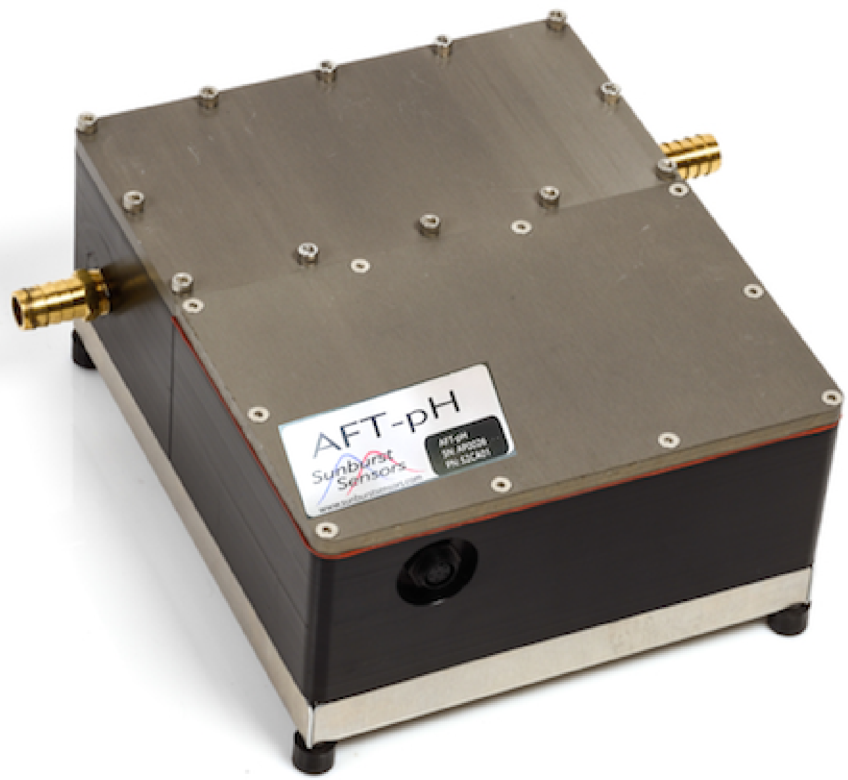
Operation Manual AFT-pH



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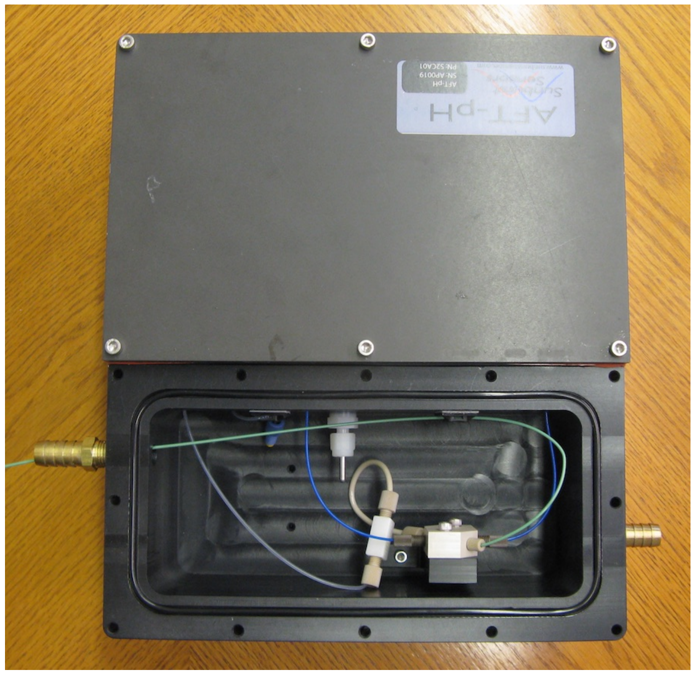
Cleaning your AFT for return to Sunburst Sensors

After making seawater measurements and before storing the AFT or returning it to Sunburst Sensors for refurbishment, the AFT wet chamber should be flushed with deionized water after removal from a seawater line to prevent mineral and/or reagent build-up in the plumbing. The lid to the wet chamber should be removed (Figure **??**, and the surfaces gently wiped with a clean cloth before long term storage. The flow cell should also be flushed with deionized water using the procedure described in section 7.



Warnings and Safety

To prevent damage to the Autonomous Flow-Through instrument (AFT), please carefully read the operating instructions before attempting to use your instrument. The cable provided is for bench-top programming and download of the AFT data and is NOT submersible!

Handling

The AFT is reagent-based with the reagent stored in sealed foil bags underneath the instrument. It is possible, though very unlikely, that these bags may leak or rupture. In case of exposure to the reagent, please refer to the material safety data sheets in section 9 of this manual.

AFT Power

The AFT is powered externally using common wall outlet power. Observe common safety protocols when using any external power, especially in a wet environment. While the instrument is diode protected for reverse voltage, large voltages will damage the instrument. Connect with care!

1 Introduction to the AFT-pH

1.1 What's in the box...

The rugged instrument case for your AFT should contain the following upon arrival:

1. AFT-pH Instrument
2. AFT Operating Manual
3. Communication/Power Cable
4. AFT Software Disc
5. De-Clogging Kit for air-locked pump
6. Pre-Deployment Checklist
7. Inlet pressure gauge assembly
8. Any external instruments or reagent ordered, though these may ship separately.
9. Power cable adapter kit.

If any of these materials is damaged or missing, please contact Sunburst Sensors immediately.

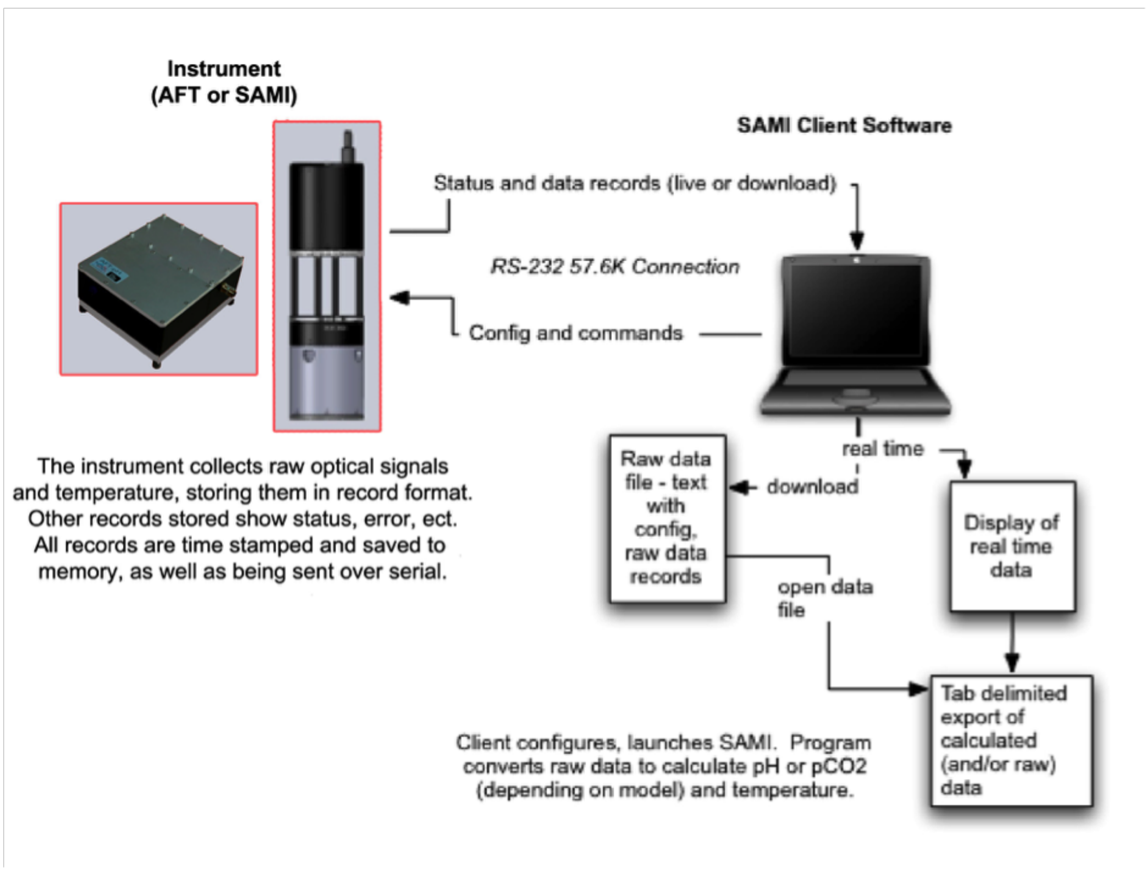


Figure 1: Operation overview.

1.2 Overview of Communication

Figure 1 gives an overview of how the AFT-pH operates and interacts with the AFT-Client software. The AFT uses a time-stamped, records based system to store and transmit data. There are two main types of records; Data and Status. Data records consist of raw measurement data, while status records contain information about the state of the instrument (start, stop, battery low, error, etc.)

Once running, all records are stored to internal memory for later download. Additionally they are transmitted over the serial port, though for energy efficiency the port only wakes up long enough to send the data.

Data records transmitted to the client can be displayed in real time via the **Real Time Data** button (enabled once data is detected). The user selects a column set to choose which quantities to view. Data can be shown in columnar (spread-sheet) display or as a graph.

The SAMI Client software sends configuration data (start time, sampling interval, etc.) and commands to the AFT (start, stop, erase, etc.) It also allows the download of data from the instrument. Data is downloaded into a text file that contains the configuration data and raw signal intensities as well as any status records. The user can then open and parse that file or data can be exported to tab-delimited files for use in other graphing or analytical software from the data viewer (Section 4).

1.3 AFT-pH Hardware

The AFT is divided into three discrete sections, the dry chamber, wet chamber, and reagent housing. These are described below.

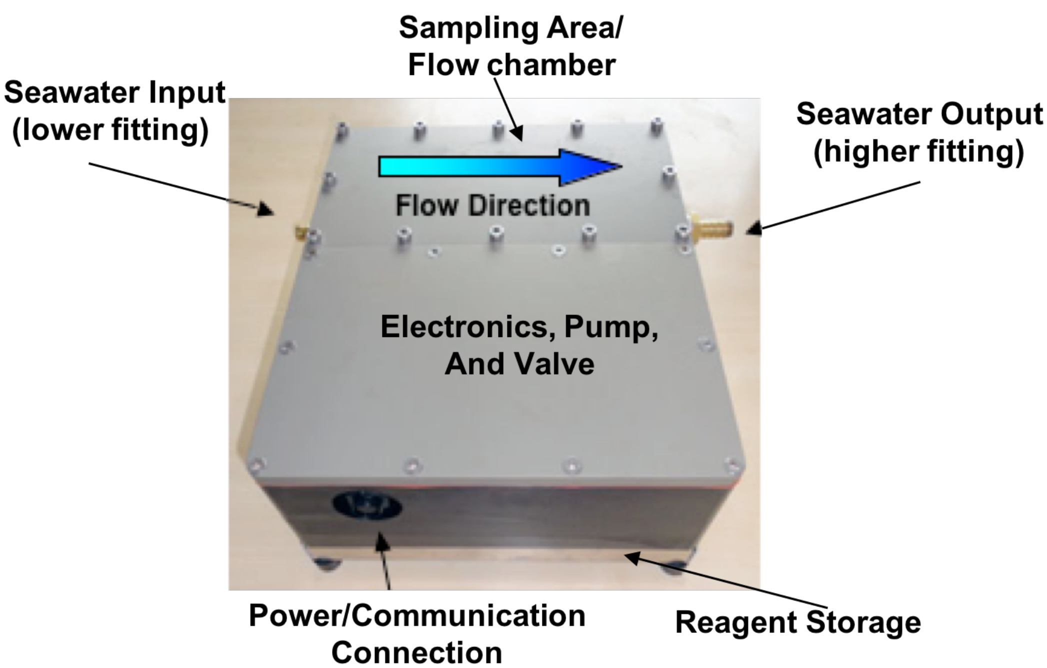


Figure 2: AFT hardware description.

Dry chamber: This houses backup batteries, electronic controller board, optics, pump and valve. This area must be kept closed during operation and dry at all times.

Wet chamber: This is the area that the seawater flows through. Within this section are the seawater inlet, flow cell, mixer, and thermistor. The flow cell outlet should be directed to the seawater outlet to prevent reagent from contaminating the seawater being measured.

Reagent housing: This compartment underneath the AFT stores the bag of reagent.

Cable: See Section 4.3.

2 AFT Deployment Considerations

The AFT-pH is recommended for use in waters with salinity and pH ranges of 25-40 and 7-9, respectively, at temperatures ranging from 0 to 35°C. The AFT can be configured to measure waters with lower salinity and pH. The AFT is intended for measurements of flow-through seawater from a ship sampling line, but can also be used to measure pH of discrete samples. Recommended configurations for both are described here.

2.1 Installation for flow-through seawater measurement

Figure 3 shows two possible configurations for installing the AFT with other instruments present. Both configurations are suggestions and may not be applicable to the user's actual infrastructure. These configurations are suggested because they should reduce the pressurization and temperature effects from having any significant impact.

