WET Labs

Beam Attenuation Meter

BAM

User's Guide

This 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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BAM Warranty

Standard 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.

Annual Servicing Extended Warranty

WET Labs will extend the warranty on this to five years if it is returned annually for servicing. This includes calibration, standard maintenance and cleaning. Charges associated with this annual service work and shipping are the responsibility of the customer.

Shipping Requirements

1. Please retain the original Pelican® shipping case. It meets stringent shipping and insurance requirements, and protects your instrument.
2. Service and repair work cannot be guaranteed unless the instrument is shipped in its original case.
3. Clearly mark the RMA number on the outside of your case and on all packing lists.
4. Return instruments using 3rd day air shipping or better: ***DO NOT*** ship via ground.

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.

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1. Description

The Beam Attenuation Meter (BAM) is a transmissometer specifically designed for Autonomous Underwater Vehicles (AUV's) where size and drag are primary considerations. The BAM utilizes a rigid face plate for optical stability and a recessed sensing volume for low profile applications. The BAM is available in three wavelengths:

Red	(650 nm):	Best for particle dynamics, e.g. mass concentration estimates.
Green	(530 nm):	Best for estimates of in-situ visibility.
Blue	(470 nm):	Best for estimating blue light penetration.

2. Instrument Operation

2.1 Deliverables

The standard BAM delivery package includes the following:

- BAM instrument
- A short pigtail lead with the mating connector to BAM's bulkhead connector
- This manual
- Calibration sheet
- CD with Host software
- **Optional**: test cable

2.2 Meter Setup and Functionality Check

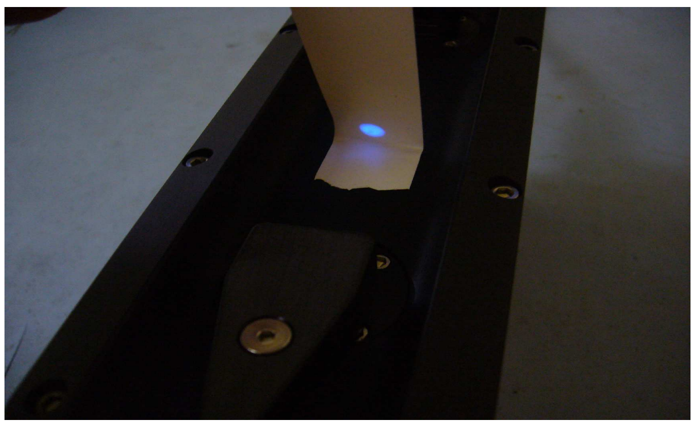
1. Copy the contents of the CD to the host computer.
2. Connect the BAM to the host computer. WET Labs recommends using the optionally available test cable for pre-deployment checkout. Test cables are available with a connector for a 9V battery or spade connectors if you are using a regulated power supply.
3. Open the ECOview software program. The software will prompt you to:
   a) Select the appropriate COM Port on the host PC. Set ECOView's baud rate (19200).
   b) Select the meter's device file. (This is also on the CD.)
   c) Select the Raw Data tab in the software to view incoming data.

4. Supply power to the meter.

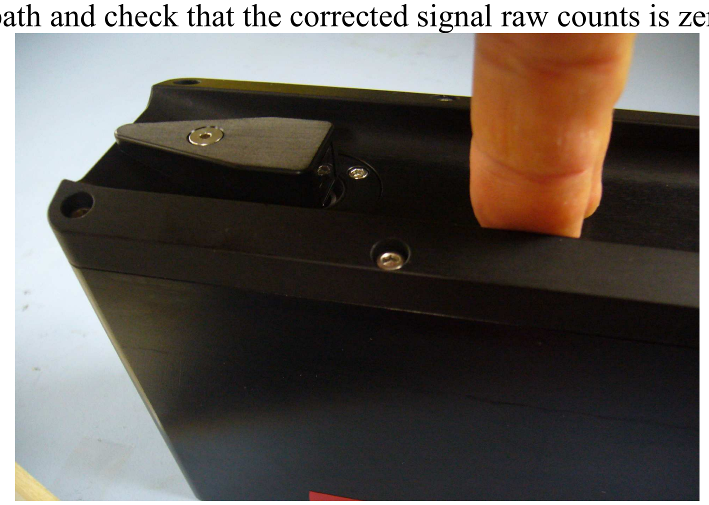
Data should appear in the Raw Data tab. See Section 2.6 for a description of the data output. See Section 2.7 for upkeep and maintenance and Section 2.3 for pre-deployment check out.

