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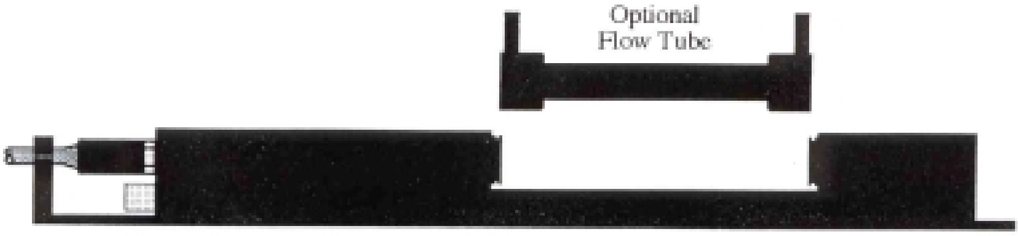
Transmissometer Manual



Length, 26.4", Width, 1.5", Height, 2.75"

20 cm Transmissometer Outline Drawing

Serial Number T1022

Note To Users:

This 20 cm Beam Transmissometer is a very delicate optical instrument. Please handle with care. Be sure windows are cleaned before each calibration and operation.

LIMITED PRODUCT WARRANTY

For a period of one year from the date of shipment *SEA TECH, INC.* guarantees its products to be free from defects in materials and workmanship. In the event a product malfunctions during this period, the companies obligation is limited to repair of the defective item at our factory, or the defective item may be replaced at our option. Repairs or replacements under warranty will be at no cost to the customer. This warranty is void if, in our opinion, the instrument has been damaged by accident, mishandled, altered or repaired by the customer. The customer should call for Return Authorization before returning the instrument to the factory. Instruments should be returned prepaid and carefully packed in the original shipping container as the customer will be responsible for freight damage if the instrument is improperly packed. The customer will be charged a $100 minimum plus shipping costs if an instrument is returned for warranty repair and no defect is found by the factory. Incidental or consequential damages or costs incurred as a result of product malfunction are not the responsibility of *SEA TECH, INC.*

Note:

The transmissometer is shipped with the light attenuator mounted on the transmitter window end cap. This light attenuator is used to calibrate the transmissometer expanded scale, (see page 3, transmissometer calibration). This light attenuator should be removed before transmissometer use. To remove the light attenuator slide it towards the opposite window and then remove the "O" ring on the window end cap. Stow both the "O" ring and light attenuator in a safe place so that they can be used in the future for calibration of the expanded scale.

20 cm TRANSMISSOMETER

The Sea Tech dual range transmissometer measures beam attenuance or beam transmittance which is a well-defined optical parameter. The light intensity in a well-collimated beam of light decreases exponentially according to the relationship

$$I(r) = I(0)\, e^{-cr}$$

where I(r) is the light intensity at distance r from the source and c is the beam attenuation coefficient. If cr=1, the light intensity will have decreased by 1/e. A transmissometer tends to be most accurate in the region where c is on the order of 1/r. This occurs because at greater distances, light intensities are very low. At very short distances, cr is close to zero, making measurement difficult in clean water. To solve this problem, normally a transmissometer with one-meter path length is offered so that sensitivity is increased making it possible to measure clean water environments.

Instead of extending path length to achieve higher sensitivity, this transmissometer incorporates a 5X expanded scale. The expanded scale has one-meter path length sensitivity and is implemented electronically rather than mechanically. The result is a significant reduction in instrument size. Expanding the scale is accomplished by multiplying transmission by a factor of five and offsetting zero to 80%. The expanded scale output voltage is an analog voltage, (-5VDC to +5VDC) which is proportional to approximately 60 to 100% light transmission in water. Zero output on this range is approximately 80% light transmission.

A transmission range of 0 to 100%, having 20 cm path length sensitivity is also provided. Output voltage on this scale is also an analog voltage (0 to 5VDC) which is also proportional to 0 to 100% light transmission in water.

Transmission range is remotely selectable via the gain control line, 0 VDC selects the 80-100% range and 5 VDC selects the 0-100% range.

Transmission is measured using a red, 660 nm modulated Light Emitting Diode (LED), and a synchronous silicon light detector. The instrument is not sensitive to ambient light, it is temperature compensated, and has excellent long term stability.