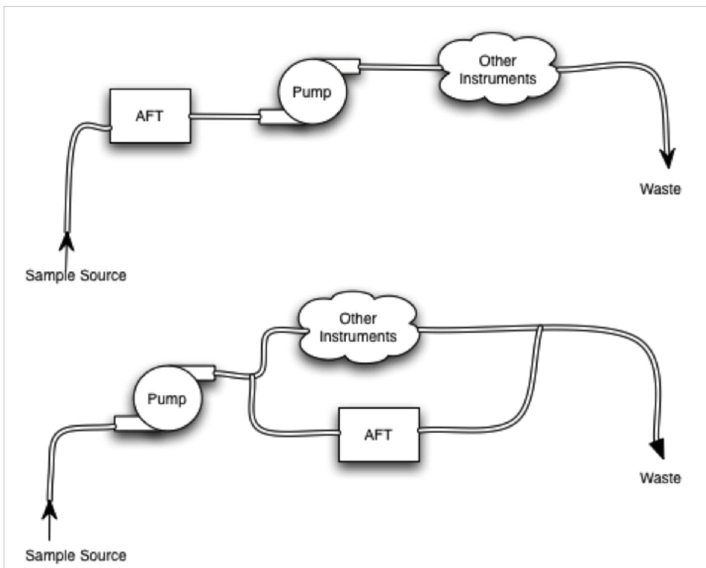


Figure 3: Schematic of recommended installation configuration with other instruments present.

2.1.1 Pressure

Although the AFT flow chamber has been pressure tested for leakage to 12 psi, ideally there will be 0 psi in the flow chamber during use. Care must be taken to maintain pressure well below 12 psi at all times to avoid leakage into the electronics or the surrounding laboratory area. Negative pressure can cause bubbles and positive pressure can lead to inaccurate measurements. A flow rate of 2–4 $\mathrm{L\,min^{-1}}$ is recommended.

The flow chamber has an o-ring seal. If the user opens the flow chamber, care must be taken to ensure the o-ring is not damaged or dirtied. It should be cleaned and checked if the chamber is opened.

2.1.2 Temperature Change

Because the AFT is using temperature readings as part of each pH measurement, it is important that the sample not be warmed or cooled significantly from where the sample is being drawn. Be aware that pumps and long lines can change the temperature. Since heat exchange is a function of temperature gradient, the user may want to insulate the inlet line if there is a large temperature difference between the sample and the laboratory.

If the temperature difference between the source water and the AFT is greater than 2 °C, the pH should be corrected to in situ temperature. In order to report pH at in situ temperature, in situ temperature must be measured, and the pH can be corrected using the following equation:

$$pH_{is} = pH_m + 0.015(T_m - T_{is}) \tag{1}$$

where pH_{is} is in situ pH, pH_m is pH measured by the AFT, T_{is} is in situ temperature in C, and T_m is temperature measured by the AFT in C.

2.1.3 Seawater contamination from AFT

The AFT-pH uses visible light absorbance to measure pH. Any instrument upstream of the AFT-pH that alters the visible spectrum of the sample will interfere with pH measurements.

The AFT-pH instrument will inject $\sim 50\,\mu$L of reagent into the sample stream with each measurement. This may interfere with measurements from other instruments. The user should consider this when configuring the AFT into a instrument lineup.

2.2 Using the AFT to measure the pH of discrete samples

The AFT-pH can be configured by Sunburst Sensors to measure the pH of discrete samples. If you intend to use your AFT to measure discrete samples, please contact sales or technical support (note that an AFT configured this way will use different software and firmware). In this configuration, the AFT will have an additional 3-way solenoid valve to switch between sampling through the wet chamber and sampling through the tubing that comes out the side of the instrument. When sampling from the tubing, the sample should be placed in a thermostatted water bath. The water bath should be circulated through the wet chamber of the AFT, with care to not apply excessive positive or negative pressure. The inlet tubing should be placed inside the sample (see Figure 4). Failure to circulate thermostatted water through the wet chamber will result in poor accuracy and precision in the pH measurement, as pH is highly temperature sensitive. Note that when measuring the pH of discrete samples, on the **Settings** tab, **SAMI/AFT** panel, "Bottle" must be chosen by entering a "1." in the box.

2.3 pH Range

The measurable pH range of the AFT-pH is dictated by the pK_a of the indicator, *meta*-cresol purple (mCP), and is 7–9 in the standard configuration. Below and above this range, absorbances become unreliable, and accuracy degrades. Different pH indicators in combination with different optics can be used to target a different pH, but the targeted range will not exceed 2 pH units. Targeting a pH range other than 7–9 requires using an indicator that is not as well characterized as mCP, and could result in less accurate pH measurement. Table 1 summarizes available indicators and their pH ranges at salinity of 35.

2.4 Salinity Range

The pK_a of the indicator is dependent on temperature and salinity, and thus both need to be measured for accurate pH measurement. If salinity is known to ± 1 PSU, using the average, constant

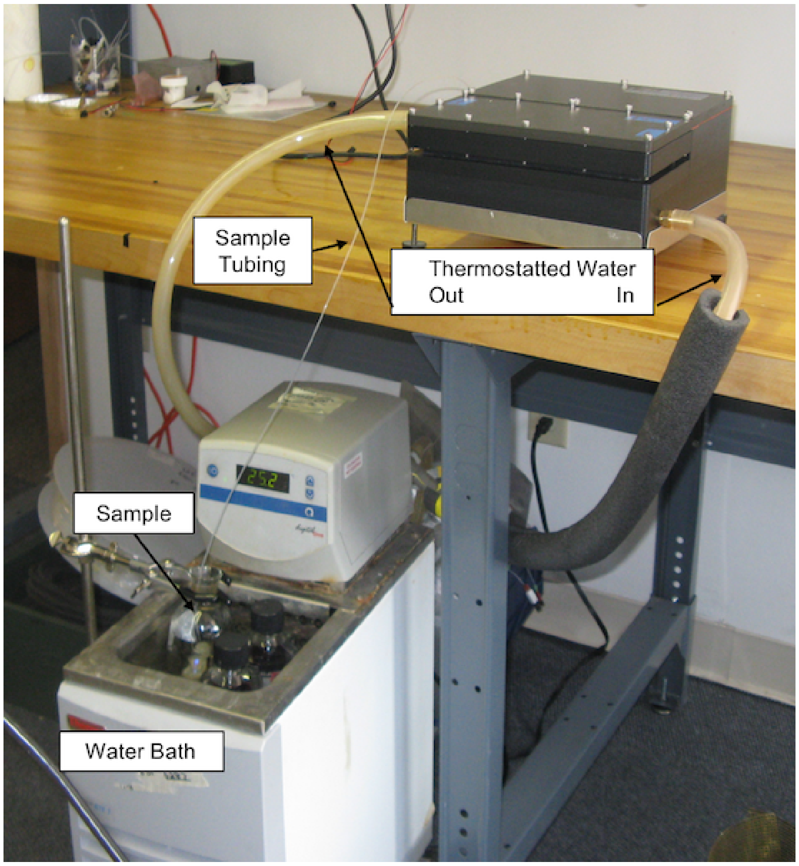


Figure 4: Recommended configuration for measuring pH on discrete samples.

salinity to calculate the measured pH is adequate. If salinity varies at the deployment site, salinity should be measured with an external instrument. The salinity logged by a AFT that is controlling a TSG can be used with AFT Client software to calculate pH. If the TSG logs salinity independently, QC_PH can be used to calculate pH with the measured salinity.

AFT-pH instruments will be accurate to ± 0.004 pH through the salinity range of 25–40. Limited results from lower salinities have given accuracies better than ± 0.015 pH.

2.5 Measurement Frequency

By collecting a higher quantity of data points you will more quickly use reagent, battery life, and memory, which will shorten the longevity of your collection time. We encourage you to weigh your options to maximize the effectiveness of your deployment while considering the questions you are trying to answer through your research. Use tables 2 and **??** to help you decide upon the appropriate parameters for your deployment.

Additionally, the internal pump appears to be less efficient at cold temperatures. In order for your SAMI to provide the best data, we recommend that the instrument be set to a higher number of flush pumps. Please contact Sunburst for instructions. Note that this will decrease battery life.

Indicator	**pH Range***
thymol blue	7.5–9.5
meta-cresol purple	7.1–9.1
phenol red	6.5–8.5
bromo-cresol purple	4.9–6.9

Table 1: pH Measurement Range
*at salinity 35 and 15°C

Measurement interval (min)	Measurement frequency (d^{-1})	AFT total reagent life (d), 550 mL
15	96	114
30	48	229
60	24	458
120	12	916

Table 2: Reagent Life

2.6 Deployment in High TDS or Highly Productive Areas

The AFT-pH pumps about 3 mL of seawater through the system for every pH measurement. The hardware can become clogged or malfunctional and optical throughput can degrade due to fine particles or biological fouling. If you are running water with high TDS through the AFT-pH, we suggest that you flush your instrument wet chamber and flow cell with DI or tap water regularly (monthly or more often if necessary). See section 7 for details.

3 AFT-pH Theory of Operation

meta-cresol purple (mCP) is a pH sensitive dye that has been purified to use in AFT instruments to increase measurement accuracy (Liu et al 2011). A seawater sample stream is pumped through the instrument and injected with mCP solution. Two wavelength-specific LEDs send alternating pulses of light through the indicator-sample mixture as it is pumped through a flow cell. Changes in absorbance at the two wavelengths, Beer's law, and the known molar absorptivities of the indicator can be used to calculate the concentration of protonated and un-protonated indicator. The indicator $\mathrm{pK_a}$is then used to calculate pH using a derivation of the Henderson-Hasselbach equation.

3.1 Equilibrium Reaction

Spectrophotometric pH determination is based on the equilibrium reaction of a pH-dependent indicator. A diprotic sulfonephthalein indicator, mCP, is used as the reagent. A single 50 μL pulse of reagent is introduced into the seawater stream. The acidic ($\mathrm{HI^-}$) and basic ($\mathrm{I^{2-}}$) forms of the indicator are found in varying quantities based on the pH of the seawater being tested.

Indicator equilibrium is described by Equation 2:

$$\mathrm{HI^-} \xrightleftharpoons{K_a{}'} \mathrm{H^+} + \mathrm{I^{2-}} \tag{2}$$

where $K_a{}'$ is the apparent dissociation constant. The acidic and basic forms of the indicator are measured at peak absorbance wavelengths of 434 nm ($\mathrm{HI^-}$) and 578 nm ($\mathrm{I^{2-}}$), respectively. The diprotic $\mathrm{H_2I}$ form is not present at seawater pH and therefore is not considered in our applications.

Combining the log form of the indicator equilibrium expression, Beer's Law, and the Henderson-Hasselbalch equations results in Equation 3.

$$pH = pK_a{}' + log\left(\frac{R - e_1}{e_2 - Re_3}\right), \tag{3}$$

where $pK_a{}'$ is the log of the apparent dissociation constant, R is the absorbance ratio A_{578}/A_{434} and the e_i are the temperature-dependent ratios of the molar absorptivities (ϵ) of $\mathrm{HI^-}$ and $\mathrm{I^{2-}}$ at 434 and 578 nm. Equations 3–10 define temperature-dependent values for $pK_a{}'$ and e_i used for purified mCPin AFT instruments. T is temperature in Kelvin, t is temperature in Celcius, and S is salinity.

$$\begin{aligned} pK_a{}' = &- 241.462 + 7085.72T^{-1} + 43.8332ln(T) - 0.0806406T - 0.3238S^{0.5} + 0.0807S \\ &- 0.01157S^{1.5} + 0.000694S^2 + 0.6367 \end{aligned} \tag{4}$$

$$e_1 = \epsilon a_{578}/\epsilon a_{434} \tag{5}$$

$$e_2 = \epsilon b_{578}/\epsilon a_{434} \tag{6}$$

$$e_3 = \epsilon b_{434}/\epsilon a_{434} \tag{7}$$

$$\epsilon a_{434} = 18834 + 28.7533(25 - t) \tag{8}$$

$$\epsilon a_{578} = 97.75 \tag{9}$$

$$\epsilon b_{434} = 2296 - 7.6338(25 - t) \tag{10}$$

$$\epsilon b_{578} = 40427 + 73.7198(25 - t) \tag{11}$$

3.2 Optical Path

The AFT uses pulsed LEDs with narrow band filters at wavelengths corresponding to maximum optical absorbance for the protonated and deprotonated forms of the reagent. A reference photodiode tracks changes in the light sources. LEDs are imbedded in the flow cell which is mounted on the controller board. The flow-cell optical path length is 1 cm.

3.3 Fluid Path

The AFT uses a 50 μL solenoid pump to drive reagent through the system. A solenoid valve allows the same pump to introduce a single pulse of reagent into the stream for each pH measurement. A section of PEEK tubing upstream of the flow cell ensures thorough mixing of the sample and reagent prior to optical measurements. The sample's blank signal intensity (I_0) is established by taking measurements while pumping pure sample through the flow cell. After measuring the blank signal, reagent is introduced into the flow stream and signal intensity (I) is collected as the pump pushes the mixture through the flow-cell. At each measurement, reference intensities ($I_{0_{ref}}$ and I_{ref}) are also measured. The absorbance at each wavelength is calculated as:

$$A = -log\left(\frac{I}{I_0} \times \frac{I_{0_{ref}}}{I_{ref}}\right) \tag{12}$$

3.4 pH Perturbation and Data Record

Each pH data record consists of 28 light intensity measurements at each wavelength. The first four measurements are averaged and used as the blank intensity values (I_0). pH and indicator concentration are calculated for each of the subsequent measurements. The addition of the mCPindicator will slightly alter the pH of the sample. The pH of the initial sample is determined by extrapolating to the pH at zero indicator concentration using a regression of pH vs. indicator concentration (Seidel et al. 2008).

