The Auto-BOD Mk II Assembly and Operation Instructions

The WHOI Auto-BOD Mk-II represents the latest generation **AUTO**matic **B**iological **O**xygen **D**emand drawdown measurement system. With the exterior constructed using corrosion free materials, this relatively maintenance free instrument is easily disassembled to fit into a watertight case for transport. The 12 sample bottles are held in pie shaped plastic holders that provide an integral alignment and carousel locking feature suitable for at-sea use. Data are presented in a real time fixed field length string and also recorded onto an internal micro SD card for additional backup. Diagnostic routines to provide continuous micro-stepping for fine spot transit sampling or carousel re-alignment are enabled by setting an internal hardware jumper.

Power is provided to the unit by a 12V wall type supply, however since the power consumption is relatively low with an average current draw of 70 mA, remote operation via an 8 cell battery pack or 12V sealed Lead-acid battery is possible. The firmware as supplied is intended for ‘Close and Play’ operation, that it no interaction other than removing the shipping lock down screws, connecting the power/data cable, loading the bottles in their carriers, and insuring a micro SD card is installed is necessary to start a run.

To aid with splash tolerance, particularly in salt water – at sea environments, all electronic and internal drivetrain elements are protected with custom gaskets and a drive shaft O-ring seal. Power is provided and serial EIA-232 data are presented via a single 3 meter long cable. Since most modern computers no longer support EIA-232 ports, a 232-USB serial converter is required.

A high torque brushed DC motor permits fast bottle to bottle transit time and a power efficient translation of the sample carousel. On power up, the carousel will transit to the starting 'Home' position on the seam between Bottle 12 and Bottle 1. The Optode is programmed to provide 1 Hz samples, and a complete 12 bottle 25/sample per bottle scan is possible in less than 15 minutes allowing (4) complete time aligned rotations per hour.

A top mounted Liquid Crystal Display (LCD) provides the operator with a read out of all fundamental parameters such as elapsed time, Amplitude, Phase, Bottle being sampled, sample number, and temperature. Between bottle transits are indicated and the dwell time remaining until the start of the next carousel rotation is also shown, something not provided in the primary data stream. The firmware and serial number reported immediately after power is applied. The LCD is a useful aid when computer free internal logging is desired.

Assembling the Unit

The instrument is shipped fully assembled and with the bottles removed from the holders to reduce the chance of breakage. The carousel is locked in place with (2) removable thumb screws oriented 180 Degrees apart on either side of the base. The other components include a 3 meter long Power/Data cable, the bottle holders, the individual bottles, the external power supply, a programming lock out extension cable, and a small servicing tool kit. Set up and commissioning of the system should take less than an hour with securing and aligning the bottles in the pie slices taking the longest. A procedure to perform a sensor calibration using saturated water at a nominal temperature is described later.

AutoBOD and System components

Power and Data are provided over a single 3 meter long cable that breaks out into power and DB-9 Serial connectors. The programming DB-9M to DB9-F lock out cable data cable may also be used to extend the dual cable even further. The primary purpose of this cable however is to insure that in the event of the logging computer inadvertently power cycling, the AutoBOD will not interpret this as a firmware programming request and reset the instrument during the middle of a run.

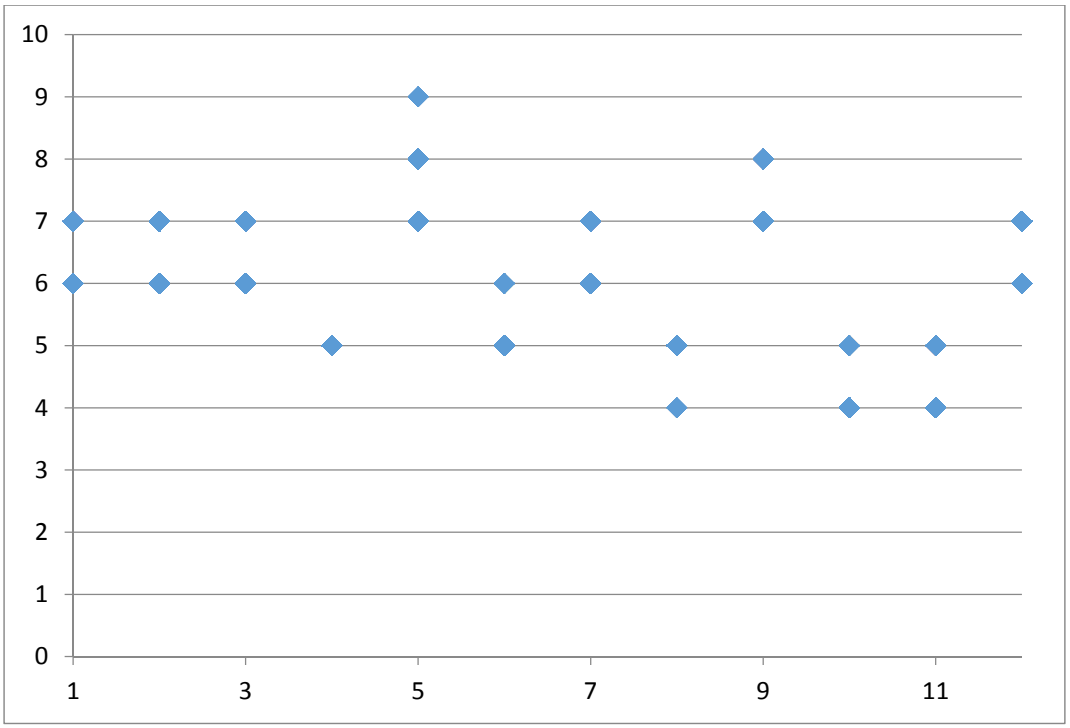
An On/Off switch is not provided, so powering down the unit only can occur by unplugging the wall supply or breaking the connection with the cable adapter. **Reverse polarity protection is provided internally.** The power supply convention is center is Positive (9-16V) and the Barrel is the Ground.

