Thompson O-124-N / Dunbar O-131-N

Data Report NBP1901

RVIB Nathaniel B. Palmer

December 20, 2018 – January 23, 2019

Transport of the Antarctic Peninsula & Bellingshausen Sea: Antarctic Slope Current Origins

United States Antarctic Program

Data Report Prepared By:
Matt Pullen

Table of Contents

Introduction

The NBP data acquisition systems continuously log data from the instruments used during the cruise. This document describes:

- The structure and organization of the data on the distribution media
- The format and contents of the data strings
- Formulas for calculating values
- Information about the specific instruments in use during the cruise
- A log of acquisition problems and events during the cruise that may affect the data
- Scanned calibration sheets for the instruments in use during the cruise.

The data is distributed on a DVD+R or CD-ROM written in ISO9660 level-1 format. It is readable by virtually every computing platform.

All the data has been archived using 'tar' and compressed using 'gzip', identified by the '.tz' extension. Tools are available on all platforms for uncompressing and de-archiving these formats: On Macintosh use the built-in Archive Utility, or tar in the terminal. On Windows operating systems use WinZip or 7Zip.

MultiBeam and Bathymetry data, if collected, are distributed separately.

IMPORTANT: Read the last section, "Acquisition Problems and Events," for important information that may affect the processing of this data.

Distribution Contents at a Glance

Volume 1 of 1: NBP1901

File	Description
/	Root level directory
NBP1901.gmt	GMT binary file of MGD77 data
NBP1901.mgd	Full Cruise MGD77 data file
NBP1901.trk	Text file of cruise track
1901DATA.docx	Data Report NBP1901 (MS Word)
1901DATA.pdf	Data Report NBP1901 (PDF format)
INSTCOEF.TXT	Instrument Coefficient File
/process	Processed data
1901JGOF.tz	JGOFS format data files
1901MGD.tz	MGD Data
1901PCO2.tz	Merged pCO2 data files
1901PROC.tz	Other processed data
1901QC.tz	Daily RVDAS QC postcript plots
/rvdas/nav	Navigation data
1901adcp.tz	ADCP Data Sets
1901gyr1.tz	Gyro raw data
1901s330.tz	Seapath 330 data
1901seap.tz	Seapath 200 data
/rvdas/uw	Underway data
1901bwnc.tz	Baltic winch data
1901ctdd.tz	CTD depth data
1901eng1.tz	Engineering data
1901grv1.tz	Gravimeter data
1901hdas.tz	HydroDAS raw data
1901knud.tz	Knudsen raw data
1901mbdp.tz	Multi-beam depth
1901mwx1.tz	Meteorology raw data
1901ndfl.tz	Digital Fluorometer raw data
1901pco2.tz	pCO_2 raw data
1901pguv.tz	GUV raw data
1901rtmp.tz	Remote Temperature data
1901tsg1.tz	Micro TSG1 data
1901tsg2.tz	Micro TSG2 data
/Imagery	Cruise Imagery
1901Imag.tz	Collection of Imagery Files
/ocean	Ocean data
1901ctd.tz	CTD Data

Extracting Data

The data files will have a ".tz" extension on the filename. The ".tz" extension is for files whose contents have been archived using the "tar" utility and compressed with the "gzip" utility.

An example of creating a compressed archive file:

```
tar -czvf archive_filename files_to_archive
```

An example of listing the files in an archive:

```
tar -tzvf archive_filename
```

An example redirecting the list output to a file, where `contents.list` is the name of the file to create:

```
tar -tzvf archive_filename > contents.list
```

An example extracting all files from the archive:

```
tar -xzvf archive_filename
```

An example extracting specific files from the archive:

```
tar -xzvf archive_filename list_of_files_to_extract
```

Distribution Contents

Cruise Track

The distribution DVD includes a GMT cruise track file (NBP1901.trk). It contains the longitude and latitude at one-minute intervals extracted from the NBP1901.gmt file.

Satellite Images

Satellite Images processed for this cruise can be found in the directory, /Imagery in two subdirectories, ice and wx (weather). Files are named using the convention, IdDDDYYA.jpg where:

Id = image type (ice = ice, wx = weather)
DDD = year-day
YY = year
A = allows for multiple images of one type for one day

NBP Data Products

Two datasets are created on each cruise: JGOFS and MGD77.

The data processing scripts used to produce JGOFS and MGD77 data sets create a lot of intermediate files. These files are included on the data distribution media in a file called 1901proc.TAR. They are included to make re-processing easier in the event of an error, but no extensive detail of the formats is included in this document. If you have any questions, please contact itvessel@usap.gov.

JGOFS

The JGOFS data set can be found on the distribution media in the file /process/NBP1901JGOF.tar. The archive contains one file produced for each day named jgDDD.dat.gz, where DDD is the year-day the data was acquired. The ".gz" extension indicates that the individual files are compressed before archiving. Each daily file consists of 22 columnar fields in text format as described in the table below. The JGOFS data set is created from calibrated data decimated at one-minute intervals. Several fields are derived measurements from more than a single raw input. For example, Course Made Good (CMG) and Speed Over Ground (SOG) are calculated from gyro and GPS inputs. Daily plots during the cruise are produced from the JGOFS data set. Note: Null, unused, or unknown fields are indicated as "NAN" as 9999 in the JGOFS data.

Field	Data	Units
01	UTC Date	dd/mm/yy
02	UTC Time	hh:mm:ss
03	Seapath Latitude (negative is South)	tt.tttt
04	Seapath Longitude (negative is West)	ggg.gggg
05	Speed Over Ground	knots
06	GPS HDOP	-
07	Gyro Heading	Degrees (azimuth)
08	Course Made Good	Degrees (azimuth)
09	Mast PAR	µEinstein's/meter2
10	Sea Surface Temperature	°C
11	Sea Surface Conductivity	siemens/meter
12	Sea Surface Salinity	PSU
13	Sea Depth (uncorrected, calc. sw soud vel. 1500 m/s)	meters
14	True Wind Speed (max speed windbird)	meters/sec
15	True Wind Direction (max speed windbird)	degrees (azimuth)
16	Ambient Air Temperature	°C
17	Relative Humidity	%
18	Barometric Pressure	mBars
19	Sea Surface Fluorometry	volts (0-5 FSO)
20	Transmissometry	%
21	PSP	W/m2
22	PIR	W/m2

MGD77

The MGD77 data set is contained in a single file for the entire cruise. It can be found in the top level of the distribution data structure as NBP1901.mgd. The file NBP1901.gmt is created from the MGD77 dataset using the “mgd77togmt” utility. NBP1901.gmt can be used with the GMT plotting package.

The data used to produce the NBP1901.mgd file can be found on the distribution media in the file /process/1901proc.tar. The data files in the archive contain a day’s data and follow the naming convention Dddd.fnl.tz, where ddd is the year-day. These files follow a space-delimited columnar format that may be more accessible for some purposes. They contain data at one-second intervals rather than one minute and are individually “gzipped” to save space. Below is a detailed description of the MGD77 data set format. The other files in the archive contain interim processing files and are included to simplify possible reprocessing of the data using the RVDAS NBP processing scripts.

All decimal points are implied. Leading zeros and blanks are equivalent. Unknown or unused fields are filled with 9’s. All “corrections”, such as time zone, diurnal magnetics, and EOTVOS, are understood to be added.

Col	Len	Type	Contents	Description, Possible Values, Notes
1	1	int	Data record type	Set to "5" for data record
2-9	8	char	Survey identifier	
10-12	3	int	Time zone correction	corrects time (in chars 13-27) to UTC when added; 0=UTC
13-16	4	int	Year	4 digit year
17-18	2	int	Month	2 digit month
19-20	2	int	Day	2 digit day
21-22	2	int	Hour	2 digit hour
23-27	5	real	Minutes x 1000	
28-35	8	real	Latitude x 100000	Positive = North, Negative = South. (-9000000 to 9000000)
36-44	9	real	Longitude x 100000	Positive = East, Negative = West. (-18000000 to 18000000)
45	1	int	Position type code	1 = Observed fix, 3 = Interpolated, 9 = Unspecified
46-51	6	real	Bathymetry, 2-way travel time	In 10,000th of seconds. Corrected for transducer depth and other such corrections.
52-57	6	real	Bathymetric, corrected depth	In tenths of meters
58-59	2	int	Bathymetric correction code	This code details the procedure used for determining the sound velocity correction to depth
60	1	int	Bathymetric type code	1 = Observed, 3 = Interpolated (Header Seq. 12), 9 = Unspecified
61-66	6	real	Magnetics total field, 1st sensor	In tenths of nanoteslas (gammas)
67-72	6	real	Magnetics total field, 2nd sensor	In tenths of nanoteslas (gammas), for trailing sensor
73-78	6	real	Magnetics residual field	In tenths of nanoteslas (gammas). The reference field used is in Header Seq. 13
79	1	int	Sensor for residual field	1 = 1st or leading sensor, 2 = 2nd or trailing sensor, 9 = Unspecified
80-84	5	real	Magnetics diurnal correction	In tenths of nanoteslas (gammas). (In nanoteslas) if 9-filled (i.e., set to "+9999"), total and residual fields are assumed to be uncorrected; if used, total and residual are assumed to have been already corrected.
85-90	6	F6.0	Depth or altitude of magnetics sensor	(In meters). Positive = Below sea level, 3 = Above sea level
91-97	7	real	Observed gravity	In 10th of mgals. Corrected for Eotvos, drift, tares
98-103	6	real	EOTVOS correction	In 10th of mgals. E=7.5 V cos phi sin alpha + 0.0042 V*V
104-108	5	real	Free-air anomaly	In 10th of mgals, G = observed, G = theoretical
109-113	5	char	Seismic line number	Cross reference for seismic data
114-119	6	char	Seismic shot-point number	
120	1	int	Quality code for navigation	5 = Suspected, by the originating institution 6 = Suspected, by the data center 9 = No identifiable problem found

Science of Opportunity

ADCP

The shipboard ADCP system measures currents in a depth range from about 30 to 300 m -- in good weather. In bad weather or in ice, the range is reduced, and sometimes no valid measurements are made. ADCP data collection is the OPP-funded project of Eric Firing (University of Hawaii) and Teri Chereskin (Scripps Institution of Oceanography). Data is collected on both the LMG and the NBP for the benefit of scientists on individual cruises, and for the long-term goal of building a profile of current structure in the Southern Ocean.

A data feed is sent from the ADCP system to RVDAS whenever a reference layer is acquired. This feed contains east and north vectors for ship's speed, relative to the reference layer, and ship's heading. Collected files (one per day) are archived in 1901adcp.tar in the directory /rvdas/nav.

pCO_2

The NBP carries a pCO2 measurement system from Lamont-Doherty Earth Observatory (LDEO). pCO2 data is recorded by RVDAS and transmitted to LDEO at the end of each cruise. You will find pCO2 data in a file named 1901pco2.tar in the /process directory, which contains the pCO2 instrument's data merged with GPS, meteorological and other oceanographic measurements. For more information contact Colm Sweeney (csweeney@ldeo.columbia.edu).

Cruise Science

CTD

The CTD data has been placed in the tar file /ocean/NBP1901ctd.tar. The archive contains tar files NBP1901proc.tar.

RVDAS

The Research Vessel Data Acquisition System (RVDAS) was developed at Lamont-Doherty Earth Observatory of Columbia University and has been in use on its research ship for many years. It has been extensively adapted for use on the USAP research vessels.

Daily data processing of the RVDAS data is performed to calibrate and convert values into useable units and as a quality-control on operation of the DAS. Raw and processed data sets from RVDAS are included in the data distribution. The tables below provide detailed information on the sensors and data. Be sure to read the "Significant Acquisition Events" section for important information about data acquisition during this cruise.

Sensors and Instruments

RVDAS data is divided into two general categories, *underway and navigation*. They can be found on the distribution media as subdirectories under the top level rvdas directory: /rvdas/uw, and /rvdas/nav. Processed oceanographic data is in the top level directory, /process. Each instrument or sensor produces a data file named with its channel ID. Each data file is g-zipped to save space on the distribution media. Not all data types are collected every day or on every cruise.

The naming convention for data files produced by the sensors and instruments is

```
NBP[CruiseID][ChannelID].dDDD
```

Example: `NBP1901mwx1.d025`

- The CruiseID is the numeric name of the cruise, in this case, NBP1901.
- The ChannelID is a 4-character code representing the system being logged. An example is "mwx1," the designation for meteorology.
- DDD is the day of year the data was collected

Underway Sensors

Meteorology and Radiometry

Measurement	String ID	Collection Status	Rate	Instrument
Air Temperature	mwx1 (met)	Continuous	1/sec	RM Young 41372LC
Relative Humidity	mwx1 (met)	Continuous	1/sec	RM Young 41372LC
Wind Speed / Direction	mwx1 (pus,sus)	Continuous	1/sec	Gill Instruments 1390-PK-062
Barometer	mwx1 (met)	Continuous	1/sec	RM Young 61201
PAR	mwx1 (met)	Continuous	1/sec	Biospherical Instruments QSR-240
PIR	mwx1 (met)	Continuous	1/sec	Eppley PIR
PSP	mwx1 (met)	Continuous	1/sec	Eppley PSP
GUV	pguv	Continuous	2/sec	Biospherical Instruments GUV-2511

Geophysics

Measurement	String ID	Collection Status	Rate	Instrument
Gravimeter	grv1	Continuous	1/sec	BGM3/210
Bathymetry	knud	Continuous	varies	Knudsen Chirp
Bathymetry	mbdp	Continuous	varies	Kongsberg EM122

Oceanography

Measurement	String ID	Collection Status	Rate	Instrument
Conductivity	tsg1,tsg2	Continuous	0.5/sec	Sea-Bird SBE 45
Ocean Surface Temperature	rtmp	Continuous	1.2/sec	Sea-Bird SBE 38
Transmissometer	hdas	Continuous	0.5/sec	WetLabs C-Star
Fluorometer	hdas	Continuous	0.5/sec	WetLabs AFLT
pCO_2	pco2	Continuous	0.017/sec	LDEO instrumentation
ADCP	adcp	Continuous	1/sec	UHDAS
Bathymetry	sim1	Continuous	varies	Simrad EK60 Sonar

Navigational Instruments

Measurement	String ID	Collection Status	Rate	Instrument
Heading, Speed, Course, GPS, Heave, Roll and Pitch	s330	Continuous	1/sec	Seapath 330 GPS
Heading, Speed, Course, GPS, Heave, Roll and Pitch	seap	Continuous	1/sec	Seapath 200 GPS
Heading, Speed, Course, and GPS	PCOD	Continuous	1/sec	Furuno GP-330B
Heading	gyr1	Continuous	0.2/sec	Yokogawa Compass

Data

Data is received from the RVDAS system via RS-232 serial connections. A time tag is added at the beginning of each line of data in the form,

```
yy+dd:hh:mm:ss.sss [data stream from instrument]
```

where

yy	= two-digit year
ddd	= day of year
hh	= 2 digit hour of the day
mm	= 2 digit minute
ss.sss	= seconds

All times are reported in UTC.