2.3 Pre-Deployment Checks

1. Check the light source with a piece of white paper in the light path.



2. Block the light path and check that the corrected signal raw counts is zero.



```
CSTR-0000  12683       0       0      99.999           527
```

3. The signal raw count value and the corrected signal raw count value should both go to zero. The

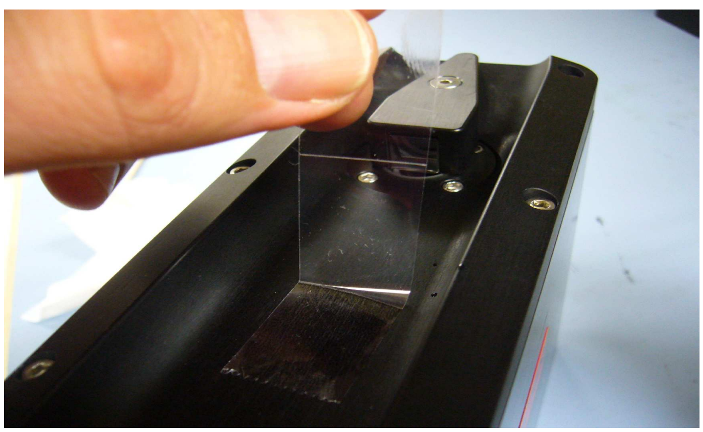
calculated beam c value is not meaningful when the light value is blocked. The instrument outputs 99.999 for the calculated beam c with the signal blocked. Blocked values of a few counts above or below zero are not significant and can be ignored. Blocked values greater that 50 counts are a cause for concern and may indicate an instrument that needs to be serviced. Clean the optics and re-test. If a high blocked value persists, contact the WET Labs support team.

4. With an unobstructed light path check that the corrected signal raw counts approaches the clean air value on the instrument's calibration sheet and/or previous tracking values.

```
CSTR-0000  12681      12977      12966      0.551      527
```

5. Clean air values will only approach or equal the factory air values in very controlled environments. If you are at sea you should expect to get within 500 counts. On shore in a controlled environment you should get within 100 counts. Larger differences between the current air values and the factory air values are a cause for concern and may indicate an instrument that needs to be serviced. Clean the optics and re-test. If a large difference persists, contact WETLabs Support.

6. Check for a "mid- range" value using a material that partially blocks the light, for example a piece of tape.



```
CSTR-0000  12683      10523      10510      2.651      527
```

7. The best practice is to squirt a dilute solution of detergent onto the instrument prior to putting it into the water. This will help keep the optics clean through the surface layer of the water. After each operation or exposure of the instrument to natural water flush the instrument with clean fresh water, paying careful attention to the exposed optical faces. It is very important to make sure that salt water does not dry on the instrument as salt crystals are very persistent and can be difficult to remove. After flushing, a few squirts of a dilute solution of detergent onto the optical faces followed by a final rinse with filtered distilled water will keep the optic surfaces clean.

2.4 Deployment

There are two through holes located at the bottom of the pressure housing. These holes are tapped #10-24 for mounting applications.

The pressure housing contains an internal vacuum applied at the factory. This pressure housing is rated to 1000m.

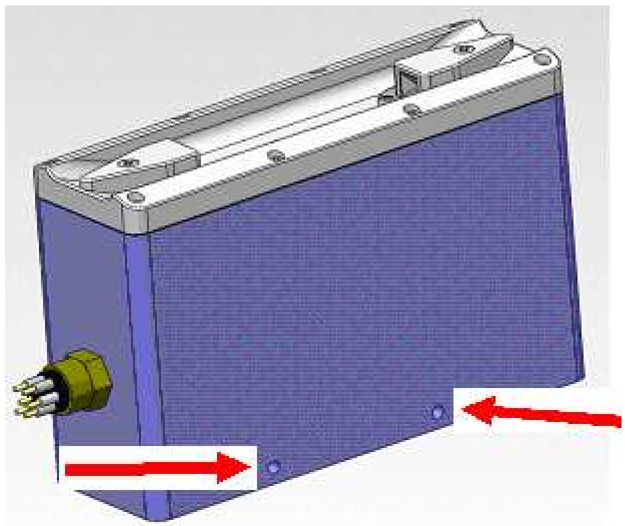


Figure 2: BAM Instrument, arrows indicate mounting holes

2.4.1 Mounting

When mounting BAM on a cage or lowering frame, take care to electrically isolate the instrument from the metal frame and clamps. A thin sheet of rubber or dielectric tape can be used to prevent metal-to-metal contact.

