



Combination Scattering Meter and Fluorometer

ECO BB2F

User's Guide

This user's guide is an evolving document. If you find sections that are unclear or missing information, please let us know. Please check our website periodically for updates.

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Attention!

Return Policy for Instruments with Anti-fouling Treatment

WET Labs cannot accept instruments for servicing or repair that are treated with anti-fouling compound(s). This includes but is not limited to tri-butyl tin (TBT), marine anti-fouling paint, ablative coatings, etc.

Please ensure any anti-fouling treatment has been removed prior to returning instruments to WET Labs for service or repair.



ECO Sensor Warranty

This unit is guaranteed against defects in materials and workmanship for one year from the original date of purchase. Warranty is void if the factory determines the unit was subjected to abuse or neglect beyond the normal wear and tear of field deployment, or in the event the pressure housing has been opened by the customer.

To return the instrument, contact WET Labs for a Return Merchandise Authorization (RMA) and ship in the original container. WET Labs is not responsible for damage to instruments during the return shipment to the factory. WET Labs will supply all replacement parts and labor and pay for return via 3rd day air shipping in honoring this warranty.

Shipping Requirements for Warranty and Out-of-warranty Instruments

1. Please retain the original shipping material. We design the shipping container to meet stringent shipping and insurance requirements, and to keep your meter functional.
2. To avoid additional repackaging charges, use the original box (or WET Labs-approved container) with its custom-cut packing foam and anti-static bag to return the instrument.
 - If using alternative container, use at least 2 in. of foam (NOT bubble wrap or Styrofoam “peanuts”) to fully surround the instrument.
 - Minimum repacking charge for ECO meters: \$25.00.
3. Clearly mark the RMA number on the outside of your shipping container and on all packing lists.
4. Return instruments using 3rd day air shipping or better: do **not** ship via ground.

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1. Overview

1.1 Specifications

Model	BB2F	BB2FB
Mechanical		
<i>Diameter</i>	2.48 in (6.3 cm)	2.48 in (6.3 cm)
<i>Length</i>	5.0 in (12.7 cm)	10.0 in (25.4 cm)
<i>Weight in air</i>	0.9 lbs (0.4 kg)	2.1 lbs (0.96 kg)
<i>Weight in water</i>	0.05 lbs (0.02 kg)	0.3 lbs (0.14 kg)
<i>Material</i>	Acetal copolymer	Acetal copolymer
Environmental		
<i>Temperature range</i>	0–30 deg C	0–30 deg C
<i>Depth rating</i>	600 m	300 m
<i>Pressure/temperature sensor (optional)</i>	Yes	Yes
Electrical		
<i>Digital output resolution</i>	12 bit	12 bit
<i>Internal data logging</i>	Yes	Yes
<i>Internal batteries</i>	No	Yes
<i>Connector</i>	MCBH6M	MCBH6M
<i>Input</i>	7–15 VDC	7–15 VDC
<i>Current, typical</i>	80 mA	80 mA
<i>Current, sleep</i>	85 μ A	85 μ A
<i>Data memory</i>	50,000 samples	50,000 samples
<i>Sample rate</i>	to 10 Hz	to 10 Hz
<i>RS-232 output</i>	19200 baud	19200 baud
Optical		
<i>Scattering wavelengths</i>	470 and 700 nm	470 and 700 nm
<i>Fluorometer excitation</i>	470 nm	470 nm
<i>Fluorometer emission</i>	695 nm	695 nm
<i>Accuracy, (min.)</i>	0.005 m^{-1} @ 1 Hz	0.005 m^{-1} @ 1 Hz
<i>Sensitivity, blue</i>	4.1 x 10 ⁻⁵ m^{-1}/sr	4.1 x 10 ⁻⁵ m^{-1}/sr
<i>Sensitivity, red</i>	2.1 x 10 ⁻⁶ m^{-1}/sr	2.1 x 10 ⁻⁶ m^{-1}/sr
<i>Linearity</i>	99% R ²	99% R ²

1.2 Connectors

The *ECO* BB2F uses a six-pin bulkhead connector; the pin functions for this connector are shown in Figure 1. Table 1 summarizes pin functions for the bulkhead connectors.

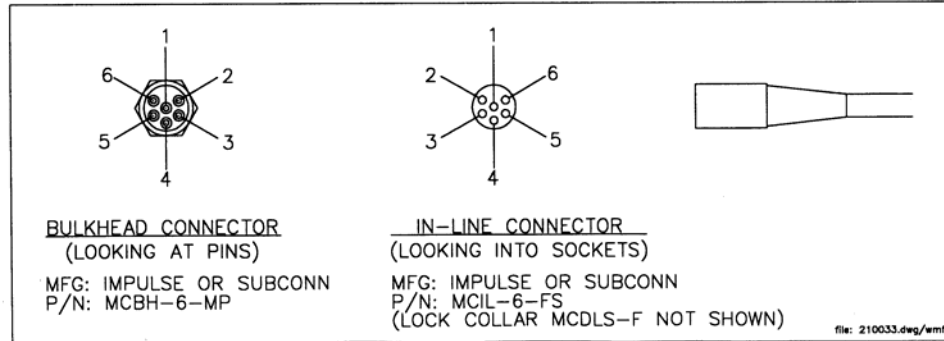


Figure 1. *ECO*-BB2F connector schematic

Table 1. Pinout summary for *ECO* BB2F connectors

Pin (or Socket)	Function
1	Ground
2	RS-232 (RX)
3	Reserved
4	V in
5	RS-232 (TX)
6	Reserved

WARNING

If you are going to build or use a non-WET Labs cable, do not use the wire from pin 3 or the *ECO* meter will be damaged.