The 125 ml bottles are packed without the stoppers installed and removed from the holders. An integral alignment post in the holder is provided to set the Optode spot direction. The hole in the center of the post will accept a small wood cotton swab shaft. A single or fractional wrap of electrical tape some is sometimes required to provide compliance between the holder and the eccentricity of undersized bottles. A second single exterior wrap of tape around the holder and the bottle insures the bottles are held firmly in place.

Bottle in Holder showing Spot orientation

When apply the tape, work from the middle while pulling tight from either side so it will not exert a small force and skew the spot position in the holder. The AutoBOD utilizes a spot seeking routine that optimizes the Optode fiber illumination so some amount of misalignment or movement is acceptable.

When initially setting the bottles up in the holders, a quick 15 to 30 minute diagnostic can be performed by normally running the AutoBOD and interpreting the Bottle vs Spot Seek value provided in the data string. The routine that seeks a spot advances the carousel to a location prior to where it would be illuminated and then advances in small increments while testing the signal amplitude returned. When an amplitude threshold of 1000 is observed, the carousel then advances a slightly smaller interval to will place the fiber in an optimum alignment. The step amount required for each individual bottle spot lock is presented as the next to last value in the data string prior to the serial number and <CR><LF> ending the scan.

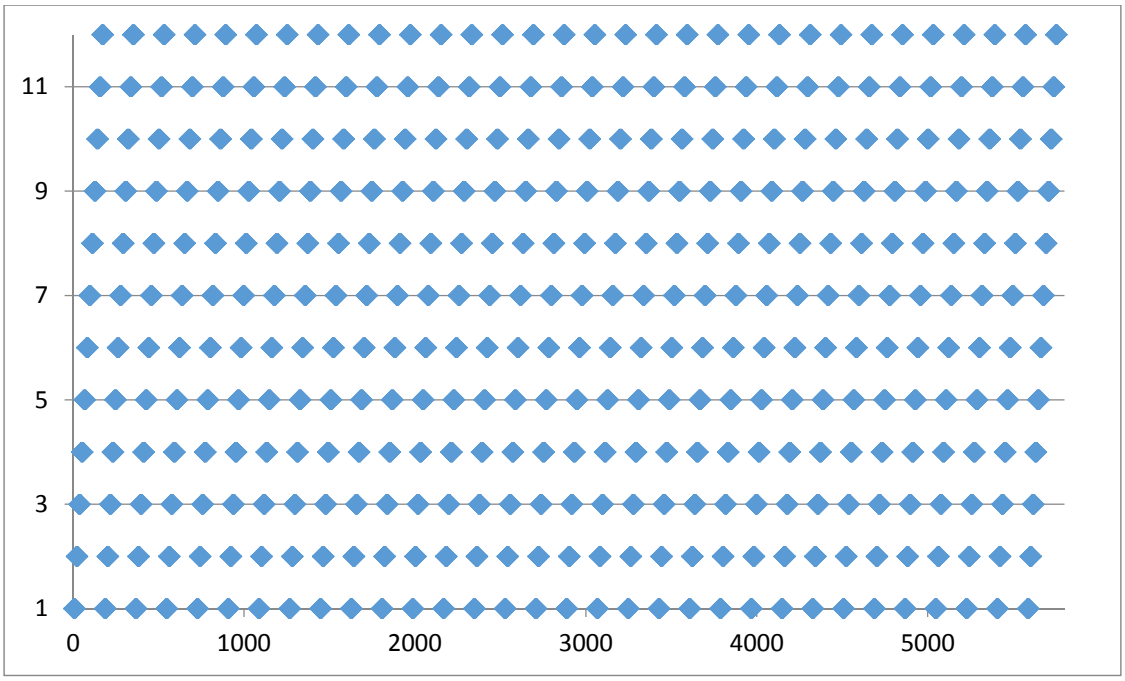


This plot shows typical Spot Seek intervals required for each bottle. The range of steps required in this example is 4 to 9 with the average being in the vicinity of 6. This is reasonably good positioning to insure spot detection for all bottles, a step count from 5-8 is ideal. **Usually looking through the bottle at the Optode light after the while slightly rotating the bottle to maximize the eclipse during the first rotation is all that is required.**

While becoming familiar with the instrument and understanding how well it is performing, the engineering data provided in the data string can be quite helpful. For example in addition to bottle number, the raw encoder output is provided. This could be interpreted later with the Spot Seek count to determine if a bottle was disturbed or shifted during a run.