3.5 Validation

The AFT-pH is validated by measuring the pH of Tris buffer at $\sim 25\,°C$. pH accuracy is better than or equal to $\pm\,0.004$ at the time the AFT is sent to the customer.

3.6 References

For more information see the following references:

Delvalls, T.A., Dickson, A.G., 1998. The pH of Buffers Based on 2-amino-2-hydroxymethyl-1,3-propanediol. Deep-Sea Research I, 45, 1541–1554.

Liu, X., Patsavas, M.C., Byrne, R.H., 2011. Purification and Characterization of meta-Cresol Purple for Spectrophotometric Seawater pH Measurements. Environmental Science and Technology, 45, 4862–4868.

DeGrandpre, M.D., Spaulding, R.S., Newton, J.O., Jaqueth, E.J., Hamblock, S.E., Umansky, A.A., Harris, K.E, 2014. Considerations for the measurement of spectrophotometric pH for ocean acidification and other studies. Limnology and Oceanography: Methods. 12, 830–839.

Martz, T.R., Carr, J.J., French, C.R., DeGrandpre, M.D., 2003. A submersible autonomous sensor for spectrophotometric pH measurements of natural waters. Anal. Chem, 75, 1844–1850

Seidel, M.P., DeGrandpre, M.D., Dickson, A.G., 2008. A sensor for in situ indictor-based measurements of seawater pH. Mar Chem. 109, 18–28.

4 Software Installation, Communication and Power Cables

The AFT-pH requires the use of its own client software for programming, download and data interpretation.

4.1 SAMI_Client Installation

AFT software is available for both Windows (XP and later) and Mac (OS X). To install the software, simply insert the AFT Software disc, navigate to the **SAMI_Client Application** folder and drag the folder for your computer platform to an appropriate location on your hard drive. You may want to create a shortcut to your application, but it is important that the application itself remain in the folder with the various sub-folders and other files for it to operate correctly. When you open the SAMI_Client, if connected to the internet, the software will automatically search for updates. You can update your software at `http://www.sunburstsensors.com/swupdate`

4.2 USB Serial Driver

Also on the disc is the driver for the serial-USB converter that is part of your communication cable. Most modern computers will already have appropriate drivers installed or automatically install this driver from the internet. If your computer does not recognize the USB-serial converter when the cable is plugged in, you can opt to install from this folder. You may also use the internet to download the latest driver from `http://ftdichip.com/Drivers/VCP.htm`

4.3 AFT Cables and Bulkheads

The black communication cable included with your instrument will have a 6-pin connector on one end and on the other end, two diverging cables: a USB-serial converter and an AC power plug. The communication cable's bulkhead attachment should be attached to the side of your AFT instrument.

Pin	Connection
1	DTR
2	RXD
3	TXD
4	Signal GND
5	Power +
6	Power GND

Table 3: Cable pin assigments.

Figure 5: Bulgin cable connector.

4.4 Communicating

Once your instrument and computer are properly interfaced, you may start communicating with the instrument. Under **Preferences** (in the **Edit** menu for PCs, and in the **SAMI Client** menu for Macs) select the appropriate serial port. Click the **Serial Open** button to establish communication with your AFT. The indicator next to the Serial Port text will specify if your AFT is interfaced with your computer (Figure 6). A red dot indicates a closed serial port while a green dot indicates an open serial port.

To save battery power, the instrument will time-out after 3 minutes.

Failure to connect usually indicates that the wrong port has been selected. Double check your port settings if you cannot connect. See also the troubleshooting section.

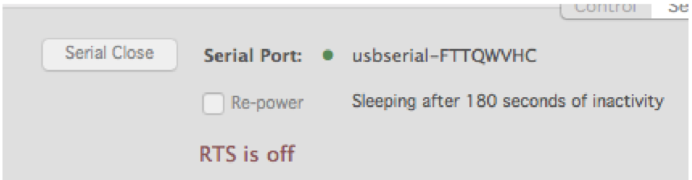


Figure 6: Instrument interface.

5 SAMI_Client Interface

SAMI_Client is the interface for your instrument. SAMI_Client version 2 is used for the iSAMI, PiSAMI, and SAMI2 and AFT instruments built in 2019 or later. SAMI2 and AFT instruments build in 2018 or earlier use SAMI_Client version 1. The **SAMI Client** menu is divided into six menus and three tabs to help you organize the information that you will be communicating to your instrument.

The **Control Tab** is where you will find buttons that manage basic operations such as establishing communication, downloading and erasing data, as well as launching and stopping the instrument.

The **Settings Tab** is where the deployment parameters and settings will be configured. The start time, interval between measurements, and any external device settings are set here.

The **Utility Tab** contains an interactive display that shows live data being collected. There are also controls that will allow you to create a pumping cycle so you can easily flush the instrument.

5.1 File Menu

Open Data File: Imports data files for data processing.

Import Hex File: Imports data that was stored by custom user systems in hex format.

Import Settings from File: Loads previously saved launch settings that have been created under the Settings Tab. This feature will save you time once you have decided upon your customized launch settings.

Save Settings As...: Stores launch settings from your Settings Tab so they may be easily loaded at a later time. The **Import Settings from File** option will load these settings which you have chosen under the SAMI Box in the **Settings** tab.

Exit (PC only): Shuts down AFT Client Software. This does not disrupt AFT operation. This function is located in the **SAMI_Client** menu on a Mac.

About... (PC only): Software credits and version number displayed in dialogue window. This function is located in the **SAMI_Client** menu on a Mac.

5.2 Edit Menu

The **Preferences** tool under this heading (PC only) is important for communication with your instrument. If using a Mac, **Preferences** is found under **SAMI_Client** menu. **Preferences** contains a dropdown menu that is populated with the serial ports on your computer. To communicate successfully with your AFT, the correct serial port must be selected. If the correct serial port is not present in the list, you may need to wait for the rest of the ports to be identified. Check the **Auto-Open serial port** box to automatically establish communication with your AFT once the correct serial port has been selected. You will also set your AFT to default to either Local Time or GMT on the **Preferences** page.

5.3 SAMI Menu

Read SAMI Settings: The SAMI Launch Setting programmed into your AFT can be viewed by choosing this option. A separate window will appear with the Settings displayed in list format. This option is only active if the AFT is **NOT** running **AND** the **Port Powered** box is checked on either the **Control** or **Utility** tab.

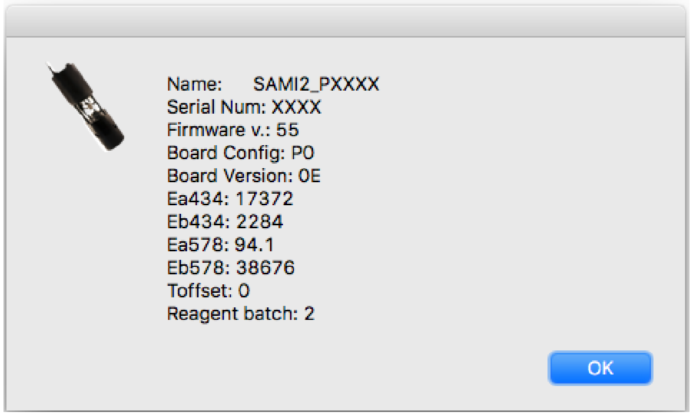


Figure 7: Read calibration window.

Read/Edit SAMI Text: The text added to the AFT under the **Edit Text** button on the control tab can be viewed by selecting this option. This option is only active if the AFT is *NOT* running *AND* the **Port Powered** box is checked on either the **Control** or **Utility** page.

Update Firmware: This action will be performed when software updates become available through Sunburst Sensors. As you receive or download newer versions of the **SAMI_Client**, upgrades to the firmware may accompany these. If required, an advisory message suggesting update of the firmware will appear when you first connect to the AFT.

Read Cal Info: Figure 7 lets you view E values, AFT temperature offset compared to NIST-traceable standard, and reagent type (1 is un-purified; 2 is purified). These values should match the values on the calibration certificate that was shipped with the AFT after the most recent refurbishment. If values do not match, contact Sunburst Sensors before deployment.

5.4 Help Menu

Various documents are available via the Help menu, including this manual, release notes for the software detailing what changes have been made, use of external instruments, etc.

View Sunburst Website: This heading will direct you to `http://www.sunburstsensors.com` for convenient access to our business, research, and contact information.

Send us Email: Directs email to Info@sunburstsensors.com

About SAMI application (PC): Brings up an information and credits window.

Check for Updates: If you have an internet connection the AFT Client software will automatically check the Sunburst Sensors website for updates to the software upon launch. You can manually check via this menu item.

5.5 Control Tab

The **Control** tab is where you establish communication and power with the AFT, start and stop sample collection, and download data.

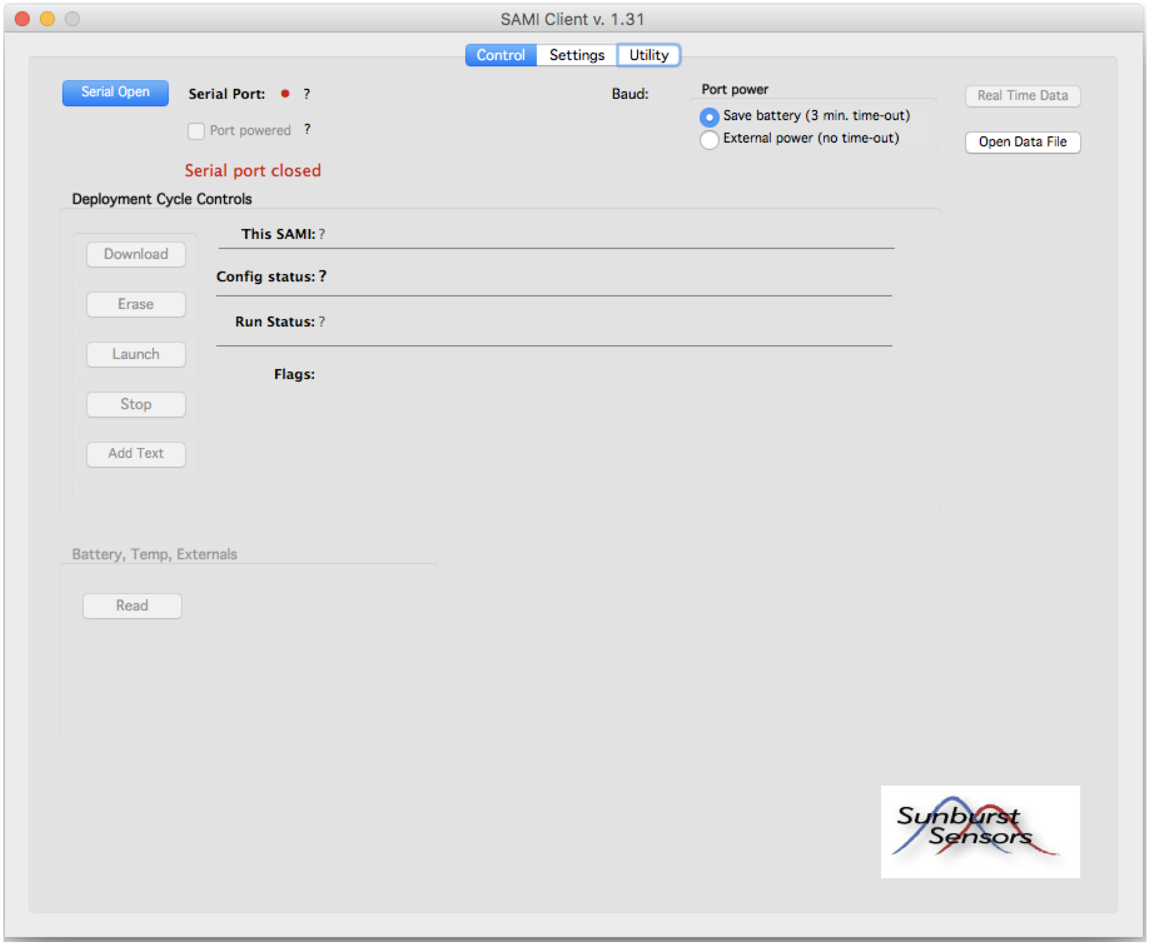


Figure 8: Control tab.

5.5.1 Serial Communication

The **Serial Open**/**Serial Close** button engages **SAMI_Client** to communicate with your instrument. To establish communication, attach the communication cable to your computer and and power AFT. In **Edit** → **Preferences** (PC), or **SAMI Client** → **Preferences** (Mac) select the appropriate serial port. Click the **Serial Open** button to begin communication with your AFT. The indicator next to the Serial Port text will specify if your AFT is interfaced with your computer. A red dot indicates a closed serial port while a green dot indicates an open serial port (Figures 6 and 8).

If the **Auto-Open Serial** box is checked in the **Preferences** pop-up page, the **Serial Open**/**Serial Close** button will no longer be visible and the AFT will automatically try to establish communication when it is powered on.