The red wavelength, 660 nm was chosen to eliminate attenuation due to dissolved humic acids (the so-called "yellow matter" in water). The yellow matter absorbs light strongly at shorter wavelengths but this effect can be ignored for wavelengths longer than 600 nm. Using this wavelength, a much better correlation exists between light transmission and suspended particulate material in the water column.

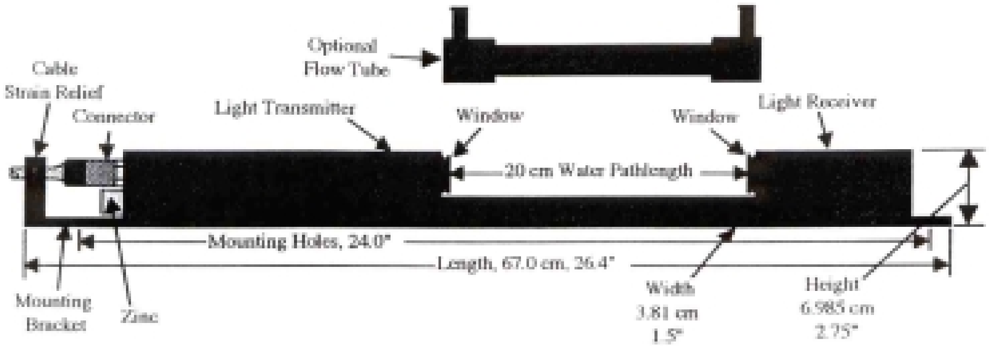
Optical design features a collimated LED transmitter with a beam divergence of less than twelve milliradians, and a optical receiver having an acceptance angle of less than thirty milliradians in water. This collimated optical design reduces transmission error caused by the inclusion of scattered light.

The transmissometer is constructed using plastic materials minimizing corrosion problems in sea water. The hardware used is stainless steel. To prevent corrosion of the hardware be sure to wash the instrument with fresh water after each deployment in salt water. Also clean and dry both transmissometer windows to prevent the build up of deposits on the optical windows. The deposits will be any organic or inorganic materials in the water and can be extremely difficult if not impossible to remove from the window surfaces at a later date.

Depth capability is 2,000 meters. The instrument is portable, easily deployed and has low power requirements. It is supplied with a built-in mounting bracket. An interconnecting cable, (one half meter in length) is also supplied with the instrument to facilitate mounting and checkout in the user's system.

Several options and accessories are available to enhance transmissometer performance and to interface the instrument with computers, recorders, current meters, CTD's, etc. For example, the smart optical sensor, SOS, 20 cm transmissometer has both analog and RS-232 digital outputs with two programmable input / output lines. Please contact Sea Tech for further information regarding these options and accessories.