The Long Wave Infra-Red (LWIR) thermometer used to determine the sample temperature also provides an internal sensor body temperature. This performs two functions; serving as a long term incubator air temperature sensor and it is also used internally to improve the LWIR temperature determination algorithm. A rule of thumb is that as long as the sensor temperature and temperature being reported are within 5 Deg. C of each other, no further temperature compensation analysis is required. The AutoBOD internally dissipates 850 mW with the majority of that being immediately under the top cover, so only a small amount of bottle self-heating occurs.

Another diagnostic that can be determined from the normal operation data set is to sequentially plot out the bottle numbers. This as simple as plotting out the bottle number column and using the X-Y graph feature in Excel;



Plot showing 32 complete rotations over 8 hours with no missing bottles shown

To account for misalignments or the possibility of a bottle turning in the holder, the Spot Seek routine looks for a threshold event within a defined table rotation zone before advancing to the next bottle. Since the AutoBOD is designed to determine rate of change measurements, this is performed to keep the sampling times aligned for each bottle, i.e Bottle # 6 occurs at nearly the same time during each rotation even if bottles are missing or are not detected. The carousel simply does not rush to the next location resulting in a corresponding bottle sample interval time skew.

To assemble a bottle in the holder simply place a bottle on a bench and for safety press the holder down to the bench from either side. Some bottles will be nominally tight and others will be loose requiring at most a single wrap of electrical tape to make them snug. Once fitted, rotate the bottle until the spot aligns with the post in the front of the holder. The spots are generally installed orthogonal to the printing on the bottle so a clear view of the Optode light is visible. A bottle loaded onto the carousel should not rotate in the holder, however adding an additional wrap of tape around the seam of the holder and bottle will lock it in place. This allows the bottle to be handled afterwards for refilling with little if any movement occurring. Do not overtighten the bottles with too much tape. Repeat for the remaining 11 bottles.

AutoBOD Operation

The instrument firmware is intended to simplify and reduce steps to initiate a BOD run. The micro SD card records all data presented including the time stamp for every bottle scan presented. An internal register creates sequentially numbered files that will only increment with a

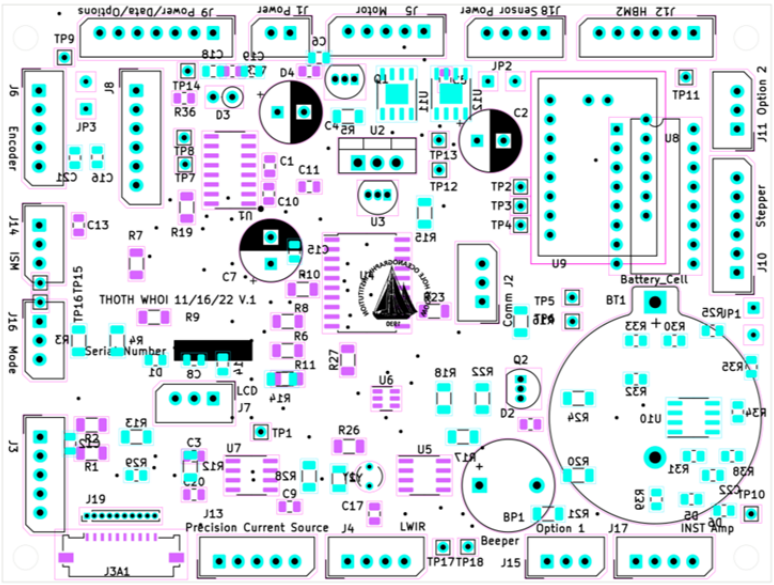
complete power cycle. On power up the front LCD screen will indicate the time, version of the program, and serial number in the format ABOD046.AB3 with ABOD identifying it as an AutoBOD File, 046 being the 46th start of the instrument, and AB3 indicating the data being from Serial Number 3. The .AB3 extension is a .txt file and can be read into the processing program or MatLab without the need for conversion.

On power up the carousel will rotate to the home position just forward of Bottle #1, set the clock to 00:00:00, and then commence. After a complete rotation the carousel will transit to home and then wait until a top of, quarter past, bottom, or quarter before the hour. The clock on the LCD will continue to update at 1 Hz intervals indicating the time remaining until the start of the next cycle. A beep tone is heard when the run starts and then again at the beginning of every rotation sequence.

The Real Time Clock (RTC) is programmed to display elapsed time from the initiation of the run after reaching the Home position. The firmware will set the clock to 00:00:00 on 01/01/23. Actual time can be programmed via a software upload and the circuit board has a back-up battery holder (CR2032 coin cell). The decision to go with elapsed time vs pre-programmed time was two-fold. First the instrument will start to take sample within a few minutes of power up rather than waiting for a 15 minute from the top of the hour interval. Second, the instrument clock will work reliably without any concern that the RTC has been corrupted during shipping or extreme laboratory conditions. A firmware upgrade will allow actual time to be loaded from the logging computer without the need for a specific program change.