5.5.2 Power Settings

Port Powered/Re-power: The AFT has an internal battery that will make sure that data is stored when the instrument is not powered. However, the AFT must be connected to an outlet in order for you to communicate with it and run it. The communications will time out after 3 minutes, unless you override this feature by selecting the **External Power** radio button. If the port does time out, you can re-open it by simply clicking the **Re-power** check box. If

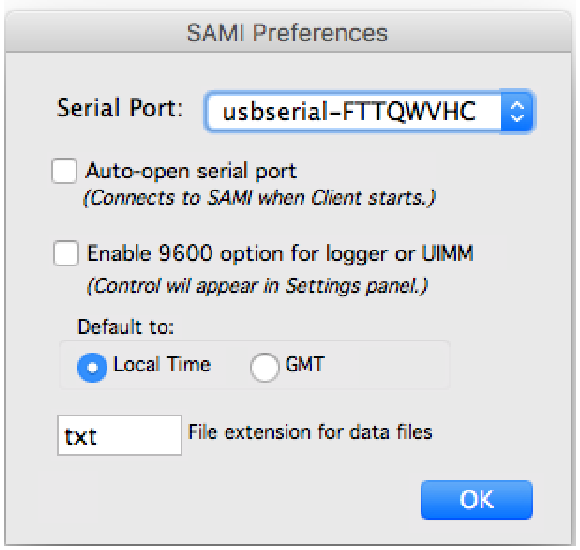


Figure 9: Communication preferences pop-up window

communications has timed-out, you cannot send commands or program the AFT until the port is re-powered.

If the AFT is running, however, the AFTwill send data out over the serial port after each measurement or other event, even if the port is timed out (The AFT powers up the port just long enough to send data).

Save Battery: The **Save battery** option allows the AFT to go into time-out after three minutes. This is not necessary with the AFT, since it is not powered with a battery. This function may also be controlled from the **Utility** tab.

External power: You can select this option to keep communication open with the **SAMI_Client** at all times. If **External Power** is selected, the message "Port power on until disconnected" will appear under serial port. This function may also be controlled from the **Utility** tab.

5.5.3 Deployment Cycle Controls Panel

Download: The **Download** button will copy data stored on your AFT to a location you select on your computer. A default file name of `SAMI_UnitName_DDMMYY` will be suggested in the save dialog. Data will not be erased from the AFT by using the Download function. If download fails, try it again.

Erase: The **Erase** button will clear the memory on the AFT of the data that it previously collected. To launch your AFT you must erase all data stored on the AFT. If you wish to save the data from your last data collection you MUST download the information before it is erased. If you attempt to erase data before it has been downloaded, you will get a warning message "Data has not been downloaded!" **OK** will erase all data and settings!

Add Text: The **Add Text** button allows you to add notes to the instrument's memory. The notes will be displayed in the data output files and can be accessed from the toolbar **SAMI → Read SAMI Text**.

Launch: Unless the AFT has been erased, it cannot be launched. Prior to launch, use the controls in the **Settings** tab to configure the AFT (see section 5.6). If you have set a launch time that has passed, you will get the message "Start is less than 10 seconds from now! Would you like to start in 10 seconds?". This may be OK for bench-top testing, but if you require data aligned to the hour, or a particular stop time, you should program the start time accordingly.

Stop: The **Stop** button will end the launch of your instrument and sampling will cease. Data will be saved in the memory of your instrument.

5.5.4 Configuration status Panel

Serial Port Opened: The AFT has established communication with your computer.

Config loaded and AFT started: Indicates that your program has launched and measurement collection has begun.

(#:) of Pages downloaded This message appears when a measurement sequence has been stopped and you have downloaded a file.

Erased: The memory has been cleared and you may begin another measurement sequence.

5.5.5 Flags

The Flags section will display messages that indicate status:

This AFT: Name: SN: Hardware: Firmware:

Recording Started: Data is being collected and stored in your instrument's memory.

Recording Stopped: The measurement sequence has stopped. The data has not yet been downloaded or erased.

Downloaded: The measurement sequence has been stopped. The data has been downloaded, but not erased. Erase your data before continuing with another sequence of measurements.

Run Status:

While the program is running, the **Run Status** will display the date, time, number of data files collected, and the memory used. The **Run Status** section will remain blank if the program is not running, the files have been downloaded, or the data file is erased.

5.5.6 Battery, Temp, Externals Panel

Clicking the **Read** button updates information on the battery voltage, and the temperature in Celcius. The AFT is not configured to run external devices.

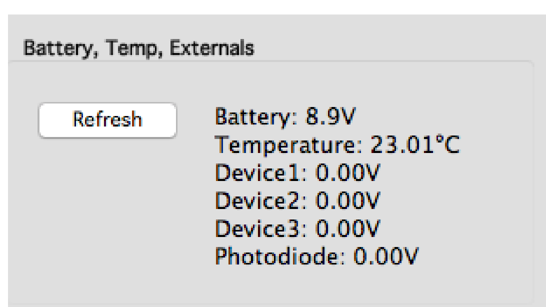


Figure 10: Battery, Temperature, Externals panel

5.6 Settings Tab

Overview The **Settings** tab contains the various control panels used to configure the instrument prior to a deployment. These control panels allow the user to set the start time and run duration, sampling interval, etc. It is important to note that these settings are not sent to the instrument until the user launches the unit via the **Launch** button in the **Deployment Cycle Controls** (section 5.5.3).

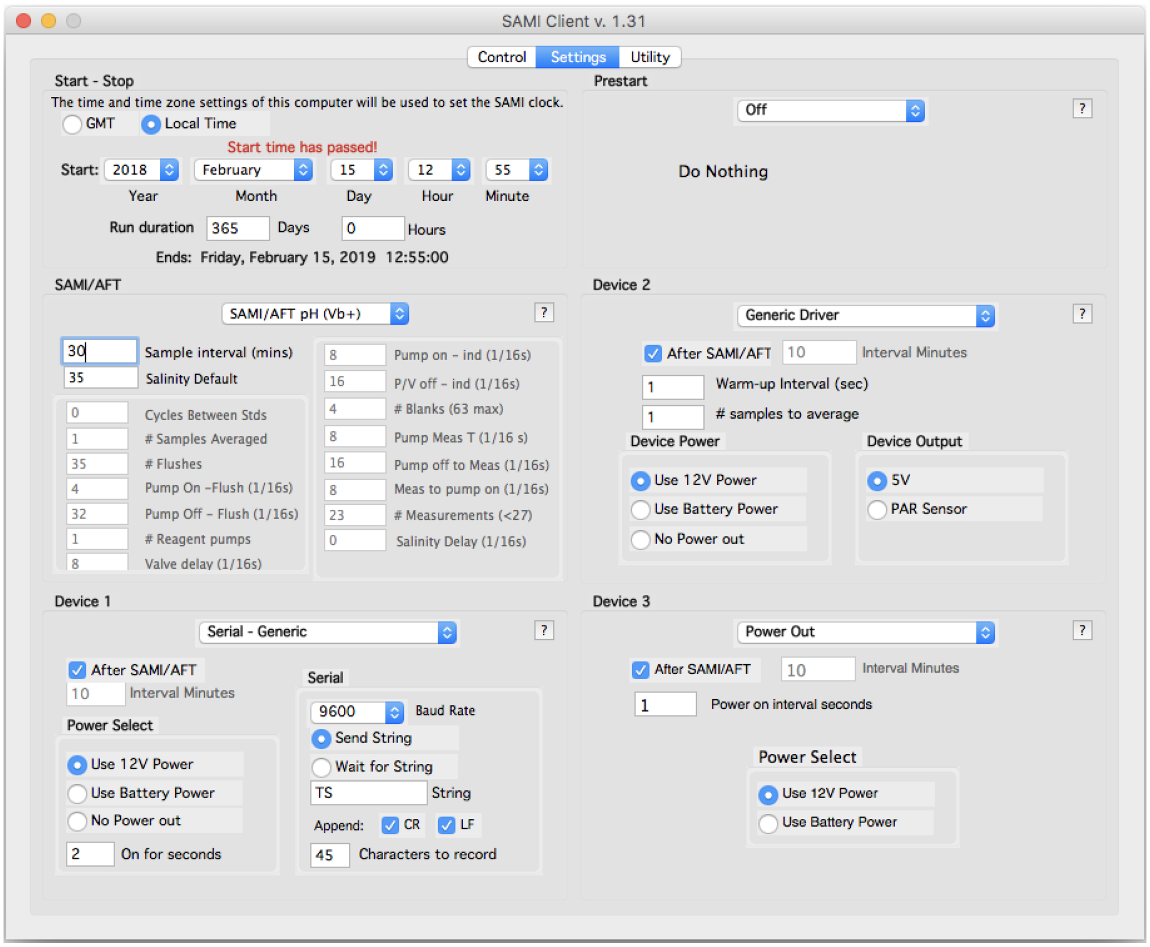


Figure 11: Settings tab.

5.6.1 Start-Stop Panel

In the **Start-Stop** panel in the upper left hand corner of the **Settings** tab you will enter your deployment start time and the run duration. You may enter the exact time you wish to launch your instrument, accurate to five minutes. Note that you may display your time in GMT or local time. However, **data is stored on the AFT in GMT, regardless of the time format set here.** When you enter the run duration in the specified box, a message appears below which will calculate the end time and date.

In the event that the start time has passed, you will receive a message informing you the start time has passed. When you Launch your instrument a message box will ask if you wish to begin sampling in ten seconds. By selecting **OK** measurements will begin immediately. Otherwise you may select a new start time by selecting **Cancel**.

5.6.2 SAMI/AFT Panel

The **SAMI/AFT** panel is where you will enter the sampling interval. In the dropdown menu in the top center of the box, select **SAMI-pH (Vb+)**. The sample interval must be entered in minutes and with a time of no less than five minutes (15 min or longer is optimal). If you enter a time less than 15 minutes, the Client will give you a warning, which can be ignored. Enter the approximate or measured salinity of the sample in **Salinity Default**. This salinity will be used to calculate pK_a for the pH measurement. The grayed-out controls on the right hand side of the control panel are not user adjustable, but visible for trouble shooting and support.

5.6.3 External Device Panels

External devices are not supported by the AFT.

5.7 Utility Tab

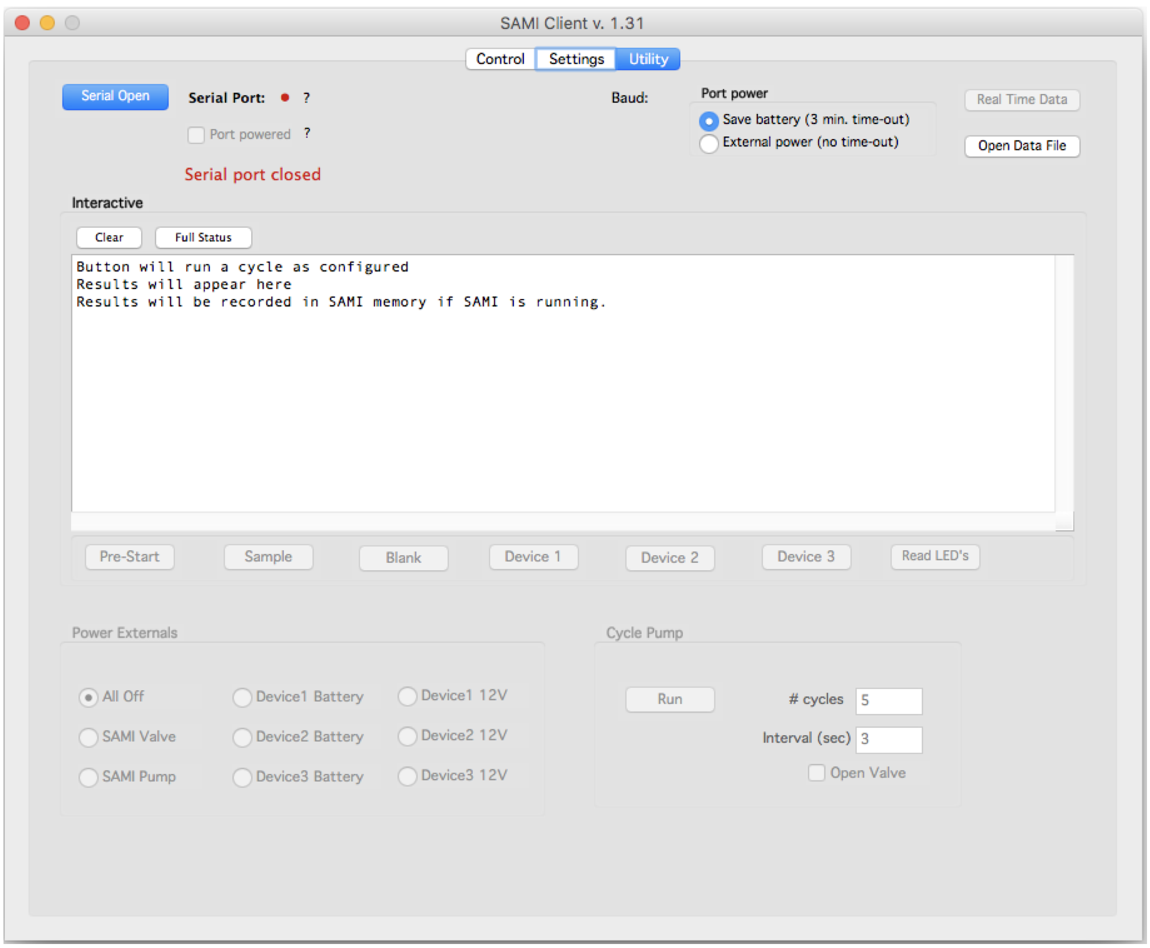


Figure 12: Utility tab.

