LI-COR Radiation Sensors

Instruction Manual

Underwater Type SB:

- **LI-192SB Underwater Quantum Sensor**
- **LI-193SB Spherical Quantum Sensor**

LI-COR Underwater Radiation Sensors, Type SB Instruction Manual

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How to Use this Manual

This manual contains the operation and maintenance information for all LI-COR underwater, type SB sensors.

The first section of the manual contains general information which relates to all LI-COR underwater sensors (i.e., operation, recalibration, etc).

After the general information you will find specific information about each sensor.

When reading through the manual you should first read the general information and then read the specific information for your sensor (i.e., the LI-192SB Underwater Quantum or LI-193SB Spherical Quantum Sensor).

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Section I
General Information

TYPE "SB" SENSORS

LI-COR type SB underwater sensors are characterized by having the underwater cable terminated with a BNC connector which then connects to a calibration connector. Figure 1 shows a typical SB type sensor.

"SB" type underwater sensors include the LI-192SB Underwater Quantum Sensor, and the LI-193SB Spherical Quantum Sensor. The type SB terrestrial sensors include the LI-190SB Quantum Sensor, the LI-191SB Line Quantum Sensor, the LI-200SB Pyranometer Sensor, and the LI-210SB Photometric sensor.

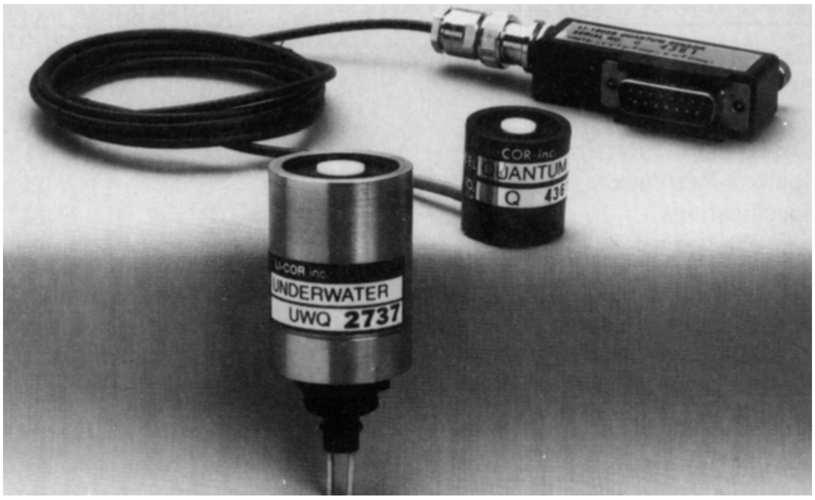


Figure 1. "SB" type sensors are terminated with a BNC connector which connects to the calconnector.

SENSOR RECALIBRATION

Recalibration of LI-COR radiation sensors is recommended every two years. The LI-192SB Underwater Quantum Sensor may be returned to LI-COR for recalibration or recalibrated using the LI-COR 1800-02 Optical Radiation Calibrator. The LI-193SB Spherical Quantum Sensor must be returned to LI-COR for recalibration.

OPERATION

Type SB sensors utilize a Calconnector (Calibration connector) which provides direct unit readout with LI-COR models LI-185B Quantum/Radiometer/Photometer, LI-188B Integrating Quantum/Radiometer/Photometer and LI-1776 Solar Monitor. If the Calconnector is detached from the sensor cable at the BNC connection, the sensor can be connected to the LI-1000 DataLogger, the LI-189 Quantum/Radiometer/Photometer, the LI-510B Integrator or LI-550B Printing Integrator.

The Calconnector for underwater sensors contains the calibration resistances (potentiometers) for direct unit readout when the sensor is used in air or in water. For underwater readings there is also a potentiometer that compensates for the immersion effect. Because of this standardized sensor output, radiation sensors can be used interchangeably with any LI-COR LI-185B, LI-188B or LI-1776 without calibrating the instrument to the sensor. This applies to LI-COR sensors of the same type, or different types of LI-COR radiation sensors.

If a type SB underwater sensor is used with the LI-1776 for in water measurements, the user must multiply the reading by the immersion effect listed for the sensor. When working in low light conditions keep in mind that the LI-1776 does not have the same low-range accuracy for low light levels as the LI-185B or LI-188B. (See Section 1-1a, in the LI-1776 Instruction Manual).