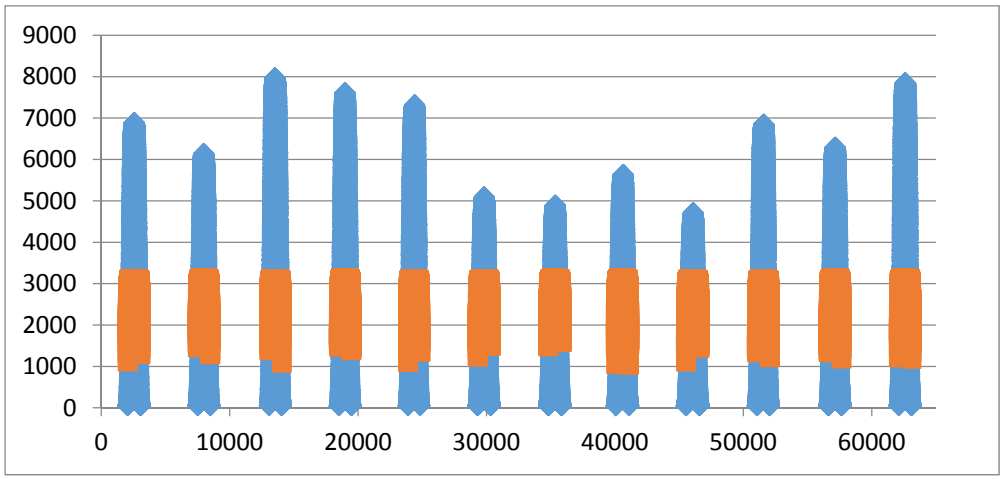
Diagnostic Routines Prior to Normal Operation

The acquisition program starts up without the need for any configuration. The carousel is delivered pre-calibrated so that it will seek a position prior to the bottle and then seek a spot until an amplitude threshold is met, typically 1000 counts. Two diagnostic routines are available by inserting a jumper in the 3 pin J16 “Mode” connector that is located along the same edge of the micro-SD card shown in the circuit board figure below. Color coded jumper shunts are provided, RED for *microstep* and BLACK for *table cal*.



These functions are polled only on power up and inserting them afterwards will have no effect. The micro-step routine is a recommended diagnostic to perform as it provides raw scans as the fiber transits the spot, useful for determining how well aligned the bottles are in their holders.

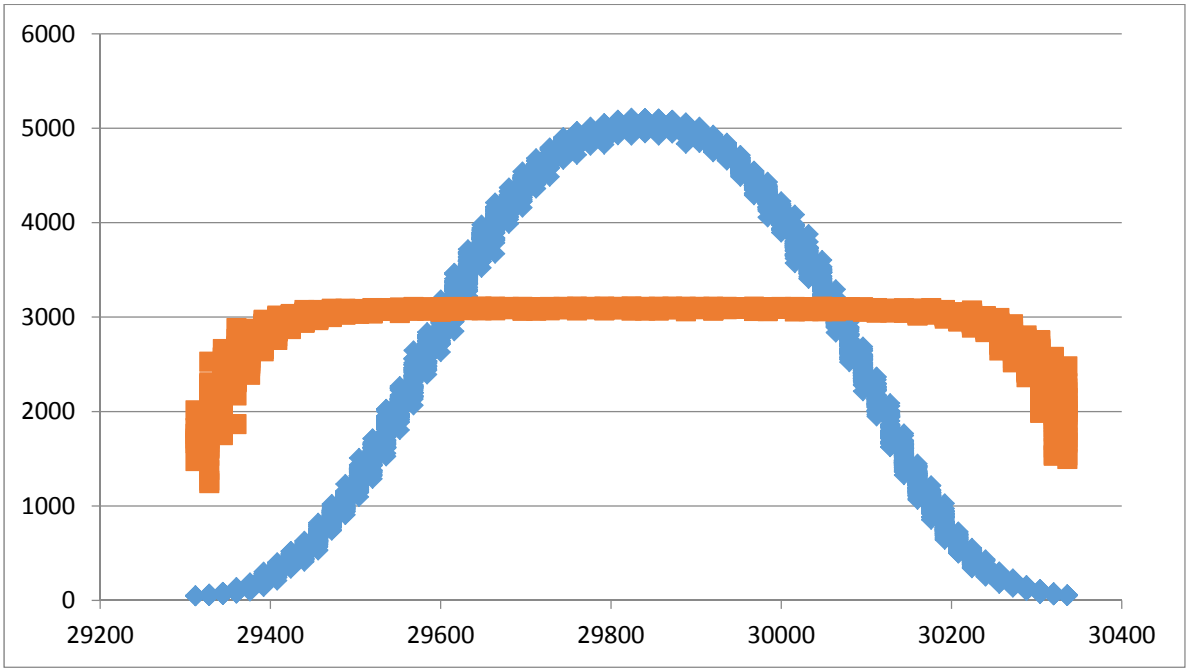
The micro-step routine works independently of the table encoder and steps the carousel in small intervals while measuring the Optode. After each step the Optode is measured and the amplitude is tested for an amplitude threshold above 50, a value that indicates the detectable edge of a spot. If this condition is met, then the data is presented. An example of an 8 hour 12 bottle scan using the micro-step diagnostic;



Amplitude (Blue) and Phase (orange) for all 12 bottles vs Carousel Encoder Position

Plotting a detail (below) of any bottle shows the carousel rotation as the spot transits in front of the Optode fiber. With an amplitude threshold above 1000 counts, the Phase can be shown to be somewhat constant, and in particular over many cycles.

