



Spectral Absorption and Attenuation Meter

ac-s

User's Guide

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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.



ac-s Warranty

This unit is guaranteed against defects in materials and workmanship for a period of one year after the original date of purchase. WET Labs will supply all replacement parts and labor and pay for return via 3rd day air shipping in honoring this warranty. This warranty is considered void if the factory determines that the unit was subjected to abuse or neglect beyond the normal wear and tear of field deployment, or in the event the pressure cans have been opened by the customer. The customer should call for a Return Manufacturer's Authorization (RMA) before returning the instrument to the factory and is responsible for shipping costs to WET Labs. WET Labs is not responsible for shipping damage done during the return shipment. WET Labs assumes no liability for equipment damage, personal injury or loss of data resulting from use of this instrument, except for that stated in this warranty.



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1. Instrument Setup and Testing

This section provides an introduction to the ac-s and describes how to set up and perform air tracking and bench testing prior to deploying the ac-s.

The ac-s is delivered in a sturdy wooden shipping container with the following components:

- ac-s, with one absorption flow tube and one attenuation flow tube
- four flow sleeves
- four protective black plastic caps
- dummy plug with lock collar
- this manual
- WETView User's Guide
- WETView software and instrument-specific calibration information
- Ten-foot test cable
- double "Y" de-bubbler tubing
- stainless steel intake screens

Familiarize yourself with the ac-s: remove the black plastic flow tubes by grasping the flow tube sleeves and sliding them away from the ends of the flow tube (toward the middle of the flow tube). You only have to slide the collars about ½ in. to unlock the flow tube from its fixed position. The flow tube will lift out, exposing the transmitter and detector windows on the lower and upper flanges respectively. Observe the flow tubes. The attenuation tube is different from the absorption tube. Its flow chamber is plastic and the two sleeves on the tube are identical. This tube installs on the "c" side of the instrument (the side with the identical looking windows). The "c" tube has no "up or down" orientation. The absorption tube is lined with a quartz tube and one of the two sleeves is flat on top (the lip present on all the other sleeves is missing). This tube installs on the "a" side of the instrument, which can be identified by the "a" detector on the upper flange and is the only window, which is clearly different from the other three. The flat flow tube sleeve goes on this detector.

You may want to mark the tubes and their orientation with tape or marking pen before using the instrument at sea so there is no confusion upon reinstalling the tubes after cleaning the optics. Reinstall the flow tubes before bench testing your instrument. If you have removed the plastic caps from the stainless nozzles, replace them at this time.

1.1 Installing WETView

WETView displays data produced by WET Labs ac meters. It runs on PC-compatible computers with at least 16 Mb of memory and 3 Mb free hard disk space running Windows-95 or later operating system.

1. Insert the WETView CD in the host computer.
2. Double-click on the SETUP.EXE icon. Setup will guide you through the rest of the installation process.



When installed, the following files should be on the hard disk: WETVIEW.EXE, WETVIEW.UIR, ACSXXX.DEV, AIRXXYYY.CAL. The .DEV and .CAL files are the calibration files for your particular instrument. They are not installed by setup and will need to be copied to the hard drive manually.

Caution

If you have old device files from previous calibrations, you should rename them or archive them in a different directory so that they will not be overwritten.

1.2 Bench Testing

The following items are needed to bench test the ac-s:

- A clean, solid lab table or work bench
 - The ac-s with 10-foot test cable (or sea cable)
 - A 10–35 volt power supply (the ac-s requires 10–35 VDC)
 - A PC with WETView installed.
1. Connect the test cable to COMM1–COMM4 of the computer. Connect the power leads to the power supply. The black lead is the V+ lead. Before connecting the cable to the instrument, use a multimeter to check the input power.
 2. Connect the ground probe to pin 1 on the pigtail connector (the center pin as you are looking into the connector). Connect the hot probe to pin 4 (Figure 4). You should measure the power supply voltage across these two pins.
 3. Turn the power supply off.
 4. Connect the pigtail to the instrument. Push the connector straight on to avoid damaging the pins. Apply power to the instrument and allow it to begin warming up.
 5. Run WETView. When the interface is displayed, you will need to provide a .DEV file name. Click on the <O> button in the center top of the screen or choose “Open Device File” from the File Menu at the top left of the screen. The program will ask you to choose the proper COMM port. Select COMM1 through COMM4 as appropriate. Note that WETView supports COMM1 through COMM4 only.
 6. Click on the center button or <F1> to start displaying data. After 5–10 seconds, tabular data should be displayed on the right side of the screen. A real time graph will begin to develop, depending on the graph parameters set at the time. Refer to the WETView User’s Guide for details of running the WETView software.
 7. After a short time, again click on the center button that will stop the data collection and ask for a file name to apply to the data if you should want to archive it. Press ESC

if you do not want to save the data. To quit the program, choose QUIT from the File menu. At this point you have successfully completed a bench test of the instrument.

1.3 Air Tracking

WET Labs provides an air calibration (.CAL) file similar to the device (.DEV) file and can be applied in WETView in the same manner. The DEV file provides the clean water offsets so that when measuring clean, fresh water, the instrument's output should be very nearly 0.0 for all channels. The .CAL file provides the offsets that provide 0.0 values when the instrument is clean and dry and measuring air values. This is a useful tracking tool for catching instrument drift, filter aging and improper cleaning.

When you install WETView, the latest air .CAL file should be transferred to your WETVIEW directory. The name of the file takes the form AIRXXYYY.CAL where XX is the calibration number; YYY is the instrument serial number.

When a .DEV file is opened in WETView, it will display *.DEV in the dialog box, which will list all the .DEV files on the default drive. If you change the *.DEV to *.CAL, the available .CAL files will be displayed. Select the latest .CAL file and start collecting data. Make sure the black plastic caps are installed on the flow tube nozzles so no ambient light can enter the flow tubes. If the instrument is clean and dry, the values displayed in WETView should be very close to 0.0 (within 0.005–0.01). If the values are within this range, the instrument is clean and ready to deploy. If the values are outside this range, the first step is to re-clean the instrument and then reapply the .CAL file offsets.

1.4 Cleaning

1. Remove flow tubes and all O-rings. Remove the sleeves from the flow tubes. Wash the windows with a mild detergent diluted with distilled, reverse osmosis-filtered (RO) or de-ionized (DI) water and rinse the flow tubes. Use Kimwipes or other lint-free tissues to wash the windows. Rinse the meter off completely with water to ensure no soap residue is left inside the flow tubes or on the windows.
2. Dry the meter. Place the instrument in a protected area where it can dry completely. Using a small heater to blow warm air over the meter may help speed the process. Using dry nitrogen to blow-dry the meter and remove water from the small grooves around the windows will also help speed the process. It is suggested that the instrument be left overnight to dry out completely. Reassemble the meter. Carefully replace O-rings and slide collars back on to the flow tubes. Replace O-rings around the windows.
3. Clean windows using a Kimwipe or lens paper. Place a couple of drops of methanol or ethanol on the Kimwipe. With firm pressure, gently wipe the windows with methanol. This should remove any visible streaks on the windows. If necessary, follow with a dry wipe in one direction across the window face. Blow off any lint or dust with a dry air source.

4. Clean the flow tubes by putting a few drops of methanol on a Kimwipe and, using a wooden dowel rod, carefully slide the Kimwipe through the flow tube. Repeat this procedure with both flow tubes. Examine each flow tube when you are through to ensure there are no streaks or small pieces of lint left on the inside of the flow tube.
5. Dry the windows. Since small amounts of moisture can affect the air readings, it is important to ensure the meter is completely dry. Using nitrogen to blow dry the windows immediately before replacing the flow tubes works very effectively. This will remove any water or methanol trapped in the small grooves around the window.
6. Replace the flow tubes. Carefully slide the flow tubes into place without sliding dirt across the windows. Slide the sleeves up around the windows and over the O-rings, making certain they are firmly in place and aligned correctly. Use small black caps, or black electrical tape, over each of the nozzles on the flow tube to provide a dark environment and to keep the meter clean and free of moisture while obtaining data.
7. Turn the meter on and allow it to warm up for at least 15 minutes. When the meter is stable you should be able to collect 10 minutes worth of data and the values should not vary more than 0.005 m^{-1} over the 10-minute time period.
8. Collect data. Record a one- to two-minute file and save data. Repeat steps 4–6 until you can collect three data files, cleaning the windows after each file, such that the average values for each channel vary by no more than 0.005 m^{-1} .

The meter is calibrated over a specific range of internal temperatures (refer to your calibration sheet). If the meter's internal temperature is higher than the maximum calibration range, it may be operating out of spec. Setting the meter in a shallow pan of water (immerse most of the lower can) can help keep the instrument cool. This process should be repeated until the air values are within specification. This may take three or more iterations but is very important to be done carefully before taking your instrument to sea. The air calibration procedure should be done again at the end of a cruise or data collection period to track the instrument's performance over time.