IMPORTANT: Each sensor is to be used only with the Calconnector that is supplied with it (i.e., the sensor serial number and the Calconnector serial number must be the same).

Type SB sensors can be used with millivolt recorders (or data loggers) if the millivolt adapter (included with each Calconnector) is connected to the Calconnector, and the wire leads are connected to the recorder. In this case a LI-COR Light Meter or Integrator is not used. This arrangement is often acceptable for radiation levels down to 10% of full sunlight. Below 10%, the recorder must be very sensitive to pick up the small voltage signal. The recorder should have a high impedance input (>1 megohm, such as potentiometric types), and the range adjustment should be 0-10 mV, or a more sensitive range. Cable lengths over 75 m (225 ft.) can be used, *but with lengthy cable, movement within the water can cause excessive noise*.

The sensor Calconnector contains a 604 ohm resistor for millivolt applications. When the millivolt adapter is used, connection is made with this resistor in the Calconnector. IMPORTANT: *If the sensor is used in water, the immersion effect must be allowed for in the millivolt reading*. See the "Certificate of Calibration".

For low light levels, the LI-192SB should be connected directly to the LI-185B or LI-188B (without using the millivolt adapter), which can provide a millivolt output using the RECORDER output to a millivolt recorder (100 mV full scale). The 2223S Recorder Leads are used to connect the LI-185B or LI-188B to the millivolt recorder. Also, either an LI-510B or LI-550B integrator could be used with the 192M Module installed.

The Calconnector is attached to the end of the 2222UWB Underwater Cable that is to be used with the readout instrument.

On LI-COR underwater cables the white wire is positive and the black wire is negative. See calconnector drawing (Appendix) for connection details between the cable assembly and the connector. The center pin of the connector has a negative signal. This is done because the trans-impedance amplifier used in LI-COR light meters requires a negative signal.

For data logger and millivolt applications where the millivolt adapter is used, the positive (red) lead should be connected to the low impedance (common terminal) when plus or minus signal capability is available on the data logger or recorder. This will minimize noise.

If plus or minus capability is not available on the data logger or recorder, the red lead should be connected to the positive input and the black lead to the negative input. If noise difficulties are encountered, consult LI-COR for special wiring instructions.

The Calconnector and millivolt adapter are not weatherproof. If the millivolt adapter is attached to the Calconnector for connection to a data logger or millivolt recorder, this connection should be made at the recorder end (indoors). This is done to protect the Calconnector, and to eliminate thermocouple effects that could be caused by exposing the Calconnector to rapidly-changing direct solar radiation. These effects are not noticeable when the Calconnector is used indoors out of direct radiation.

CALIBRATION

The calibration is obtained at LI-COR using a standard radiation source which has been calibrated against a National Institute of Standards and Technology lamp. The photon flux density from the standardized lamp is known in terms of micromoles s^{-1} m^{-2}, where one micromole = 6.023 x 10^{17} photons. The uncertainty of the calibration is ± 5%.

The lamp used in LI-COR's calibration is a high intensity standard of spectral irradiance (G.E. 1000 Watt type DXW quartz halogen) supplied with a spectral irradiance table.

The following procedure was used to calculate the quantum flux output from the lamp. The lamp flux density (ΔE) in watts m^{-2}, in an increment at wavelength Δλ can be expressed as

$$\Delta E = E(\lambda)\Delta\lambda$$

where E(λ) is the spectral irradiance of the lamp at wavelength λ.

The number of photons $s^{-1}m^{-2}$ in Δλ is

$$\text{Photons } s^{-1}m^{-2} = \left[\frac{\lambda}{hc}\right]E(\lambda)(\Delta\lambda)$$

where h is Plank's constant and c is the velocity of light. This can be summed over the interval 400-700 nanometers (nm) to give

$$\text{Photons } s^{-1}m^{-2} = \left[\frac{1}{hc}\right]\int_{400}^{700}\lambda E(\lambda)(\Delta\lambda)$$

The result is adjusted to micromoles $s^{-1}m^{-2}$ by dividing by 6.023 x 10^{17}.

CLEANING INFORMATION

DO NOT use alcohol, organic solvents, abrasives, or strong detergents to clean the diffusor element on LI-COR light sensors.

The acrylic material used in LI-COR light sensors can be crazed by exposure to alcohol or organic solvents, which will adversely affect the cosine response of the sensor.

Clean the sensor ***only*** with water and/or a mild detergent such as dish-washing soap. LI-COR has found that vinegar can also be used to remove hard water deposits from the diffusor element, if necessary.