The figure below represents a single bottle detail from the same data set of un-averaged sampling encompassing 32 rotations. The table is resolved internally to 12 bits of resolution and is presented as an 8 sample total yielding 16 bit result. There are no outliers or skewing due to spot rotation.



Small Step detail show spot sensitivity for Amplitude (blue) and Phase (orange) vs carousel encoder position.

Data Format

Data are presented at 1 Hz in fixed length fields at 19,200 Baud, No Parity, 1 Stop bit;

0004718 3109 001574 1 08144 02 013 01/02/23 01:01:47 12.12 10.64 06 00002<CR><LF>
0004713 3103 001582 1 08144 02 014 01/02/23 01:01:49 12.12 10.71 06 00001<CR><LF>
0004713 3103 001583 1 08144 02 015 01/02/23 01:01:51 12.12 10.69 06 00002<CR><LF>
0005709 3115 001566 1 13632 03 001 01/02/23 01:02:31 12.13 10.82 06 00487<CR><LF>
0005717 3116 001564 1 13632 03 002 01/02/23 01:02:33 12.13 10.80 06 00482<CR><LF>
0005722 3110 001572 1 13632 03 003 01/02/23 01:02:35 12.13 10.80 06 00485<CR><LF>

The fields in order are;

Amplitude, typically no larger than 9999
Phase, typically no larger than 9999
Optode Calculated O2 (re 20 Deg C)
error code (0 to 5)
Carousel Encoder raw position (0-65,535)
Bottle Number (1-12)
Sample Number (1-15)
Date
Elapsed time from start
Internal LWIR sensor temperature in Deg C.
Bottle LWIR temperature in Deg C.
Steps required to acquire spot (1 to 15)
Serial Number or Light Level
<CR><LF> Carriage Return and Line Feed

An extra white space is provided before the temperature so the string length will not vary when negative values are presented. Acceptable error codes are 0 (no) and 5 (excessive illumination).

Data Processing

Pending

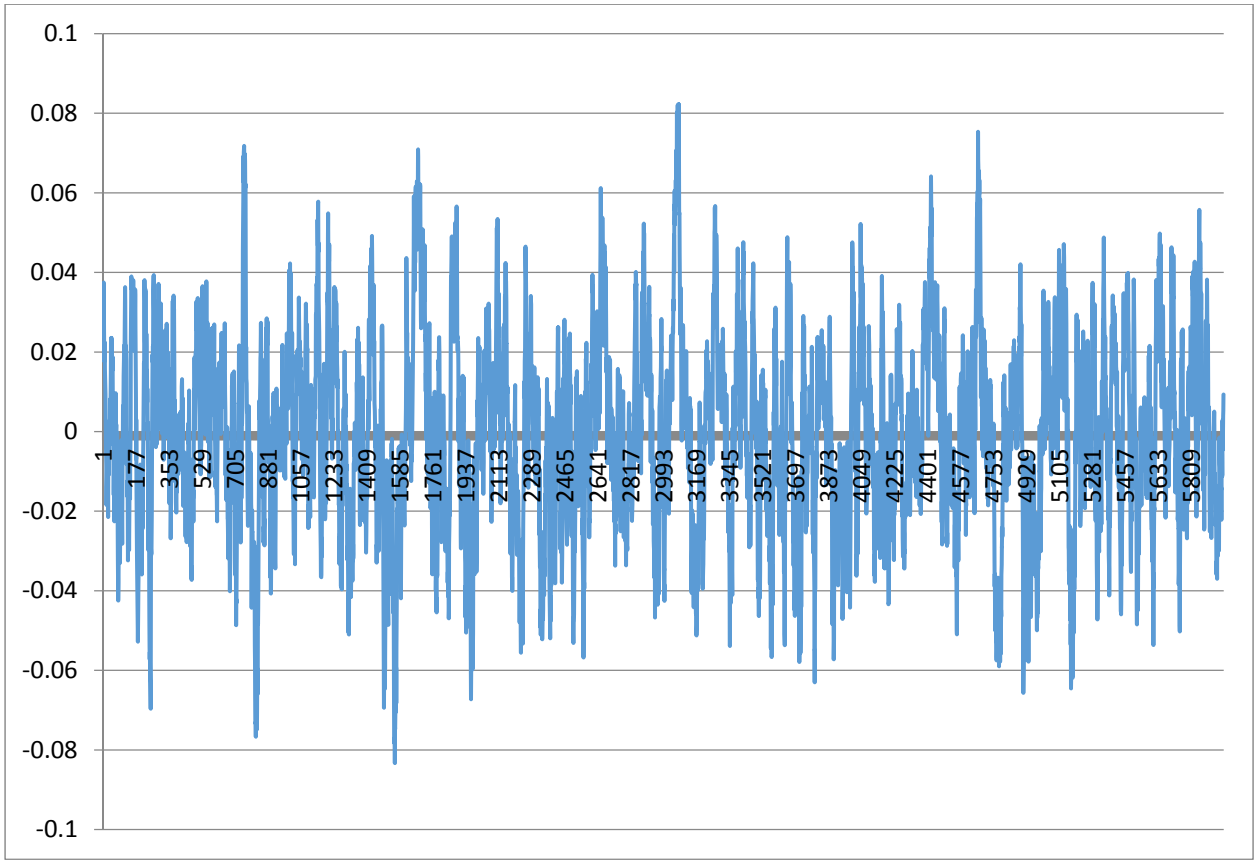
Pre-operation Saturated Water Calibration Procedure