Note

The ac-s time averages its dark offsets. If the flow tubes are removed, incoming light corrupts the dark readings. Following flow tube replacement while the meter is still running, either wait three minutes for the dark offsets to stabilize, or cycle the power to the instrument, resetting the dark offsets.

1.5 System Requirements

This section explains the basic system components necessary to operate the ac-s. Note that components will vary depending on whether the ac-s is used for profiling, on a mooring, or underway flow.

Instrument

The ac-s and its flow tube assembly form the basic optical sensor.

Pump

The flow-through system will typically require an ancillary pump to assure proper operation. Pump requirements depend upon desired flow rates, required depth of operation, power availability, and existing hardware.

Cabling

The ac-s requires a minimum of four conductors for power and RS-485 output. (Three conductors for RS-232 output).

Power Supply

The ac-s requires a 10–35 VDC supply, capable of providing a minimum of 10 watts continuous output. Additional wattage will be required to also drive a pump from the same supply. If a longer cable is used, power losses must be accounted for in determining the power supply voltage and power requirements.

Serial Communications

Data from the ac-s is transmitted via both RS-232 and RS-485 depending on which sockets are connected to the instrument's bulkhead connector. Regardless of the mode of transmission you use, you must have a serial interface on your computer or data logger capable of accepting data from the instrument at a rate of 115,200 baud. If you have an instrument with RS-485 output and are using a computer with standard RS-232 communication ports or USB ports, optional protocol converters can be readily obtained.

Host/Data Logger

The ac-s can be interfaced to any computer or data logger capable of supporting a 115,200 baud rate serial interface. If you plan to use our WETView software acquisition package you will need a computer running Windows 95 or newer.

Software

The WETView host software package interfaces directly to the ac-s via your computer serial port. WETView allows real-time graphical visualization of the data in any of several ways such as a function of time, depth, or wavelength. WETView automatically applies calibration constants, temperature corrections and generates a tab-delimited ASCII text file that can be imported into programs such as Excel or MatLab for post-processing or manipulation.

2. Operation

2.1 Basic Power On

1. **Check cable wiring.** Make sure the “+” lead of the test cable is connected to the “+” terminal of your power supply. Make sure the “-” lead of the test cable is connected to the “-” terminal of your power supply. Verify that your power supply is providing between 10 and 35 VDC, and is rated for at least 2 amps.

WARNING!

Power input on this unit is diode-protected from reverse polarity power-up, but this is not 100 percent insurance against damaging the meter, nor will it protect it from over-voltage.

2. **Cable connections.** The surface (dry) end of the cable should have terminations for an RS-232 connection into the computer and leads that connect to a power supply. Attach the power leads to a stable power source that supplies 10–35 VDC to the ac-s. Make sure the polarity is correct before switching on the power supply. Connect the RS-232 connector to the desired serial port of the data collection computer. If your instrument is sending data in the RS-485 format, an RS-485-to-RS-232 or RS-485-to-USB converter is required to allow proper operation. Plug the submerged (wet) end of the cable into the ac-s. Applying a small amount of silicone grease or equivalent to the base of the instrument bulkhead makes the plug insertion easier and provides greater assurance of a good seal. Use a connector lock ring if one is available.
3. **Turn on power supply.** To verify basic operation when not hooked directly to a computer, remove one of the flow tubes and, in a darkened environment, place a white piece of paper into the beam path. You should be able to see the beam image on the piece of paper. You should be able to hear a faint whirring of the filter wheel motor if you place your ear directly against the lower can. If you neither hear the motor nor see the beam, the unit is not working. In this case, check your connections and your power supply. If the instrument still does not run, you may want to seek technical assistance from the factory.
4. **For optimum stability allow the instrument to warm up for 3–5 minutes before collecting data.** While this is not an absolute requirement, the instrument’s electro-optics are subject to an initial stabilization period.

2.2 Mounting and Deploying the Meter

ac-s operation is optimized for a vertical to forty-five degrees off-vertical orientation with the bulkhead connector facing upward ([Figure 1](#)). If your application requires a horizontal mounting, take care to provide proper pump priming and to avoid trapping air

bubbles in the flow tubes. This can be accomplished by taking the system to a depth of 20 meters and allowing the required in-water warm up period to occur at depth. This helps the pump to prime properly and compresses small air bubbles, allowing them to be expelled from the ac-s.

In addition, operating the instrument in the horizontal position could potentially cause small variations in the meter's response due to the different orientation of the filter wheel's rotational plane. Therefore, we recommend that both air and water calibrations be done in the orientation in which the meter will be deployed to obtain the best results.

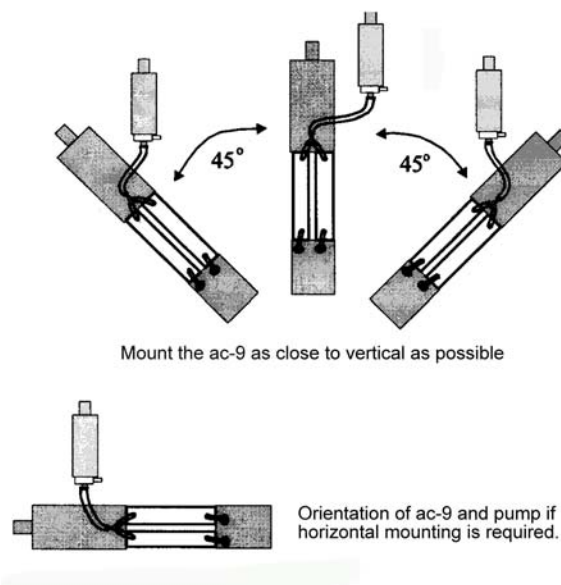


Figure 1. ac-s mounting positions

Specific mounting instructions will depend upon implementation of the sensor. To assure long term instrument integrity and optimum operation, observe the following basic procedures:

1. **Do not make direct contact between the ac-s pressure housing and a metal frame or hose clamp.** The ac-s is available in one of two pressure-housing materials. Aluminum is used for full ocean depth rated units and an acetal copolymer plastic is used for the standard units rated to 500 meters. The aluminum housing is hard anodized with a special plastic impregnation to assure minimum corrosion damage and to provide electrical isolation from the aluminum housing and its surrounding environment. However, metal-to-metal contact with the housing can damage this coating and result in possible corrosion of the pressure case. We recommend a neoprene spacer between the unit and its frame or clamp. At the very least, any contact area should be taped carefully to assure mechanical and electrical isolation.
2. **Do not apply torsional stress to the instrument housing.** The optical path is encased in a rigid housing, but is still subject to distortion if the unit is subjected to undue stress. The instrument has a delicate optical path that is subject to

misalignment if stress is applied unevenly to the upper and lower cans. Make sure the unit is mounted on at least two points and that neither point is a stress point.

3. Make sure you have provided for an unobstructed upward flow through the flow chambers and the pump (Figure 2).

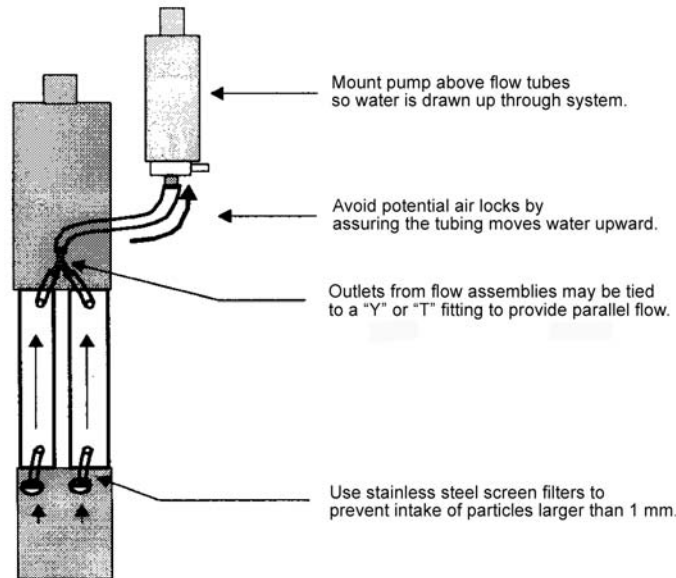


Figure 2. Proper connection of ac-s flow tube

The following suggestions will help you obtain the highest quality data from your ac-s:

- The instrument is extremely sensitive and should be handled carefully.
- A sturdy shipping/transport container should be used to transport your instrument to the field. The instruments are sturdy, but the optics can be jarred out of alignment when subjected to shock.
- The data will be adversely influenced by bubbles, dirt or grease in the flow path or misalignment of the flow tubes. Make sure that the flow tubes, pump tubing and screens are free of dirt and grease. Clean with ethanol or warm soapy water. Rinse with clean tap or distilled water. Do not allow water to dry on the windows as this will leave a residue that may be hard to remove.
- Secure the ac-s to a sturdy cage or lowering frame that will protect the instrument from striking the deck, ship's side, or sea bed. Use a dielectric isolator (rubber sheeting or thick tape) to isolate the instrument's aluminum case from the steel cage.
- When clamping the instrument to the cage, make certain no torsional stresses are applied. Even slight wracking of the instrument can alter the beam alignment. This will severely degrade the data quality, especially on the 'c' side, which requires an extremely tight alignment tolerance.