Figure 1 Outline Drawing, 20 cm Transmissometer, 2000 m



<u>20 cm Transmissometer Specifications</u>

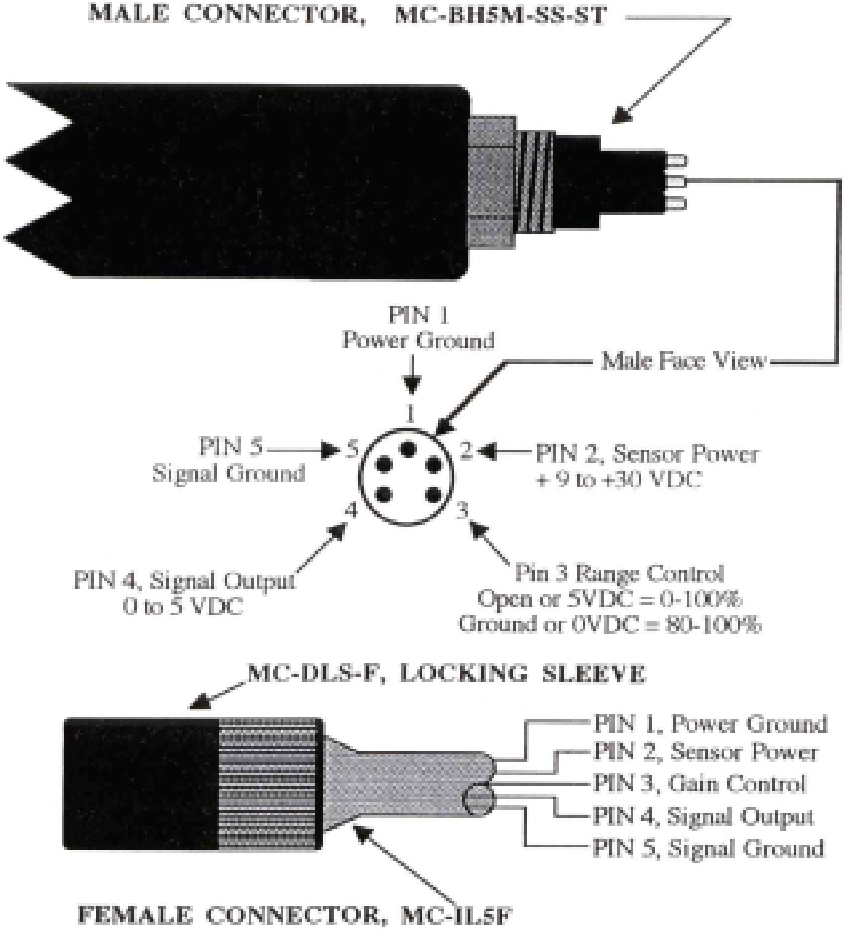
Water Path Length		20 cm
Beam Diameter		5 mm
Transmitted Beam Collimation, (in water)		< 12 milliradians
Receiver Acceptance Angle, (in water)		< 30 milliradians
Light Source, Wavelength, FWHM		LED, 660 nm, 25 nm
TRANSMISSION:	Range (in water)	0-100%, 80-100%
	Accuracy	0.1%
	Linearity	0.1%
	Temperature Stability	< 0.02% F.S./ °C, (0-30° C)
POWER SUPPLY:	Voltage	7 to 15 VDC
	Current	≈ 20 mA
DIMENSIONS:	Length	26.38", 66.99 cm
	Width	1.50", 3.81 cm
	Height	2.750", 6.985 cm
WEIGHT:	In Air	3.81 LB, 1.73 kg
	In Water	1.76 LB, 0.80 kg
DEPTH CAPABILITY:		2,000 meters

20 cm TRANSMISSOMETER OPERATION

Wiring Instructions:

The power source should be between 7 and 15 VDC, nominally 12 VDC. The wiring diagram, see Figure 2 shows transmissometer connector wiring. Observe polarity when connecting the power supply to the transmissometer, connect positive to pin 2 and negative to pin 1. The signal output voltage is on pin 4 and pin 5 is signal ground. Pin 3 is range control, 5-VDC on this pin sets transmissometer range to 0-100% and 0-VDC sets the range to 80-100%.

Figure 2 Transmissometer Connector Wiring



Mounting Instructions:

The transmissometer bottom cover plate is extended at both ends to serve as a mounting bracket and cable strain relief support as shown in figure 1. The bottom cover plate is pre-drilled for two 1/4" mounting bolts spaced exactly 24.00" apart. Do not use the flat head screws on the bottom cover plate for mounting purposes. When mounting the instrument, make sure that no bending or twisting forces are applied to the mounting bracket. These forces could miss align the transmissometer and change transmissometer calibration. To avoid this problem, monitor the transmissometer air calibration voltage and make sure it does not change when the instrument is installed in the users system.

AIR CALIBRATION:

Perform this procedure before each use of the transmissometer to insure data accuracy. The values recorded during the Water Calibration are quite stable but long term stability of the light source and other parameters are not. These instabilities can be compensated for by measuring the following parameters and using this data to re calibrate transmissometer output.

1) Set the range to 0-100%, block the transmissometer light path and measure and record the zero voltage output voltage, Vz. It should be approximately 0.000 VDC.

2) Clean the windows with kimwipes and a solution of soap and water. When the windows are clean, record the value of the transmissometer output voltage in air, Vb. Repeat this step as many times as necessary to insure that Vb is stable and at a maximum.

3) Set the range to 80-100% and record the expanded scale output voltage in air, Ve-air.

4) The expanded scale offset voltage, Ve-os is obtained by partially blocking the light beam with the light attenuator supplied. Turn the screw into the light beam until the output voltage is near zero but not negative. Record the expanded scale offset voltage, Ve-os.

5) With the light attenuator in place and the expanded scale output voltage near 0.0 volts, set the range to 0-100% and record the offset voltage, Vos.

Calibration, 0-100% Range:

The wavelength of the light source is 660 nm. At this wavelength the maximum value for light transmission, %T in a 20 cm path length of particle free water is 92.98%, (4.649 VDC).