Pending

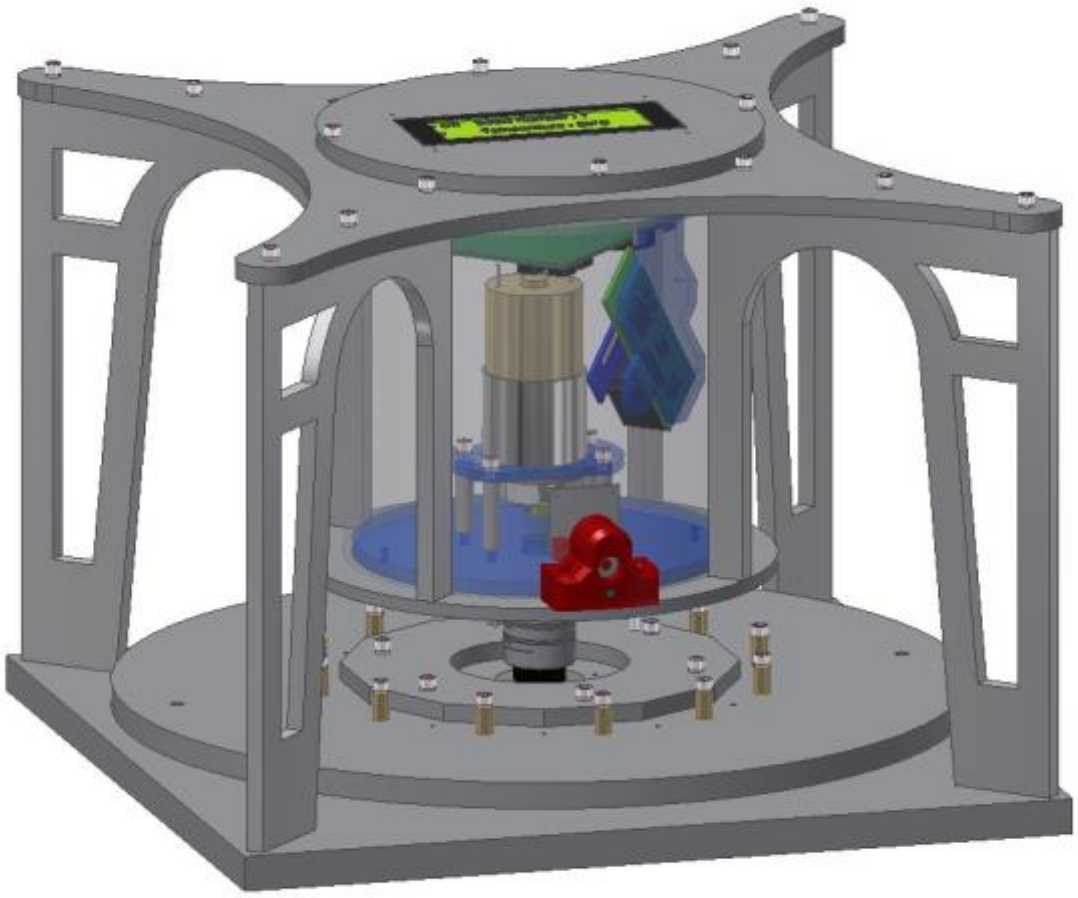
Specifications

12 Bottle Sample Time: Less than 15 minutes locked to 00:00, 00:15, 00:30, and 00:45 minutes from the top of the hour.
Serial Data Output: 19,200 Baud, N, 8, 1
Data Format: Fixed field length delimited by a <CR><LF>
Bottle to Bottle Transit Time: 14 seconds
Bottle Spot and Centering time: Less than 15 seconds
Pre-Sample Dwell: 2 seconds
Sample Rate: 1 Hz
Samples per Bottle: 25
Carousel Resolution: 12 bits
Operating Voltage: 9-16 V at 60 mA, 85 mA during transit
Dimensions: 12 inches x 12 inches (base) x 9.25 (height)
Weight: 5.07 kg empty, 8.52 kg with (12) loaded bottles
Individual bottle weight: 288 g