-
- Once every couple of days, take a data file in air to track any instrument drift. The instrument must be very clean and completely dry to achieve an accurate air calibration measurement. Using compressed dry nitrogen or oil-free dry air to blow the instrument's flow tubes and windows dry will speed the drying process.
 - Upon deployment, the instrument should be lowered to just below the water's surface. Turn on the instrument and pump and check to ensure that the pump has primed and is operating properly. Lower the package to a depth of 10–20 meters. Run the instrument for 3–5 minutes to allow the motor controller to stabilize, the flow tubes to clear and the instrument to begin to equilibrate with the water temperature.
 - After the warm up period, raise the package to just below the surface and begin data collection. The initial depth will be dependent on the natural surface conditions and the amount of bubbles that the ship itself is generating. Steadily lower the cage through the water column.
 - The upcast can proceed immediately after the downcast. It is your choice whether to open a new data file for the upcast or include the down and upcast data in a single file.
 - Once the cage is back to the just below the surface, stop the data collection and turn off the pump. Carefully bring the cage on deck and lash it down. Give the cage and instrument a fresh water wash down after every cast. If this is not practical, wash the instrument at the end of each data collection day. Holding a hose (at low pressure) over the pump discharge port will flush the tubing and the flow tubes. Rinse the flanges and connectors. If leaving the instrument on deck for more than a few minutes, cover the cage with a tarp to avoid over-heating the instrument due to solar insolation. At the end of each data collection day, remove the tubes and carefully clean and dry both the flow tubes and windows. Failure to flush the instrument with fresh water may cause corrosion damage over time.

2.3 Data Collection

WET Labs offers several output configuration options to provide flexible interfacing to different systems. These various output protocols are discussed at length in the Data Processing Section of the manual. Unless supplied with a custom output protocol the instrument powers up in a free run mode. This means that when turned on the unit automatically begins acquiring data and outputting that data in its appropriate format. Typically the instrument comes supplied with RS-485 and RS-232 output operating at 115,200 baud.

RS-485: For longer cable lengths and maximum data integrity, RS-485 protocol is the preferred method of data transfer. Data is transmitted from the instrument in a binary format. To view this data, you must have a program capable of reading binary data. If you are using our WETView software package, the binary read is done automatically. If

you do not plan to use WETView or a WET Labs data logger, consult the Data Processing section of this manual for a detailed description of the binary data format.

RS-232: Operating across an RS-232 cable, you can obtain binary data from the instrument. If you are using WETView, read the operational instructions contained in the software manual.

2.4 Care and Maintenance

Built for field deployment, the ac-s requires minimal maintenance. However, following these simple recommendations will assure optimum data integrity as well as longer instrument life.

After a field deployment of the ac-s you should clean the instrument prior to storage. Refer to Section 1.4 for detailed cleaning procedures. The following steps will help prolong the life of the instrument:

1. **Rinse the pressure housing.** If a dummy plug for the connector is available, install it on the main bulkhead connector before flushing the instrument. Begin with a thorough rinsing of the unit and its flow tubes with fresh water. After rinsing, towel-dry the pressure housing and remove the flow tubes.

WARNING!

Do not use acetone on the windows. It will damage the window holders.

2. **Wash the windows.** The windows should be cleaned with dilute soapy water, followed by ethyl alcohol, and should receive a final rinse with distilled or reverse osmosis-filtered water. This will remove any fingerprint oil, grease or other contaminants from the windows. Use lint free lens cleaning paper to avoid scratching the windows or detectors.
3. **Wash the flow tubes.** To clean the absorption path's reflective tube, carefully plunge an alcohol-soaked tissue through the tube and rinse thoroughly with distilled water. Whenever plunging a tissue through the tube, use a wooden or plastic dowel to prevent scratching the sides of the tube. After rinsing, dry the tube either by blowing dry nitrogen through it or by plunging a soft tissue. The attenuation path flow tube is virtually maintenance free, except for occasional cleaning. Follow the same basic procedures supplied for cleaning the absorption path tube. Remove the flow tube sleeves when drying the flow tubes.
4. **Store the meter.** Store and transport the ac-s in a shock-protected environment. Typically, units are shipped in a sturdy wooden crate. Using the crate will assure that you can safely transport the instrument, providing it is handled in a reasonably careful fashion.

3. Data Processing

Data from the ac-s is acquired and processed through the following steps.

3.1 Analog Acquisition

Optical radiation at the reference and signal channels is continuously monitored by operational amplifiers operating in a current to voltage configuration. The amplifiers are configured for a gain of approximately 10^7 for the reference channels and approximately $2 * 10^6$ for the signal channels.

3.2 Analog-to-Digital Conversion

The A/D used in the ac-s supports six input channels that are triggered pair wise. Four channels are dedicated to the attenuation beam reference and signal channels and the absorption beam reference and signal channels. Another channel is dedicated to the output of the optional pressure sensor amplifier. The sixth channel is preceded by an 8 channel analog mux, and is used to sample ancillary analog signals including the internal and external temperatures via thermistors within the unit. During a single filter wheel rotation, the A/D concurrently samples all 4 signal and reference detectors for both beams. Ancillary signals are sampled during the “dark” periods when the beams are not passing through the filters.

3.3 Digital Processing and Data Output

The CPU takes multiple samples of both signal and reference channels, accumulates them through the sampling period, and then averages the values at the end of the sampling period. Once averaged, light and dark values are collected for each channel. The CPU takes the difference of these values to derive its output value. Once signal data is accumulated over a given filter wheel rotation its output is transmitted through the RS-232/RS-485 port. For a more detailed explanation, see Section 6.4, Signal Processing.

3.4 Data Format

The ac-s outputs data in binary format. If you will not be collecting the data using WETView, your collection system will need to be able to handle binary data. Beware that some serial port terminal programs such as HyperTerminal are not capable of capturing true binary data streams. HyperTerminal, for example, fails to capture ASCII NULL characters (hex 00). WETView is capable of processing collected binary files in addition to serial data. If you prefer to use your own software to process the ac-s output data, please refer to Appendix A for a description of the ac-s data packet formatting.

3.5 Post Processing

Once accumulated by a host computer the data must be post processed to yield meaningful scientific data.

The primary transfer equation for yielding the attenuation coefficient, **c**, or the absorption coefficient, **a**, for a given wavelength is:

$$Tr = e^{-\mathbf{c}x} \quad (1)$$

where Tr is the transmittance, c is the attenuation coefficient, and x is the pathlength of the water volume being measured. The following treatment applies to the absorption case if **c** is replaced by **a**. The pathlength of the ac-s is fixed at 25 cm. In the case of the ac-s the transmittance is computed by taking the ratio of the signal value to the reference value:

$$Tr = (C_{sig}/C_{ref}) / N \quad (2)$$

Substituting equation (2) into equation (1) we get,

$$(C_{sig}/C_{ref}) / N = e^{-\mathbf{c}x}, \quad (3)$$

where Csig and Cref are the signal and reference count values from the instrument and N is an instrument specific calibration constant obtained in the laboratory using clean water. For more information about how N is derived, see Section 4, Calibration and Characterization.

We therefore can solve for **c** (or **a**) by,

$$\mathbf{c} = -1/x [\ln (C_{sig}/C_{ref}) - \ln (N)] \quad (4)$$

$$\text{or } \mathbf{c} = -1/x (\ln(C_{sig}/C_{ref})) - (-1/x (\ln(N))) \quad (5)$$

$$\text{or } \mathbf{c} = [(\ln(N)/x) - (\ln(C_{sig}/C_{ref})/x)] \quad (6)$$

Since the ac-s pathlength is a fixed constant at 25 cm, we only require the determination of (ln(N)/x) in order to accurately measure **c**. This value is derived for each channel and is supplied with each instrument's calibration data sheet as the "Water Offset" value and is referred to as C_{off} in equation (7).

The temperature correction is applied using the temperature from the reference line and the channels correction table from the configuration file. The approximate correction value is linearly interpolated from the table. First, the correct temperature bin is determined by finding the two bin temperatures, T_0 and T_1 , that bracket the current temperature. Then, using the values, Δ_{T_n} and $\Delta_{T_{n+1}}$, from the table, we obtain

$$\Delta_T = \Delta_{T_n} + \frac{(T - T_0)}{(T_1 - T_0)} * (\Delta_{T_{n+1}} - \Delta_{T_n}) \quad (7)$$

where,

Δ_T = compensation constant

T = current temperature

T_0 = first bin temperature

T_1 = second bin temperature

Δ_{T_n} = first value

$\Delta_{T_{n+1}}$ = second value

This temperature correction is automatically applied by our WETView software. If you are manually processing the raw data stream, this correction must be applied to arrive at the temperature-corrected absorption and attenuation coefficients.

