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APPLICATION NOTE NO. 11 QSP-L **Revised February 2010**

Calculating Calibration coefficients for Biospherical Instruments PAR Light Sensor *with* Built-In Log Amplifier

This application note applies to the following Biospherical Instruments PAR light sensors, which all have a built-in log amplifier:

- QSP-200L and QCP-200L - no longer in production
- QSP-2300L, QSP-2350L, QCP-2300L, QCP-2300L-HP, and MCP-2300 - current production

These PAR sensors are compatible with the following Sea-Bird CTDs:

- SBE 9*plus*
- SBE 16 or 19 – These PAR sensors may not be compatible with 6-cell housing version of these CTDs; consult Sea-Bird.
- SBE 16*plus*, 16*plus*-IM, or 19*plus* – CTD's optional PAR connector **not** required when using one of these PAR sensors. The PAR sensor interfaces with an A/D voltage channel on the CTD.
- SBE 16*plus* V2, 16*plus*-IM V2, or 19*plus* V2 –The PAR sensor interfaces with an A/D voltage channel on the CTD.
- SBE 25 – CTD's PAR connector (standard on current production SBE 25s, optional on older versions) **not** used with these PAR sensors. The PAR sensor interfaces with an A/D voltage channel on the CTD.

Note: The CTD voltage channel for use with the PAR sensor can be single-ended or differential.

SEASOFT computes PAR using the following equation:

$$\text{PAR} = [\text{multiplier} * (10^9 * 10^{(V-B)/M}) / \text{calibration constant}] + \text{offset}$$

Enter the following coefficients in the CTD configuration (.con or .xmlcon) file:

M = 1.0 and **B** = 0.0 (Notes 2 and 3)
calibration constant = $10^5 / Cw$ (Notes 2 and 4)
multiplier = 1.0 for output units of µEinsteins/m²·sec (Note 5)
offset = $-(10^4 * Cw * 10^V)$ (Note 6)

Notes:

1. In our SEASOFT V2 suite of programs, edit the CTD configuration (.con or .xmlcon) file using the Configure Inputs menu in Seasave V7 (real-time data acquisition software) or the Configure menu in SBE Data Processing (data processing software).
2. Sea-Bird provides two calibration sheets for the PAR sensor in the CTD manual:
   - Calibration sheet generated by Biospherical, which contains Biospherical's calibration data.
   - Calibration sheet generated by Sea-Bird, which incorporates the Biospherical data and generates M, B, and calibration constant needed for entry in Sea-Bird software (saving the user from doing the math).
3. For all SBE 911*plus*, 16, 16*plus*, 16*plus*-IM, 16*plus* V2, 16*plus*-IM V2, 19, 19*plus*, 19*plus* V2, and 25 CTDs, M = 1.0. For SBE 9/11 systems built before 1993 that have differential input amplifiers, M = 2; consult your SBE 9 manual or contact factory for further information. B should always be set to 0.0.
4. Cw is the *wet* µEinsteins/cm²·sec coefficient from the Biospherical calibration sheet. A typical value is 4.00×10^{-5}.
5. The multiplier can be used to calculate irradiance in units other than µEinsteins/m² sec. See Application Note 11General for multiplier values for other units.
   The multiplier can also be used to *scale* the data, to compare the *shape* of data sets taken at disparate light levels. For example, a multiplier of 10 would make a 10 µEinsteins/m²·sec light level plot as 100 µEinsteins/m²·sec.
6. Offset (µEinsteins/m²·sec) = $-(10^4 * Cw * 10^V)$, where V is the *dark voltage*.

   For typical values ($Cw = 4.00 \times 10^{-5}$ and Dark Voltage = 0.150), offset = -0.5650. The dark voltage may be obtained from:
   - Biospherical calibration certificate for your sensor, or
   - CTD PAR channel with the sensor covered (dark) -- in Seasave V7, display the *voltage output* of the PAR sensor channel.

   Instead of using the dark voltage to calculate the offset, you can also directly obtain the offset using the following method: Enter M, B, and Calibration constant, and set offset = 0.0 in the configuration (.con or .xmlcon) file. In Seasave V7, display the *calculated PAR output* with the sensor dark; then enter the negative of this reading as the offset in the configuration file.