Input power of 7–15 VDC is applied to pin 4. The power supply current returns through the common ground pin. The input power signal has a bi-directional filter. This prevents external power supply noise from entering into *ECO*-BB2F, and also prevents internally generated noise from coupling out on to the external power supply wire. Data is sent out the serial output pin.

1.2.1 *ECO* BB2FB Connectors

The *ECO* BB2FB (unit with internal batteries) has a second bulkhead connector that comes with a jumper plug to supply power to the unit. The pin functions for this connector are shown in Figure 2. Table 2 summarizes pin functions for the 3-socket bulkhead connector.

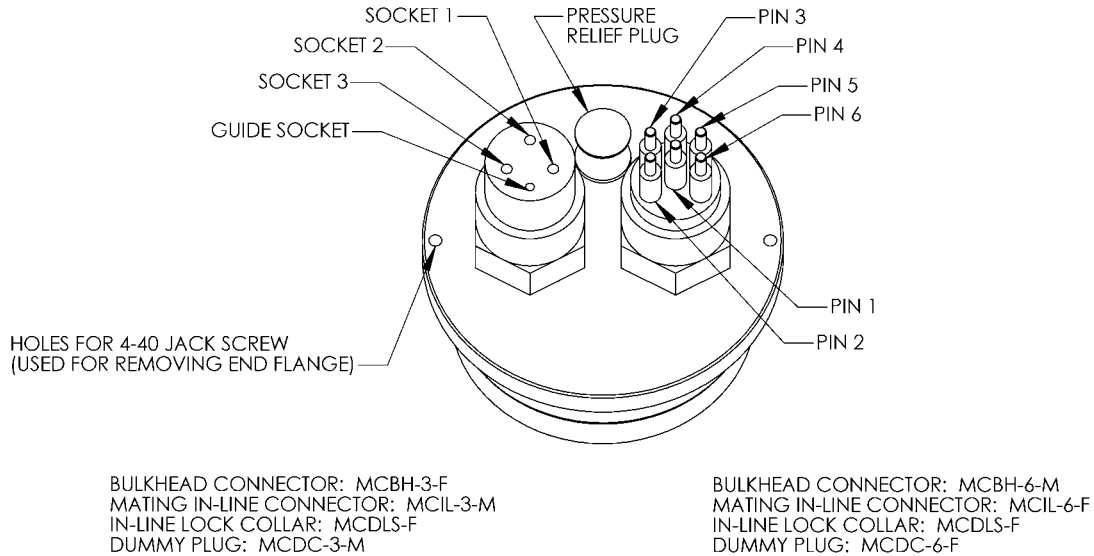


Figure 2. *ECO* BB2FB connector schematic

Table 2. Pinout summary for *ECO* 3-socket connector

Pin (or Socket)	Function
1	V in
2	N/C
3	Battery out

1.3 Optional Equipment

1.3.1 Test Cable

A test cable is optionally supplied with each unit. This cable includes three legs:

1. A power interface module provides power to the instrument from the connected 9 V battery.
2. A DB-9 serial interface connector.
3. A six-socket in-line connector plugs into the sensor to provide power and obtain signal.

1.3.2 Copper Faceplate

ECO meters are optionally equipped with copper faceplates to improve the meter's resistance to biofouling. Refer to Section 3.4.1 for important details on maintenance and cleaning.

1.3.3 Batteries

ECO units with internal batteries are supplied with six 9-volt Lithium batteries as their power source. They can use either standard alkaline cells for a total capacity of approximately 1000 mA-hrs, or for longer deployments, LiMnO₂ cells to achieve more than 2000 mA-hrs of operational capacity. Actual total usage time of the internal batteries is a function of several parameters. These include nominal water temperature, sequence timing, sample periods, and total deployment duration.

WARNING!

Pin 6 is always “hot.” Be sure to keep the dummy plug on the BB2FLB and BB2FLSB when not in use.

For even greater deployment capability contact WET Labs for information on external battery packs.

1.3.4 External Thermistor

ECO meters are optionally equipped with an external thermistor. The thermistor is calibrated at WET Labs and the calibration coefficients are supplied on the instrument’s calibration sheets. Thermistor output is in counts and can be converted into engineering units using the instrument’s device file and ECOView software or the raw data can be converted in the user’s software (e.g. MATLAB or Excel) using the calibration equation:

$$\text{Temperature (deg C)} = \text{Scale Factor} * (\text{Counts} - \text{Offset})$$

1.3.5 Pressure Sensor

ECO meters are optionally equipped with a strain gauge pressure sensor. The pressure sensor is calibrated at WET Labs and the calibration coefficients are supplied on the instrument’s calibration sheets. Pressure sensor output is in counts and can be converted into engineering units using the instruments device file and ECOview software or the raw data can be converted in the user's software (e.g. MATLAB or Excel) using the calibration equation:

$$\text{Relative Pressure (psi)} = \text{Scale Factor} * (\text{Counts} - \text{Offset})$$

Please note that strain gauge pressure sensors are susceptible to atmospheric pressure changes and should be “zeroed” on each deployment or profile. The calibration equation for pressure above should be used first to get the relative pressure and the cast offset should then be subtracted to get the absolute pressure:

$$\text{Absolute Pressure (psi)} = \text{Relative Pressure (psi)} - \text{Relative Pressure at Atmospheric/Water interface (psi)}$$

WARNING

Do not exceed 300 m (500 psi).

Pressure Sensor Maintenance

A plastic fitting and capillary tube, both filled with silicone oil, provide a buffer between the pressure transducer and seawater. The transducer is both sensitive and delicate. Following the procedures below will ensure the best results and longest life from your pressure sensor.

Pressure is transmitted from the water to the stainless steel transducer diaphragm via a capillary tube filled with silicone oil. The inert silicone oil protects the pressure sensor from corrosion, which would occur after long exposure to salt water. The capillary tube will generally prevent the oil from escaping from the reservoir into the water. However, you may occasionally wish to ensure that oil remains in the reservoir on top of the transducer.