3.6 Temperature-dependent Absorption Correction

Absorption of water shows a temperature dependency that is wavelength-dependent. While existent throughout the visible portion of the spectrum, at infrared wavelengths the effect must be taken into account. With regard to the ac-s, the water absorption temperature effect must be considered to correct the absorption and attenuation at wavelengths above 700 nm.

Experimental results show that a_{T^*} , the water-specific absorption correction due to temperature at 715 nm is approximately 0.0035 per m-deg. Various researchers (Pegau, Moore) have derived results ranging from 0.0024 to 0.0035. The corrected 715 nm absorption is then determined using

$$a_{715T} = a_{715m} - [a_{T^*} * (T_m - T_{cal})] \quad (8)$$

where a_{715T} is the water temperature corrected absorption at 715 nm, a_{715m} is the measured absorption at 715 nm, T_m is the water temperature at the time of measurement and T_{cal} is the water temperature at time of calibration. T_{cal} is recorded at the time of calibration and is provided with the instrument calibration sheet.

Work is being done to determine the corrections for other wavelengths above 700 nm.

Note

WETView does not perform this water-based absorption temperature correction.

3.7 Scattering Correction

The absorption meter uses a reflective tube to collect scattered light. Because of the reflective tube and detector design, some of the light scattered at angles wider than 41.7 degrees (with respect to the optical axis) is lost. This results in a scattering error for the absorption meter. This error was empirically determined by measuring apparent **a** and **c** values in the presence of increasing concentrations of a scattering agent (Maalox). The error in all channels was between 18 and 19 percent throughout most of the **a**-meter's dynamic range. The relationship between **a** and **c** remains linear throughout most of a given wavelength channel's dynamic range. (>.998) For very high **c** values ($> 12 \text{ m}^{-1}$) we noticed a slight roll-off in **a**.

The imperfect reflectivity of the reflecting tube and other imperfections cause scattered light errors in the absorption meter. The magnitude of these errors must be corrected to obtain accurate absorption values. There are several alternatives in performing the scattered light correction. The simplest involves subtracting the temperature-corrected a_{715} measurement. Assuming that water is the only species present that absorbs light at 715 nm, and assuming that the scattering error is spectrally independent, we can use this wavelength to provide a base for the scattering error correction. This technique is commonly used in bench-top spectrophotometric measurements. We present one recommended method developed by Dr. Ron Zaneveld at Oregon State University (SPIE 1992) that has thus far proven to be a robust correction mechanism.

For what follows we assume that pure water absorption and attenuation have been subtracted.

For a given wavelength (λ) the absorption tube overestimates the absorption coefficient as it does not measure all of the scattered light. In what follows we will designate the proportion of the total scattering coefficient that the device does not receive by $k_a(\lambda)$.

If the shape of the scattering function does not change much as a function of wavelength, we may assume that $k_a(\lambda)$ is not a function of λ .

4. Calibration and Characterization

The ac-s is a dual path absorption and attenuation meter whose output values are related to a specific reference medium that is clean water. The instrument is calibrated to provide a reading of 0.0 for all channels in clean fresh water. The offset value, determined during our calibration process, is the number which, when added to the raw instrument output in clean water, provides zeroes for all wavelengths with the meter at a specific temperature. This offset value is referred to as N in the preceding sections. This is an important consideration for users who want to compare data from other transmissometers that do not read 0.0 in clean water. Therefore, the final output of the WETView software is the absorption and attenuation with clean water attenuation subtracted.

4.1 Temperature Correction

Beyond confirming basic instrument operation and alignment, temperature corrections are the first tests performed on the meter. Temperature corrections are requisite to all other tests. Corrections are performed using WETView. WETView employs a correction algorithm that uses multiple offset values, ΔT_n values obtained by measuring output differences over small temperature increments. Instrument values are collected and averaged every one half to one degree Celsius through the operational temperature range of the instrument. From these values we generate a table of temperature compensation offsets [ΔT_n]. This table is contained in each instrument's device file. Using the table, WETView then applies the algorithm [$a' = a_{raw} - \Delta T_n$] for given temperatures in the table. For temperatures that fall between table values, the program applies a linear interpolation upon the data for further correction. By using this scheme, we can thus effectively compensate for non-linear changes due to temperature in the instruments' output. For a description of this algorithm please refer to section 3.5, Post Processing.

4.2 Precision

Precision is determined by running the meter for an interval of time (approximately 20 minutes) and determining the standard deviation of the signal at each wavelength for at least 100 samples. We perform this measurement in air. With one-second binning of the signals, nominal performance is approximately 0.010 m^{-1} for wavelengths below 450 nm, and approximately 0.002 m^{-1} for wavelengths 450 and above.

It should be noted that both air value and water value measurements can be difficult to perform. If running the tests in air, you must insure that the flow tubes, windows and o-rings are completely clean and dry. Do not allow any ambient light penetration into the cells. Use a cap or black tape to seal the flow tube nozzle openings.

When operating the instrument in water, use clean water, free of bubbles, and do not exceed flow rates of 1–2 liters per minute.

4.3 Absolute Calibration

Absolute calibration of any underwater optical absorption or attenuation sensor is difficult as there are no absolute standards that can readily be used. The most obvious choice for a calibration medium, pure water, is difficult to obtain, is unstable once it is made, and its absolute optical properties are not well known. Nevertheless, pure water is the baseline for all oceanic property measurements. At WET Labs, we produce our calibration water with a custom de-ionization and filtration system. After de-ionization, the water is processed by a series of filters and held in a 60-liter reservoir that re-circulates through an ultra-violet chamber and additional filters. Water for calibration is drawn through a final 0.01-micron ultrafilter before being used. This system allows the highly reactive de-ionized water to equilibrate, and the ultra-violet chamber prevents any biological contamination from entering the reservoir.

A qualitative but surprisingly accurate test of water purity can readily be obtained using a beaker and a small laser in a darkened room. By shining the laser through the water and viewing slightly off axis to the impinging beam, one can readily detect scatterers in the water. Try this first with some tap water. It will show you what to look for. Be very careful to not look directly into the beam, and **do not** try this test with a high power laser. The pointing lasers used in lectures work very well for this task. If you see more than one or two large scatterers in the beam path, your water is unsuitable for a clean water calibration. WET Labs and researchers from several institutions are presently developing methods for effective field calibration and in-situ calibration techniques. We provide tech notes on these methods as they are developed and validated.

4.4 Linearity and Dynamic Range

To determine linearity of the absorption and attenuation detection systems we first vary scattering agent concentrations and plotted apparent “a” and “c.” Typically linearity in “c” throughout the dynamic range is extremely high with a regression coefficient of 0.9999. Linearity in “a” exceeds 0.998. Although this test doesn’t truly measure “a,” it does give a good indication of response.

4.5 Air Calibration and Tracking

During the factory calibration, clean water values are obtained and used to correct the meter’s output. We then thoroughly dry the meter and record air values. We supply these values with the calibration page shipped with each meter. These air values represent the effective measurement of air for a calibrated instrument. This means that if the instrument user cleans the windows and flow tubes and makes an air measurement and that if the air measurement matches the factory supplied air values, then resulting clean water measurements should provide zero values. Equally important—if the air values taken in the field differ from factory air values, then that difference may be applied as a correction factor to the original water calibration values contained in the DEV file:

$$\mathbf{a}'_{\text{clean}} = \mathbf{a}_{\text{clean}} + (\mathbf{a}'_{\text{air}} - \mathbf{a}_{\text{air}}) \quad (1)$$

where:

$\mathbf{a}_{\text{clean}}$ is the clean water offset value supplied with the ac meter

$\mathbf{a}'_{\text{clean}}$ is the corrected clean water offset

\mathbf{a}_{air} is the factory supplied air value

\mathbf{a}'_{air} is the field obtained air values

Alternatively, the offset air value difference can be applied directly to the data as a post-processing step. Obtaining air values in the field is a much more straightforward process than obtaining clean water values. This is a powerful technique that can track and compensate for instrument drift and filter aging. Care must be taken when implementing this technique since a drop of water or smudge on the windows will result in a reading quite different from the factory air values. This difference might be interpreted as instrument drift. By iterating this process several times (re-cleaning the instrument and obtaining a new set of air values), you will gain experience in differentiating true instrument drift from smudged optics.

Caution

Back up the factory DEV file before making any modifications to it.

Effective air calibration requires:

1. The instrument's optical path is clean and dry.
2. The instrument's optical path is completely shielded from ambient light.