The **Utility** tab is generally used for trouble-shooting, to flush the AFT prior to deployment or storage, and for data processing.

5.7.1 Serial Port Open-Close, Port Power

These functions can be controlled from the **Control** tab or from the **Utility** tab in SAMI Client version 1 version 2, these controls are only available from the **Control** tab.. See explanation in section 5.5.4.

5.7.2 Interactive

The **Interactive** panel will give you live feed on the data that your instrument is collecting . With each measurement, a string of information is written to the window. The first line will start with "Launch." The next line will have the headers for the following columns of data: sample type, year-day, initial internal temperature, (434 nm reference, 434 nm signal, 578 nm reference, 578 nm signal)$_n$, final internal temperature, battery voltage, external temperature. All readings are 12-bit when using SAMI Client version 1, 12-bit for version 2. n is # Blanks plus # Measurements from the Settings; default is 27. Data will be written to the screen each time a measurement is taken. This information is mostly for trouble-shooting. The records are not processed (i.e. pH, etc. is not calculated). At the top of the display you will notice a button marked **Clear** which will clear the display. The **Clear** button will not erase data from the memory.

Read LEDs: The **Read LEDs** button allows the user to check the Reference and Signal intensities of the instrument. This can help alert the user to problems such as a blocked flow cell path or malfunctioning valve and can otherwise help to ensure the instrument is ready to deploy. LED signals shoud be greater that 1000 when using SAMI Client version 1, greater than 6000 for version 2.

Pre-Start: The instrument can be programmed to perform functions while it is waiting to start. If this has been configured, it will read battery and temperature as programmed in the **Pre-start** panel of the **Control** tab.

Sample: The **Sample** button will run a measurement according to your programmed specifications. The measurement will not be saved in your stored data but will display in the **Interactive** panel, unless the instrument has been launched.

Device 1, 2, 3:

This will take a reading of the device selected. The data will not be saved in your stored data but will display in the **Interactive** panel.

5.7.3 Power Externals

The **Power External** buttons located beneath the Interactive screen and can power the pump or valve. External devices are not supported by the AFT.

5.7.4 Cycle Pump

The **Cycle Pump** function is available to flush your instrument. Flushing is an important function for the health of your AFT as well as to maintain a clear optical path. To flush the AFT you will need to attach the small fluid bag that came with the AFT or submerge the inlet tubing in deionized water, and click on **pH Flush**. The instrument will need to be flushed after each deployment. *Do not* check the **Open Valve** box, as this will flush the instrument with reagent.

The **Open Valve** box will initiate the valve during the pumping cycle. When this boxed is checked, reagent will be pumped through the instrument.

The # **cycles** refers to the number of 50 μL pumps you wish to flush through the instrument. You may choose up to 99. **Interval (secs)** refers to the amount of time between each 50 μL pump (1 s or greater).

5.8 Viewing Data

Data can be viewed in real time or imported from a file after download. On the **Control** or **Utility** tab the **Read Real Time** button becomes activated when the software detects a new measurement record (if you have connected to a AFT that is already running) or immediately after the **Launch** button is pushed. Data that has been previously downloaded can be imported by selecting the **Open Data File** button or selecting **Import Data File** from the File menu.

5.8.1 Data Overview:

Raw AFT data is stored as records while the AFT is running. These same records are transmitted over the serial port as well, so the client software will recognize and interpret them in real time.

Raw Record Structure: There are two main types of records recorded by the instrument. There are data records and information records. Every record leads with an identifying number (Record Type) and a 4-byte time stamp. Information records note events such as start, stop, low battery and possible errors if one should occur. Data records follow the type/time fields with a series of fields composed of the various readings (e.g. temperature, dark signal) needed for the measurement. In raw format these readings are not especially informative except in trouble-shooting situations.

Computed fields: Computed fields consist of data derived from the raw records. For example, the raw thermistor reading is stored as a 12- or 14-bit number. The temperature field is the temperature calculated from that raw number. Time is stored as a 4-byte number reflecting total seconds since Jan 1, 1904, while calculated fields allow time to be displayed in a variety of formats.

5.8.2 Viewing real time data:

The **Real Time Data** button plots data that is being collected by the instrument in real time. When you click on the **Real Time Data** button, a pop-up with a drop down menu titled Column Set will appear. AFT Client has a number of previously compiled parameter sets that you can choose from in Column Set Lists. Choose **pH_ConstSal**. Be sure that the approximate salinity is entered in **Salinity Default** on the **Settings** tab. Select **Make View Win** to view the data. A new window will open with data in spreadsheet format. A drop down menu titled **Display Type** allows you to view data in spreadsheet or scatter plot format.

Spreadsheet: The Spreadsheet format will allow you to view the data being collected as a list (Figure 14).

Scatter Plot: Under the Scatter Plot data display select the x-axis and y-axis parameters you wish to plot (Figure 15).

Creating your own set of parameters to view: If a pre-fabricated set of parameters does not include the information that you would like to view, you may create and name your customized **Column Set List**. By selecting **Edit List...** from the **Column Set** drop-down window you will receive a Set List Editor. You may adapt a previously existing list or create a new one.

Editing a pre-existing list is done by highlighting the list you wish to edit and clicking the button in the lower right hand corner labeled **Edit**. A list of the parameters appears in a new

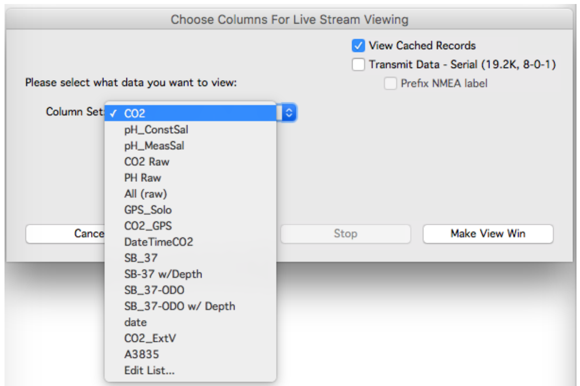
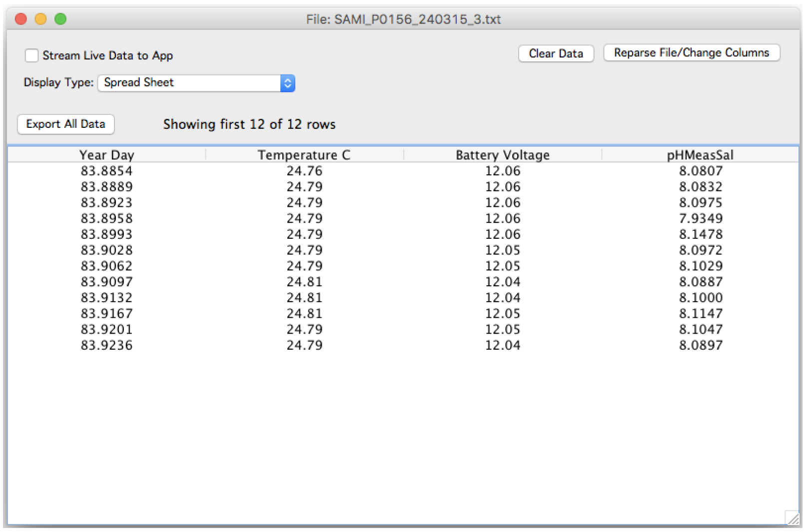


Figure 13: Real-time data dropdown menu.



Year Day	Temperature C	Battery Voltage	pHMeasSal
83.8854	24.76	12.06	8.0807
83.8889	24.79	12.06	8.0832
83.8923	24.79	12.06	8.0975
83.8958	24.79	12.06	7.9349
83.8993	24.79	12.06	8.1478
83.9028	24.79	12.05	8.0972
83.9062	24.79	12.05	8.1029
83.9097	24.81	12.04	8.0887
83.9132	24.81	12.04	8.1000
83.9167	24.81	12.05	8.1147
83.9201	24.79	12.05	8.1047
83.9236	24.79	12.04	8.0897

Figure 14: Processed data in spreadsheet format.

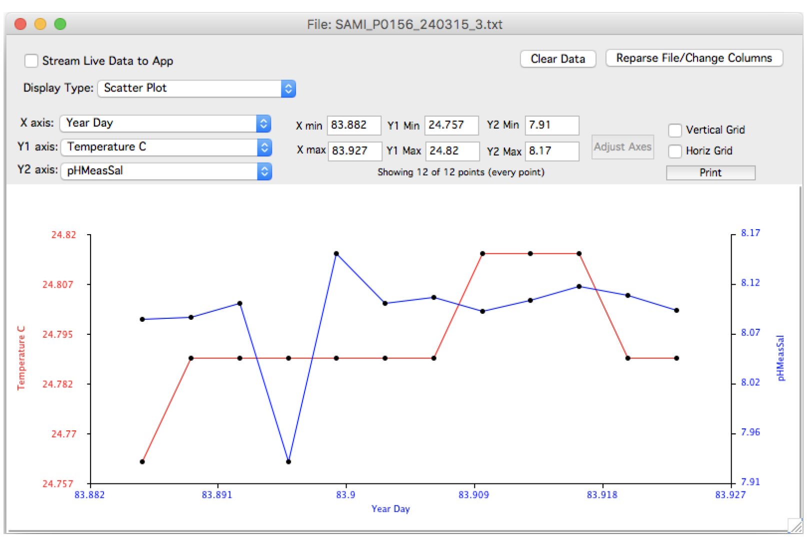


Figure 15: Processed data in scatter plot format.

window. The left side window labeled **Columns** will display all parameters contained in the **Column Set List**. Clicking the **Add** button below the window will make available two drop down menus on the right side of the window. The **Column Type** drop-down menu will provide you with the classifications of parameter we have to choose from. You may be interested in viewing raw data or processed data. By selecting the type of data you can choose the exact parameter you wish to plot in the **Column Name** drop-down menu below. There you may select from a number of different parameters to populate your **Column Set List**: sample or reference signals of a specific wavelength, ratio of signals to reference, temperature, time, battery voltage, and pH.

To create your own **Column Set List**, return to the **Column Set List** editor. Select **Add** from the buttons at the bottom of the window. A **Column Editor** will appear with an untitled **Column Set List**. Name your Set List and populate the parameters in the same fashion as described above.

5.9 Data Processing

5.9.1 Processing text files

Once data has been downloaded, you can view raw and processed data with AFT Client software. Go to **File** menu and select **Open Data File**. A window will appear that asks you to select what data you want to extract from the file. In the drop down menu, select **pH_ConstSal** for constant salinity (the approximate salinity of your sample must be entered in the **Salinity Default** box on the **Settings** tab). If you logged CTD data independently and want to use the measured salinity, you will need to process the data using **QC_PH**, as described in section 6.

Next, click on the **Parse File** button. Data can be viewed as a spreadsheet or scatter plot and exported as a text file. Although you can only view the first 500 rows of data, you can process and export the entire data file. Note that this is preliminary data. **QC_PH**, included on your disc, filters and processes the data more thoroughly. This is described in section 6.

5.9.2 Processing hex files from a custom interface

The AFT data can be collected from the user's system via RS-232. Data collected this way will be in hex format. A hex file can be imported and processed in **SAMI_Client**. From the **File** menu select **Import hex File.** In the dropdown menu choose **pH_ConstSal**. In the upper right hand corner of the **Import** menu, select **Choose Config File** and choose a configuration file. A configuration file is saved when you launch the AFT. If you did not save the configuration file when you started the instrument, a generic configuration file can be saved at any time. Once the hex data is imported, the functions of the program are the same as when reading AFT txt files.

6 Processing Data With QC_PH

QC_PH is a standalone Matlab program that reads data files from the AFT Client. This program does a better job of filtering out outlying blanks and sample points that resulted from air bubbles, and flags those points as well as points where a mechanical error such as a failed valve or pump might have occurred. pH values calculated from **SAMI_Client** and **QC_PH** will differ slightly, due to blank filtering and smoothing by **QC_PH**. **QC_PH** provides more reliable pH values.

6.1 Installing Matlab Runtime and QC_PH Application

On the AFT disk, open the folder **QC_PH**, copy the appropriate folder for Macintosh or PC to your computer and open the folder, then double-click on the application. For PC the application will be a *.exe file, for Macintosh this will be a *.dmg file. This will guide you through installation of Matlab runtime as well as **QC_PH**. It will require web access and will take a bit of time, depending on the speed of the internet connection. Future updates to **QC_PH** will install quickly. If you need a complete installer (no internet access), please contact technical support. The default folder for the application is Programs\Sunburst Sensors\. You can move an alias or shortcut of the application to a more convenient location.

6.2 Running QC_PH

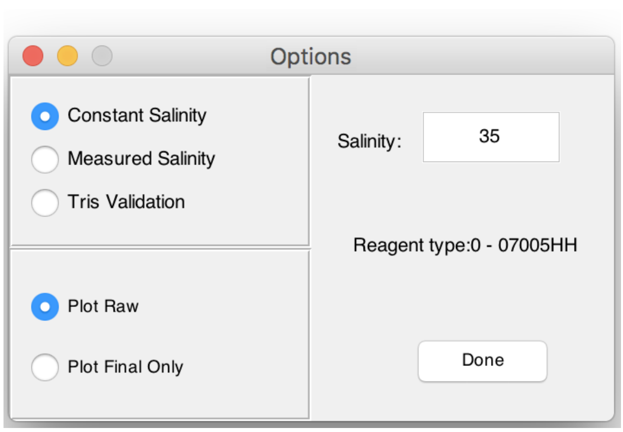


Figure 16: PH Options.