WARNINGS

Never touch or push on the transducer.

Never attempt to fill the reservoir except by the procedure below.

Refilling procedure

1. Thoroughly clean the top of your instrument.
2. Completely remove the white nylon Swagelock fitting using a 9/16-in. wrench.
3. Add silicone oil (Dow Corning DC200) to within 1/16-in. of the top of the threaded cavity.
4. Wipe clean the o-ring at the base of the Swagelock fitting.
5. Hold a tissue over the end of the capillary tube.
6. Screw the Swagelock fitting into the end flange until finger tight.
7. Tighten it an additional 1/8 turn using a wrench only if necessary.
8. Wipe up any excess oil that may have squirted out of the capillary tube.

Hints

- If you can see drops of oil in the capillary tube, refilling is unnecessary.
- Rinsing the instrument with fresh water will help keep the tube end open.

1.4 Delivered Items

The standard *ECO* delivery consists of the following, dependent on the model of meter ordered.

- the instrument itself
- this user's guide
- ECOView user's guide
- ECOView host program and instrument-specific device file (on CD)
- instrument-specific calibration sheet
- protective cover for optics
- BB2F only: stainless steel mounting bracket and hardware (See Appendix A for details)
- Fluorescent stick for bench testing

Auxiliary parts

- Silicone oil (Dow Corning DC200) (pressure sensor units only)
- Internal battery units: six 9-V Lithium batteries (installed)
- Internal battery units only:
 - jumper plug for autonomous operation
 - 2 end flange O-rings (size 224) and two vent plug O-rings (size 010)
 - 2 jacking screws for connector flange removal
 - One 3/32-in. hex key for jacking screws
 - 3 pre-cut segments (7 inches) of 0.036-inch diameter monofilament for end flange
 - 3 pre-cut segments (0.25 inch) of 0.094-inch diameter white nylon bar stock for replacing the white plastic dowel pin.

2. Theory of Operation

The *Environmental Characterization Optics*, or *ECO* miniature combination scattering meter and fluorometer allows the user to measure backscattering at two wavelengths (470 and 700 nm) at 117 degrees and chlorophyll fluorescence within the same volume. This angle was determined as a minimum convergence point for variations in the volume scattering function induced by suspended materials and water itself. Therefore, the signal measured by this meter is less determined by the type and size of materials in the water and more directly correlated to the concentration of the materials.

The *Environmental Characterization Optics*, or *ECO* miniature fluorometer allows the user to monitor chlorophyll concentration by directly measuring the amount of chlorophyll-*a* fluorescence emission from a given sample volume of water. Chlorophyll, when excited by the presence of an external light source, absorbs light in certain regions of the visible spectrum and re-emits a small portion of this light as fluorescence at longer wavelengths. The *ECO* uses two bright blue LEDs (centered at 455 nm and modulated at 1 kHz) to provide the excitation source. A blue interference filter is used to reject the small amount of red light emitted by the LEDs. The blue light from the sources enters the water volume at an angle of approximately 55–60 degrees with respect to the end face of the unit. Fluoresced light is received by a detector positioned where the acceptance angle forms a 117-degree intersection with the source beam. A red interference filter is used to discriminate against the scattered blue excitation light. The red fluorescence emitted is synchronously detected by a silicon photodiode.

The *ECO* uses three LEDs (modulated at 1 kHz) for source light. The source light enters the water volume and scattered material is detected by a detector positioned where the acceptance angle forms a 117-degree intersection with the source beam. Figure 3 shows the optical configuration for the *ECO-BB2F*.

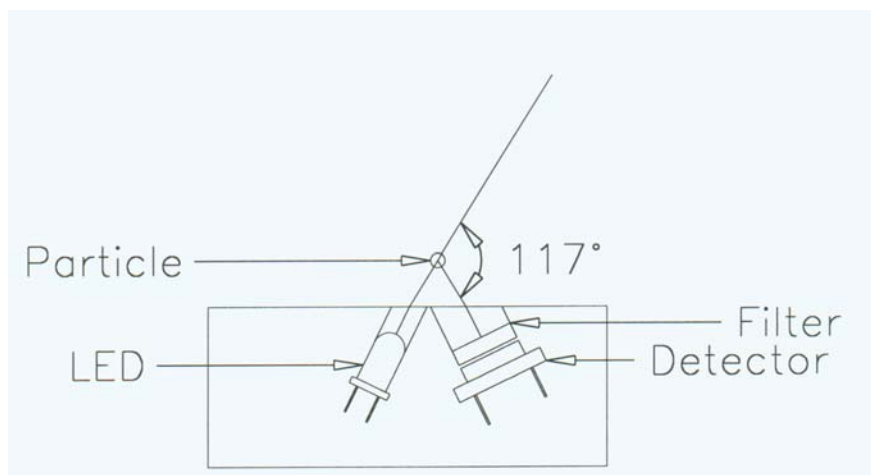


Figure 3. Optical configuration of *ECO-BB2F* scattering meter

3. Instrument Operation

Please note that certain aspects of instrument operation are configuration-dependent. These are noted where applicable within the manual.

3.1 Initial Checkout

Supplied from the factory, *ECOs* are configured to begin continuously sampling upon power-on. Electrical checkout of *ECO* is straightforward.

Connect the 6-socket connector on the optionally available test cable to the instrument to provide power to the LEDs and electronics (see Section 1 for a diagram of the pinouts of *ECO-BB2F*). Connect the battery leads on the test cable to the 9V battery supplied with the meter. Light should emanate from the meter.

3.2 Operating the Sensor for Data Output

Note

ECO scattering meters are sensitive to AC light. Before making measurement, turn AC lighting off.