To perform air tracking we recommend the following basic procedures.

1. Remove flow tubes and clean and dry completely. Remove the sleeves from the flow tubes to assure there is no trapped moisture. Allow the flow tubes to sit in a dry environment with good air flow.
2. Clean and completely dry the optical windows of the instrument. If the optics have not been cleaned for some time, clean with a mild solution of detergent and distilled water, rinse, and wipe dry. Follow with a single wipe across each window with an ethanol-soaked lens tissue (or other low water content alcohol-type solvent) and then a single wipe with a dry tissue. If the windows are already fairly clean, simply use the ethanol wipe procedure. You may wish to apply a stream of pressurized air or nitrogen around the windows to force moisture from the window mount.

WARNING

Beware of using standard air compressor air. It can blow oil all over the optics.

3. Allow the unit to sit open for an hour or two to assure that it dries.
4. Reassemble and insert flow tubes.
5. Turn on meter and allow it to warm up about 5 minutes.
6. Block ambient light from the flow tube entrances and obtain values using WET View or your own custom program. Record and save about 5 minutes worth of data. Examine your data in a spreadsheet. At one second binning (2 samples) the data should maintain a standard deviation of 0.002 m^{-1} or less above 450 nm. If you have a substantial slope to the data over the acquisition period your meter may have some residual moisture in the flow tubes or on the windows. If the optical path isn't getting dry, use a small flow of dry nitrogen through the tubes while sampling.
7. Remove flow tube and re-clean the windows. The single wipe technique with ethanol will work fine at this point.
8. Repeat steps 4–6 until mean values stabilize over three cycles. Use these values as air calibration values.

5. Specifications

Physical Parameters

Size	31 x 4.1 in diameter (79 x 10.4 cm diameter)
Weight	
(in air)	13 lbs (5.9 kg) acetal copolymer
(in water)	2.5 lbs (1.1 kg) acetal copolymer
Rated depth	500 m

Electrical Parameters

Input	10–35 VDC
Power requirement	10 watts (excluding pump power requirement)
Temperature range	0–30 deg C
Serial output	RS-232 and RS-485

Optical Parameters

Spectral range	400–730 nm
Resolution	4 nm
Pathlength	25 cm (10 cm available)
FWHM	15 nm typ.
Output Wavelengths	80–90

Measurement Parameters

Precision	
(450–750nm)	+/-0.001 m ⁻¹ typ., 0.003 max @ 4 Hz
	+/-0.0005 m ⁻¹ typ., 0.0015 max @ 1 Hz
(400–449 nm)	+/-0.05 m ⁻¹ typ., 0.0012 max @ 4 Hz
	+/-0.003 m ⁻¹ typ., 0.006 max @ 1 Hz
Accuracy	+/- 0.01 m ⁻¹
Dynamic range	0.001–10 m ⁻¹
Sample rate	4 scans/sec

5.1 Connectors

The ac-s has two bulkhead connectors mounted on the top flange. The power and data connector has six pins and connects to the sea or test cable. It provides input power to the instrument and data output in RS-232 and RS-485 formats. A second connector with three sockets provides power to the pump (Figure 3). Pin or socket numbers are molded into the rubber bodies of the plugs (Figures 4 and 5).

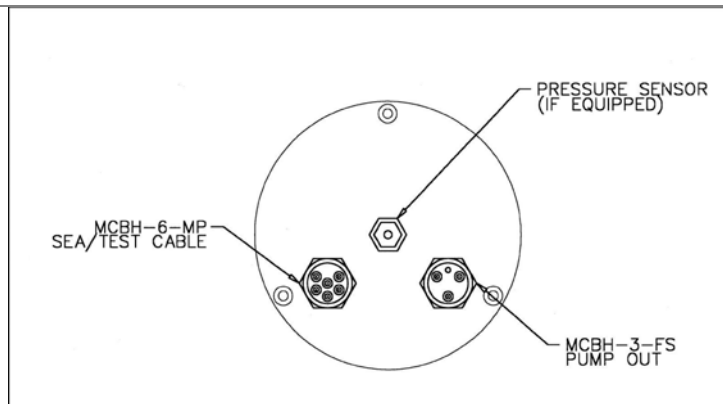


Figure 3. Top Flange Connectors

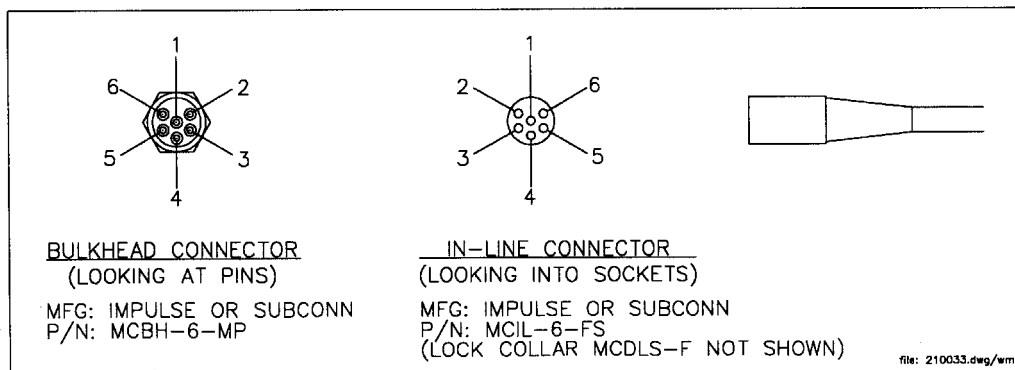


Figure 4. Sea/Test Cable Connector Pin and Socket Arrangements

Sea/Test Cable Connector Pin or Socket Function	
1	Common
2	RS-232 Receive
3	RS-485 +
4	Voltage in +10 to +35 VDC
5	RS-232 Send to Host
6	RS 485 -

Voltage supplied to the instrument is internally jumpered to provide power output to the pump port connector. Power is applied to the pump connector whenever the meter is powered.

WARNING

If the meter is deployed without a plug in the pump connector socket, the socket contacts will suffer rapid corrosion. Eventually, the corrosion could travel through the connector, causing the meter to flood.

Always put a pump plug or dummy plug in this socket!

Pin and socket assignments for the pump power connector are shown below.

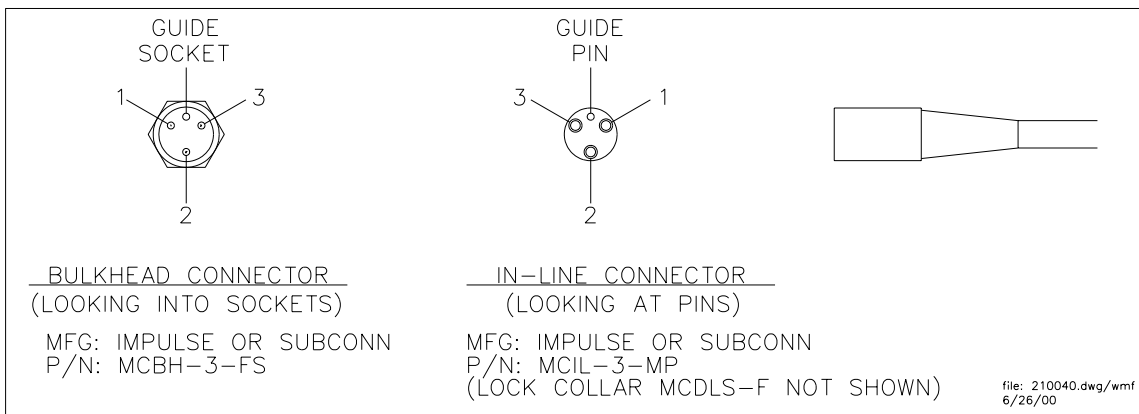


Figure 5. Pump Cable Connector Pin and Socket Assignments

Pump Power Cable Connector Pin or Socket Function	
1	Common
2	Power Output (10–35 VDC)
3	N/C

5.2 Power Requirements

Voltage input:	10–35 VDC
Power requirements:	(may differ by +/- 10 percent)
Lamp 1	2.5 watts
Lamp 2	2.5 watts
CPU board	0.3 watts
A/D board	0.5 watts
Motor and controller	0.6 watts
Other electronics	0.5 watts
<u>DC/DC converters</u>	<u>2.1 watts</u>
TOTAL	9.0 Watts

6. Technical Reference

Figure 10 shows a diagram of the ac-s. The unit consists of two pressure housings separated by an aluminum “unistrut” frame. The “bottom” pressure cylinder houses the light sources, filter wheel, motor controller and transmitter optics. The “top” can houses the receiver optics and the control and acquisition electronics for the unit. The absorption and attenuation beam paths and flow tube assemblies are between the receiver and transmitter housings. Power and communications in and out of the unit are provided via the 6-pin bulkhead connector at the end of the receiver housing.