To run **QC_PH**, double click on the icon. You will be prompted to choose the AFT data file. After reading the file, the app will ask you to choose **Constant Salinity**, **Measured Salinity**, or **Tris Validation**. Choose **Constant Salinity** if salinity was not measured, but you know the approximate value. Enter the salinity in the **Salinity** box. Choose **Measured Salinity** if you have a data file from a CTD that was deployed with the AFT. You will next be prompted to choose the CTD file. This file must be a tab delimited text file in the format: mm/dd/yy Tab hh: mm: ss Tab salinity. The times in the CTD file must cover all times in the SAMI file. If they do not, you can copy a line of data to the top or bottom of the file, using an appropriate time. Choose **Tris Validation** if you are running a Tris buffer with known pH for validation of instrument accuracy.

QC_PH will calculate pH and shows plots of signals, absorbances, blanks, point pH, temperature, and final pH. These plots can be useful in troubleshooting a AFT. You can set the range of samples to view by changing the **Start Sample** and **End Sample** and selecting **Re-Plot** on Figure 1. Select **Save Figs** to save the figures and **Close All** to close the Figure

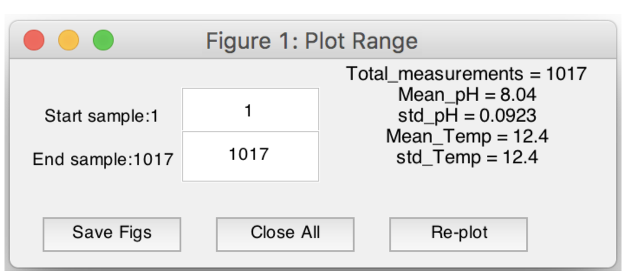


Figure 17: Range of points to plot.

windows. Figures and a text file of
the output data will be saved in a folder named “Filename_Results.”

6.3 Interpreting QC_PH Data and Figures

QC_PH will plot several figures. The figures that are often used to determine data quality and instrument performance are described here.

The **Intensity/Absorbance** plot indicates instrument performance (Figure 18). The top plot is reference signals, which should remain constant, but might degrade gradually over the course of a deployment. The middle plot is signals through the optical cell. These signals start high at the beginning of a sample (blank), drop as indicator moves through the cell, and gradually increase back to the blank values. Smooth curves indicate the AFT is working well, whereas flat lines or many spikes in signals indicates malfunction. The signals are plotted “Raw” and after outlying points are filtered out. Each line is for one sample measurement.

The **Blank** plot plots the signals of the blanks measured at the beginning of each sample (Figure 18). These signals will degrade gradually over the course of a deployment, but should not have large spikes, and should remain above 1000 for Sami Client version 1, 4000 for version 2). Each point is the blank for one pH measurement.

The point pH plot (not shown) shows the pH measured at each point during the sample measurement. The final pH is an extrapolation of point pH versus total indicator concentration to the pH at zero indicator. Each line is one pH measurement.

The Flags plot indicates problems that might have occurred during a sample measurement. If flags are all 0, there are no obvious errors. Any flags on 1 indicate that a blank value was not consistent from other blanks, and the pH measured could be erroneous. Flags on 2 indicate that the signal was saturated at some point during the measurement, and the pH measured could be erroneous. Flags on 3 indicate that the pump was not working, and the pH measurement will read NaN (not a number). Flags on 4 indicate that at least one point during the measurement was an outlier. The software will throw out the outlier, so this flag does not necessarily indicate an erroneous pH measurement.

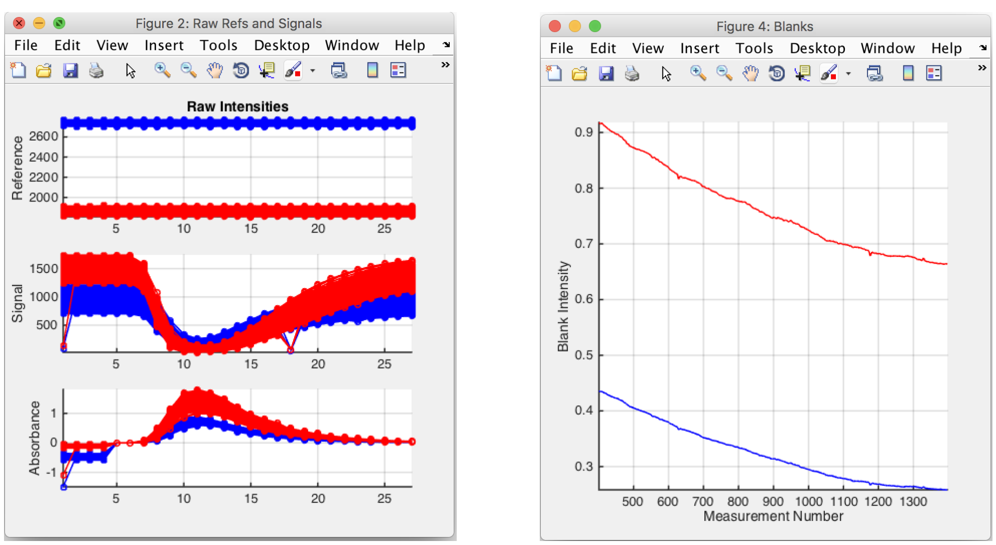


Figure 18: Signal intensity plots (left) are plotted as 28 points for each measurement (top: reference signals, middle: signals through cell, bottom: absorbances through cell); ratios of blank signal/reference signal (right) are plotted as one point per measurement (434 nm signal shown in blue; 578 nm signal shown in red).

The **Final pH** plot shows the temperature and pH measured throughout the deployment (Figure 19). Each point in one pH measurement. pH noise from one measurement to another should be less than 0.002 pH and temperature noise should be less than 0.05 °C. As blank signals degrade, pH precision might also degrade.

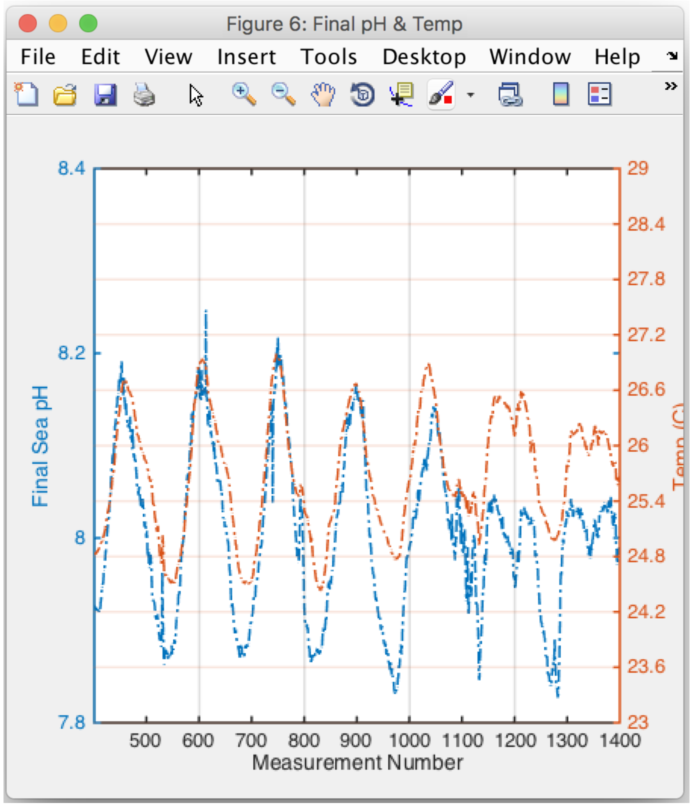


Figure 19: Final pH (blue) and Temperature (orange), plotted as one point per measurement.

The data output file will contain columns for date, pH measured, the potential error of the measured pH (estimated from the fit of the plot of point pH versus total indicator concentration), temperature measured, and flags. In the flags column 0000 indicates no flags, 0001 (1 line on plot) indicates a blank flag, 0010 (2 line on plot) indicates a saturated signal, 0100 (3 line on plot) indicates pump failure, 1000 (4 line on plot) indicates an outlier. If the file is opened in Excel the leading zeros will be absent. The flags are described in more detail above.

7 Care and Maintenance

7.1 General Cleaning

After your AFT has been in use, even for short periods of time, we recommend flushing it with deionized water to solvate any crystals of indicator or salt that may have formed. WARNING: Failure to flush your AFT may result in your instrument's inability to function properly!

7.2 Clearing air-locked or clogged AFT-pH

An air lock can occur when the instrument runs samples out of the water, allowing air to be pumped into the tubing before it is deployed. If you are testing the AFT on a bench top, be sure to attach a bag of deionized water to the inlet or place the inlet into a beaker of deionized water. When deployed in water with high amounts of sediments, materials can also cause a clog in the instrument. An air lock or a clog can be cleared with the steps below.

1. Remove the screws from the wet chamber and take the lid off the AFT (Figure 20).

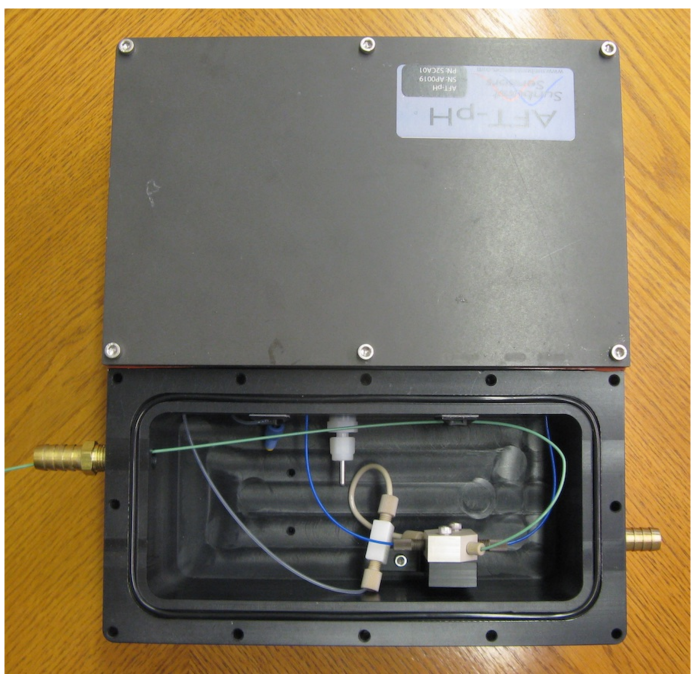


Figure 20: AFT with wet chamber lid open.

2. Fill the syringe with deionized water and connect to the blue fitting on the intake tubing inside the wet chamber of the AFT (Figure 21).

3. Connect the AFT to power and a computer with the Client software installed. Open **SAMI_Client**. In the **Utility** tab under the **Cycle Pump** panel, set the # **cycles** to 10. Apply a constant pressure to the syringe and click **Run**. **Open Valve** should *NOT* be checked.

   The deionized water should move through the system and come out of the cell outlet tube (long green tubing protruding from the PEEK cell). This step may be repeated a couple of times. If the water does not move through the instrument, contact Sunburst Sensors for additional technical support.

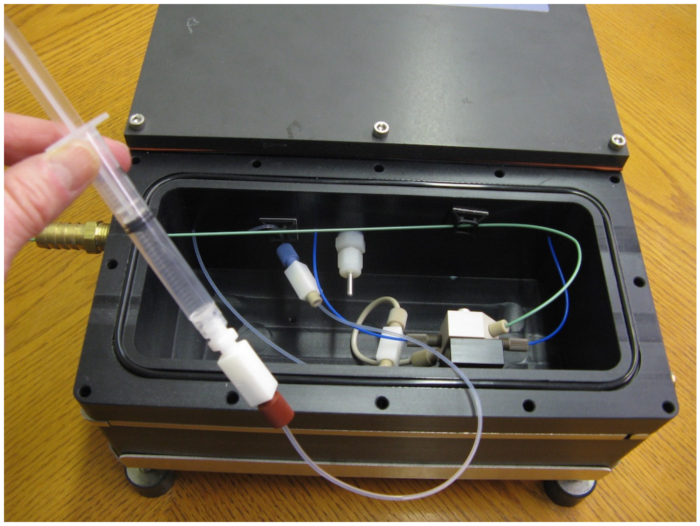


Figure 21: Clearing an air-locked AFT

4. Once fluid begins to move through the system, insert the intake tubing (the tube with the blue fitting where the syringe was attached) into a beaker with a few hundred milliliters of deionized water, or connect the blank bag to the inlet.

5. Next flush the AFT using deionized water from the beaker or the bag. On the **Utility** tab under the **Cycle Pump** panel set the # of cycles to 99 and click on **Run**. Make sure the intake tube is in the deionized water before pressing the **Run** button. **Open Valve** should *NOT* be checked.

   The deionized water should move through the system normally. If the water is not moving through the instrument, contact Sunburst Sensors for technical support at techsupport@sunburstsensors.com.

8 Troubleshooting

These are a few common questions that we receive at Sunburst Sensors. If you do not see your question here, please contact us at techsupport@sunburstsensors.com.