Mathematical Derivation

1. Using the sensor output in volts (V), Biospherical calculates:
   light (µEinsteins/cm^2·sec) = Cw * ($10^{\text{Light Signal Voltage}}$ - $10^{\text{Dark Voltage}}$).

2. SEASOFT calculates: light (µEinsteins/m^2·sec) = [multiplier * 10^9 * $10^{(V - B)/M)}$ / Calibration constant] + offset
   where M, B, Calibration constant, multiplier, and offset are the SEASOFT coefficients entered in the CTD configuration file.

3. To determine Calibration constant, let B = 0.0, M = 1.0, and multiplier = 1.0. Equating the Biospherical and SEASOFT relationships:
   10^4 (**cm^2/ m^2**)* Cw * ($10^{\text{Light Signal Voltage}}$ - $10^{\text{Dark Voltage}}$) = (10^9 * 10^V) / Calibration constant + offset

   Since offset = - (10^4 * Cw * $10^{\text{Dark Voltage}}$), and V = Light Signal Voltage:
   Calibration constant = 10^9 / (10^4 * Cw) = 10^5 / Cw

   Example:
   If Wet calibration factor = 4.00 x 10^{-5} µEinsteins/cm^2·sec, then C = 2,500,000,000 (for entry into configuration file).

Notes:

- See Application Note 11S for integrating a Surface PAR sensor with the SBE 11*plus* Deck Unit (used with the SBE 9*plus* CTD).
- See Application Note 47 for integrating a Surface PAR sensor with the SBE 33 or 36 Deck Unit (used with the SBE 16, 16*plus*, 16*plus* V2, 19, 19*plus*, 19*plus* V2, or 25 CTD).

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APPLICATION NOTE NO. 7

Revised September 2008

Calculation of Calibration Coefficients for Sea Tech, Chelsea (Alphatracka), and WET Labs Cstar Transmissometers

Sea-Bird SEASOFT software (SEASAVE V7 and SBE Data Processing) can output the following transmissometer results:

Light transmission [%] = (M * voltage output) + B
Beam attenuation coefficient c = - (1 / z) * ln (light transmission [decimal])

where

M and B are the calibration coefficients.
z is the transmissometer path length (meters).
Light transmission [decimal] is light transmission [%] divided by 100.
M, B, and z are input to the CTD configuration (.con) file.

Note: In our SEASOFT-Win32 suite of programs, edit the CTD configuration (.con) file using the Configure Inputs menu in SEASAVE V7 (real-time data acquisition software) or the Configure menu in SBE Data Processing (data processing software).

M and B are listed on the Sea-Bird Calibration Sheet, and are calculated by Sea-Bird as follows:

M = (Tw / [W0 – Y0]) * (A0 - Y0) / (A1 - Y1)
B = -M * Y1

where the parameters are listed on the Sea-Bird Calibration Sheet:

- A0 = factory voltage output in **air** (factory calibration from transmissometer manufacturer) ~4.751
- Y0 = factory **dark or zero** (blocked path) voltage (factory calibration from transmissometer manufacturer) .060
- W0 = factory voltage output in pure **water** (factory calibration from transmissometer manufacturer)
- Tw = % transmission in pure water
  For transmission **relative to water** (light transmission in pure water = 100%), set Tw = 100%. **or**
  For transmission **relative to air** (light transmission in air = 100%), set Tw to a value from Table 1 in this document.
- A1 = current (most recent) voltage output **in air** 4.08425
- Y1 = current (most recent) **dark or zero** (blocked path) voltage .056

Because obtaining a good pure water calibration can be difficult in the field, the voltage output in air is used as the reference to track the instrument drift over time. By comparing the original voltage output in air to subsequent voltage outputs in air in the field, the initial instrument slope (derived from the pure water calibration) can be adjusted to correct for instrument drift.

Sea-Bird does an initial calculation of M and B, based on A1 and Y1 measured at Sea-Bird, and using Tw=100% (providing transmission measurements relative to water). These values are tabulated on the Calibration Sheet, and are input to the CTD configuration (.con) file by Sea-Bird.