The delimiters that separate fields in the raw data files are often spaces and commas but can be other characters such as : = @. Occasionally no delimiter is present. Care should be taken when reprocessing the data that the field's separations are clearly understood.

In the sections below a sample data string is shown, followed by a table that lists the data contained in the string.

Each section on the next page describes a type of data file (file name extension in parentheses) followed by a typical line of data in the file. In the table(s) for each section is a description of the fields within each line of data. Note: most data files listed below will be included with each cruise's data distribution; however some types of files may be omitted if the instrument was not operating during the cruise. The available data files can be found in the /rvdas/uw and /rvdas/nav directories on the distribution disc.

Underway Data /rvdas/uw

Sound Velocity Probe (svp1)

```
15+055:20:27:24.018  1535.43
```

Field	Data	Format	Unit
1	RVDAS time tag	yy+ddd:hh:mm:ss.sss	UTC
2	Sound Velocity, from ADCP sonar well	xxxx.xx	m/s

Meteorology (mwx1)

MET

```
15+055:20:27:24.636 MET,12.1,-39,-6.07,77.4,178.0729,0.809536,-0.1235019,268.1754,267.9648,970.7878
```

Field	Data	Format	Unit
1	RVDAS time tag	yy+ddd:hh:mm:ss.sss	UTC
2	MET Flag		
3	Power Supply Voltage	vv.v	V
4	Enclosure Relative Humidity (not implemented)	xx.x	%
5	Air Temperature, Celsius	xx.x	C
6	Air Relative Humidity	xx.x	%
7	PAR (Photosynthetically Available Radiation)	xxx.xxxx	mV
8	PSP (Shortwave Radiation)	x.xxxxxx	mV
9	PIR Thermopile (Longwave Radiation)	x.xxxxxx	mV
10	PIR Case Temperature	xxx.xxxx	K
11	PIR Dome Temperature	xxx.xxxx	K
12	Barometer	xxx.xxxx	mBar

PUS

```
15+055:21:47:42.452 PUS,A,037,014.36,M,+325.38,-010.29,60,0F
```

Field	Data	Format	Unit
1	RVDAS time tag	yy+ddd:hh:mm:ss.sss	UTC
2	PUS Flag		
3	A	x	A
4	Port Wind Relative Direction	xxx	degrees
5	Port Wind Relative Speed	xxx.xx	m/s
6	M = Meters (for previous)	x	M
7	Sound Speed	xxx.xx	m/s
8	Sonic Temperature	xxx.xx	C
9	Unit Status*	xx	numeric
10	Checksum	xx	alphanumeric

Status

00 = Good, 60 = Good. Any other value indicates fault

SUS

```
15+055:21:50:48.409 SUS,A,338,012.63,M,+326.15,-009.05,60,0F
```

Field	Data	Format	Unit
1	RVDAS time tag	yy+ddd:hh:mm:ss.sss	UTC
2	SUS Flag		
3	A	x	A
4	Starboard Wind Relative Direction	xxx	degrees
5	Starboard Wind Relative Speed	xxx.xx	m/s
6	M = Meters (for previous)	x	M
7	Sound Speed	xxx.xx	m/s
8	Sonic Temperature	xxx.xx	C
9	Unit Status*	xx	numeric
10	Checksum	xx	alphanumeric

Status

00 = Good, 60 = Good. Any other value indicates fault

Knudsen (knud)

Field	Data	Format	Unit
1	RVDAS time tag	yy+ddd:hh:mm:ss.sss	UTC
2	3.5kHz = Low frequency in use	x.xxxx	3.5kHz
3	Low Frequency Depth	xxxx.xx	m
4	Valid Flag	x	0
5	12.0kHz = High frequency in use	xx.xxxx	12.0kHz
6	High Frequency Depth	xxxx.xx	m
7	Valid Flag	x	0
8	Sound Speed Velocity	xxxx	m/s
9	Latitude	xx.xxxxxx	degrees
10	Longitude	xx.xxxxxx	degrees

Gravimeter (grv1)

```
15+056:14:21:21.153 01:025268 00
```

Field	Data	Format	Unit
1	RVDAS time tag	yy+ddd:hh:mm:ss.sss	UTC
2	01:	xx:	01
3	Gravity Count*	xxxxxx	Flit Count
4	Error Flag	xx	numeric

Error Flag

00 = All well, 01 = CPS malfunction, 02 = Sensor Malfunction, 03 = CPS and sensor Malfunction

A gravity tie is taken at the start of the cruise and applied throughout the cruise. There is no accounting for drift after the pre-cruise gravity time. The post cruise gravity tie is available by requesting it from ethq@usap.gov.

pCO_2 (pco2)

```
15+056:14:41:10.392 2015056.60236 2608.36 30.14 977.91 48.25 368.76 353.92 -1.18 -1.26 0.00 Equil
```

Field	Data	Format	Unit
1	RVDAS time tag	yy+ddd:hh:mm:ss.sss	UTC
2	pCO_2 time tag*	yyyyddd.ttt	UTC
3	Raw Voltage (IR)	xxxx.xx	mV
4	Cell Temperature	xx.xx	C
5	Equilibration Pressure	xxx.xx	mBar
6	Flowrate	xxx.xx	cm^3/min
7	pCO_2 Pressure	xxx.xx	µAtm
8	VCO_2 Concentration	xx.xx	ppm
9	Equilibrator Temperature, RTD	xx.xx	C
10	Equilibrator Temperature, SBE38	xx.xx	C
11	Valve Position	xx	numeric
12	Flow Source*		text

pCO_2 time tag

ttt = fractional time of day

Flow Source

Equil = pCO_2 Measurement

Micro TSG (tsg1, tsg2)

```
15+056:15:06:06.644  -1.1809,  2.73404,  34.0574, 1442.367
```

Field	Data	Format	Unit
1	RVDAS time tag	yy+ddd:hh:mm:ss.sss	UTC
2	Temperature	xx.xxxx	C
3	Conductivity	xx.xxxx	s/m
4	Salinity	xx.xxxx	PSU
5	Sound Velocity	xxxx.xxx	m/s

Remote Temperature (rtmp)

```
15+056:15:10:38.244 -1.4644
```

Field	Data	Format	Unit
1	RVDAS time tag	yy+ddd:hh:mm:ss.sss	UTC
2	Temperature, Seawater Intake	xx.xxxx	C

GUV (pguv)

```
15+057:14:51:33.808 022615 065133 .000132 .010878 .047479 .004407 -.002799 .014652 .027558 .094395
.417814 -4.466095
```

Field	Data	Format	Unit
1	RVDAS time tag	yy+ddd:hh:mm:ss.sss	UTC
2	Date	mmddyy	UTC-4
3	Time	hhmmss	UTC-4
4	Ed0GND (sensor ground voltage)	xxxxxx	V
5	Ed0320 (downwelling 320nm irradiance)	xxxxxx	µW
6	Ed0340 (downwelling 340nm irradiance)	xxxxxx	µW
7	Ed0313 (downwelling 313nm irradiance)	xxxxxx	µW
8	Ed0305 (downwelling 305nm irradiance)	xxxxxx	µW
9	Ed0380 (downwelling 380nm irradiance)	xxxxxx	µW
10	Ed0PAR (downwelling 400-700nm irradiance)	xxxxxx	µE
11	Ed0395 (downwelling 395nm irradiance)	xxxxxx	µW
12	Ed0Temp (sensor array temperature)	xxxxxx	C
13	Ed0Vin (input voltage)	x.xxxxxx	V

Engineering (eng1)

```
15+057:16:41:24.536 12.25 23.21 507.8  0.6 162.6 -751.9 0 0 NAN NAN -10.3  7.2
```

Field	Data	Format	Unit
1	RVDAS time tag	yy+ddd:hh:mm:ss.sss	UTC
2	Supply Voltage	xx.xx	V
3	Case Temperature	xx.xx	C
4	Seawater Flow, Aquarium Room	xxx.x	l / min
5	Seawater Flow, Helo-deck	x.x	l / min
6	Seawater Flow, Hydro-lab	xxx.x	l / min
7	Seismic Air Pressure	xxx.x	lbf/in^2
8	Not Currently Hooked Up	x	0 or NAN
9	Not Currently Hooked Up	x	0 or NAN
10	Not Currently Hooked Up	x	0 or NAN
11	Not Currently Hooked Up	x	0 or NAN
12	Altimeter for Yo-Yo Camera - **Rarely used***	xx.xx	m
13	Transmissometer for Yo-Yo camera - **Rarely used***	xxx.x	%

Altimeter

This is rarely used, and only provides real data when connected. When not connected, provides a value approx = -10.

Transmissometer

This is rarely used, and only provides real data when connected. When not connected, provides a value range of approx = 0 to 10.

Hydro DAS (hdas)

```
15+057:16:07:09.456 12.15038 12.39402 336.5517 4431.724 -1 20.5 64 33.5 43.5
```

Field	Data	Format	Unit
1	RVDAS time tag	yy+ddd:hh:mm:ss.sss	UTC
2	Supply Voltage	xx.xxxxx	V
3	Case Temperature	xx.xxxxx	C
4	Fluorometer	xxx.xxxx	mV
5	Transmissometer	xxxx.xxx	mV
6	Sea Water Valve*	x	-1 or 0
7	Flow Meter 1 Frequency	xx.x	Hz
8	Flow Meter 2 Frequency	xx.x	Hz
9	Flow Meter 3 Frequency	xx.x	Hz
10	Flow Meter 4 Frequency	xx.x	Hz

Sea Water Valve

-1 = Stern Thruster Valve, 0 = Moon Pool Valve

Winch (bwnc, cwnc, twnc)

```
15+057:14:12:24.405 02RD,2015-02-26T14:55:32.051,STBD TRAWL,00000064,-00000.0,-00023.2,3594
```

Field	Data	Format	Unit
1	RVDAS time tag	yy+ddd:hh:mm:ss.sss	UTC
2	LAN ID		alphanumeric
3	LCI-90i Date and Time	yyyy-mm-ddThh:mm:ss.sss	
4	Winch Name		alphabetical
5	Tension	xxxxxxxx	lbs
6	Speed	xxxxx.x	m/min
7	Payout	xxxxx.x	m
8	Checksum	x.xxxx	numeric

Multibeam (mbdp)

```
15+058:22:04:52.826 $KIDPT,594.68,7.67,12000.0*43
```

Field	Data	Format	Unit
1	RVDAS time tag	yy+ddd:hh:mm:ss.sss	UTC
2	KIDPT	x.x	m
3	Depth at Transducer	x.x	m
4	Distance to Waterline from Transducer	x.x	m
5	Maximum Range in Use	x.x	alphanumeric
6	Checksum	xx	UTC

Fluorometer (ndfl)

```
18+121:00:00:21.785 99/99/99    99:99:99        0.71    695     155     559
```

Field	Data	Format	Unit
1	RVDAS time tag	yy+ddd:hh:mm:ss.sss	UTC
2	Ignore	x.x	n/a
3	Ignore	x.x	n/a
4	Chlorophyll Signal	xx.xx	µg/l
5	Wavelength (Not used)	xxx	nanometers
6	Chlorophyll Counts	xxxx	Counts
7	Internal Thermistor (Not used)	xxx	Therm

Navigational Data */rvdas/nav*

GPS (s330, seap, PCOD)

1. ***Seapath 330***
    a. NMEA 0183 strings
        i. GPZDA
        ii. GPGGA
        iii. GPVTG
        iv. GPHDT
        v. GPRMC
    b. Proprietary Strings
        i. PSXN 20
        ii. PSXN 22
        iii. PSXN 23
2. ***Seapath 200***
    a. NMEA 0182 strings
        i. GPZDA
        ii. GPGGA
        iii. GPVTG
        iv. GPHDT
    b. Proprietary Strings
        i. PSXN 20
        ii. PSXN 22
        iii. PSXN 23
3. ***Furuno GP-330B***
    a. NMEA 0183 strings
        i. GPZDA
        ii. GPGGA
        iii. GPVTG
        iv. GPRMC
        v. GPGLL
        vi. GPDTM