What do I do if I cannot communicate with the instrument? You will not be able to communicate with your instrument if the correct serial port has not been selected. In **SAMI_Client** select **Edit** → **Preferences** and try choosing another serial port from the menu. Many times it may take some time for the computer to fully populate the list. You may need to wait until another serial port appears in the drop-down menu. The COM port on the PC will typically be the last one in the list. On a Mac the serial port will be named `USB-serial XXXXXXXX` where "X" represents alpha-numeric characters.

On Windows operating systems (7, 10) it is sometimes helpful to go to the **Device Manager (Control Panels, System and Maintenance, System)** and look for the **Ports** to verify your USB-Serial converter is working. There should be at least one USB Serial Port under **Ports (COM & LPT)**. Double click to open and verify that it is the FTDI converter and not some other device. Use this port number in the SAMI Client Preferences.

If you do not see a USB serial port, it is likely that you will need to install the driver. Try unplugging and re-plugging the cable to the PC. This should prompt an install dialog. If this does not work, you can manually install the driver from the install CD or from `http://ftdichip.com/Drivers/VCP.htm`

On some PCs switching to another USB port will solve the problem. Also, it is occasionally useful to restart the AFT Client software and/or the PC itself.

What happens if the signals drop? This is very likely due to an obstruction in the path of the optical cell. Commonly, it is air bubbles which can be flushed out by continually pumping. If you use the **Cycle Pump** function on the **Utility** tab of **SAMI_Client** to pump deionized water (after filling the wet chamber with DI or tap water) through the instrument, the problem will often be resolved.

What should the signal intensities be? If you are using **SAMI_Client** version 2.01 or higher, signal intensities can range from 0 to 16383. If any signal intensity is at or near 16000, the channel may be saturated with light, giving erroneous results. Reference and signal intensities should be greater than ∼6000 for a blank (DI, seawater, etc.). Lower intensities will result in higher noise in absorbance and thus pH measurements. However, if during a measurement signal intensities are low but reference intensities are not, the flow cell needs to be flushed with DI or tap water. Dark signals will normally range from ∼200–400. Higher or erratic dark signals could indicate an electronic problem with your AFT. Contact Sunburst if any abnormal signals cannot be rectified.

If you are using **SAMI_Client** version 1.35 or lower, signal intensities can range from 0 to 4095. If any signal intensity is at or near 4000, the channel may be saturated with light, giving erroneous results. Reference and signal intensities should be greater than ∼1000 for a blank (DI, seawater, etc.). Lower intensities will result in higher noise in absorbance and thus pH measurements. However, if during a measurement signal intensities are low but reference intensities are not, the flow cell needs to be flushed with DI or tap water. Dark signals will normally range from ∼50–200. Higher or erratic dark signals could indicate an electronic problem with your AFT. Contact Sunburst if any abnormal signals cannot be rectified.

How do I flush my AFT? There is a function on the **Utility** tab of the **SAMI_Client** labeled **Cycle Pump**. Under cycle pump you may flush your AFT without disrupting the programmed measurement routine. In addition, the user may use the de-clogging kit that is included with all new pH instruments. See section 7 for instructions on using the de-clogging kit.

My Spreadsheet Maker did not populate the Column Set List! It is very likely that the file included on your instrument disc was not copied over to your computer. Please double check that every file on the disc has been successfully transferred including a file labeled `ColumnSettings.txt`.

QC_PH will not read my CTD file. Make sure that your CTD file is formatted correctly (see Section 6) and that the times cover all times in the SAMI file. Extra lines of data can be pasted at the top and bottom of the file to include missing times, if necessary.

What if I cannot rectify my problem? Contact Sunburst Sensors, our information is found on the front of this manual. We will work with you to find the fastest and most economical solution to your problem. Never hesitate to give us a call or send us an e-mail at techsupport@sunburstsensors.com.

9 Low level operation of the AFT

The AFT has a very robust, user-friendly client that is recommended for programming, downloading, and updating. That being said, there are some users who wish to have a lower level control of the instrument. This document attempts to explain the low level operation of the AFT.

RS-232 Serial Communication

The AFT uses RS-232 to communicate with 8-none-1 settings. RTS must be held high to turn on the RS-232. When RTS is asserted the AFT will begin to send status strings every second. For interactive use, these status strings should be turned off using the `F5A` command (see Low Level Commands below). Once this command is issued, however, the client software will not recognize the AFT as being connected. It can be turned back on by `F01` if you need to use the client.

Once communications have been established the AFT needs to be stopped (if it is running), downloaded (if there is data), and erased.

The command sequence for this is:

Q5A - stop running and close memory
D## - send ## pages of memory over serial port
E5A - erase memory, including RAM variables

At this point the AFT must be configured before it can be used again, setting the time, sample interval, etc. Configuration is discussed next. While the AFT does not have a strict polling mode, it can be configured to start long in the future and sent commands to do measurements on a set interval. To get a measurement once the unit is configured, just send `R`. (All commands are `CR` terminated as discussed below.)

Configuring the AFT

The configuration string sets the various parameters required by the AFT to operate. It sets the time and date, the start time and end time. It tells the AFT which drivers to use for the AFT itself (e.g. is it a pH unit or CO_2 unit?) and what drivers to use for any devices that are connected to the AFT. The configuration string also contains all the parameters required by the various drivers, including timings of pumps, valves, etcetera.

The configuration string is 116 bytes (232 hex characters) in length, which is padded to 128 bytes (256 hex characters), followed by 128 bytes (256 hex characters) of user text and terminated with a null character. Each byte is represented by a two character hex string. The beginning of the string specifies the time parameters and mode, followed by sampling intervals, driver info and pointers to parameters.

The configuration string is sent or retrieved to/from the AFT by client software using `L` command which is described in section 9.

+++++++**Overview of Configuration String for Firmware 50**+++++++++

Description	**Units**	**bytes**	**position in string**
Launch time (GMT)	secs from 1/1/1904	4	0
Start time from launch	secs from launch	4	8
Stop time from start	secs from start	4	16
Mode	switch bits (see below)	1	24
For AFT, Dev1, Dev2, Dev3, Prestart (5 per row)			
Interval	secs	3	26, 36, 46, 56, 66
Driver	n/a	1	32, 42, 52, 62, 72
PointerToParams	offset from pos 78	1	34, 44, 54, 64, 74
Global configuration	switches	1	76

Bit 0 Run main serial port at 57600 or 9600
Bit 1 Send ^(record type) before a driver starts
Bit 2 Send live records over serial
Bit 3..6 Not assigned, set to zero
Bit 7 Extend Global config.

For AFT, Dev1, Dev2, Dev3, Prestart (pointed to by above)

Parameter bytes various max of 15 78 for AFT, others vary

Max config string length = 13 + (5x5) + 1 + (5x15) = 114 bytes (228 hex chars, padded to 256 chars)

Mode bits

Bit 0 PMI sampling schedule enabled
Bit 1 AFT sampling schedule enabled
Bit 2 Slot 1 follows AFT sample
Bit 3 Slot 1 independent schedule
Bit 4 Slot 2 follows AFT sample
Bit 5 Slot 2 independent schedule
Bit 6 Slot 3 follows AFT sample
Bit 7 Slot 3 independent schedule

++

Example of a Configuration String

SAMI-pH programmed on Oct. 6, 2011

AFT uses driver 10,11 (pH-average) on 30 min intervals

All devices follow AFT

Device 1 - Serial + Power
Device 2 - Generic 0–5 V + Power
Device 3 - Power
Prestart - 4 hour intervals for DI pump

:ConfigHex (232 characters)

CAB39E84 000000F4 01E13380 57 000708 0A01 00258 030A 000258 0017 000258 011A 003840 001
C 07 000123042001080810041008170010010120256400043338333500020001020000000000000000000000000
00000000000000000000000000000000000000000000000000000000000000000000000000

General timing and mode

CAB39E84 - Time of programming (GMT) - Oct 6, 2011 18:05:56 (total seconds from 1/1/1904)
000000F4 - Time until start - 244 sec
01E13380 - Time from start until stop - 365 days (315360000 sec)
57 - Mode bits - (01010111 - Bits 6,4,2 = all devices follow AFT sample, bit 0= prestart schedule on, bit 1 = AFT schedule on)

000708 - AFT interval (1800 sec - 30 min)
04 - AFT Driver (CO_2 Ave+)
01 - Pointer to params (AFT always 01)

00258 - Device 1 interval (10 minutes - overridden by mode bits above)
03 - Device Driver
0A - Pointer to params (position relative to byte 1 of AFT driver in bytes)

00258 - Device 2 interval (10 minutes - overridden by mode bits above)
00 - Device Driver
17 - Pointer to params (position relative to byte 1 of AFT driver in bytes)

000258 - Device 3 interval (10 minutes - overridden by mode bits above)
01 - Device Driver
1A - Pointer to params (position relative to byte 1 of AFT driver in bytes)

003840 - Prestart interval (14400 sec - 4 hours)
00 - Driver
1C - Pointer (pre-start has no params)
07 - Global parameter switch - send live records, with record type early at 57.6K

SAMI-pH Driver 10/11 Parameters explained

In the example above the SAMI-pH is using driver 10/11, which is default.

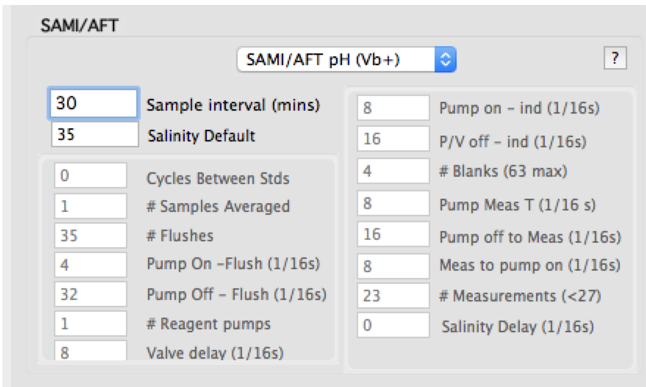
0001230420010808100410081700 - *driver 10 parameters (SAMI-pH Vb+ driver) see figure 22*

10010120256400043338333500 - *parameters for serial + power driver*

020001 - *02 Duration 00 Power select 01 # samples to average*

0200 - *02 Duration 00 Power select*

Padding
0000000000000000000000000000000000000000000000000
0000000000000000000000000000000000000



Parameter	**dec**	**hex**
Cycles Between Stds	0	00
# Samples Averaged	1	01
# Flushes	35	23
Pump On-Flush(1/16s)	4	04
Pump Off-Flush(1/16s)	32	20
# Reagent pumps	1	01
Valve delay(1/16s)	8	08
Pump on-ind(1/16s)	8	08
P/V off-ind(1/16s)	16	10
# Blanks	4	04
Pump Meas T(1/16s)	16	10
Meas to pump on(1/16s)	8	08
# Measurements	23	17
Salinity Delay(1/16s)	0	00

Figure 22: SAMI-pH settings in decimal and hexidecimal format.

Command Format

- Command format: one letter followed by a number of arguments as hex numbers and ending with carriage return (`CR`).
- Args may be separated by Space, Tab, comma, '/' or ':' the first separator may be omitted. For example "T 03/05/29 5 12:30:06" is equivalent to "T3 5 29,5,12 30 06"
- 123 is equivalent to 000123 if a long word is expected 0123 if a word or 23 if a byte.
- If more bytes are entered than the command uses the left most (first entered) bytes are ignored. For example, a command that takes a byte will read `1A2B` as `2B`.
- Arguments are represented as follows:

  (`B`) One byte (`S`) 12 bits (`W`) 2 bytes (`L`) 3 bytes (`E`) 4 bytes (`X`) don't care, () none, (`N`) nibble

  {} indicates return expected using above while {R} means returns record

  (`5A`) sending `5A` enables a variant of the commands normal function
- Arguments in [ ] are optional. Typically these optional arguments are present for a "write" to the AFT and omitted if the user wants to "read" from the AFT.
- No backspace or delete support for cmds sent - type non-hex arg with `CR` to abort.
- Results (reads) are returned as space separated hex and terminated with `CR`.
- Commands that are illegal or malformed return `?`, error code in hex followed by return.
- Any input returns `!` if a command or process is running.
- Echo is off by default. Echo off suppresses prompts and error text. Use `I` command to enable echo.

Command List

C (){R} Run Blank cycle on SAMI-CO_2

() - no argument required
{R} - returns a data record
A valid configuration is required. If AFT erased then error returned.
Returns (and if running writes) a data record.

D (W,[B],[W]) {memory stream} Dump Memory

(W - arg1) is number of pages beginning from page 0.
[B - arg2] - optional format switch 0 for binary, 1 for hex (default is binary)
[W - arg3] - optional start page
B - bit 0=1 send as hex return after page, bit 0=0 send as binary
Begins streaming memory with first data record.

E ([B]){W} Erase

() - no argument erases AFT memory
(5A) - for safety erase all of memory and clear ram vars.
{W} - returns the first unerased page or 8000 if all are erased
Erase shuts down all activity including time keeping but allows serial commands.
Stops real time clock

F (B)() Status ticks on/off & special cmd mode

(5A) - turns ticks off -turn off 1/sec status from AFT Enable Debug commands
(55) - turns on optional commands (see section below)
(any other byte) - turns ticks on and disables optional commands

G ([B])() Open flash and start recording

Starts real time clock if it is not running Clears n_drec number of records, n_erec number of error records. n-bytes Number of bytes stored - Is set to the start of the page after the last un-erased page. Restarting without erase is supported.

