responses:

Y + RETURN - yes
N + RETURN - no
RETURN - no
<break> - abort the function (and no)

RETURN - All user entered responses must be terminated by pressing RETURN (entering a <cr>) before the LI-1800 will take any action.

DELETE - Entry errors can be corrected with the DELETE key prior to pressing RETURN. The DELETE key deletes the character to the left of the cursor and then backs up one space.

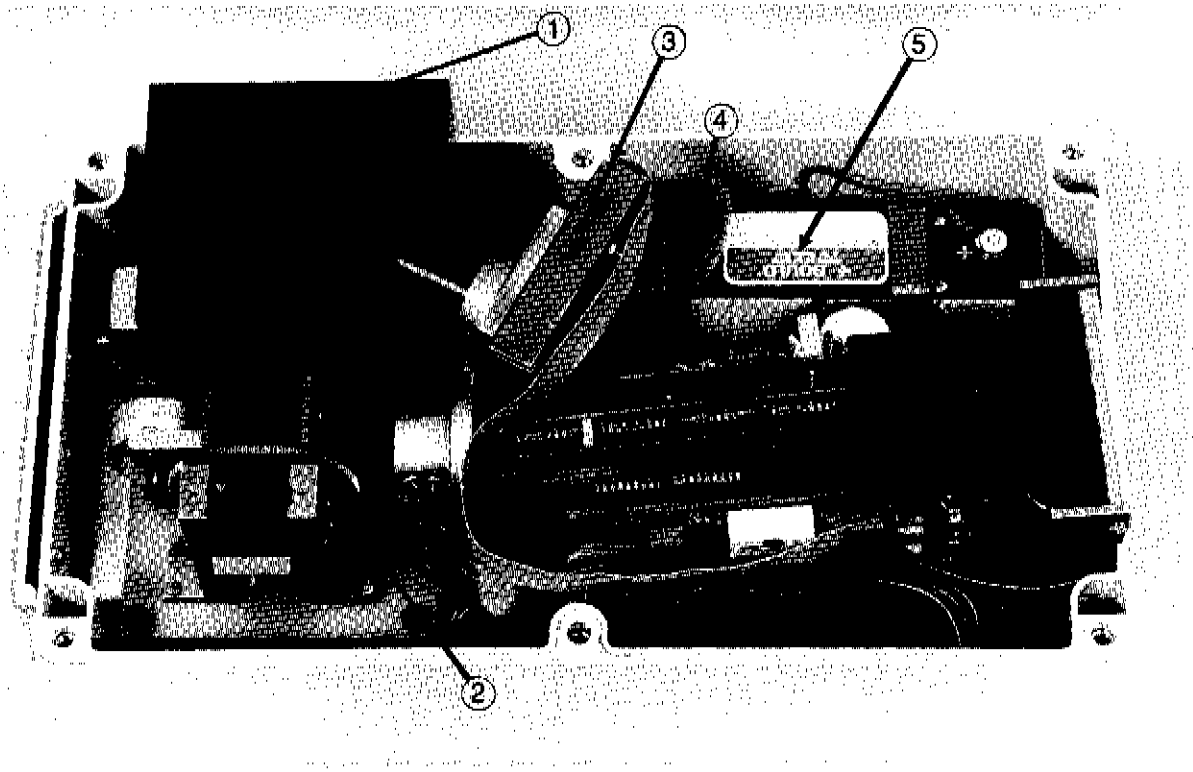
Section II
Theory of Operation

This section gives a brief description of how the LI-1800 works and an overview of the theory of operation. For a more detailed discussion of spectroradiometry, several references are given in Appendix D.

2.1 System Description

The LI-1800 Portable Spectroradiometer is designed to obtain spectral radiation data quickly and easily. Spectral data is fundamental to radiation measurement in that it provides "quality" as well as "quantity" information about a light source.

The major components of the LI-1800 are shown in Figure 2-1.



The LI-1800 is a completely self-contained, battery-operated, microprocessor-controlled spectroradiometer for rapid acquisition of spectroradiometric, radiometric, and photometric data. The standard optical receptor of the LI-1800 is a PTFE-dome cosine receptor with a 180° (2π steradian) field of view. The monochromator is a holographic grating, motor-driven scanning type (typically 35 nm s^{-1}) which disperses the radiation into its spectral components. At the entrance to the monochromator is a filter wheel with seven filters and an opaque target. The filters reject out-of-band energy (including higher spectral orders) to reduce stray light. The opaque target is placed over the entrance slit before and after each scan to provide dark-signal monitoring. The dark signal is automatically subtracted from the measured signal after each scan. The detector, located at the exit slit of the monochromator, is a silicon photodiode operating in the photovoltaic mode. The internal

computer handles all collection, storage, communication and manipulation of data files. A block diagram of the LI-1800 operation is given below.

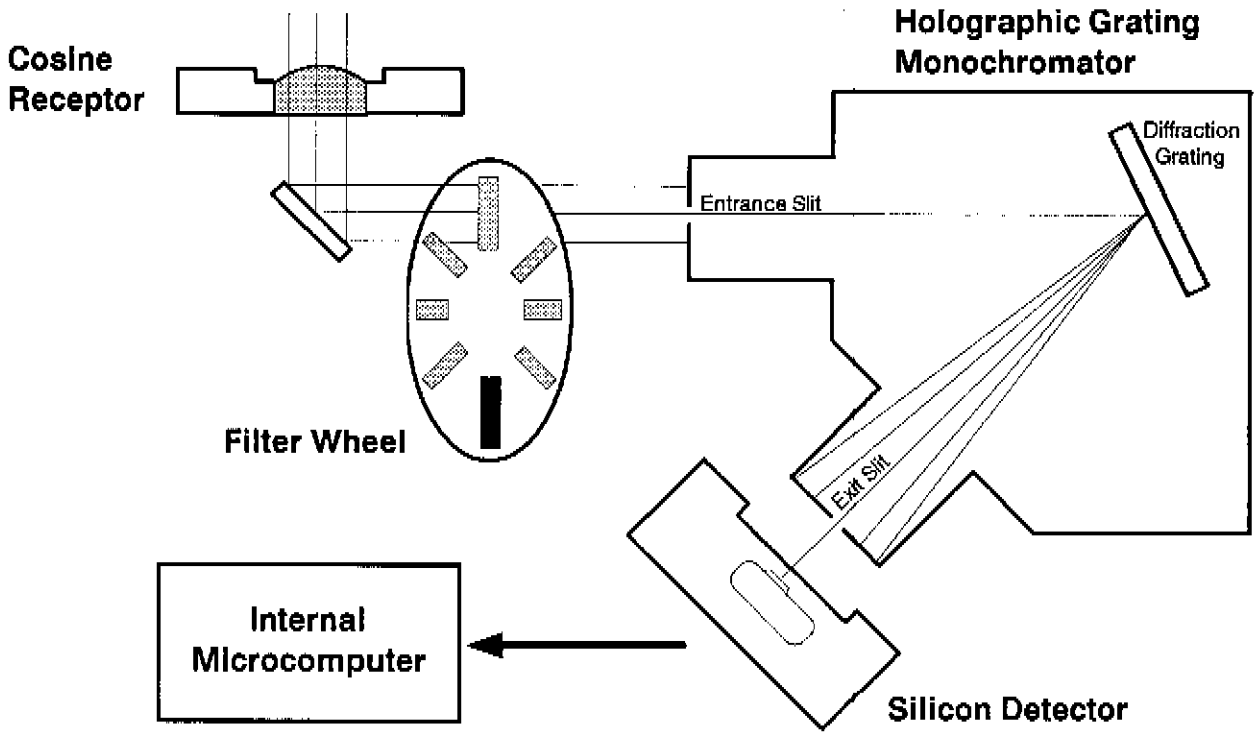


Figure 2-2. LI-1800 operational diagram.

A major feature of the LI-1800 is the "on-board" computer/electronics package which controls the wavelength drive, digitization of the analog signal, storage of the digital data, and file management operations; it also monitors battery voltage, filter wheel operation, and communications to the terminal. Internal RAM capacity is 512 K bytes total, in sixteen 32 K byte banks. Scan limits are 300 to 850 nm (optional 1100 nm), with selectable scan intervals of 1, 2, 5, or 10 nm. Approximately 600 scans from 350 to 850 nm with 2-nm step size fills the memory. All operations are implemented through the use of two-letter commands, supplemented by a series of prompts for limits, intervals, file names, remarks, etc. The data reduction software includes routines for the conversion to quantum (photon flux) units, photosynthetically active radiation, illuminance, linear combinations of files, and ratios and products of files. Data may be sent (via RS-232) to a printer in digital format, plotted on a dot-matrix printer, or downloaded to mainframe or personal computers for further analysis or archival purposes.

2.2 LI-1800 Optical System

Light quality refers to how light is distributed with respect to wavelength. Some light sources, such as lasers, have an extremely narrow distribution. The He-Ne laser only emits at 632.8 nm, and it appears red to the eye. The setting sun can also appear red, but its spectral distribution is very broad and irregular.

The LI-1800 measures the spectral concentration of radiant power by first dispersing the radiation with a diffraction grating monochromator, and measuring the energy in each narrow waveband of the resulting spectrum with a silicon detector.

COSINE RECEPTOR

The standard cosine receptor is a translucent (PTFE) collector which samples radiant flux according to the cosine of the incident angle (follows Lambert's cosine law), and will accept radiation from all angles of a hemisphere. This allows the spectroradiometer to measure flux densities per unit area (m^2). A spectroradiometer which lacks an accurate cosine correction can have significant error under diffuse radiation conditions which occurs, for example, when measurements are made under plant canopies or in the air at low solar elevations. A more complete description of the cosine relationship as well as typical cosine and azimuthal response data for the LI-1800 standard cosine receptor is given in Section IX.

FILTER WHEEL

The collected radiant power must first pass through the filter wheel before it enters the monochromator. The LI-1800 only measures at one location in the spectrum at a time; light at other wavelengths is not needed, and indeed is not even wanted, since it will induce errors if it finds its way to the detector. The filter wheel serves to reduce this "stray" light by filtering out light that is not in the same region of the spectrum as that being measured. The operation of the filter wheel is totally automatic, and is controlled by the internal computer. Sequential filter positions correspond with the following wavelength intervals: 1-298 (open, no filter); 299-348; 349-418; 419-558; 559-678; 679-775; 776-938; 939-2598; 2599 and up (open, no filter).

The filter wheel also serves as a dark reference. One of the slots in the filter wheel is blocked by a black surface. When the wheel is in this position, there is no light reaching the detector, and any output by the detector is considered the true zero level. *The dark reading is automatically checked before and after each scan.* If the difference in dark readings is more than 3 mV, a warning message (xx MV DRIFT) is displayed on the terminal. The most likely cause of differing dark readings is a temperature difference of the detector before and after the scan. When the drift error message is displayed after a scan, the scan should be retaken if possible.

MONOCHROMATOR

The monochromator disperses the polychromatic radiation transmitted through the filter wheel into narrow wavebands and passes each to the detector. It does not isolate truly monochromatic radiant power. Essential components of the monochromator include the entrance slit, grating and exit slit.

The entrance slit is a rectangular opening through which radiation must pass to get into the monochromator. The smaller the entrance slit, the more spectrally "pure" the resulting dispersed radiation will be.

The holographic grating is the actual wavelength dispersing component in the monochromator. As radiation from the entrance slit strikes the grating, it is diffracted toward the exit slit. The net result of this diffraction is that different wavelengths are projected at slightly different angles toward the exit slit. By changing the angle between the entrance slit and the face of the grating (accomplished by rotating the grating with a calibrated reproducible drive mechanism), selected wavelengths of light can be made to pass through the exit slit, while the rest are absorbed by the blackened interior of the monochromator.

The purpose of the exit slit is to restrict and define the waveband of radiation which reaches the detector. Since radiation directed at the exit slit has been spectrally dispersed by the grating, the width of the exit slit directly determines the spectral width of the waveband that reaches the detector. For example, when the 1/2 mm slits are used with the LI-1800's visible range monochromator (300-850 nm), the half power bandwidth is 4 nm, and the total bandwidth is 8 nm. Thus, when the grating is set at 500 nm, the detector senses 496

through 504 nm; it "sees" all of the radiation at 500 nm, half the radiation at 498 and 502 nm, and no radiation below 496 or above 504 nm (Figure 2-3).

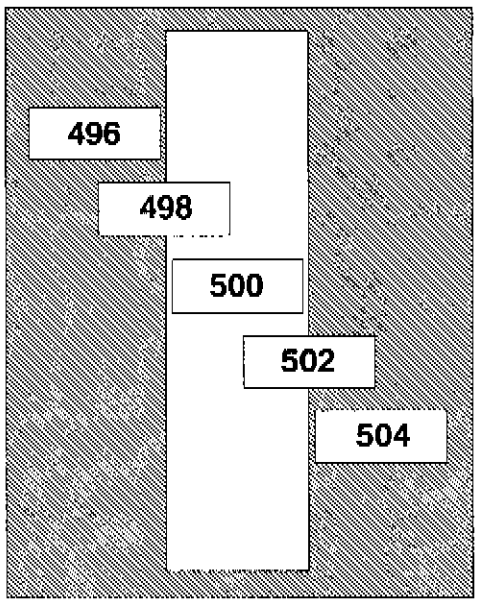


Figure 2-3. Monochromator exit slit. The radiant power passing through the exit slit is proportional to the fractional area of each rectangle that is not blocked by the side walls of the exit slit (assume equal power at each wavelength).

Entrance and exit slits are usually the same size. With narrower slits greater resolution is possible, but the total amount of radiation reaching the detector is reduced. Selection of slit size is a trade-off between wavelength resolution and signal-to-noise ratio. Additional information on monochromator slits as well as a procedure for changing slits is given in Section VIII.

DETECTOR

After emerging from the monochromator, the radiant power is received by the detector which produces a current proportional to the amount of radiation. This current signal is amplified, converted to a voltage, passed through an analog-to-digital converter, and is made available to the internal microcomputer.

The detector in the LI-1800 is a silicon photodiode. Silicon has several advantageous properties: it is mechanically rugged, it does not fatigue, and it has good temperature and long term stability. The temperature stability is best at wavelengths between 400 and 950 nm. Beyond these wavelengths, the silicon's temperature stability degenerates markedly. This is not a problem as long as measurements are taken at about the same temperature at which the instrument was calibrated.

The LI-1800 is calibrated at approximately 25 °C. The temperature dependence of the detector is:

-0.1% / °C, at 350 nm
0.05% / °C, from 400 - 950 nm
0.5% / °C at 1000 nm
1-2% / °C at 1100 nm

If the LI-1800 is to be used at temperatures greatly different from 25 °C it is best to calibrate at, or near the operating temperature. This is particularly true if high accuracy is desired in the 1000-1100 nm waveband.

2.3 Instrument Calibration

The LI-1800 has been calibrated by LI-COR and the calibration information is stored as data files in the LI-1800's memory. Calibration of the LI-1800 involves the use of a standard lamp of known spectral power distribution to establish the instrument's response function. The calibration files relate the detector signal (mV) to the irradiance (or radiance) at each wavelength.

When the LI-1800 is calibrated, all elements of the optical path (the radiation receptor, fiber probe (if any), filter wheel, monochromator slits and grating, silicon detector) affect the calibration file. If the radiation receptor or some other optical component is changed, the calibration file becomes invalid for the new optical configuration. Accordingly, each optical receptor used with the LI-1800 requires a unique calibration file. LI-COR has designated the following calibration files for the various optical inputs:

COSC	Calibration file for the standard cosine receptor.
RCOS	Calibration file for the 1800-11 Remote Cosine Receptor.
TELA	Calibration file for 1800-06 Telescope Option A (15° field of view).
TELB	Calibration file for 1800-06 Telescope Option B (3° field of view).
TELE	Calibration file for the combination of 1800-06 options C and E.
TELF	Calibration file for the combination of 1800-06 options C and F.

The presence of these files in the LI-1800 can be verified using the list command (*L). Note that the 1800-12 External Integrating Sphere uses a reference scan as the standard and does not need a unique calibration file (see Section XI).

Absolute calibration of the LI-1800 is derived from lamp standards of spectral irradiance (W m^{-2} nm^{-1}), which produce a known output when operated according to prescribed conditions. At LI-COR, working standard lamps are used for all factory calibrations. A working standard is prepared by calibrating against a primary standard supplied by the U.S. National Bureau of Standards (NBS). Both primary and working standards are 1000 watt quartz tungsten halogen lamps operating at a color temperature of 3150 °K. The maximum uncertainty of the spectral irradiance for a working standard is estimated to be 4% at 300 nm and 2% from 500 to 1100 nm.

An absolute calibration file is generated for each LI-1800 receptor by averaging 10 scans of the working standard lamp in 1 nm steps for the full wavelength range (e.g. 300-1100 nm). This generates a detector output file which contains the average photodiode signal (in millivolts) for 10 scans at each wavelength. The calibration file is computed by dividing the detector output file by a lamp file containing the true spectral irradiance (W m^{-2} nm^{-1}) of the lamp. LI-COR calibrations are stated as ±3 to 10% (depending on wavelength) relative to NBS. It is important to note that these values apply only at the time of calibration. Instrument drift with time will add to the uncertainties.

The LI-1800 measures from unknown radiation sources (E_u) following the equation:

$$E_u = \frac{D_u}{K}$$

where

$$K = \frac{D_s}{E_s}$$

and

D_u = detector output with unknown source (mV)
K = calibration file = spectroradiometer's response function (mV m^2 nm W^{-1})
D_s = detector output with standard source (mV)
E_s = absolute standard of spectral irradiance (W m^{-2} nm^{-1})

The LI-1800 can automatically divide the detector output file by the calibration file as discussed in Section III.

IMPORTANT: In order to maintain the LI-1800 within its specified accuracy, recalibration is recommended every 6 months. This can be accomplished using the 1800-02 Optical Radiation Calibrator, or by returning the LI-1800 to LI-COR (or a LI-COR distributor) for a factory calibration.

Many concepts concerning LI-COR calibration procedures for lamps and spectroradiometers are explained in greater detail in a calibration report which is available upon request (Appendix D).

Section III
Software Overview

3.1 The Operating System

Operation of the LI-1800 is entirely computer controlled. The user interacts with the instrument's internal computer through a terminal using a menu of simple two character commands to control all phases of instrument operation.

When a command is entered, the LI-1800 asks the necessary questions for the execution of the command. For example, when told to scan, the LI-1800 asks for the wavelength range to be scanned, the wavelength sampling interval to be used, the number of scans to be averaged, and the name of the file in which to store the data.

FILE STRUCTURE

Data storage in the LI-1800 is based upon a file system. A file is usually generated by scanning, which is the process of recording detector output as a function of wavelength over a specified wavelength range. A file can also be generated by entering values from the terminal, or by numerical operations on existing files, such as dividing one file by another to create a third file.

Associated with every file is a unique name, generated by the user, and information concerning the file, such as the wavelength range, the date the file was created, and the user entered remarks concerning the file. The information about the file is stored in the file "header". A sample file header, as it would appear on a printed page, is shown below:

```
FILE: JJ3   CHAMBER 6 SCAN 3      - Name and remarks.
LIMS: 300 TO 1100 NM              - Spectral limits of the file.
INT: 2 NM                         - Data interval.
DATE: 06/28  15:05                - Date and time of file creation.
#SCANS: 1                         - # of scans averaged.
```

Once created, a file remains in memory until deleted by the user.

FILE NAMES AND REMARKS

File names can have up to 4 characters, numbers, punctuation marks, or spaces. Each file has a unique name given to it by the user when it is created. Some examples of valid file names are:

```
ABCD
Z1
   ?  (3 spaces and a ?)
5 W!
```

The remarks field in the file header can contain up to 15 user entered characters, and is optional.

The pound symbol (#) is reserved for a particular operation, as explained in the discussion of "Sequential Files" below.

PROTECTING A FILE

If the first two characters of the remarks field of a file are asterisks (**), then that file is protected and cannot be deleted or overwritten. The exception to this is the **!! command which deletes all data files in memory.**

An existing file can be protected by using the RE command (rename) to change the remarks field and add the asterisks.

SEQUENTIAL FILES

The pound character (#) has a special meaning when used in a file name; it is the access character for automatic sequential file generation. When # is specified as the file name, the LI-1800 will actually name the file ##nn, where nn is the next integer above the number associated with any currently existing sequential file. For example, if the list of files is currently

DATA
R
COSC

and # is specified as the name of a file to be created, then the list of files will become

##00
DATA
R
COSC

Subsequent use of the # specifier would generate files ##01, ##02, etc. This feature is most useful with the PR command which is used to configure the LI-1800 to automatically record scans at a user specified time interval.

DEFAULT FILE NAMES

Whenever the LI-1800 prompts for the name of a file ("FILE:"), you can just pressing RETURN to use the most recently referenced file (except sequential files).

If the most recently referenced file was "#" or "##nn", then press RETURN in response to the FILE: prompt in a scan (SC) or create (CR) mode results in the newly generated file being named the next higher sequential file even though the new name is not immediately displayed to the user.

If the most recent file name referenced was "#", then pressing RETURN in response to the FILE: prompt during a data calculation or output function (such as IT or PL) results in a "CAN'T FIND" message being displayed. In this case the full sequential file name (##nn) must be entered in order to perform the desired function. However, if the most recently referenced file was "##nn", then pressing RETURN in response to the FILE: prompt during a data calculation or output function causes the LI-1800 to use the currently referenced file for the selected function.

MEMORY BANK SELECTION

The internal memory of the LI-1800 is configured as a series of banks. Each bank represents a 32K byte block of memory. The total memory capacity of the LI-1800 is 512K bytes RAM. 256K bytes are standard and an additional 256K bytes are available in the form of an optional memory board (256KM Memory Board).

Each 32K bank operates as a separate entity, with no automatic bridging or switching between banks (the only exceptions are the functions whose mnemonic starts with an asterisk (*), such as *B). For example, if you try

to divide by a calibration file that is not in the currently selected bank, the LI-1800 will issue a "FILE NOT FOUND" message. The calibration file for the optical receptor in use must be in the currently selected bank. The memory bank selection command (ME) and the copy command (CO) which is used to copy a file from one bank to another are described in Section 4.4.

IMPORTANT: The automatic divide parameter and file name are unique within each bank. Switching to a new file bank will disable the automatic divide even if the file is resident, unless it has been previously set using the PA command from the new bank.

When one memory bank is full, the user must switch to a new bank. Bank numbers range from 0 to 19 depending on the combination of RAM boards which are installed in the instrument. To find out which banks are operative, use the *L command to list the contents of all banks.

FILE SIZE

There is no arbitrary maximum number of files that can be held in memory; the limit is strictly determined by the available memory and the size of the individual files.

A file header occupies 50 bytes of memory, plus 3 bytes for each data point in the file. A file ranging from 300 nm to 850 nm in steps of 5 nm would have 111 data points and occupy 383 bytes of memory. The number of bytes available for new files can be found by doing a *L command. The *L command gives the memory available in all banks. The last line of the listing for each bank is MEM:xxxxx, where xxxxx is the remaining memory in bytes.

3.2 Setup and Configuration

The discussion below provides a basic instrument configuration which will allow you to scan a light source using the standard cosine receptor. The discussion of each software command is abbreviated to provide greater continuity. Section IV provides a complete discussion of all of these commands.

At this point it is assumed that a terminal is connected to the LI-1800, and that the LI-1800 and the terminal are turned on and working properly. If that is not true consult Sections I and V.

- Use the list command (*L) to list the contents of the memory in all banks. (Remember all commands use upper case letters.)

  Press SHIFT *, then L, and then RETURN.

Note the speed at which lines are sent to the terminal. If you are using a one or two line terminal it may be too fast. This speed can be changed by using the wait command (WA) to change the length of the delay in sending a line to the terminal. (Many terminals, such as the older 1800-01A, also have a feature which allows you to scroll the display to see lines previously displayed. This is accomplished with the arrow keys in the lower left corner on the 1800-01A.)

- Enter the wait command (WA) to view or to change the end-of-line delay.

  Type W, then A, and then RETURN.

  The LI-1800 responds by listing the value of the old end-of-line wait (in milliseconds) and prompting you for a new value.

- Enter 1000 to set the end-of-line delay at 1 second.

- Repeat the "*L" command and note the difference in the speed with which new lines are displayed.

Continue to use the wait command (WA) until you find a speed that suits you. (The range is 0 to 5000).

If at any time you wish to accept the current value of the wait function and not enter a new value, simply press RETURN without entering a number.

SETTING THE TIME

- Enter the time command (TI) to set the LI-1800's internal clock.

The LI-1800 responds with the current month, day, hour and minute displayed in *Month/Day Hour:Minute* format. The SET (Y/N) prompt is sent to ask you if you want to reset this value.

- Enter Y if you wish to reset time and date. (If it is already correct you can press RETURN to retain the current values.)

- Enter the current date and time in MM.DD.HH.MM format (put periods or spaces in-between each value).

  For example, if the current date and time are May 12 and 3:25 pm, the new date and time are entered as 5.12.15.25.

The LI-1800's internal clock is a 24 hour clock. Thus, 7:00 pm is entered as 19:00.

SETTING THE SYSTEM PARAMETERS

The system parameters are contained in a list which is accessed using the parameter command (PA).

- Execute the parameter command (PA).

The LI-1800 responds by displaying a list of the current parameters which include the automatic divide, scanning interval, monochromator limits, signal offset, ratio function limits, device baud rate, monochromator reset wavelength, monochromator offset, and battery threshold level. The "SET (Y/N)" is sent to ask you if you wish to change any of the parameters. For the purposes of this discussion we will only concern ourselves with the first three parameters.

- Enter Y to make changes to the parameter list (or press RETURN to leave it unchanged).

Assuming Y was entered, the LI-1800 responds with the prompt DIV (Y/N). The DIV (Y/N) prompt is used to initiate the automatic file divide feature of the LI-1800. In our example, we want to set the divide to Yes in order to divide all scan files, which contain only the mV output of the detector, by a calibration file for the standard cosine receptor (named COSC).

IMPORTANT: The calibration file must reside in the same memory bank as the scan file in order for automatic division to occur.

- Enter Y to implement the automatic divide and enter the file name COSC in response to the FILE: prompt to select the standard cosine receptor calibration file.

If the automatic divide was not set, the files could still be divided by a calibration file at a later time using the divide command (DI).

If the LI-1800 displays a FILE NOT FOUND message after the file name COSC is entered, it is likely that the currently selected bank does not contain any calibration files. If this is the case, press the CLEAR (break) to exit the parameter list and then go to the discussions on selecting memory banks and copying files between

memory banks in Section 4.4.

The next prompt is INT: which allows you to set the default scanning interval. Valid choices are 1, 2, 5, or 10 nm.

- Enter 2 to scan in 2 nm steps over the specified wavelength range.

The LI-1800 responds with the prompt LOMONO: which is used to set the lower limit of the scanning range.

- Enter 300 to set the lower monochromator limit at the lowest wavelength. (Since the default is 300 it is probably set correctly but go ahead and enter 300 anyway.)

The HIMONO: prompt is used to set the upper limit of the scanning range.

- Enter either 850 or 1100 to set the upper wavelength limit at the highest wavelength for the monochromator option you purchased.

- Press CLEAR (same as BREAK on other terminals) to terminate any further changes and to leave all other parameters the same. Be sure to press RETURN on the last parameter changed before you press CLEAR, or that parameter will not be changed.

The system parameters are retained as a permanent part of the LI-1800's memory and will not change unless they are changed using the PA command.

SCANNING A RADIATION SOURCE

Scanning is the process of collecting spectral data. The user specifies the name of the data file, the remarks, the upper and lower wavelengths, and the number of scans to be averaged into one file.

- Type S, then C, and RETURN to initiate the scan command (SC).

- Type DATA (and RETURN) in response to the FILE: prompt to name the new file DATA.

- Type TEST DATA in response to the REM: prompt to add a remark that will be retained in the "header" of the data file.

- Type 300 (and RETURN) in response to the LO: prompt to set the lowest wavelength of the scan. (You can also just press RETURN to use the lower limit set in the parameters which happens to be 300 in this case.)

- Type 1100 (and RETURN) in response to the HI: prompt to set the highest wavelength of the scan (or press RETURN for the default value). Type 850 instead of 1100 if your instrument has a 300-850 nm monochromator.

The #SCANS: prompt is asking for the number of consecutive scans to be averaged during the scanning process. The default (just press RETURN) is 1, and the acceptable range is from 1 to 255.

- Press RETURN to choose the default value of 1 scan.

The scan number, date and time will be shown on the terminal. Next you will hear a dull clicking sound as the monochromator grating is rotated in 2 nm steps, as specified in the parameters. After the scan, the LI-1800 will send the "FCT:" prompt from which you can enter any command.

- Perform the list command (LI) to list the contents of the currently selected bank. The file DATA should be listed.

Now that you have a data file in memory you can use it to learn some of the other LI-1800 commands. For instance, you can perform calculations using the illuminance command (IL) or the chromaticity coordinate command (CC). The contents of the DATA file can be listed to the terminal or output to a printer using the show command (SH). A plot of the DATA file can be made (on EPSON compatible printers) using the plot command (PL).

These commands and many others will be discussed in detail in Section IV.

Section IV
LI-1800 Software

In this section the carriage return after each command, which is accomplished by pressing RETURN on the terminal keyboard, is often represented by <cr>.

4.1 Setup and Configuration Commands

The following commands are used to setup and configure the LI-1800. For special Data Communications configurations, see Section 4.8

WA - End-of-line delay
TI - Time
PA - Parameters
H0 - (H ZERO) Header off
H1 - (H ONE) Header on
LA - User labels
BA - Battery Voltage (check or monitor)

WA Wait

The wait command sets a time delay at the end of each non-prompting line sent to the terminal. This permits data to be easily read on one or two line terminals. The delay is specified in milliseconds, and can range from 0 to 5000.

EXAMPLE:

1800 Response	**User Response**	**Comments**
FCT:		Enter any command.
	WA <cr>	Wait function.
OLD: 0 mS		Current delay is 0 milliseconds.
NEW:		Enter desired delay in milliseconds.
	1000 <cr>	Implement 1 second end of line delay.
FCT:		Enter any command.

SPECIAL CONSIDERATIONS:

Pressing RETURN (<cr>) in response to the NEW: prompt will retain the old delay.

The end-of-line delay is part of permanent memory; turning the power off does not affect the end-of-line delay.

See the END-OF-LINE discussion in Section 4.8 for further details on WA.

TI Time

Current month, day, hour and minute are displayed in a Month/Day Hour:Minute format. The user may reset these values.

EXAMPLE:

1800 Response	User Response	Comments
FCT:		Enter any command.
	TI <cr>	Time function.
06/15 13:33		Current time is June 15, at 1:33 pm.
SET(Y/N)		
	Y <cr>	Change the time.
MM.DD.HH.MM		Enter Month.Day. Hour. Minute.
	7.8.9.10 <cr>	July 8 at 9:10 am.
07/08 09:10		New time verification.
FCT:		Enter any command.

SPECIAL CONSIDERATIONS:

Pressing RETURN (<cr>) in response to the prompt to enter the new date and time will retain the current month, day, hour, and minute.

The time and date are retained as part of the permanent memory.

When entering the month, day, hour, and minute, any non-numeric character (comma, period, letter, space, etc.) can be used as a delimiter between the entries. In the example above, the entry could also have been 7 8 9 10 followed by RETURN.

The clock accuracy under constant temperature conditions will be within 1 minute per month; this accuracy will degrade in fluctuating or extreme temperatures.

PA Parameters

Automatic divide, scanning interval, monochromator limits, signal offset, ratio function limits, device baud rate, monochromator reset wavelength, monochromator offset, and battery threshold level are displayed. The user is given the option of changing any of them.

EXAMPLE:

1800 Response	User Response	Comments
FCT:		Enter any command.
	PA <cr>	Parameter function.
DIV: NOT SET		No automatic divide.
INT: 2		Scanning interval = 2 nm.
MONO: 300-1100		Lower limit=300 nm, upper limit=1100.
OFFSET: 0		Numerical offset for signal noise.
RAT N: 640-660		Numerator limits for RA (Ratio) command.
RAT D: 720-740		Denominator limits for RA command.
DEV BAUD: 4800		RS-232C output port baud rate = 4800.
RESET WAVE: 0		Reset wavelength of the monochromator.
MONO OFFSET: 0		Monochromator offset value.
THRESHOLD: 6.058		Voltage at which LOW BATT is displayed.
SET(Y/N)		Y <cr> to set, <cr> to leave as is.
	Y <cr>	Make changes.
DIV(Y/N)		
	Y <cr>	Implement automatic divide.
FILE:		
	COSC <cr>	Use calibration file COSC.
INT:		
	2 <cr>	Set data interval to 2 nm.
LOMONO:		Lower monochromator limit.
	<break>	Terminate changes.
FCT:		Enter any command.

SPECIAL CONSIDERATIONS:

These values are part of the LI-1800's permanent memory, and are thus retained at power off.

All numeric values will default to their current values in this routine. For example, pressing RETURN for the divide file name causes the last file name referenced to be used.

DIVIDE

When the automatic divide is set, any data file generated by a scan is automatically divided by the selected file. The file named as the divide file is generally a calibration file, although it need not be.

If the file specified for the automatic divide does not exist, the user is prompted to enter another file name. If no files exist in memory, the automatic divide prompt is bypassed, and thus cannot be implemented.

SCANNING INTERVALS

User-selectable wavelength drive intervals are 1, 2, 5, and 10 nm.

MONOCHROMATOR LIMITS

The monochromator limits set in the parameters are the default limits for a scan, provided the automatic divide is not set. If the divide is set, the default limits are the limits of the divide file.

No physical harm can be done by setting the monochromator limits beyond the range of the monochromator. With the automatic divide parameter turned off, it is possible to scan outside the monochromator limits to determine the presence or absence of radiant flux. For example, it is possible to scan above 1100 nm using the 300 - 1100 nm monochromator, although the sensitivity of the silicon detector decreases rapidly above 1100 nm. (The 300-850 nm monochromator will not scan above 850 nm.)

IMPORTANT: Any scans taken beyond the limits of the calibration file will contain only the uncalibrated detector output (mV) and should be used only for qualitative determinations of radiant flux. If the mechanical limits of the monochromator (0 - 850 nm or 0 - 1200 nm) are exceeded, a "WAVE ERR" message will be sent to the terminal during the scan or during a subsequent scan.

SIGNAL OFFSET

OFFSET compensates for the noise in the detector and amplifier of the LI-1800. This value is found by measuring the average dark signal (in mV) and is subtracted from the "raw" data during each scan (see Section 7.4). This OFFSET value is in addition to the dark reading that is automatically subtracted.

RESET WAVELENGTH

Reset wave is the wavelength value to which the monochromator will return after scanning. The LI-1800 scans from numerically higher to lower wavelengths and the monochromator remains at the lowest wavelength after the scan. At the beginning of the next scan, the monochromator grating is rotated to the highest wavelength causing a short time delay between the time the scan command is issued and the time the scan begins. However, if this time delay is undesirable, RESET WAVE can be set to return the monochromator to the specified starting wavelength immediately after each scan instead of before. For example, if you are measuring a wavelength band from 400 to 700 nm, you may want to set the RESET WAVE to 700.

CAUTION: If the RESET WAVE parameter is implemented, the grating motor remains energized after the monochromator is repositioned. This causes an additional current drain (about 400 mA) which can greatly reduce battery life, unless a "break" or power off is used, or the RESET WAVE is set to zero (which will also disable the command).

MONOCHROMATOR OFFSET

MONO OFFSET is an integer value that offsets the monochromator 1/4 nm for each increase of the integer value. Thus, a setting of 3 will offset the monochromator by 3/4 nm. A positive value will offset the monochromator and shift the "raw" data toward 1100 nm. A negative value will offset the monochromator and shift the "raw" data toward 300 nm. The synchronize function (SY) must be executed to implement the change. Since MONO OFFSET causes a shift in the "raw" data but not the calibration file, the LI-1800 should also be recalibrated. MONO OFFSET is related to wavelength accuracy which should be checked before changing this parameter. Wavelength accuracy is checked by scanning a radiation source with known spectral lines (see Section 7.6).