BAM's electronics are not grounded to the case. However, ground potentials between various instruments on a cage or lowering frame may attack the pressure housing, causing corrosion.

2.5 Data Collection

For digital operation, the BAM must be connected to a host system that will receive a RS-232 signal at 19200 baud.

2.6 Data Output

Data is output from the instrument in the following order:

Instrument serial number in the first column

CSTR-0000 11829 13838 13695 0.003 527

Reference raw count value in the second column

CSTR-0000 11829 13838 13695 0.003 527

Signal raw count value in the third column

CSTR-0000 11829 13838 13695 0.003 527

Corrected signal count value in the fourth column
CSTR-0000 11829 13838 13695 0.003 527

Calculated beam c in inverse meters in the fifth column

CSTR-0000 11829 13838 13695 0.003 527

Internal thermistor raw count value in the sixth column

CSTR-0000 11829 13838 13695 0.003 527

2.7 Upkeep and Maintenance

BAM is a compact instrument and its maintenance can be easily overlooked. However, the transmissometer 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 pressure windows. Soapy water will cut any grease or oil accumulation. Be careful not to scratch the pressure windows when cleaning. Use lint-free tissues such as Kimwipes® for wiping the lenses.

This section describes routine processes to check that the instrument is functioning and that the instrument is providing good data. We also describe the routine maintenance required to keep the instrument functioning at its best.

When stored, the instrument should be protected from dust and particularly from stack blow down if on deck. Prior to deployment, the instrument output should be evaluated. During missions, instrument output should be tracked.

The clean air output value for the instrument is provided on the factory calibration sheet. This is provided as the corrected signal counts in clean air: CSC_{air}. We recommend using the CSC_{air} value to:

1. monitor basic operation of the instrument,
2. decide when to clean the instrument,
3. decide when you have a clean instrument.

Tracking the CSC_{air} value over time is the single best way to monitor the performance of the instrument and maximize the utility of the instrument.

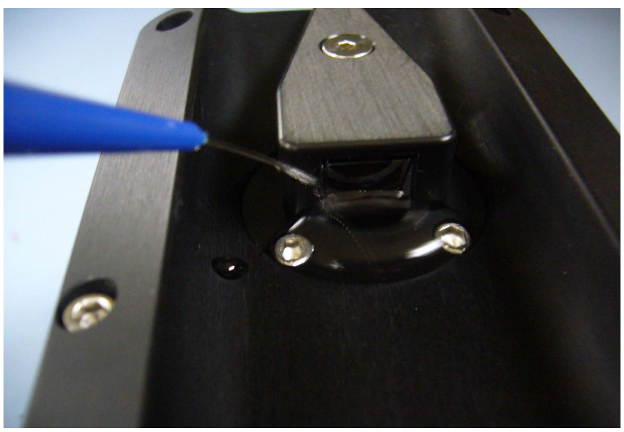
We recommend you assemble a maintenance kit that consists of:

- A 500 ml squirt bottle of a dilute detergent solution. A commercial detergent such as Microclean or Dawn works well. Two drops of detergent in a 500 ml squirt bottle filled with 0.2 or 0.4 µm filtered distilled and deionized water is sufficient.
- A 500 ml squirt bottle of 0.2 or 0.4 µm filtered distilled and deionized water
- Lint-free laboratory wipes
- Cotton or lint-free swabs
- Compressed clean air source
- A notebook for recording maintenance dates and tracking output.

2.7.1 Cleaning the Optics

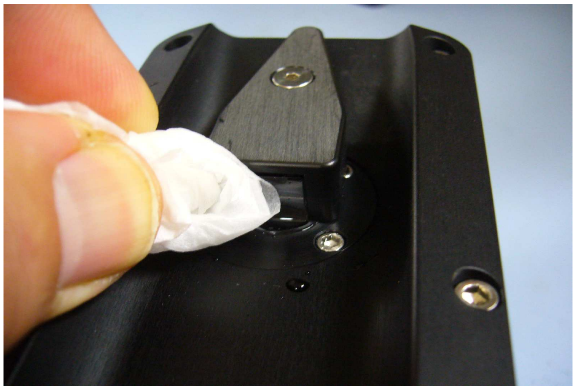
When it becomes necessary to clean the optical windows, remove the two protective caps and follow the steps below.