6.1 Mechanical

The ac-s is housed in two robust pressure housings made from acetal copolymer, separated by an anodized aluminum unistrut frame.

The flow tube assemblies are integral to the optical behavior of the ac-s. They are optical components that help produce a very precise measurement, and thus they need to be dealt with accordingly. Before using, inspect both tubes and make sure they are free of stains and dust. The reflective flow tube for the absorption measurement operates using the principle of internal reflection. To maintain its reflective properties, it requires a thin air gap between the outer wall of the quartz tube and the inner wall of the surrounding sleeve. The reflective tube should be periodically checked for leaks. To determine if the tube is maintaining its reflective properties, immerse it in water and point towards a fairly light background. The inside of the tube should appear uniformly bright. If the tube has leaked, call the factory for repair instructions or tube replacement.

6.2 Optics

The ac-s performs concurrent measurements of the water’s attenuation and absorption characteristics by incorporating a dual path optical configuration in a single instrument. Each path contains its own source, optics, and detectors appropriate to the given measurement. The two paths share a common filter wheel, control and acquisition electronics. For purposes of description, we refer to the beam performing the attenuation measurement as the **c beam** (Figure 7) and the beam used to make the absorption measurement as the **a beam** (Figure 8).

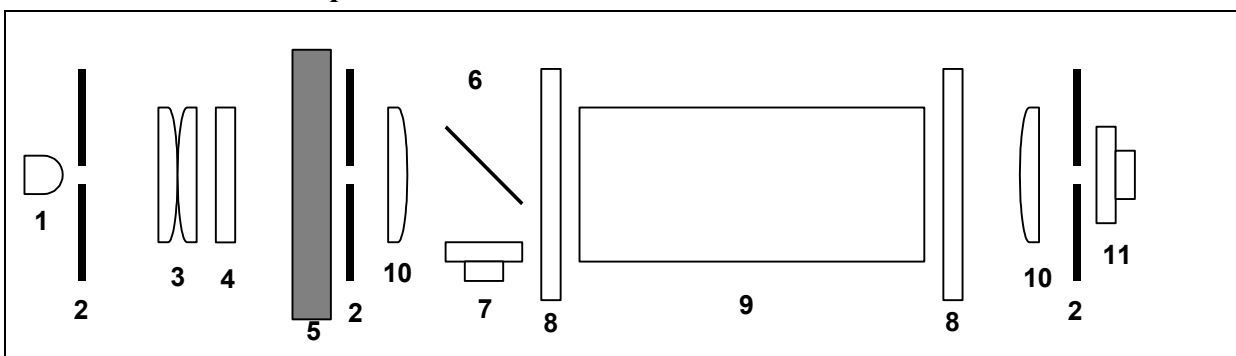
6.2.1 Filter Wheel

The filter wheel holds two sections of a Linear Variable Filter (LVF), centered 180 degrees from each other on the filter wheel (see Figure 6). The two filter sections are cut from a single LVF such that a portion of the spectrum around 550 nm is covered by both filters. This overlap is to allow for merging of the data from both filter sections. Each filter covers approximately a 72 degree section of the beam path across the filter wheel. The filter wheel rotates at a tightly controlled 8.0 rps, such that the shorter wavelength of each filter section is traversed before the longer wavelength. As shown in Figure 6.



Figure 6. ac-s filter wheel

6.2.2 c Beam Optics



- | | |
|-----------------|-------------------------------|
| 1 Lamp | 7 Reference detector |
| 2 1 mm aperture | 8 6 mm quartz pressure window |
| 3 Lenses | 9 Flow tube |
| 4 IR Filter | 10 Singlet lens |
| 5 Filter wheel | 11 Signal detector |
| 6 Beam splitter | |

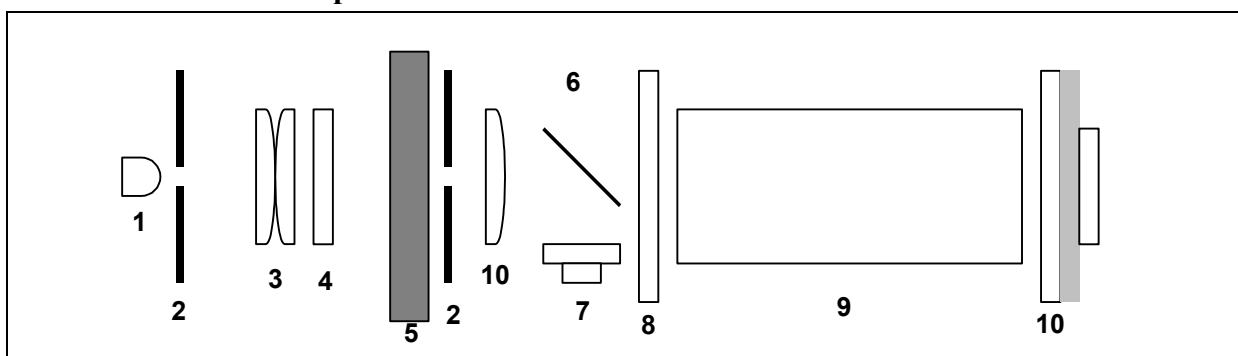
Figure 7. Schematic Representation of **c beam** optics

Light from a DC incandescent source passes through a 1 mm aperture. The light is then focused through a filter section, onto a 1 mm aperture, creating a narrow band spectral output. The light then passes through a collimating lens and then through a beam splitter, creating a primary beam and a reflected beam. The reflected beam intensity is measured by a reference detector. Using a ratiometric scheme with the reference and signal detectors, we compensate for long-term lamp drift. The primary beam then passes through a pressure window into the sample water volume. The scattered light that hits the blackened surface of the flow tube is absorbed and therefore does not contribute to the measurement of transmitted intensity. Light radiated through the flow path is therefore subject to both scattering and absorptive losses by the water.

A black flow tube encloses the c beam water path. Scattered light that hits the blackened surface of the flow tube is absorbed and therefore does not contribute to the measurement of transmitted intensity. Light radiated through the flow path is therefore subject to both scattering and absorptive losses by the water.

Once through the water path, the light passes through another pressure window and then is re-focused through a lens upon a receiver detector. A 1 mm aperture is placed directly in front of the detector, creating a 0.75-degree acceptance angle in water.

6.2.3 a Beam Optics



- | | |
|-----------------------|-------------------------------|
| 1 Lamp | 6 Beam splitter |
| 2 1 mm aperture | 7 Reference detector |
| 3 6 mm aperture | 8 6 mm quartz pressure window |
| 4 38 mm singlet lens | 9 Reflective flow tube |
| 5 Interference filter | 10 Diffuser/Signal detector |

Figure 8. Schematic Representation of a beam optics

The a-beam and c-beam optics are similar. The a-beam light is 45 degrees out of phase from that of the c beam. Beam splitter optics and aperturing of the beam are identical with the c beam source optics.

The a beam sample water volume is enclosed by a reflective flow tube. Light passing through the tube is both absorbed by the water itself and by various pigments contained in particulate matter within the sample volume. Forward scattered light is reflected back into the water volume by the reflective tube. The light is then collected by a diffused large area detector at the far end of the flow tube.

The flow tube uses the internal reflection principle in reflecting light back into the water volume. A clear quartz tube is employed. The outer perimeter of the tube is enclosed by a thin annular volume of air. Using the Fresnel Equation, one can see that with an index of refraction of 1.33 in water and index of refraction of 1 in air, the total internal reflection is achieved to 41.7 degrees with respect to the optical axis.

6.3 Electronics

The main electronic components of the ac-s consist of a power and i/o (input/output) board, a microprocessor board, an A/D board, an amplifier board, a motor controller board, a dc motor with an integrated position encoder, two incandescent lamps and four photodiode detectors.

6.4 Signal Processing

The purpose of the ac-s signal processing circuitry is to take a raw optical signal and make it into a physically meaningful measurement ready for output. Signals from the absorption path and attenuation path detectors go through several levels of analog and digital processing before they are registered as output from the unit. To understand the exact nature of the ac-s signal processing, it is first necessary to better understand the primary data sampling. Figure 9 is a timing representation of the ac-s detector signals through a single filter wheel rotation. It shows how each of the two filter sections are brought in line with the optical path once per revolution.