> *Example*: The Sea-Bird Calibration Sheet shows the following values:
> A0 = 4.743 volts 4.751 Y0 = 0.002 volts 0.060 W0 = 4.565 volts 4.651
> Tw = 100% (for transmission relative to water) z = 0.25 m (25 cm)
> The current calibration provides the following voltages: A1 = 4.719 volts Y1 = 0.006 volts
> Calculating the calibration coefficients:
> M = (100 / [4.565 – 0.002]) * (4.743 - 0.002) / (4.719 - 0.006) = 22.046
> B = -22.046 * 0.006 = -0.132
>
> The transmissometer is deployed and outputs 3.56 volts. SEASAVE V7 (or SBE Data Processing) calculates:
> Light transmission [%] = (M * voltage output) + B = (22.046 * 3.56) – 0.132 = 78.351%
> Beam attenuation coefficient c = - (1 / z) * ln (light transmission) = - (1 / 0.25) * ln (0.78351) = 0.976

Field Recalibration

For field recalibration, connect the transmissometer to the CTD, run SEASAVE V7, and view the transmissometer voltage with the light path in air (A1), and then with the light path blocked (Y1). Recalculate M and B, using the new values for A1 and Y1 and the original factory values for A0, Y0, and W0, and enter M and B in the .con file. Refer to the Configuration Sheet in your CTD manual to determine the appropriate output channel for the transmissometer voltage.

- To obtain the in-air reading, verify that the transmissometer lenses are clean and dry. Consult the transmissometer manual for recommendations on cleaning the lenses.
- To obtain the blocked voltage reading, use an opaque material.

Discussion of Transmission and Beam Attenuation Coefficient Relative to Water vs. Relative to Air

Many optical oceanographers prefer reporting transmissometer measurements relative to water, because they are not based on (the currently accepted) values of Tw relative to air, which are subject to interpretation and may change in the future (see Table 1 below). Consequently, as of April 2004, Sea-Bird is calculating M and B relative to water, and indicating those values on the Calibration Sheet and in the configuration (.con) file. However, if desired, you can calculate M and B relative to air, and input those values in the .con file.

The relationship between measurements relative to air and relative to water is:

Light transmission (relative to air) =
Light transmission (relative to water) * Light transmission of pure water (relative to air)

But,

c = - (1 / z) * ln (light transmission [decimal])

Therefore, rewriting the light transmission equation in terms of the beam attenuation coefficient c:

c (relative to air) =
c (relative to water) + c of pure water (relative to air)

Note that if M and B are calculated and entered in the configuration (.con) file relative to water, light transmission and beam attenuation are calculated by SEASOFT relative to water. Conversely, if M and B are calculated and entered in the configuration (.con) file relative to air, light transmission and beam attenuation are calculated by SEASOFT relative to air.

Light transmission of pure water relative to air is dependent on the path length and wavelength of the transmissometer. Table 1 lists the pure water percent transmission values (Tw), **relative to air**, for transmissometers with various wavelengths and path lengths. The values have been derived with help from transmissometer manufacturers and references in the literature, and seem to be generally accepted. However, variations of several percent in reported coefficients exist in the literature. Therefore, these values may be subject to change or debate; you may wish to consult the literature, and calculate M and B using your desired value of Tw.

Table 1. Nominal values of % transmission in pure water, **relative to air**, for transmissometers of listed wavelength and path length. Values derived with help from Wet Labs using listed references. Historical Sea Tech values are also included.

Wavelength	10cm	25cm	Reference
488 nm (blue)	99.8%	99.6%	1, 2
532 nm (green)	99.5%	98.8%	1, 2
660 nm (red)	96.0%	90.2%	1, 3
660 nm (red)	96.4%	91.3%	4 ***(historical Sea Tech value)***

References:

1. Pope and Fry, Applied Optics, Vol. 36.
2. Morrel, 1994 as communicated by WetLabs.
3. Smith and Baker, 1998, Applied Optics, Vol. 20, No. 2.
4. Original Sea Tech Transmissometer manual.

.05~~6~~

~~4.0~~ 4.08425

M = (100/(4.651 − .060)) * (4.751 − .060)/(4.08425 − .05

4.591 4.691

21.7817 4.02825

= 25.365346

B = −M × .056

~~B~~ = −1.42046