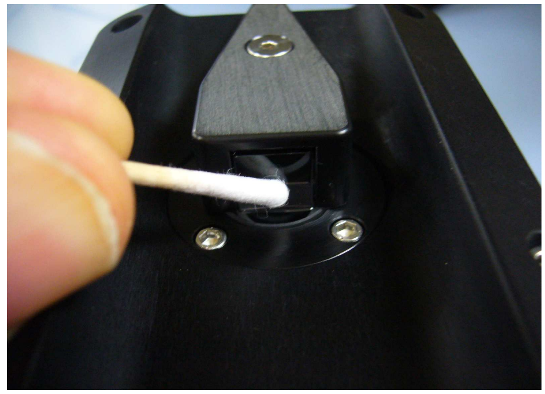
1. For routine cleaning of the optical faces, squirt a small amount of a dilute solution of detergent onto the optical face of the exposed glass cube. We recommend using a commercial detergent such as Microclean or Dawn. Two drops of detergent in a 500 ml squirt bottle filled with 0.2 µm filtered distilled and deionized water is sufficient to break surface tension on the optical face and dislodge particles and minor surface oils. Unfiltered DI water will also work, but may leave some particles on the optical surface. If the instrument is more severely fouled, use a standard detergent solution first and then follow with the dilute solution.



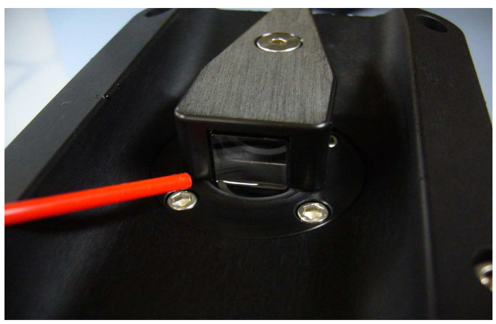
2. Use a “lint-free” laboratory cleaning wipe (e.g. Kimwipe) to gently rub the optical surface to remove particles and fouling films. You can also use a swab. Care must be taken that fibers do

not remain on the optical surface.





3. Use compressed air to dislodge any final particles and dry the optical surface. You should assume you will wet, clean and dry each optical surface a couple of times before you reach a stable clean air value.



2.8 Data Analysis

BAM corrected signal count output values increase linearly with increasing transmittance over the instrument's measurement range. The output is proportional to the amount of light received by the detector. With the instrument in water, the corrected signal counts (CSC) or output voltage should vary from a minimum value equaling the dark value (obtained by a blocked beam reading) to a maximum signal equal to the corrected signal counts or voltage obtained during the clean water calibration (CSCcal). The ratio of the signal output to the calibration output is the transmittance ratio and will vary from 0 to 1, or 0 to 100 percent. Transmittance is related to the beam attenuation coefficient c by the relationship

$$\mathbf{Tr} = e^{-\mathbf{cx}}$$

where x is the pathlength through the water volume. BAM's path length 10cm.

WET Labs has adopted the convention that the measured beam c is relative to the clean water calibration value, and hence does not include the beam attenuation coefficient for pure water at a given wavelength and temperature.

2.8.1 Calibrated Instrument Output

BAM transmittance is expressed as

$$\mathbf{Tr} = (CSC_{sig} - CSC_{dark}) / (CSC_{cal} - CSC_{dark})$$

where:

- CSC_{sig} is the measured output signal
- CSC_{dark} is the dark offset for the instrument (factory-supplied). CSC_{dark} is obtained by blocking the light path.
- CSC_{cal} is the factory-supplied corrected signal counts for clean water.

The beam attenuation coefficient is calculated by:

$$c = - 1/x * \ln (\mathbf{Tr})$$

$$= - 1/x * \ln [(CSC_{sig} - CSC_{dark}) / (CSC_{cal} - CSC_{dark})]$$

The corrected signal count value is derived from the signal raw count value after correction for instrument variance due to temperature. Most of this variance is due to inherent output changes in the LED. The signal is corrected by applying a linear ratio with slope and offset coefficients based on an optical reference measurement. This is accomplished in the instrument firmware as follows:

$$C_{sig} = M_{sig} * (C_{slope} * (M_{ref} / S_{ref}) + C_{offset})$$

C_{sig} is defined as the Corrected Signal

M_{sig} is defined as the Measured Signal

C_{slope} is defined as the Correction fit Slope

C_{offset} is defined as the Correction fit Offset

S_{ref} is defined as the Set baseline Reference value

M_{ref} is defined as the Measured Reference

The correction slope and offset come from the equation of a best linear fit of relative signal to relative reference from a test temperature run. The temperature run is repeated with these coefficients loaded into the instrument to verify its internal correction performs to within the 0.02% full scale per deg C specification.