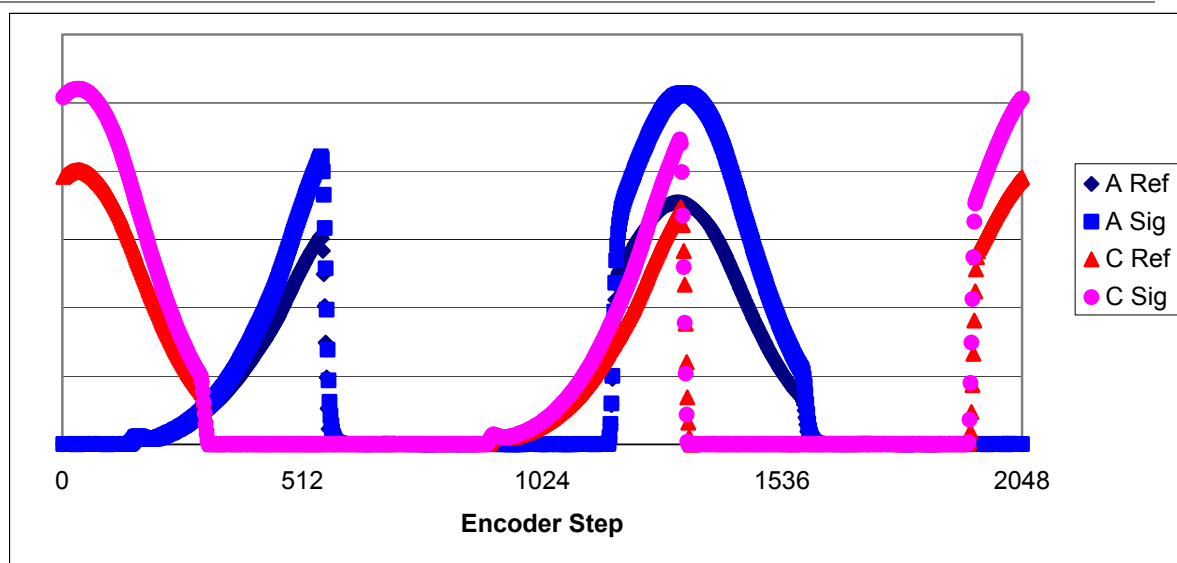


Figure 9. Signal timing for one filter wheel revolution

Each trace represents the optical signal from a detector as the filter wheel spins through its cycle in relation to the motor encoder position (1 to 2048). During the filter wheel rotation, the signals output from each detector are continuously monitored and amplified through analog current-to-voltage amplifier circuitry. The current-to-voltage amplifier serves as the primary gain stage for each signal. Typical gains for the channels are set at 2M for the signal detectors and 10M for the reference detectors. After the primary gain stage, the signal is passed through three more analog stages for level shifting, voltage inversion(except the A signal), and buffering. At this point, the signal is ready for digitization.

The CPU monitors the motor encoder output to determine when the start of the “blue” filter section is about to pass through the attenuation beam path (encoder step 900 in Figure 9). At that point, the CPU starts concurrent sampling of all four signal channels. Throughout the first sample window (encoder steps 900-1640 in Figure 9), the CPU collects 60 A/D samples at 140 ksamples/sec for each channel. The CPU then waits for the next encoder edge before collecting the next burst of 60 samples. This resynchronization is necessary to reduce the effects of rotational jitter on the sampled data. The sampling continues until slightly past the point where the absorption beam has finished traversing the filter section (encoder step 1640, above). The CPU then waits for the approach of the “red” filter section, and repeats the sampling process again. Due to the positioning of the beams and the filters, timing-wise, the c-beam intersects one filter section for about 1/8 revolution before the a-beam intersects the other filter. This staggering of the filters relative to the beams is the reason for the phase differences between the a and c signal traces seen in Figure 9.

Once the signals have been sampled through one full revolution of the filter wheel, the CPU averages the bursts of 60 A/D samples to a single mean value for each burst. From within the sample buffers, dark reference values are also obtained and averaged

for each signal. The dark values are then also time averaged with previous dark values to further reduce noise in the dark measurement. Once averaged, the dark values are then subtracted from the raw light values in order to create a given datum point:

$$\begin{aligned}C_{sig} &= C_{sig_{light}} - C_{sig_{dark}} \\C_{ref} &= C_{ref_{light}} - C_{ref_{dark}} \\A_{sig} &= A_{sig_{light}} - A_{sig_{dark}} \\A_{ref} &= A_{ref_{light}} - A_{ref_{dark}}\end{aligned}$$

The CPU collects and buffers one revolution of raw signal data and then outputs 86 signal and reference values for both the attenuation and absorption channels in wavelength order starting at approx 400 nm, along with internal and external temperature, and rotational and timing data. Please bear in mind that although the data is all output at once, the sampling occurs sequentially, such that the first c-beam output wavelength is sampled one half revolution (6.25 ms) before the 44th output wavelength. From one output wavelength to the next, the time delay is approximately 488 us. Also keep in mind that the a-beam data has the same time delay between output spectrum halves, with the additional condition that the “red” filter is sampled prior to the “blue” filter. That means that the 44th output point was actually sampled 6.25 ms before the first output point. Due to the amount of time required to send the data, and requirements on the CPU during sampling, the next data sample is not captured until a full even number of revolutions have passed following completion of the data averaging and output. Currently this is every 4 revolutions, or twice per second.

Appendix A: Data Record Format

The ac-s outputs its data as binary records. If you use a terminal emulator program to connect to the ac-s, the incoming data will appear as seemingly random characters. Table 4 shows a sample hexadecimal snapshot of binary data collected from an ac-s. The leftmost column and header rows in are for reference only, and do not appear in the output data. Table 5 shows the breakout of each field within the data record. Note: You should ensure that your data collection program is capable of reading a binary bit stream.

Table 1. Sample ac-s Data Record

row offset	0	1	2	3	4	5	6	7	8	9	a	b	c	d	e	f
000:	53	d0	03	01	53	00	00	02	4e	1e	01	ba	21	29	35	ff
010:	00	ff	00	02	d0	04	01	53	00	00	02	4e	1a	01	ba	02
020:	a1	7a	e4	b9	d7	01	d5	02	b0	00	07	1b	02	01	56	04
030:	05	03	63	04	f4	03	10	04	98	03	da	05	ab	03	ac	05
040:	3b	04	69	06	7c	04	77	05	f5	04	fe	07	67	05	52	06
050:	c6	05	ae	08	69	06	4a	07	9f	06	66	09	88	07	3a	08
060:	96	07	33	0a	c9	08	47	09	ab	08	1b	0c	32	09	6a	0a
070:	dc	09	0e	0d	c7	0a	a8	0c	2f	0a	2f	0f	84	0c	0f	0d
080:	9a	0b	5c	11	63	0d	9a	0f	23	0c	9d	13	69	0f	3a	10
090:	c5	0d	f8	15	8d	11	01	12	70	0f	5b	17	c9	12	d8	14
0a0:	32	10	ce	1a	25	14	d2	16	17	12	61	1c	b5	16	e8	18
0b0:	20	14	08	1f	85	19	2b	1a	5b	15	e7	22	8e	1b	ad	1c
0c0:	be	17	d8	25	c7	1e	5d	1f	3d	19	ef	29	33	21	3b	21
0d0:	e4	1c	17	2c	d5	24	48	24	b4	1e	6f	30	ad	27	7f	27
0e0:	9f	20	de	34	b9	2a	f7	2a	b6	23	65	38	f3	2e	8e	2d
0f0:	e7	26	0b	3d	4e	32	5d	31	29	28	c6	41	d1	36	49	34
100:	84	2b	82	46	63	3a	4f	37	d9	2e	49	4a	f4	3e	6a	3b
110:	3b	31	17	4f	b2	42	96	3e	bc	34	09	54	a0	46	f8	42
120:	6a	37	22	59	d2	4b	90	46	4e	3a	6c	5f	5a	50	7d	4a
130:	75	3d	ea	65	44	55	ba	4e	f0	41	b3	6b	9a	5b	67	53
140:	a2	45	b5	72	35	61	6f	58	73	49	be	78	df	67	9b	5d
150:	41	4d	cb	7f	79	6d	d1	61	e2	51	ab	85	d7	73	ed	66
160:	64	55	77	8c	10	79	f4	6a	be	59	19	92	12	7f	cd	6e
170:	ef	5c	a0	97	d4	85	7d	72	eb	60	01	9d	63	8b	00	76
180:	c2	63	41	a2	bd	90	5e	7a	22	67	e0	a7	92	98	2f	7d
190:	b7	6a	c6	ac	8c	9d	1a	81	13	6d	75	b1	37	a1	cc	84
1a0:	35	70	05	b5	aa	a6	4f	87	25	72	54	b9	bf	aa	85	89
1b0:	cd	74	63	bd	75	ae	5d	8c	20	76	2b	c0	b9	b1	d0	8e
1c0:	1e	77	95	c3	6e	b4	ce	8f	aa	78	9c	c5	93	b7	3c	90
1d0:	c0	79	3e	c7	05	b9	11	91	5e	79	8e	c7	e6	ba	63	91
1e0:	9c	79	82	c8	2d	bb	23	91	5d	79	13	c7	d9	bb	56	90
1f0:	b5	78	5b	c7	00	bb	07	8f	ac	77	2f	c5	83	ba	1e	8e
200:	28	75	c6	c3	76	b8	ab	8c	52	74	0d	c0	f8	b6	c8	8a
210:	1e	72	00	bd	e6	b4	5c	87	8e	6f	ad	ba	60	b1	6e	84
220:	a9	6d	0a	b6	5c	ad	f9	81	58	6a	07	b1	b7	a9	ee	7d
230:	9c	66	a8	ac	6e	a5	37	79	72	62	eb	a6	8b	9f	e9	74