1. Connect the 6-socket connector to the instrument to provide power to the LEDs and electronics. Connect the DB-9 connector to a computer with the ECOView host program installed on it.

WARNING!

Always use a regulated power supply to provide power to ECO sensors if not using the 9V battery provided with the test cable: power spikes may damage the meter.

2. Start ECOView. Select the appropriate COM Port and Device File. Supply power to the meter, then click on the **Start Data** button. Output will appear in the Raw Data window. Test the instrument's signal using the fluorescent stick. *ECO* is sensitive to room lighting; for best results, perform test in ambient light only (turn off AC lighting). Remove the protective cover. Hold the fluorescent stick 1–4 cm above the optical paths in an orientation that maximizes exposure of the stick. (Parallel with the beams, not intersecting them). The signal will increase toward saturation (maximum value on characterization sheet). The sensor will operate until you select **Stop Data** in ECOView, or until it completes the requested samples.
3. Check the settings for the ECO and change if necessary. ECOView factory settings for continuous operation:
 - Set Number of Samples = 0
 - Set Number of Cycles = 0.

-
4. If the meter does not light after performing step 3, check the battery. Replace if necessary, perform steps 2 and 3 to verify communication. If it still does not light, contact WET Labs.

Refer to the ECOView User's Guide for details about using the software.

3.3 Deployment

The meter is ready for submersion and subsequent measurements when power is supplied. Note that for units with internal batteries, power is supplied by securing the jumper plug to the six-pin connector. Some consideration should be given to the package orientation. Do not face the sensor directly into the sun or other bright lights. For best output signal integrity, locate the instrument away from significant EMI sources.

Caution

The BB2F should be mounted so that the red LED source will not "see" any part of a cage or deployment hardware. This will affect the sensor's output.

Other than these basic considerations, one only needs to make sure that the unit is securely mounted to whatever lowering frame is used and that the mounting brackets are not damaging the unit casing. The instrument can be used in a moored or profiling mode.

3.4 Upkeep and Maintenance

We highly recommend that ECO meters be returned to the factory annually for cleaning, calibration and standard maintenance. Contact WET Labs or visit our website for details on returning meters and shipping.

The *ECO-BB2F* is compact device and its maintenance can be easily overlooked. However, it is a precision instrument and does require a minimum of routine upkeep. After each cast or exposure of the instrument to natural water, flush the instrument with clean fresh water, paying careful attention to the sensor face. Use soapy water to cut any grease or oil accumulation. Gently wipe clean with a soft cloth. The sensor face is composed of ABS plastic and optical epoxy and can easily be damaged or scratched.

WARNING!

Do not use acetone or other solvents to clean the sensor.

At the end of an experiment, the instrument should be rinsed thoroughly, air-dried and stored in a cool, dry place.

3.4.1 Copper Faceplate Cleaning and Maintenance

The copper faceplate needs to be removed from the meter for thorough cleaning to maximize anti-fouling capability.

1. Remove faceplate using a small Phillips screwdriver to remove the screws that attach the plate to the optics head.

WARNING!

Be sure to retain and re-use the factory-installed screws as they are vented for pressure compensation.

2. Wash the copper faceplate with soapy water. Rinse and dry thoroughly. It is normal for copper to corrode and turn green, especially after the instrument has been removed from the water. This corrosion will slightly reduce the shutter's anti-fouling ability the next time it is deployed.
3. Buff the faceplate with a pad of green Scotch Brite[®] (or similar) until shiny.
4. Re-install faceplate.

4. BB2FB: Using Internal Batteries

ECO sensors powered with internal batteries can either run directly from the internal batteries or can operate from power supplied by an external DC power supply (7–15 volts). Internal-to-external source conversion is facilitated by a jumper plug that plugs into the unit’s bulkhead connector. When inserted, the plug forms a connection from the battery to the electronics. By removing the plug, the instrument can be powered and communicate via a test or deployment cable. Setup conditions, instrument checkout, real-time operation, and data downloading are thus all achieved identically to the methods prescribed for the BB unit.

4.1 Removing End Flange and Batteries

WARNING!

Changing the batteries will require opening the pressure housing of the ECO sensor. Only people qualified to service underwater oceanographic instrumentation should perform this procedure. If this procedure is performed improperly, it could result in catastrophic instrument failure due to flooding or in personal injury or death due to abnormal internal pressure as a result of flooding.

WET Labs Inc. disclaims all product liability from the use or servicing of this equipment. WET Labs Inc. has no way of controlling the use of this equipment or of choosing qualified personnel to operate it, and therefore cannot take steps to comply with laws pertaining to product liability, including laws that impose a duty to warn the user of any dangers involved with the operation and maintenance of this equipment.

Therefore, acceptance of this equipment by the customer shall be conclusively deemed to include a covenant by the customer to defend and hold WET Labs Inc. harmless from all product liability claims arising from the use and servicing of this equipment. Flooded instruments will be covered by WET Labs Inc. warranties at the discretion of WET Labs, Inc.

1. Make sure the instrument is thoroughly dry.
2. Remove the dummy plugs.
3. With connector end flange pointed downwards away from face, release seal from vent plug.
4. Remove moisture from vent plug area.
5. Using needle nose pliers, remove filament from end flange.
6. Lift flange from pressure housing until seal is broken. The jacking screws can be used to “push” the flange from the pressure housing and then can be removed or left in the end flange.
7. Remove any excess moisture from flange–can seal area.
8. Work end flange out of pressure housing and remove any residual moisture. Remove the gray foam spacer and the neoprene insulator.
9. The battery pack is connected to the processor boards by a six-pin Molex connector: do NOT pull too hard or far on the battery pack or it will come unplugged and the unit returned to WET Labs.

10. Gently pull the white cord at the loop to remove the battery pack from the pressure housing.
11. Remove the black plastic protectors from the ends of the long screws securing the batteries.
12. Loosen and remove the screws (3/16-in slotted driver).