Again, the value of the air calibration voltage, (Vb) may change with time. Normally this is due to changes in LED light output, window transmission or instrument stability. These changes can be compensated for and will not affect the accuracy of the transmissometer data if the following corrections are applied:

$$Vc = (Va/Vb) \cdot K \cdot (Vx - Vz) \text{ and } \%T = 20 \cdot Vc$$

Vc = Calibrated Output Voltage, (≤ 4.649 VDC, ≤ 92.98% Transmission)
K = 1.000, Water Calibration Constant
Va = 4.657, Transmission voltage in Air, (Recorded at Water Calibration time, 3/3/98)
Vb = 4.657, Transmission voltage in Air, (Current Value)
Vx = x.xxx, Data value (Transmissometer Output Voltage)
Vz = 0.000, Zero Offset with the transmissometer light path blocked, 0-100% Range

Calculate $\%Tair = 20 \cdot (Va/Vb) \cdot K \cdot (Vb-Vz)$

Calibration, 80-100% Range:

The slope, (A) and offset, (B) for the 80-100% range are calculated as follows:

$$\%Tos = 20 \cdot (Va/Vb) \cdot K \cdot (Vos-Vz).$$

$$A = (\%Tair - \%Tos) / (Ve\text{-}air - Ve\text{-}os)$$

$$B = \%Tos - (A \cdot Ve\text{-}os)$$

Light transmission, %T for the 80-100% range is then:

$$\%T = A \cdot Ve + B$$

Note: Calibration Data, SN-T1022. Values in Blue are determined during Water Calibration, Values in Red are determined prior to each use of the Transmissometer.

OPTICAL PROPERTIES IN WATER

The Sea Tech 20 cm pathlength transmissometer has been designed to provide accurate *in -situ* measurements of beam transmission and or the concentration of suspended matter in optically pure water.

The two basic processes that alter the underwater distribution of light are absorption and scattering. Absorption is a change of light energy into other forms of energy whereas scattering entails a change in direction of the light without loss of energy.

In a pure absorbing medium, the loss of light due to absorption in a well-collimated beam of monochromatic light will be given by $I(z) = I(o)e^{-az}$, where "a" is the absorption coefficient with units of m^{-1}. Similarly, in a pure scattering medium, the light redirected from a well-collimated beam of monochromatic light will be given by $I(z) = I(o)e^{-bz}$, where "b" is the volume scattering coefficient with units of m^{-1}. Since attenuation is defined as the sum of absorption and scattering, we get a + b = c, where "c" is the beam attenuation coefficient.

The light lost from a well-collimated monochromatic beam of light in a scattering and absorbing medium is thus given by $I(z) = I(o)e^{-cz}$. This can be rewritten as $T(z)=I(z)/I(o) = e^{-cz}$, where T(z) is the percent light transmitted over a distance, "z". It should be noted that transmission is always over a given distance, whereas the beam attenuation coefficient, "c", is independent of distance. "c" is computed by $-\ln(T)/z$, where z is the pathlength of the instrument.

The simple exponential relationship holds only if the light is monochromatic. The Sea Tech transmissometer employs a light emitting diode (LED) light source with a wavelength of 660 nm, which is in the red part of the spectrum. This LED is nearly monochromatic.

A beam attenuation coefficient, "c", can be divided into three parts: 1) That due to water, c_w; 2) that due to suspended particulate matter, c_p; and 3) that due to dissolved materials (mostly humic acids or "yellow matter"), c_y. Hence, $c=c_w+c_p+c_y$. Each of these components has distinct spectral characteristics. Yellow matter absorbs strongly in the blue part of the spectrum. This absorption decreases exponentially with increasing wavelengths. The beam attenuation coefficient for particulate matter is much less wavelength dependent. It varies approximately as λ^{-1}. The attenuation spectrum of natural waters is a composite of the three components, depending on the relative concentrations. The yellow matter is a by-product of organic decay and can be present in large amounts in lakes, reservoirs, and near-shore waters. At 660 nm, the attenuation of yellow matter is negligible, however, so that the attenuation is due to particulate matter and sea water only.