BATTERY THRESHOLD LEVEL

THRESHOLD is the voltage at which the LOW BATT message and the current battery voltage will appear

on the terminal. THRESHOLD is factory set at 6.058 V. However, if more notice is desired before instrument shutdown, this value can be increased. By setting this to a high value, the LOW BATT message will constantly appear, which allows the battery voltage to be monitored. Automatic shutdown will occur at approximately 5.3 V. If the THRESHOLD is set at a high level, be sure to occasionally let the battery drain until automatic shutdown occurs before recharging. This deep cycling enhances battery life.

RELATED COMMANDS

SC, PT, RU, AL - Automatic divide used if set.
CA, SC, RU, CR - Monochromator limits and data interval used.
RA, QR - Ratio function uses limits set with RAT N and RAT D.
DU, IL, IT, LA, LI, PA, PP, PT, RA, SH, SP - Device baud rate used when transferring data to an output device.

H0 Header Off
H1 Header On

Header Off suppresses the file header information on existing files from being displayed on the terminal when that file is referenced. Header On causes the header information to be displayed.

The second character in each command is zero and one, respectively.

EXAMPLE: Compare the effects of H0 and H1 on the PL(PLOT) function.

1800 Response	**User Response**	**<or>**	**1800 Response**	**User Response**
FCT:			FCT:	
	H0 <cr>			H1 <cr>
FCT:			FCT:	
	PL <cr>			PL<cr>
FILE:			FILE:	
	TEST <cr>			TEST <cr>
LO:			FILE: TEST CHAMBER #1	
			LIMS: 300 TO 1100 NM	
	400 <cr>		INT: 2 NM	
etc.			DATE: 06/28 15:05	
			#SCANS: 1	
			LO:	
				400<cr>
			etc.	

SPECIAL CONSIDERATIONS

H1 (or H0) remains in effect until power off or until H0 (or H1) is executed. The default value at power on is H1 (Header On).

H0 is useful for lower baud rates and 1 or 2 line terminals when the user is already familiar with the header information of the files.

RELATED COMMANDS

H1 and H0 affect the following commands:
- Data Manipulation: DI, ED, MU, XF
- Data Calculation: IL, IT, PP, QI, Qr, RA, CC
- Data Output: AN, PL, QA, QP, QS, SH

LA Labels

The label command allows the user to specify up to five labels for data output and calculation functions. The LA command displays these labels, and gives the user an opportunity to modify them.

The format of a label is a:bbbbbbbbbbbbb

The label is defined as any alpha-numeric character, followed by a colon and then up to 13 alpha-numeric characters or spaces. The first character, which precedes the colon, serves as an identifier for that label. The characters following the colon are the label. To reference a particular label, enter its identifier in response to a LABEL: prompt.

EXAMPLE:

1800 Response	User Response	Comments
FCT:		Enter any command.
	LA <cr>	Label function.
DEV(Y/N)		Output labels to a device (if connected).
	<cr>	No.
W:W/M2/NM E: MOL/S/M2/NM I:W/M2 P: MOL/S/M2 R:REFLECTANCE		Label list. The 5 existing labels are listed.
SET (Y/N):		
	Y <cr>	Make changes.
OLD: W:W/M2/NM		
NEW:		
	<cr>	Keep first label as is.
OLD: E: MOL/S/M2/NM		
NEW:		
	T:TRANSMITTANCE <cr>	Change 2nd label.
OLD: I:W/M2		
NEW:		
	<break>	No more changes.
FCT:		Enter any command.
	PL <cr>	Plot on the plotter/printer.
etc.		
LABEL:		Prompt for the label.
	W <cr>	Enter identifier (W) for the W/M2/NM label.

SPECIAL CONSIDERATIONS

Labels are part of the LI-1800's permanent memory, and are thus retained at power off.

If a one character entry is made in response to the LABEL: prompt that does not correspond to any label identifier, that character will be used as the label.

A null entry (just <cr>) in response to a LABEL: prompt will result in no label.

If two or more labels have the same identifier, only the first of those labels can ever be accessed.

Invalid entries (ones whose second character is not a colon) are ignored.

There is no automatic association between a particular command (such as PP) and correct labels. The responsibility for choosing the appropriate units for the label lies wholly with the user.

RELATED COMMANDS

The following commands ask for a label:
Data Output: DU,PL,QD,QP,QS,SH
Data Calculation: IL,IT,PP,QI,QR,RA

BA Battery

Monitors and displays current battery voltage.

EXAMPLE:

1800 Response	User Response	Comments
FCT:		Enter any command.
	BA <cr>	
6.95		Battery voltage (Volts)
6.95		
6.95		
6.95		
6.84	<break>	
FCT:		

Battery voltage will be continuously displayed until the BREAK or CLEAR key is used to terminate the command.

RELATED COMMANDS:

PA - Set a threshold value for battery voltage for the LOW BATT message.

4.2 Instrument Calibration Commands

Calibration of the LI-1800 involves generating a file that, for each wavelength, contains the relationship of detector signal to spectral irradiance (or radiance). This file is known as the CAL file. In general, the CAL file values depend upon the optical path to the detector. Thus, the particular light receptor, the fiber probe (if any), the filter wheel, the monochromator slits and grating, and the silicon detector all affect the CAL file. It follows, then, that *a separate CAL file is needed for each light receptor used*, such as the standard cosine receptor, or the remote cosine receptor with the fiber probe, etc. The integrating sphere does not require a calibration file for normal usage since data is generated by dividing sample and reference scans. (See Section XI)

There are two steps in generating a CAL file for a particular instrument and light receptor. The first step is to execute a scan of a standard radiation source. This will generate a file containing detector output voltages for each wavelength. The second step is to divide this file by a file containing the true spectral irradiance of the standard radiation source for each wavelength.

In practice, the calibration is done by scanning a standard lamp whose spectral output is known. Below is an example of the sequence of events necessary to generate and use a calibration file.

STEP	WAVELENGTHS (nm) ...552 553 554...	UNITS nm
1. Scan the standard lamp, measure detector output:	20730 20230 19720	mV
2. The Lamp Data, or true spectral irradiance, is known:	...0.1323 0.1331 0.1340...	$W\ m^{-2}\ nm^{-1}$
3. The CAL file is computed by dividing detector output by Lamp Data:	...156700 152000 147200..	$mV\ m^{2}\ nm\ W^{-1}$
4. Scan an unknown source measure detector output	...45280 45300 45330...	mV
5. Divide this data by the CAL file:	...0.2890 0.2980 0.3079...	$W\ m^{-2}\ nm^{-1}$

The calibration command (CA) guides the user through the process of generating a CAL file for the LI-1800. This corresponds to the first three steps above.

CA Calibrate

The calibration command is used to generate a calibration file.

EXAMPLE:

1800 Response	User Response	Comments
FCT:		Enter any command.
	CA <cr>	Calibrate.
CUT:		
	<cr>	See explanation below.
LMP FILE:		
	LAMP <cr>	Lamp data in LAMP.
CAL FILE:		
	RCOS <cr>	CAL file to be called RCOS.
REM:		
	**RMTE COSINE <cr>	Protect the file.
LO:		
	300 <cr>	
HI:		
	1100 <cr>	Cal file range: 300-1100nm.
#SCANS:		
	10 <cr>	Average 10 scans.
1 06/15 13:33		Scan number and date displayed.
2 06/15 13:33		
...		
10 06/15 13:37		

SPECIAL CONSIDERATIONS:

The lamp data file should be generated prior to calibration by using the CR (create) function. Lamp data for the standard lamp is normally entered in 10 nm intervals. When the scan(s) are taken to generate the calibration file (usually an average of 10 scans is taken, at 1 nm intervals), the LI-1800 automatically interpolates the lamp data for the wavelengths where there is not a corresponding point in the lamp file. The data interval in the CAL file is set in the parameters (PA); it is the scanning interval (INT) used during a scan.

Two different lamps can be used to generate a CAL file. For example, if lamp A is used between 300 and 500 nm, and lamp B between 500 and 1100 nm, the following would need to be done.

1. Set the scan cutoff ('CUT') to 500 nm.
2. When "LOLMP" is prompted, enter the name of the lamp data file to be used over the 300 to 500 nm range. Similarly, in response to the "HILMP" prompt, enter the name of the lamp data file for the upper range.

   IMPORTANT: The wavelength limits of the two standard lamp files should overlap at the scan cutoff by an amount equal to the data interval used in both lamp files. In our example, the lamp data for lamp A should cover the range 300-510 nm, and lamp B should be 490 to 1100 nm.

3. Lamp A is scanned the number of times specified in the #SCANS prompt.
4. When 'CHANGE' is displayed, change to lamp B and press <cr>. Lamp B will then be scanned the same number of times.

IMPORTANT: The LI-1800 does not automatically change CAL files when the input receptor is changed.

The appropriate CAL file must be specified in the parameters (PA function) for a given memory bank in order for the raw data to be automatically divided by the CAL file. Optionally, the raw data can be manually divided by the appropriate calibration file.

RELATED COMMANDS:
PA - Data interval of the cal file. Used to automatically divide raw data by a CAL file.
CR - Creating a lamp data file from the terminal.

4.3 Scanning and Data Collection Commands

The LI-1800 acquires data by scanning. Scanning is initiated by a keyboard command from a terminal, or a preprogrammed clock-driven interrupt (see Section 4.9). Single wavelength monitoring is also possible.

The following commands are discussed in this section:

SY - Synchronize the filter wheel and monochromator.
SC - Scan over a specified wavelength interval.
PT - Single wavelength monitoring.

SY Synchronize

Synchronizes the monochromator and filter wheel positions.

EXAMPLE:

1800 Response	**User Response**	**Comments**
FCT:		Enter any command.
	SY <cr>	Takes about 15 seconds to perform.
FCT:		Enter any command.

SPECIAL CONSIDERATIONS:

Wavelength synchronization is to 632.8 nm.

This function should be executed before testing the wavelength accuracy of the monochromator, and after a complete power disconnect or any internal servicing. The monochromator should also be synchronized after changing the MONO OFFSET parameter. Failure to synchronize after any mechanical disturbance of the monochromator will result in the message "WAVE ERR" or "FILTER ERR" being displayed when a scan is attempted.

Synchronization occurs automatically before scanning at a preprogrammed power on (see PR command), and anytime upon occurrence of a WAVE ERR.

SC Scan

Scanning is the process of collecting spectral data. The user specifies the destination file, the upper and lower wavelength limits, and the number of scans to be averaged into one. If the automatic divide is set, it is performed after the last scan.

EXAMPLE:

1800 Response	User Response	Comments
FCT:		Enter any command.
	SC <cr>	
FILE:		
	NEW <cr>	File will be called NEW.
REM:		
	TEST DATA <cr>	
LO:		
	300 <cr>	
HI:		
	1100 <cr>	300-1100 nm.
#SCANS:		Number of scans to average.
	<cr>	Defaults to 1 scan.
1 11/01 06:45		Scan #, date and time displayed.
FCT:		Enter any command.

SPECIAL CONSIDERATIONS:

If the file name specified already exists, the user will be asked if the file should be overwritten (purged). If not, a new file name will be requested. Remarks can be the same in any two files.

The upper and lower limits will default to either the monochromator limits (as set in PA), or else the automatic divide file limits, if set. If an invalid limit is entered, the default limit will be used.

IMPORTANT

In normal operation the automatic divide in the parameters is set to yes, and the appropriate calibration file is designated as the denominator in the division. Failure to set this parameter for each bank will result in a file which contains only the uncalibrated detector output in mV (see Section 4.2).

The scanning interval is determined from the parameters (PA), or the automatic divide file.

The number of scans to average may be any number between 1 and 255. The default is 1.

If, upon entering the limits of the file, the LI-1800 responds with a 'RAM OVFL' error message, this means there is not enough room to store the file in the currently selected bank.

RELATED COMMANDS:

PA - Automatic divide, scanning interval, wavelength limits.
SY - Synchronize monochromator and filter wheel.

PT Point Scan

Allows a single wavelength to be monitored at a rate of about once per second. If the automatic divide is set, the division is performed before the data is output.

EXAMPLE:

1800 Response	User Response	Comments
FCT:		Enter any command.
	PT <cr>	
WAVE:		Enter the desired wavelength (nm).
	550 <cr>	
I,P:		Irradiance or photon flux density.
	I <cr>	
10/24 14:30		Time stamp (mm/dd hh:mm).
550 .1233E 1		
550 .1234E 1		
550 .1233E 1		
550 .1233E 1		
etc.		
	<break>	Continues until <break>.
FCT:		

SPECIAL CONSIDERATIONS:

If an output device, such as a printer, is connected to the LI-1800 (see Section 5.4), the prompt

DEV(Y/N)

will be asked. A 'Y' response will cause the PT data to be output to the device instead of the terminal. The device format is 4 readings per line instead of the 1 reading per line that the terminal receives.

If the automatic divide is not set, the I,P: prompt will not be asked, and the output will have units of mV (simply detector output). If the I,P prompt is asked (meaning the automatic divide will be performed), a 'P' response specifies that a quantum transform is to also be performed. Assuming the automatic divide file is a calibration file, the resulting units would be μmol s^{-1} m^{-2} nm^{-1} for the 'P' response, and W m^{-2} nm^{-1} for the 'I' (default) response.

IMPORTANT: LI-1800's with software version LI-1800.04.07 and prior, give incorrect values when the "P" option is used.

Every twenty data values, the LI-1800 will re-establish the dark reading, resulting in a slight pause in the data sampling. At the same time it will show the current date and time.

The actual sampling rate depends upon the amount of light measured, whether or not the automatic divide is set, the end of line delay (WA) and handshaking (D1).

RELATED COMMANDS:

PA - Automatic divide.

4.4 File Handling Commands

Several commands exist for file handling: listing, renaming, and deleting.

LI Lists existing file names, creation dates, and remarks on current bank.
***L** Lists existing file names, creation dates, and remarks on all banks.
DE Delete a file.
RE Rename a file and/or edit the remarks.
CL Delete all unprotected files.
!! Deletes all files on the currently selected bank (even protected).
CO Copies a file from one bank to another.
ME Changes currently selected bank.

LI List
*L List

The LI command lists all files names, remarks, and creation dates, and remaining memory (in bytes) on the bank in use. The *L command is the same as LI except that *L lists all banks instead of just the currently selected bank.

EXAMPLE:

1800 Response	**User Response**	**Comments**
FCT:		Enter any command.
	LI<cr>	
BANK 1 SUN 04/11 12:00 CLEAR SKY ROOM 04/11 11:30 FLUOR.LAMP TEST 04/11 11:28 COSC 01/12 23:59 **CAL FILE LAMP 01/12 23:45 **LAMP DATA		List of files in memory bank 1.
MEM: 27326		Remaining memory in bytes.
FCT:		Enter any command.

SPECIAL CONSIDERATIONS:

The newest file appears at the top of the list.

RELATED COMMANDS:

WA - On one or two line terminals, provides a convenient rate for reading the list.

DE Delete

Deletes an existing file in the currently selected bank.

EXAMPLE:

1800 Response	User Response	Comments
FCT:		Enter any command.
	DE <cr>	
FILE:		
	JUNK <cr>	
		Momentary delay.
JUNK DELETED		
FCT:		

SPECIAL CONSIDERATIONS:

If the file is protected (** in first two characters of remarks), then the file name will be rejected and "PROTECTED" will be displayed because the file cannot be deleted. (Protected files can be deleted by using the RE command to change the remarks or by using the !! command to delete all files.)

If the file to be deleted is in another bank, the LI-1800 will send a "CAN'T FIND" message since only one bank can be accessed at a time.

If the file being deleted is not the most recently created file (i.e., not at the top of the stack of file names generated by LI), then the instrument will automatically move the files down that are above the one being deleted to conserve memory. This process can take up to several seconds to complete if a lot of data has to be moved. *It is therefore critical that the LI-1800 be allowed to complete the entire process, or else data can be lost.*

IMPORTANT: Do not press "CLEAR" (<break>) on the 1800-01B or turn the power off until the FCT: prompt is displayed after a DE. Similarly, do not attempt a DE if the battery is low (LOBATT message) and an unknown amount of operating time remains.

RELATED COMMANDS:

RE - To protect or unprotect files.

RE Rename

Allows a file to be renamed and its remarks field changed.

EXAMPLE:

1800 Response	User Response	Comments
FCT:		Enter any command.
	RE <cr>	
OLD:		
	ETR <cr>	Or any other file that exists in the current bank.
NEW:		
	<cr>	Keep name the same.
OLD REM: IMPORTANT DATA		
REM:		
	**IMPORTANT <cr>	Protect this file.
FCT:		Enter any command.

SPECIAL CONSIDERATIONS:

Pressing RETURN in response to the NEW: prompt will preserve the former name and remarks, if any.

Files CANNOT be renamed as sequential (##) files. Therefore, to change the remarks of a sequential file, the file name as well as the remarks must be changed.

RELATED COMMANDS:

LI - Shows all file names and remarks in the currently selected bank.
*L - Shows all file names and remarks in all banks.

CL Clear Bank
!! Clear Memory

The CL command deletes ALL unprotected files in the bank that is currently in use. The !! command deletes ALL files *including* protected files in *all* banks.

CAUTION

The !! command should be used very carefully since it will delete even protected files (such as calibration files!).

EXAMPLE:

1800 Response	**User Response**	**Comments**
FCT:		Enter any command.
	CL<cr>	
CLEAR(Y/N):		
	Y<cr>	Verification
FCT:		Enter any command.

SPECIAL CONSIDERATIONS:

The CL command should also be used with care since all but the protected files are deleted. Important data could inadvertently be lost.

RELATED COMMANDS:

LI - To see which files would be deleted.
DE - To delete individual files, one at a time.
RE - To change protected status.
CO - To copy important files into another bank before using the CL command.

ME Memory Select

The ME select command changes the memory bank that is currently in use.

EXAMPLE:

1800 Response	User Response	Comments
FCT:		Enter any command.
	ME<cr>	
BANK:		Select bank number.
	1<cr>	
FCT:		All functions now operate on files in bank 1.

SPECIAL CONSIDERATIONS:

Each memory bank operates independently of the others. There are no bridges or links between banks that would make them appear as one, large, continuous bank. Most commands (except those preceded by a *) operate only on one bank at a time. See Section 3.1.

Valid bank numbers are 0 through 19 depending on the system configuration.

RELATED COMMANDS:
LI - To see which files exist on the current bank.
***L** - To see which banks exist and to see the files each bank.
CO - To copy a file from one bank to another.

CO Copy

The CO command copies a file from one bank to another.

EXAMPLE:

1800 Response	User Response	Comments
FCT:		Enter any command.
	CO <cr>	
ORG BANK:		Which bank is the file in now?
	1 <cr>	
ORG FILE:		What is the name of the file to transfer?
	COSC <cr>	
DEST BANK:		Transfer to which bank?
	2 <cr>	
DEST FILE:		File name in new bank.
	CAL1 <cr>	
FCT:		COSC now appears in bank 2 under the name CAL1.

SPECIAL CONSIDERATIONS:

After switching to an empty bank, the calibration file must be copied into the new bank in order to use the automatic divide feature when scanning. The automatic divide feature of the parameters must then be set from the new bank using the PA command.

To give the destination file the same name as the source file, just press RETURN in response to the DEST FILE: prompt.

RELATED COMMANDS:

ME - Specify which is the active memory bank.
LI - To find out which files are in the bank currently being used.
*L - To find out which files are in all banks.

4.5 Data Manipulation Commands

Data residing in the LI-1800's file system may be manipulated and edited in several ways. In addition, a file may be created directly from the terminal by manually entering the data. This section covers the following commands:

CR - Creates a file from the terminal using manually entered data.
ED - Edit an existing file.
DI - Divide two files, store contents in a third file.
MU - Multiply two files, store contents in a third file.
XF - Transformation of the form F = aA + bB + c, where F, A, and B are files, and a, b, and c are constants.

SPECTRAL RANGE AND INTERVAL

Since the functions DI, MU, and XF operate on 2 files, there must be some consistency between the two in terms of their spectral ranges and data intervals. In general, the following rules apply:

1. The wavelength limits chosen for the computed file must be within the intersection of the limits of the two existing files. Thus, if file A spans 400 to 700 nm, and file B spans 300 to 600 nm, the limits on the file resulting from the division of files A and B must be within a 400 to 600 nm range.

2. The data interval of the computed file must be a common denominator of the intervals of the two existing files, chosen from the following set: 1, 2, 5, or 10 nm. The table below gives permissible values of the data interval for computed files, given the intervals of the two operator files.

FILE A

FILE B	1 nm	2 nm	5 nm	10 nm
1 nm	1,2,5,or 10	2 or 10	5 or 10	10
2 nm	2 or 10	2 or 10	10	10
5 nm	5 or 10	10	5 or 10	10
10 nm	10	10	10	10

CR Create

The CR command creates a file using data entered from the terminal.

EXAMPLE:

1800 Response	User Response	Comments
FCT:		Enter any command.
	CR <cr>	
FILE:		
	NEW<cr>	
REM:		
	CREATED FILE <cr>	
LO:		
	400 <cr>	
HI:		
	700 <cr>	Limits (400-700 nm) for 'NEW' file.
400:		
	1.234<cr>	
410:		
	1.250<cr>	
(etc.)		
700:		
	.6680<cr>	
FCT:		Enter any command.

SPECIAL CONSIDERATIONS:

The data interval is determined from PA (parameters). Wavelength limits can be defaulted; the wavelength limits defined in the parameters will result.

Numbers should be entered using the characters 0 thru 9 plus a decimal point. If no decimal is entered, it is assumed that it lies to the right of the entry (e.g. 900 = 900.). Only 4 significant digits are used by the LI-1800. The numeric range of acceptable entries is -99999999999999 to 999999999999999. The closest non-zero numbers to zero that can be entered are -.0000000000001 and .00000000000001.

Data can also be entered in exponential format. Examples of suitable entries are 1.234E5, -1234.E7, -123.4E-10. If the decimal point is missing, it is assumed to be immediately prior to the 'E'.

The DELETE key can be used to correct entries before pressing RETURN and the ED command can be used to change an entry after all values are entered.

<break>ing out of the CR function before all the entries are made will leave the file intact, with zero values for all un-entered wavelengths.

A null entry (just <cr>) to a prompt for data for a particular wavelength will cause 0 (zero) to be entered as the data value.

RELATED COMMANDS:

PA - Used to set the wavelength interval for the data file, as well as the default wavelength limits. The automatic divide has no effect on a CR generated file.
ED - For correcting erroneous entries after all entries are made.

ED Edit

The contents of an existing file may be edited using this command. Note that only values for existing wavelengths may be modified; the wavelengths themselves remain the same. The header information, including the spectral range, cannot be changed.

EXAMPLE:

1800 Response	**User Response**	**Comments**
FCT:		Enter any command.
	ED <cr>	
FILE:		Specify file for editing.
	DATA <cr>	
		Header information displayed here, if not suppressed by the H0 function.
WAVE:		Starting wavelength (nm) to be edited.
	550 <cr>	
550NM .0000E00		
550NM:_		
	444 <cr>	Change this value to **444.**
550NM: 444		
WAVE:		
	<cr>	Press RETURN to view next wavelength in the file.
552NM: .1240E2		
552NM:	<break>	Stop editing.
FCT:		Enter any command.

SPECIAL CONSIDERATIONS:

Each entry in a file is edited beginning at the specified wavelength and continuing to the end of the file. <break> will terminate editing before the end of the file.

The default wavelength at any time is the last wavelength edited plus the data interval.

DI Divide

Two files can be divided, and the result stored in a third file.

EXAMPLE:

1800 Response	User Response	Comments
FCT:		Enter any command.
	DI <cr>	
NUM:		Specify numerator file.
	CEO <cr>	
		Header information for CEO is displayed, if not suppressed by the H0 function.
DENOM:		Specify denominator file.
	REF5 <cr>	
		Header information for REF5 is displayed, if not suppressed by the H0 function.
LO:		Lowest wavelength for spectral range of computed file.
	400 <cr>	
HI:		Highest wavelength for spectral range of computed file.
	1100 <cr>	
INT:		Data interval.
	2 <cr>	
QUO:		Name the quotient file.
	NEW <cr>	
REM:		Enter remarks for quotient file.
	CEO/REF5 <cr>	
		Brief pause while divide executed.
FCT:		Enter any command.

SPECIAL CONSIDERATIONS:

The computed file cannot also be one of the operand files.

Permissible data intervals of the resultant file depend on the intervals of the operand files. See the note at the beginning of this section.

The maximum wavelength range possible can be obtained by defaulting the LO and HI values.

MU Multiply

Two files can be multiplied, and the result stored in a third file.

EXAMPLE:

1800 Response	User Response	Comments
FCT:		Enter any command.
	MU <cr>	
FILEA:		Name of first file.
	GG1 <cr>	
		Header information for GG1 displayed unless suppressed by H0.
FILEB:		Name of second file.
	AG3	
LO:		Lowest wavelength for spectral range of computed file.
	400 <cr>	
HI:		Highest wavelength for spectral range of computed file.
	700 <cr>	
INT:		Data interval.
	2 <cr>	
PROD:		File name for the product.
	BL2 <cr>	
REM:		Remarks for the product file.
	GG1*F7A <cr>	
		Brief pause while multiply executed.
FCT:		Enter any command.

SPECIAL CONSIDERATIONS:

The computed file cannot be one of the operand files.

Permissible data intervals of the resultant file depend on the intervals of the operand files. See the note at the beginning of this section.

The maximum wavelength range of the resultant file can be obtained by defaulting the LO and HI values.

XF Transformation

A transformation of the form F = aA + bB + c can be performed, where a, b, and c are numeric constants, A and B are existing files, and F is the computed file. Among other things, this command can be used to add, subtract, and average files.

EXAMPLE:

1800 Response	User Response	Comments
FCT:		Enter any command.
	XF <cr>	
FILEA:		Name of first file.
	S <cr>	
		Header information for S displayed if not suppressed by H0.
A=		The constant a.
	1 <cr>	
FILEB:		Name of second file.
	T<cr>	
		Header information for T displayed if not suppressed by H0.
B=		The constant b.
	-1 <cr>	
C=		The constant c.
	0 <cr>	Transformation will be file T subtracted from file S.
LO:		Lowest wavelength for spectral range of computed file.
	300 <cr>	
HI:		Highest wavelength for spectral range of computed file.
	850 <cr>	
INT:		Data interval.
	2 <cr>	
FILEF:		Name the computed file
	NEW <cr>	
REM:		Enter remarks for computed file.
	S-T <cr>	
		Brief pause while transformation is executed.
FCT:		

SPECIAL CONSIDERATIONS:

The maximum range of the resultant file can be obtained by defaulting the LO and HI limits.

The resultant file cannot also be one of the operand files.

Permissible data intervals of the resultant file depend on the intervals of the operand file. See the note at the beginning of this section.

The default values of the constants a, b, and c are zero.

4.6 Data Calculation

The LI-1800 has the capability of doing various operations on a data file, including spectral integration, computing ratios of bandwidths, calculating CIE chromaticity coordinates, a quantum transformation and a photometric transformation. This section describes the commands for doing these types of operations.

IT - Integration over a specified waveband.
QI - Quantum transformation, and integration over a specified wavelength range.
PP - Photosynthetic photon flux density. Same as QI for 400 to 700 nm.
IL - Illuminance. Weights data by standard observer curve, and integrates over wavelength range 370-790 nm.
RA - Ratios one wavelength band by another in a specified file.
QR - Quantum ratio. Performs a quantum transformation before computing the ratio.
CC - Calculates CIE chromaticity coordinates (X, Y, Z, x, y, u', v').

If an RS-232C device is plugged into the output port when a data calculation function is performed, the results will be output to the device and displayed on the terminal.

IT Integrate
QI Quantum Integrate

The integrate command (IT) performs an integration over a user specified wavelength range in a single data file. This command is used to calculate irradiance from spectral irradiance, or to aid in finding mean values (integrated number divided by the wavelength range).

Quantum integrate (QI) is the same as IT except a quantum transformation is applied to the data first. This function can be used to calculate quantum flux density over any wavelength range.

EXAMPLE:

1800 Response	User Response	Comments
FCT:		Enter any command.
	IT <cr>	
FILE:		
	DATA<cr>	
		Header information displayed if not suppressed by H0.
LO:		
	300 <cr>	Lower limit for wavelength range.
HI:		
	800 <cr>	Upper limit for wavelength range.
LABEL:		
	W <cr>	'W' previously set as an identifier.
		Brief pause for integration.
.4510E 03 W/M2		451 W m^{-2}.
		(Output to device if connected)
FCT:		Enter any command.

SPECIAL CONSIDERATIONS:

The data wavelength interval used for the integration is the same as the data interval of the file.

The full wavelength range can be used in the integration by defaulting the LO and HI limits.

Integration is done according to the trapezoidal rule of numerical integration, wherein half of the endpoint values and all the intermediate values are summed, then multiplied by the data interval.

The quantum transformation is based on the equation

$$QI = \frac{1}{Bhc} \int_{\lambda_L}^{\lambda_H} \lambda \cdot S(\lambda)\, d\lambda$$

where: $B = 6.02 \times 10^{17}$ photons / μmole
λ = wavelength, nm
$h = 6.62 \times 10^{-34}$ watt s^2 (Planck's constant)
$c = 3.00 \times 10^{17}$ nm / sec (speed of light)
S = Data file.

This is evaluated numerically as

$$QI = .00835 \left(\frac{\lambda_L \cdot S(\lambda_L) + \lambda_H \cdot S(\lambda_H)}{2} + \sum_{\lambda_{L+1}}^{\lambda_{H-1}} \lambda_n \cdot S(\lambda_n) \Delta\lambda \right)$$

$n = L+1, L+2 \ldots H-1$

RELATED COMMANDS:

H0, H1 - Controls file header suppression.
LA - Labeling output.

PP PPFD

Computes photosynthetic photon flux density (PPFD) for a spectral irradiance file whose wavelength limits are at least 400 - 700 nm. This functions the same as the QI command, except limits of 400 and 700 nm are used.

EXAMPLE:

1800 Response	User Response	Comments
FCT:		Enter any command.
	PP <cr>	
FILE:		
	SCAN <cr>	
		Header information for SCAN displayed if not suppressed by H0.
LABEL:		
	UMOL/S/M2 <cr>	
		Brief delay for calculation.
.1820E+4 UMOL/S/M2	<cr>	1820 μmol s^{-1} m^{-2}.
		(Output to device if connected)
FCT:		Enter any command.

SPECIAL CONSIDERATIONS:

File name will be rejected if the wavelength limits are not at least 400-700 nm; 'LIM ERR' will be displayed.

It is assumed that data in the file being used to compute PPFD has units of W m^{-2} nm^{-1}. The result would then have units of μmol s^{-1} m^{-2}, where 1 μmol s^{-1} m^{-2} = 6.022 x 10^{17} quanta s^{-1} m^{-2}.

RELATED COMMANDS:

H0,H1 - Controls file header suppression.
LA - Set up user defined labels.
QI - General limits for photon flux density.

IL Illuminance

Calculates illuminance in lux for a spectral irradiance file having a wavelength range of at least 370 to 790 nm.

EXAMPLE:

1800 Response	User Response	Comments
FCT:		Enter any command.
	IL <cr>	
FILE:		
	SCAN <cr>	
		Header information for SCAN displayed if not suppressed by H0.
LABEL:		
	L <cr>	L previously defined as an identifier.
		Brief delay for calculation.
.5762E 05 LUX		57620 Lux.
		(Output to device if connected)
FCT:		Enter any command.

SPECIAL CONSIDERATIONS:

If the wavelength limits of the file are less than 370-790 nm, 'SHORT RANGE' will be displayed, and then illuminance will be calculated from the available data.

It is assumed that the data in the file is in units of W m^{-2} nm^{-1}; the result of the IL function would then have units of lux. Alternatively, if the file is a radiance measurement (W m^{-2} nm^{-1} str^{-1}), the IL function would result in units of luminance (cd m^{-2}, or nits).

Illuminance is calculated using the CIE standard observer curve, which is contained in the memory of the LI-1800.

RELATED COMMANDS:

H0,H1 - Control file header suppression.
LA - Set up user defined labels.

RA Ratio
QR Quantum Ratio

The ratio command (RA) calculates the ratio of the integrated values of two bandwidths for a specified file. The quantum ratio (QR) command is the same as RA, but a quantum transformation is performed first.

EXAMPLE:

1800 Response	User Response	Comments
FCT:		Enter any command.
	RA <cr>	
FILE:		
	SCAN <cr>	
		Header information for SCAN displayed if not suppressed by H0.
LABEL:		
	<cr>	No label.
		Brief delay for calculation.
.1200E+1		Ratio is 1.2
		(Output to device if connected.)
FCT:		Enter any command.

SPECIAL CONSIDERATIONS:

The file name will be rejected if the ratio limits do not actually exist in the file; 'LIM ERR' will be displayed.

RELATED COMMANDS:

PA - Set up wavelength limits of the numerator and denominator for the ratio command.
H0, H1 - Control file header suppression.
LA - Set up user defined labels.

CC Chromaticity Coordinates

Calculates CIE chromaticity coordinates (X, Y, Z, x, y, u′ , v′) for a source or an object.

EXAMPLE for a SOURCE:

1800 Response	User Response	Comments
FCT:		Enter any command
	CC <cr>	
S,O:		Source or object? Default is Source.
	S <cr>	Source.
FILE:		
	CIE <cr>	
LABEL:		Label for the Y value (see COLORIMETRY OVERVIEW below).
	LUX <cr>	Brief pause while chromaticity coordinates are computed.
X = .1584E 04		
Y = .1655E 04 LUX		
Z = .8579E 03		
x = .3866E 00		
y = .4040E 00		
u′ = .2185E 00		
v′ = .5139E 00		
FCT:		Enter any command.

EXAMPLE FOR AN OBJECT:

1800 Response	User Response	Comments
FCT:		Enter any command.
	CC	
S, O:		Source or object?
	O <cr>	
FILE:		File Name?
	GREY <cr>	
STD:		Standard. Choices are A, E, or D_{65} or a user entered file.
	D65 <cr>	
LABEL:		Label for the Y coordinate.
	REFLECT <cr>	Brief pause while chromaticity coordinates are computed.
X = .1710E 02		
Y = .1799E 02 REFLECT.		
Z = .1959E 02		
x = .3217E 00		
y = .3290E 00		
u'= .1978E 00		
v'= .4683E 00		
FCT:		Enter any command.

RELATED COMMANDS:

WA - Set adequate delay for two line terminals so results can be viewed.

SPECIAL CONSIDERATIONS:

If a device is connected to the output port, the results are automatically routed to it.

If the data file used for the color computations covers less than the range 370 to 790 nm, the warning "SHORT RANGE" will be displayed, but computations will proceed with 0's being assumed for the missing data. Negligible errors result from a short range if the region 400 to 750 is covered and there is not a lot of NIR or UV radiation relative to the visible. NOTE: When using the 1800-12 Integrating Sphere, data should not be taken below 390 nm due to the decreased signal-to-noise ratio (see Section XI).

COLORIMETRY OVERVIEW (See also Appendix D):

Colorimetry is a color measurement technique which attempts to correlate measurements of physical data, from a light source or an object, with its perceived color. Color matching is a basic element in the field of colorimetry and is based on the principle of trichromacy, which states that in order for the color of two objects to appear to match, three values must be identical. These values are the tristimulus values and are designated as X, Y and Z.

Sources. The tristimulus values for light sources are obtained by integrating, over the visible range, the product of the spectral power distribution $S(\lambda)$ with human color matching functions $x(\lambda)$, $y(\lambda)$, and $z(\lambda)$.

$$X = 683\sum_{790}^{370} S(\lambda)\, x(\lambda)\, \Delta\lambda$$

$$Y = 683\sum_{790}^{370} S(\lambda)\, y(\lambda)\, \Delta\lambda$$

$$Z = 683\sum_{790}^{370} S(\lambda)\, z(\lambda)\, \Delta\lambda$$

These color matching functions represent an average human observer as determined by the International Commission on Illuminance (CIE). (The LI-1800 uses the CIE 1931 data for a 2 degree field of view.)