4.2 Replacing End Flange and Batteries

1. Replace the batteries.
2. Re-install the screws:
 - Align the groove in each of the plates so the six-wire extension bundle will fit in it along its length.
 - Be careful not to cross-thread into the bottom end plate nor to over-tighten the screws.
 - If they are too tight, the fiber washers that act as separators between the batteries will flex.
 - Make sure there are equal amounts of screw threads protruding from the bottom end plate when they are secure. This will ensure the pack is straight and will fit into the pressure housing with no difficulty.
3. Re-install the black plastic protective covers on the ends of the screws.
4. Remove and check the pressure housing O-ring for nicks or tears. Replace if necessary. Before re-installing, apply a light coat of vacuum grease on the O-ring.
5. Carefully replace the battery pack in the pressure housing. Place the neoprene insulator on the battery assembly and lay the white cord on the top.
6. Plug in the two-pin, then the six-pin Molex connectors. Sensor operation can now be tested if desired.
7. Align the hole in the end flange (NOT the jack screw holes) with the white dowel pin. While coiling the six wire bundle and making sure none are pinched between the end flange and the pressure housing, position the flange on the housing. Leave space to re-insert the gray foam spacer, making sure the cut-out accommodates the vent plug screw.
8. Push the end flange all the way on to the pressure housing, making sure no wires are pinched. Be sure the vent plug does not pop up. If it does, you'll need to re-position the foam spacer.
9. Re-insert the monofilament.

4.3 Checking Vent Plug

If there is fouling on the vent plug, it should be cleaned and the two 010 O-rings replaced. Otherwise, this mechanism should be maintenance-free.

WARNING!

The pressure housing is made of plastic material that scratches easily. Do not let the screwdriver slip and scratch the can when removing or replacing the vent plug. Use a toothpick (something softer than the plastic) to remove the O-rings from the vent plug.

1. Pull vent plug out about half way; hold plug while unscrewing the truss screw. When screw is removed, pull vent plug from end flange.
2. “Pinch” bottom O-ring around vent plug to form a small gap you can work a toothpick into. Use the toothpick to help roll the bottom O-ring off the plug.
3. Perform the same procedure with the top O-ring.
4. Clean the vent plug and vent plug hole using a dry lint-free tissue or cotton swab.
5. Lightly coat two undamaged or new O-rings with silicon grease. Install the top O-ring (nearest to large end of plug) first, then the bottom one.
6. Insert vent plug into its hole in the end flange and hold it while inserting the truss screw. Rotate the vent plug to begin tightening the screw. Finish tightening using a screwdriver, being careful not to over-tighten truss screw.

Note

A portion of the truss screw head has been removed to allow for venting in case of pressure buildup.

5. Data Analysis

Data from the *ECO* meter is output in counts from the sensor, ranging from 0 to 4120 +/- 3. The ECOView host program will automatically perform the necessary calculations for both scattering and fluorescence.

- Calibration yields scattering data in the form of volume scattering coefficients, $\beta(\theta, \lambda)$ with units of $\text{m}^{-1} \text{sr}^{-1}$, where θ is angle and λ is wavelength.
- Characterization yields fluorescence data in the form of $\mu\text{g/l}$ (chlorophyll).

5.1 Scattering Data Corrections

Attenuation coupling—For the population of photons scattered within the remote sample volume in front of the sensor face, there is attenuation along the path from the light source to the sample volume to the detector. This results in the scattering measurements being underestimates of the true volume scattering in the hydrosol. Corrected volume scattering coefficients can be obtained by accounting for the effect of attenuation along an average pathlength. This average pathlength was numerically solved in the weighting function determinations developed by Dr. Ron Zaneveld that are used in the calibration procedures.

Since the calibration of the *ECO-VSF* uses microspherical scatterers, the component of attenuation that can be attributed to scattering is incorporated into the scaling factor, i.e., the calibration itself. Thus, only absorption of the incident beam needs to be included in the correction.

The dependence on absorption, a , is determined as follows, where the measured scattering function at a given value of a , $\beta_{\text{meas}}(\text{angle}, a)$, is corrected to the value for $a = 0 \text{ m}^{-1}$, $\beta_{\text{corr}}(117^\circ, a=0)$:

$$\beta_{\text{corr}}(117^\circ, a=0) = \beta_{\text{meas}}(117^\circ, a) \exp(0.0391a)$$

Absorption can be measured with an ac-9 device. For each *ECO-BB2F* wavelength, the matching absorption coefficient must be used from the ac-9. Because the *ECO-BB2F* incorporates short pathlengths and relatively small scattering volumes in its measurements, this attenuation error is typically small, about 4 percent at $a = 1 \text{ m}^{-1}$.

Temperature correction—Output from an LED reference detector is provided, which gives an indication of relative LED intensity during operation. Work is presently under way to incorporate this signal as an ongoing correction for measurements. Largest expected deviations in the calibration coefficients are about 10 percent in the temperature range 0–28 degrees C. Note that these errors become more pronounced for very clear waters. If the instrument is planned for use in clear water environments at the ends of this temperature range, it is recommended that a request be made for calibration data to be collected as close to the expected environmental temperature as possible.

5.2 Derived Parameters

5.2.1 Volume Scattering of Particles

The corrected volume scattering of particles, $\beta(117^\circ, \lambda)$ values represent total volume scattering, i.e., scattering from particles and molecular scattering from water. To obtain the volume scattering of particles only, subtract the volume scattering of water, $\beta_w(117^\circ, \lambda)$:

$$\beta_p(117^\circ, \lambda) = \beta(117^\circ, \lambda) - \beta_w(117^\circ, \lambda)$$

where $\beta_w(117^\circ, \lambda)$ is obtained from the relationship (from Morel 1974):

$$\beta_w(\theta, \lambda) = 1.38(\lambda/500\text{nm})^{-4.32}(1+0.3S/37)10^{-4} (1+\cos^2\theta(1-\delta)/(1+\delta))\text{m}^{-1}\text{sr}^{-1}, \delta=0.09$$

where S is salinity.