2009S LOWERING FRAME

The 2009S Lowering Frame provides for the placement of two cosine sensors, one each for upwelling and downwelling radiation, or a single underwater spherical sensor (Figure 2). Each LI-COR underwater sensor has three 6-32 tapped mounting holes on the underside of the sensor for connection to the mounting ring. Corrosion resistant mounting screws are included with each sensor.

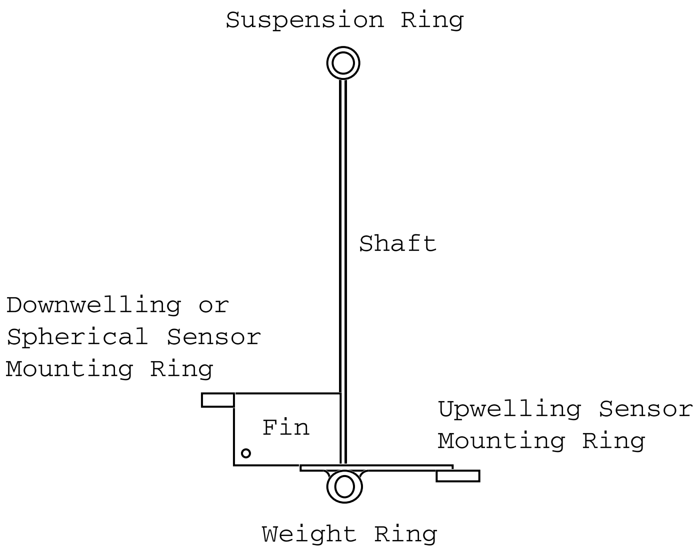


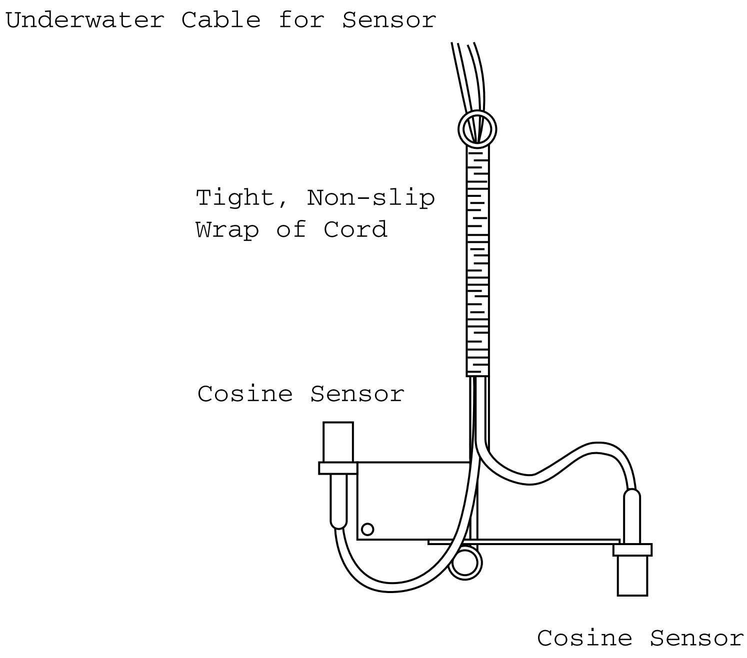
Figure 2. 2009S Lowering Frame.