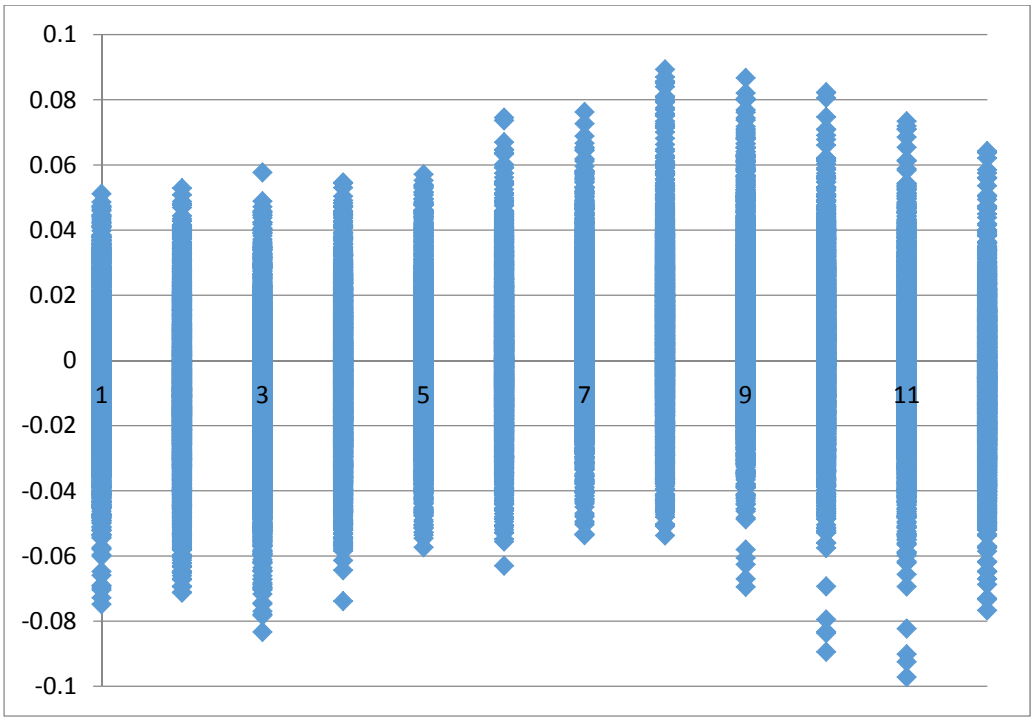
Supporting Figures



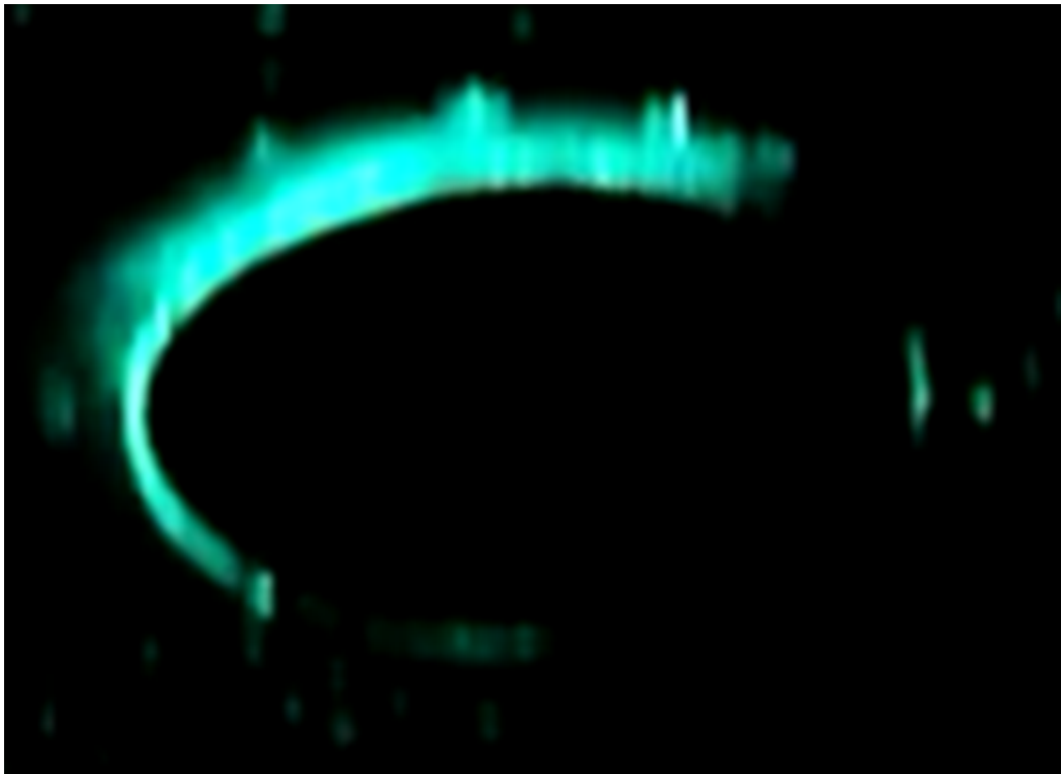
Bottle to Bottle Temperature Variability over 8 hours