3. Technical Reference

3.1 Optics

BAM's optical path begins with a LED light source located near the outside of the transmitter housing (Figure 2). The light from the LED (shown as a blue line) is projected on a small aperture and is then collimated. A small portion of the light is split off by the beam splitter to provide reference light to track the LED performance. The rest of the light passes through a clear pressure window and enters the sample volume where it is attenuated by the natural scattering and absorption properties of the water. The remaining light passes through the receiver housing pressure window and, after final focusing, is gathered by the receiver detector.

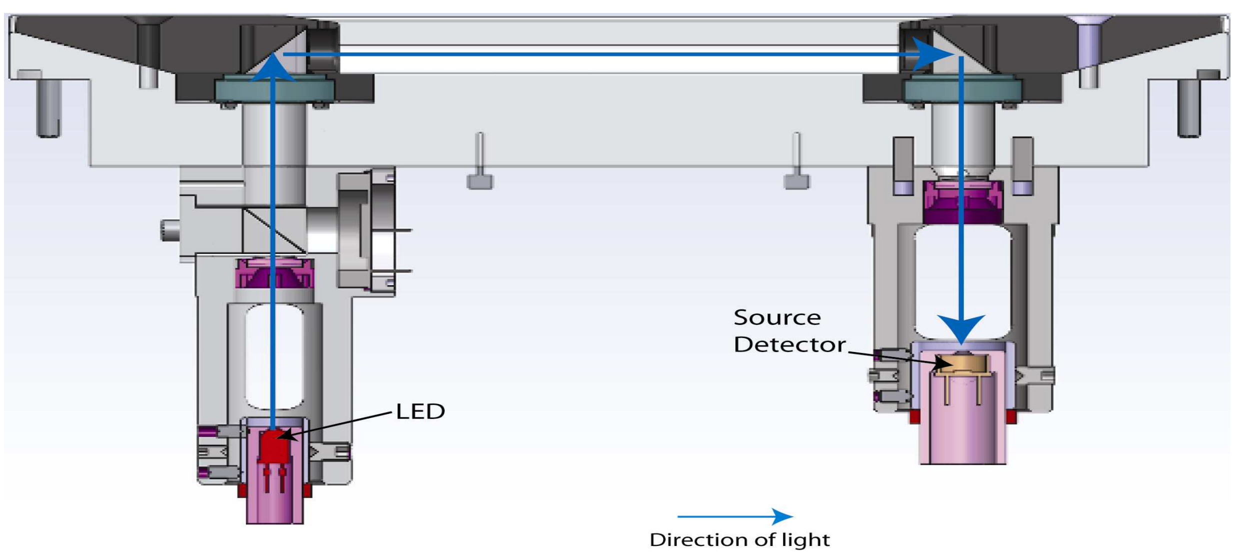


Figure 2. Relationship between transmitter and receiver optics

3.2 Electronics

BAM uses a modulated LED light source rather than an ordinary incandescent lamp. This increases the rejection of ambient light and stabilizes the instrument. The BAM Electrical Block Diagram is shown in Figure 3.

A micro-controller modulates the LED. The LED light output is monitored using a reference detector photodiode. The output of the reference detector is amplified, and fed into the micro-controller's analog to digital converter. The modulated LED light passes through the external sample volume (the flow tube). The resulting modulated light is received by the C detector photodiode. This signal is amplified, and then sent to the micro-controller's analog to digital converter. This information is then used to correct the signal for temperature. The micro-controller outputs a RS-232 signal with the instrument serial number, raw reference counts, uncorrected signal counts, corrected signal counts and an internal thermistor. See section 7.2 for full details on the RS-232 output.