row offset	0	1	2	3	4	5	6	7	8	9	a	b	c	d	e	f
240:	e3	5e	ec	a0	25	9a	16	70	00	5a	c2	99	56	93	db	6a
250:	ef	56	69	92	46	8d	4f	65	ba	52	0f	8b	15	86	9e	60
260:	82	4d	b2	83	db	7f	d9	5b	53	49	5e	7c	b2	79	16	56
270:	25	45	14	75	86	72	54	51	06	40	e1	6e	75	6b	b1	4c
280:	13	3c	d0	67	9d	65	3a	47	3a	38	d5	60	f1	5e	de	42
290:	89	35	02	5a	82	58	b8	3e	05	31	52	54	47	52	bf	39
2a0:	9c	2d	be	4e	3c	4c	fc	35	79	2a	70	48	9a	47	85	31
2b0:	8c	27	36	43	35	42	52	2d	c8	24	33	3e	15	3d	5c	2a
2c0:	3b	21	5a	39	39	38	a5	26	da	1e	9d	34	98	34	30	23
2d0:	b3	1c	1c	30	50	30	03	20	bb	19	bf	2c	49	2c	1c	22
2e0:	43	00	ff	00	ff	00	02	d0	03	01	53	00	00	02	4e	1e

Table 2. Breakout of Data Record Fields for Table 1

Byte Offset	Num Bytes	Data	Description
00f	4	ff00ff00	Packet registration
013	2	02D0	Record length of full packet (not including chksum) = 720
015	1	04	Packet Type 03 and above designates an ac-s meter
016	1	01	reserved
017	1	53	meter type—53 indicates an ac-s
018	3	000002	serial number
01b	2	4e1a	sample to sample delta time in 25 us counts (0.49985 sec)
01d	2	01ba	reserved
01f	2	02a1	reserved
021	2	7ae4	raw external temp counts = 22.14° C
023	2	b9d7	raw internal temp counts = 17.91° C
025	2	01d5	reserved
027	2	02b0	reserved
029	4	00071b02	time in milliseconds since power up (465666 = 7.761 mins)
02d	1	01	reserved
02e	1	56	Number of output wavelengths = 86 decimal
02f	2	0405	raw cref ₁ counts
031	2	0363	raw aref ₁ counts
033	2	04f4	raw csig ₁ counts
035	2	0310	raw asig ₁ counts
037	2	0498	raw cref ₂ counts
:			
2d7	2	20bb	raw cref ₈₆ counts
2d9	2	19bf	raw aref ₈₆ counts
2db	2	2c49	raw csig ₈₆ counts
2dd	2	2c1c	raw asig ₈₆ counts
2df	2	2243	checksum
2e1	1	00	pad byte
2e2	4	ff00ff00	start of next packet

Primary Processing

When receiving binary packets from an ac-s, the first thing to look for is the packet registration, which is four characters. The characters, in hex, are FF 00 FF 00. After successfully receiving these characters, the 2 byte packet length is the next item to be received. The packet length includes all bytes sent in the packet, including the 4 byte packet registration, and excluding the two byte checksum and the pad byte. The packet length varies from meter to meter depending on the number of output wavelengths.

The next byte is a packet type identifier used by WETView to distinguish between ac-s and Histar data packets. It should be 3 or higher for the ac-s.

The next byte is reserved for future use.

The serial number is a standard four-byte long integer. The first byte of the serial number denotes the instrument type. The remaining three bytes are the binary serial number.

The sample to sample delta time (which also roughly tracks the filter wheel rate) can be calculated from the 2 integer bytes that are sent with this formula:

$$\text{delta time (in seconds)} = (2 \text{ byte unsigned integer} \times 0.000025\text{s})$$

The following 4 bytes are currently used for diagnostic purposes.

The next two bytes represent the raw external temperature voltage counts from across a thermistor. The external temp is calculated by a polynomial that converts counts to degrees C. Calculate the temp using the polynomial:

$$y = a \times \text{counts}^3 + b \times \text{counts}^2 + c \times \text{counts} + d$$

where $a = -7.1023317 \text{ E-13}$, $b = 7.09341920 \text{ E-8}$, $c = -3.87065673 \text{ E-3}$, and $d = 95.8241397$

The internal temperature is given as a reading from a thermistor. The manufacturer of the thermistor provides a function to convert resistance to temperature. The two byte value in the data packet represents the voltage drop across the resistor. To determine the resistance of the thermistor, first convert the counts (16 bit unsigned integer) to volts using the equation:

$$\text{volts} = (5 \times \text{counts} / 65535)$$

then convert volts to resistance:

$$\text{resistance} = 10,000 \times \text{volts} / (4.516 - \text{volts})$$

then finally convert resistance (*res*) to degrees C:

$$temp = \frac{1}{a + b \times \ln(res) + c \times (\ln(res))^3} - 273.15$$

where $a = 0.00093135$, $b = 0.000221631$, and $c = 0.000000125741$

The next four bytes are also currently used for diagnostic purposes.

Next is a four byte unsigned integer value representing the time in milliseconds since the instrument was started up.

Following that is a one byte value that is reserved for future use.

Next is a one byte unsigned integer representing the number of output wavelengths.

Next is the data for the scan. The values are the averaged signal counts (dark count subtracted) for each detector at each output bin. The counts are 16 bit unsigned values, transmitted in the order $c_{ref1}, a_{ref1}, c_{sig1}, a_{sig1}, c_{ref2}, \dots, c_{refn}, a_{refn}, c_{sign}, a_{sign}$, where n is the number of output wavelengths. The output wavelengths are in increasing wavelength order, running from approximately 400 nm to 715 nm or higher.

Following the data, at the end of the packet, a two byte checksum is sent. This checksum is the unsigned 16 bit sum of all characters sent in the packet, including the identifier (FF 00 FF 00) and up to the last data byte preceding the checksum field.

One pad character (00) is sent following the checksum, before the next packet identifier is sent.

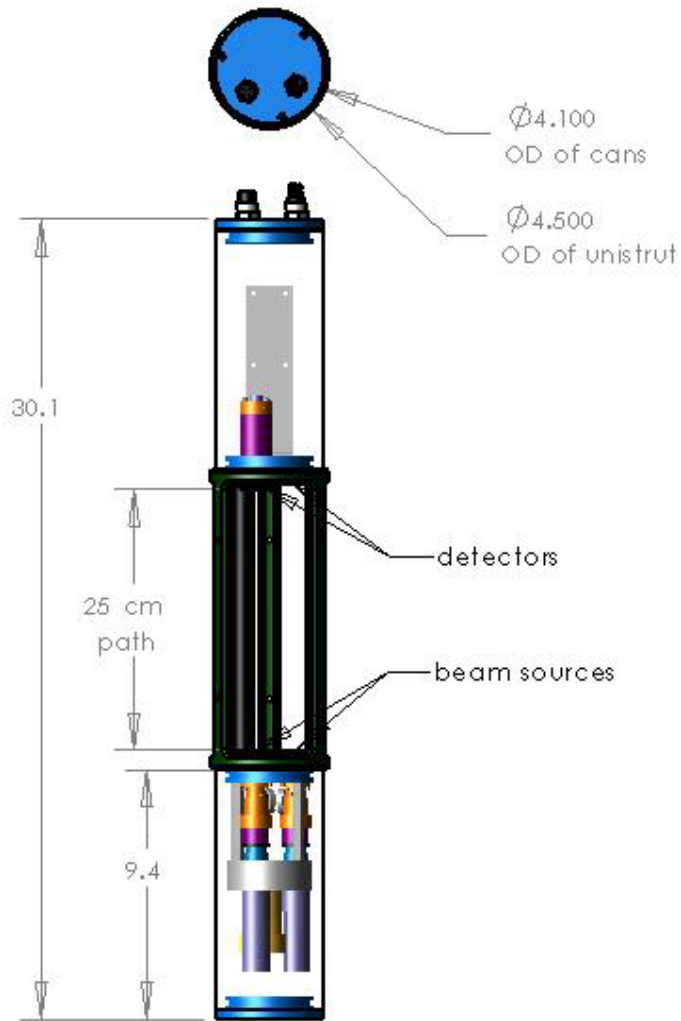


Figure 10. ac-s system diagram

Revision History

Revision	Date	Revision Description	Originator
1	2/4/04	Draft document	B. Rhoades
A	2/10/04	New document (DCR 364)	D. Hankins, B. Rhoades