The Y tristimulus value for a source is the illuminance in lux (or luminance if a radiance measurement is made) and is the same number as is computed using the IL function.

Objects. The perceived color of an object is dependent upon its spectral transmittance or reflectance $S(\lambda)$ and also the spectral distribution $F(\lambda)$ of the illuminating source. The tristimulus values are computed from

$$X = k\sum_{790}^{370} F(\lambda)\, S(\lambda)\, x(\lambda)\, \Delta\lambda$$

$$Y = k\sum_{790}^{370} F(\lambda)\, S(\lambda)\, y(\lambda)\, \Delta\lambda$$

$$Z = k\sum_{790}^{370} F(\lambda)\, S(\lambda)\, z(\lambda)\, \Delta\lambda$$

where k is a normalizing factor:

$$k = \frac{100}{\sum_{790}^{370} F(\lambda)\, y(\lambda)\, \Delta\lambda}$$

For objects, the tristimulus value Y is the luminous reflectance or transmittance in percent.

The 1800-12 External Integrating Sphere can be used to generate the reflectance or transmittance file for the object. The spectral distribution of the source can be measured, or one of a number of standard distributions can be assumed. The LI-1800 has in its memory 3 standard distributions. When prompted (STD:) for the standard illuminant to be used, the user can specify one of these three or his own:

Response	Resulting illuminant
A	Typical tungsten source (2856 K blackbody)
E	Equal (uniform) spectral distribution
D65	D_{65} Natural daylight (6500 K correlated color temperature)
filename	User entered file

The user illuminant file must have a spectral range of 370 - 790 nm in steps of 5 nm. (The CR function is one way to generate this file).

Chromaticity. Color is frequently expressed in terms of two chromaticity coordinates x and y. These are related to the tristimulus values X, Y, and Z by:

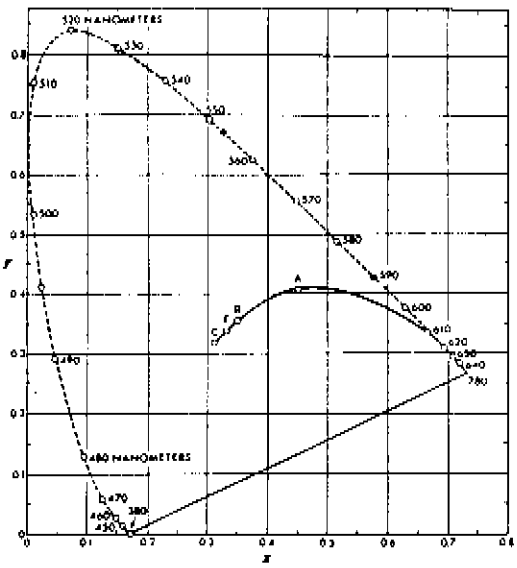
$$x = \frac{X}{X + Y + Z} \qquad y = \frac{Y}{X + Y + Z}$$

When plotted, the chromaticity will fall within a partially elliptical shaped (approximately) region known as the CIE 1931 Chromaticity Diagram. Pure spectral colors fall on the curved border, and color mixtures lie within.

Since the traditional x, y, Y representation does not represent equal color differences for incremental value changes, further mathematical manipulations are used to compensate for this problem. A frequently used variation of the chromaticity coordinates involve a transformation given by

$$u' = \frac{4X}{X + 15Y + 3Z} \qquad v' = \frac{9Y}{X + 15Y + 3Z}$$

Incremental changes in chromaticity expressed in terms of u′ and v′ represent much more uniform changes in perceived color. These supplemental chromaticity coordinates are computed by the LI-1800 as part of the CC function and lie within the CIE 1976 UCS Chromaticity Diagram.



4.7 Data Output/Input

Several functions exist for displaying all or part of the contents of a file. Data may be displayed graphically on a stripchart recorder or on labeled axes using the 6000-03B Plotter/Printer (or any printer with EPSON compatible graphics). Data listings can be directed to the terminal or to the output port (RS-232C device).

AN, QA	- Analog, or Quantum Analog. Millivolt output for a strip chart recorder.
PL, QP	- Plot, or Quantum Plot. For the 6000-03B Plotter/Printer.
SH, QS	- Show, or Quantum Show. Data listing to the terminal or output device.
DU, QD	- Dump, or Quantum Dump. Outputs all files of a bank to a terminal or output device.
*D, *Q	- Dump, or Quantum Dump. Outputs all files of all banks to a terminal or output device.
BD	- Binary Dump. Binary output of all files of a bank to a terminal or output device.
*B	- Binary Dump. Binary output of all files of all banks to a terminal or output device.
BS	- Binary Show. Binary output of one file to a terminal or output device.
BL	- Binary Load. Binary input of data to the LI-1800 that was output using BD, *B, or BS.

If an RS-232C device is plugged into the output port when SH, QS, DU, QD, *D, or *Q is performed, the user is prompted DEV(Y/N). A "Y" response will direct the output to the output device. A "N" or null response will direct the output to the terminal port.

AN Analog
QA Quantum Analog

The analog command (AN) causes the contents of a file to be sent to the output port as an analog signal, 100 mV full scale. The quantum analog command is the same as analog, except a quantum transformation is performed first.

EXAMPLE:

1800 Response	**User Response**	**Comments**
FCT:		Enter any command
	AN <cr>	
FILE:		
	RED8 <cr>	
		Header information for RED8 printed if not suppressed by H0.
LO:		
	<cr>	Let HI and LO default.
300		300 will be LO,
HI:		
	<cr>	
1100		1100 will be HI (or 850).
		Brief pause while max and min are computed.
MIN: 452 NM .1234E-4		
MIN:		Accept current minimum value or enter a new one.
	0 <cr>	Make 0 minimum.
MAX: 778 NM .1530E+1		
MAX:		Accept current maximum value or enter a new one
	<cr>	Use that value for full scale.
		Analog signal sent to output port.
FCT:		

SPECIAL CONSIDERATIONS:

The mV signal is 100 mV full scale. The maximum value specified in the prompts is assigned 100 mV, the minimum is assigned 0 mV. The resolution of the digital-to-analog converter is 1 part in 256.

The data rate is 0.6 seconds per data point. This, for example, will provide a wavelength scale of 20 nm/cm at a chart speed of 10 cm/min for a file with a data interval of 2 nm:

$$\frac{1 \text{ data point}}{0.6 \text{ sec}} \times \frac{2 \text{ nm}}{\text{data point}} \times \frac{1 \text{ min}}{10 \text{ cm}} \times \frac{60 \text{ sec}}{1 \text{ min}} = 20 \text{ nm/cm.}$$

The LI-1800 cannot check to see that the proper connector is being used. Thus, the AN or QA commands will seem to perform with any connector, although obviously only the correct one (2228S) will work.

SH Show
QS Quantum Show

The show command is used to list file contents either to the terminal or the plotter/printer. Three options exist:

S - Sequential data listing.
A - Data averaged over a broader data interval.
W - Data for particular wavelengths.

The quantum show command is the same as SH, except a quantum transformation is performed on the data first.

EXAMPLE:

1800 Response	User Response	Comments
FCT:		Enter any command.
	SH <cr>	
S,A,W:		
	A <cr>	Wavelength averaging option.
DEV(Y/N)		
	N <cr>	Send to terminal.
FILE:		
	PSC <cr>	
		Header information for PSC displayed unless suppressed by H0.
LO:		
	400 <cr>	
HI:		
	500 <cr>	
INT:		
	50 <cr>	Average interval is 50 nm.
LABEL:		
	<cr>	No label.
		What follows is data output:
MIN: 410NM .1234E 02		Minimum value in the chosen interval.
MAX: 500NM .7809E 02		Maximum value in the chosen interval.
424 .1520E 02		Mean value between 400-448nm.
474 .5612E 02		Mean value between 450-498nm.
FCT:		Enter Any Command.

SPECIAL CONSIDERATIONS:

S - Sequential Data List: This is the default option. Data is output at the existing data interval, or a greater interval if it is evenly divisible (e.g. if the data interval is 2 nm, then data could be listed in 2 or 10 nm steps, but not 5 nm); any data existing between the output interval is ignored.

All data in a file can be listed by defaulting the LO, HI, and INT prompts.

A - Averaged Data List: Any data interval may be chosen for averaging, provided that it is evenly divisible by the existing data interval. Data is averaged over each data interval. Below is an example illustrating the mechanics of this (averaging interval is 6).

DATA FILE			OUTPUT	
300	.2222E 00	---		
302	.4444E 00		302	.4074E 00
304	.5555E 00	---		
306	.6666E 00	---		
308	.5555E 00		308	.5185E 00
310	.3333E 00	---		
312	.4444E 00	---		
314	.1111E 00		314	.4814E 00
316	.8888E 00	---		
318	.5555E 00		(ignored)	
320	.3333E 00			

NOTE: To compute the average at 6 nm intervals, the LI-1800 sums the values for three wavelengths (e.g. 306, 308, and 310, centered at 308) and divides by three.

Thus, to average an entire file, the averaging interval must be equal to the spectral range of the file PLUS the data interval. For example, to average all the data values in a file whose spectral limits are 300 and 1100 nm, and whose data interval is 2, the averaging interval must be specified as 802 nm.

W - Selected Wavelengths: User is prompted to enter a wavelength and the corresponding data value is displayed. <break> is used to terminate this routine. NO WAVE is displayed if the user asks for a nonexistent wavelength.

The default wavelength is the last wavelength + the data interval.

PL Plot
QP Quantum Plot

The plot command plots a file on the 6000-03B Plotter/Printer or on printers with EPSON compatible graphics software. The Quantum Plot command is the same as Plot except the quantum transformation is done before the data file is plotted.

EXAMPLE:

1800 Response	User Response	Comments
FCT:		Enter any command.
	PL <cr>	
FILE:		
	LAMP <cr>	
		Header for LAMP displayed here unless suppressed by H0.
LO:		LO and HI are limits for the abscissa.
	300 <cr>	
HI:		
	550 <cr>	
MIN: 520 NM .2436E-03		Minimum value and its wavelength.
MIN:		
	0 <cr>	User entered data origin (ordinate) for the plot.
MAX: 300 NM .9428E 00		Maximum value and its wavelength.
MAX:		
	1 <cr>	User entered full scale (ordinate) for the plot.
LABEL:		
	REFLECTANCE <cr>	Label for ordinate.
		Data plotted on 6000-03B Plotter.
FCT:		

SPECIAL CONSIDERATIONS:

Default values for the MIN and MAX will be the displayed values, and will result in the plot filling the ordinate range of the graph. This provides maximum vertical resolution of any data set at the expense of convenient y-axis intervals.

If only a portion of the data file is to be plotted, the MIN and MAX values are computed for only that portion of the file.

DU Dump
QD Quantum Dump

Lists all files (in ASCII characters) of the currently selected memory bank to the terminal or output device. The quantum dump (QD) command is the same as DU except the quantum transformation is done first.

EXAMPLE:

1800 Response	User Response	Comments
FCT:		Enter any command.
	DU <cr>	
DEV(Y/N):		
	Y <cr>	Output to device.
LABEL:		
	<cr>	No label.
		All files dumped.
FCT:		Enter any command.

SPECIAL CONSIDERATIONS:

Files are presented in the same format as would be obtained using the SH (or QS) function with the S option, and defaulting the data interval.

*D Dump
*Q Quantum Dump

Lists the contents of all files (in ASCII characters) on all banks to the terminal or an output device. The *Q command is the same as *D except a quantum transformation is done first.

EXAMPLE:

1800 Response	User Response	Comments
FCT:	*D <cr>	Enter any command.
DEV(Y/N)	Y <cr>	Output to a device.
FCT:		

SPECIAL CONSIDERATIONS:

The format of the data will be the same as would be obtained using the SH (or QS) function with the S option, and defaulting the data interval.

BD Binary Dump
*B Binary Dump

The binary dump command (BD) lists the contents of all files the currently selected bank to the terminal or output port. The data format is the same binary format used in the LI-1800's internal storage format. Alternately, the *B command performs a binary dump of the contents of all files in all the banks.

EXAMPLE:

1800 Response	User Response	Comments
FCT:		Enter any command.
	BD <cr>	
(binary dump)		See format below.
FCT:		

SPECIAL CONSIDERATIONS:

This function is for use with user programmed terminal devices (such as personal or desktop computers). It should not be used otherwise, as it will probably cause the terminal to "hang", requiring a reset or power off/power on.

Refer to Section 5.3 for a discussion of the binary transfer functions.

The format of the binary dump is

<byte 1> <byte 2> <byte 3> <END OF LINE>
<byte 1> <byte 2> ...<byte n> <checksum> <END OF LINE>

for EACH file that is transferred. The initial three bytes tell how many bytes are in the file, and the bank in which the file resides. The number of bytes 'n' in the file is computed by

n = 256 * DECIMAL (<byte 1>) + DECIMAL (<byte 2>)

The bank address is simply DECIMAL (<byte 3>). This is followed by the end of line sequence (including the delay (set by WA) and the handshake delay (set by D1)). The 'n' bytes of the file follow, then the 8-bit checksum value for the file, and then the end of line sequence again.

The checksum is for the n file bytes only, and does not include the byte count or bank address, nor the end of line sequences. Similarly, the byte count only includes the file data, and not the end of line sequences or the checksum byte.

<break> is ignored during the actual binary transfer.

RELATED FUNCTIONS:

BS - Single file binary output.
BL - Binary load data back into the LI-1800.

BS Binary Show

Binary output of the contents of one file on the currently selected bank.

EXAMPLE:

1800 Response	User Response	Comments
FCT:		Enter any command.
	BS <cr>	
FILE:		
	DATA <cr>	
(binary transfer)		See file format below.
FCT:		

SPECIAL CONSIDERATIONS:

See the discussion of BD (binary dump).

If the file specified is not found, the first three bytes sent will be <null><null><null>.

Refer to Section 5.3.

RELATED FUNCTIONS:

BD, *B - Multiple file binary output.
BL - Load files (binary format) back into LI-1800.

BL Binary Load

Receives LI-1800 binary data from an external storage device back into the LI-1800.

EXAMPLE:

1800 Response	User Response	Comments
FCT:		Enter any command.
	BL <cr>	
	<byte 1><byte 2><byte 3>	Byte count, bank.
<return code>		
	<n file bytes><checksum>	1st file and checksum.
<return code>		
	<byte 1><byte 2><byte 3>	Byte count, bank.
<return code>		
	<n file bytes><checksum>	2nd file and checksum.
<return code>		
	<null><null><null>	No more data to send.
FCT:		

SPECIAL CONSIDERATIONS:

Refer to Section 5.3. See the discussion for BD (binary dump). Binary LOAD allows data that was output using BD, *B, or BS to be put back into the instrument. When the BL command is sent, the LI-1800 will expect to see:

1. Three byte count and bank select
2. 'n' data bytes for the file
3. 1 checksum byte

WITHOUT any end of line sequences in between. After the first three bytes are sent specifying how big the file is, and where it is to go, the LI-1800 will send a return code (1 byte only):

Code	Meaning
0	OK to proceed.
4	Aborted. Not enough RAM for file.
5	Aborted. Bank select error.

If the return code is the character '0', then the LI-1800 will expect to receive the 'n' file bytes plus 1 checksum byte. After the n+1 bytes are received, the LI-1800 will send a return code (1 byte only):

Code	Meaning
0	OK to proceed.
1	Name changed to ## file (duplicate file name).
2	Checksum error - file rejected
3	Name error (out of ## names) - file rejected.

None of these conditions will abort the binary load. BL is terminated by sending <null><null><null> (three decimal 0's) as a byte count and bank select sequence.

RELATED FUNCTIONS:

BD, *B, BS - Binary output functions.

4.8 Data Communications

The user may control the following characteristics of how the LI-1800 communicates with a terminal device:

1. The prompt character sent by the LI-1800.
2. The prompt character expected by the LI-1800 when handshaking.
3. The end-of-line sequence of the LI-1800 (<cr><lf> or <cr>).
4. Whether or not the LI-1800 echos incoming characters.

PROMPT CHARACTERS. Whenever the LI-1800 requests information from the terminal (i.e., the user), it terminates the prompting message with a special character. For example, when the LI-1800 is ready for a new command, the message "FCT:" appears on the terminal. The colon (:) is not the last character sent, however; a Device Control 1 (denoted <dc1>) is sent after the colon. Most terminals ignore that character, and do not display it. However, there are applications where a prompting character is needed (see Section V), and they usually involve interfacing the LI-1800 to a computer.

HANDSHAKING. Handshaking is simply a protocol whereby two devices (terminals, computers, etc.) signal when they are and are not ready to send or receive data. Successful handshaking prevents two devices from "talking" at the same time, or prevents one device from sending data when the destination device is not yet ready to receive it. There are many different types of handshakes used by data communications equipment. The LI-1800 can support one of these types of handshakes on its terminal port.

When it is in its handshaking mode (implemented by the D1 command), the LI-1800 will look for a special prompting character before it sends out any line of data. This character is termed the HOST'S PROMPT, and is selectable by the user. For normal communications, handshaking can be ignored. For many interfacing operations, however, it is necessary.

Note that this handshake is only half of the XON/XOFF handshake. When the LI-1800 is actually sending a line of data, it ignores incoming data from the terminal. Therefore, an XOFF character cannot be sent to the LI-1800 to halt its transmission in the middle of a line. The LI-1800 sends no lines longer than 32 characters, however.

END OF LINE. The LI-1800 terminates each line of data that it sends to the terminal with a particular sequence of characters and events that can be controlled by the user. A sample line is illustrated below:

MONO:300-850[wait]<cr>[handshake wait][<lf>]

The first [wait] is the delay (if any) that the user can set using the WA function. This is followed by a <cr>. The [handshake wait] is the period during which the LI-1800 waits to receive a HOST'S PROMPT character, if handshaking has been implemented. During the [handshake wait], the LI-1800 will respond to NOTHING except that prompt character. <break> will have no apparent effect. After that, the <lf> is sent, provided it has not been suppressed.

For a prompting line, the sequence is a bit different:

FCT:<1800 prompt>[user entry]<cr>[handshake wait][<lf>]

The [handshake wait] and <lf> are as described above, and are not initiated until the <cr> terminating the user entry is received.

The commands discussed in this section are:

DC - DataComm. Set the 1800 PROMPT, HOST PROMPT, Linefeed, and Echo.
D1 - Implement handshaking.
D0 - Turn off handshaking.

DC DataComm

Allows user to see and modify the following: LI-1800 prompt character, the expected incoming prompt in handshaking mode, the end-of-line sequence, and echo.

EXAMPLE:

1800 Response	User Response	Comments
FCT:		Enter any command.
	DC <cr>	
1800's PROMPT=17		Current prompt is decimal 17 (<dcl>).
NEW:		
	63 <cr>	Change to decimal 63 (<?>).
HOST'S PROMPT=17		Expecting <dcl> if handshake on.
NEW:?		Now prompting with <?>.
	<cr>	Retain the current value.
LF=Y		
NEW:?		
	<cr>	Leave <lf> as part of the end-of-line.
ECHO=Y		
NEW:?		
	<cr>	Continue echoing.
FCT:?		Enter Any Command.

SPECIAL CONSIDERATIONS:

The 1800's PROMPT is the character that the LI-1800 sends out as the last character of any prompting line, such as "FCT:" or "DEV(Y/N):". The POWER ON default character is decimal 17, which is a Device Control 1, or <dcl>. In general, the prompting character is referred to using the decimal equivalent. See the Appendix for a table of ASCII characters and their decimal equivalents.

The HOST'S PROMPT is the character that the LI-1800 looks for when handshaking has been implemented using the D1 command. The POWER ON default value is decimal 17.

If LF=Y, then the LI-1800 will end each line sent with a carriage return and a line feed (<cr><lf>). If LF=N then the linefeed is suppressed. The POWER ON default condition is LF=Y.

If ECHO=Y, the LI-1800 will echo all incoming data back to the terminal (except characters received after a <cr> and before the HOST prompt when handshaking is implemented). Setting ECHO=N suppresses the echo. The POWER ON default is ECHO=Y.

The configuration as set with the DC command is not part of permanent memory. POWER OFF - POWER ON will reset the conditions to their default values.

Each of the four parameters takes effect immediately upon receipt of the <cr> terminating the keyboard entry. Thus, in the example above, the prompts terminated in a <?> for the last three entries.

RELATED COMMANDS:

D1 - Implement handshaking.
D0 - Turn off handshaking.

D1 Handshake On

Implements handshaking, whereby the LI-1800 will wait to receive a special character (HOST'S PROMPT) before sending each line of data to the terminal.

EXAMPLE:

1800 Response	User Response	Comments
FCT:		Enter any command.
	D1 <cr>	Handshake on. LI-1800 will wait until it receives the HOST'S PROMPT character. Unless it has been changed, that character is a <dcl>, which can be sent from the terminal by pressing Q while holding the CONTROL key down.
	<dcl>	
FCT:		
	LI<cr><dcl>	Do a LIST while handshaking.
ABCD 02/14 12:22 DUMMY FILE		LI-1800 will wait after each line.
	<dcl>	
FIL1 02/13 10:01 TEST SCAN 6		
	<dcl>	
MEM: 32154		
	<dcl>	
FCT:		Enter Any Command.

SPECIAL CONSIDERATIONS:

Handshaking is NOT retained after POWER OFF. Thus, it will never be the POWER ON condition.

The 4 parameters accessible via the DC command (host prompt, 1800 prompt, line feed, and echo) are unaffected by the D1 command. Thus, when handshaking, the LI-1800 still sends its prompt, and the line feed and echo parameters remain unchanged. The only thing that D1 does is to cause the LI-1800 to look for the character specified as HOST PROMPT before sending each line.

RELATED COMMANDS:

DC - Sets HOST'S PROMPT.
D0 - Handshaking Off.

D0 Handshake Off

Shuts off handshaking implemented by the D1 command. The command is "D-ZERO".

EXAMPLE:

1800 Response	User Response	Comments
FCT:		Enter any command.
	D0<cr>	
FCT:		Enter any command.

SPECIAL CONSIDERATIONS:

Notice that the D0<cr> does not need to be followed by the HOST'S PROMPT character. Handshaking is shut off upon receipt of the <cr>.

RELATED COMMANDS:

D1 - Implements handshaking.

4.9 Preprogrammed Operation

The LI-1800 may be programmed to a certain extent, in that up to 4 functions may be made to execute automatically. Also, the instrument can be made to execute a scan at predetermined intervals for applications involving unattended datalogging.

The functions described in this section are:

PR - Program. Define the file name for preprogrammed scanning, and define the functions to be executed on that file.
SP - Show program. Lists the data file name and functions defined by the PR command.
AL - Alarm. Set the "wake-up" time and period to automatically run the program defined by PR.
RU - Run. Runs the program defined by PR.
EX - Execute. Executes the functions defined by PR on an arbitrary file.

REMOTE WAKE-UP CONTROL

Pin 18 on the 25-pin terminal port can be used to cause a "wake-up" if the LI-1800 power switch is in the AUTO position. Open circuit (+5 to +15 V) is the off condition. Grounding pin 18 to pin 7 triggers a wake-up (when switch is in AUTO). A "wake-up" is equivalent to what is normally the full ON position (i.e. control is from the terminal device). In this condition a stored program will not automatically execute as discussed in this section. Disconnecting pins 18 and 7 will cause the LI-1800 to power down once again.

If it is desired to have a program executed upon remote wake-up this can be accomplished by making an internal modification to the LI-1800 power supply board. Contact LI-COR for details.

PR Program

The LI-1800 can be programmed with up to 4 functions to be performed automatically on a specified data file created by a scan.

EXAMPLE:

1800 Response	User Response	Comments
FCT:		
	PR <cr>	Program function.
FILE:		
	#	Use sequential files (Section 3.1).
REM:		
	PR TEST <cr>	Each file will have the same remark.
LO:		
	300 <cr>	Each scan will be 300-1100 nm.
HI:		
	1100 <cr>	
#SCANS:		The data in each file will be a one scan average.
	1 <cr>	
FCT1:		
	IT <cr>	1st function is IT (integrate).
LO:		
	400 <cr>	
HI:		
	700 <cr>	
LABEL:		
	W/M2 <cr>	
FCT2:		2nd function is PP (photosynthetic photon flux density).
	PP<cr>	
LABEL:		
	UM/S/M2<cr>	
FCT3:		
	<cr>	Bypass functions 3 and 4.
FCT:		Enter any command.

SPECIAL CONSIDERATIONS

Unless the file name calls for sequential files (#), each time the program is run (with AL or RU) data will be placed in the same file (previous data is overwritten). The scanning interval for scans initiated by the PR command is set by the parameters.

Up to 4 functions from the following list can be specified as the program stack:

AN, QA - Analog output
IT, QI - Integration
PP - Photosynthetic photon flux density
RA, QR - Ratio
SH, QS - Show
PL, QP - Plot
CC - Color coordinates
IL - Illuminance

The PR file name and functions are retained at power off.

There is no direct command to delete a program. Deleting the named file (unless its a sequential file name) will delete the program. To delete a program which uses a sequential file name, first rename the program file, and then delete the named file. Another way to delete a program which uses sequential files is to merely change the scan interval or the monochromator limits with the PA command.

RELATED COMMANDS

SP - Lists the file name and functions specified in PR to the terminal or to the output device.
RU - Performs a scan, puts the data in the file specified by PR, and executes the functions (if any) on that file.
AL - Same as RU, except the entire operation occurs at a preprogrammed time interval.
EX - Executes the functions specified in PR on an arbitrary file.
SH - Lists the contents of a file created with AL or RU.

SP Show Program

Lists the data file and any functions specified by the PR command.

EXAMPLE (Using previous PR example)

1800 Response	**User Response**	**Comments**
FCT:		Enter any command.
	SP <cr>	
FILE: # PR TEST		File name and remarks.
FCT: ITG		Function 1.
LIMS: 400-700NM		
LABEL: W/M2		
FCT: PP		Function 2.
LABEL: UM/S/M2		
FCT:		Enter any command.

SPECIAL CONSIDERATIONS

If no program is stored, the message "NO PROG" will be displayed.

If there is a device plugged into the output port, the user will be given the option of directing the program list to that device. Otherwise, it comes to the terminal.

RELATED COMMANDS

PR - Setup the program stack.

AL Alarm

Sets the initial time and the period for automatic "wake-up", scanning, and execution of the program functions.

EXAMPLE (Using the previous PR example)

1800 Response	User Response	Comments
FCT:		Enter any command.
	AL <cr>	
CALLS:		
	24 <cr>	24 total "wakeups".
PER:		
	60 <cr>	60 minutes apart.
D.H.M.	4 11:23	Current day, hour, and minute.
D.H.M:		Day.Hour.Minute for first wakeup.
	4.12.0 <cr>	1st wakeup at noon on the same day.
SET AUTO		Set switch on the LI-1800 to the Auto position (a beeping sound will be heard until Auto is set).
(repetitious beeping)		

With this setup, the LI-1800 will "awaken" every hour and make a scan. At the end of 24 hours, there will be files ##00 through ##23 in memory, and the functions IT and PP will have been performed on each file and output to the device.

SPECIAL CONSIDERATIONS:

If a device is plugged into the output port, all output from the functions will be directed to the device, otherwise it will be directed to the terminal port.

A terminal need not be connected for the automatic wakeups to occur.

Make sure the PER time interval is longer than the time required to perform the scan and related functions, especially when averaging scans. If a wake-up is missed, however, subsequent wakeups will occur at delayed times.

There is no provision to view Alarm set times, they can only be set or cleared. To clear all alarms, enter the set mode using the AL command but merely press RETURN as a response to all prompts. This will not clear any previously stored alarm data files.

If Alarm is set and the program is subsequently deleted, the LI-1800 will still wake-up at the set time, synchronize, then clear the remaining alarm times and turn off.

If <break> (CLEAR key) is executed during a scan or other function performed by an alarm wake-up, it is **critical** that the Alarm is then cleared or else the LI-1800 will remain powered on even though the switch is in the AUTO position.

Make sure the battery is fully charged before setting a lengthy alarm schedule.

OPERATING THE INSTRUMENT BETWEEN SCHEDULED ALARM WAKE-UP CALLS

It is possible to operate the instrument between scheduled alarm wake-up calls, but attention must be given to avoid delaying alarm wakeups. The instrument can be taken out of the AUTO state by simply moving the power switch from AUTO to ON. This does not cancel remaining alarm wakeups; they can be re-enabled by moving the power switch to AUTO **provided** no wakeups occurred while the LI-1800 was in use.

If a wake-up does occur while the instrument is on, the alarm wake-up is forced to remain active. Although instrument operation appears undisturbed, this will cause the LI-1800 to remain powered ON even after returning the power switch to AUTO. This misleading condition can be verified by moving the power switch to ON, pressing the RETURN key, and observing if the abbreviated command list is displayed instead of the software version and date/time. (NOTE: Even if the power on display is correct, a wake-up call may still have just occurred during this verification check.) Since the current alarm wake-up is forced active but the wake-up time has passed, the LI-1800 will remain powered ON until all alarms are cleared or the instrument shuts down because of a low battery condition. Future preprogrammed alarm wakeups will not take place. Therefore, if any uncertainty at all exists about whether the instrument was ON during a time for an alarm wake-up call to occur, clear or set the alarm times to be certain future alarm wake-up calls will be executed correctly.

Moving the power switch to OFF then AUTO allows the present active alarm to immediately perform the overdue wake-up call. The PR functions will be executed, then the alarm will set the time for the next scheduled wake-up, if any (which will all be late). Otherwise turning the instrument to ON (from OFF) instead of AUTO and clearing or setting the alarm times will insure that the alarm wake-up conditions are known.

RELATED COMMANDS:

RU - Performs the same operations as will be done on a wake-up, except that it will happen immediately, and only once. It is useful for testing a program before implementing the AL and putting the instrument in AUTO mode.
PR - Define the file and the functions to be done.
SP - Show the current program.

RU Run

Executes the sequence set up in the program function (PR).

EXAMPLE: (Using the previous PR example)

1800 Response	User Response	Comments
FCT:		Enter any command.
	RU <cr>	
1 09/04 11/25 FCT: ITG		Time of first scan
		File header information displayed here unless suppressed by H0
.7235E 02 W/M2 FCT: PPFD		
		File header information displayed here unless suppressed by H0
.3178E 03 UE/S/M2 FCT:		Enter any command.

SPECIAL CONSIDERATIONS:

The output of the functions will go to the output device if any is plugged into the output port. The H0 header suppression function only affects output to the terminal, not to an output device.

RELATED COMMANDS:

PR - Program function.
SP - List current program.

EX Execute

Performs the functions specified by the PR function on an arbitrary file.

EXAMPLE: (Using the previous PR example)

1800 Response	User Response	Comments
FCT:		Enter any command.
	EX <cr>	
FILE:		
	WRM <cr>	
		File header for WRM printed here unless suppressed by H0.
FCT: ITG		
		File header information printed here unless suppressed by H0.
.2845E 02 W/M2 FCT: PPFD		
		File header information printed here unless suppressed by H0.
.1178E 03 UE/S/M2 FCT:		Enter any command.

SPECIAL CONSIDERATIONS:

The output of the functions will go to the output device if any is plugged into the output port. The H0 heading suppression function only affects output to the terminal, not to an output device.

Note that the file used does not need to be the one named in the program.

RELATED COMMANDS:

PR - Program function.
SP - List current program.

4.10 Memory Test

The CS command is used as a data confidence aid, and is useful in trouble shooting locations in memory that may be not functioning. See Section 7.2 for uses of this command.

CS Check Sum

Computes the check sum of the portion of RAM (random access memory) that is allocated to data files in the selected memory bank.

EXAMPLE:

1800 Response	**User Response**	**Comments**
FCT:		Enter any command
	CS <cr>	
FILES CHECK SUM 207		
FCT:		Enter any command

SPECIAL CONSIDERATIONS:

The check sum is an 8 bit integer (0 - 255) sum of all bytes contained in file space memory. As this sum is computed, each time it exceeds the 8 bit size (255), the carry bit is added back to the least significant bit (ones) column. If any portion of any file (data or header) is changed, either by the user or by memory malfunction, the CS value will change.

Typical use of CS would be to compare the value before and after a period of storage to verify that the memory is unchanged.

CS does not change the values of any stored files.

Section V
Interfacing the LI-1800

5.1 Terminal Configuration

Any terminal device connected to the LI-1800 should be configured for 7 data bits, 0 parity, and a baud rate of 300, 1200, 2400, or 4800.

The LI-1800 transmits 7 data bits and a 0 (zero) parity bit. On incoming data, it looks for 7 data bits and ignores any parity. Thus, any consistent terminal configuration will work, such as 7 data bits and a 0 parity bit, or 8 data bits and any parity.

In its default (power on) state, the LI-1800 will echo incoming data. Thus, the terminal should have its local echo suppressed to avoid double characters appearing on the display. If your terminal has a "DUPLEX" switch, setting it to "FULL" will accomplish this. Alternatively, the LI-1800 can be made to suppress its echo (see Section 4.8). The terminal must also function in a character mode (unless the LI-1800 is not echoing data). That is, when a key is pressed on the terminal, it is sent immediately. Terminals that function in block mode (not sending any keystrokes until a <cr> (carriage return) is pressed, and then sending the entire sequence) will not function satisfactorily with the LI-1800.

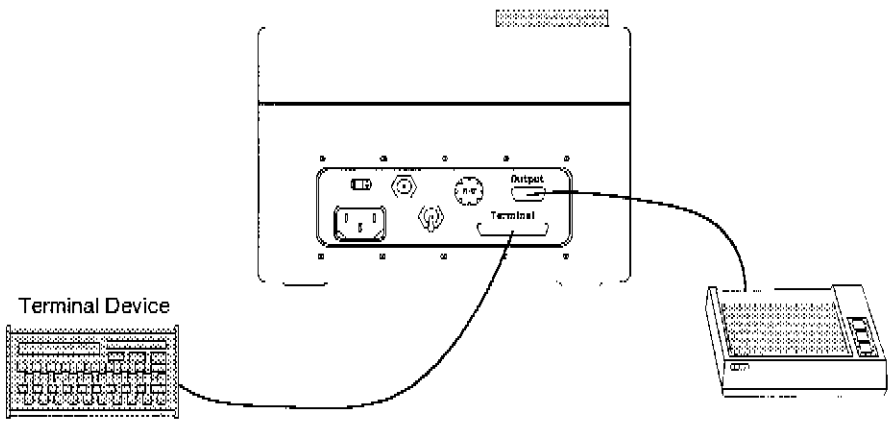


Figure 5-1. Terminals connected to the LI-1800 terminal port.

1800-01B PORTABLE TERMINAL

The 1800-01B is a portable terminal which draws power from the LI-1800 and is powered on when the LI-1800 is turned on. There is not a separate ON/OFF switch for the 1800-01B. The communication parameters (baud rate, parity, etc.) of the 1800-01B have been properly configured at the factory. It should not be necessary to make any changes in order to use the 1800-01B with the LI-1800.

If you wish to re-configure the 1800-01B, this can be accomplished by pressing the SHIFT and ESCAPE keys simultaneously. The configuration parameters are given as four sets of eight binary digits. The default configuration for the LI-1800 should appear as follows:

12345678	12345678	12345678	12345678
10000000	10101010	00000000	00000000

After the first 8 digits are displayed, the terminal is waiting for new digits to be entered. If no change is needed, press RETURN to proceed to the next 8 digits. After the last group, verify that OPERATING MODE=001. Change if necessary or accept with RETURN.

Next the prompt CONTRAST=00X is displayed. The user may set the value X between 001 and 007 for the best viewing angle. When satisfied, press RETURN. The prompt UNIT ADDRESS is displayed. This prompt is not important for the LI-1800. Press RETURN again and the prompt COLUMNS=040 is displayed. Press RETURN again to accept the default answer and to exit SETUP MODE.

NOTE: The DELETE key is not active in SETUP MODE. If you make a mistake, exit SETUP MODE and go through the setup sequence again. To quickly exit the SETUP MODE and leave all prompts unchanged, press the TransTerm label which resets the terminal.