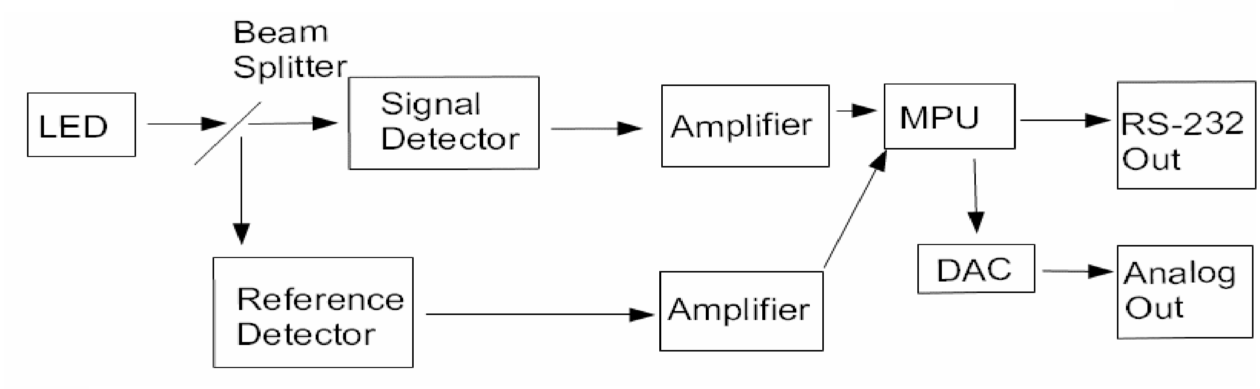


Figure 3. Block diagram of BAM's main electronic components

3.2.1 Pin Description

The BAM uses a six-pin bulkhead connector. The pinout for this connector is shown in the Connectors section below. Note that the pinout is compatible with the WET Labs ECO meters, and the same optional test cable can be used for either instrument.

Input power is applied on the 7–15 VDC power input wire. The power supply current returns through the common ground signal. The input power signal is filtered to prevent external power supply noise from entering into BAM, and also prevent internally generated BAM noise from coupling out on to the external power supply wire.

The output signal is at full scale (See Specification Sheet) when the light beam is clear and the transmittance is 1. The output signal decreases linearly with decreased transmittance. When the light beam is completely blocked and the transmittance is zero, the output signal is 0.

There is only one ground internal to the BAM instrument. The BAM mechanical case is floating, and is not connected to the internal BAM power supply ground.

RS-232 communication is accomplished through instrument transmit pin 5 and instrument receive pin 2.

3.2.2 Power Dissipation

The BAM power supply uses a high efficiency power supply to reduce power dissipation. Current draw should remain steady to within +/-5mA under most conditions.

3.2.3 Input Power Over-voltage Protection

WARNING!

Do not exceed the maximum input voltage specification of 15 volts in a typical application.

3.2.4 Input Voltage Reversal

The BAM power supply is protected from reversed input power and ground conditions caused by errors in system level cables and wiring. A series diode protects the BAM power supply from the reversal of input voltage polarity. As long as the reversed voltage is less than 30 V, the BAM power supply will not be damaged. After the system wiring has been corrected, the BAM power supply will then operate properly.

3.3 Mechanical Components

BAM is housed in a robust pressure vessel made from hard anodized 7075 aluminum (1,000 m depth rating). One of the main advantages of BAM is its compact size.

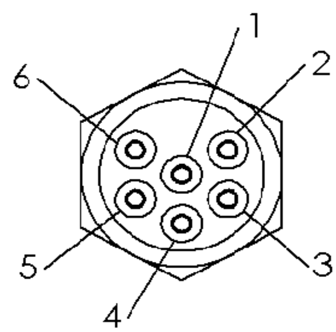
WARNING!

If the pressure housing is opened for any reason, your warranty will be voided. Additionally, the BAM must be re-pressure tested prior to using in the field. We cannot be responsible for leakage that occurs after you open the instrument.

3.4 Connectors

The standard bulkhead connector for BAMs is a 6-pin bulkhead connector.

Pinout summary for MCBH-6-MP BAM connectors

Pin	***Function***	***MCBH-6-MP***
1	Ground	
2	RS-232 RX	
3	Reserved	
4	V+	
5	RS-232 TX	
6	Reserved	

3.5 Serial Port Configuration

Date Rate	Data Type
19200 baud	8 data bits, 1 stop bit, no parity, no flow control

3.5.1 Serial Output Description

The RS-232 output from the digital BAM is a single column of numbers whose values range between 0 and 16380 counts. Note that the RS-232 output is limited to a cable length of 15 feet.

BAM-0000	11829	13838	13695	0.003	527
BAM-0000	11807	13798	13679	0.015	527
BAM-0000	11785	13776	13681	0.013	527
BAM-0000	11772	13761	13681	0.013	527
BAM-0000	11761	13751	13683	0.012	527
BAM-0000	11753	13742	13683	0.012	527

column 1: instrument serial number
column 2: reference raw count value
column 3: signal raw count value
column 4: corrected signal raw count value

column 5: calculated beam C in inverse meters
column 6: internal thermistor raw count value

3.6 Terminal Communications

As an alternative to the ECOView host software, BAM can be controlled from a terminal emulator or customer-supplied interface software. This section outlines low-level interface commands for this type of operation. Serial port configuration requirements are the same as above.

