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**APPLICATION NOTE NO. 91**

**May 2011**

**Calculating Calibration Coefficients for WET Labs C-Star Transmissometer  
(voltage or RS-232 output sensor)**

*Note: Procedures in this application note are valid for Seasave V7 and SBE Data Processing version 7.21d and later.*

Sea-Bird SEASOFT V2 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).  
M, B, and z are input to the CTD configuration (.xmlcon) file.  
Light transmission [decimal] is light transmission [%] divided by 100.

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 output in **air** ( $V_{air}$  in factory calibration from WET Labs)
- Y0 = factory **dark or zero** (blocked path) output ( $V_d$  in factory calibration from WET Labs)
- W0 = factory output in pure **water** ( $V_{ref}$  in factory calibration from WET Labs)
- 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) output in **air**
- Y1 = current (most recent) **dark or zero** (blocked path) output

**Note:** The C-Star comes with a calibration sheet that lists values for  $V_{air}$ ,  $V_d$ , and  $V_{ref}$ . Each of these values is supplied in terms of both voltage and counts.

- Use the **voltage values** in the Sea-Bird software if using a **voltage output sensor**.
- Use the **counts values** in the Sea-Bird software if using an **RS-232 output sensor** (compatible only with SBE 16plus V2, 16plus-IM V2, or 19plus V2 CTDs).

Because obtaining a good pure water calibration can be difficult in the field, the output in air is used as the reference to track the instrument drift over time. By comparing the original output in air to subsequent 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 Sea-Bird Calibration Sheet, and are input to the CTD configuration (.xmlcon) file by Sea-Bird.

*Example:* The Sea-Bird Calibration Sheet shows the following values for a voltage output C-Star:  
A0= 4.743 volts    Y0 = 0.002 volts    W0 = 4.565 volts    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

## Setting up Configuration (.xmlcon) File in Seasave or SBE Data Processing

Use the Configure Inputs menu in Seasave V7 (real-time data acquisition software), or the Configure menu in SBE Data Processing (post-processing software), to create / modify the .xmlcon file (see software Help files).

- For the voltage (analog) output C-Star: Select *Transmissometer – WET Labs C-Star* for one of the **external voltage channels** on the CTD. The software prompts for M, B, and Path length (m).
- For the RS-232 (digital) output C-Star (SBE 16*plus* V2, 16*plus*-IM V2, or 19*plus* V2 CTDs only): Select *Transmissometer – WET Labs C-Star* for one of the **RS-232 channels on the CTD**. The software prompts for M, B, and Path length (m).

**Note:** The configuration file can only be saved as an .xmlcon file (not a .con file) if the C-Star is one of the sensors.

## Field Recalibration

For field recalibration, connect the transmissometer to the CTD, run Seasave V7, and view the C-Star output 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 .xmlcon file. Refer to the Configuration Sheet in your CTD manual to determine the appropriate output channel for the transmissometer.

- To obtain the in-air reading, verify that the C-Star lenses are clean and dry. Consult the C-Star 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 (currently accepted) values of Tw relative to air, which are subject to interpretation and may change in the future (see Table 1). As of April 2004, Sea-Bird calculates M and B relative to water, and indicates those values on the Calibration Sheet and in the configuration file. If desired, you can calculate M and B relative to air, and input those values in the configuration file.

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

$$\text{Light transmission (relative to air)} = \text{Light transmission (relative to water)} * \text{Light transmission of pure water (relative to air)}$$

But,

$$c = - ( 1 / z ) * \ln ( \text{light transmission [decimal]} )$$

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

$$c \text{ (relative to air)} = c \text{ (relative to water)} + c \text{ of pure water (relative to air)}$$

Note that if M and B are calculated and entered in the configuration 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 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 transmissometer's path length and wavelength. Table 1 lists 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; 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.

<u>Wavelength</u>	<u>10 cm</u>	<u>25 cm</u>	<u>Reference</u>
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 ( <i>historical Sea Tech value</i> )

References:

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

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## Application Note Revision History

<b>Date</b>	<b>Description</b>
May 2011	Initial release - created for WET Labs C-Star, which was removed from Application Note 7 because of changes in calibration terminology and availability of RS-232 output.