The 1800-01B is factory set for the proper configuration and for 4800 baud. To exit "set up" mode and save the changes, continue pressing the RETURN key. For the configuration changes to take effect, reset the terminal after exiting the setup mode.

For complete information on the 1800-01B, see the TransTerm 6 owner's manual included with the terminal.

Do not press <ctrl> S on the keyboard or the terminal will appear to lock-up. If this occurs, the terminal can be reset by pressing the reset key located in the TransTerm label in the upper right side of the keyboard.

The <delete> key is labeled DELETE and is immediately above the return key. The CLEAR key is configured as a break key.

The 1800-01B circuitry has been modified for use with the LI-1800 and cannot be used with an AC adapter as a power source as stated in the TransTerm owner's manual.

1800-01A PORTABLE TERMINAL

The 1800-01A Portable Terminal has its own ON/OFF keys which are located on the upper left side of the keyboard. The ON/OFF keys on the 1800-01A affect only the operation of the terminal and not the LI-1800. Both devices need to be turned on and off separately. The 1800-01A will beep when the ON key is pressed.

IMPORTANT: The 1800-01A also has its own internal rechargeable battery which has a battery life approximately equal to that of the LI-1800. When the 1800-01A's batteries are depleted, it will automatically draw power from the LI-1800 in order to remain operational. To recharge the 1800-01A, select the proper voltage on the AC adapter and plug the AC adapter cord into the jack located on the right side panel. This recharges only the 1800-01A, not the LI-1800.

The 1800-01A contains a 48 line buffer which allows you to view the last 48 lines which were shown on the LCD display. The arrow keys on the left side of the keyboard are used to scroll the display to see lines which are no longer displayed. To avoid confusion, always use the down arrow key to scroll the display to line 48 before entering commands.

The 1800-01A break key is located in the upper right side of the keyboard. To use, press the FUNCTION key, and then the BREAK key. For some functions (such as point scans) it may be necessary to repeatedly press the FUNCTION and BREAK keys.

The communication parameters (baud rate, parity, etc.) of the LI-1800 and the 1800-01A have been properly configured at the factory. It should not be necessary to make any changes in order to make them work together. If you wish to re-configure the 1800-01A, this can be accomplished by pressing the FUNCTION key, and then pressing the SET UP key. The default configuration for the LI-1800 should appear as follows:

12345678	12345678	12345678	12345678
10000000	10101000	10110011	00000000

Changes are made with the up, down, right arrow and left arrow keys.

The 1800-01A is factory set for the proper configuration and for 4800 baud. To exit this "set up" mode, press the SET UP key a second time.

For complete information on the 1800-01A, see the TransTerm III owners manual.

1800-01 PORTABLE TERMINAL

The 1800-01 Portable Terminal is an older model of the 1800-01A and 1800-01B terminals. The 1800-01 is configured by setting eight toggle switches located inside the terminal case on the rear of the printed circuit board. The switches may be accessed via the small hole in the back panel of the unit. The switches should be set according to the diagram below:

SWITCH: 1 2 3 4 5 6 7 8
0 1 0 x x x 1 0

0 0 0	- 300 baud
0 1 0	- 1200
0 0 1	- 2400
1 1 1	- 4800

The switches are factory set for the proper configuration and for 4800 baud.

The <cr> key is labeled "RETURN". The <delete> key is labeled "DELETE" and is immediately above the return key. The "CLEAR" and "ENTER" keys are not used with the LI-1800. The break "key" is a button located on the side of the case and operates similar to a break key on a typical keyboard.

The 1800-01 does not have an internal battery and has to draw its power from the LI-1800. CAUTION: Do NOT use the AC adapter for the 1800-01 terminal when using the terminal with the LI-1800. The AC adapter is only for use when connected to other devices that do not make use of pins 9 and 10 in the RS-232C connector.

5.2 Connecting to a Computer

Most desktop and personal computers can be interfaced to the LI-1800. The main requirement is that the computer have an RS-232C interface that can be configured to match the LI-1800.

Terminal emulator and graphics software is available from LI-COR for the IBM PC, XT, AT, PS/2 or compatibles (model 1800-14) and Hewlett-Packard series 200 (model 1800-15) or series 85 microcomputers (model 1800HP85).

A partial list of the 1800-14 software functions is given below:

Software Function Summary:

- Allows the computer to function as a terminal for the LI-1800.
- File management functions allow LI-1800 data files to be stored on disk, and moved to and from the LI-1800 (binary transfer). Files can be created, deleted, edited, copied, divided by other files, or transformed using a function similar to the LI-1800 transform command (XF).
- Output functions include printing data files, printing single plots, printing multiple plots on the same axes, displaying single and multiple plots on the CRT, displaying trace files.
- Integration of data over specified wavelength limits.
- Calculation of illuminance (or luminance), CIE chromaticity coordinates, photosynthetic photon flux density, correlated color temperature, uniform color space coordinates.

LI-1800 Software Requirement: Version 4.05 or greater (LI-1800 serial number 139 or higher).

Computer Requirements:

Computer: IBM PC, XT, AT, PS/2 or compatible.
Graphics Adapter Cards: Supports CGA, monochrome CGA, EGA, EGA 64, monochrome EGA, VGA, IBM 8514, Hercules monochrome, AT&T 400, IBM 3270 PC.
Memory Requirement: 512K bytes RAM minimum.
Operating System: Requires IBM DOS 2.0 or greater.
Interface: RS-232C.
Printing Devices Supported:
Printing data files: Any RS-232C compatible printer.
Printing plots of data files: Printers with EPSON compatible graphics.

The transfer of ASCII data to an IBM PC or compatible can also be accomplished using any program which can act as a terminal and write incoming ASCII data into a data file. Most commercially available communication packages perform this type of data transfer. Several inexpensive programs and their manufacturers are listed below.

Program Name: ProComm
Datastorm Technologies, inc.
P.O. Box 1471
Columbia, MO 65205

Program Name: PC-Talk
Freeware
P.O. Box 862
Tiburon, CA 94920

To transfer ASCII data to the Apple Macintosh, you will need a Hayes compatible modem cable and one of the commercially available software communication programs. One such program is "Red Ryder" which is available from the Freesoft Company at a nominal cost.

Program Name: Red Ryder
The Freesoft Company
150 Hickory Drive
Beaver Falls, PA 15010

The computer can be interfaced at either the terminal port or the output port, depending upon what you wish to accomplish.

USING THE OUTPUT PORT

The baud rate of the receiving device must be 300, 1200, 2400, or 4800, and coincide with the baud rate specified as the DEV BAUD in the list of parameters (PA command).

The computer has to act as DTE (Data Terminal Equipment), and be in a "read only" state, as the LI-1800 cannot read any incoming data from its own output port.

The LI-1800 will handshake with the output port by not sending data when Data Terminal Ready (pin 20) is

low. Data transfer to the output port is still initiated with the controlling terminal.

USING THE TERMINAL PORT

The most useful way of interfacing a desktop computer to the LI-1800 is to use the terminal port. This allows the computer to function as the controlling terminal. The simplest mode is for the computer to function as a "dumb" terminal. Some personal computers function this way in their base state; others need an executing program within them for this to happen.

A more powerful technique is to have the computer function as a "smart" terminal. This allows data sent from the LI-1800 to be recorded in memory or on the mass storage device of the computer. Various other terminal functions could be programmed, such as automatically sending data to the LI-1800 using the CR command, or (if the computer has graphics capability) plotting data sent from the LI-1800. This "smart" terminal mode is used by the 1800-14 software.

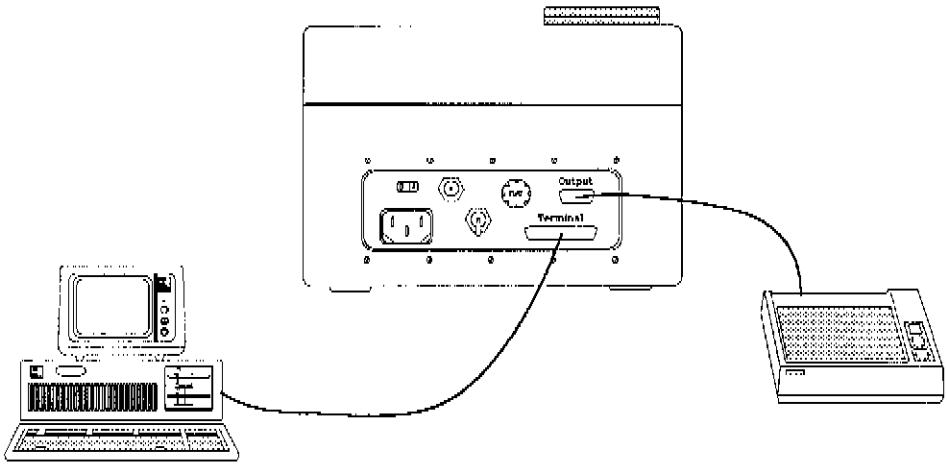


Figure 5-2. A computer connected to the terminal port can act as both a terminal and a data storage/data analysis device.

CABLE REQUIREMENTS

The terminal port of the LI-1800 (configured as Data Communication Equipment) can be connected to an IBM PC or compatible using the 1000-04 RS-232C Cable (flat ribbon cable, included). For computers with a standard IBM AT 9-pin RS-232C connector, use the optional 1800-04 RS-232C Cable. To connect the LI-1800 output port to a printer or computer, use the 2232S output cable (and the 1000-04 RS-232C cable if the gender is wrong).

5.3 Binary Transfers

The binary transfer functions are made for interfacing to a desktop computer, and they greatly reduce the time and complexity of transferring files to and from the LI-1800. For example, a file having 401 points (300 to 1100 in steps of 2) takes nearly a minute to list to the terminal using (ASCII) SH, option S at 4800 baud. The same file when output using BS (Binary Show) will take about 4 seconds to send. The main disadvantage is that what is sent is only decipherable by a computer.

What is binary format ? Files are stored in the memory of the LI-1800 in a much different manner than they appear when printed on the terminal or output device. When files are printed, the LI-1800 must convert the data from its internal format to the format that you are accustomed to seeing. This internal format is (somewhat loosely) referred to as binary format. When any of the functions BS, *B, or BD are performed, the LI-1800 sends out the files without doing this conversion, saving time and reducing the amount of data that is sent. Similarly, the BL (binary load) function loads a file into the LI-1800 about 100 times faster than can be done using a computer and the CR function.

What is it good for ? If you never plan on interfacing your LI-1800 to a desktop or personal computer, read no further. Otherwise, binary transfers may prove to be very useful to your application. Binary transfers will allow you to get selected (or all) LI-1800 files out of the instrument and onto your mass storage device in a minimum of time and in a minimum of space. Also, these files can be put back into the LI-1800 using the BL function just as rapidly. And, it is fairly easy to write your own program for converting a binary format file on your mass storage device to the normal format if you wish to print it or otherwise use the data independently of the LI-1800.

LI-1800 Internal Storage Format. Files have two distinct parts as they are stored internally: a header and data. The header always fills the first 50 bytes of the file. The data follows, taking 3 bytes per data point. Thus, a file having data every 2 nm between 300 and 1100 nm will take 50 + (3 × 401) = 1253 bytes. Numbering the bytes from 0:

Bytes	Represent	Format
0 - 3	Addresses	(not needed to interpret data)
4 - 7	File name	ASCII
8 - 9	Low Limit	Integer
10 - 11	High Limit	Integer
12 - 13	Interval	Integer
14	Create Time min	BCD
15	Create Time hour	BCD
16	Create Time day	BCD
17	Create Time month	BCD
22 - 23	# Scans	Integer
24 - 39	Remark	ASCII
40 - 49	Reserved	
50 - 52	1st data point	Floating Point
53 - 55	2nd data point	Floating Point
:	:	:

Interpreting Integers

Integers are stored in 2 bytes in 2's complement form:

```
      <-----------Byte 1----------> <-----------Byte 2---------->
Bit#: 15  14  13  12  11  10  09  08  07  06  05  04  03  02  01  00

Value:  16384    4096    1024    256  128  64  32  16   8   4   2  1
  -32768     8192    2048     512
```

Sum the values for each bit that is set. Negative integers will have bit 15 set.

EXAMPLE:

Bytes	Integer Value
00000000 00000000	0
00000001 00000000	256
00000000 00000001	1
11111111 11111111	-1
00100011 01000111	9031

Interpreting Floating Point Values

Floating point numbers (all the data values) are stored in three bytes: 2 for the mantissa, and one byte for the exponent.

```
        <---------- MANTISSA ----------------> <----- EXPONENT ----->
        <-------- byte 1 ------> <-- byte 2 --> <------- byte 3 ----->
Bit #:  15 14 13 12 11 10 09 08 07 06 ..... 00 07 06 05 04 03 02 01 00

Value:  -1   1   1   1      . . .                1   -128 64 32 16 8  4  2  1
        2^0  2   2^2 2^3                        2^15
```

1. Determine the exponent E by summing the values of set bits 0 thru 7 of byte 3. Note that if bit 07 is set, the exponent is negative.

2. If bit 15 of the mantissa is set, then take the binary complement of the 16 bits (change 1's and 0's) and add 1 (00000000 00000001) to the mantissa.

3. Sum the values of the set bits in the mantissa to M.

4. The floating point number X is $X = M * 2^E$. If step (2) was performed, then make X negative.

EXAMPLE:

Bytes	Value
01000000 00000000 00000010	2.0
01011001 01001110 00000111	89.3
10110010 10100101 11111011	-.0188

SAMPLE BASIC PROGRAM SEGMENT:

```
100  ! Y$ IS 3 BYTE STRING, CONVERT TO FLOATING PT X
110  S=0 ! S is a sign flag
120  E=NUM(Y$[3]) ! Exponent
130  IF BIT (E,7) THEN E=E-256
140  FOR I=2 TO 1 STEP -1 @ Y(I)=NUM(Y$[I]) @ NEXT I
150  IF NOT BIT(Y(1),7) THEN 210
160  S=1 ! Negative number
170  ! Find INTEGER value of first 2 bytes.
180  X=NUM$(6$[1])*256+NUM$(Y$[2])
181  IF BIT (X,15) THEN X=X-32768
182  ! BINCMP(X) does 16 bit binary complement
```

```
190  X=BINCMP(X)+1
210  M=0 @ N=-1
220  FOR I=1 TO 2
230  FOR B=7 TO 0 STEP -1
240  N=N+1 @ IF BIT(Y(I),B) THEN M=M+1/2\N
250  NEXT B
260  NEXT I
270  IF S THEN M=-M
280  X=M*2\E
```

Interpreting Binary Coded Decimal

Binary coded decimal is used for the time stamp of a file. Simply use the decimal value of each 4 bit segment as the value of the number.

EXAMPLES:	Byte	BCD value
	00100011	23
	00011001	19

An Example:

```
FILE:COSC          **NEW DOME CAL
LIMS:300-1100NM
INT:1NM
DATE:01/09 16:04
#SCANS:0

NM
300    .5868E 04    301    .5912E 04    302    .5982E 04    303   .6082E 04
304    .6209E 04    305    .6356E 04    306    .6508E 04    307   .6648E 04
:
etc.
```

A hex representation of the first 70 bytes of this file as it is stored internally (and as it is sent during a binary transfer) is:

	0	1	2	3	4	5	6	7	8	9
0	82	85	82	7F	43	4F	53	43	01	2C
10	04	4C	00	01	04	16	09	01	F3	3B
20	98	84	00	00	2A	2A	4E	45	57	20
30	44	4F	4D	45	20	43	41	4C	00	00
40	34	F9	4B	0B	CC	79	6D	14	B8	EB
50	5B	B4	0D	5C	56	0D	5D	7B	0D	5F
60	0C	0D	61	0B	0D	63	55	0D	65	B3
70	0D	etc.								

It is obvious that all manner of characters, control characters, and un-interpreted characters will be sent to the terminal during a binary transfer. The only ones that make any sense (in ASCII) are the file name and the remarks.

Interfacing for a binary transfer. To successfully make use of the binary transfer functions, the device being interfaced to the LI-1800 should:

1. Be able to function as a terminal to allow normal communication with the LI-1800. The binary transfers only occur on the terminal port, and normal communications are required to set up the binary transfers. Also note that 8 data bits per character are required to prevent loss of data.

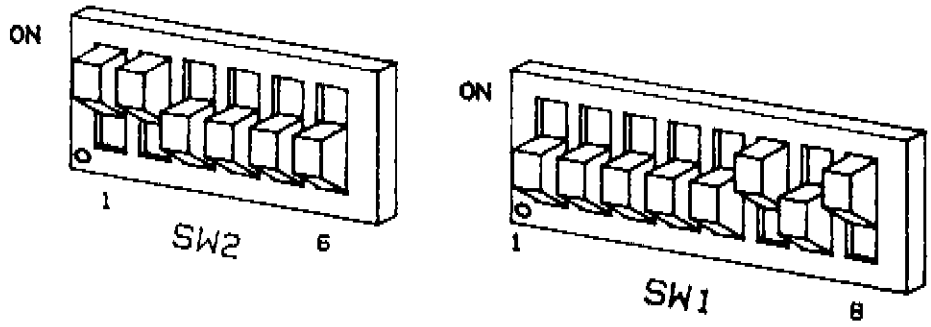
2. Be able to accept blocks of characters up to 2500 characters in length without a break or pause.

3. Be able to accept these characters without interpreting any of them. That is, a <cr> will not necessarily mean "end of the line", since several <cr> characters could be part of the data itself. Counting characters is the only way of knowing when the binary transfer is over.

For further details, consult the descriptions of the functions BS, BD, *B, and BL.

5.4 6000-03B Plotter/Printer

The 6000-03B serial configuration is determined by 2 banks of DIP switches located on the serial interface board. They are set at LI-COR for 2 stop bits, parity odd and disabled, flag positive, and 4800 baud:



Consult the EPSON Serial Interface manual for additional information on these switches.

The 6000-03B is connected to the OUTPUT port of the LI-1800 using the 2232S output cable.

Use the PA command with the LI-1800 to establish the proper baud rate for communicating with the 6000-03B. The relevant parameter is "DEV BAUD".

A simple way to test the operation of the 6000-03B is to execute a <cr> on the terminal in response to a FCT: prompt. The LI-1800 will respond with

DEV (Y/N):

if the connector is plugged into the output port. Enter "Y<cr>", and the menu of commands will be printed on the 6000-03B.

The plotting capability can be tested by executing a PL command, and specifying an existing file.

The plotting function (PL) of the LI-1800 is a software function written specifically for the EPSON printers and other printers with EPSON compatible graphics software. (NOTE: On some early models of EPSON printers the graphics software was an extra cost option, not standard equipment. The plotting software may not function correctly for some of the early EPSON model MX-80 printers.) The plotting software does not work universally with other printers. However, any printer with an RS-232C interface can be used to print out a data file using the show command (SH).

5.5 Stripchart Recorder

A stripchart recorder may be connected to the LI-1800 output port by using the 2228S recorder leads. Connect the RED wire on the cable to the (+) terminal of the recorder, and the BLACK wire to the (-) terminal. Full scale signal will be 100 mV. The recorder's impedance should be greater than 100K ohms.

Data is sent to the stripchart recorder by using the AN or QA commands. The rate of data transfer is 1 data value every 0.6 seconds; thus, a file containing 401 data points (300 nm to 1100 nm every 2 nm) would take 240 seconds to transfer.

Section VI
Maintenance

6.1 General Comments

Little maintenance of the LI-1800 is required. If the instrument is used in an environment where water vapor may condense inside, the desiccant packs should be periodically dried.

Use only alcohol or mild detergent solutions to clean the exterior. Functionally, the only item that needs cleaning is the diffuser surface. Do not use petroleum based or strong solvents.

When using the instrument where rain or spray is possible, keep the instrument level or tilted with the connector panel down. Do not allow water to stand in the panel, as it could damage the connectors. Use of the carrying case with the end flap zipped down on both sides will shield the panel from direct spray and protects the instrument box from wear.

The white case is sealed to keep the interior clean. To this end, the optics input port should always be covered with either the cosine head or fiber probe housing, complete with O-ring. Clean the bottom of these items before installing them, but leave a thin film of silicone grease on the O-ring.

The motor gears should not require lubrication unless they have been cleaned, in which case only a high temperature, low volatility grease should be used, such as Dow Corning Molycote 33.

There are no mechanical adjustments which need to be made.

6.2 Desiccant

Two desiccant packs are located inside the instrument to maintain low interior humidity and prevent condensation when the temperature is reduced.

Check that the desiccant packs still have blue color showing in their windows. If the color is pale or slightly pink, dry the pack in an oven for one-half hour at 300 to 350 °F. Replace when cool.

Desiccant should be checked prior to use in cold temperatures or if conditions are favorable for condensation to form inside the case.

6.3 Fuses

The AC power input is protected with a fuse located in the holder on the upper center of the recessed connector panel. The correct value for either line voltage selections is a 0.25 amp, 250 volt fast blow type, 0.25 x 1.25 inches, such as AGC 1/4.

An internal 2 amp fuse is used in the battery circuit, and is located on the power supply board. A blown fuse here indicates whether a circuit malfunction or an inadvertent connection of pin 9 of the 25 pin terminal port connector. Loading this pin with 2 to 4 amps could blow the internal fuse. Loading in excess of this amount will merely cause automatic shutoff, which can be reset by moving the power switch OFF then ON.

The external battery leads have a 1 amp fuse in a self-contained fuse holder.

6.4 Removing the Cover

1. Remove the two phillips flat head screws and lift off the optics input device.

2. There are two more phillips flat head screws in the bottom of the input port. Remove these.

3. Loosen the 6 screws in the top of the white case until disengaged - do not remove screws.

4. Carefully lift off the cover. If it binds, avoid tearing the O-ring seal by pulling slowly on the seal so that it remains with the cover.

REPLACING THE COVER

1. Be certain no electrical cables are in a position where they could be pinched by the cover.

2. Check the O-ring seal in the lid to be certain that it is seated in the cover groove.

3. If any service work was done, check that:
   - cables are clear of moving parts,
   - all connectors are properly seated,
   - circuit boards are fully plugged in and seated in the grooved block on the base plate,
   - the screws securing the card cage are tight,
   - the circuit card retaining rod is in place.

4. Place the cover on the box, and push it down all the way around to make sure that it is properly seated.

5. While holding the cover down, start all 6 cover screws; snug them all down before final tightening. Do not over tighten.

6. Replace the two flat head screws in the optical input port.

7. Clean the base of the optical input device, leaving a thin film of silicone grease on the O-ring, and install the device.

6.5 Mirror

The input mirror must be clean. DO NOT TOUCH THE SURFACE.

Dust may be removed with clean air or lens tissue. Do not rub excessively and never use any solvent which can leave a deposit.

6.6 Battery

The battery is a nickel-cadmium type which does not give off appreciable amounts of hydrogen and oxygen gases. With proper care, this battery will provide many years of service.

Recharging is necessary approximately once per month during periods of disuse, since there is a small current drain (approximately 2 mA) needed for memory retention and time keeping, as well as a slight self discharge effect inherent in the battery. High temperatures result in faster discharge rates.

The battery is charged simply by connecting the AC line cord. The instrument can be operated in this

condition, although the charge rate will probably be slowed. Normal charging rate is 400 mA, but when the instrument drain exceeds 400 mA the charge rate will be reduced. For instrument drains exceeding 800mA, the battery must supply the difference. This condition will occur when using the older 1800-01 terminal (which draws its power from the LI-1800) while scanning. An external battery can also be used to charge the LI-1800 (Section 1.5).

Normal recharging time is 16 hours. Leaving the AC cord plugged in continuously will not seriously overcharge the battery, since there is an automatic charging reduction, but it will cause the battery to lose its capacity due to the memory effect described below.

Nicad batteries have a memory effect. For example, if the LI-1800 were used for only 2 hours and then fully recharged, after many such cycles the battery's capacity would be reduced to 2 hours. This effect can usually be reversed by repeatedly letting the battery fully discharge (at least to the point where the LI-1800 shuts itself off) and then fully recharging it.

Avoid charging in temperatures outside of the 0 to 45 °C range! Extreme temperatures while charging can cause battery leakage or failure. Never fast charge the battery or subject it to charging rates higher than 400 mA, otherwise the battery may release caustic solutions and become unusable. **CAUTION:** Battery leakage or gaseous discharges caused by improper charging or abuse can result in dangerous pressure increases in the LI-1800's sealed housing.

It is possible to use the LI-1800 with the battery disconnected if external power (battery or AC) is connected. CAUTION - In this mode, loss of external power will cause loss of stored data. The older 1800-01 terminal is not recommended for this mode of operation.

To replace the battery, disconnect the wires and remove the four screws holding the retaining strips. Replace the battery and reconnect. To preserve stored data during this process, connect the AC power. **NOTE:** Batteries with less than 3 volts open circuit should be charged by a 400 milliamp charger until the voltage rises above 3 volts prior to installation in the LI-1800. The charge circuit may malfunction if the battery is below 3 volts.

CAUTION: Do not short circuit the battery, as burns and/or damage may result.

The usual failure mode of Nicad batteries is that one or more cells short circuit. Rejuvenation is sometimes possible by applying high current pulses, but the results are usually short lived.

If you are using the 1800-01A Portable Terminal, it has its own rechargeable battery and must be charged separately.

6.7 Printed Circuit Boards

If servicing is required, the entire circuit board assembly must removed in order to remove any of the boards from the assembly. The circuit card assembly is removed by unscrewing the two screws that secure it to the LI-1800 base plate. It should not be necessary to disconnect any cables in order to lift the circuit board assembly up high enough to remove (or install) a board.

Before replacing the assembly, make sure all boards are pushed securely into the edge-card connector. All boards are kept in position by a grooved block on the base plate. Rock each board as necessary and push down to get them into the groove. Foam padding in the cover keeps the boards in the grooves; a retaining rod keeps them from being knocked out of the connector.

The retaining rod is held in place by a small spring clip. When positioning the rod, insert it from the card nearest the outside (farthest from the battery) and push through the hole in each card. Insert the clip in the rod, and position the lever end of the rod towards the monochromator. This assures that the instrument lid will clear the rod.

Lower the assembly into place and align the two screws on the frame assembly with their respective screw holes. Start both screws before tightening either.

Section VII
Performance Verification

7.1 PROM Self Test

Each time the LI-1800 is powered on, it automatically verifies that the internal PROMs (Programmable Read-Only Memory) containing the instrument software have not changed (i.e. become defective). This is done by comparing a computed check sum against a stored value of the original check sum for each PROM chip. If an error is detected, the message(s)

ERROR PROM #n

is (are) sent to the terminal, where n is an integer that corresponds to the offending PROM's number. The message is sent at 4800 baud, since all of this occurs before the initializing <cr> is received from the terminal. If the terminal is set to another baud rate the message may appear as random characters, if at all.

Note any numbers associated with these messages when corresponding with the factory concerning repairs.

7.2 RAM Test

If there is a suspicion that stored data is being altered due to defects in RAM (Random Access Memory), the CS command may help confirm this. If the CS value changes when no files have been altered, one or more bad locations in RAM would be a likely cause.

To determine which file covers the bad memory location, additional information is needed. Changes in the integrated value (IT function) for each file would be one possibility; however, if the bad memory was in one of the file headers, the CS would change without the IT values changing.

A procedure for testing all of RAM and pinpointing bad memory locations is:

1. Delete all unnecessary files. For all remaining files, such as calibration files, print out all data values using SHow with the Sequential option.

2. Determine the remaining bytes of memory using LIst.

3. Fill the memory to within 50 or 100 bytes with two files. To do this, it is necessary to set the monochromator limits in the parameters to limits well beyond the capability of the monochromator. DO NOT SCAN WITH THESE LIMITS.

   Set the LOMONO limit to 0, and the HIMONO limit to X, where

   $$X = \frac{(B - N*50 - 100)}{3*N}$$

   B is the number of bytes remaining (from LI function), and N is the number of files that are to be saved in the remaining space. Use N=2 for the first try. Also, set the data interval (INT) to 1.

4. To create a file (again, DO NOT SCAN) use the CR function, and <break> out of it when the first data value is prompted for. This will leave all the data values in the new file at 0.

5. The object is to fill the space with 2 files of non-zero data. At this point, 1/2 the space is filled with zero data. The transform function (XF) can be used on the zero data file to generate a second file of any desired value. The zero file can then be deleted, and the XF used again to generate a second non-zero file.

   EXAMPLE: Use CR to generate a zero file named ZERO.
   Use XF with these parameters:
   FILEA: ZERO
   A: O
   FILEB: ZERO
   B: O
   C: 1234 or any integer
   FILEF: F
   REM: ABCDEFGHIJKLMNO

   Delete file ZERO. Again use the XF function to generate a second file, called G. Use file F for FILEA and FILEB.

6. Calculate the integrated value (IT) for each file in memory. Print these out, or write them down for future reference. Compute the check sum (CS) for all the files, and record it.

7. At some future time (or after cycling the instrument through its environmental temperature extremes), recheck the CS and IT values. No change, accompanied by no change in the header information, indicates a passed test.

   If a change is found, the location can be pinpointed by using the SHow function, Sequential option, to find the value(s) that have changed. Note that the MAX and MIN indicators can be used to locate the wavelength, rather than printing out the entire file. <break> will abort the SH function, once the desired information is obtained.

   It is possible to "work around" a bad location in memory until repairs can be made. If the location is in high (last filled) memory, keep unnecessary files deleted so that the location is not encountered. If the location is in low (first filled) memory, position a "dummy" file over the offending location, and do not delete any files under it (i.e. do not delete any files that appear
   under that file as listed by the LI function).

7.3 Drift

As mentioned in Section II, when pre- and post scan dark readings differ by more than 3 mV, a drift message is displayed:

n MV DRIFT

where n is the number of mV by which the two readings differ. Two conditions may generate a drift message; scanning while the instrument is changing temperature (for example, taking the instrument from a warm building out doors on a cold day and immediately taking a scan), or operating the instrument at high temperatures, which greatly increases the noise and the probability of drift. This message indicates that data that is small in magnitude is likely to have additional error since the dark reading that is subtracted may not be accurate.

If repeated messages occur, a test to check the performance is described below in Section 7.4. Other factors that can cause drift would be a detector or power supply malfunction, and defective grounding or shielding. These are independent of temperature or temperature change, and require servicing.

7.4 Dark Signal and NEI

The ability to make measurements at low levels of radiation is ultimately limited by the amount of dark signal inherent in the instrument detector and amplifiers. This is termed noise, and can be described in terms of the detector output signal in mV, or else in terms of the irradiance that would have been necessary to generate that signal. The latter is termed NEI, or "noise equivalent irradiance". Generally, it is desirable to measure irradiances at least 100 times as great as the NEI, but this is not always possible.

The LI-1800 automatically measures a dark reading before and after each scan. The initial dark reading is subtracted from the measured data as a scan is taken. Ideally, measurements made in the dark would be all zeros. This is usually not the case, however, although the subtraction does reduce these measured dark values by several orders of magnitude. The remaining amount typically corresponds to 10^{-13} Amp of detector output current. The reason for the imperfect dark reading correction is that the LI-1800 does not make use of a chopped optical system; the trade-off is for fast scanning, portability, and overall ruggedness.

To observe instrument noise, take a scan in a totally dark environment with the parameters (PA function) set for DIV: NOT SET. Use the SHow function or PLot function to determine the peak-to-peak fluctuations present in the resulting data. To see the apparent offset average of all the data, use the SHow function, Average option, and choose an interval equal to the wavelength range plus the data interval (e.g. if 300 to 1100 in steps of 2 nm, use 802 nm for the interval). These data are a measure of the system noise in mV. The dark signal can be reduced by setting the OFFSET in the Parameters to be the average value from the dark scan (in mV). This value is also subtracted from the raw mV signal of the detector after each scan. Use caution in using these values as data can be ruined.

The average value is typically less than 1 mV, any higher values can indicate a malfunction. The peak-to-peak fluctuations of individual points are typically less than 8 mV for a single scan at room temperature. Scan averaging reduces these fluctuations.

NEI can be computed by doing the above experiment with the DIV: set to the calibration file. NEI is spectrally highest where the magnitude of the calibration file is the lowest - generally in the UV region. NEI depends upon temperature and all those factors that directly influence the magnitude of the calibration file (slit width, grating type, collector type, etc.).

NEI can be used to determine the error associated with a measurement due to electronic noise:

$$\% \text{ ERROR} = \frac{\text{NEI}}{\text{M}} \times 100$$

where M is the measured value, and NEI corresponds to the same spectral range as M.

7.5 Maximum Signal Capability

Radiation which exceeds the full scale capacity of the instrument is recorded and displayed as .0000 E 00. The maximum detector output is approximately 2.0×10^{6} mV (displayed as .2000E07) so the corresponding spectral irradiance value is found by dividing this value by the calibration file. Maximum spectral irradiance values vary due to the wavelength dependence of the calibration file.

NOTE: High intensity sources which overrange the LI-1800 can still be measured by reducing radiant flux with a neutral density filter.

Generally, 10 W m^{-2} nm^{-1} is measurable at any wavelength, with much higher values measurable at many wavelengths.

7.6 Wavelength Accuracy

An excellent way to check the wavelength accuracy is to scan a light source with known spectral lines. Among the most common are mercury and fluorescent lamps, which have single emission lines at 404.7, 435.8, 546.1, and 1014.0. Lasers, such as HeNe which emits at 632.8 nm, are another possibility. The wavelength offset parameter of the PA command can be used to offset the monochromator in order to compensate for some errors in wavelength accuracy (see Section 4.1).

7.7 1800-10 Quartz Fiber Optic Probe

The simplest test of the probe is to inspect it for broken fibers. Hold the large housing end so that it is in contact with a lighted fluorescent lamp tube. It is necessary to illuminate the fibers with a wide field diffuse source. Observe the input end - the glow of all the fibers should be nearly uniform. The inspection is facilitated with an eye loupe or low power microscope. Typically one or two fibers will be dim or dark due to polishing fractures. Losses exceeding this amount do not directly affect the accuracy of self calibrating devices such as the 1800-12 integrating sphere, but directly affect the accuracy of the 1800-11 Remote Cosine Collector. Please contact the factory with specifics if excessive losses are observed.

The best test of overall performance is the efficiency test. Choose a bright, uniform, diffuse light source that covers the entire 300 to 1100 nm range and has a field of view of more than 30 degrees. Blue sky away from the sun is a good example, but shield the end of the fiber tip from direct sun. With no attachments on the small end of the fiber probe, aim the probe at the light source and take a scan. The scan should NOT be divided. Remove the fiber probe from the LI-1800, point the empty input port of the LI-1800 at the same source, and take another scan. If the source is blue sky, shade the sun from the input port. Divide the first scan taken using the fiber probe by this second scan. The resultant file represents the fiber probe collection efficiency. The values should be near or above 0.2 (20%) at all wavelengths, except for an absorption dip at 940 nm. Lower values may indicate broken fibers, misaligned bundle lenses, or a misaligned mirror in the LI-1800.

7.8 Miscellaneous Operational Notes

High Temperature Operation: Be aware that when the instrument is in direct sunlight, its internal temperature will exceed the air temperature. The upper limit storage and operating temperature is 45 °C (113 °F).

Factory calibration is performed about 25 °C. For high temperature operation, it is best to calibrate the LI-1800 at the operational temperature. Detector temperature coefficients are small (0.05% / °C) in the 400-950 nm range, but increases to 0.5 - 2.0% per °C in the 1000-1100 nm range.

Detector Drift: Silicon's temperature stability is a function of wavelength (see Detector Temperature Coefficient in Specifications at the back of the manual). High accuracy at wavelengths above 800 nm require that the instrument be calibrated at about the same temperature at which it is used.

Calibration Stability: Annual drift is typically within 5%. A simple check on the calibration is to scan a tungsten lamp over the full range in 1 nm increments, dividing by the calibration file. If the plotted result has steps and jags in it that are not due to the lamp, then re-calibration is necessary. This can be misleading in the UV range due to the low signal to noise ratio involved. Steps may show up at the wavelengths where the filter wheel changes positions (see Section II). Calibration is recommended once every 3 to 6 months (see Section II and XIII).