3.6.1 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
$mnu	none	Prints the menu
$pkt	single number, 0 to 65535	Number of individual measurements in each packet
$rls	none	Reloads settings from flash
$run	none	Executes the current settings
$sto	none	Stores current settings to internal flash

4. Theory of Operation

In general, losses of light propagating through water can be attributed to two primary causes: scattering and absorption. By projecting a collimated beam of light through the water and placing a focused receiver at a known distance away, one can quantify these losses. The ratio of light gathered by the BAM's receiver to the amount originating at the source is known as the beam transmittance (Tr). This is the fundamental measurement performed by the BAM. Suspended particles, phytoplankton, bacteria and dissolved organic matter all contribute to the losses sensed by the BAM. They, combined with the intrinsic optical properties of the water itself, govern the radiative transfer properties within the earth's natural waters. Thus, the information provided by the BAM provides both an indication of the total concentrations of matter in the water as well as a value of the water clarity.

The beam attenuation coefficient (c) is an absolute term to represent these losses. For a given wavelength, transmittance is related to the beam attenuation coefficient by the following transfer equation:

$$Tr = e^{-cx}$$

where x is the pathlength (10cm) of the water volume being measured.

5. Calibration

Each BAM is subjected to several tests including a clean water reading and blocked path to provide the calibration values required to obtain good data in the field. These values are listed on the calibration sheet supplied with the instrument.

The clean water calibration is done using water from WET Labs calibration facility. It goes through several stages of de-ionization, UV screening and ultra filtering to remove particles, bacteria and ions. This water is used to obtain the reference value of the instrument provided on the calibration sheet.

The offset value is obtained by blocking the beam with the instrument clean and dry. This value is recorded and provided on the calibration sheet.

An air reading is also obtained with the instrument clean and dry. This value is used as a reference when cleaning the optics and as an aid in tracking instrument drift.

6. Characterization

Prior to shipment, each BAM is characterized to ensure that it meets the instrument's specifications. WET Labs characterization procedure is described below.

6.1 Procedure

There are two main steps in the tuning and testing of the BAM. Calibration is performed before the unit is put in its enclosure. Final Testing is done with the unit completely assembled.

6.1.1 Pure Water Reference

Clean, de-ionized water is used to set the "CSCref" of the BAM. This reference signal is obtained by immersing the BAM in clean water and measuring the average output signal over 30–45 seconds. This signal is provided as the CSCref parameter on the calibration sheet.

6.1.2 Response Time (Time Constant)

The response time for the BAM is limited by the internal averaging for each measurement. This is the “ave” setting displayed in the menu. In general the response will be 2 samples or 2X the sample rate. One sample where the signal is transitioning and 1 sample at the new value. For example, an instrument set to output at 1sample/second will respond full scale in 2 seconds. An instrument set to 16samples/second will respond to a full scale change in signal in 1/8 of a second.

6.1.3 Pressure

To ensure the integrity of the housing and seals, each BAM is subjected to a wet hyperbaric test. The testing chamber applies a water pressure to 20% the specified depth rating.

6.1.4 Mechanical Stability

The BAM is subjected to a mechanical stability test. This involves subjecting the unit to mild vibration and shock. The air, water, and dark voltages must remain the same before and after the mechanical stability test.

6.1.5 Temperature Stability

To verify temperature stability, the instrument is run through a temperature profile. The instrument is brought from room temperature up to approximately 38°C then down to <3°C and back to room temperature. This test is preformed twice, once to obtain temperature correction coefficients and again to verify that the instrument preforms as expected.

6.1.6 Electronic Stability

This value is computed by collecting a sample once every second 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.

6.1.7 Noise

Noise is computed from a standard deviation over 60 samples. These samples are collected at one-second intervals for one minute. A standard deviation is then performed on the 60 samples, and the result is the published noise on the calibration form. The calculated noise must be below 2 counts.

6.1.8 Final Water Blank Test

Clean, de-ionized, pure water is introduced into the sample volume. The output signal is recorded through a terminal program for 30-45 seconds. This test is repeated 3 times, cleaning between each sample.