INTERRELATION OF OPTICAL PARAMETERS AND PARTICULATE PROPERTIES

The light scattering characteristics of a single particle depend on its shape, size, and internal index of refraction distribution. A typical collection consists of particles of many sizes, shapes and indices of refraction. These parameters, as well as the particle concentration, vary from location to location. It is thus to be expected that the relation between optical and particle parameters varies also.

Fortunately, the nature of suspended matter does not change much in a well-defined region, so that optical devices are useful for the determination of particle concentrations. In each region, however, the optical device must be separately calibrated against particle concentration. Off the Oregon coast, for example, Peterson [1977] found different slopes for the correlation of suspended mass and light transmission in the surface zone and near the bottom.

The correlation between particle concentration and beam attenuation is linear, as will be shown below.

A given type of particulate matter has a given beam attenuation coefficient $c_p{}^*$ per unit volume for a given wavelength. For N particles per unit volume the attenuation coefficient is $Nc_p{}^*$. The total attenuation coefficient must also include water, c_w and since the wavelength is in the red we can ignore yellow matter, c_y so:

$$c = c_w + Nc_p{}^*$$

The attenuation of a well-collimated beam of light is then:

$$I(z)/I(o) = e^{-cz} = e^{-(c_w + Nc_p{}^*)z}$$

or:

$$I(z)/I(o) = e^{-c_w z} e^{-Nc_p{}^* z}$$

$e^{-c_w z}$ is a constant for a given instrument at a given wavelength, so we set it equal to T_w. We then get:

$$I(z)/I(o) = T_w e^{-Nc_p{}^* z}$$

and taking the logarithm:

$$Ln[I(z)/I(o)] = Ln(T_w) - Nc_p{}^* z$$

Since $I(z)/I(o)$ is the transmission and $Ln(T_W)$ is a constant (set it K_1) and c_p*z is also a constant (set it K_2), we then get:

$$\text{Ln Transmission} = K_1 - NK_2$$

The logarithm of the transmission is thus linearly proportional to the particulate concentration.

TRANSMISSOMETER ACCURACY

Accuracy of the transmissometer measurements are mainly controlled by particle concentration, instrument pathlength, and instrument calibration. We have seen that $T(z) = e^{-cz}$. If cz is large, T(z) is small and problems will be encountered with signal-to-noise ratio. When cz is small, T(z) is large and accuracy is limited by the stability and calibration of the instrument. For these reasons the instrument is most accurate when the magnitude of cz is such that T(z) falls somewhere between 90% and 1 %. In turbid water valid measurements can readily be made at much lower light levels than 1% (photodiodes are linear over several orders of magnitude), but then the instrument rapidly becomes insensitive to changes in particle concentration when light transmission decreases below 1%. In clean water (%T ≥ 93%), where small changes in transmission must be measured, careful calibration of the transmissometer and high accuracy recording equipment is required. These points are demonstrated by the data in Table 1.

The HEBBLE calibration data from a field experiment in mid-Atlantic waters where bottom nepheloid suspended particle data was obtained at a depth of 5,000 meters has been expanded in Table I. This data demonstrates the response that can be expected from the 5, 10, 20 and 100 cm transmissometers over a wide range of particulate suspensions. Since we are interested only in the beam attenuation coefficient due to suspended particles, c_p the attenuation coefficient for clean water, c_W must be subtracted from the value of c listed in Table 1. The beam attenuation coefficient, c_W for particle free water at 660 nm is 0.364 m^{-1}. Table 1 then shows that the ratio of particulate beam attenuation coefficient c_p, $(c-c_W)$, to total suspended mass, (TSM) for the HEBBLE data is approximately $1m^{-1}$/mg/l. This corresponds to field values ($c_p \approx 0.1m^{-1}$ for 100 μg/l) obtained by Peterson [1977]. In the following examples related to sensitivity and dynamic range, we will assume that $c_p = 1\ m^{-1}$ for a total suspended mass concentration of 1 mg/l. The user should be aware that this ratio of beam attenuation coefficient to total suspended mass must be determined experimentally since it is a function of particle size distribution, particle shape distribution, particle refractive index and wavelength. To demonstrate this point, laboratory calibration data has been included in Table 1 for Diatomaceous earth since this material is commonly used to calibrate optical instruments that measure turbidity.