Section VIII
Optional Monochromator Slits

8.1 1 mm and 1/4 mm Slits

Two optional slit sizes are available for the LI-1800 (1 mm and 1/4 mm). Compared to the standard 1/2 mm slits, the 1 mm slits provide greater sensitivity (but less bandwidth resolution) and the 1/4 mm slits provide greater resolution (but less sensitivity). These slits can be installed by the user. Calibration is required for each set of slits and can be performed at the factory or by the user with the 1800-02 Optical Radiation Calibrator.

The 1/4 mm slits can be ordered using LI-COR model number 1800-20, and the 1 mm slits are model 1800-21. Specifications for each of the slits are given below.

SPECIFICATIONS (based on 2 mV RMS detector noise)

Bandwidth:	300-850 nm	300-1100 nm
1 mm slits	8	12
1/2 mm slits	4	6
1/4 mm slits	3	4

Noise Equivalent Irradiance (standard cosine receptor, 300-850 nm monochromator, W cm^{-2} nm^{-1})

	1 mm slits	1/2 mm slits	1/4 mm slits
300 nm	1.5×10^{-8}	6.0×10^{-8}	2.4×10^{-7}
350 nm	1.0×10^{-8}	4.0×10^{-8}	1.4×10^{-7}
400 nm	6.3×10^{-9}	2.5×10^{-8}	1.0×10^{-7}
500-800 nm	2.0×10^{-9}	8.0×10^{-9}	3.2×10^{-8}
800-850 nm	6.3×10^{-9}	2.5×10^{-8}	1.0×10^{-7}

Noise Equivalent Irradiance (standard cosine receptor, 300-1100 nm monochromator, W cm^{-2} nm^{-1})

	1 mm slits	1/2 mm slits	1/4 mm slits
300 nm	1.8×10^{-8}	7.0×10^{-8}	2.8×10^{-7}
350 nm	1.0×10^{-8}	4.0×10^{-8}	1.6×10^{-7}
400 nm	3.8×10^{-9}	1.5×10^{-8}	6.0×10^{-8}
500-800 nm	2.0×10^{-9}	8.0×10^{-9}	3.2×10^{-8}
800-1040 nm	1.5×10^{-9}	6.0×10^{-8}	2.4×10^{-8}
1100 nm	3.8×10^{-9}	1.5×10^{-8}	6.0×10^{-8}

Noise Equivalent Irradiance (1800-11 Remote Cosine Receptor, 300-850 nm monochromator, W cm^{-2} nm^{-1})

	1 mm slits	1/2 mm slits	1/4 mm slits*
350 nm	5.0×10^{-8}	2.0×10^{-7}	8.0×10^{-7}
400 nm	2.5×10^{-8}	1.0×10^{-7}	4.0×10^{-7}
500-800 nm	7.5×10^{-9}	3.0×10^{-8}	1.2×10^{-7}
800-850 nm	2.5×10^{-8}	1.0×10^{-7}	4.0×10^{-7}

Noise Equivalent Irradiance (1800-11 Remote Cosine Receptor, 300-1100 nm monochromator, W cm^{-2} nm^{-1})

	1 mm slits	1/2 mm slits	1/4 mm slits*
350 nm	5.0×10^{-8}	2.0×10^{-7}	8.0×10^{-7}
400 nm	1.8×10^{-8}	7.0×10^{-8}	2.8×10^{-7}
500-800 nm	8.8×10^{-9}	3.5×10^{-8}	1.4×10^{-7}
800-1040 nm	7.5×10^{-9}	3.0×10^{-8}	1.2×10^{-7}
1100 nm	1.5×10^{-8}	6.0×10^{-8}	2.4×10^{-7}

* Using the 1/4 mm slits with 1800-11 Remote Cosine Receptor may not be possible for some applications because of reduced sensitivity. Contact LI-COR for details.

8.2 Slit Changing Procedure

1. Remove the 4 screws holding the mirror and filter wheel assembly onto the base plate on which the monochromator also sits.

2. Carefully lift this assembly off. Note that its alignment is achieved through two dowel pins which may drag a bit when removed.

3. The cable to the filter position encoder can be disconnected. Note that the corner of the connector that is beveled goes on top and toward the monochromator. CAUTION: Some units do not have this connector; the wires are soldered directly. Do not disconnect.

4. Using a hex key, loosen the two set screws that hold the detector mounting ring onto the monochromator exit slit tube. Slide the detector off, and set it aside.

5. The entrance and exit slit tubes are held on by 4 screws. Remove the screws and remove the tubes by lightly tapping up and down on the tube ends until they come free.

   The monochromator base plate can be removed to provide better access to the slit tube screws. This is done by removing the 4 cap screws with a hex key. Do not alter any mirror or motor adjustment settings.

6. When replacing the slit tubes, make sure the thin metal baffle is in place prior to pushing the tubes onto the alignment pins, unless no baffles are present. Be sure to observe any orientation instructions which may be attached to the tubes.

7. If the monochromator base plate was removed, re-install it by starting the 4 cap screws, tightening each until 1/2 turn remains, sliding the monochromator towards the corner opposite the circuit boards, and tightening the cap screws.

8. Replace all parts. Make sure the detector is fully seated onto the exit tube and is horizontal.

Section IX
The Standard Cosine Receptor

9.1 Calibration

The calibration file for the standard cosine receptor is named COSC and covers the wavelength range 300-1100 nm (or 300-850 nm). Any scan which uses the standard cosine receptor should be divided by the COSC file; use the PA command for automatic division, or the DI command for manual division. Failure to divide by the calibration file will result in scan files whose data represents only the uncalibrated detector output in millivolts.

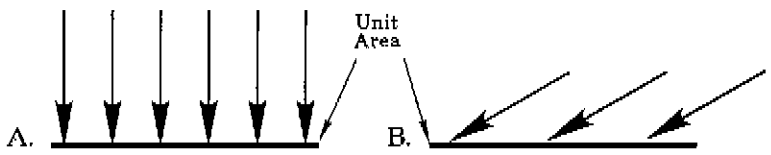
9.2 Cosine Response

Measurements intended to approximate radiation impinging upon a flat surface (not necessarily level) from all angles of a hemisphere, are most accurately obtained with a cosine corrected receptor. A receptor with a cosine response (follows Lambert's cosine law) provides measurements of flux densities through a plane surface. This allows the sensor to measure flux densities per unit area (m^2). A receptor without an accurate cosine correction can give severe errors under diffuse radiation conditions such as within a plant canopy, at low solar elevation angles, under fluorescent lighting, etc.

The cosine relationship can be thought of in terms of radiant flux lines striking a flat surface. Lambert's cosine law is explained by illustrating radiation flux lines impinging upon a surface normal to the source (figure A) and at an angle of 60 degrees from normal (figure B). Figure A shows 6 rays striking a unit area, but at a 60 degree angle, only 3 rays strike the same unit area. This is illustrated mathematically as follows:

S = (I) (cosine 60°) per unit area
3 = (6) (0.5) per unit area

where S = vertical component of solar radiation; I = solar radiation impinging perpendicular to a surface and cosine 60° = 0.5



The diffuser used in the standard cosine receptor is formed from a PTFE sheet. Specially selected and processed PTFE is used to maximize performance. The domed shape results in improved cosine response compared to flat surfaces, which lose too much light at high angles of incidence. The thickness (.03") is a compromise designed to maximize light input at 300 nm while minimizing specular transmission at 1100 nm. Minor scratches in the diffuser surface will not effect the performance of the receptor.

The table below shows typical cosine and azimuthal response data for the cosine collector and 1800-11 remote cosine collector.

TYPICAL COSINE COLLECTOR PERFORMANCE

Collector	True Cosine Response Averaged Over Azimuth (%)	(zenith range)	Maximum Variation From Mean of Azimuthal Response (%)	(zenith range)
STANDARD	± 8	0 - 70	± 4	0 - 45
			± 8	0 - 60
1800-11 REMOTE	± 8	0 - 60	± 4	0 - 45

More accurate cosine response is possible only with special purpose collectors such as limited waveband or specialized integrating sphere designs.

Improvements to the angular characteristics of the collectors would require tradeoffs with one or more of the following characteristics of the LI-1800:

1) Ability to handle the entire 300 to 1100 nm spectral range with one optical input device.
2) Weatherproof housing.
3) Stability.
4) Optical throughput.

Any alterations to the cosine collector would require a subsequent re-calibration.

Section X
1800-11 Remote Cosine Receptor

10.1 Calibration

The calibration file for the 1800-11 Remote Cosine Receptor is named RCOS and covers the wavelength range 330-1100 nm (or 330-850 nm). Any scan which uses the 1800-11 should be divided by the RCOS file; use the PA command for automatic division or the DI command for manual division. Failure to divide by the calibration file will result in scan files whose data represents only the uncalibrated detector output in millivolts.

The 1800-11 calibration file does not cover the range 300-330 nm because the signal-to-noise ratio is generally not high enough for accurate calibrations. The low signal-to-noise ratio from 300-330 nm is caused by the reduced throughput of the 1800-10/1800-11 combination (approximately 20% of the standard cosine receptor) and by the relatively low output of quartz halogen calibration lamps in that spectral region.

10.2 Installation

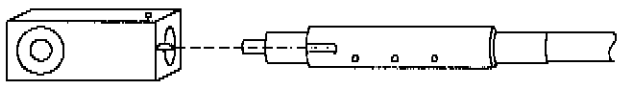
The 1800-11 is an optional accessory used with the 1800-10 Quartz Fiber Optic Probe. The probe uses a quartz fiber optic bundle which connects to the optical input port of the LI-1800. The housing mounts onto the LI-1800's input port, and contains two quartz lenses which focus the bundle energy onto the entrance slit of the monochromator. The 1800-11 is mounted on the receptor end of the fiber probe and is useful for collecting radiant flux in areas of difficult sampling geometry.

The following steps can be used to mount the fiber probe on the LI-1800 and then mount the 1800-11 on the fiber probe.

1) Remove the 2 retaining screws (phillips head) from the standard cosine receptor and pull the receptor straight up and off of the LI-1800 optical input port.

2) Install the fiber probe housing on the optical input port, making sure that the guide hole on the fiber probe is aligned with the guide pin on the optical port. To maintain accurate optical alignment, it is necessary for the probe housing to be screwed down using the two 4-40 x 3/8 flat head screws provided. This is the same size screw that is used with the cosine head. Make certain the fiber probe housing is securely fastened to the LI-1800, *as slight movements can cause large errors.*

3) Align the notch on the receptor end of the fiber probe with the post on the 1800-11 and slide the 1800-11 onto the fiber probe. There is an O-ring inside the 1800-11 which seals around the end of the probe. A very slight amount of silicone grease will aid in pushing the probe through the O-ring.



4) Secure the 1800-11 to the fiber probe with the set-screw on the side of the 1800-11 (a hex key is provided).

10.3 Precautions

- Measurements should be made with the fiber probe as straight as is practical, and without movement of the fiber probe.
- The PTFE diffuser can be dented or scratched and should be protected when not in use.
- If the 1800-11 is removed from the fiber probe, replace the red plug which was inserted in the 1800-11 when it was shipped. This will prevent dust from accumulating inside the 1800-11.
- Do not coil the fiber probe to a diameter less than 6 inches, as quartz fibers could be broken.
- Do not stretch the fiber probe.
- Do not allow anything to touch or strike the fiber ends on the probe.
- Keep the protective plastic covers in place when not using the probe.
- Do not disassemble the probe, as alignment may be lost.

A performance test for the fiber probe is given in Section 7.7.

10.4 Cosine Response

See Section 9.2

Section XI
1800-12S External Integrating Sphere and Power Supply

11.1 Instrument Description

The 1800-12 External Integrating Sphere is an instrument for collecting optical radiation that has been reflected from or transmitted through a sample material. The sphere is designed for use with the LI-1800 Portable Spectroradiometer and 1800-10 Quartz Fiber Optic Probe.

Figure 11-1 illustrates the major components of the 1800-12S and Figure 11-2 identifies each of the ports on the 1800-12.

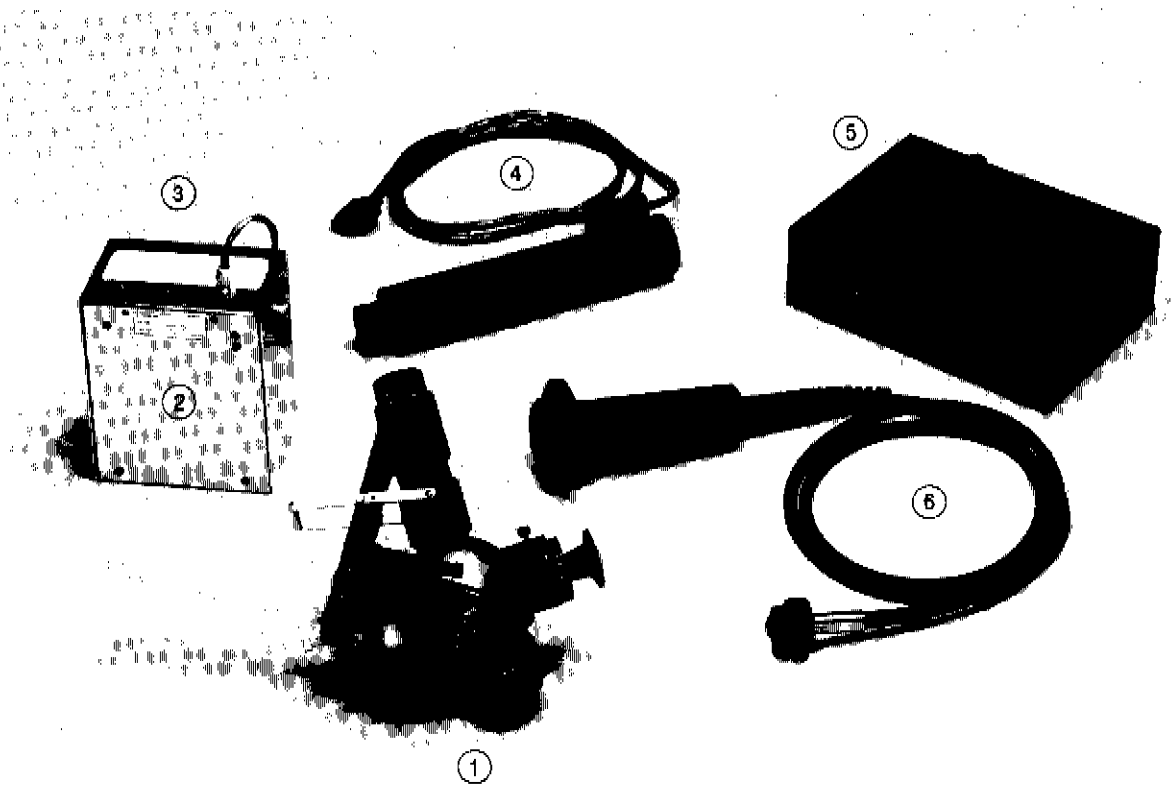


Figure 11-1. The 1800-12 External Integrating Sphere (1), the 1800-12B Regulated Power Supply (2), the 12B/1 Rechargeable Battery (3), the illuminator (4), the LI-6020 Battery Charger (5), and the 1800-10 Quartz Fiber Optic Probe (6).

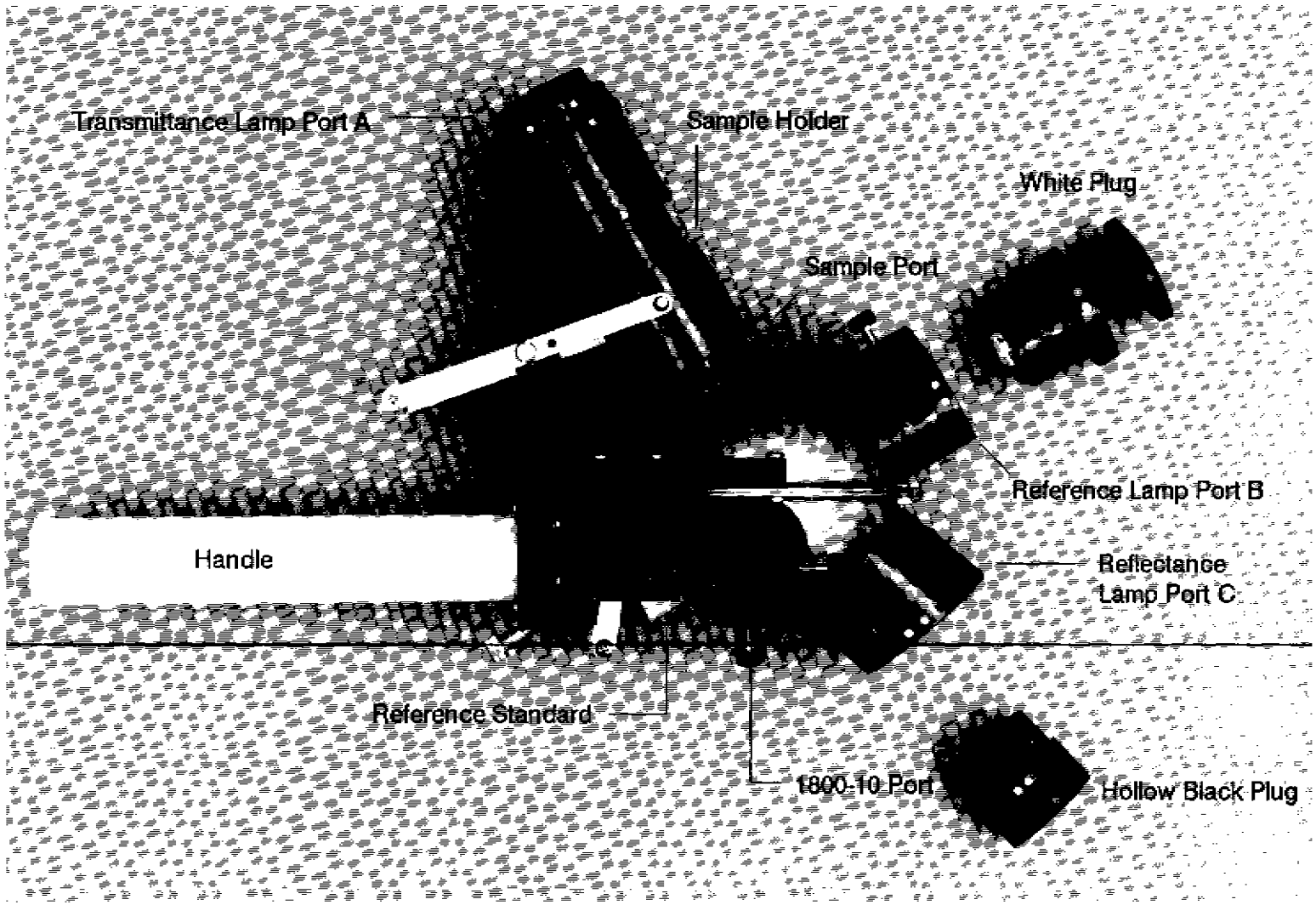


Figure 11-2. Parts of the 1800-12 External Integrating Sphere.

11.2 Theory of Operation

The purpose of an integrating sphere is the collection of all the radiation that is reflected from or transmitted through a surface so that it can be measured. The 1800-12 is an external integrating sphere, which means that the sample is external to the sphere; when it is in place, a small part of the sample actually makes up part of the sphere wall. Internal integrating spheres, a style which is different from the 1800-12, have the sample entirely inside the sphere, generally near the center.

Figure 11-3 schematically presents the important features of an external integrating sphere. Note that the radiation receptor does not "see" any part of the sample; its field of view is instead entirely occupied by the sphere wall.

A critical feature of any integrating sphere is that all points of the wall be illuminated uniformly by internal reflections. If there are bright or dark areas, then the part of the wall that the receptor sees becomes critical and the measurement cannot be trusted. To accomplish uniform illumination of the walls, the sphere is internally coated with a highly reflective, diffusive material. In the case of the 1800-12, that material is barium sulfate. The 1800-12 also has no baffles which could trap energy and cause non-uniformities. In addition, port areas are kept small to prevent non-uniformities. Sample and reference ports have sharp edges to preserve all radiation emanating from a surface.

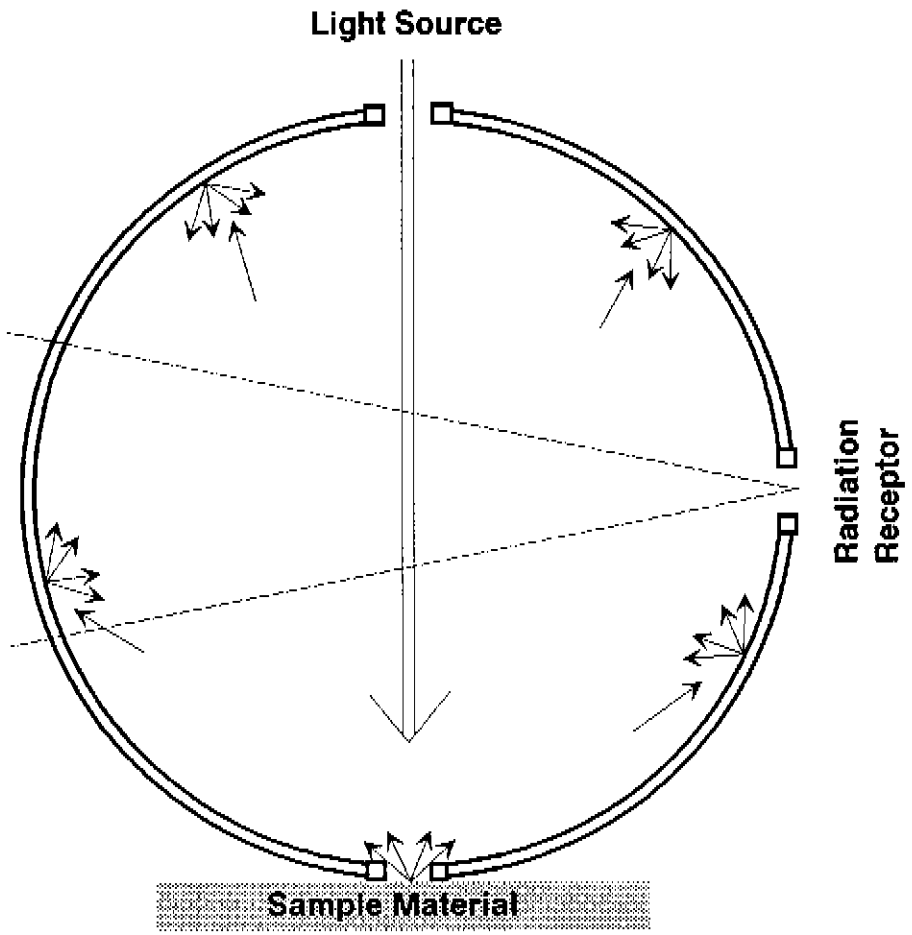


Figure 11-3. 1800-12 operational schematic diagram.

11.3 Reflectance

A measurement of reflectance involves comparing the wall illumination caused by a focused beam of radiation reflected from the sample material (Figure 11-4) to that reflected from the white reference material (Figure 11-5). The technique used is similar to double-beam systems except that instead of optical chopping, the two measurements are done sequentially. The 1800-12 uses the same illuminator for both sample and reference measurements; it is moved from one port to the other between measurements. This requires excellent short term stability of the illuminator, achieved by using a regulated power supply.

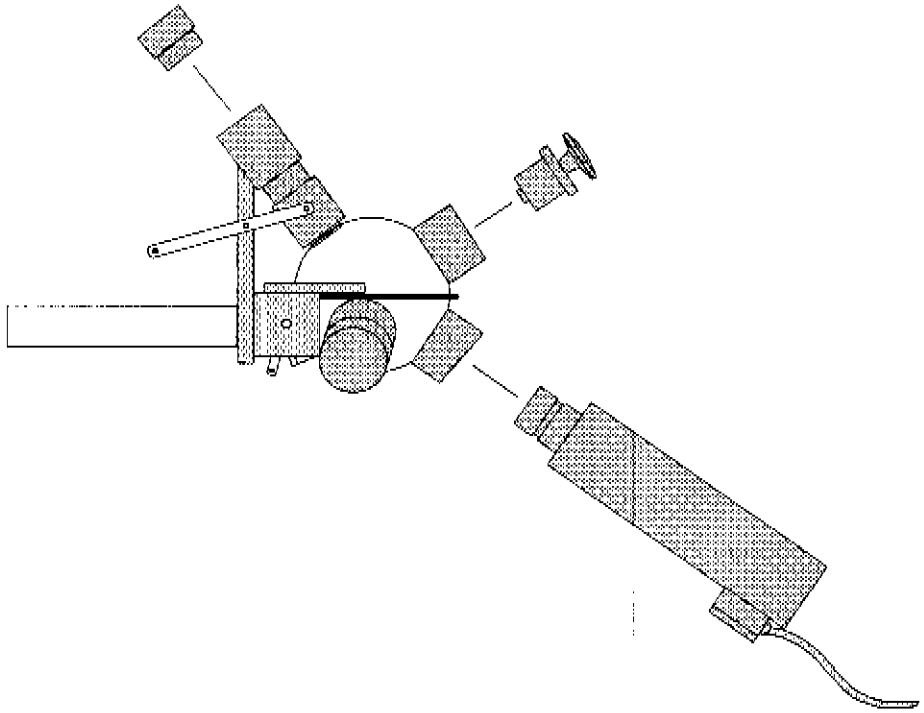


Figure 11-4. 1800-12 configured for sample reflectance measurements.

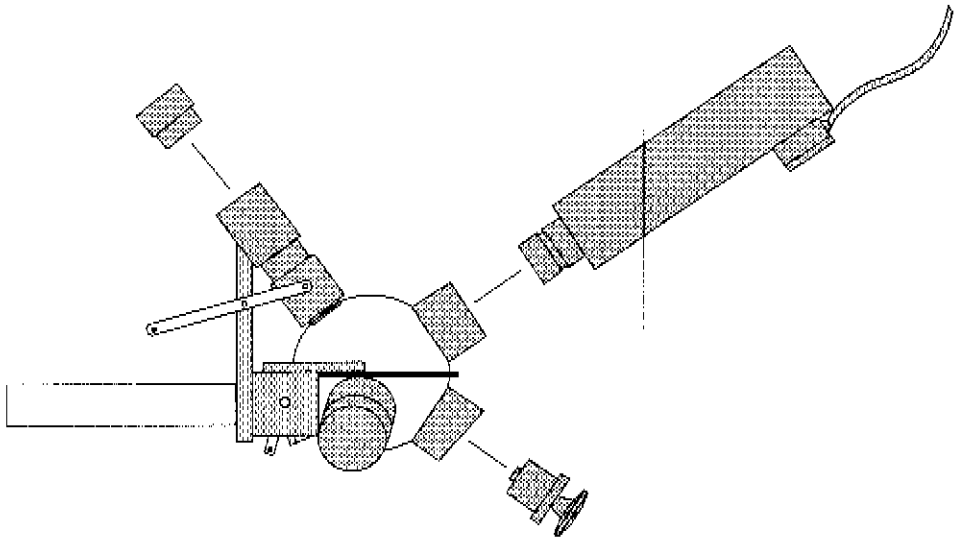


Figure 11-5. 1800-12 configured for a reference measurement.

In theory, the reflectance R_s of a diffuse sample is

$$R_s = \frac{I_s}{I_r} \qquad 11.1$$

where I_s is the measured sphere output when the sample is illuminated and I_r is that measured when the reference material is illuminated.

In practice, however, this may not necessarily be the case for two reasons:

1. The reference material is not 100% reflective which causes the measured R_s value to be slightly higher than the true R_s.

2. The beam of radiation illuminating the sample or reference is not perfectly collimated. This means that some "stray" radiation is directly getting to the sphere walls without first striking the sample or reference.

If the reference material has a reflectance R_r, and I_d is the illumination due to "stray" radiation, then

$$R_s = \frac{(I_s - I_d)\, R_r}{(I_r - I_d)} \qquad 11.2$$

R_s is the value of "Total Reflectance" as there is not a specular trap. The measurement geometry is known as "0/d", that is, illuminated perpendicular to the surface and viewed diffusely. (Actually, the incident angle of reflectance is 10° which preserves the specular component of reflectance).

I_d can be measured by illuminating the sample port with no sample in place (with no radiation external to the sphere that can leak in through the uncovered sample port). Most of the radiation from the illuminator will pass out through the sample port. The only radiation illuminating the wall will be "stray". Since I_d is quite small, it is usually ignored. If it is not small compared to the expected measured reflectance, then it should be subtracted as shown (also check illuminator alignment, Section 11.8).

11.4 Transmittance

A measurement of transmittance involves comparing the wall illumination caused by radiation that has been transmitted through the sample (Figure 11-6) to that of a reference measurement (Figure 11-5) in which the radiation did not pass through the sample. The 1800-12 uses the same illuminator for both measurements; it is moved from one port to the other.

For diffusive samples, if the reference material has a reflectance R_r less than 1 (100%), then the sample transmittance T_s is

$$T_s = \frac{I_s\, R_r}{I_r} \qquad 11.3$$

where I_s is the measured sphere output when radiation is transmitted through the sample and I_r is the measured sphere output when the reference material is illuminated. The proper configuration for the transmittance reference (I_r) is the same as that used for the reflectance reference.

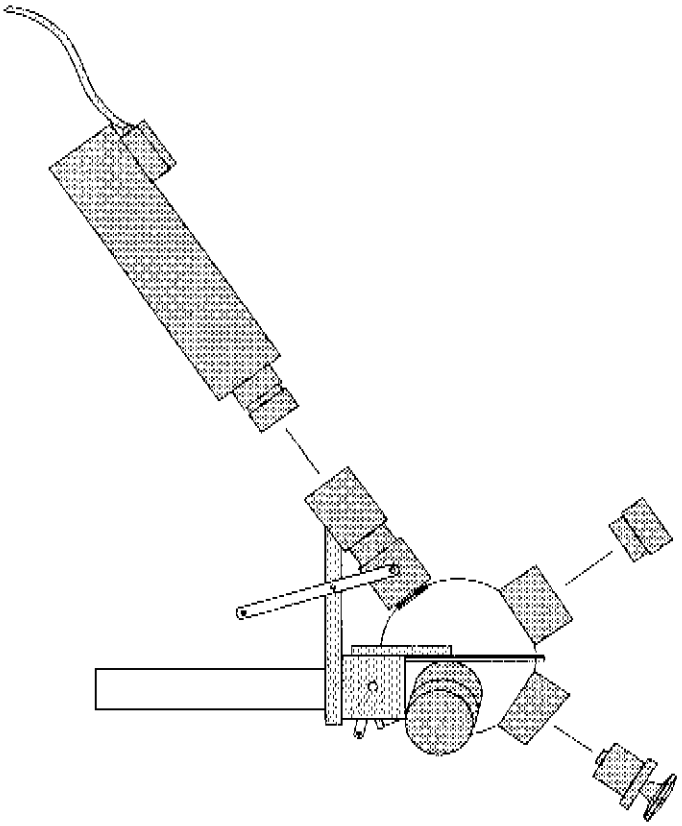


Figure 11-6. 1800-12 configured for sample transmittance measurements.

11.5 Non-diffuse (Specular) Materials

For transmittance measurements of sample material that is not diffusive (e.g. a piece of glass), the reflectance of the sphere wall opposite the sample port becomes important, since all the radiation coming through the sample is striking that one small spot before being diffused around the sphere. If this part of the sphere wall has a reflectance that differs from that of the reference material, then an error will be introduced in the transmittance measurement. Normally, this error is only a few percent. Non-diffuse reflective samples (e.g. mirrors) also have this potential problem.

When measuring the transmittance of non-diffusive samples, the configuration illustrated in Figure 11-6 could be used for the reference measurement with the sample removed from the holder. Then, the same portion of the sphere wall will receive the direct beam radiation for both the reference and sample measurements, and its reflectivity relative to the reference material does not matter. However, this method has a serious problem in that the reflectance from the sample back into the sphere effectively raises the sphere efficiency (energy out per energy in) giving transmittance values that are too large, since the sample is not in place for the reference measurement. For example, a sample whose reflectance (sphere side) is 50% can potentially raise the measured transmittance by 1.1 to 55%. This points out the desirability and importance of having the sample in place for both the reference and transmittance measurements, as indicated in Figures 11-5 and 11-6.

IMPORTANT: The 1800-12 Integrating Sphere has not been designed for optimum performance measuring non-diffuse (specular) materials.

11.6 Pre-Operation Procedures

THE BATTERY

If the instrument remains unused for long periods, the 12B/1 Rechargeable Battery Pack should be occasionally charged, at least every two months (Section 11.8). The battery life of the 12B/1 Rechargeable Battery Pack is 1.5 hours of continuous operation. When the battery voltage drops to a certain level, an audible tone from the 1800-12B Regulated Power Supply will sound. A few minutes of effective life remains at this point. Low batteries should be recharged as soon as possible. If the LI-1800 is being used, it is good practice to repeat a scan that is in progress when the tone sounds, after installing a fresh battery.

CAUTION: Never short circuit the battery connections.

FILAMENT IMAGERY

Plug the illuminator cable into the connector on the 1800-12B Regulated Power Supply. It can be locked in place by sliding the locking bracket. Insert the 12B/1 battery plug into the power supply receptacle. Power the illuminator on using the ON/OFF switch.

A check of filament imagery should be done after shipment to verify correct alignment of the illuminator. Initial measurements of stray light and relative sphere efficiency are done at the factory and data is supplied with the instrument. The user can verify these parameters by following procedures in Section 11.8.

INSTALLING THE REFERENCE STANDARD

NOTE: The 1800-12 is shipped with two reference disks; both are appressed to a matte glass plate to preserve the surface texture during shipping, handling, and storage.

Remove one reference standard from the glass plate by slowly sliding and rotating the standard as it is lifted away from the glass. NOTE: Any time the sphere is subjected to rough shipping or handling the standard should be stored in contact with freshly cleaned glass matte surface.

Visually inspect (but DO NOT TOUCH) the surface. It should be smooth and flat. Withdraw the retaining screw and open the reference holder. Position the standard, being careful not to gouge the fragile surface. Allow the spring to close the holder and move the standard carefully until its retaining boss is inside the hole on the reference holder. Turn the retaining screw until light pressure is applied. The screw prevents the standard from being accidentally dislodged. Figure 11-7 illustrates the positioning of the standard in the holder.

Small indentations will occur where the edges of the reference port touch the disk surface. These are not a problem.

11.7 Operation

MEASUREMENTS: REFERENCE, TRANSMITTANCE, REFLECTANCE

The 1800-12 Integrating Sphere has 5 ports, or openings (Figure 11-2). In addition, the sample holder has a port for the illuminator. Thus, the key to correctly using the sphere is to know what goes where in the 6 possible locations.