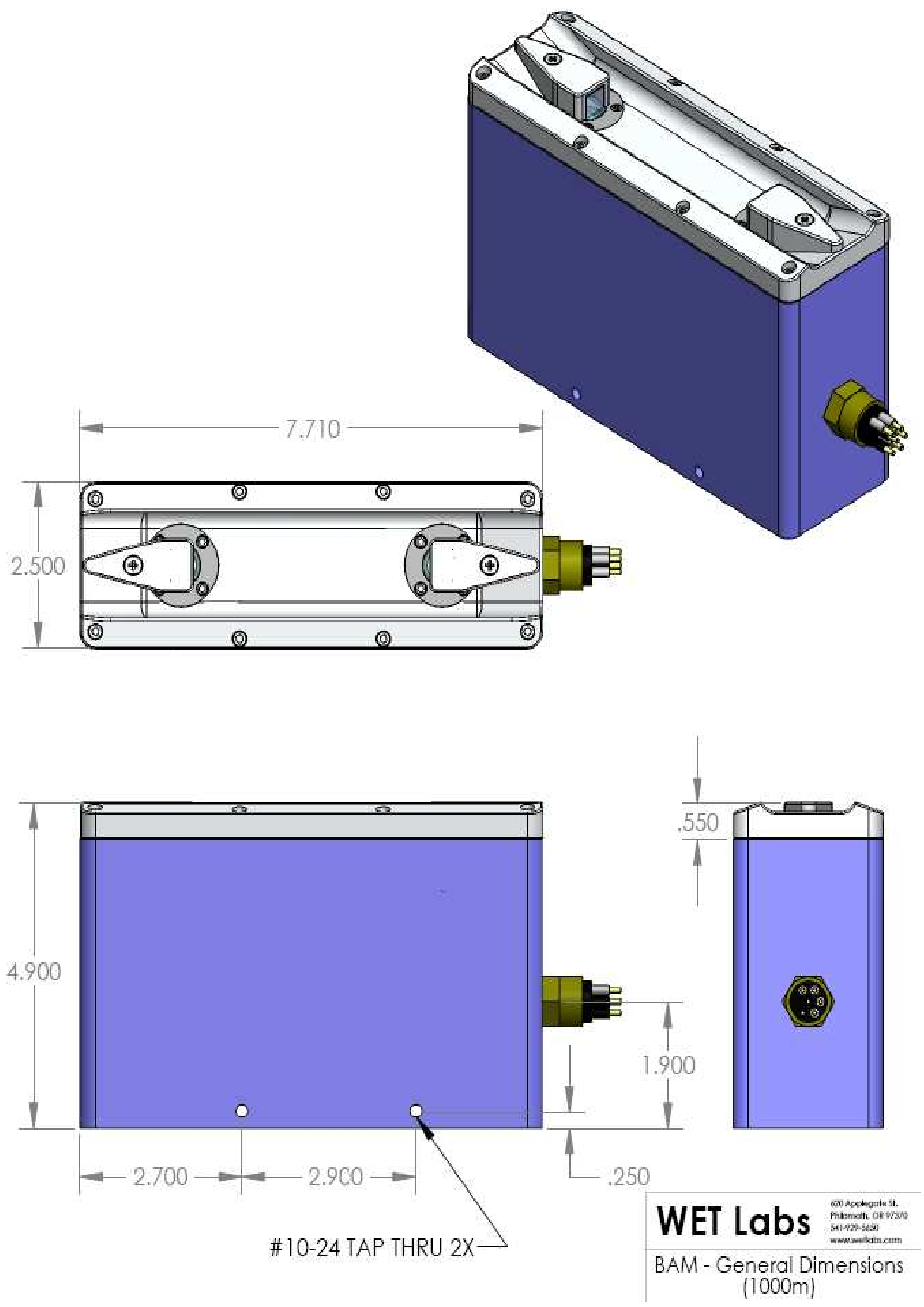
6.1.9 Voltage and Current Range Verification

To verify that the BAM operates over the entire specified voltage range (7–15 V), a voltage-sweep test is performed. The BAM is operated over the entire voltage range, and the current and operation is observed. The current must remain constant at both 7 and 15V.

6.1.10 Linearity

A full scale linearity test is randomly performed on BAMs to confirm linearity. This consists of using a multiple point suspended particle dilution series to characterize the response of the instrument to varying levels of turbidity. The linear regression value must be better than 0.9900.

7. Appendix A: Dimensional Drawing (10cm)



WET Labs

Revision History

Revision	Date	Revision Description	Originator
A	10/27/10	New document (DCR 676)	A. Barnard, J.Koegler, C.Wetzel