For total scattering of pure water,

$$b_w(\lambda) = 0.0022533 (\lambda/500\text{nm})^{-4.23}.$$

For total scattering of seawater (35–39 ppt),

$$b_{sw}(\lambda) = 0.0029308 (\lambda/500\text{nm})^{-4.24}.$$

For backscattering by water, divide b_w or b_{sw} by 2. The units for the b coefficients are (10^{-4} m^{-1}).

5.2.2 Backscattering Coefficients

Particulate backscattering coefficients, $b_{bp}(\lambda)$ with units of m^{-1} , can be determined through estimation from the single measurement of $\beta_p(117^\circ, \lambda)$ using an X factor:

$$b_{bp} = 2\pi X \beta_p(117^\circ)$$

From measurements of the volume scattering function with high angular resolution in a diversity of water types, Boss and Pegau (2001) have determined X to be **1.1** (Boss, E., and S. Pegau, 2001. The relationship of scattering in an angle in the back direction to the backscattering coefficient, *Applied Optics*). This factor estimates b_{bp} with an estimated uncertainty of 4 percent. The conversion can be used for $\beta(117^\circ)$ measurements made at any visible wavelength.

To compute total backscattering coefficients, $b_b(\lambda)$ with units of m^{-1} , the backscattering from pure water, $b_{bw}(\lambda)$ (see Table above), needs to be added to $b_{bp}(\lambda)$:

$$b_b(\lambda) = b_{bp}(\lambda) + b_{bw}(\lambda).$$

5.2.3 Fluorescence Response

The scale factor is factory-calculated by obtaining a consistent output of a solution with a known concentration, then subtracting the meter's dark counts. The scale factor, dark counts, and other characterization values are on the instrument's characterization sheet.

For chlorophyll, WET Labs uses the chlorophyll equivalent concentration (CEC) as the signal output using a fluorescent proxy approximately equal to 16.8 µg/l of a *Thalassiosira weissflogii* phytoplankton culture.

$$\text{Scale Factor} = 16.8 \mu\text{g/l} \div (\text{CEC} - \text{dark counts})$$

$$\text{Example: } 25 \div (3198 - 71) = 0.0080.$$

The scale factor is then applied to the output signal to provide the direct conversion of the output counts to chlorophyll concentration. WET Labs supplies a scale factor that can be found on the instrument-specific calibration sheet that ships with each meter. While this constant can be used to obtain approximate values, field calibration is highly recommended.

Because of the varied environments in which each user will work, it is important to perform characterizations using similar seawater as you expect to encounter *in situ*. This will provide an accurate dark count value, equivalent phytoplankton types and similar physiological conditions for calculating the scale factor, thereby providing an accurate and meaningful calibration. Once a zero point has been determined and a scale factor established, obtaining a "calibrated" output simply involves subtracting the digital dark counts value from output when measuring a sample of interest and multiplying the difference by the instrument scaling factor:

$$[\text{XX}]_{\text{sample}} = (\text{C}_{\text{output}} - \text{C}_{\text{dc}}) * \text{Scale Factor}$$

where

$[\text{XX}]_{\text{sample}}$ = concentration of a sample of interest (µg/l)

C_{output} = raw counts output when measuring a sample of interest

C_{dc} = dark counts, the measured signal output of meter in clean water with black tape over the detector

Scale factor = multiplier in µg/l/counts

6. Testing and Calibration/Characterization

Prior to shipment, each *ECO* is tested and calibrated/characterized to ensure that it meets the instrument's stated specifications. Scattering channels are typically configured for a measurement range of 0–10 m^{-1} . Fluorescence channel(s) are characterized using a specific concentration of a fluorescing material that yields a scaled output range of 0.04–70 $\mu\text{g/l}$ chlorophyll.

6.1 Testing

Dark Counts: Pure, de-ionized water is used to set the “zero” level of the meter. This zero level is set for 125 counts (+/-75) on all models.

Pressure: To ensure the integrity of the housing and seals, ECOs are subjected to a wet hyperbaric test before final testing. The testing chamber applies a water pressure of at least 50 PSI.

Mechanical Stability: Before final testing, the ECO-BB2F meters are subjected to a mechanical stability test. This involves subjecting the unit to mild vibration and shock. Proper instrument functionality is verified afterwards.

Electronic Stability: This value is computed by collecting a sample once every 5 seconds for twelve hours or more. After the data is collected, the standard deviation of this set is calculated and divided by the number of hours the test ran. The stability value must be less than 2.0 counts/hour.

Noise: Noise is computed from a standard deviation over 60 samples, collected at one-second intervals for one minute. The standard deviation is calculated on the 60 samples, and the result is the published resolution on the calibration sheet. The calculated standard deviation value must be below 2 counts.

Voltage and Current Range Verification: To verify that the *ECO* operates over the entire specified voltage range (7–15 V), a voltage test is performed at 7 and 15 V. The meter is operated over the entire voltage range, and the current draw and operation is observed. The current must remain constant at both 7 and 15 volts.

6.2 Scattering Calibration

Each meter ships with a calibration sheet that provides instrument-specific calibration information, derived from the steps below.

1. For a given scattering centroid angle (θ_c), compute the weighting function $W(\theta, \theta_c)$, by numerical integration of sample volume elements according to the sensor geometry.
2. Determine scattering phase functions, $\beta(\theta, \lambda)/b(\lambda)$, for the polystyrene bead microsphere calibration particles by weighting volume scattering functions computed

from Mie theory according to the known size distribution of the polystyrene bead microsphere polydispersion and normalizing to total scattering.