The tables on the next page, along with Figures 11-4, 11-5, and 11-6 illustrate the configurations. Color coding on the integrating sphere is used as a configuration aid for each mode of measurement. The color code is based on two rules:

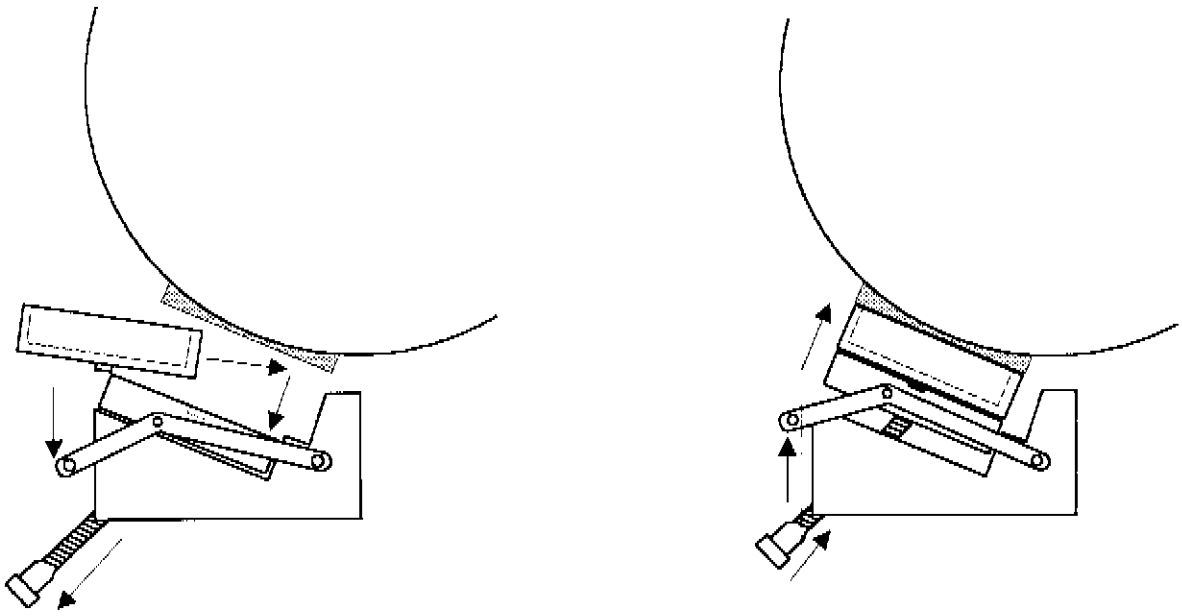


Figure 11-7. Positioning the reference standard in the holder.

1. When joining any marked part, the 4 dots on the part must align with the 4 dots on the port. There are 3 marked ports; and 3 marked parts: the illuminator, the white plug, and the black plug.

2. For each mode, the specified color dots on the port and corresponding part must match at each position; the color depends on the mode:

   WHITE - Reference **YELLOW** - Transmittance **RED** - Reflectance

INTEGRATING SPHERE CONFIGURATIONS

Reflectance Measurements

	Reflectance Reference	**Reflectance Dark Reading**	**Reflectance Sample**
Quantity Measured	I_r	I_d	I_s
Sample Port	Sample	Nothing	Sample
Lamp Port A	Hollow Black	Hollow Black	Hollow Black
Lamp Port B	Lamp	White Plug	White Plug
Lamp Port C	White Plug	Lamp	Lamp
Dot Color	White	Red	Red

For the equations below, assume $R_r = 1$ for a newly pressed barium sulfate reference.

$$\text{Reflectance of a diffuse sample } R_s = \frac{(I_s - I_d)\, R_r}{(I_r - I_d)} \qquad 11.4$$

If I_d is found to be negligible, it can be ignored. Subtraction is performed using the XF command.

Transmittance Measurements

	Transmittance Reference	Transmittance Sample
Quantity Measured	I_r	I_t
Sample Port	Sample	Sample
Lamp Port A	Hollow Black	Lamp
Lamp Port B	Lamp	Hollow Black
Lamp Port C	White Plug	White Plug
Dot Color	White	Yellow

$$\text{Transmittance of a diffuse sample } T_s = \frac{I_t\, R_r}{I_r} \qquad 11.5$$

REMOVING THE SAMPLE HOLDER

The sample holder can be used with objects up to 1.3 cm thick. However, for measuring the reflectance of objects that do not fit in the sample holder, the holder can be taken off by removing the 4 screws around the base of the plastic handle. The spare handle, included with the 1800-12, can then be inserted in the hole for the tripod mount.

USING THE LI-1800 PORTABLE SPECTRORADIOMETER

The 1800-12 External Integrating Sphere uses the 1800-10 Quartz Fiber Optic Probe to transmit radiation to the LI-1800 optical input port (Figure 11-8, 11-9). The fiber probe contains two quartz lenses which focus the fiber bundle energy onto the entrance slit of the monochromator.

The following steps can be used to first mount the fiber probe on the LI-1800 and then mount the 1800-12 on the fiber probe:

1) Remove the 2 retaining screws (phillips head) from the standard cosine receptor and pull the receptor straight up and off of the LI-1800 optical input port.

2) Install the fiber probe housing on the optical input port, making sure that the guide hole on the fiber probe is aligned with the guide pin on the optical port. To maintain accurate optical alignment, it is necessary for the probe housing to be screwed down using the two 4-40 x 3/8" flat head screws provided.

This is the same size screw that is used with the cosine head. Make certain the fiber probe housing is securely fastened to the LI-1800. *Slight movements can cause large errors.*

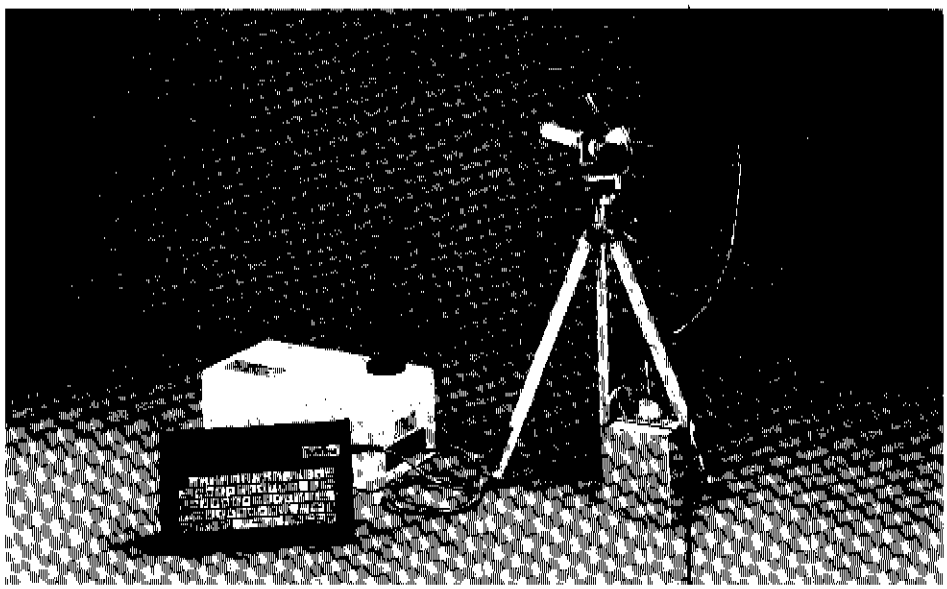


Figure 11-8. 1800-12 configured for use with the LI-1800.

3) The small end of the fiber probe attaches to a collar that is secured by two set screws (a hex key is provided).

4) The collar on the fiber probe fits into the measurement port of the integrating sphere and is held in place using the thumb screws on the port.

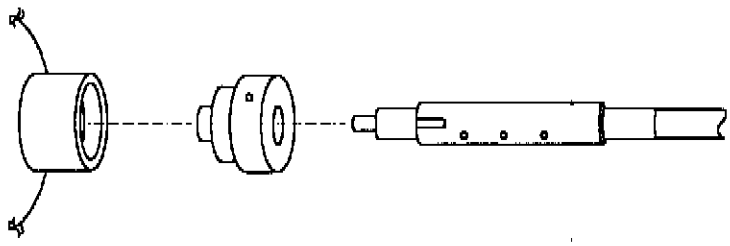


Figure 11-9. Connecting the fiber probe to the 1800-12.

CAUTION: Do not twist or stretch the fiber probe. Do not coil the fiber probe under 6 inches in diameter.

Once the sphere is configured for a particular measurement, that measurement is taken by instructing the LI-1800 to scan. Thus, for example, the reflectance data I_r, I_s, and I_d (Eq. 11.2) would take the form of files in the memory of the spectroradiometer, and the computed data R_s would be a file as well.

Data below 390 nm is generally inaccurate since the illuminator's optics transmit little UV radiation. However, the lamp does have a small output in the UV which enables collection of qualitative data to 360 nm, although it may be heavily contaminated with stray radiation.

Three scans are generally used to characterize a homogeneous sample; one each for reference, reflectance, and transmittance. Non-homogeneous samples (e.g. leaves) require two reference scans. When measuring leaves or other non-homogeneous materials, a separate reference scan for reflectance and transmittance is required if absorptance is to be computed (absorptance = 1 - reflectance - transmittance). The key is that the same side of the sample must be illuminated. The side that is facing the inside of the sphere for the reflectance measurement and reference must be facing away from the sphere's interior (but still over the port) for the transmittance measurement and its reference.

Both the reflectance and transmittance files can be divided by the reference file using the DI function after the fact, or by setting the automatic divide (in PA function) to be the reference file before taking the reflectance or transmittance scans. NOTE: Be sure the calibration file is not being divided into the three scans. It is changed using the PA function.

A typical sequence of operations to collect reflectance, transmittance, and absorptance data for the top and bottom surfaces of leaves or other <u>non-homogeneous</u> materials using the LI-1800 and 1800-12 is as follows:

1) Change the automatic divide in the parameters (PA) to N (not set).

2) Use the H0 function to suppress the header information.

3) Take a reference standard scan with the top surface of the sample facing the sphere's interior. File name STDT.

4) Change the automatic divide in the parameters to Y and enter STDT as the file to divide by.

5) Take a reflectance scan of the top surface of the material. File name REFT.

6) Before changing the position of the material in the sample holder, take a transmittance scan through the bottom of the sample. File name TRB.

7) Change the automatic divide in the parameters to N.

8) Turn the material over and take a reference standard scan with the bottom of the material facing the inside of the sphere. File name STDB.

9) Change the automatic divide in the parameters to Y and designate STDB as the file to divide by.

10) Take a reflectance scan of the bottom surface of the material. File name REFB.

11) Take a transmittance scan through the top of the sample. File name TRT.

12) Find the absorptance of the top surface using the transform (XF) function. The equation used in this computation is $F = aA + bB + c$. In this example, F = absorptance, a = -1, A = REFT, b = -1, B = TRT, and c = 1. File name ABST.

13) To find absorptance of the bottom surface, use the transform function with a = -1, A = REFB, b = -1, B = TRB, and c = 1. File name ABSB

For <u>homogeneous</u> materials the procedure can be simplified by taking only one reference scan. There is not need to turn the sample over either; leave it in the same position for all three scans.

1) Set the parameters (PA) for NO DIVIDE.

2) Configure for Reference (white dots aligned) and scan, file name STD.

3) Set the parameters for auto-divide by file STD.

4) Configure for Reflectance (red dots aligned) and scan, file name REFL.

5) Configure for Transmittance (yellow dots aligned) and scan, file name TRAN.

6) Absorptance can be calculated from 1 - TRAN - REFL.

FOR BEST RESULTS . . .

A certain amount of care and technique is required to get consistent, high accuracy with the 1800-12. Below are some items to keep in mind:

1. Keep the inside of the sphere clean and dry. Dust and debris should be removed carefully with dry air.

   CAUTION: The sphere coating is fragile and may be damaged by cleaning with a high pressure air source. Always keep the ports covered and the cap on the illuminator when not in use. In dusty environments, store all components in a clean plastic bag. NEVER apply water or any other solvent to the sphere.

2. A reflectance or transmittance measurement is only as good as the reference. Periodic renewal of the reference disk is necessary. See Section 11.8.

3. Allow the illuminator lamp to warm up at least 30 seconds before taking any data. It can be shut off between measurements to preserve battery life. For highest accuracy at shorter wavelengths, a longer warm up time may be needed.

4. If using the fiber optic cable, try to preserve its orientation from one measurement to the next. In other words, don't have it coiled for the reference measurement and uncoiled when scanning the sample.

5. Illuminator output can vary 5% or more if its orientation with respect to gravity is changed. This is due to sag of the hot filament combined with lamp envelope imperfections (see "Checking the Lamp Gravity Effect", Section 11.8). This error can be eliminated by maintaining the sphere ports A, B, and C (Figure 11-2) in a horizontal plane. Attaching the sphere to a standard camera tripod is a convenient way to do this.

6. Do not severely jar the illuminator while the lamp is lit, otherwise the lamp output could change or the lamp could fail. Be careful when inserting the illuminator into a port, do so slowly.

7. When measuring leaves or other non-homogeneous materials, a separate reference scan for reflectance and transmittance is required if absorptance is to be computed (absorptance = 1 - reflectance - transmittance). The key is that the same side of the sample must be illuminated. The side that is facing the inside of the sphere for the reflectance measurement and reference must be facing away from the sphere's interior (but still over the port) for the transmittance measurement and its reference.

8. Measurements of small leaves or any sample smaller than the illuminated spot require special techniques. LI-COR staff can provide suggestions. Avoid making masks or sample holders which intercept any part of the illuminator beam. Trying to correct data contaminated in this way is exceedingly difficult.

9. When measuring samples which are thick or have rough surfaces, make sure that no ambient light enters the sphere around the sample. This can be accomplished by placing a black cloth cover over the sphere and the sample.

10. Optically "thick" samples may yield low values of reflectance or transmittance because radiation may be scattered out the sides of the sample and never enter or re-enter the sphere.

11. The regulated power supply may be used while charging batteries by connecting it to the battery charger with the special cable provided. **IMPORTANT:** Do not charge batteries simultaneously.

11.8 Maintenance

RECHARGING THE BATTERIES

Make sure the AC line voltage matches that of the LI-6020 Battery Charger. Plug into AC and connect the battery (or batteries). The CHARGE lamp will illuminate until all batteries are charged. Recharging time will vary from approximately 2 hours for one battery to 8 hours for 4 batteries charging simultaneously.

Often, extra batteries are purchased for portable electronic instruments. Sometimes these batteries are stored until the battery in operation runs down, with the expectation that the stored battery will be in good condition. This is not always true.

Although lead-acid batteries are durable, long-life batteries, the following tips will ensure their maximum life expectancy.

1) Storing the battery in a discharged state will ruin it. All batteries that have been used during the day should be charged at the end of that day. Waiting until all of the batteries are drained before charging could take several days and be harmful to the batteries which were discharged first.

2) Do not leave the charger connected to batteries if the CHARGE lamp stays on much longer than the times indicated above. This indicates a damaged battery or malfunctioning charger.

3) Store batteries in a cool place.

4) Batteries in storage should be either recharged or rotated into use every 2 months.

CHECKING ILLUMINATOR ALIGNMENT

The illuminator is designed such that a real image of the lamp filament is formed at approximately the exit plane of the illuminator and the sample plane is illuminated by an image of the condenser lens. This assures optimum efficiency for all wavelengths by providing more light into the sphere and less dark reading "stray" light. Rough handling can alter this alignment.

To check illuminator alignment, place a translucent target (such as a piece of graph paper) at the exit hole, turn on the lamp, and observe the pattern. Avoid looking directly into the light, as it is very intense. The entrance ports of the sphere are elongated holes 1.14 by 2.08 centimeters. The filament image, which appears on the target as a blurry rectangle, must fall within this size and be as well centered as possible in the opening.

To adjust the alignment:

1. Remove the screws marked "A" in Figure 11-10a, and lift the cover off, being careful not to strain the wires connected to the lamp socket.

2. If the image is off center, lateral adjustment of the lamp socket is made by loosening screws "B" (Figure 11-10b) slightly until bracket "C" can be moved by slight pressure. Avoid overly loosening or removing these screws.

3. If the image of the filament is excessively blurry or indistinct, focusing can be done by moving the lamp closer to or further from the condenser lens. If the lamp is too close to the lens, an orange haze will

surround the image. If the lamp is too far from the lens, a blue haze will surround the image. The optimal position is that which minimizes both colors of haze simultaneously.

To adjust the lamp-lens distance, loosen screws "D" (Figure 11-10b), and slide the bracket forward or backward. If this does not provide enough travel, it is necessary to loosen screws "E" and move the lamp socket. This may affect the lateral adjustment. If the lamp socket cannot be moved sufficiently, the bulb itself can be very carefully bent forward or backward, but the leads must not be bent right at the glass interface.

CAUTION: Do not overtighten screws "E" or the lamp socket will be broken.

Additional aids to these adjustments are as follows:

With the lamp off, loosen three set screws "F" (Figure 11-10a) and remove the end cover. Room light will pass back through the optics and appear as a circle of light on the lamp. Look closely at the lamp filament. It should be centered within this circle of light. If it is not centered, lateral adjustment is needed. If the position of the lamp centering in the circle of light appears to change when viewed from different angles, focusing is needed.

When all alignment and focusing adjustments are made, re-tighten all screws and reassemble. Recheck the illuminator using the translucent screen.

Errors which can result from incorrect alignment are:

1. Loss of sensitivity at all wavelengths or at certain spectral regions.
2. Increased stray light.
3. Inability to make accurate readings, particularly of transmittance.
4. Increased variation due to gravitational orientation. See discussion entitled "CHECKING LAMP GRAVITY EFFECTS" below.

CHECKING SPHERE EFFICIENCY

Set the sphere to the reference mode with no sample present (white dots aligned). Scan the full wavelength range of the LI-1800 (390-850, or 390-1100nm) and plot the results, and compare with the efficiency data initially supplied with the 1800-12. As the sphere coating ages and becomes soiled, the magnitude of these values will decrease.

Illuminator misalignment will also cause the same thing, although it can cause more severe drop in certain spectral regions. When the values fall to about 1/3 of the original values, sphere recoating is advised unless the noisiness of the data is not considered a problem. The accuracy is not affected, only the signal to noise ratio. Fiber optic degradation can also cause these values to drop.

STRAY LIGHT

To check stray light, configure the sphere for reflectance (red dots aligned), but use no sample. Take one or more scans. Divide this file by the reference file (taken with no sample), and plot the results. The values should be under 1/2 % (0.005) and relatively constant across the spectrum. High values indicate misalignment or dirty optics. The resultant file is the value of I_d in Eq. 11.2.

The exit lens of the illuminator can be dusted off by blowing dry air towards the lens from the exit hole. If it is

necessary to thoroughly clean the lens, it must be removed. This should only be attempted by qualified personnel and the exact insertion depth and orientation must be preserved.

Another cause of high stray light readings is port misalignment, such that the projected spot from the illuminator strikes part of the edge of the sample port. This can be checked by holding a translucent target over the sample port hole and observing the illuminated spot, which should be completely contained in the perimeter of the hole with a dark ring completely encircling the spot. If it is not, sphere or illuminator damage has occurred.

BEAM BALANCE

Beam balance is a test of sphere efficiency for light entering the reference position and sample position illuminator ports.

1. Configure for reference measurements (white dots), with a white, diffuse reflector (such as the spare reference) in the sample port, and take one or more scans.

2. Configure the sphere for reflectance (red dots). In addition, exchange the reference and the sample, so that the illuminator is again shining on the reference disk, but in the reflectance mode. Take one or more scans.

3. Divide the reflectance file by the reference file. The average value of the result should be 1.00 $\pm$0.01 assuming both references have equal reflectances.

4. Carefully replace the reference.

If the results from number 3 above are out of tolerance, it may be an indication of sphere damage, or a reference with poor surface conditions rendering it insufficiently reflective. It may also indicate significant illuminator misalignment.

TRANSMITTANCE MODE CHECK

Configure the sphere for a reference (white dots aligned) with no sample in place, and take a scan. Reconfigure for transmittance (yellow dots aligned) still with no sample in place, and take a scan. Divide the transmittance data by the reference data; this is a measure of a 100% transmitting specular sample, which depends on sphere wall reflectance. In a newly coated sphere, the average value should be greater than 0.97.

CLEANING THE SPHERE

The only practical method for cleaning the interior is by blowing clean, dry air into the sphere.

CAUTION: High pressure air can damage the barium sulfate coating of the sphere, and is particularly harmful to the reference.

When cleaning the exterior, make sure no contamination of the interior occurs, either through the ports or through the hemisphere edges.

PACKING A REFERENCE STANDARD

The reference in the 1800-12 should be periodically checked for cleanliness. An easy test is to visually compare the used reference to the unused spare reference which is provided with the 1800-12. Surface damage (except at the port edges) or visible contamination indicate the need to repack. However, it is wise to

repack before visual clues so indicate.

By comparing the spare reference either through the beam balance test, or by direct substitution while measuring a stable highly reflective sample, a comparison can be obtained. When the user's criteria is exceeded, exchange the references, renewing the one that will now become the spare. Manufacturers stated values of reflectance are 0.99 from 450 to 900 nm. It is wise to renew references if the values have dropped more than 2%, or if there is any doubt about their quality. The material does not age as such, but is easily contaminated.

If the reference needs to be replaced, use only spectrophotometric grades of barium sulfate such as Eastman Chemical #6091 "Kodak White Reflectance Standard" (catalog number 118 1841) or suitable products from E. Merck Co. of Germany.

The reference standards are shipped pressed to matte glass plates to preserve their surface texture and to prevent damage in shipping and handling. To remove, press the glass down firmly and use a twisting, sliding motion while separating to prevent powder from adhering to the glass and tearing the surface. The standards should be stored against the glass whenever rough handling may be expected. **Be sure** the matte side of the glass is clean prior to contact with the powder to prevent contamination.

Eventually, all references need to be repacked due to contamination, surface defects, or crumbling, in order to restore optimum reflectance. LI-COR offers a repacking service, as well as replacement reference disks (9918-041), replacement powder (9918-044), and a repacking kit (9918-045, which was not included with the earliest instruments).

Repacking does not require that all material be removed (unless contaminated by liquid), but only the top few millimeters need to be scraped away. Sufficient new powder is added to achieve the optimum density of 2 g/cm^3. Weighing the material to be added is recommended until one has become experienced. **CAUTION:** Only clean stainless steel utensils should be used to handle the powder. Place the thin support plate on a flat surface and position the cup directly in the center so the small projection fits into the hole. Packing is done with the *freshly cleaned* matte (finely ground) glass attached to the large clear block. Packing is done in steps - overfilling slightly, pressing, scraping material toward the center, adding more and pressing, etc. After the final pressing, the glass must be removed carefully as described earlier to preserve the flat surface. The amount of force required makes it advisable to use a small press for any more than touch-up work.

CHANGING THE ILLUMINATOR LAMP

The 1800-12L Lamp should provide approximately 50 hours of operating time. To replace the illuminator lamp, remove screws A (Figure 11-10a) and D (Figure 11-10b) completely, and carefully lift out the entire bracket and socket assembly. Loosen the 4 small screws G (Figure 11-10c) retaining the lamp leads and replace the lamp. The lamp is a type 787 or equivalent 6V, 10W, 3100K halogen type with smooth envelope.

CAUTION:

- Be certain no portion of the glass on the new lamp touches the socket.
- Do NOT over-tighten the 4 small screws (G) holding the lamp leads or the socket may break. They should be snug, however. Be certain the lamp bulb is thoroughly clean before reassembly.
- Scratches and fingerprints on the bulb can cause it to fail prematurely or even explode.
- Never look directly at the lighted bulb.

Replace the socket and align as described above (see CHECKING ILLUMINATOR ALIGNMENT). Coarse adjustments are possible by bending the lamp leads, being sure not to stress or crack the metal to glass seal area of the lamp. It is helpful to look at the old lamp being replaced to see what direction it was bent and by how much. The important thing is to position the filament in the same place as before.

CHECKING LAMP GRAVITY EFFECT

Configure the sphere for reference mode (white dots aligned) with no sample present. Turn on the lamp and let it warm up for 30 seconds. Set the LI-1800 to point scan (PT command) at a wavelength such as 700 nm. Hold the sphere with the illuminator horizontal and slowly rotate it about the cylindrical axis of the illuminator. That is, rotate the sphere so as to roll the illuminator.

Observe the minimum and maximum values obtained while rotating the sphere. A difference of 1% is ideal, but some lamps may exhibit differences up to 5% due to thickness variation in the glass envelope. Greater differences may indicate loose parts or poor alignment.

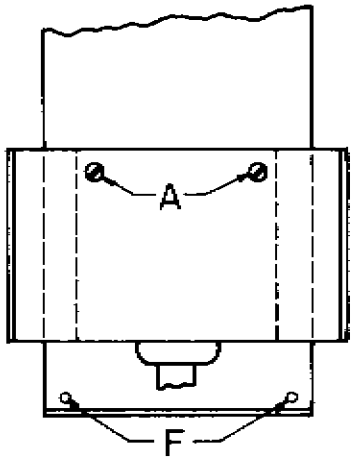
The lamp gravity effect will not be a problem if the sphere is always oriented so that the colored dots face up.

CHECKING FIBER OPTIC STABILITY

Configure the sphere and LI-1800 as described in LAMP GRAVITY CHECK. Slowly and very carefully flex the fiber optic cable, keeping the sphere and illuminator fixed, and observe the readings from the point scan. Be certain both ends of the probe are securely fastened.

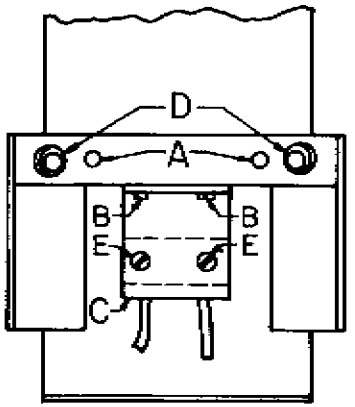
Any changes in the readings due to moving the cable may indicate broken fibers in the probe, or loose parts. Normally this effect is negligible.

11-10a



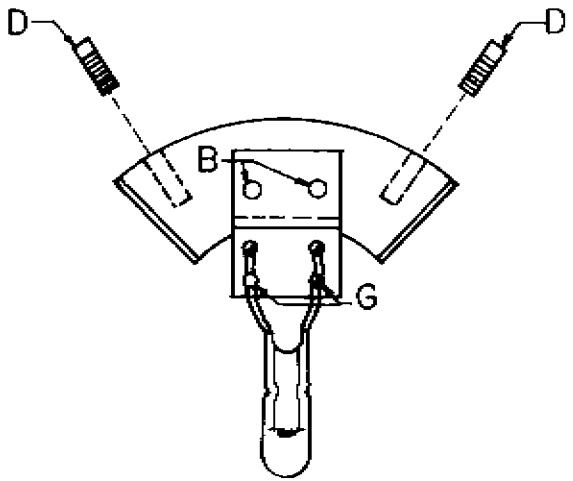
TOP VIEW

11-10b

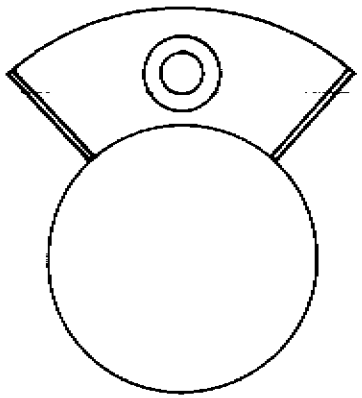


TOP VIEW
WITH COVER
REMOVED

11-10c



PARTIAL
FRONT VIEW



BACK VIEW

Figure 11-10a. (left) Illuminator with lamp cover on.
Figure 11-10b. (center) Illuminator with lamp cover off.
Figure 11-10c. (right) Lamp bracket, side view.

Section XII
1800-06 Telescope/Microscope Receptor

12.1 General Information

The 1800-06 Telescope/Microscope Receptor collects radiant flux emitted by a source or reflected from an object and transfers it to the LI-1800 Portable Spectroradiometer which measures the spectral power distribution. Spectral radiance, luminance, chromaticity coordinates, photon radiance, and other important optical quantities are then computed by the LI-1800 from this energy distribution. Alternatively, the LI-210 Photometric Sensor or the LI-190 Quantum Sensor could be used as the photodetector.

12.2 Assembling the Lens Options

The 1800-06 Telescope/Microscope Receptor has five operational modes which provide flexibility in adapting to specific object size or field of view (FOV) requirements. For telescopic measurements, three lens options are available; the 1800-06A 15° FOV Accessory, the 1800-06B 3° FOV Accessory, and the 1800-06D Mount for Canon Camera Lenses. For microscopic measurements either the 1800-06C Microscope Accessory or the UV quartz microscope option is used. In addition, at least eight different optical configurations are possible depending on the choice of extension tube, microscope objective lens, or camera lens. Thus, the proper application of the 1800-06 requires that the user know how to correctly join the various parts to produce the desired configuration.

Color coded parts aid in the assembly of each option. The color code is based on two rules:

1. One color represents each operational mode.
2. All parts used in a particular configuration should have the same color dot.

White	1800-06A 15° FOV Accessory
Blue	1800-06B 3° FOV Accessory
Yellow	1800-06C Microscope Accessory
Red	UV Quartz Microscope
No Color	1800-06D Mount for Canon Camera Lens

1800-06A 15° FIELD OF VIEW ACCESSORY

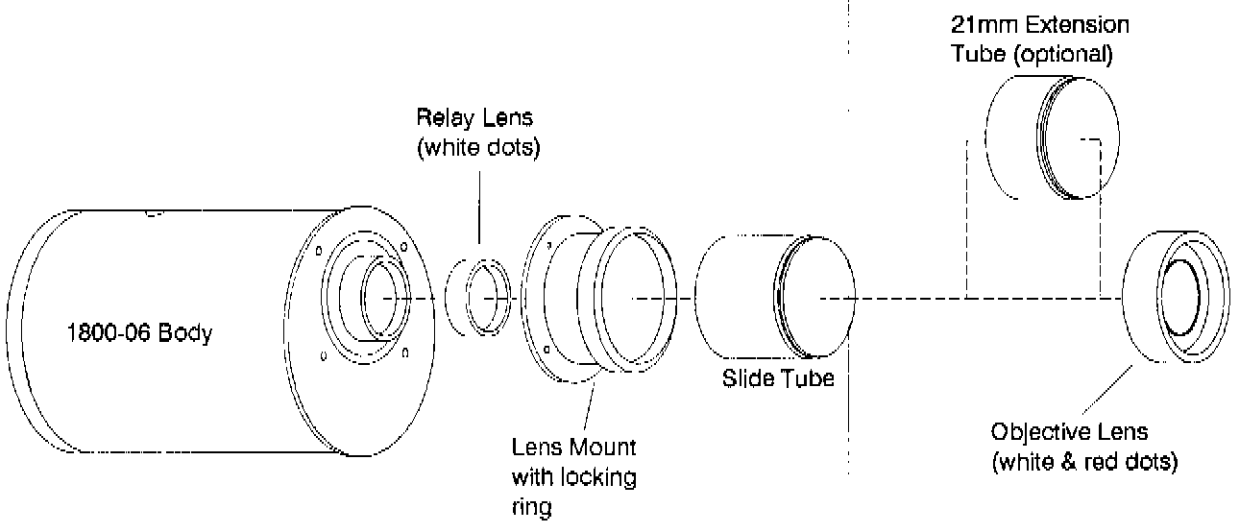
The 1800-06A is a 15° FOV option consisting of two quartz lenses. One is termed the objective lens (white and red dots) since it is affixed to the standard mount at the front of the 1800-06 Telescope and is closest to the object being measured. The other is a secondary or relay lens (white dots) which is positioned behind the standard mount.

To install the relay lens, take off the standard mount by removing the four screws which hold it to the telescope body. Insert the relay lens (with dots oriented away from the telescope) on the front plate of the telescope and gently tighten the two set screws with the provided hex key.

NOTE: Damage to the relay lens may occur if the set screws are overtightened.

To install the objective lens, re-attach the standard mount (be certain that the rubber O-ring is positioned in the groove surrounding the relay lens) with four screws. The objective lens is then screwed clockwise onto the threaded end of the sliding tube which protrudes from the standard mount. Some resistance is felt on the last

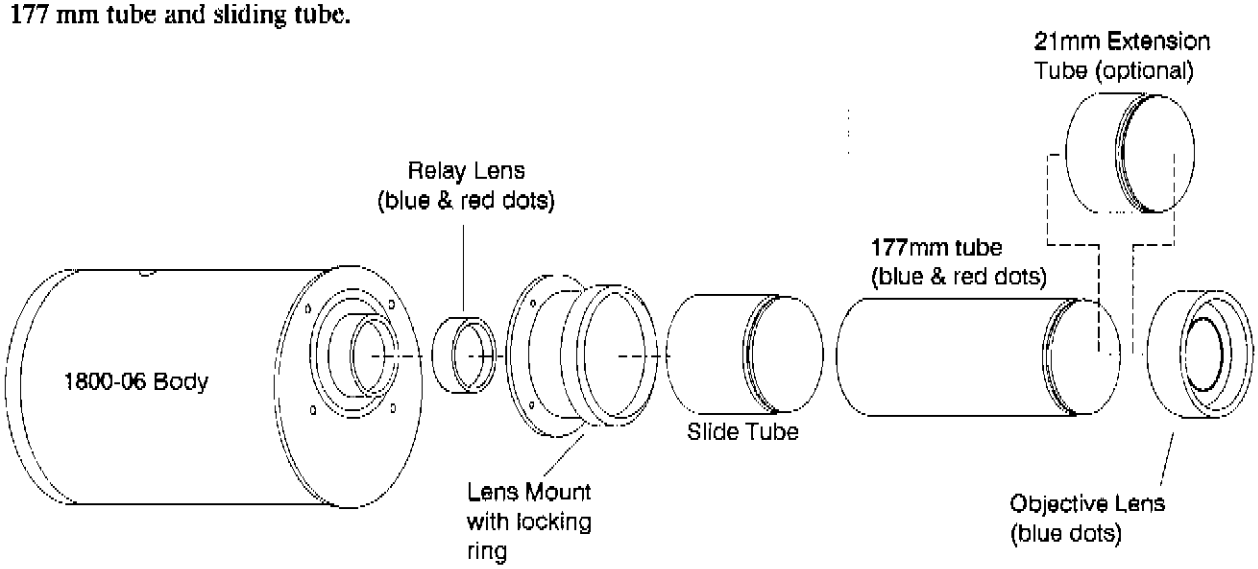
rotation as O-ring sealing takes place. Excessive resistance may indicate a dry O-ring. If this occurs, lubricate the O-ring by applying a small amount of silicone vacuum grease (supplied with the 1800-06). Note that all tube joints have O-ring seals which will require periodic lubrication. If the sliding tube turns in the mount, tighten it by firmly rotating the knurled locking ring clockwise.



The focusing range using these standard lenses is from infinity down to 20.8 cm (minimum objective diameter is 4.6 cm at full aperture). With the 21 mm extension tube included, objects as small as 2.3 cm in diameter may be measured from a distance of about 14 cm. The extension tube (white and blue dots) is threaded on both ends and is placed between the objective lens and sliding tube.

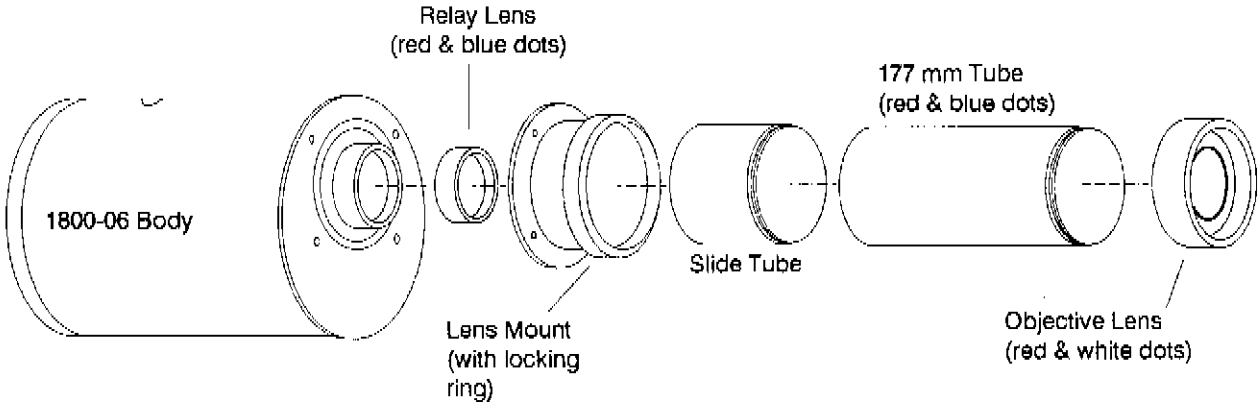
1800-06B 3° FIELD OF VIEW ACCESSORY

The 1800-06B is a 3° FOV option consisting of two quartz lenses of long focal length. The relay lens (blue and red dots) and objective lens (blue dots) are installed as described for the 1800-06A with one exception. The objective lens is first connected to a 177 mm tube (blue and red dots, threaded on both ends) which is then joined to the sliding tube on the telescope's standard mount. In this configuration, the 1800-06B is designed for viewing objects at distances of 3 meters or more with good sensitivity at a small field of view. By adding the 21 mm extension tube, objects down to 8.9 cm in diameter may be measured from a distance of about 1.9 meters. The extension tube is inserted between the objective lens and 177 mm tube, or between the 177 mm tube and sliding tube.