GPZDA

```
15+051:21:02:04.507 $GPZDA,210204.39,20,02,2015,,*6F
```

Field	Data	Format	Unit
1	RVDAS time tag	yy+ddd:hh:mm:ss.sss	UTC
2	$GPZDA		
3	Time	hhmmss.ss	UTC
4	Day	dd	UTC
5	Month	mm	UTC
6	Year	yyyy	UTC
7	(empty field)	x	Blank or 0
8	Checksum	xx	alphanumeric

GPGGA

```
15+051:21:02:02.507 $GPGGA,210202.38,7712.979244,S,16741.040258,W,1,12,0.7,-5.04,M,-55.90,M,,*6F
```

Field	Data	Format	Unit
1	RVDAS time tag	yy+ddd:hh:mm:ss.sss	UTC
2	$GPGGA		
3	Time	hhmmss.ss	UTC
4	Latitude	ddmm.mmmmmm	degrees
5	North or South (for previous)	x	N or S
6	Longitude	ddmm.mmmmmm	degrees
7	East or West (for previous)	x	E or W
8	GPS quality indicator*	x	0,1,2,3,4,5, or 6
9	Number of satellites in use (00-99)	xx	00-99
10	HDOP	x.x	
11	Antenna height	x.xx	m
12	M = Meters (for previous)	x	M
13	Geoidal height	x.xx	m
14	M = Meters (for previous)	x	M
15	Age of DGPS corrections (seconds)	x.x	seconds
16	Station ID of DGPS (if used)	x	numeric
17	Checksum	xx	alphanumeric

Quality

0 = invalid, 1 = GPS SPS, 2 = DGPS, 3 = PPS, 4 = RTK, 5 = float RTK, 6 = dead reckoning

GPVTG

```
15+051:16:47:06.625 $GPVTG,357.84,T,251.99,M,9.5,N,17.7,K,A*15
```

Field	Data	Format	Unit
1	RVDAS time tag	yy+ddd:hh:mm:ss.sss	UTC
2	$GPVTG		
3	Heading	x.xx	degrees
4	T = True (for previous)	x	T
5	Heading	x.xx	degrees
6	M = Magnetic (for previous)	x	M
7	Speed over Ground (knots)	x.x	knots
8	N = knots (for previous)	x	N
9	Speed over Ground (kilometers per hour)	x.x	km/h
10	K = km per hour (for previous)	x	K
11	Mode*	X	A,D,E, or N
12	Checksum	xx	alphanumeric

Modes

A = GPS used, D = DGPS used, E = Dead reckoning used, N = Invalid position / velocity

GPRMC

```
15+051:21:02:04.741 $GPRMC,210204.38,A,7712.979182,S,16741.063669,W,9.4,270.82,200215,105.6,E,A*06
```

Field	Data	Format	Unit
1	RVDAS time tag	yy+ddd:hh:mm:ss.sss	UTC
2	$GPRMC		
3	Time	hhmmss.sss	UTC
4	Status*	x	A or N
5	Latitude	ddmm.mmmmmm	degrees
6	North or South (for previous)	x	N or S
7	Longitude	ddmm.mmmmmm	degrees
8	East or West (for previous)	x	E or W
9	Speed over Ground, True	x.x	knots
10	Course over Ground True	x.xx	degrees
11	Date	ddmmyy	UTC
12	Magnetic Variation	x.x	degrees
13	East or West (for previous)	x	E or W
14	Mode*	x	alphanumeric
15	Checksum	xx	UTC

GPHDT

```
15+051:21:02:04.741 $GPHDT,268.87,T*06
```

Field	Data	Format	Unit
1	RVDAS time tag	yy+ddd:hh:mm:ss.sss	UTC
2	$GPHDT		
3	Heading, True	x.xx	degrees
4	T = True (for previous)	x	T
5	Checksum	xx	alphanumeric

GPGLL

```
16+077:00:00:00.725 $GPGLL,6356.6505,S,05716.0002,W,000000,A,A*4F
```

Field	Data	Format	Unit
1	RVDAS time tag	yy+ddd:hh:mm:ss.sss	UTC
2	$GPGLL		
3	Latitude	ddmm.mmmmmm	degrees
4	North or South (for previous)	x	N or S
5	Longitude	ddmm.mmmmmm	degrees
6	East or West (for previous)	x	E or W
7	Time of Position (not received)	hhmmss.ss	UTC
8	Status*	x	A or V
9	Mode*	x	alphanumeric
10	Checksum	xx	alphanumeric

Status

A = Data Valid, V = Data not valid

Modes

A = GPS used, D = DGPS used, E = Dead reckoning used, M = Manual input mode, S = Simulator Mode, N = Invalid position / velocity

GPDTM

```
16+077:00:00:02.527 $GPDTM,W84,,0000.0000,N,00000.0000,E,0.0,W84*5F
```

Field	Data	Format	Unit
1	RVDAS time tag	yy+ddd:hh:mm:ss.sss	UTC
2	$GPDTM		
3	Local Datum Code*	XXX	alphanumeric
4	Local datum subdivision code	x	numeric
6	Lat offset	x	alphanumeric
7	North or South (for previous)	x	N or S
8	Lon offset	x	alphanumeric
9	East or West (for previous)	x	E or W
10	Altitude offset, meters	x,x	numeric
11	Reference datum code*	xxx	alphanumeric
12	Checksum	xx	alphanumeric

Datum Codes

W84 = WGS84, W72 = WGS72, S85 = SGS85, P90 = PE90, 999 = User defined

PSXN 20

```
15+051:22:20:58.740 $PSXN,20,1,0,0,0*3A
```

Field	Data	Format	Unit
1	RVDAS time tag	yy+ddd:hh:mm:ss.sss	UTC
2	$PSXN		
3	20		
4	Horizontal position and velocity quality*	x	0,1,2
5	Height and vertical velocity quality*	x	0,1,2
6	Heading quality*	x	0,1,2
7	Roll and pitch quality*	x	0,1,2
8	Checksum	xx	alphanumeric

Qualities

0 = Normal, 1 = Reduced Performance, 2 = Invalid data

PSXN 22

```
15+051:22:20:59.019 $PSXN,22,0.43,0.50*3B
```

Field	Data	Format	Unit
1	RVDAS time tag	yy+ddd:hh:mm:ss.sss	UTC
2	$PSXN		
3	22		
4	Gyro calibration value since system startup	x.xx	degrees
5	Short-term gyro offset	x.xx	degrees
6	Checksum	xx	alphanumeric

PSXN 23

```
15+051:22:20:58.748 $PSXN,23,-0.20,-0.09,279.85,0.24*34
```

Field	Data	Format	Unit
1	RVDAS time tag	yy+ddd:hh:mm:ss.sss	UTC
2	$PSXN		
3	23		
4	Roll, port side up is positive	x.xx	degrees
5	Pitch, bow up is positive	x.xx	degrees
6	Heading, True	x.xx	degrees
7	Heave, positive is down	x.xx	m
8	Checksum	xx	alphanumeric

Gyro Compass (gyr1)

```
15+055:20:27:23.653 $HEHDT,087.31,T*12
```

Field	Data	Format	Unit
1	RVDAS time tag	yy+ddd:hh:mm:ss.sss	UTC
2	$HEHDT		
3	Heading	x.xx	degrees
4	T = True (for previous)	x	T
5	Checksum	xx	alphanumeric

ADCP Course (adcp)

```
15+049:20:20:57.327 $PUHAW,UVH,-0.07,-4.59,179.3
```

Field	Data	Format	Unit
1	RVDAS time tag		
2	$PUHAW		
3	UVH		
4	Ship Speed relative to reference layer, east vector	x.xx	knots
5	Ship Speed relative to reference layer, north vector	x.xx	knots
6	Ship heading	x.xx	degrees

Processed Data */process*

pCO_2 – Merged

```
15+055:11:24:43.960 2015055.46596 2534.72 32.41 975.33 48.86 356.94 341.67 -1.20 -1.27 0.00 Equil -
75.9209 178.9696 -1.435 33.852 2.26 7.86 137.38 975.34 163.80 9.31 253.75 NaN -1.27 33.84 -1.14 -
1.0
```

Field	Data	Format	Unit
1	RVDAS time tag	yy+ddd:hh:mm:ss.sss	UTC
2	pCO_2 time tag*	yyyyddd.ttt	UTC
3	Raw Voltage (IR)	xxxx.xx	mV
4	Cell Temperature	xx.xx	C
5	Equilibration Pressure	xxx.xx	mBar
6	Flowrate	xxx.xx	cm^3/min
7	pCO_2 Pressure	xxx.xx	µAtm
8	VCO_2 Concentration	xx.xx	ppm
9	Equilibrator Temperature, RTD	xx.xx	C
10	Equilibrator Temperature, SBE38	xx.xx	C
11	Valve Position	xx	numeric
12	Flow Source*		text
13	Latitude	xx.xxxxx	degrees
14	Longitude	xxx.xxxxx	degrees
15	Sea Water Intake Temperature	xx.xxx	C
16	Sea Surface Salinity	xx.xxx	PSU
17	Sea Surface Fluorometry	x.xxx	mg/m^3
18	True Wind Speed	x.xx	m/s
19	True Wind Direction	x.xx	degrees
20	Barometric Pressure	xxx.xx	mBar
21	Hydro-Lab H_2O Flow Rate	xxx.x	l / min
22	Speed over Ground	x.xx	knots
23	Course Made Good	xx.xx	degrees
24	Unused		
25	TSG2 Temperature	x.xx	C
26	TSG2 Salinity	xx.xx	PSU
27	TSG1 Temperature	x.xx	C
28	Sea Water Valve*	x	-1 or 0

pCO_2 time tag

ttt = fractional time of day

Flow Source

Equil = pCO_2 Measurement

Sea Water Valve

-1 = Stern Thruster Valve, 0 = Moon Pool Valve

Calculations

PAR

Coefficients parc1 and parcv for this cruise can be found in the `instrument.coeff` file as the variable labeled PAR, respectively. Variable par is the raw data in mV, as described in the "mwx1" file description. The calibration scale and probe offset dark are values taken from the PAR Cal Sheet.

```
par = raw data mV
calibration scale = 5.8644 V/(µEinstiens/cm2sec)
parc1 = 1 / scale = .17
probe offset dark = -.1 mV
parcv = dark x 1000 mV/V = -0.0001 V
((par / 1000 mV/V) – parcv) x parc1 x 10000 cm2/m2 = µEinstiens/m2sec

Calculations (extracted from the C code):
/* Convert from mV to V */
par /= 1000;
/* (par V - vdark V) / Calibration Scale Factor V/uE/cm2sec */
parCalc = (par - parcv) * parc1 * 10000;
```

PSP

Coefficient pspCoeff for this cruise can be found in the `instrument.coeff` file as the variable labeled PSP1. Variable psp is the raw data in mV, as described in the "mwx1" file description.

```
psp = raw data mV
calibration scale =  pspCoeff x 10^-6  V/(W/m2)
psp / (scale x 1000 mV/V) = W/m2

Calculations (extracted from the C code):
     /* Convert from mV to W/m^2  */
     pspCalc = (psp * 1000 / pspCoeff);
```

PIR

Coefficient pirCoeff for this cruise can be found in the `instrument.coeff` file as the variable labeled PIR1. Variable pir_thermo is the raw data in mV, pir_case is the PIR case temperature in Kelvins and pir_dome is the PIR dome temperature in Kelvins, as described in the "mwx1" file description. Hard-coded "C" coefficients are shown below:

```
Dome constant = 3.5
Sigma = 5.6704e-8

pir_thermo = raw data mV
calibration scale = pirCoeff x 10^-6  V/(W/m2)
pir_thermo / (scale x 1000 mV/V) = W/m2

Calculations (extracted from the C code):
      /* convert mV to W/m^2 */
     pirCalc = (pir_thermo * 1000 / pirCoeff)
     /* correct for case temperature */
     pirCalc += sigma * pow(pir_case,4)
     /* correct for dome temperature */
     pirCalc -= 3.5 * sigma * (pow(pir_dome, 4) - pow(pir_case, 4))
```

Acquisition Problems and Events

This section lists problems with acquisition noted during this cruise including instrument failures, data acquisition system failures and any other factor affecting this data set. The format is ddd:hh:mm (ddd is year-day, hh is hour, and mm is minute). Times are reported in UTC.