H (N){S} Read one adc channel

(N) - Channel 0..7 or
{S} - returns in Hex ADC count Voltage = (S/4096)*5.00V
0 - Photo Reference, gated in firmware so not useful
1 - Photo Signal, gated in firmware so not useful
2 - Battery if 12V is enabled else 0 V= count/4096*5V*3 Volts
3 - Thermistor
4 - 3rd Party input J6 pin8 - 5V full scale
5 - 3rd Party input J6 pin8 - 5V full scale
6 - 3rd Party input J6 pin8 - 5V full scale
7 - 3rd Party input J6 pin8 - Photo diode amplified current input

Special

If arg ≥ 80 turn on 12 V and read Batt, therm, 5 V in 1, 5 V in 2, 5 V in 3, photodiode restore 12 V

Returns {S S S S S S}

I ([B]){B} Immediate read status sw & bus

arg switches
Bit 0 Pump on
Bit 1 Valve on
Bit 2 12V on
Bit 3 Reserved - was Battery sense enable
Bit 4 debug LED off
Bit 5 echo off
Bit 6 Reserved
Bit 7 Reserved
Return Switches {B} as in arg

J (B) invokes loader returns nothing, used to load firmware after erase

(5A) - branch to loader
(5C) - Erase Board Type and SN 128 Bytes in microcontroller flash

L ([5A]){ConfigString} Load or Read Config + UserText

-- Read or load a string. Consisting of Configuration string (+ fill to 256 bytes) + UserText
() No argument gets configuration string from board.
(5A) - start 4 byte timer at zero and wait for CR from board After receiving carriage return, send load data as packed hex with no separator.
First non-hex non-return character causes abort of load.
Either a null between byte 256 and 512 or 512 bytes is a valid termination. Any non hex is an error.
Returns 2-byte checksum read from flash after write.
Successful load starts real time clock. Erase or reset stops clock

M ([B]){S,S,S,S,S,S} Measure LEDs w/o pumping

Read the ADC values no pump cycle
Arg default = FF (read all)
Bits enable sending of data below bit 2..7 - blue ref...dark signal
Returns {S} in same order as below
bit2 - Dark ref
bit3 - Dark signal
bit4 - LED1 ref
bit5 - LED1 signal
bit6 - LED2 ref
bit7 - LED2 signal

N ([B] B W W)

Compare or write a byte value to a range of memory W as page count
Verify N(byte value, word Start_page, word count_pages) Return (0 if true, first failed page if false)
Write N($5A, byte value, word Start_page, word count_pages)
Progress reporting
Returns hight byte of page +1 for each page started then XX last page address where

XX=00 for good FF for fail
(Should fix this, should be page started then 2 byte end address and 00 or FF)

O ([B]) {B} Read or write port A - set bits enable power out functions

() - no arg is 'read' with {B} returned as described below
(B) - arg writes to port A to turn on/off power out as below

Bit0 - 12 V
Bit1 - Valve - J4 pin6
Bit2 - Pump - J4 pin7
Bit3 - 3rd party power J5 pin 6
Bit4 - 3rd party power J5 pin 5
Bit5 - 3rd party power J5 pin 4
Bit6 - Select 12 V for 3rd party power
Bit7 - Select Battery for 3rd party power
Note that if both bit 6 and 7 are set, bit 7 is cleared - 12 V is selected

P ([B],[B]) Pump and valve powering

() - no argument pump and valve off
(B1) - one arg set pump and valve on or off
(B1,B2) - 2 args set on or off and restore after arg2 1/8 seconds
B1 - bit 0 turns pump on, bit 1 turns valve on
B2 - time to hold state of B1 before returning to original state (1/8's sec)
Turns on 12 V supply if required and restores to original state
Return Null just carriage return after time out - single threaded

Q (5A)() Close flash and stop recording.

R ([B])(R) Run sample cycle on device

Arg Slot Default device is AFT - 0 slot1..3, PMI is 4
Arg set bit 3 returns test error/info rec
Arg bit 2 selects error/info record
A valid configuration is required. If erased then error.
Returns (and if running writes) a data record

S ([B]){: E,W,L,L,L,W,W} Ask for status from AFT (note this is auto sent when RTS is high)

(B) If arg=0 (default) returns **:** followed by **:**
{E} time in seconds since L command - Cleared by Erase
{W} statusflags - Cleared by Erase, defined here:

bit 0 Clock started
bit 1 Recording started
bit 2 Recording ended on time
bit 3 Recording ended memory full
bit 4 Recording ended due to error, failure, or user stopped
bit 5 Data downloded
bit 6 Flash Open
bit 7 *Low or no battery before start 256*t_pmi seconds - fatal
bit 8 Battery low on measure cycle - fatal
bit 9 Battery low on blank cycle - fatal

bit 10 *Battery low on external device cycle - fatal
bit 11 *External device 1 fault - fatal for device shut it down
bit 12 *External device 2 fault - fatal for device shut it down
bit 13 *External device 3 fault - fatal for device shut it down
bit 14 Erased
bit 15 Power on flags not valid

(* Not yet implemented)

{L} - n_rec (3) number of data records - Cleared by Erase
{L} - n_erec (3) number of error records - Cleared by Erase
{L} - n_bytes (3) Number of bytes stored including config and user text as full pages - Cleared by Erase
If arg=1 returns Name(16) SN(4) FirmwareVer(4) AFT board version(2) AFT board Config(2) Cal(24) Cksum(1)
If arg=2 returns 128 bit microcontroller flash Name(16) SN(4) calibration TBD Checksum(1)

Commands turned on by `F55` command

@ ([X],[X],[X]...)(T) Test the command parser

Debug tool only works if echo is on.
Reports in text the number and value of args.

A (X)(T) List all commands

Debug tool only works if echo is on.
Lists all the commands.

B ( )(S) Battery Voltage

S the battery voltage 12 V must be enabled $V_bat = Arg * 5 * 3/4096$

T () (s) Thermistor Voltage

$V = 4096 * ThermistorRes/(ThermistorRes + 17400)$

Debug tools hidden - enabled by `F5A`

Z (W)( ) Set breakpoint

^C Break to debugger

^T Show current program address and reg.

Extra debug commands for now

K Send error CF with 2 extra bytes &h0201

V No arg send 'Hello World' out secondary port and echo for 10 sec then return 'Done'

V Any arg send 'Hello World' out serial port and return 0 if all
characters echo - for tester

W Return status word, MFG code, etc.

X Sleep for ever but wake every 8 sec and send time - reset to exit

Y Show time, internal flags, wake counter

Notes

While DTR is present on the serial port command mode is maintained and 5 V power is on. 12 V power is off by default but can be turned on with `I` or `O` command.

12 V power will cycle on and off as needed to run pump or valve.

*** Command Error Codes ***

`00` Wrong Number of Arguments
`01` Command Not Implemented
`02` Invalid Arguments
`03` Command Buffer Overflow
`04` Invalid Command Enter A return for a list of commands
`05` Error in config data
`06` > 2000 pages
`07` Invalid Configuration
`08` Bad Key
`09` Flash is Open
`0A` Flash is Not Open
`0B` Too Many Arguments
`0C` Too Few Arguments
`0D` Memory Full
`0E` Not Valid With Echo Off
`0F` Unimplemented Extenstion Index in Configuration
`10` Flash Data not erased
`11` Invalid Arguments

Error conditions

No battery - If main battery without load at wake from sleep is below Vmin.

AFT counts no battery event and schedules next wake for measurement.

Note that AFT does not attempt to write Flash memory on backup battery.

If 2 byte no battery count overflows AFT shuts down completely.

If AFT awakes to find battery restored it writes an error record with counts and time and resumes normal operation.

Battery fail - if AFT tries to power up analog, pump, valve, or external device and battery falls below Vmin:

> write an error record
>
> close Flash page
>
> shutdown completely until handshake from host.

Warranty

Sunburst Sensors, LLC warrants to the original purchaser that instruments manufactured by Sunburst Sensors shall be free from defects in materials and workmanship for the life of the product. Under this warranty, the instrument will be repaired or replaced as deemed appropriate by Sunburst Sensors without charge for parts or labor when the instrument is shipped prepaid to our location. This warranty does not apply to any instrument which has not been installed or used in accordance with proper operation and installation specifications. Sunburst reserves the right to void any warranty, written or implied, if upon Sunburst's examination of the instrument reveals failure was due solely, or in part, to accident, misuse, neglect, abuse, alteration, improper installation, unauthorized repair or improper testing by the buyer. Sunburst shall not be liable under any circumstances for indirect, special, consequential, or incidental damages in connection with, or arising out of, the sale, performance, or use of the instrument covered by this warranty. When a Product is returned to Sunburst Sensors for refurbishment/recalibration this service is considered normal preventative maintenance. Recalibration of your instrument shall not be treated as a warranty service unless recalibration of your instrument is required as the result of repairs to the instrument pursuant to this Warranty. Your instrument may only be repaired and refurbished by a certified, trained specialist from Sunburst Sensors, LLC. Breach of this requirement without prior consultation from Sunburst Sensors may result in the voiding of your Warranty.

If you would like more information on your AFT for self-repair or refurbishment please contact Sunburst Sensors. After notification is given that the interior of the instrument will be accessed, Sunburst Sensors is no longer responsible for defects incurred under the by the user.

Material Safety Data Sheet

1. IDENTIFICATION OF THE SUBSTANCE/PREPARATION AND OF THE COMPANY/UNDERTAKING
Product name: m-Cresol Purple sodium salt
Product Number: 211761
Company: Sigma-Aldrich
3050 Spruce Street
SAINT LOUIS, MO 63103
USA
Telephone: +18003255832
Fax: +18003255052
Emergency Phone: (314) 776-6555

2. COMPOSITION/INFORMATION ON INGREDIENTS
Synonyms: m-Cresolsulfonphthaleinsodium salt
Formula: $C_{21}H_{17}NaO_5S$
Molecular Weight: 404.41 g/mol
CAS-No. EC-No. Index-No. Classification Concentration
m-Cresol Purple sodium salt
62625-31-4 263-656-9 - - -

3. HAZARDS IDENTIFICATION
Not a hazardous substance or preparation according to EC-directives 67/548/EEC or 1999/45/EC.

4. FIRST AID MEASURES
If inhaled
If breathed in, move person into fresh air. If not breathing give artificial respiration.
In case of skin contact
Wash off with soap and plenty of water.
In case of eye contact
Flush eyes with water as a precaution.
If swallowed
Never give anything by mouth to an unconscious person. Rinse mouth with water.

5. FIRE-FIGHTING MEASURES
Suitable extinguishing media
Use water spray, alcohol-resistant foam, dry chemical or carbon dioxide.
Special protective equipment for fire-fighters
Wear self contained breathing apparatus for fire fighting if necessary.
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6. ACCIDENTAL RELEASE MEASURES
Personal precautions
Avoid dust formation.
Environmental precautions
Do not let product enter drains.
Methods for cleaning up
Sweep up and shovel. Keep in suitable, closed containers for disposal.

7. HANDLING AND STORAGE
Handling
Provide appropriate exhaust ventilation at places where dust is formed. Normal measures for preventive fire protection.
Storage
Store in cool place. Keep container tightly closed in a dry and well-ventilated place.

8. EXPOSURE CONTROLS/PERSONAL PROTECTION
Personal protective equipment
Respiratory protection
Respiratory protection is not required. Where protection from nuisance levels of dusts are desired, use type N95 (US) or type P1 (EN 143) dust masks. Use respirators and components tested and approved under appropriate government standards such as NIOSH (US) or CEN (EU).
Hand protection
For prolonged or repeated contact use protective gloves.
Eye protection
Safety glasses.
Hygiene measures
General industrial hygiene practice.

9. PHYSICAL AND CHEMICAL PROPERTIES
Appearance
Form powder.
Color
Dark red
Safety data
pH: No data available.
Melting point: No data available.
Boiling point: No data available.
Flash point: No data available.
Ignition temperature: No data available.
Lower explosion limit: No data available.
Upper explosion limit: No data available.
Water solubility: No data available.

10. STABILITY AND REACTIVITY
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Storage stability
Stable under recommended storage conditions.

Materials to avoid
Strong oxidizing agents.

Hazardous decomposition products
Hazardous decomposition products formed under fire conditions. Carbon oxides, sulfur oxides

11. TOXICOLOGICAL INFORMATION

Acute toxicity
No data available.

Irritation and corrosion
No data available.

Sensitization
No data available.

Chronic exposure
IARC: No component of this product present at levels greater than or equal to 0.1% is identified as probable, possible or confirmed human carcinogen by IARC.

Potential Health Effects
Inhalation: May be harmful if inhaled. May cause respiratory tract irritation.
Skin: May be harmful if absorbed through skin. May cause skin irritation. Eyes: May cause eye irritation.
Ingestion: May be harmful if swallowed.

12. ECOLOGICAL INFORMATION

Elimination information (persistence and degradability)
No data available.

Ecotoxicity effects
No data available.

Further information on ecology
No data available.

13. DISPOSAL CONSIDERATIONS

Product
Observe all federal, state and local environmental regulations.

Contaminated packaging
Dispose of as unused product.

TRANSPORT INFORMATION

ADR/RID
Not dangerous goods.

IMDG
Not dangerous goods.
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IATA
Not dangerous goods.

REGULATORY INFORMATION

Labeling according to EC Directives
Further information: The product does not need to be labeled in accordance with EC directives or respective national law.