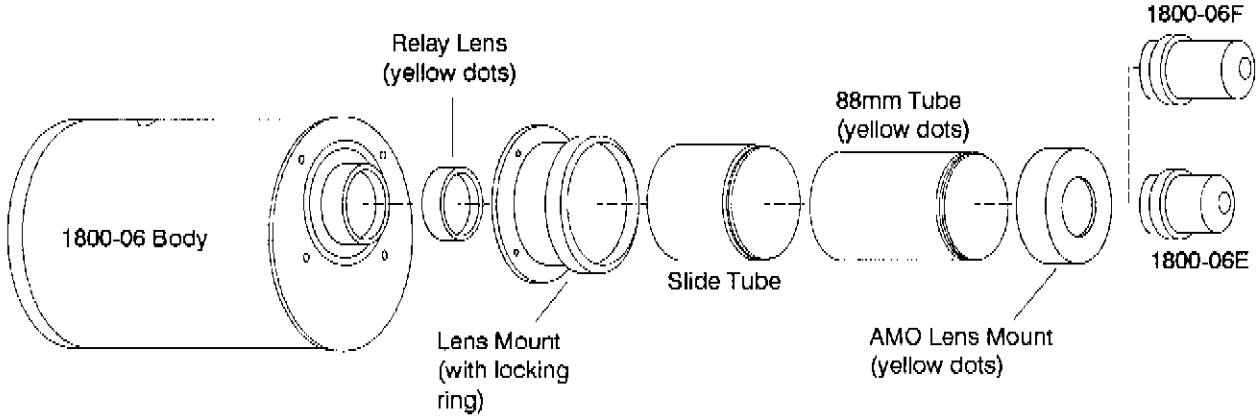
UV QUARTZ MICROSCOPE

The UV quartz microscope is configured using components of options A and B which have red dots (relay and objective lenses, 177 mm tube). It focuses at about 6.4 cm from the end of the objective lens for measuring objects which fill the 3.5 mm diameter field of view (full aperture). Since the lenses are quartz, measurements can be made from 300 to 1100 nm.



1800-06C MICROSCOPE ACCESSORY

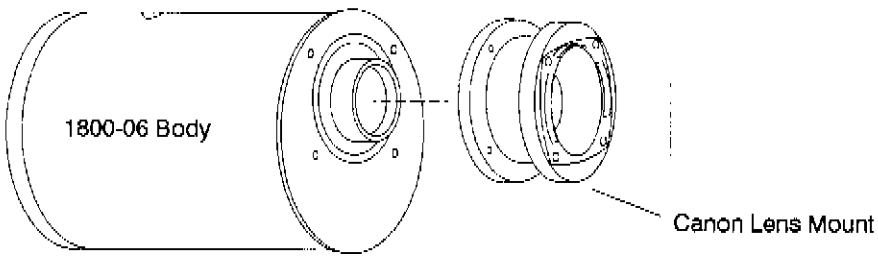
The 1800-06C is the microscope option for using standard American Microscope Objectives (AMO). Components of the 1800-06C are coded with yellow dots and consist of a relay lens, AMO mount, and 88 mm tube. The relay lens is installed as described for the 1800-06A. The AMO mount is first connected to the 88mm tube (threaded on both ends) which is then joined to the sliding tube on the standard mount at the front of the 1800-06 Microscope. A low power (7x) objective lens (1800-06E) or medium power (18x) objective lens (1800-06F) is screwed onto the AMO mount. Field diameters are 1.8 mm for the 1800-06E (full aperture) and 0.8 mm for the 1800-06F. Since the objectives are made of glass, measurements are limited to 370-1100 nm.



The 1800-06E focuses at about 12.7 mm, and the 1800-06F focuses at about 3 mm from the end of the objective lens.

1800-06D MOUNT FOR CANON CAMERA LENS

The 1800-06D camera lens mount allows direct attachment of 35 mm camera lenses having Canon type bayonet mounts. It replaces the standard mount on the front plate of the telescope body. The advantages of this mount include higher sensitivity when using the internal diffuser, and a variety of fields of view, from wider than 15° to narrower than 3 degrees depending on the focal length chosen. For example, a 500 mm lens will give a field of view of 1.2° at the full aperture of the telescope. Also, use of a 200 mm f/4 lens will provide about 8 times better sensitivity when using the internal diffuser than provided by the 1800-06B at a similar field of view. The use of large aperture catadioptric lenses is not recommended since these lenses provide no measurable energy along their central axis where the fiber optic probe is most efficient.



12.3 Connecting the 1800-06 to the LI-1800

Radiant flux collected by the 1800-06 Telescope/Microscope is transferred to the LI-1800 Portable Spectroradiometer by means of the 1800-10 Quartz Fiber Optic Probe. Insert the tip (notch upward) of the fiber optic bundle completely into the adapter on the output port of the 1800-06 Body and tighten the two set screws with a small hex key. Secure the 1800-10 to the optical port of the LI-1800 according to steps 1 and 2 given in Section 10.2.

12.4 Measurement Procedure

REFLEX VIEWING

A reflex viewer is used to accurately align and focus an image of the source onto the internal field of view wheel. This viewer utilizes an internal mirror which selects between view (V) and measure (M) mode in a manner similar to a single lens reflex camera. When viewed through the window (on top of the 1800-06 body), the source appears inverted from side-to-side and the user sees exactly what the 1800-06 measures. In measure mode (selector to "M" position), collected radiant flux passes directly to the output port without loss from a beam splitter or mirror.

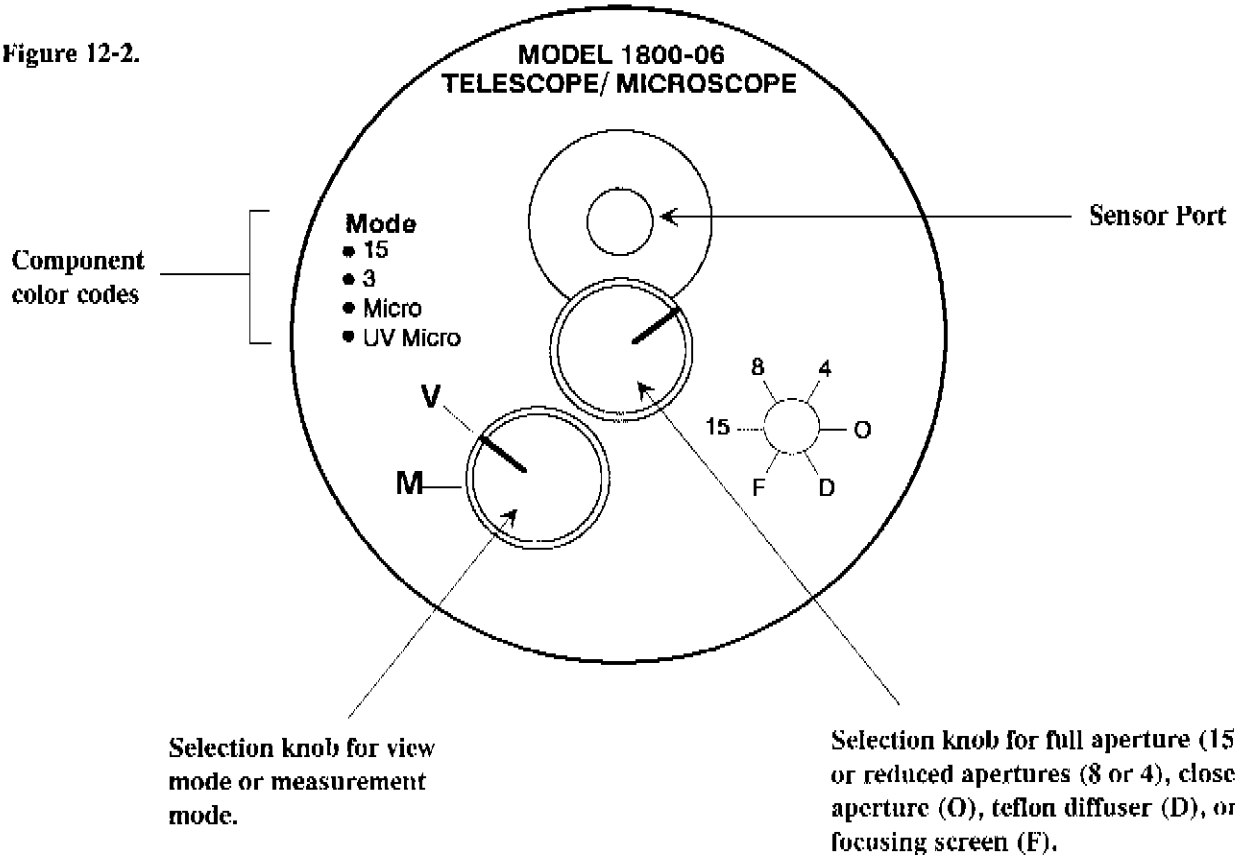
FIELDS OF VIEW

A six-position field stop wheel provides apertures which define 3 different fields of view. The 15, 8, and 4, positions are the direct angular full FOV for the 15° operational mode (1800-06A); these positions also designate angle ratios and object sizes for the other operational modes (Table 12-1). In remote spectral measurements, use of a distinct FOV permits collection of light from the area of interest and rejection of all other light. This is essential if areas adjacent to the measured area have different spectral properties. Other knob selectable positions on the field stop wheel include a ground glass screen for visual focusing (F), a teflon diffuser (D) for measuring highly polarized sources, and a closed aperture (O) for checking dark signal level.

Table 12-1. Angular field of view (degrees) or object size (mm) for each operational mode at different aperture settings.

	Selected FOV Aperture		
Operational Mode	**15**	**8**	**4**
1800-06A	15°	8°	4°
1800-06B	3°	1.6°	0.8°
Quartz Microscope	3.5 mm	1.9 mm	0.9 mm
1800-06C/1800-06E	1.8 mm	1.0 mm	0.5 mm
1800-06C/1800-06F	0.8 mm	0.4 mm	0.2 mm

Figure 12-2.



HOW TO FOCUS

For options A and B focusing on the viewed object is accomplished by moving the sliding tube in or out.

NOTE: Do not withdraw the sliding tube more than 19 mm from full insertion in the standard mount.

To slide the tube, turn the knurled locking ring counter-clockwise about 1/2 turn, then grasp the knurled area on the objective, and while turning clockwise, withdraw it from the mount. It may require a firm force initially to move the sliding tube due to the seating of its O-ring seal.

Whenever the tube is completely removed from the standard mount, be sure that the lock ring is loosened several turns to prevent damage to the split collar inside the lock ring when reinserting the tube.

It is important to note that focusing is generally not critical since images are not being transmitted, only an average of all measured radiation in the field of view. Focusing merely ensures that the field of view has sharply defined edges. To aid focusing, set the FOV selector to the "F" position where the operator now views a ground glass screen image and hence eye accommodation cannot effect the result. The sliding tube can be moved to obtain the clearest image. Tighten the locking ring when focusing is complete.

Both microscope modes should be operated with the sliding tube fully inserted. Focusing is performed by movement of the microscope objective with respect to the object.

If easier focusing is desired, an accessory focusing stage (1800-06G) may be required.

LI-1800 CALIBRATION FILES

Factory generated calibration files for each operational mode are created at full aperture (aperture setting = 15). For calibrated measurements at reduced apertures, the appropriate calibration file must be multiplied by the factors listed on the accompanying calibration certificate.

This data is based on median values between 400 and 1100 nm and is accurate to $\pm$3% if measured on the actual system as it will be used. Otherwise $\pm$6% data is provided due to fiber probe differences, etc. The actual factor has a slight spectral dependence, which for exacting measurements can be incorporated. Factors provided are nearly equivalent to those observed at 500 nm when measuring a uniform diffuse field. The factors at 1100 nm are reduced by about 5%, and those for 400 nm are increased about 7%. The values increase rapidly in the UV, reaching a 10% increase near 350 nm. These changes are due to the changing numerical aperture of the fiber optic probe.

When making an absolute measurement of spectral radiance, any data file generated by a scan must be divided by the proper calibration file (see Section 4.1 for setting the automatic divide parameter). The calibration certificate lists the file names provided with the instrument. Calibration files for the 3 degree (1800-06B) and quartz microscope modes can be created from the TELA file by multiplying it by a constant factor 0.97 using the XF function (see Section 4.5).

When using self-calibration techniques (i.e. referencing to a white reflectance panel for reflectance measurements), the automatic divide should be disabled (DIV: NOT SET) prior to making a scan. In this case the multiplying factors for reduced apertures are not necessary.

It is important to realize that reduced FOV settings decrease the measurement signal to noise ratio by the same amount as the listed factor. Therefore, it is always best to use the largest FOV setting possible. For example, the 3° option (1800-06B) when used at full field (aperture setting = 15) will be approximately 12 times more sensitive than the 15° option (1800-06A) used at aperture setting = 4 to measure a 4° FOV.

Section XIII
1800-02 Optical Radiation Calibrator

13.1 General Information

The 1800-02 Optical Radiation Calibrator is a portable, self-contained calibration system used to calibrate optical radiation measurement instrumentation over the 300-1100 nm wavelength range. The essential parts of the 1800-02 are shown below.

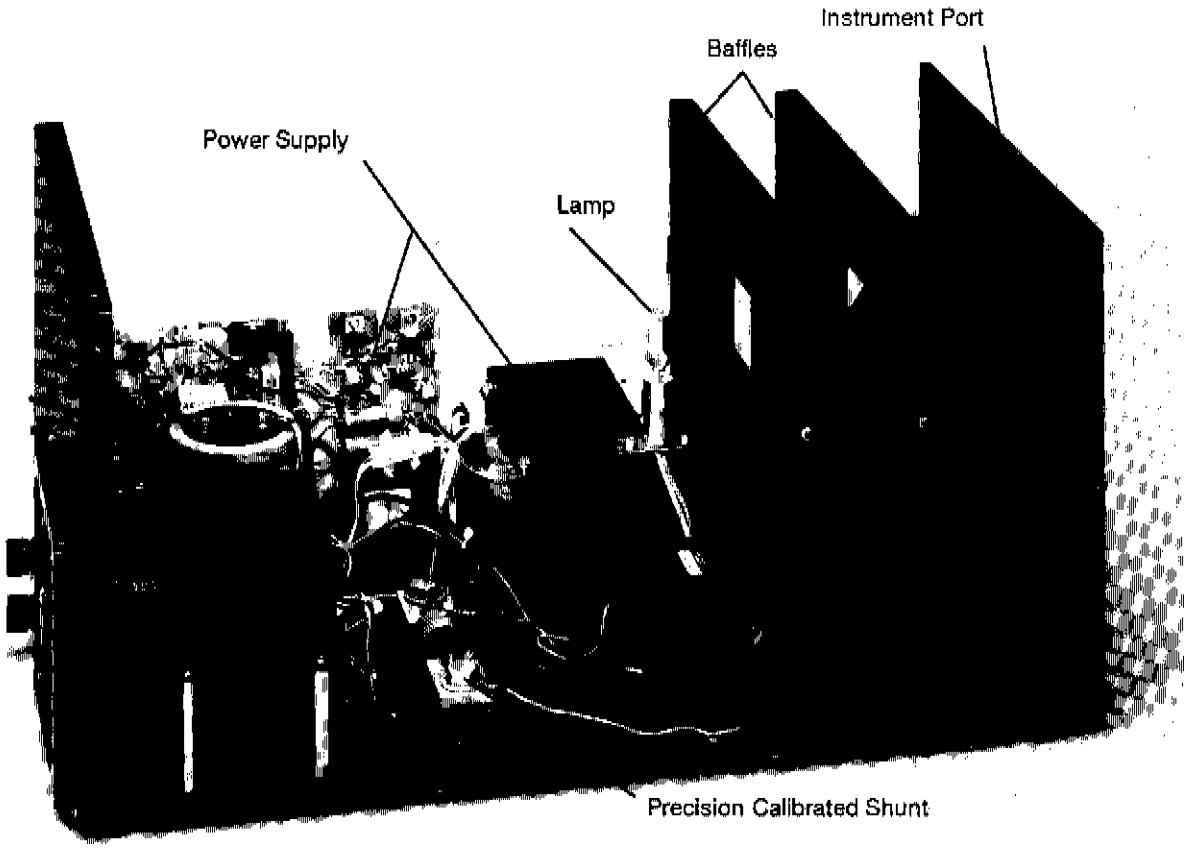


Figure 13-1. The 1800-02 Optical Radiation Calibrator.

OPERATIONAL FEATURES

The 1800-02 is designed to accommodate a variety of radiation measurement instrumentation by utilizing interchangeable mounting ports. LI-COR instrumentation that can be calibrated with the 1800-02 includes the LI-1800 Portable Spectroradiometer, the LI-1800UW Underwater Spectroradiometer and most broadband radiation sensors and meters. (Only the operation with the LI-1800 Portable Spectroradiometer

will be discussed in this manual).

The calibration lamp is a 200 Watt quartz tungsten halogen type and is operated at an approximate color temperature of 3150 °K.

The lamp holder is designed for rapid lamp replacement without complex optical alignments.

The self-contained packaging serves as an optical bench for lamp positioning and also reduces stray light with its interior baffles.

A highly-regulated power supply controls both current and voltage (constant power). Regulation of power results in increased lamp stability because the radiant output of the lamp stays more nearly the same.

When turned on, the lamp is powered up slowly to prevent filament shock. A "ready" indicator light shows when the 1800-02 is operating under normal conditions.

The 1800-02 is designed to operate within its specifications at international voltages and frequencies.

Lamp current can be measured across a precision calibrated shunt (0.1% accuracy) through external jacks on the control panel.

13.2 Theory of Operation

In general, most manufacturers of optical radiation measurement instrumentation perform calibrations on specially equipped optical benches in optically blackened rooms. Laboratory calibration systems such as these usually contain a 1000 Watt quartz halogen working standard lamp mounted in a precise orientation and energized by a highly-regulated, direct current power supply. This power supply also frequently provides a controlled warm-up to the lamp. Current to the lamp is measured across a precision shunt with a voltmeter of appropriate accuracy. In addition, the optical bench usually contains fixtures for mounting sensors and instruments at a precise distance from the lamp filament and in a precise orientation.

Working standard lamps are calibrated via transfer calibration from a *Reference* standard (also called a shelf standard). The working standard is often the same type of lamp as the reference standard and is operated at the same current. Reference standards are expensive and are used only to calibrate working standard lamps.

Several factors in these systems are critical for accurate calibrations. The first is the accuracy of the calibration transfer to the working standard. In addition, there are a number of factors in the set-up of the calibration system which contribute to the uncertainty of calibrations. The positioning of the lamp is critical. It must be in correct horizontal, vertical, and rotational alignment. The sensor or optical receptor of the measurement device must also be placed at a precise distance from the filament. Laser alignment techniques are often used to minimize errors in both lamp and sensor alignments. Other important factors include the accuracy to which lamp current (or power) can be measured and maintained, and stray light (the optically darkened room and baffling techniques reduce this factor).

In comparison to laboratory calibration systems, the 1800-02 contains most of the same components on a smaller scale. The 1800-02 contains a calibrated 200 Watt quartz halogen lamp mounted with a bayonet type FEV holder in a precise orientation that is 20.3 cm (8.00 inches) from the instrument port. The holder allows for replacement lamps (model number 1800-02L) to be rapidly installed in the same orientation, eliminating difficult lamp alignments.

A highly regulated power supply controls both the current and the voltage (constant power). The power to the lamp is maintained at a constant level (± 0.1% accuracy). Regulation of lamp power results in increased lamp stability as compared to systems regulating only current because the radiant output of the lamp stays more nearly the same.

When turned on the power supply slowly builds up the power supplied to the lamp. This prevents "filament shock" which occurs if power is increased too quickly. The power-up period lasts for approximately 30 seconds and ends with the "ready" indicator on the control panel being illuminated.

The power supply also has an over-current protector that automatically shuts the power supply down if lamp current exceeds 1.8 amps. If there is a surge, it may also blow a fuse. If the line voltage is too low the "ready" indicator will not light, thus signaling that the lamp is operating in an unstable condition that would affect calibration accuracy.

The 1800-02 utilizes a precision shunt which allows for periodic measurement of lamp current, voltage and power through the external test jacks (0.1% accuracy).

The enclosure of the 1800-02 serves the same function as many of the components in a laboratory optical system. The base plate acts as an optical bench for mounting the lamp and lamp holder in a fixed location. The front panel is used to mount the receptor ports at a fixed distance from the lamp. The cover and the interior baffles reduce stray light in much the same way as an optically blackened calibration room.

There are two important differences between the 1800-02 and most laboratory calibration systems. First, the lamp in the 1800-02 is a 200 Watt quartz halogen lamp whereas most laboratory systems use a 1000 Watt quartz halogen lamp. The lower radiant output of the 200 Watt lamp is compensated for by reducing the distance between the lamp filament and the sensor or receptor to 20.3 cm (8.0 inches). This geometry results in output irradiances that are as high as those obtained from 1000 Watt systems.

The second difference is the calibration accuracy of the lamp. The calibrated 1800-02L is slightly less accurate than the working standard lamps used in most laboratory calibration systems because the 1800-02 is calibrated by a transfer calibration (Section 13.3). In the calibration transfer the working distances from the lamp to the receptor vary considerably between the laboratory calibration system and the 1800-02.

13.3 Calibration of the 1800-02L Lamp

Lamps are calibrated by calibration transfer from a working standard lamp (FEL, 1000 Watt quartz halogen). Transfer is accomplished using a temperature controlled spectroradiometer to compare readings over the 300-1100 nm wavelength range.

The transfer calibration begins by calibrating the spectroradiometer using the known output of the working standard lamp. After the spectroradiometer is calibrated it can then be used to measure the irradiance from the uncalibrated lamp. A plot of spectral irradiance from a typical 1800-02L Lamp is shown in Figure 13-2. The spectral irradiance data can then be used to compute other lamp data such as illuminance, photosynthetic photon flux density, irradiance (300-1100 nm), etc.

An important factor in the transfer calibration is the lineage of the LI-COR working standard lamp. LI-COR's working standard lamp is calibrated through a calibration transfer (similar to the above process) from a reference standard lamp obtained from the National Bureau of Standards. NBS standards of spectral irradiance have stated uncertainties of about $\pm$ 2% at 300 nm and $\pm$ 1.4% from 450 to 1100 nm. The basis is the NBS 1973 scale of spectral irradiance.

A small loss in accuracy (as compared to the original NBS calibrated lamp) occurs each time a transfer calibration is performed. The magnitude of the loss depends on the accuracy of the measurement device (spectroradiometer in LI-COR's case) and the accuracy of the calibration set-up (filament to sensor distance, etc). For more details, an application note entitled "Calibration Procedure for LI-COR Radiation Sensors and Lamps" is available from LI-COR.

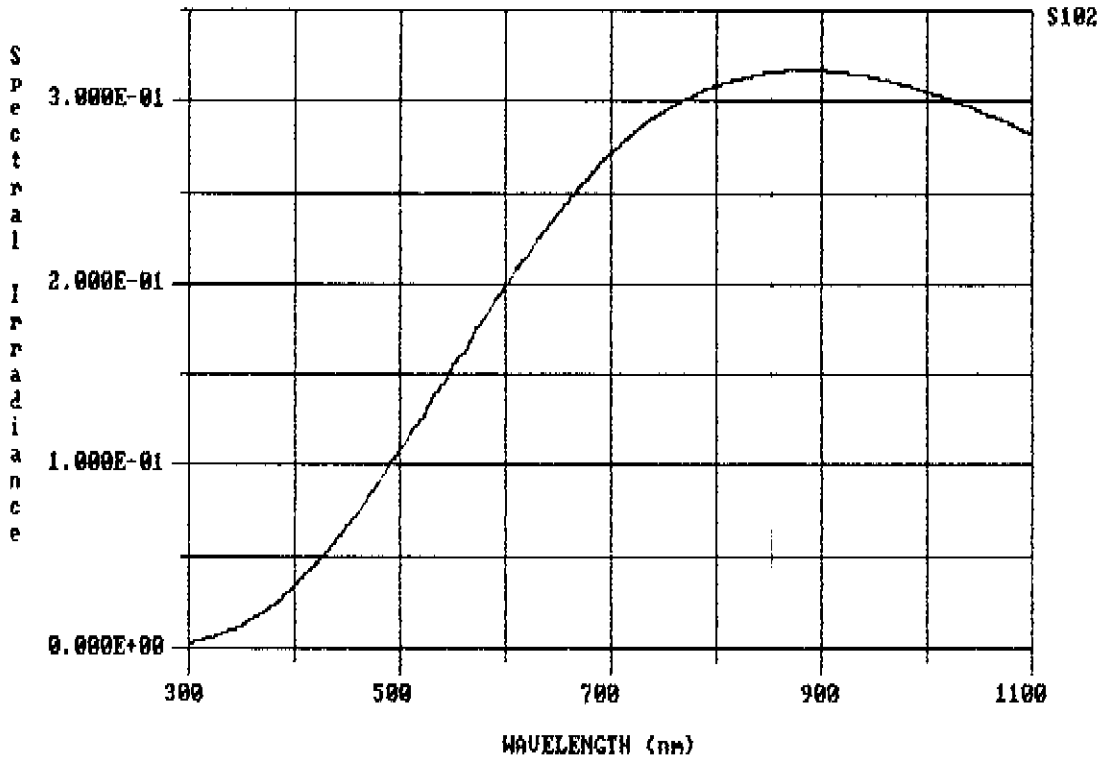


Figure 13-2. Spectral output of a typical 1800-02L Lamp

Calibration data for the 1800-02 is given on the certificate of calibration. Each 1800-02L Calibrated Lamp (the original or a replacement) has a certificate of calibration generated specifically for that lamp.

The calibration data for the lamp appears in several forms on the certificate including spectral irradiance (W m^{-2} nm^{-1}), irradiance (W m^{-2}), illuminance (lux, footcandles), photosynthetic photon flux density (μmol s^{-1} m^{-2}), photosynthetic irradiance (W m^{-2}), CIE chromaticity coordinates (x,y,u'v'), and correlated color temperature (K).

13.4 Preoperation Procedures

LAMP INSTALLATION

Before shipping, the lamp is removed and packed in a compartment at the end of the shipping carton. Handle the lamp carefully at all times to prevent damaging the filament or the quartz envelope.

To install the lamp, remove all the screws located near the edges of the cover on the top, the sides, and along the bottom of the sides (a total of 18 screws). Do not remove the 4 recessed screws located near the ventilation holes on the sides. These screws hold a light baffle over the ventilation holes. Take off the cover by slowly lifting it straight up and off. It may catch on the baffles, but a slight side to side motion should free it up.

CAUTION: To prevent electrical shock, the power cord should be unplugged whenever the cover is off or any of the interior components are being serviced. All components and connectors inside the 1800-02 are capable of delivering a hazardous electric shock.

The lamp should always be handled with the tissue paper wrapping between your fingers and the envelope of the lamp (Figure 13-3). Failure to do so will leave an oily residue from your fingers on the envelope which can result in premature lamp failure. If the lamp envelope is inadvertently touched, it must be cleaned with a lint free cloth and a methanol-water mixture before energizing to prevent burning any residue onto the quartz bulb. The contact pins on the bottom of the lamp should also not be touched when installing the lamp.

In order for the halogen regenerative cycle of the lamp to function properly the lamp must operate at a very high temperature. To prevent the circulation fan from cooling the lamp a protective baffle has been placed over the fan which extends down to the shunt resistor. This baffle should not be removed since it will effect the operation of the lamp.

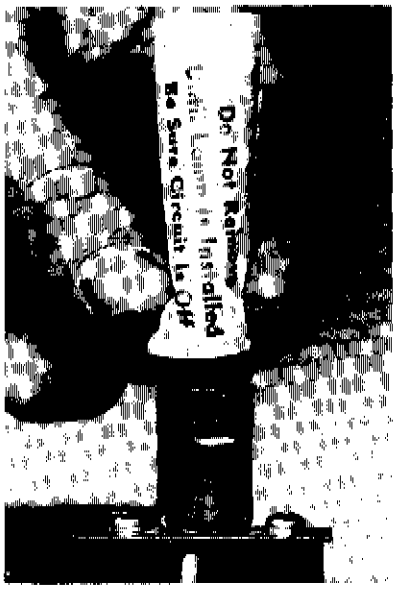


Figure 13-3. Correct lamp installation procedure.



Figure 13-4. Incorrect lamp installation procedure.

The lamp socket is a bayonet type which requires the lamp to be pushed down and twisted into place. Grasp the lamp by the base so that all downward pressure is only on the base (Figure 13-3) and not on the more fragile envelope. For proper alignment the lamp must fit tightly into the socket.

Several aspects of the lamp installation are critical for proper operation. First, the lamp must be installed in the proper direction. There are two possible orientations, but only one is correct since the lamp is calibrated in just one specific orientation and should be installed as shown in Figure 13-5. The filament support wire should be on the side opposite the instrument port and the black mark on the ceramic base of the lamp should also face away from the instrument port. Installing the lamp backwards will result in irradiance values that could deviate from those indicated on the certificate of calibration.

A second critical aspect of lamp installation is that the position of the socket must not be changed. If the position of the socket changes, the filament to sensor distance will change resulting in different irradiance values at this new distance. Normally the socket can only be moved by loosening the screws on top of the mounting posts. However, a strong sideward pressure during installation can cause the lamp socket to bend causing poor lamp orientation.

The lamp should fit snugly in the socket with minimal movement toward or away from the instrument port.

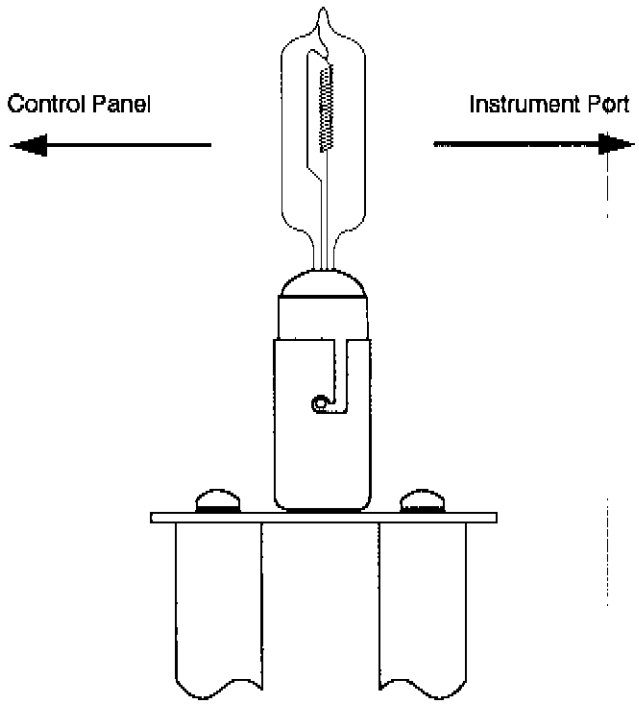


Figure 13-5. The lamp should be installed with the filament support wire facing away from the instrument port as shown.

SETTING THE POWER JUMPER

Each lamp is calibrated at a specific power setting This setting can vary from lamp to lamp so a jumper is provided which allows the user to adjust the power setting. The jumper is initially set at the factory but it should be checked after the lamp is installed.

The power jumper is located on the circuit board (Figure 13-6). The power setting is given on the calibration certificate (power tap#) for the lamp as a number from 1 to 4 which corresponds to the 4 pairs of pins on the jumper connector (numbered 1 through 4 from left to right). The power (Watts) associated with each setting is given below.

1	2	3	4
175.9	183.5	191.5	199.8

To change the power jumper, pull the black plastic jumper straight back and off of the pins and then push it back onto the proper pair of jumper pins. Be careful so that the pins are not bent or damaged.

Before replacing the cover, check the various wiring connectors on the circuit board to make sure they have not been loosened during shipment. In particular, check the lamp sensing connector (Figure 13-6). Lamp damage could result if this connector is loose while the 1800-02 is running.

Replace the cover and screw in all the screws around the cover. It is important that all screws are put back in place since they add to the rigidity of the case and keep light from penetrating through the cover. Note that the side of the cover with the notch in it goes on the side with the instrument port.

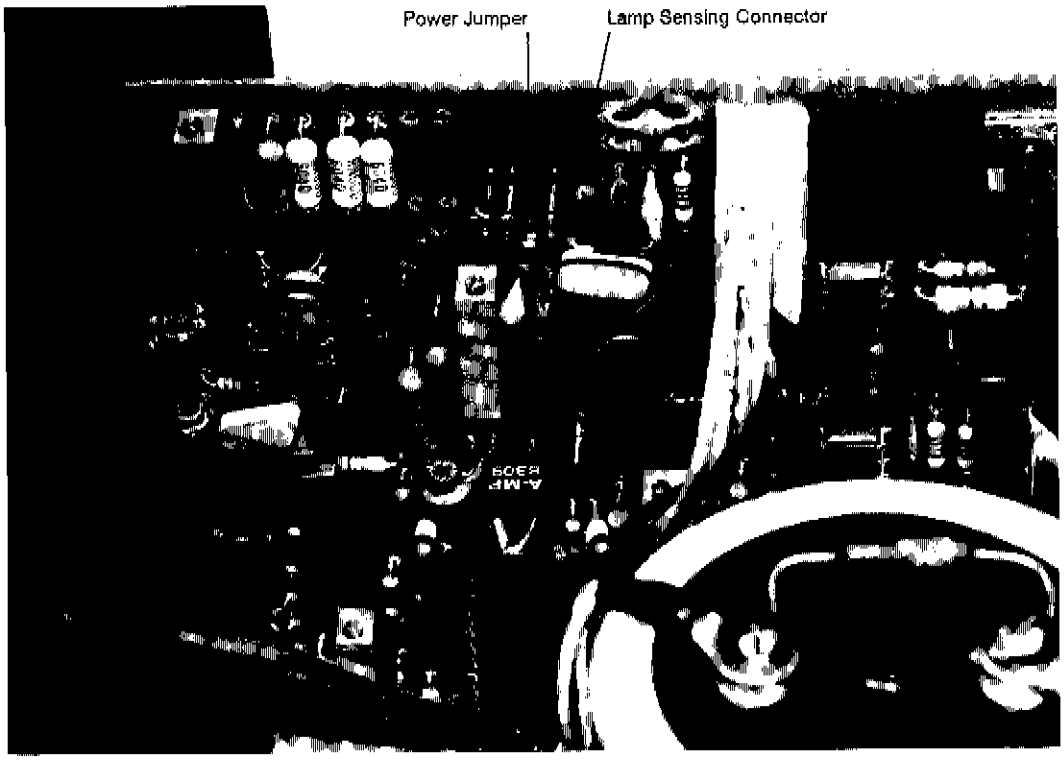


Figure 13-6. Location of the power jumper.

FUSE INSTALLATION

The lamp is protected with a 2 amp fuse located on the control panel (Figure 13-9). The power supply is also protected with a fuse located directly beneath the lamp fuse. A 3 amp fuse should be installed for operation with 210-252 VAC and a 6 amp for 105-126 VAC.

LINE VOLTAGE

Line voltage is connected via the 3 prong receptacle located on the bottom center of the control panel (Figure 13-9). The correct line voltage must be selected on the slide switch (labeled AC VOLTAGE) located immediately to the left of the AC receptacle. Select "115" for 105-126 VAC or "230" for 210-252 VAC. The frequency range is 48-66 Hz. Voltage lower than rated will not damage the instrument but may cause the power supply to shut itself off because it cannot maintain the lamp at the necessary power level. This feature will prevent erroneous data at voltages below the rated values.

INSTALLING THE MOUNTING PORT

Two mounting ports are included with the 1800-02. The first (Figure 13-7) is the standard instrument port which is designed for the cosine receptor of the LI-1800 Portable Spectroradiometer or the LI-1800UW Underwater Spectroradiometer. The second mounting port (Figure 13-8) is designed to accommodate the 1800-11 Remote Cosine Receptor of the LI-1800 Portable Spectroradiometer and LI-COR broad band radiation sensors.