Start	End	Description
18+359:13:27		Data collection begins. **5955.081821 S, 7040.888227 W**
18+359:13:27	18+361	GUV had incorrect calibration coefficient applied
19+001:06:00	19+001:14:00	Sea Water wall was off due to operational issues - affects TSG and Fluorometer
19+002	19+012:18:00	NBP1901seap and NBP1901s330 log files were both receiving the same input from the Seapath 200 GPS
	19+020:19:49	Data collection completes. **5948.743250 S, 6744.823949 W**

Appendix A: Sensors

NBP1901 Sensors

Sensor	Description	Serial	Last Cal Date	Comments
Meteorology and Radiometry				
Port Anemometer	Gill Instruments 1390-PK-062	924057	11/18/2009	
Stbd Anemometer	Gill Instruments 1390-PK-062	847014	9/29/2010	
Bridge Anemometer	RM Young 5106	WM128975	10/27/2011	ECO Use
Barometer	RM Young 61201	00872	5/20/2015	
Barometer	Vaisala PTB210B	M2750443	7/13/2016	
Temperature / Humidity	RM Young 41382LC	06733	10/6/2016	
PIR	Eppley PIR	32845F3	11/7/2017	
PSP	Eppley PSP	32850F3	11/7/2017	
PAR (Mast)	Biospherical Instruments QSR-2200	20546	3/8/2017	
GUV (Mast)	Biospherical Instruments GUV-2511	25110203114	12/6/2017	

Sensor	Description	Serial	Last Cal Date	Comments
Underway Seawater Sampling System				
Micro-TSG	Sea-Bird SBE 45	4550449-0242	4/2/2017	Primary
Micro-TSG	Sea-Bird SBE 45	4566350-0389	4/25/2018	Secondary
Digital Remote Temp	Sea-Bird SBE 38	3849120-0178	2/7/2017	
Transmissometer	WetLabs C-Star	CST-439DR	7/29/2016	
Fluorometer	WetLabs AFLT	FLRTD-397	4/20/2017	

Sensor	Description	Serial	Last Cal Date	Comments
CTD				
Altimeter	Valeport VA-500	51520	7/10/2015	
Carousel Water Sampler	Sea-Bird SBE 32	3214153-0140	NA	
SBE 11+ Deck Unit	Sea-Bird SBE 11+	11P47914-0768	NA	
Conductivity (Primary)	Sea-Bird 4C 6800m	40924	7/12/2016	
Conductivity (Secondary)	Sea-Bird 4C 6800m	40926	7/12/2016	
Dissolved Oxygen	Sea-Bird SBE 43	43082	8/22/2017	Primary
Dissolved Oxygen	Sea-Bird SBE 43	43152	8/1/2017	Secondary
Fluorometer	WetLabs FLRTD	FLRTD-855	5/16/2018	
CTD Fish	Sea-Bird SBE 9+	09P70675-1130	4/23/2018	
CTD Pressure Sensor	Sea-Bird SBE 9+	120089	4/23/2018	
PAR	Biospherical Instruments QSP-200L4S	70555	12/12/2016	
Surface PAR	QSR-2200	20546	3/8/2017	Fed to CTD, on Mast
CTD Pump 1	Sea-Bird 5T, PN 90160	051626 3.0K	8/8/2017	Primary
CTD Pump 2	Sea-Bird 5T, PN 90543	051627 3.0K	8/8/2017	Secondary
Temperature	Sea-Bird 3plus 6800m	31238	7/8/2016	Primary
Temperature	Sea-Bird 3plus 6800m	31457	7/12/2016	Secondary
Transmissometer	WetLabs C-Star	CST-892DR	11/10/2016	

Appendix B: Calibration Sheets

Gravity

BGM3 ship-to-shore gravity tie report

AUKON, vessel: R/V Palmer

Release Date: 2018/10/13 12:54:22 UTC

Sensor: S210
Software version: 1.2
Port/Pier/Berth: Prat Pier, Punta Arenas, Chile

Gravity station number	9337-50
Station name	Harbour Admin. Building
mGal at pier	981281.95
Tie start time UTC	2018/10/13 12:27:36.064
Samples used	3600
Land tie used	Yes
Water height to pier 1	10 ft 6 in
Water height to pier 2	10 ft 8 in
Water height to pier 3	10 ft 10 in
Average of filtered counts	25190.930257694
Filter length	181
Scale factor	4.994070552
NEW BIAS	**855477.67**

Table 1: Gravity tie information

Gravity Tie Spreadsheet

The fields outlined in BOLD MUST BE FILLED IN for this spreadsheet to operate properly. The automatically calculated values show up in the shaded fields.

Date: 10/13/2018
Location: Punta Arenas, Chile
Station: Harbour Admin. Bldg.
Latitude: 53 09 S
Longitude: 070 55 W
Elevation: 2.8 meters
Gravity: 981320.82

Reference Code Numbers:
Station no. 9337-50
ISGN no. 51230N

	Value	Time (GMT)
Ship's meter before gravity tie (Filt Counts)	25190.33	10:45
Ship's meter after gravity tie (Filt Counts)	25190.76	13:45
Average	25190.62	
Ship Gravimeter's Calibration Constant	4.99407055	
Corrected ship's meter (QC Grav (mgal))	125803.36	

	Value	Time (GMT)
Ship's meter before gravity tie (serial, RVDAS)		
Ship's meter after gravity tie (serial, RVDAS)		
Average (for comparison check only)	#DIV/0!	

Portable Gravimeter Interval Factor: 1.01007 From Table 1 of Model G #807 Meter

Station	Value	Time (GMT)	Temp	Date	OBS mgal, averaged
Pier measurement 1	4908.69	10:55	53.5	October 13, 2018	
Pier measurement 2	4908.63	10:59	53.4	October 13, 2018	4958.08
Pier measurement 3	4908.63	11:02	53.4	October 13, 2018	
Average	4908.65				
Station measurement 1	4908.63	11:16	53.4	October 13, 2018	OBS mgal, averaged
Station measurement 2	4908.63	11:18	53.5	October 13, 2018	4958.06
Station measurement 3	4908.63	11:20	53.4	October 13, 2018	
Average	4908.63				
Pier measurement 4	4908.63	11:25	53.4	October 13, 2018	OBS mgal, averaged
Pier measurement 5	4908.63	11:27	53.4	October 13, 2018	4958.05
Pier measurement 6	4908.63	11:29	53.5	October 13, 2018	
Average	4908.63				

Date of last tie	6/17/2017
Gravity Bias from last tie	855501.33
Drift since last tie	16.26
Drift RATE since last tie	1.02

OBS Differences	
Station to Pier (1, 2, & 3 averaged)	0.02
Station to Pier (4, 5, & 6 averaged)	0.00
Averaged Differences	0.01
Gravity at pier	981320.83
Elevation of pier above gravimeter, meters	0.4
Earth differential gravity, mgal/meter	0.3
Gravity at ship's gravimeter	981320.95
Gravity Bias **(for reference only)**	855517.59
Gravity Bias from GUI **(USE IN RVDAS)**	

Comments

This tie was done by George Aukon. The weather was extremely windy. Because of the weekend I have used the gravity marker outside the Port Administration Building.

Note about Elevation of Pier: *If pier is below the ship's gravimeter, this value is negative. If above, positive.*

Meteorology

Anemometers

Cal sheet not required

Barometer

R.M. Young Company
2801 Aero Park Drive
Traverse City, Michigan 49686 USA

CALIBRATION REPORT
Barometric Pressure

Customer: *Lockheed Martin Corp*

Test Number: 5520-01B
Test Date: 20 May 2015
Customer PO: 4100959204
Sales Order: 4756

Test Sensor:
Model: 61201 Serial Number: *BP00872*
Description: Barometric Pressure Sensor

Report of calibration comparison of test barometric pressure sensor with National Institute of Standards and Technology traceable standard pressure calibrator at five pressures in the R.M. Young Company controlled pressure facility. Calibration accuracy ± 1.0 hPa.

Reference Pressure (hPa)	Voltage Output (millivolts)	Indicated (1) Pressure (hPa)
800.0	0	800.0
875.0	1252	875.1
950.0	2501	950.1
1025.0	3750	1025.0
1100.0	4997	1099.8

(1) Calculated from voltage output

All reference equipment used in this calibration procedure have been tested by comparison to traceable standards certified by the National Institute of Standards and Technology.

Reference Instrument	Serial #	NIST Test Reference
Druck Pressure Controller Model DPI515	51500497	0046591
Fluke Multimeter Model 8060A	4865407	8604897

Tested By: _____

METEOROLOGICAL INSTRUMENTS
Tel: 231-946-3980 Fax: 231-946-4772 Email: met.sales@youngusa.com Website: youngusa.com
ISO 9001:2008 CERTIFIED

VAISALA

Certificate report no. H44-16280021

CALIBRATION CERTIFICATE

Instrument	PTB210B Digital Barometer
Serial number	M2750443
Manufacturer	Vaisala Oyj, Finland
Calibration date	13th July 2016

The above instrument was calibrated by comparing the readings of the instrument to the factory working standard of Vaisala.

The pressure readings of the factory working standard have been calibrated at an ISO/IEC 17025 accredited calibration laboratory (FINAS), Vaisala Measurement Standards Laboratory (MSL), by using MSL working standards traceable to NIST.

Calibration results

Reference hPa	Observed hPa	Correction* hPa	Acceptance limit hPa
510.0	510.0	0.0	± 0.2
610.0	610.0	0.0	± 0.2
700.0	700.0	0.0	± 0.2
810.0	810.0	0.0	± 0.2
910.0	910.0	0.0	± 0.2
950.0	950.0	0.0	± 0.2
1000.0	1000.0	0.0	± 0.2
1098.0	1098.0	0.0	± 0.2

*To obtain the true pressure, add the correction to the barometer reading.
Interpolated corrections may be used at intermediate readings of the scale of the barometer.

Equipment used in calibration

Type	Serial number	Calibration date	Certificate number
PPC4	670	2015-08-21	K008-Y01989

Uncertainty (95 % confidence level, k=2)

Pressure ± 0.15 hPa

Ambient Conditions

Humidity	39 %RH ± 5 %RH
Temperature	21 °C ± 1 °C
Pressure	1002 hPa ± 1 hPa

Technician

doc223087-B

Vaisala Oyj | PO Box 26, FI-00421 Helsinki, Finland

Temperature / Humidity

R.M. Young Company
2801 Aero Park Drive
Traverse City, Michigan 49686 USA

YOUNG

CALIBRATION REPORT
Temperature

Customer: *Lockheed Martin*

Test Number: 6006-01T
Test Date: 6 October 2016
Customer PO: 4102685716
Sales Order: 5771

Test Sensor:
Model: 41382LC2 Serial Number: *TS06733*
Description: Temperature/Relative Humidity Sensor

Report of calibration comparison of test temperature sensor with National Institute of Standards and Technology traceable standard thermometer at three temperatures in the R.M. Young Company controlled temperature calibration facilities. Calibration accuracy ± 0.2° Celsius.

Reference Temperature (degrees C)	Current Output (mA)	Indicated (1) Temperature (degrees C)	Calculated (2) Temperature (degrees C)
45.29	19.27	45.47	45.28
19.95	15.24	20.27	19.97
-10.38	10.41	-9.94	-10.38

(1) Calculated from current output.
(2) Calculated values using derived formula: T = -75.745 + mA * 6.27899

All reference equipment used in this calibration procedure have been tested by comparison to traceable standards certified by the National Institute of Standards and Technology.

Reference Instrument	Serial #	NIST Test Reference
Brooklyn Thermometer Model 43-FC	8006-118	W204690
Brooklyn Thermometer Model 22332-D5-FC	25071	W204691
Brooklyn Thermometer Model 2X400-D7-FC	77532	W204692
Keithley Multimeter Model 191	15232	7124815

Tested By: S Sage

METEOROLOGICAL INSTRUMENTS
Tel: 231-946-3980 Fax: 231-946-4772 Email: met.sales@youngusa.com Website: youngusa.com
ISO 9001:2008 CERTIFIED

PIR

EPLAB

THE EPPLEY LABORATORY, INC.

12 Sheffield Avenue, PO Box 419, Newport, Rhode Island USA 02840
Phone: 401.847.1020 Fax: 401.847.1031 Email: info@eppleylab.com

Calibration Certificate

Instrument: Precision Infrared Radiometer, Model PIR, Serial Number 32845F3

Procedure: This pyrgeometer was compared against Eppley's Blackbody Calibration System under radiation intensities of approximately 350 Wm^{-2} with an average ambient temperature of 21°C according to procedures described in Technical Procedure, TP05 of The Eppley Laboratory, Inc.'s Quality Assurance Manual on Calibrations.

Transfer Standard: Eppley Precision Infrared Radiometer, Model PIR, Serial Number 32227F3

Results:

Sensitivity: **$S = 4.16\ \mu V / Wm^{-2}$**
Uncertainty: $U_{95} = \pm 1.7\%$ (95% confidence level, k=2)
Resistance: 712 Ω at 23°C

Date of Test: November 7, 2017

Traceability: This calibration is traceable to the International Practical Temperature Scale (IPTS). Additionally, transfer standard PIR #32227F3 provides traceability to the World Infrared Standand Group (WISG) of pyrgeometers housed at the Infrared Radiometry Section of the World Radiation Centre (WRC-IRS). Unless otherwise stated in the remarks section below or on the Sales Order, the results of this calibration are "AS FOUND / AS LEFT".

Due Date: Eppley recommends a minimum calibration cycle of five (5) years but encourages annual calibrations for highest measurement accuracy.

Customer: NSF/Lockheed Martin/LEIDOS
Port Hueneme, CA

Signatures: Dulsa L. Gentry
In Charge of Test:

Thomas J. Kirk
Reviewed by:

Eppley SO: 65087

Date of Certificate November 8, 2017

Remarks:

PSP

EPLAB

THE EPPLEY LABORATORY, INC.

12 Sheffield Avenue, PO Box 419, Newport, Rhode Island USA 02840
Phone: 401.847.1020 Fax: 401.847.1031 Email: info@eppleylab.com

Calibration Certificate

Instrument:	Precision Spectral Pyranometer, Model PSP, Serial Number 32850F3
Procedure:	This pyranometer was compared in Eppley's Integrating Hemisphere according to procedures described in ***ISO 9847 Section 5.3.1*** and Technical Procedure, TP01 of The Eppley Laboratory. Inc.'s Quality Assurance Manual on Calibrations.
Transfer Standard:	Eppley Standard Precision Pyranometer, Model SPP, Serial Number 37501F3
Results:	**Sensitivity:** **$S = 6.89\ \mu V / Wm^{-2}$** Uncertainty: $U_{95} = \pm 0.91\%$ (95% confidence level, k=2) Resistance: 706 Ω at 23°C
	Date of Test: November 7, 2017
Traceability:	This calibration is traceable to the World Radiation Reference (WRR) through comparisons with Eppley's AHF standard self-calibrating cavity pyrheliometers which participated in the Twelfth International Pyrheliometric Comparisons (IPC XII) at Davos, Switzerland in September-October 2015. Unless otherwise stated in the remarks section below or on the Sales Order, the results of this calibration are "AS FOUND / AS LEFT".
Due Date:	Eppley recommends a minimum calibration cycle of five (5) years but encourages annual calibrations for highest measurement accuracy.
Customer:	NSF/Lockheed Martin/LEIDOS Port Hueneme, CA
Signatures:	Debra L. Guisty In Charge of Test: Thomas J. Kirk Reviewed by:
Eppley SO:	65088
Date of Certificate	November 8, 2017
Remarks:	

PAR (Mast)

Biospherical Instruments Inc.