TABLE 1, CALIBRATION DATA FROM A LABORATORY AND FIELD EXPERIMENT

TSM (mg/l)	C (m^{-1})	T (1m)	T (20cm)	T (10cm)	T (5cm)
HEBBLE PROJECT					
.000	.364	.6949	.9298	.9642	.9820
.001	.365	.6942	.9296	.9642	.9820
.005	.368	.6921	.9290	.9639	.9818
.010	.373	.6887	.9281	.9634	.9815
.050	.408	.6650	.9216	.9600	.9798
.100	.452	.6363	.9136	.9558	.9776
.250	.584	.5577	.8898	.9433	.9712
.500	.804	.4475	.8515	.9227	.9606
1.000	1.244	.2882	.7797	.8830	.9397
2.500	2.564	.0770	.5988	.7738	.8797
5.000	4.764	.0085	.3857	.6210	.7880
10.000	9.164	.0001	.1600	.4000	.6324
25.000	22.364	.0000	.0114	.1068	.3269
50.000	44.364	.0000	.0001	.0118	.1088
100.000	88.364	.0000	.0000	.0001	.0121
250.000	220.364	.0000	.0000	.0000	.0000
DIATOMACEOUS EARTH					
.001	.364	.6949	.9298	.9642	.9820
.005	.366	.6935	.9294	.9641	.9819
.010	.368	.6921	.9290	.9639	.9818
.050	.383	.6818	.9263	.9624	.9810
.100	.401	.6696	.9229	.9607	.9801
.250	.454	.6351	.9132	.9556	.9776
.500	.549	.5775	.8960	.9466	.9729
1.000	.734	.4800	.8635	.9292	.9640
2.500	1.294	.2742	.7720	.8786	.9373
5.000	2.214	.1093	.6422	.8014	.8952
10.000	4.064	.0172	.4436	.6660	.8161
25.000	9.614	.0001	.1462	.3824	.6184
50.000	18.864	.0000	.0230	.1516	.3894
100.000	37.364	.0000	.0006	.0238	.1544
250.000	92.864	.0000	.0000	.0001	.0096

When the correlation between the beam attenuation coefficient and suspended mass cannot be determined experimentally as in Table 1, then a calibration diagram of specific beam attenuation developed by Spinrad will be useful. With *a priori* estimates of the shape of the particle size distribution and particle composition (i.e., refractive index and density) it is possible to predict the ratio of beam attenuation coefficient to suspended mass. Refer to, Spinrad, R. W. (1986), use of the specific beam attenuation coefficient for identification of suspended particulate material, *Ocean Optics VIII*, SPIE Proc. 637, 135-140).

TRANSMISSOMETER SENSITIVITY

The sensitivity of the 20 cm transmissometer to changes in suspended mass for both clean and turbid water conditions is shown in the following examples. For these examples it will be assumed that the smallest change in transmission that can be measured by the user's equipment is 0.1%. It should be noted here that the transmissometer noise level is approximately 0.01% so with a high resolution data acquisition system more precise measurements are possible than given in these examples.

CLEAN WATER EXAMPLE - In clean water, the change in the beam attenuation coefficient, Δc for a 0.1% change in transmission is:

$$\Delta c = 5 \ln(.9288) - 5 \ln(.9298) \approx 0.005 \ m^{-1}$$

Since we assumed the specific beam attenuation for these examples would be 1 m^{-1}/mg/l then:

$$\textit{CLEAN WATER SENSITIVITY} = (0.005 \ m^{-1})/(1 \ m^{-1}/mg/l) = 0.005 \ mg/l$$

So in clean water an increase of 0.005 mg/l in suspended mass results in a decrease of 0.1% in transmission for a 20 cm pathlength.

TURBID WATER EXAMPLE - In turbid water, the change in the beam attenuation coefficient, Δc for a 0.1% change in transmission is:

$$\Delta c = 5 \ln(.009) - 5 \ln(.01) \approx 0.5 \ m^{-1}$$

Since we assumed the specific beam attenuation for these examples would be 1 m^{-1}/mg/l then:

$$\textit{TURBID WATER SENSITIVITY} = (0.5 \ m^{-1})/(1 \ m^{-1}/mg/l) = 0.5 \ mg/l$$

So in turbid water an increase of 0.5 mg/l in suspended mass results in a decrease of 0.1% in transmission for a 20 cm pathlength.

CALIBRATION

Calibration of the transmissometer at the factory includes alignment, temperature compensation, and determination of the water calibration constant, K corresponding to 92.98% transmission in optically pure particle free water.

