APPLICATION NOTE NO. 7   Revised May 2011

Calculation of Calibration Coefficients for
Sea Tech and Chelsea (Alphatracka) Transmissometers

Note: See Application Note 91 for the WET Labs C-Star Transmissometer.

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).
> Light transmission [decimal] is light transmission [%] divided by 100.
> M, B, and z are input to the CTD configuration (.con or .xmlcon) file.

Note: 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).

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)
- Y0 = factory **dark or zero** (blocked path) voltage (factory calibration from transmissometer manufacturer)
- 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**
- Y1 = current (most recent) **dark or zero** (blocked path) voltage

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 or .xmlcon) file by Sea-Bird.

> *Example*: The Sea-Bird Calibration Sheet shows the following values:
> | | | |
> |---|---|---|
> | 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

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 or .xmlcon 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). 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:

> Light transmission (relative to air) =
> Light transmission (relative to water) * 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 (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 or .xmlcon) 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 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	10 cm	25 cm	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 WET Labs.
3. Smith and Baker, 1998, Applied Optics, Vol. 20, No. 2.
4. Original Sea Tech Transmissometer manual.

Application Note Revision History

Date	Description
November 1996	Initial release.
September 2001	Add references to modifying .con file using Configure menu in SEASAVE or SBE Data Processing in Windows software.
March 2004	• Correct the equation for calculating M **from**: M = (Tw / **W0**) * (A0 - Y0) / (A1 - Y1) **to:** M = (Tw / **[W0 - Y0]**) * (A0 - Y0) / (A1 - Y1) • Change *default* value for Tw to 100% (providing output relative to water), instead of value from Table 1 (providing output relative to air). Most optical oceanographers prefer reporting transmissometer measurements relative to water, because they are not based on values of Tw that are subject to interpretation. Accordingly, the template document used to report calibration coefficients was also updated to reflect corrected equation and value of Tw. Values of M and B will now be calculated, tabulated on calibration sheet, and input to .con file based on Tw = 100%. However, *relative to air* value of Tw will also be provided on calibration sheet, so user can easily recalculate M and B relative to air if desired.
September 2008	• Incorporate Seasave V7, eliminate Seasoft-DOS. • In the title, clarify which transmissometers this application note applies to.
February 2010	• Change Seasoft-Win32 to Seasoft V2. • Add info on .xmlcon. • Update address.
May 2011	Remove WET Labs C-Star from application note because of changes in its calibration terminology and availability of RS-232 output; it is now covered in Application Note 91.