CALIBRATION CERTIFICATE

Calibration Date	3/8/2017
Model Number	QSR2200
Serial Number	20546
Operator	TPC
Standard Lamp	91453(7/20/16)
Probe Excitation Voltage Range:	6 to 18 VDC(+)
Output Polarity:	POSITIVE

Probe Conditions at Calibration(in air):

Calibration Voltage:	6	VDC(+)
Probe Current:	4.0	mA

Probe Output Voltage:

Probe Illuminated	88.8	mV
Probe Dark	1.0	mV
Probe Net Response	87.8	mV
RG780	1.1	mV

Corrected Lamp Output:

Output In Air (same condition as calibration):

8.379E+15	quanta/cm²sec
0.013914	uE/cm²sec

Calibration Scale Factor:

(To calculate irradiance, divide the net voltage reading in Volts by this value.)

Dry:	1.0481E-17	V/(quanta/cm²sec)
	6.3114E+00	V/(uE/cm²sec)

Notes:

1. Annual calibration is recommended.
2. Calibration is performed using a Standard of Spectral Irradiance traceable to the National Institute of Standards and Technology (NIST).
3. The collector should be cleaned frequently with alcohol.
4. Calibration was performed with customer cable, when available.

QSR240R 05/24/95

GUV (Mast)

Biospherical Instruments Inc.

System Calibration Certificate

THE INSTRUMENTS REFERENCED BELOW WERE FACTORY TESTED AND CALIBRATED BY

BIOSPHERICAL INSTRUMENTS INC.
5340 Riley Street
San Diego, California 92110 USA

Instruments: GUV-2511 No 25110203114

Optical Calibrations:

NIST Traceability. For wavelengths longer than 313 nm, the specific instruments cited here were calibrated using a 1000W FEL #V-041(7/21/16) following procedures and standards traceable to NIST Standard of Spectral Irradiance F616. Traceability paths and all procedures for all calibrated lamps and associated apparatus (shunts, power supplies, DMMs, etc) are maintained following calibration methodologies per National Bureau of Standards (US) (NBS) Special Publication 250-20 Spectral Irradiance Calibrations (1987) and NBS Publication 594–13 Optical Radiation Measurements: The 1973 Scale of Spectral Irradiance (1977).

Solar Calibrations. Lamp calibrations are problematic for solar UV measurements (wavelengths below 320 nm) because the solar spectrum is radically different from the lamp spectrum and changes greatly as a function of wavelength. Solar calibrations are achieved through direct comparison with measurements of a high resolution scanning spectroradiometer in San Diego (SUV-100), which is part of the National Science Foundation's UV Monitoring Network. The SUV-100 instrument has a bandwidth of 1 nm. Calibrated filter radiometer data therefore report spectral irradiance at the channel's nominal wavelengths with a bandwidth of 1 nm. Solar calibrations are typically accurate to within ±10% for solar zenith angles smaller than 75°. At larger solar zenith angles, UV channels have a greater uncertainty due to the rapid change of the solar UV spectrum.

Note that this certificate contains a subset of the information delivered in the calibration database 25110203114v10_12-2017.mdb. This database is required for operation of this system using Biospherical Instruments Inc.'s Logger® software.

Biospherical Instruments Inc.

GUV-2511 Calibration Certificate

System Serial Number	25110203114	Date of Calibration	12/6/2017
Calibration database	25110203114v10_12-2017.mdb	Date of Certificate	12/6/2017
DASSN	0069	Standard of Spectral Irradiance	V-041(7/21/16)
Microprocessor Tag Number	4	Operator	TC

Monochromatic Channels	Address	Wavelength [nm]	Responsivity [Amps per µW/(cm²·nm)]	ScaleSmall [Volts per µW/(cm²·nm)]	ScaleMedium [Volts per µW/(cm²·nm)]	ScaleLarge [Volts per µW/(cm²·nm)]	OffsetSmall [volts]	OffsetMedium [volts]	OffsetLarge [volts]	Measurement Units
Ed0320	2	320	2.3842E-10	2.4319E-05	7.1051E-03	2.2425E+00	3.4492E-05	3.2554E-05	5.6504E-04	µW/(cm²nm)
Ed0340	6	340	1.8676E-10	1.9050E-05	5.5656E-03	1.9092E+00	4.2136E-05	4.1875E-05	7.6934E-04	µW/(cm²nm)
Ed0313	8	313	2.2846E-10	2.3303E-05	6.8081E-03	2.3899E+00	9.1228E-04	9.0624E-04	-1.2773E-03	µW/(cm²nm)
Ed0305	10	305	1.1615E-11	1.1847E-06	3.4613E-04	1.1897E-01	3.5080E-04	3.5087E-04	1.1382E-03	µW/(cm²nm)
Ed0380	12	380	8.3114E-11	8.4776E-06	2.4768E-03	7.9442E-01	2.8388E-04	2.7513E-04	-3.8577E-05	µW/(cm²nm)
Ed0395	18	395	2.9356E-10	2.9944E-05	8.7482E-03	2.7653E+00	3.8212E-04	3.8356E-04	1.4618E-03	µW/(cm²nm)

Broadband Channels	Address	Wavelength [nm]	Responsivity [Amps per µE/(cm²·s)]	ScaleSmall [Volts per µE/(cm²·s)]	ScaleMedium [Volts per µE/(cm²·s)]	ScaleLarge [Volts per µE/(cm²·s)]	OffsetSmall [volts]	OffsetMedium [volts]	OffsetLarge [volts]	Measurement Units
Ed0PAR	13	400-700	1.7122E-05	1.7465E+00	5.1025E+02	1.8033E+05	5.6671E-04	5.6137E-04	-4.7669E-04	µE/(cm²sec)

Auxilliary Channels	Address	Wavelength	Responsivity	ScaleS	ScaleM	ScaleL	OffsetS	OffsetM	OffsetL	Measurement Units
Ed0Temp	22	0	1	0.01	0.01	0.01	0	0	0	C
Ed0Vin	27	0	1	-0.25	-0.25	-0.25	0	0	0	V

Calibration Data – Do Not Destroy

page 2 of 2

Underway Seawater Sampling System

Micro-TSG 1

Sea-Bird Electronics, Inc.
13431 NE 20th Street, Bellevue, WA 98005-2010 USA
Phone: (+1) 425-643-9866 Fax (+1) 425-643-9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 0242
CALIBRATION DATE: 02-Apr-17

SBE 45 CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Siemens/meter

COEFFICIENTS:

```
g = -9.982038e-001          CPcor = -9.5700e-008
h =  1.522508e-001          CTcor =  3.2500e-006
i = -4.303026e-004          WBOTC = -0.0000e+000
j =  5.783952e-005
```

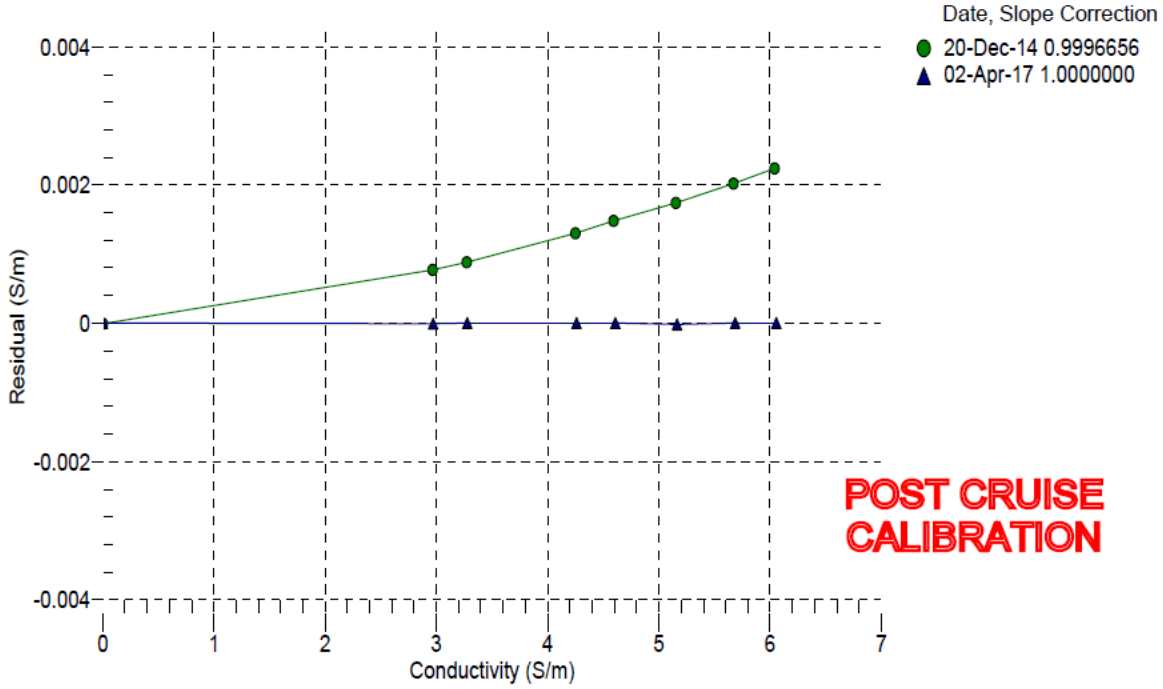
BATH TEMP (° C)	BATH SAL (PSU)	BATH COND (S/m)	INSTRUMENT OUTPUT (Hz)	INSTRUMENT COND (S/m)	RESIDUAL (S/m)
22.0000	0.0000	0.00000	2566.64	0.00000	0.00000
1.0000	34.7888	2.97384	5119.28	2.97383	-0.00001
4.5000	34.7689	3.28069	5312.80	3.28070	0.00001
15.0000	34.7272	4.26184	5888.15	4.26184	0.00000
18.5000	34.7186	4.60681	6077.20	4.60681	0.00000
24.0000	34.7094	5.16448	6370.62	5.16447	-0.00001
29.0000	34.7049	5.68612	6632.98	5.68612	0.00000
32.5000	34.7030	6.05846	6813.84	6.05847	0.00000

f = Instrument Output(Hz) * sqrt(1.0 + WBOTC * t) / 1000.0

t = temperature (°C); p = pressure (decibars); δ = CTcor; ε = CPcor;

Conductivity (S/m) = $(g + h * f^2 + i * f^3 + j * f^4) / 10 (1 + \delta * t + \varepsilon * p)$

Residual (Siemens/meter) = instrument conductivity - bath conductivity



Sea-Bird Electronics, Inc.
13431 NE 20th Street, Bellevue, WA 98005-2010 USA
Phone: (+1) 425-643-9866 Fax (+1) 425-643-9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 0242
CALIBRATION DATE: 02-Apr-17

SBE 45 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

COEFFICIENTS:

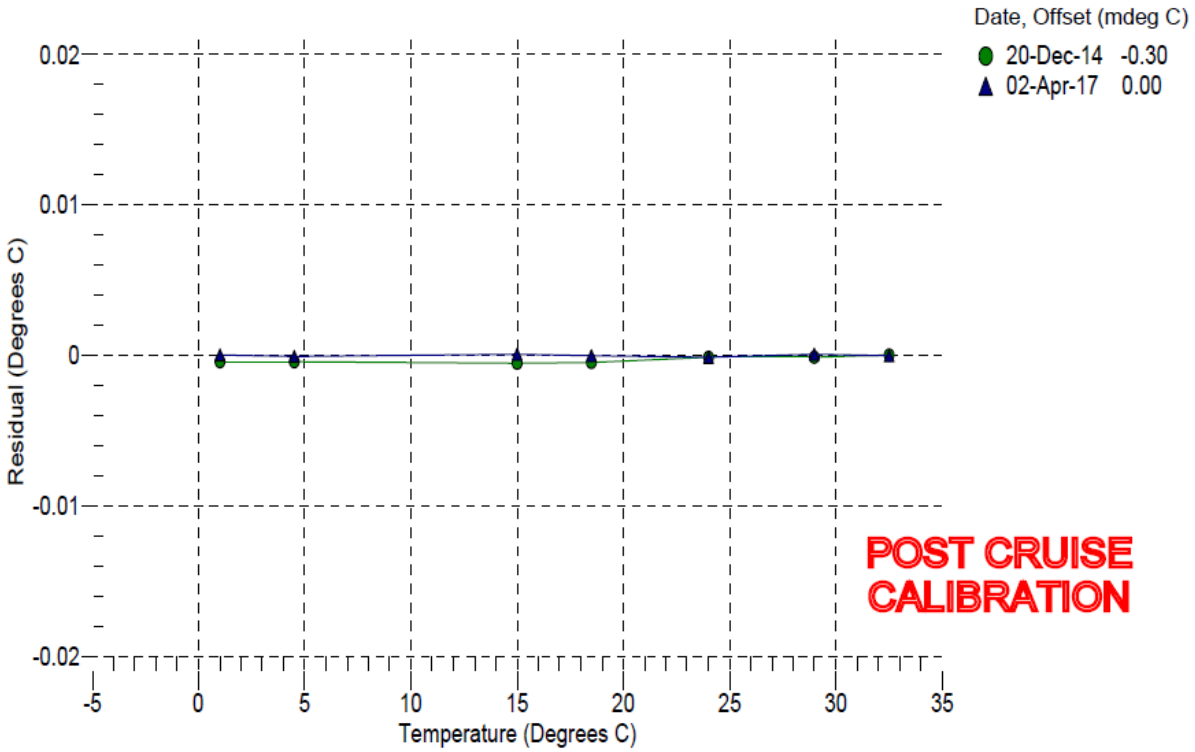
a0 = 3.676223e-005
a1 = 2.754692e-004
a2 = -2.489671e-006
a3 = 1.542625e-007