The mounting ports are installed with two 6 x 32 - 1/2 flat head screws and are positioned by a guide hole which fits over a screw head on the front panel. The guide hole is the hole at the top of the mounting port pictured in Figure 13-7.

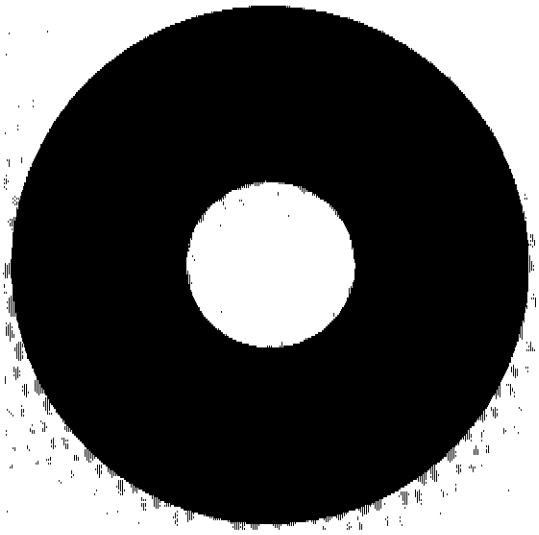


Figure 13-7. Standard instrument mounting port.

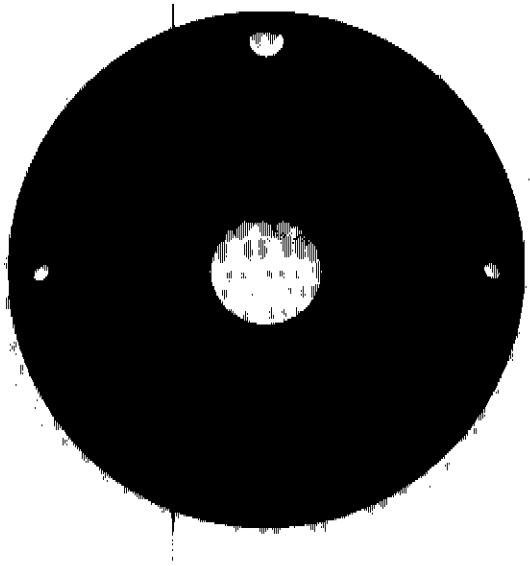


Figure 13-8. 1800-11 mounting port.

13.5 General Operation

CAUTION: Do not look directly at the lamp while it is operating.

It is advisable (though not absolutely necessary) to keep a log of the running time of the 1800-02L Lamp.

ON/OFF SWITCH

The two position ON/OFF switch is located in the center of the control panel (Figure 13-9).

> CAUTION: Do not turn on the 1800-02 with the cover off. All parts carry high voltages which can deliver an electric shock if touched while the instrument is operating.

After the ON/OFF switch is turned on, the indicator labeled POWER on the left side of the control panel (Figure 13-9) will light showing that the power supply is receiving power. This indicator does not necessarily indicate that the power supply is operating properly.

If the power indicator fails to light, it could be caused by one of several conditions including a blown fuse, improper line voltage, or power supply failure. See Section 9.4 of the 1800-02 Instruction Manual for complete information on troubleshooting.

After the ON/OFF switch is turned on, power to the lamp is steadily increased until it reaches the level set by the power jumper. When this power level is reached, the "ready" indicator on the left side of the control panel is illuminated to indicate the instrument is operating at normal power levels (Figure 13-9). After the ready indicator comes on, wait an additional five minutes for the lamp to reach thermal equilibrium.

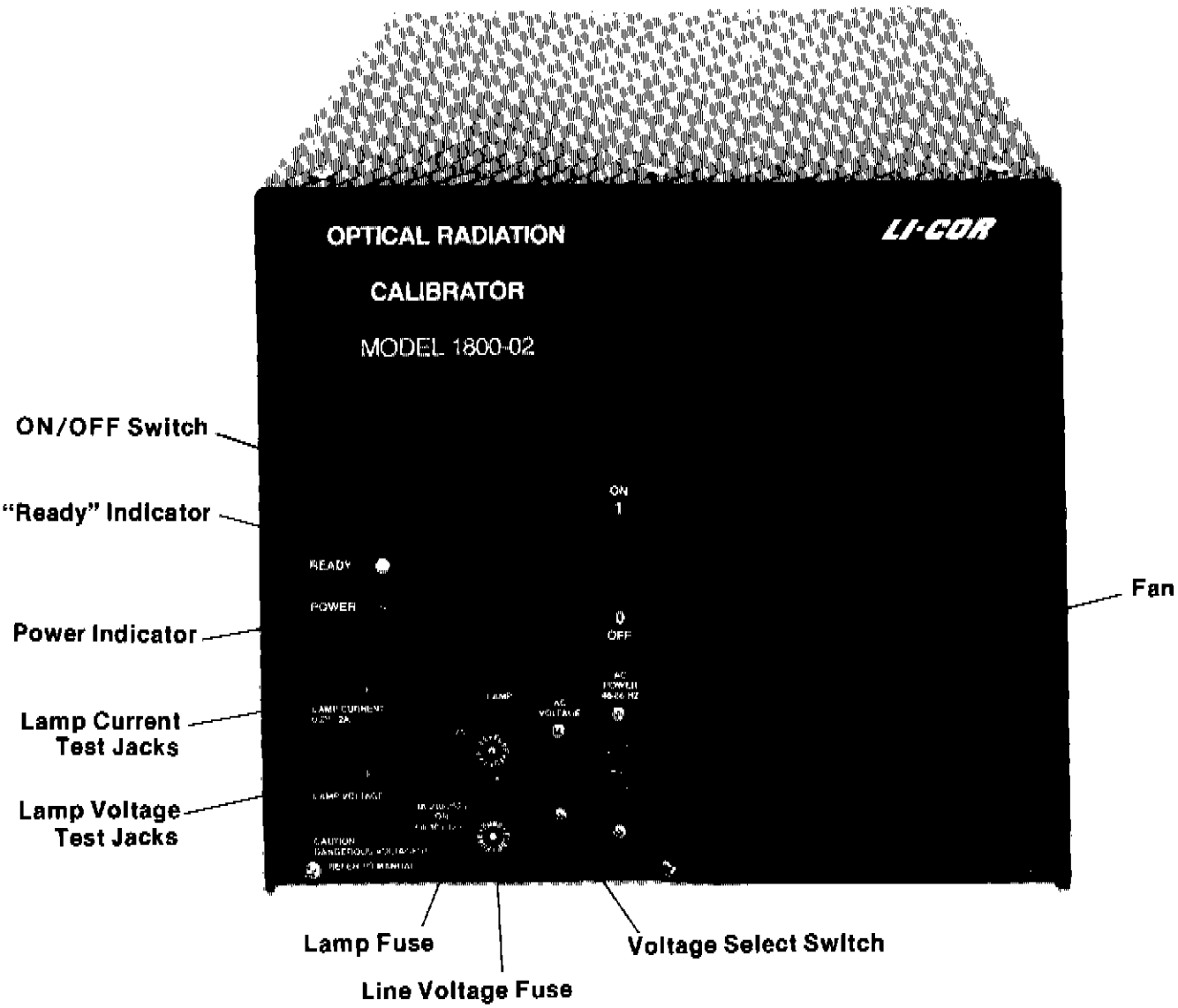


Figure 13-9. 1800-02 Control Panel.

IMPORTANT: The 1800-02 should not be picked up and moved while the lamp is turned on; damage to the lamp could result.

LAMP VOLTAGE/CURRENT MEASUREMENT

Measurement of lamp current and voltage provides a method for periodically monitoring lamp stability. Since the power supply is highly regulated, this measurement need not be taken every time the 1800-02 is used. However, if the lamp current and voltage are measured and lamp power is computed when the lamp is first installed, this can be used for routine comparisons throughout the lifetime of the lamp. The lamp power should be measured approximately every 10 hours of operation.

Lamp current can be measured by attaching a voltmeter to the LAMP CURRENT test jacks located on the left hand side of the control panel (Figure 13-9). Lamp current can be calculated by measuring the proportional voltage across the test jacks where 0.2 Volts = 2 Amps.

CAUTION: The measurement jacks carry hazardous voltages. Avoid personal contact with connections. These jacks have a high voltage with respect to earth ground and must never contact ground or the chassis of the instrument. Use only measuring instruments with a 500 volt or greater isolation from the AC power source. Probes should be insulated 2 mm diameter "tip plugs" or "phone tips". The contact pin should not be inserted more than 15 mm into the panel. Avoid probe types which could inadvertently short circuit against the metal panel beyond the insulating bushings.

Lamp voltage can be measured using the LAMP VOLTAGE test jacks located directly beneath the LAMP CURRENT test jacks on the left side of the control panel (Figure 13-9). Lamp voltage ranges from 112 to 118 volts.

Using the lamp current and voltage information, lamp power can be computed by multiplying the current by the voltage. Lamp power is one of the four values selected by the power jumper as given below.

1	2	3	4
175.9	183.5	191.5	199.8

The measured values should be $\pm$ 0.1% of the value of the jumper setting (25 °C). Temperature variations of $\pm$ 25 °C can cause an additional change of $\pm$ 0.25%.

Since the power supply of the 1800-02 is designed to provide constant power to the lamp, it is this value of lamp power that should be monitored in order to gage system stability. Acceptable limits of drift are $\pm$ 0.2% from the values given above. A 0.1% change in power will result in a 0.26% change in the calibration of the lamp at 300 nm; and 0.12% at $\geq$ 600 nm.

If a drift higher than the amounts above are encountered, please refer to Section 13.7 for instructions in troubleshooting.

LAMP LIFE

As the lamp ages its resistance will likely change. Lamp resistance is equal to lamp voltage divided by lamp current. If the lamp resistance changes by more than 2.0% while power values are correct it is advisable to check the lamp base contacts (Section 13.7) and retake the lamp voltage and current measurement. If no change is noted, the lamp has drifted more than an average amount and is probably nearing the end of its life.

The lamp should frequently be observed in its unenergized state to ensure that the quartz envelope is clear and undistorted. Note that the bottom of the lamp normally develops a yellowish brown color.

Lamps are rated to hold the initial calibration values and tolerances to $\pm$ 1.0% for 50 hours of operation. For

the best accuracy the lamp should be changed at that time. (It is a good idea to keep a log of the operation time of the 1800-02L Lamp.) It is expected that most lamps will hold to ± 2% if used until burnout. This is normally adequate for routine calibrations, but the lamp should be carefully monitored after 50 hours. The data acquired within the last 10 minutes of lamp life should be discarded.

13.6 Calibrating the LI-1800

Before beginning the calibration, the noise equivalent irradiance (dark signal) and wavelength accuracy should be checked as described in Sections 7.4 and 7.6 (respectively).

The lamp data on the 1800-02 Certificate of Calibration is entered as a file using the LI-1800's create command (CR). Data is entered from 300 -1100 nm in 10 nm steps (set these wavelength limits and interval using the PA function).

INSTALLING THE LI-1800

The standard instrument port of the 1800-02 joins with the standard cosine receptor of the LI-1800. The cosine receptor fits snugly into the inside diameter of the instrument port with the PTFE dome aligned in the center of the port's aperture.

Before installation clean the PTFE dome of the cosine receptor so that there is no dirt or finger prints on it. A soft cloth or a lintless wiper moistened with alcohol should be used. Great care should be exercised to prevent deforming the dome while cleaning it.

The LI-1800 is held in place by two threaded rods and a back brace (Figure 13-10). The threaded rods are installed by screwing them into holes located in the lower left corner and in the center near the top of the front panel. On the top of the front panel there are two screw holes in close proximity. It is the lower of the two holes that the rod should be screwed into.

The back brace can now be put on the rods and wingnuts screwed part of the way onto the rod. The back brace should be put on the rods with the foam pointing inward toward the front panel.

Install the LI-1800 by laying it on its side and sliding it in-between the support rods. Align the cosine receptor with the standard instrument port and push it all the way in until the top surface of the cosine receptor is against the back of the instrument port. Push the back brace tight against the back of the LI-1800 and tighten the wingnuts until the foam on the rod is compressed to 1/3 of its original size. There should be a small gap along the length of the bar, so that only the foam touches the back of the LI-1800.

Due to the weight of the LI-1800, the clamp bar may not be able to accurately position the instrument merely by tightening the wingnuts. It is advisable to gently rock the LI-1800 back and forth during the tightening to allow it to come into the correct position (cosine receptor completely parallel to and contacting the joining surface of the instrument port).

For accurate calibration, it is very important that the cosine receptor is perpendicular to the adjoining surface of the 1800-02 instrument port (i.e. the plane of the top of the LI-1800 should be parallel to the plane of the front panel of the 1800-02). If the surface supporting these instruments is not flat, it will not be possible to correctly position the LI-1800 with respect to the 1800-02.

Turn the 1800-02 on and allow it to warm-up.

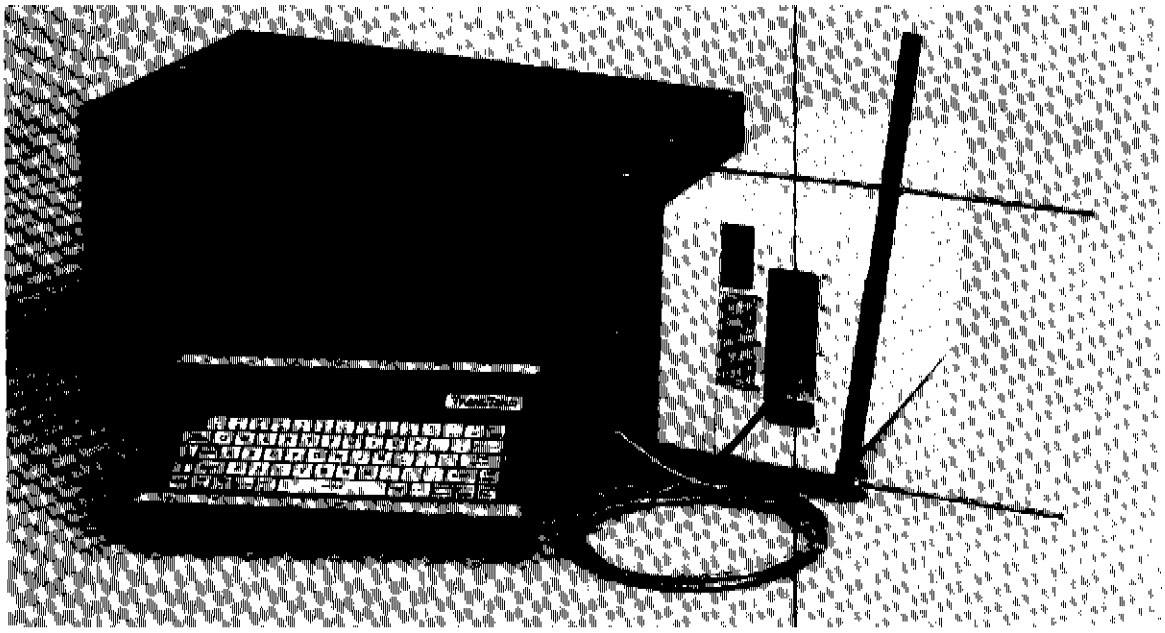


Figure 13-10. LI-1800 installed on the 1800-02

MAKING A CALIBRATION FILE

Before starting, the data interval in the parameters (PA) of the LI-1800 should be re-set to 1 nm and the wavelength limits to 300-850 (1100 nm optional).

NOTE: Calibration files with intervals other than 1 nm can limit future scanning intervals. For instance, a scan in 1 or 2 nm intervals cannot be accomplished if the calibration file contains data at 5 nm intervals.

The LI-1800's calibration function (CA) can now be used to generate a new calibration file in the LI-1800's memory. The LI-1800 will automatically interpolate between the data points in the lamp file (10 nm intervals) when making a calibration file with a data interval smaller than 10 nm.

For the best possible signal to noise ratio in the ultraviolet region of the spectrum, at least 6 scans should be averaged when the calibration is being performed.

After the new calibration file is generated compare it to the old calibration file. If large shifts in a particular region of the spectrum or a large overall offset have occurred, LI-COR should be contacted.

CALIBRATING THE 1800-11 TO THE LI-1800

Calibration of the 1800-11 Remote Cosine Receptor requires the use of the 1800-11 mounting port (Figure 13-8). This port can be attached to the front panel of the 1800-02 as described in Section 13.4.

The 1800-11 is positioned by sliding it into the port's slot and securing it in place with the thumb screw nearest the slot on the outside of the port.

There are two details that are important for properly mounting the 1800-11. First, the top of the 1800-11 should be flat against the back wall of the mounting port. This will assure that the 1800-11 is at the correct distance and that the receptor surface is parallel to the plane of the calibration port. Second, the 1800-11 should be slid into the slot (toward the center) until the corners of the 1800-11 fit all the way into milled

notches in the sensor port wall (Figure 13-11). This ensures that the receptor surface is centered in the aperture of the port.

The calibration procedure of the 1800-11 now follows the procedure described for the LI-1800 with two exceptions. The number of scans averaged while calibrating the 1800-11 should be at least 12. This yields the best possible signal to noise ratio. Also, the lower limit of the calibration file should be set at 330 nm. This is necessary because below 330 nm the signal to noise ratio for this receptor is so low that any data gathered is nearly meaningless.

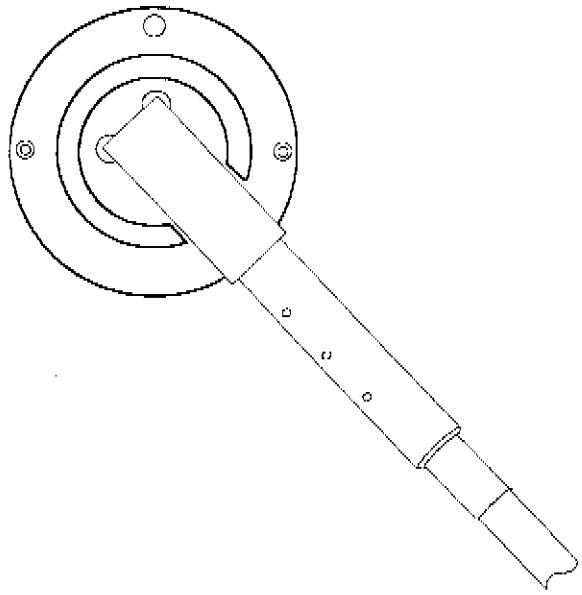


Figure 13-11. Proper installation of the 1800-11 requires fitting the corner of the 1800-11 into the milled slots in the sensor mounting port.

13.7 Maintenance

CHANGING THE LAMP AND LAMP MAINTENANCE

The 1800-02L lamp is rated for 50 hours of operation within 1% of the output values given on the calibration certificate. Occasionally the lamp contacts will develop a residue on the exterior which will begin to change the resistance of the lamp. This residue can usually be cleaned off with a lintless cloth and alcohol. If necessary the contacts can be lightly scraped.

The procedure for changing the lamp is much the same as that described in Section 13.4 for installing the lamp after shipment. These sections should be read before changing the lamp.

CLEANING THE DUST SCREEN

The fan on the lower right hand side of the control panel has a dust screen in front of it which keeps dust from being sucked into the 1800-02. This screen should be periodically checked and cleaned when it becomes noticeably dirty.

The screen can be removed by taking off the black plastic holder that keeps it in place. This holder snaps

onto and off of the body of the fan on each of its four sides. After the screen is removed it can be rinsed with clean water, dried and replaced.

REPAIRING PAINT CHIPS ON THE MOUNTING PORTS

If any large (1 mm^2) chips occur on the painted surfaces of the mounting ports they should be repaired if possible. Chips in the paint can cause reflections into the sensor receptors, however this would result in only a very small calibration error.

The mounting ports have been painted with 3M ECP2200 paint which is a flat black paint with a high absorption of optical radiation. If a paint with known optical properties is unavailable, an average quality flat black paint can be used to cover the chips.

TROUBLE-SHOOTING

This manual is not intended to be used for repair or recalibration of the 1800-02. Please consult the 1800-02 instruction manual for troubleshooting instructions.

13.8 1800-02RA Spectral Radiance Accessory

The 1800-02RA Spectral Radiance Accessory attaches to the LI-COR 1800-02 Optical Radiation Calibrator to provide a source of spectral radiance for calibrating the 1800-06 Telescope/Microscope Receptor. The 1800-02RA contains a specially prepared diffuser, which is mounted in the end of the device, and is directly illuminated by the calibration lamp in the 1800-02. The characteristics of the diffuser and its distance from the lamp were chosen to provide for easy calculation of spectral radiance values for calibration.

MOUNTING THE 1800-02RA

Before mounting the 1800-02RA, observe the interior of the tube and the surface of the white diffuser; both should be free of dust and lint. Any accumulated dust and/or lint can be removed by blowing dry, oil-free air or dusting gas across the surface. Remove the instrument mounting port (or sensor mounting port) from the 1800-02 and install the radiance accessory with the two 4-40 x 1/2" flat head screws provided.

GENERATING A SPECTRAL RADIANCE CALIBRATION FILE

Each 1800-02L Calibration Lamp is supplied with calibration data which gives the spectral irradiance of the lamp in W m^{-2} nm^{-1}, at 10 nm intervals over the 300-1100 nm wavelength range. To convert this spectral *irradiance* lamp data to spectral *radiance* data, multiply by 0.10. For example, if the calibration lamp has an output of 0.035 W m^{-2} nm^{-1} at 400 nm, the value used with the 1800-02RA spectral radiance accessory should be 0.035 x 0.1 = 0.0035 W m^{-2} nm^{-1} $steradian^{-1}$. The spectral radiance data calculated in this manner are only valid for the calibration lamp whose serial number matches the calibration data, and only when used with the 1800-02RA using the procedure described in the following operational instructions.

The LI-1800 Portable Spectroradiometer can be used to generate the spectral radiance lamp file for use with the 1800-06. Continuing the example above, assume that the spectral *irradiance* lamp data have already been entered in the LI-1800 as a file name L101. A spectral *radiance* lamp file is generated by using the LI-1800's transform (XF) command (Section 4.5, LI-1800 Instruction Manual) and specifying L101 as both File A and File B, and then

specifying the constant A as 0.1 and constants B and C as zero. If we named the resulting file R101, then we would use the R101 file as the lamp file when performing the calibrate (CA) function (Section 4.2) to generate a new calibration file for the 1800-06 Telescope/Microscope Receptor. When using the 1800-06 receptor, any scan files that are divided by this new radiance calibration file will have units of W m^{-2} nm^{-1} steradian^{-1}.

CONFIGURING THE LI-1800 AND 1800-06 TELESCOPE/MICROSCOPE ACCESSORY

Install the desired objective lens combination onto the 1800-06 body, and connect the body to the LI-1800 with the 1800-10 Quartz Fiber Optic Probe. Insert the tip (notch upward) of the fiber optic bundle completely into the adapter on the output port of the 1800-06 body and tighten the two set screws with a small hex key. Attach the 1800-10 Quartz Fiber Optic Probe to the LI-1800 as follows:

1. Remove the 2 retaining screws (phillips head) from the standard cosine receptor and pull the receptor straight up and off of the LI-1800 optical input port.

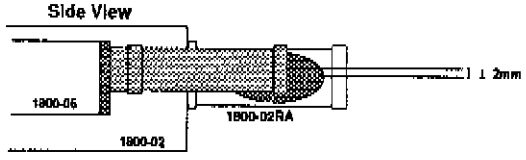
2. Install the fiber probe housing on the optical input port, making sure that the guide hole on the fiber probe is aligned with the guide pin on the optical port. To maintain accurate optical alignment, it is necessary for the probe housing to be screwed down with the two 4-40 x 3/8" flat head screws provided. This is the same size screw that is used with the standard cosine head. Make certain the fiber probe housing is securely fastened to the LI-1800, *as slight movements can cause large errors.*

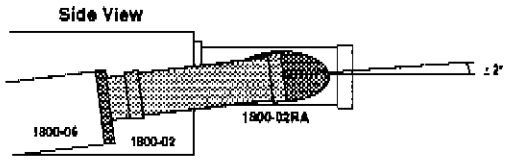
Although any lens/aperture combination can be calibrated directly with the 1800-02 and 1800-02RA, a single calibration file will generally suffice for use with objective lens options A, B, or the Quartz Microscope configuration. Section 12.4 contains further information on generating calibration files for each of the lens options.

The accuracy of the calibration is dependent upon the proper positioning of the 1800-06 in relation to the diffuser in the 1800-02RA. Follow these four steps to correctly position the 1800-06:

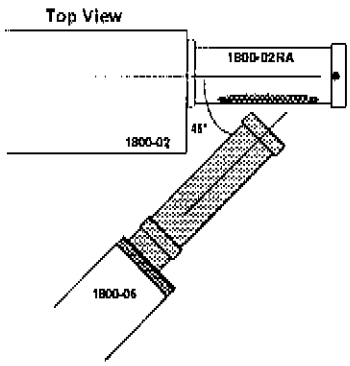
NOTE: Visual alignment in each of these four steps will provide sufficient accuracy; precise measurements are not required.

1. Support the telescope (i.e., with a tripod, etc.) so that the objective lens is level (within ± 2°) and so that the center line of the objective lens is at the same height as the center line of the 1800-02RA, as shown below.

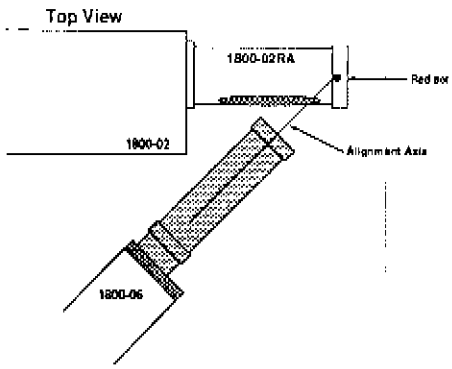




2. Orient the telescope lens tube at an angle of 45° (± 2°) from the 1800-02RA accessory tube, when viewed from directly above the equipment. In the absence of a protractor or a square, a 45° angle can be made by folding a piece of paper across opposite corners.

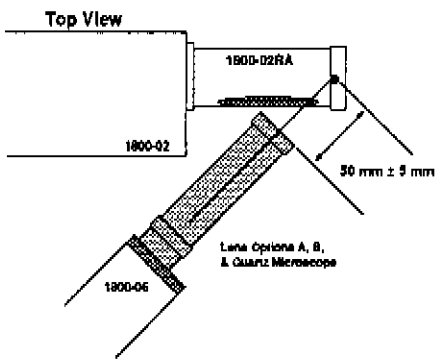


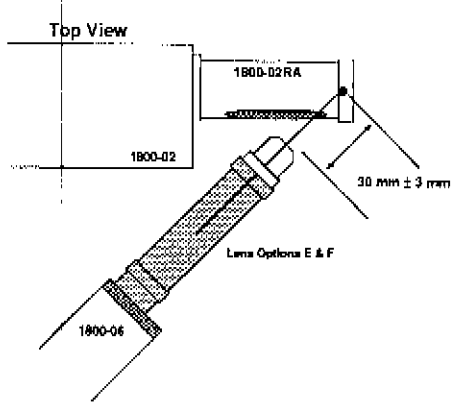
3. Aim the axis of the 1800-06 lens tube straight toward the red dot on the top of the 1800-02RA mounting tube (within ± 2 mm).



4. Adjust the distance between the end of the lens and the red dot to be:

   50 mm ± 5 mm for 1800-06 lens options A, B, or the Quartz Microscope option, or
   30 mm ± 3 mm for lens options E and F.





After completing step 4, recheck the alignment of the 1800-06 described in the steps above to make sure that the position of the Telescope/Microscope Receptor satisfies each of the 4 alignment requirements simultaneously. Secure the 1800-06 against accidental movement, and begin the calibration procedure as described in this manual, or in Section XIII of the LI-1800 instruction manual.

NOTE: Calibrations should be performed in a room with the lights turned off and the window shades closed to prevent measuring radiation from sources other than the calibration lamp.

After calibration, remove the 1800-02RA from the 1800-02 and store it in a dust proof, clean plastic bag, away from direct sunlight.

THEORY OF OPERATION

The 1800-02RA converts incident irradiance to radiance according to the properties of a characterized, stable diffusive material made from lightly compressed and sintered TFE resin. This choice of resin and processing method yields a material of widely recognized utility due to its spectral and spatial uniformity, repeatability, and high reflectance. High-temperature sintering adds durability and longevity at no significant loss in characteristics for this application. Surface finish is important in maintaining the bidirectional reflectance values assumed in this application. Since control of the manufacturing parameters results in reproducible standards, individual calibration is not required. A verification procedure after manufacture ensures that each diffuser meets the specified standards.

The diffuser is located so that it receives normal illumination by the calibration lamp direct beam, so that it can be viewed by the 1800-06 receptor at an angle 45° from normal. When the 1800-02RA was designed, the length of the mounting tube was chosen so that the characteristics of the diffuser in this geometric configuration would result in the irradiance data of the lamp being multiplied by a simple constant (0.1) in order to obtain radiance data for the diffuser. The total reflectance of the diffuser is 0.99 ± 0.01 from 350 to 1100 nm; reflectance at 300 nm is about 0.97. The surface finish of the diffuser maintains the expected reflectance at a 45° viewing angle.

The suggested viewing conditions limit the viewing area of the 1800-06 Telescope/Microscope Receptor to the central 25 mm diameter or less to limit the edge effects of the diffuser. For any given optical receptor, the 1800-06 must have a viewing diameter less than 25 mm. Verification of the viewing diameter size can be accomplished by placing the 1800-06 in View mode and shining a pen light through the viewing port so that it shines through the objective lens and onto the diffuser. The spot of light on the diffuser will be oval in shape and should be less than 25 mm in diameter if the 1800-06 is placed properly.

The radiance of the 1800-02RA under the prescribed viewing conditions and with the prescribed surface finish is 0.10 x lamp irradiance, ± 3% from 350 to 1100 nm, or ± 5% at 300 nm.

MAINTENANCE

The 1800-02RA requires no periodic maintenance provided it is kept clean, dry, and stored out of direct sunlight. If necessary, dust and lint can be removed by blowing dry, oil-free air or dusting gas across the surface. Dust can cause excessive stray light which can affect calibration values.

To remove particles that stick to the diffuser surface and will not blow off with dusting gas, the diffuser can be rinsed with distilled water. However, solvents should never be used on the diffuser and the surface of the diffuser should never be rubbed or touched unless the surface is to be refinished. If the surface of the diffuser does get damaged, it can be refinished without returning the diffuser to LI-COR. Contact LI-COR for details on the refinishing procedure.

To remove the diffuser from the 1800-02RA, follow these steps:

1. If necessary, remove the 1800-02RA from the 1800-02.

2. Remove the 2 screws retaining the protective cap which holds the diffuser onto the 1800-02RA mounting tube.

3. Hold the mounting tube upright with the mounting tube in one hand and the end cap in the palm of the other hand. Pull the end cap downward; be careful not to scrape the surface of the diffuser or to let it fall out of the end cap.

4. Remove the diffuser from the tube and take note of which side was facing outward (toward the accessory tube and calibration lamp). Since only one side of the diffuser is characterized for use, it must have the same face outward when it is reassembled.

While the diffuser is removed, the mounting tube can also be cleaned, if necessary.

Appendix A

LI-1800 Terminal and Output Port Pin Assignments

TERMINAL PORT

PIN # ON 25 PIN CONNECTOR	SIGNAL NAME
2	Data from terminal
3	Data to terminal
6	Data Set Ready
7	Signal Ground
9	+5 V Power
10	-5 V Power
18	External ON/OFF

OUTPUT PORT

9 PIN DIP	RS-232 (DCE)	ANALOG
1	pin 7 (ground)	ground
2	N/C	analog
3	pin 20 (DTR)	N/C
4	jumper to 1	N/C
5	pin 24 (reset)	N/C
6	pin 6 (DSR +5V)	N/C
7	N/C	N/C
8	pin 3 (transmit data)	N/C
9	jumper to 4	N/C

Appendix B
ASCII Table

ASCII	Decimal	ASCII	DECIMAL	ASCII	DECIMAL	ASCII	DECIMAL
<null>		0	<space>	32	@	64	96
<soh>		1	!	33	A	65	a 97
<stx>		2	"	34	B	66	b 98
<etx>		3	#	35	C	67	c 99
<eot>		4	$	36	D	68	d 100
<enq>		5	%	37	E	69	e 101
<ack>		6	&	38	F	70	f 102
<bell>		7	'	39	G	71	g 103
<bs>		8	(	40	H	72	h 104
<ht>		9	)	41	I	73	i 105
<lf>		10	*	42	J	74	j 106
<vt>		11	+	43	K	75	k 107
<ff>		12	,	44	L	76	l 108
<cr>		13	-	45	M	77	m 109
<so>		14	.	46	N	78	n 110
<si>		15	/	47	O	79	o 111
<dle>		16	0	48	P	80	p 112
<dc1>		17	1	49	Q	81	q 113
<dc2>		18	2	50	R	82	r 114
<dc3>		19	3	51	S	83	s 115
<dc4>		20	4	52	T	84	t 116
<nak>		21	5	53	U	85	u 117
<sync>		22	6	54	V	86	v 118
<etb>		23	7	55	W	87	w 119
<can>		24	8	56	X	88	x 120
		25	9	57	Y	89	y 121
<sub>		26	:	58	Z	90	z 122
<esc>		27	;	59	[	91	123
<fs>		28	<	60		92	124
<gs>		29	=	61	]	93	125
<rs>		30	>	62		94	126
<us>		31	?	63	_	95	<delete> 127

Appendix C
Error Messages

RAM OVFL Not enough memory available in the selected memory bank for the file that is to be created. Make the file smaller, or delete an existing file to free up more memory, or change to another memory bank.

LIM ERR The file does not have appropriate limits for the intended operation.

CAN'T FIND The file requested does not exist in the current memory bank.

PROTECT The requested file is protected and cannot be deleted or written. To "unprotect" a file, use the RE command.

INVAL FILE The result file cannot be one of the operand files.

INT ERR One or both operand files have data intervals that are inconsistent with the desired interval in the resultant file.

OVERLAP ERR There is no overlap between the data in the operand files.

FILTER ERR The filter wheel appears to have been out of synchronization; data may be suspect as a result.

LOBATT Low battery.

n MV DRIFT The pre-scan and post-scan dark readings differ by n mV. This message only appears if n>3.

WAVE ERR Monochromator out of synchronization during scan. Note that this is checked only if the scan passes 632.75 nm.

NO WAVE The requested wavelength does not exist in the file. During calibration: The requested lamp cut-off is not a wavelength which is being sampled.

NO PROG Requesting to run a program sequence when none has been defined using the PR function.

DUPLICATE Rename file already exists.

NO FCTS Requested to list program which contains no functions.

SHORT RANGE Wavelength limits of the requested file are not 370-790 nm or greater. Can occur when using the IL or CC functions.

Appendix D
References

1. International Commission on Illumination (1971). Colorimetry: Official Recommendations of the CIE. Publication CIE No. 15 (E-1.3.1). Bureau Central de la CIE, Paris.

2. International Commission on Illumination (1978). CIE Recommendations on Uniform Color Spaces, Color Difference Equations, Psychometric Color Terms. May, 1976. Supplement No. 2 to Publication CIE No. 15.

3. Subcommittee on Photometry of Light Sources of the Committee on Testing Procedures of the IES, "Practical Guide to Colorimetry of Light Sources," Journal of the Illuminating Engineering Society, Vol. 5, No. 4, April, 1976.

4. Wyszecki, G., and W.S. Siles (1967). Color Science - Concepts and Methods, Quantitative Data and Formulas. John Wiley and Sons, New York.

5. Judd, D.B., and G. Wyszecki (1975). Color in Business, Science and Industry. 3rd ed. John Wiley and Sons, New York.

6. LI-COR Report. 1988. Calibration Procedures for LI-COR Radiation Sensors and Lamps.

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.

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