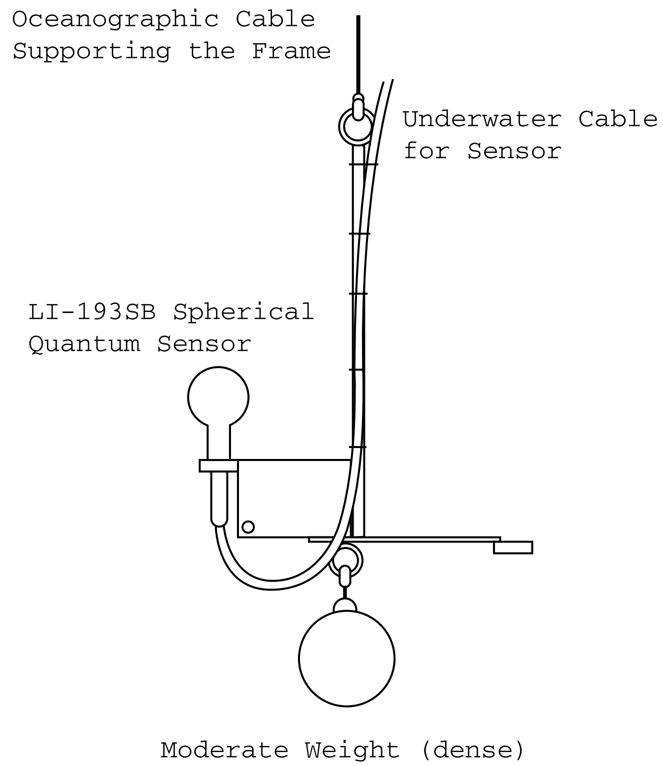
When two sensors are used, the frame is well balanced and will work well in mild currents without twisting the cables. The sensor for downwelling radiation is always attached using the mounting ring on the fin. Likewise, the sensor for upwelling radiation is attached to the opposite mounting ring. Depending on the speed of the current the frame will tilt a few degrees, but this can be minimized by hanging a compact weight from the weight ring. Moderate weights will often suffice (4 kg). Weights over 25 kg should be avoided.

The use of a single cosine sensor will require a small weight (0.2 kg) attached at the empty mounting ring or a moderate weight from the weight ring, or possibly both, depending upon the speed of the current.

The underwater cable(s) should be attached to the frame such that approximately 25 cm of cable forms a smooth arc to the underwater sensor connector and is restrained from being flexed or supporting any weight.

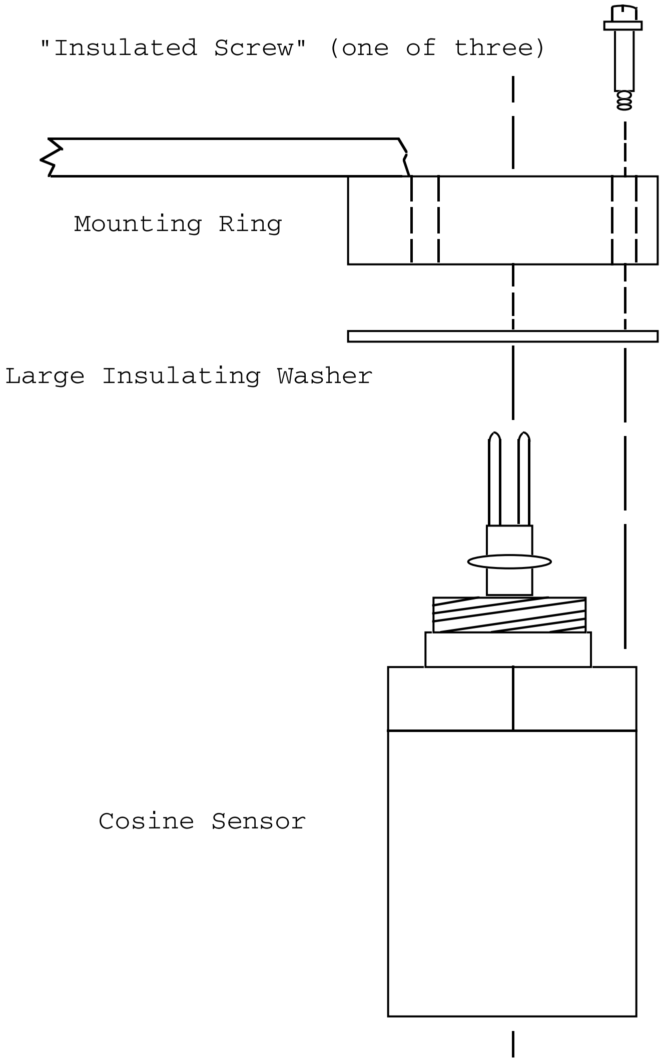
LI-COR underwater cable is not recommended as a support cable, although it can be used as a lowering cable providing it is properly attached and the attached weights do not exceed 5 kg. The cable(s) must be attached as described above. Additionally, the cable must be securely attached to the shaft of the lowering frame at multiple points so that the cable does not slip and put strain on the sensor connector. However, the cable cannot be clamped so tightly as to damage it. Possible methods to use are numerous nylon cable clamps along the length of the shaft, or a tight wrap of light cord around the shaft and cables, starting at the suspension ring and extending downward at least 25 cm.