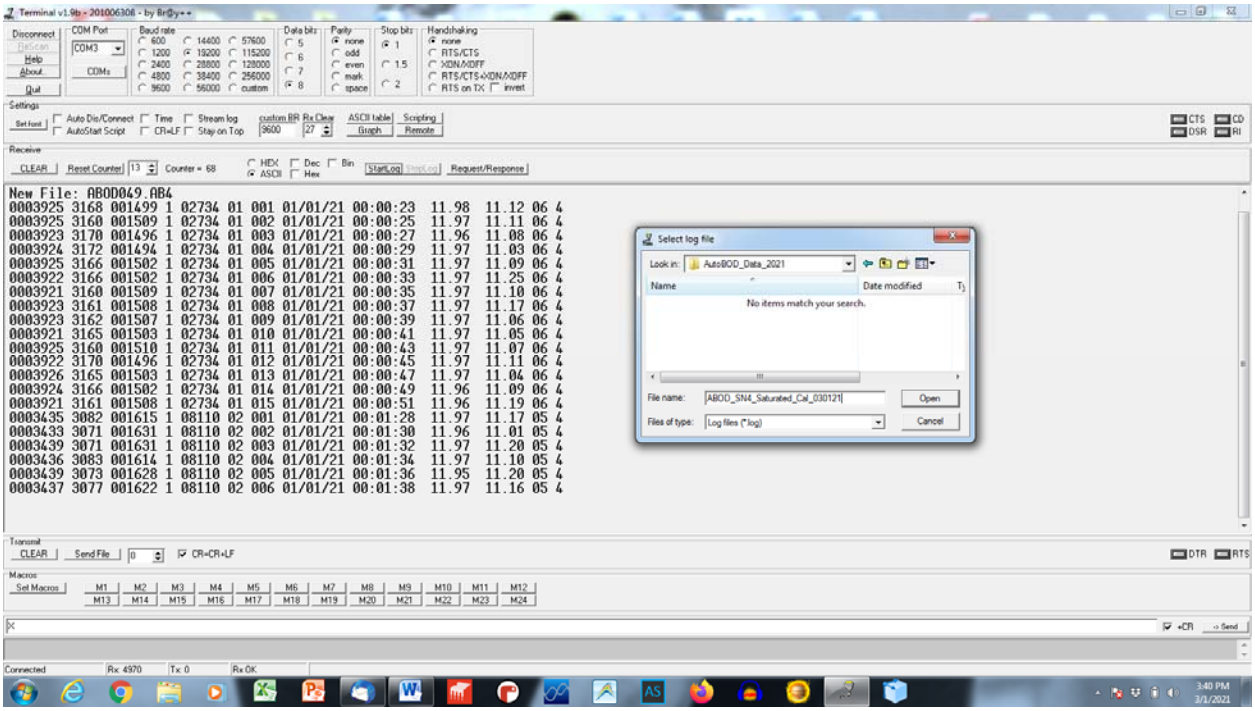
Detail of AutoBOD mechanical structure showing motor, drivetrain, FIRE, Optode carrier, and internal PCB mounting



Fifteen sample average, 36 hour, bottle to bottle temperature variability



A well centered Optode spot in eclipse


Terminal v1.9b - 20100308 - by Br@y++
New File: ABOD049.AB4
0003925 3168 001499 1 02734 01 001 01/01/21 00:00:23 11.98 11.12 06 4
0003925 3160 001509 1 02734 01 002 01/01/21 00:00:25 11.97 11.11 06 4
0003923 3170 001496 1 02734 01 003 01/01/21 00:00:27 11.96 11.08 06 4
0003924 3172 001494 1 02734 01 004 01/01/21 00:00:29 11.97 11.03 06 4
0003925 3166 001502 1 02734 01 005 01/01/21 00:00:31 11.97 11.09 06 4
0003922 3166 001502 1 02734 01 006 01/01/21 00:00:33 11.97 11.25 06 4
0003921 3160 001509 1 02734 01 007 01/01/21 00:00:35 11.97 11.10 06 4
0003923 3161 001508 1 02734 01 008 01/01/21 00:00:37 11.97 11.17 06 4
0003923 3162 001507 1 02734 01 009 01/01/21 00:00:39 11.97 11.06 06 4
0003921 3165 001503 1 02734 01 010 01/01/21 00:00:41 11.97 11.05 06 4
0003925 3160 001510 1 02734 01 011 01/01/21 00:00:43 11.97 11.07 06 4
0003922 3170 001496 1 02734 01 012 01/01/21 00:00:45 11.97 11.11 06 4
0003926 3165 001503 1 02734 01 013 01/01/21 00:00:47 11.97 11.04 06 4
0003924 3166 001502 1 02734 01 014 01/01/21 00:00:49 11.96 11.09 06 4
0003921 3161 001508 1 02734 01 015 01/01/21 00:00:51 11.96 11.19 06 4
0003435 3082 001615 1 08110 02 001 01/01/21 00:01:28 11.97 11.17 05 4
0003433 3071 001631 1 08110 02 002 01/01/21 00:01:30 11.96 11.01 05 4
0003439 3071 001631 1 08110 02 003 01/01/21 00:01:32 11.97 11.20 05 4
0003436 3083 001614 1 08110 02 004 01/01/21 00:01:34 11.97 11.10 05 4
0003439 3073 001628 1 08110 02 005 01/01/21 00:01:36 11.95 11.20 05 4
0003437 3077 001622 1 08110 02 006 01/01/21 00:01:38 11.97 11.16 05 4
Select log file
Look in: AutoBOD_Data_2021
Name
Date modified
No items match your search.
File name: ABOD_SN4_Saturated_Cal_030121
Open
Files of type: Log files (*.log)
Cancel
Connected
Rx: 4970
Tx: 0
Rx OK
3:40 PM
3/1/2021