3. By convolving $W(\theta, \theta_c)$ with $\beta(\theta, \lambda)/b(\lambda)$, compute the normalized volume scattering coefficient for each measurement angle, $\beta(\theta, \lambda)/b(\lambda)$, with units of sr^{-1} $\beta(\theta_c)/b$ for 2.00-micron diameter polystyrene bead microspheres.
4. Experimentally obtain raw scattering counts simultaneously with attenuation coefficients (C_p , using an ac-9) for a concentration series of the polystyrene bead microsphere polydispersion. Absorption by the calibration particles is assumed negligible.
5. Obtain b/counts from the slope of a linear regression between C_p (equivalent to b for the beads) and counts.
6. Multiplying the experimental b/counts by the theoretical $\beta(\theta_c)/b$ yields the calibration scaling factor, SF.
7. To obtain $\beta(\theta_c)$, subtract the dark counts from the raw counts measured, then multiply by SF.
8. This test also provides a measure of the inherent opto-electronic noise level of the instrument. A standard deviation from the average number of counts on a 1 minute data file is taken. This is translated into the resolution of $\beta(\theta_c)$ (minimum detectable signal change) in units of $\text{m}^{-1} \text{sr}^{-1}$.

Definitions of Terms

β : phase function	b : total scattering coefficient
θ : angle	θ_c : centriod angle
W : weighting function	λ : wavelength
C_p : particulate attenuation coefficient	SF : Scaling Factor
m^{-1} : per meter	sr^{-1} : per steradian

6.3 Fluorometer Characterization

Gain selection is performed at WET Labs by setting several gain settings in the instrument and running a chlorophyll (or proxy) dilution series to determine the zero voltage offset and to ensure that the dynamic range covers the measurement range of interest. The dilution series also establishes the linearity of the instrument's response. As is the case with other fluorometers, the user must perform a detailed characterization to determine the actual zero point and scale factor for his/her/particular use.

7. Terminal Communications

As an alternative to the ECOView host software, *ECO* sensors can be controlled from a terminal emulator or customer-supplied interface software. This section outlines hardware requirements and low-level interface commands for this type of operation.

7.1 Interface Specifications

- baud rate: 19200
- data bits: 8
- parity: none
- stop bits: 1
- flow control: none

7.2 Command List

Command	Parameters passed	Description
!!!!	none	Stops data collection; allows user to input setup parameters. Note that if the meter is in a sleep state, the power must be turned off for a minute, then powered on while the “!” key is held down for several seconds. If this does not “wake” the meter, refer to the ECOView user’s guide Operation Tip to “wake” a meter in a low power sleep state to enable inputting setup parameters.
\$ave	single number, 1 to 65535	Number of measurements for each reported value
\$clk	24hr format time, hhmmss	Sets the time in the Real Time Clock
\$dat	date, format ddmmyy	Sets the date in the Real Time Clock
\$emc	none	Erases the Atmel memory chip, displays menu when done
\$get	none	Reads data out of Atmel memory chip. Prints "etx" when completed.
\$int	24hr format time, hhmmss	Time interval between packets in a set
\$mnu	none	Prints the menu, including time and date
\$pkt	single number, 0 to 65535	Number of individual measurements in each packet
\$rec	1 (on) or 0 (off)	Enables or disables recording data to Atmel memory chip
\$rls	none	Reloads settings from flash
\$run	none	Executes the current settings
\$set	single number, 0 to 65535	Number of packets in a set
\$sto	none	Stores current settings to internal flash

8. Device and Output Files

Each meter is shipped with a CD containing the meter-specific device file, a sample output file, characterization information, and the applicable user's guides.

The ECOView host program requires a device file to provide engineering unit outputs for any of its measurements. Except for the first line in the device file, all lines of information in the device file that do not conform to one of the descriptor headers will be ignored. Every ECOView device file has three required elements: Plot Header, Column Count Specification, and Column Description.

8.1 Plot Header

The first line in the device file is used as the plot header for the ECOView plots.

8.2 Column Count Specification

The Column Count Specification identifies how many columns of data to expect. It follows the format "Column=n." The Column Count Specification must be present before any of the Column Descriptions are listed.

8.3 Column Description

Every column in the ECO meter's output must have a corresponding Column Description in the device file. The following notation is used in identifying the elements of each Column Description.

x = the column number, starting with 1 as the 1st column
 sc = scale
 dc = dark count: meter output in clean water with optics head taped
 mw = wavelength measured by the sensor
 dw = display wavelength—color to plot the BB data in
 v = measured volts dc

Valid Column Descriptions are listed in the subsections below.

8.3.1 Scattering Measurements

Lambda=x sc dc mw dw Scatter sensor column

8.3.2 Fluorescence Measurements

CHL=x sc dc

8.3.3 Miscellaneous

Date=x DD/MM/YY

Time=x HH:MM:SS

REF=x Reference Counts—Currently not used by ECOView

N/U=x The column is Not Used



There are several defaulted parameters that ECOView uses in the scatter calculations for the BB meters. These parameters are (a) salinity; (b) water type, fresh or sea water; (c) Chi ; and (d) theta, the measurement angle. The user may change these using the following device file elements (the values shown are the defaults).

Salinity=32 32 ppt
Water=SeaMeter is assumed to be in salt water (Use "Pure" for fresh water)
XFactor=1.1 X Factor Correction Value
Theta=117 Back scattering angle

8.4 Sample Device and Output File Formats

Because of the variety of configurations available for this instrument, each meter ships with its instrument-specific device and sample output files on the accompanying CD.