Underwater Cable for Sensor
Tight, Non-slip
Wrap of Cord
Cosine Sensor
Cosine Sensor



For long-term immersion or use in heavily ionic water, it may be necessary to provide electrical insulation between the underwater sensor(s) and the lowering frame to prevent galvanic corrosion. This is accomplished by slipping an insulating flat washer over the mounting screws down to the heads, followed by a 1/2" (13 mm) length of thin tubing over the screw threads. This tubing insulates the screws from the mounting ring.

Next, place a large flat insulating washer between the sensor and the mounting ring (with three holes for the screws). Use the "insulated" screws to attach the sensor in place. In this way neither the screws nor sensor have electrical contact with the frame.


"Insulated Screw" (one of three)
Mounting Ring
Large Insulating Washer
Cosine Sensor

LI-192SB Underwater Quantum Sensor

USE OF THE UNDERWATER QUANTUM SENSOR

The LI-192SB Underwater Quantum Sensor is used for measuring Photosynthetically Active Radiation (PAR) in aquatic environments. With its 400-700 nanometer (nm) quantum response it is a valuable tool for researching primary productivity or other projects of environmental concern. The sensor can be used in the air with accuracy similar to that of the LI-190SB Quantum Sensor. Prior to obtaining atmospheric readings, the sensor must be dried.

The sensor connector should be lubricated with a silicone grease before installing it in the mating connector of the underwater cable. **The yellow dots on the connector and the underwater cable should be aligned before pushing them together in order to obtain the proper pin connection**. If the dots are not aligned this can result in a negative reading on the readout device due to the change in polarity of the conductors. The connector pins are small and care should be taken when mating the connectors.

The quantum sensor has three 6-32 tapped holes on the underside of the sensor which are used for mounting the sensor to the 2009S Lowering Frame.

To maintain appropriate cosine correction the vertical edge of the diffuser must be kept clean. Periodically inspect the sensor for foreign deposits on the upper surfaces during prolonged submerged operation. See page 5 of this manual for detailed cleaning instructions.

IMMERSION EFFECT

A sensor with a diffuser for cosine correction will have an immersion effect when immersed in water. The radiation entering the diffuser scatters in all directions within the diffuser with more of the radiation lost through the water-diffuser interface than in the case where the sensor is in air. This results because the air-diffuser interface offers a greater ratio of the indexes of refraction than the water-diffuser interface. Thus, a greater percentage of radiation entering the diffuser in air reaches the photodiode than in the case where the LI-192SB is in water. Therefore, a normal underwater reading would need to be multiplied by this effect if the sensor is used in water.

The immersion factor is allowed for through a potentiometer in the Calconnector. Therefore, direct readout, with immersion effect allowance, is provided on the LI-185B and LI-188B using the "SENSOR (in water)" position.

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 sensor.

A sensor with a cosine response (follows Lambert's cosine law) allows measurement of flux densities through a plane surface. This allows the sensor to measure flux densities per unit area (m^2). A sensor without an accurate cosine correction can give a severe error under diffuse radiation conditions 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 radiant flux lines impinging upon a surface normal to the source (Figure 3A) and at an angle of 60° from normal (Figure 3B). Figure 3A shows 6 rays striking the unit area, but at a 60° angle only 3 rays strike at the same unit area. This is illustrated mathematically as

$$S = (I)\ (\text{cosine } 60°) \text{ per unit area}$$
$$3 = (6)\ (0.5) \text{ per unit area}$$

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

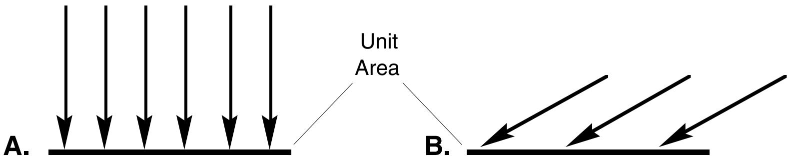


Figure 3. Lambert's Cosine Law.

COSINE CORRECTION PROPERTIES

A comparison of the sensor's cosine response curve in air and in water can be found in the "Immersion Effect of LI-COR Underwater Sensors" Report (available from LI-COR). Engineering requirements result in different correction characteristics for air and water. Overcompensation in air and undercompensation occurs in water. The better response was selected for air because in water the direct incident solar radiation does not exceed the critical angle of 48.6° (a result of the air-water interface).

SPECTRAL RESPONSE

The spectral response is similar to that of the LI-190SB Quantum Sensor (Figure 4).

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