BATH TEMP (° C)	INSTRUMENT OUTPUT (counts)	INST TEMP (° C)	RESIDUAL (° C)
1.0000	649818.7	1.0000	0.0000
4.5000	554887.7	4.4999	-0.0001
15.0000	352327.2	15.0001	0.0001
18.5000	304718.5	18.5000	-0.0000
24.0000	244011.5	23.9999	-0.0001
29.0000	200600.4	29.0001	0.0001
32.5000	175478.5	32.5000	-0.0000

n = Instrument Output (counts)

Temperature ITS-90 (°C) = $1/\{a0 + a1[ln(n)] + a2[ln^2(n)] + a3[ln^3(n)]\} - 273.15$

Residual (°C) = instrument temperature - bath temperature



Micro-TSG2

Sea-Bird Scientific
13431 NE 20th Street
Bellevue, WA 98005
USA

+1 425-643-9866
seabird@seabird.com
www.seabird.com

SENSOR SERIAL NUMBER: 0389
CALIBRATION DATE: 25-Apr-18

SBE 45 CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Siemens/meter

COEFFICIENTS:

```
g = -9.985799e-001          CPcor = -9.5700e-008
h =  1.455792e-001          CTcor =  3.2500e-006
i = -3.660237e-004          WBOTC =  1.2700e-007
j =  4.864142e-005
```

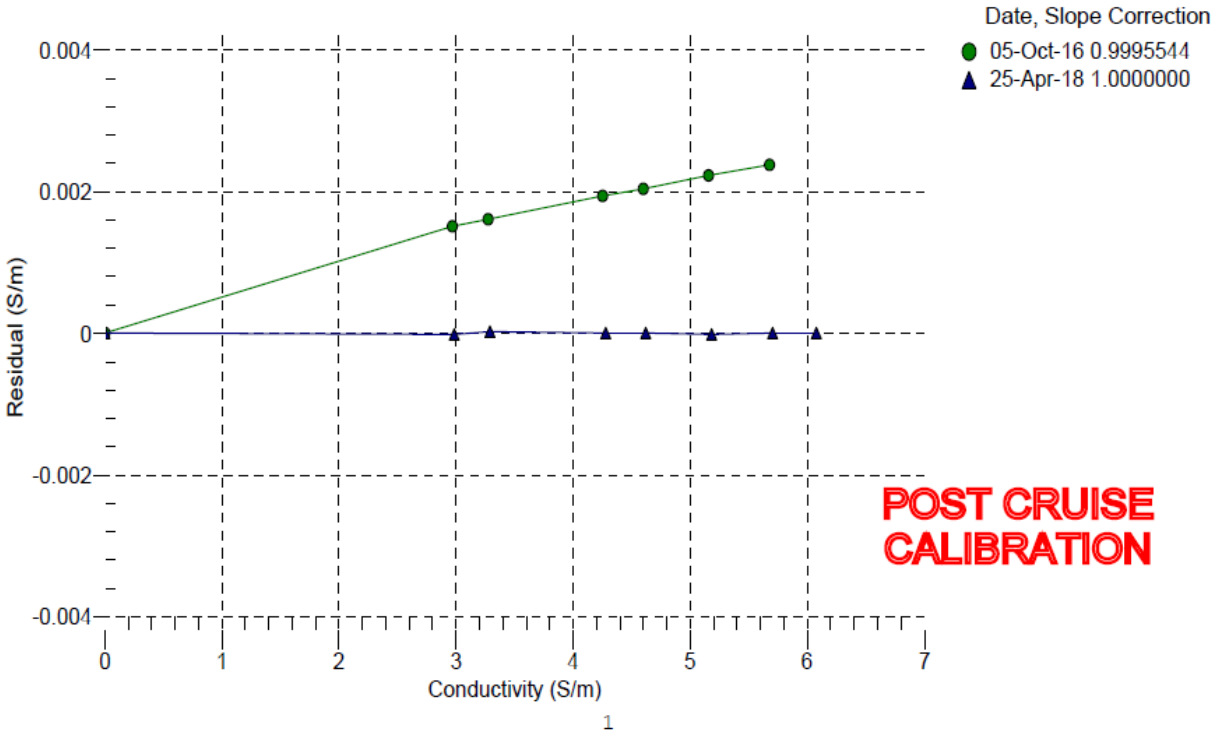
BATH TEMP (° C)	BATH SAL (PSU)	BATH COND (S/m)	INSTRUMENT OUTPUT (Hz)	INSTRUMENT COND (S/m)	RESIDUAL (S/m)
22.0000	0.0000	0.00000	2624.68	0.00000	0.00000
1.0000	34.9196	2.98395	5240.82	2.98393	-0.00002
4.5000	34.8990	3.29176	5439.06	3.29178	0.00002
15.0000	34.8558	4.27595	6028.45	4.27595	0.00000
18.5000	34.8464	4.62193	6222.11	4.62194	0.00001
24.0000	34.8356	5.18118	6522.65	5.18116	-0.00002
29.0001	34.8286	5.70412	6791.31	5.70412	0.00000
32.5000	34.8234	6.07709	6976.39	6.07709	0.00000

f = Instrument Output(Hz) * sqrt(1.0 + WBOTC * t) / 1000.0

t = temperature (°C); p = pressure (decibars); δ = CTcor; ε = CPcor;

Conductivity (S/m) = $(g + h * f^2 + i * f^3 + j * f^4) / (1 + \delta * t + \varepsilon * p)$

Residual (Siemens/meter) = instrument conductivity - bath conductivity



1

Sea-Bird Scientific
13431 NE 20th Street
Bellevue, WA 98005
USA

+1 425-643-9866
seabird@seabird.com
www.seabird.com

SENSOR SERIAL NUMBER: 0389
CALIBRATION DATE: 25-Apr-18

SBE 45 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

COEFFICIENTS:

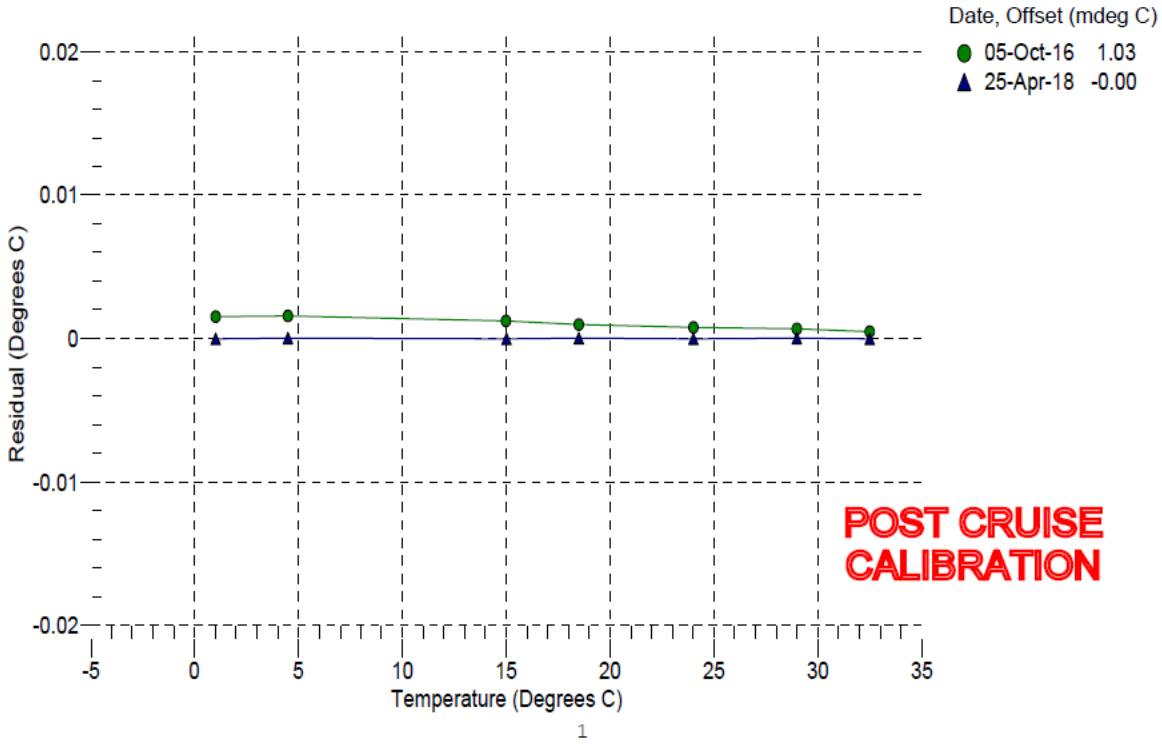
a0 = 7.863170e-006
a1 = 2.711897e-004
a2 = -2.263006e-006
a3 = 1.440061e-007

BATH TEMP (° C)	INSTRUMENT OUTPUT (counts)	INST TEMP (° C)	RESIDUAL (° C)
1.0000	828476.9	1.0000	-0.0000
4.5000	706678.1	4.5000	0.0000
15.0000	447327.3	15.0000	-0.0000
18.5000	386500.1	18.5000	0.0000
24.0000	309037.1	24.0000	-0.0000
29.0001	253723.7	29.0001	0.0000
32.5000	221749.9	32.5000	-0.0000

n = Instrument Output (counts)

Temperature ITS-90 (°C) = $1/\{a0 + a1[ln(n)] + a2[ln^2(n)] + a3[ln^3(n)]\} - 273.15$

Residual (°C) = instrument temperature - bath temperature



1

Digital Remote Temp

Sea-Bird Electronics, Inc.
13431 NE 20th Street, Bellevue, WA 98005-2010 USA
Phone: (+1) 425-643-9866 Fax (+1) 425-643-9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 0178
CALIBRATION DATE: 07-Feb-17

SBE 38 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

COEFFICIENTS:

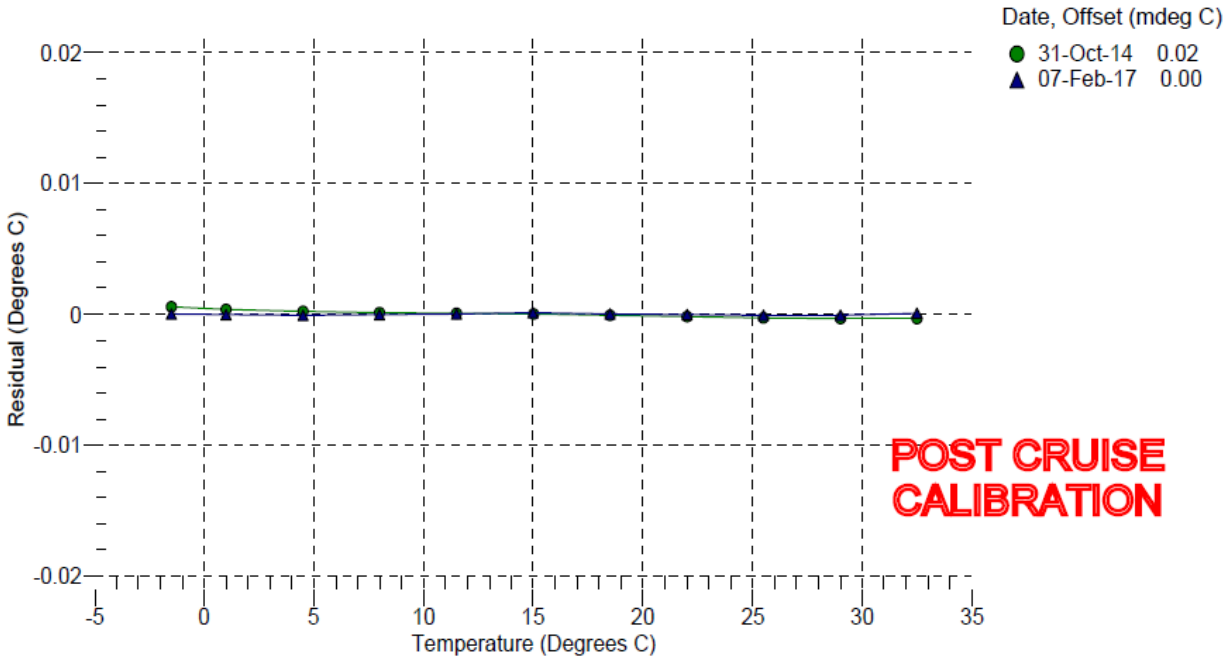
a0 = -3.943075e-005
a1 = 2.802070e-004
a2 = -2.606506e-006
a3 = 1.642771e-007

BATH TEMP (° C)	INSTRUMENT OUTPUT (counts)	INST TEMP (° C)	RESIDUAL (° C)
-1.5000	750884.0	-1.5000	0.0000
1.0000	671251.6	1.0000	-0.0000
4.5000	575382.9	4.4999	-0.0001
8.0000	494800.5	8.0000	-0.0000
11.5000	426841.3	11.5000	0.0000
14.9999	369340.5	15.0000	0.0001
18.5000	320533.9	18.5000	0.0000
22.0000	278978.8	22.0000	-0.0000
25.5000	243492.0	25.4999	-0.0001
29.0000	213097.4	28.9999	-0.0001
32.5000	186990.2	32.5001	0.0001

n = Instrument Output (counts)

Temperature ITS-90 (°C) = $1/\{a0 + a1[ln(n)] + a2[ln^2(n)] + a3[ln^3(n)]\} - 273.15$

Residual (°C) = instrument temperature - bath temperature



Transmissometer

PO Box 518
620 Applegate St.
Philomath, OR 97370

(541) 929-5650
Fax (541) 929-5277
www.wetlabs.com

C-Star Calibration

Date 7.29.16 S/N# CST-439DR Pathlength 25 cm

	Analog output	
V_d	0.057 V	
V_{air}	4.752 V	
V_{ref}	4.659 V	
Temperature of calibration water		23.7 ℃
Ambient temperature during calibration		22.8 ℃

Relationship of transmittance (Tr) to beam attenuation coefficient (c), and pathlength (x, in meters): $\mathbf{Tr = e^{-cx}}$
To determine beam transmittance: $\mathbf{Tr = (V_{sig} - V_{dark}) / (V_{ref} - V_{dark})}$
To determine beam attenuation coefficient: $\mathbf{c = -1/x * ln\ (Tr)}$

V_d Meter output with the beam blocked. This is the offset.
V_{air} Meter output in air with a clear beam path.
V_{ref} Meter output with clean water in the path.
Temperature of calibration water: temperature of clean water used to obtain V_{ref}.
Ambient temperature: meter temperature in air during the calibration.
V_{sig} Measured signal output of meter.