Alignment in air is achieved by first collimating the light source. The transmitted beam is then centered on the receiver lens and the detector is aligned to obtain maximum output. The transmissometer is installed in a temperature control chamber where temperature is cycled between 0 degrees and 25 degrees centigrade. Temperature compensation circuitry is adjusted to temperature compensate the transmissometer so that the signal output in air varies less than + or - 0.1% over the temperature range of 0 to 25 degrees centigrade.

After the transmissometer has been aligned and temperature compensated, the transmissometer voltage output in air is recorded and then it is immersed in optically pure particle free water. The transmission of this water is 69.5% as measured by a 1m beam transmissometer. We then convert from transmission readings on the 1m transmissometer, T(1m), to readings on the 20 cm transmissometer, T(0.20m). Since: $T(1m) = e^{-c}$, c=LnT(1m); and hence: $T(0.20m) = e^{(0.20)LnT(1m)}$. Therefore, a reading of 69.5% transmission on the 1m beam transmissometer is corresponds to 92.98% transmission for the 20 cm transmissometer.

With the instrument in water as described above, the transmissometer voltage on both the 0-100% and 80-100% range is recorded. The unit is then removed from water and the voltage reading in air is again recorded. This procedure is repeated to make sure all recorded values are stable and at a maximum.

The calibration of any optical instrument in terms of volume or weight of suspended matter must be done experimentally. The attenuation properties of a collection of particles depends on their size, shape, and index of refraction structure. The relationship between observed attenuation and particle volume or weight thus changes somewhat as the location of the observation changes. Nevertheless, it has been shown that the correlation coefficient between attenuation and suspended volume is .80 to .95 in the surface layer and .90 to .98 below the thermocline. The high correlation indicates that the particle properties do not change a great deal in distances of about 50 miles or in periods of weeks. The exceptions are active phytoplankton blooms, in this case the correlation can be as low as 0.70.

DATA INTERPRETATION:

Conversion of the transmissometer data from %T to c, the beam attenuation coefficient for a 20 cm transmissometer is:

$$c = -5 \ln(t), \text{ where } t = \%T/100$$

Note: (cp=c-cw) To obtain cp, attenuation due to particulate matter only, subtract cw = 0.364, attenuation of pure water from the measured beam attenuation coefficient, c.

NOTES ON INTERFACING THE TRANSMISSOMETER TO YOUR SYSTEM

High resolution measurements can be obtained with the transmissometer if your data acquisition system has a low noise analog to digital converter (ADC). Most ADC's used in systems are designed to make measurements rapidly. Acquiring data with these converters can present problems with noisy data. Two solutions for this problem normally implemented are to filter the sensor output or average several data samples. Another solution would be to use an integrating converter. From a low noise standpoint this approach is much more acceptable, especially if the integration time is 16.6 milliseconds so that interference from 60 cycle line power is canceled. Data can be obtained from the transmissometer with better than 14 bit resolution, 0.006%, using an integrating converter without filtering or averaging the data. Needless to say the integrating converter is recommended for recording transmissometer data.

Accuracy of the ADC must be considered also. 12 bit accuracy is normally quoted by the manufacturers of recording equipment but this is normally for an input of +/- 10 VDC. The output of the transmissometer is 0-5 VDC. Using this converter for measuring the transmissometer output would result in 10 bit, 0.1% accuracy since only 1/4 of the range of the converter is being used. To solve this problem a converter should be chosen that has a 0-5 VDC input for full scale output. Accuracy of the converter is mainly controlled by the temperature stability of its reference and, since temperature can vary over a large range, (the hot deck of a ship to near freezing in arctic waters) particular attention to the reference element used in the ADC is essential to obtain high accuracy recording of transmissometer data.

Response time (or time constant) of the transmissometer is 0.1 second. The instrument requires at least 3 seconds warm up time before the output data can be considered valid. The transmissometer has been temperature compensated over the range of 0 to 25 degrees centigrade, but some hysteresis between up and down cast can be expected if the instrument is hot on the deck of a ship and then immersed in cold water. To avoid this problem the transmissometer can be cooled on deck with running water or allowed to stabilize at the surface of the water before a cast is made.

Accurate data acquisition with the transmissometer can only be accomplished if strict attention is paid to the procedures outlined on page 5, the transmissometer operating instructions, i.e. clean the windows before each deployment and pay frequent attention to the air calibration.