8.4.1 Sample Device File

An instrument-specific device file is shipped with each BB meter and has the following format, where xxx is the serial number of the instrument.

```
ECO BB2F-xxx
Created on: 9/20/04

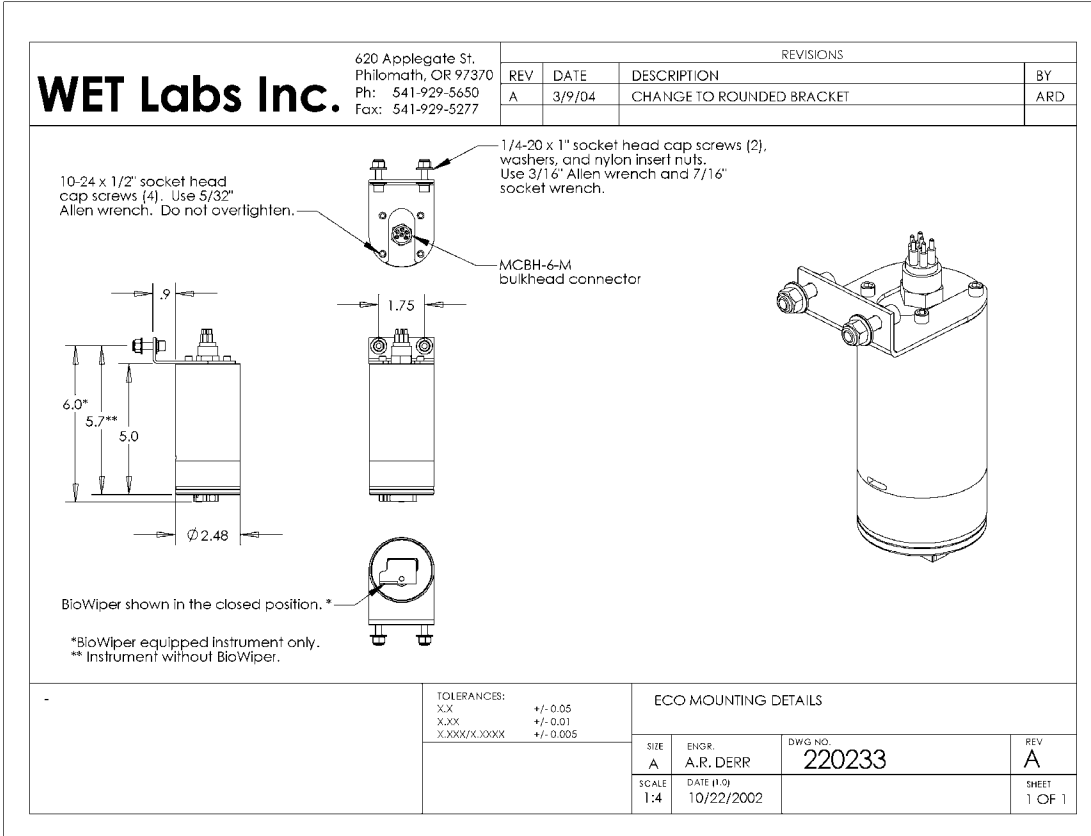
Columns=8
Date=1
Time=2
REF=3
Lambda=4 0.0026 51.0 470 470
REF=5
Lambda=6 0.0011 55.5 650 650
CHL=7 0.0181 48.0
N/U=8
```

8.4.2 Sample Output File

The basic output order is shown below. Note that RT (real time) meters have placeholder values only for date and time columns.

```
Date Time blue ref blue sig red ref red sig chl sig therm
```

Appendix A: Mounting Bracket Drawing



Revision History

Revision	Date	Revision Description	Originator
A	10/15/02	New document (DCR 242)	W. Strubhar, D. Whiteman
B	10/23/02	Add mounting hardware description (DCR 251)	A. Derr
C	2/10/03	Delete lithium battery warning (DCR 272)	D. Whiteman
D	03/03/03	Add Terminal Communications section (DCR 283)	I. Walsh
E	04/14/03	Add stop command to terminal communications (DCR 292)	W. Strubhar
F	5/29/03	Clarify equations in section 5.2.1 (DCR 303)	M. Twardowski
G	8/6/03	Add to deliverables list, correct references in Data Analysis, update device files (DCR 321)	H. Van Zee
H	9/8/03	Add calibration details from calibration sheet to user's guide (DCR 332)	D. Hankins, H. Van Zee, I. Walsh
I	11/24/03	Modify explanation for stop data collection command (DCR 342)	W. Strubhar
J	11/25/03	Update specifications (DCR 338)	I. Walsh
K	2/5/04	Correct salinity value (DCR 365)	I. Walsh, D. Romanko
L	2/17/04	Update column description for device files (DCR 367)	I. Walsh
M	3/10/04	Add new test cable description, operational description, mounting diagram (DCR 381)	A. Derr, D. Whiteman
N	5/11/04	Remove pin 6 from warning in section 1 (DCR 390)	I. Walsh
O	6/29/04	Update specifications (DCR 400)	I. Walsh
P	7/26/04	Correct scattering wavelength (DCR 404)	I. Walsh
Q	9/28/04	Add text for optional thermistor and pressure sensor (DCR 429)	I. Walsh
R	10/14/04	Add references to Lithium batteries for applicable models (DCR 433)	I. Walsh
S	7/26/05	Replace reference to Clean Water Offset with Dark Counts (DCR 468)	M. Johnson
T	12/7/05	Correct output file format, inst. Deliverables, fluorescent stick, Data analysis section (DCR 477)	M. Johnson, H. Van Zee
U	1/13/06	Clarify warranty statement (DCR 481)	A. Gellatly, S. Proctor
V	2/22/06	Clarify organization of optional equipment (DCR 487)	H. Van Zee
W	4/13/06	Add copper faceplate as optional equipment (ECR 219) (DCR 495)	M. Johnson, H. Van Zee
X	5/31/06	Add annual maintenance recommendation (DCR 498)	S. Proctor