PO Box 518
620 Applegate St.
Philomath, OR 97370

WET Labs

(541) 929-5650
Fax (541) 929-5277
www.wetlabs.com

C-Star Repairs

Date 7/11/2016 Customer NFS LMP4 ISGS

S/N# CST-439DR Repair Order 31167

Standard Service (Analog)

- Replaced cover plate seal
- Checked optics alignment
- Performed noise test: 1 sample/sec for 60 sec
- Performed stability test: 1 sample/min for 12 hrs
- Performed temperature test
- Performed water calibration
- Shake-tested unit
- Pressure-tested unit
- Updated unit's calibration sheet

Additional Repairs

Replaced TX Pressure Window.
Replaced RX Pressure Window.

Comments

Fluorometer

PO Box 518
620 Applegate St.
Philomath, OR 97370

(541) 929-5650
Fax (541) 929-5277
www.wetlabs.com

ECO Chlorophyll Fluorometer Characterization Sheet

Date: 4/20/2017 S/N: FLRTD-397

Chlorophyll concentration expressed in µg/l can be derived using the equation:

CHL (µg/l) = Scale Factor * (Output - Dark Counts)

	Analog Range 1	Analog Range 2	Analog Range 4 (default)		Digital	
Dark Counts	0.102	0.063	0.043	V	63	counts
Scale Factor (SF)	6	13	25	µg/l/V	0.0077	µg/l/count
Maximum Output	4.98	4.98	4.98	V	16330	counts
Resolution	0.8	0.8	0.8	mV	1.0	counts

Ambient temperature during characterization 22.0 °C

Analog Range: 1 (most sensitive, 0–4,000 counts), 2 (midrange, 0–8,000 counts), 4 (entire range, 0–16,000 counts).

Dark Counts: Signal output of the meter in clean water with black tape over detector.

SF: Determined using the following equation: SF = x ÷ (output - dark counts), where x is the concentration of the solution used during instrument characterization. SF is used to derive instrument output concentration from the raw signal output of the fluorometer.

Maximum Output: Maximum signal output the fluorometer is capable of.

Resolution: Standard deviation of 1 minute of collected data.

The relationship between fluorescence and chlorophyll-a concentrations *in-situ* is highly variable. The scale factor listed on this document was determined using a mono-culture of phytoplankton (*Thalassiosira weissflogii*). The population was assumed to be reasonably healthy and the concentration was determined by using the absorption method. To accurately determine chlorophyll concentration using a fluorometer, you must perform secondary measurements on the populations of interest. This is typically done using extraction-based measurement techniques on discrete samples. For additional information on determining chlorophyll concentration see "Standard Methods for the Examination of Water and Wastewater" part 10200 H, published jointly by the American Public Health Association, American Water Works Association, and the Water Environment Federation.

FLRTD-397 Revision J 3/17/08

PO Box 518
620 Applegate St.
Philomath, OR 97370

(541) 929-5650
Fax (541) 929-5277
www.wetlabs.com

WET Labs

ECO Calibration and Repairs

Date 4/20/2017 Customer Leidos Innovations Corp

S/N# FLRTD-397 Technician ZB

Diagnosis

Evaluated instrument and found no problems.

Repairs

Standard Service performed.

ECO Standard Service Definition

The bulkhead connector, pressure housing and window on the instrument are first inspected for possible damage.
The instrument then is powered on and the current data is checked to determine if the instrument is working properly.
The instrument pre-service characterization is perfromed
The head is next inspected for cracks in the LED, the detector and the motor bores.
The digital and analog operations are checked.
The instruments scaling is checked with dye or scatter proxy as determined by the instrument type.
The firmware version on the instrument is updated as necessary.
The case seals, desiccant, shaft seal, faceplate, and shaft are replaced as the instrument is reassembled.
The instrument is rescaled if needed after reassembly.
Standard testing is performed on the instrument and characterized before being returned to the customer.

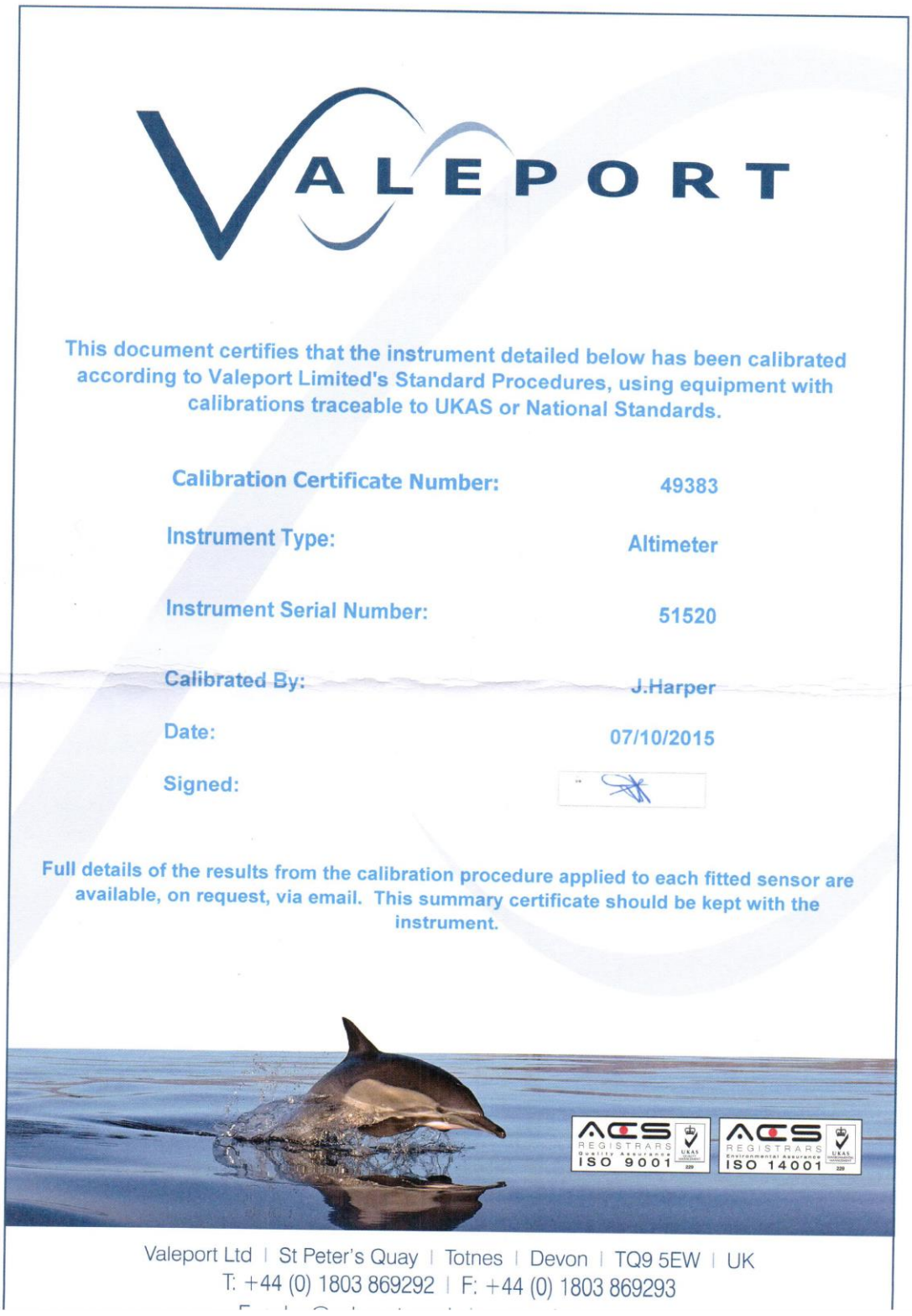
ECO Standard Testing Definition

- Performed noise test: 1 sample/sec for 60 sec
- Performed stability test: 1 sample/sec for 12 hrs as needed
- Performed thermistor calibration if installed
- Performed live 6hr pressure test: 5 samples every 4 minutes as needed
- Pressure-tested unit
- Completed instrument characterization
- Updated unit's characterization sheet and included on CD
- Updated unit's device file and included on CD

FLRTD-397 Revision L 6/9/09

CTD

Altimeter



VALEPORT

This document certifies that the instrument detailed below has been calibrated according to Valeport Limited's Standard Procedures, using equipment with calibrations traceable to UKAS or National Standards.

Calibration Certificate Number:	49383
Instrument Type:	Altimeter
Instrument Serial Number:	51520
Calibrated By:	J.Harper
Date:	07/10/2015
Signed:	

Full details of the results from the calibration procedure applied to each fitted sensor are available, on request, via email. This summary certificate should be kept with the instrument.

ACS REGISTRARS Quality Assurance ISO 9001 UKAS 229

ACS REGISTRARS Environmental Assurance ISO 14001 UKAS 229

Valeport Ltd | St Peter's Quay | Totnes | Devon | TQ9 5EW | UK
T: +44 (0) 1803 869292 | F: +44 (0) 1803 869293

Instrument Serial Number	51520
Sensor Type	500kHz Neptune
Altimeter Range (m)	100m
Certificate Number	49383

Stage 1

Test the assembled altimeter in a body of water to ensure a signal is recieved at the minimum range. Taking direct readings from the unit immerse the head till it is roughly 0.1m from the bottom, readings should come through - if not then the signal is being saturated and there is a problem

To inhibit spurious readings set using: #226;40

	Pass/Fail
Bench Test Min Range <0.1m	Pass

Stage 2

Using a mini SVS or similar, measure the average sound velocity for the water in the tow tank and input the value in the cell below.

Enter the SOS	1484.355

Input SOS value to the altimeter using: #830;1484.3550

Stage 3

Fit the altimeter into the calibration fixture and lower the assembly into the tank till it is about 0.5m down facing the far end of the tow tank and clamp in place. Using the distance markers on the wall align the front edge of the trolley with the datum line to set the front of the altimeter at stated distance from the wall.

To determine the Range Offset		
Distance m	Measured Range m	Measured Offset m
1	1.025	-0.025

Stage 4: Enter the Offset Correction
#828;-0.0250

Stage 5 - Range Check after Offset Correction			
Distance m	Measured Range m	Measured Offset m	Pass/Fail
1	0.997	0.003	Pass
5	5.003	-0.003	Pass

Stage 6: Reset the SOS
#830;1500

Stage 7: Reset maximum range to 105m	Stage 8: Reset spurious range
#823;105 (500kHz units)	#226;0

Calibrated by:	J,Harper	Date:	07/10/2015

Carousel Water Sampler

SEA-BIRD SCIENTIFIC
Sea-Bird Scientific
13431 NE 20th Street
Bellevue, WA 98005
USA

+1 425-643-9866
seabird@seabird.com
www.seabird.com

Pressure Test Certificate

Test Date: **2017-05-12**

Description: **SBE-32 Carousel**

Sensor Information:

Model Number: **SBE-32**

Serial Number: **32-0140**

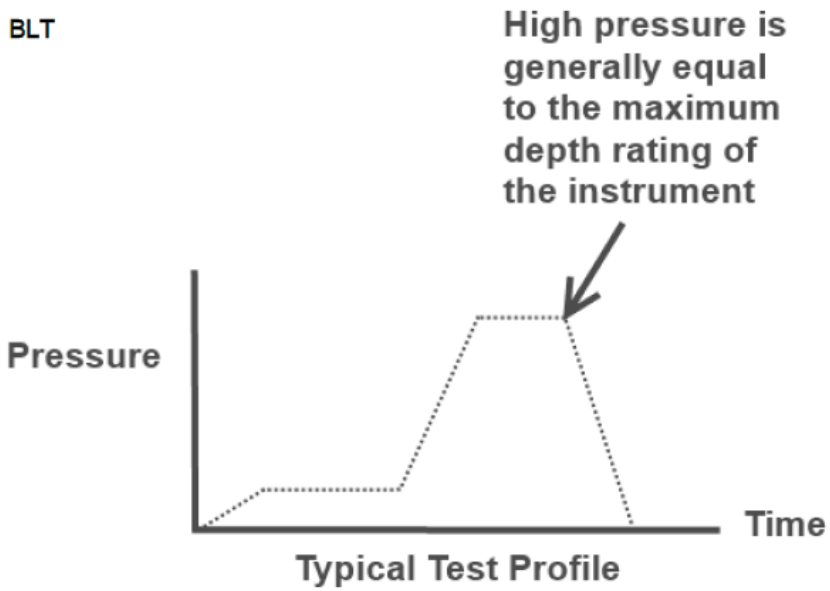
Replaced the main piston "O"-Rings.
Replaced 6-pin connector.
Replaced main housing.
*** Due to the dimensions of the CAROUSEL we are unable to perform a high pressure test at this time.**

Pressure Test Protocol:

Low Pressure Test: **50**	PSI	Held For: **60**	Minutes
High Pressure Test: **50**	PSI	Held For: **60**	Minutes

Passed Test: **True**

Tested By: **BLT**



Typical Test Profile

Conductivity (primary)

Sea-Bird Electronics, Inc.
13431 NE 20th Street, Bellevue, WA 98005-2010 USA
Phone: (+1) 425-643-9866 Fax (+1) 425-643-9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 0924
CALIBRATION DATE: 12-Jul-16

SBE 4 CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Siemens/meter

COEFFICIENTS:

```
g =  -3.98953205e+000
h =   5.33996727e-001
i =  -6.17748041e-004
j =   6.07241578e-005

CPcor = -9.5700e-008 (nominal)
CTcor =  3.2500e-006 (nominal)
```

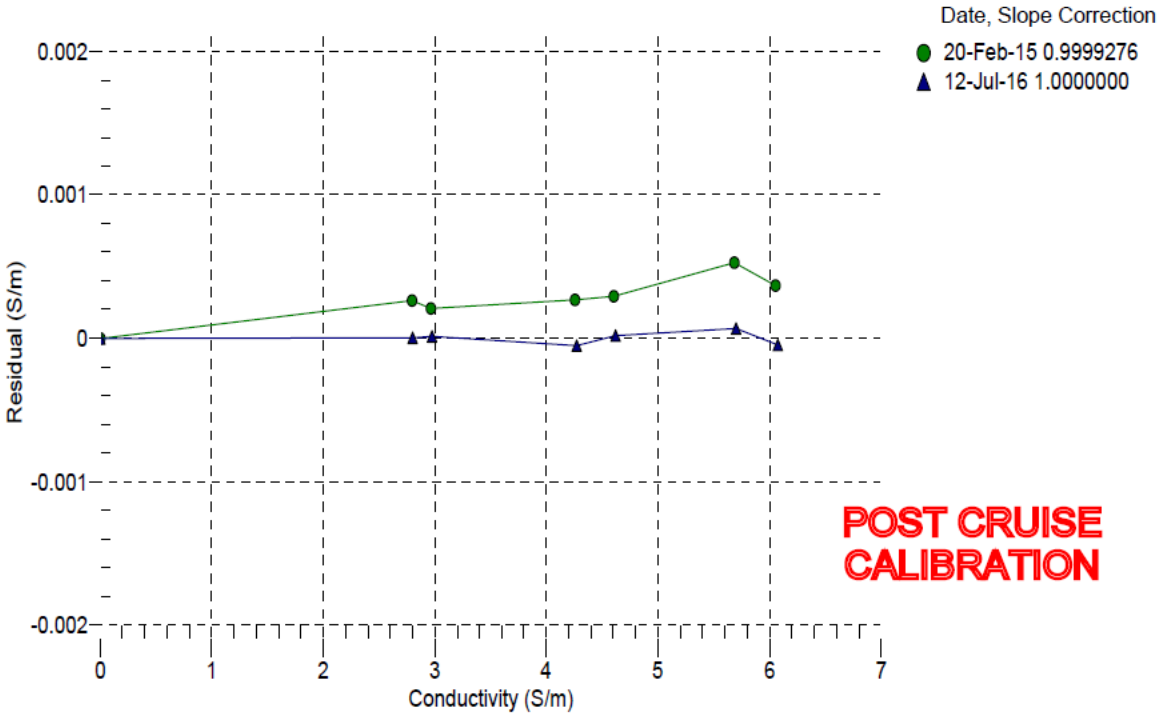
BATH TEMP (° C)	BATH SAL (PSU)	BATH COND (S/m)	INSTRUMENT OUTPUT (kHz)	INSTRUMENT COND (S/m)	RESIDUAL (S/m)
0.0000	0.0000	0.00000	2.73649	0.00000	0.00000
-0.9999	34.8078	2.80396	7.75295	2.80397	0.00000
1.0000	34.8082	2.97534	7.95718	2.97535	0.00001
15.0001	34.8101	4.27094	9.35579	4.27089	-0.00005
18.5001	34.8100	4.61763	9.69532	4.61765	0.00002
29.0001	34.8089	5.70125	10.68537	5.70132	0.00007
32.5001	34.8016	6.07373	11.00441	6.07368	-0.00005

f = Instrument Output (kHz)

t = temperature (°C); p = pressure (decibars); δ = CTcor; ε = CPcor;

Conductivity (S/m) = $(g + h * f^2 + i * f^3 + j * f^4) / 10 (1 + \delta * t + \varepsilon * p)$

Residual (Siemens/meter) = instrument conductivity - bath conductivity



Conductivity (secondary)

Sea-Bird Electronics, Inc.
13431 NE 20th Street, Bellevue, WA 98005-2010 USA
Phone: (+1) 425-643-9866 Fax (+1) 425-643-9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 0926
CALIBRATION DATE: 12-Jul-16

SBE 4 CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Siemens/meter

COEFFICIENTS:

```
g =  -3.91309829e+000
h =   5.12414297e-001
i =  -5.20191483e-004
j =   5.45810431e-005

CPcor = -9.5700e-008 (nominal)
CTcor =  3.2500e-006 (nominal)
```

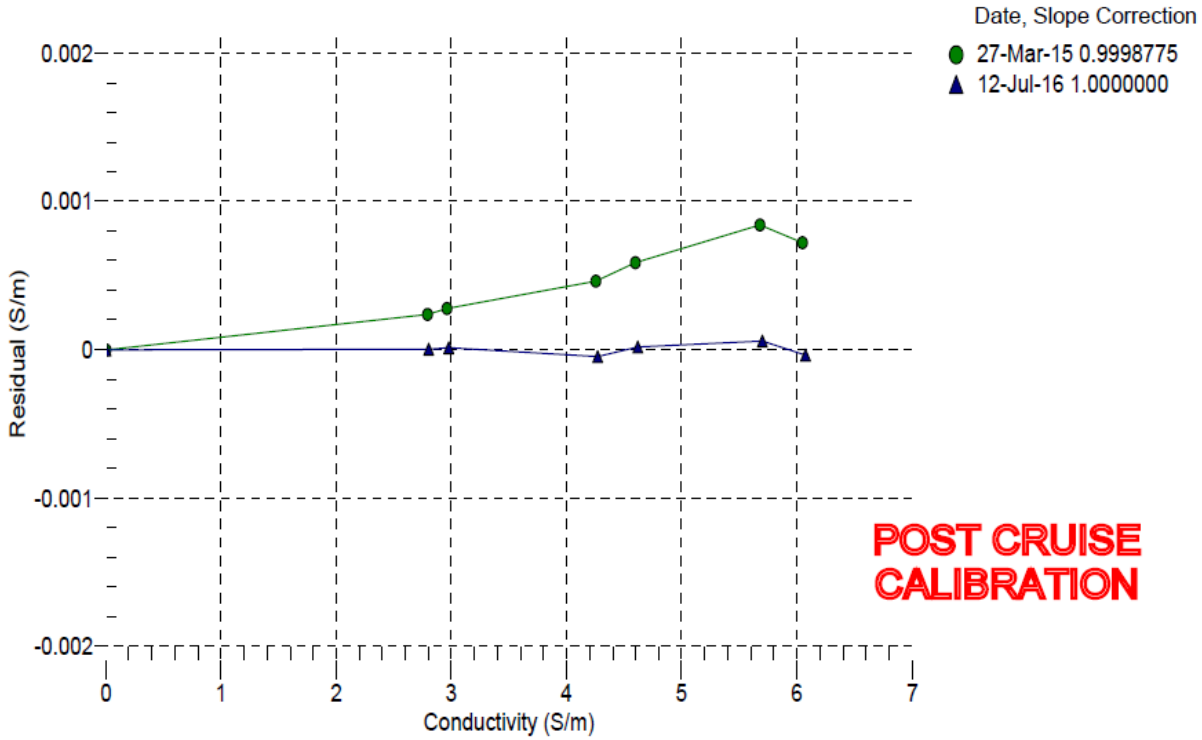
BATH TEMP (° C)	BATH SAL (PSU)	BATH COND (S/m)	INSTRUMENT OUTPUT (kHz)	INSTRUMENT COND (S/m)	RESIDUAL (S/m)
0.0000	0.0000	0.00000	2.76619	0.00000	0.00000
-0.9999	34.8078	2.80396	7.90207	2.80397	0.00000
1.0000	34.8082	2.97534	8.11066	2.97535	0.00001
15.0001	34.8101	4.27094	9.53878	4.27090	-0.00005
18.5001	34.8100	4.61763	9.88540	4.61765	0.00002
29.0001	34.8089	5.70125	10.89599	5.70131	0.00006
32.5001	34.8016	6.07373	11.22165	6.07369	-0.00004

f = Instrument Output (kHz)

t = temperature (°C); p = pressure (decibars); δ = CTcor; ε = CPcor;

Conductivity (S/m) = $(g + h * f^2 + i * f^3 + j * f^4) / 10 (1 + \delta * t + \varepsilon * p)$

Residual (Siemens/meter) = instrument conductivity - bath conductivity



Dissolved Oxygen (primary)

Sea-Bird Scientific
13431 NE 20th Street
Bellevue, WA 98005
USA

+1 425-643-9866
seabird@seabird.com
www.seabird.com

SENSOR SERIAL NUMBER: 0082
CALIBRATION DATE: 01-Aug-17

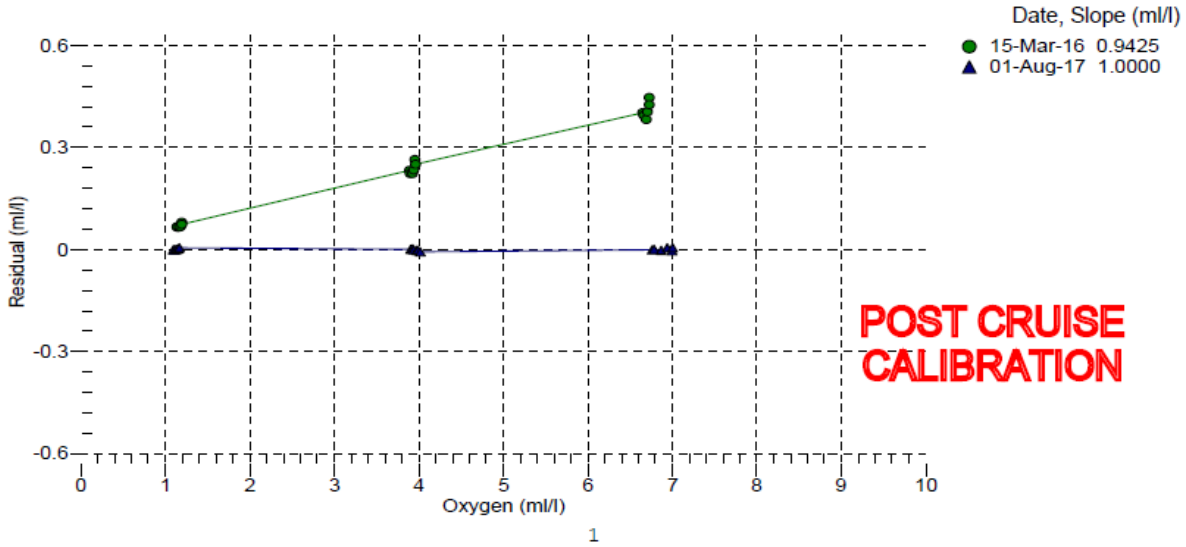
SBE 43 OXYGEN CALIBRATION DATA

COEFFICIENTS:
Soc = 0.3761
Voffset = -0.6984
Tau20 = 1.28
A = -4.1443e-003
B = 1.6754e-004
C = -2.7763e-006
E nominal = 0.036

NOMINAL DYNAMIC COEFFICIENTS
D1 = 1.92634e-4
D2 = -4.64803e-2
H1 = -3.300000e-2
H2 = 5.00000e+3
H3 = 1.45000e+3

BATH OXYGEN (ml/l)	BATH TEMPERATURE (° C)	BATH SALINITY (PSU)	INSTRUMENT OUTPUT (volts)	INSTRUMENT OXYGEN (ml/l)	RESIDUAL (ml/l)
1.09	2.00	0.00	1.001	1.09	-0.00
1.10	6.00	0.00	1.041	1.10	-0.00
1.12	12.00	0.00	1.104	1.12	-0.00
1.13	20.00	0.00	1.192	1.14	0.00
1.15	26.00	0.00	1.264	1.15	0.00
1.16	30.00	0.00	1.316	1.17	0.01
3.91	2.00	0.00	1.780	3.91	0.00
3.92	6.00	0.00	1.920	3.92	0.00
3.94	12.00	0.00	2.132	3.94	-0.00
3.97	20.00	0.00	2.424	3.97	-0.00
3.99	26.00	0.00	2.652	3.99	-0.00
4.01	30.00	0.00	2.816	4.01	-0.01
6.76	2.00	0.00	2.570	6.76	-0.00
6.79	6.00	0.00	2.811	6.79	0.00
6.87	12.00	0.00	3.196	6.87	-0.00
6.94	20.00	0.00	3.717	6.95	0.01
6.99	26.00	0.00	4.120	6.99	-0.00
7.00	30.00	0.00	4.399	7.00	0.00

V = instrument output (volts); T = temperature (°C); S = salinity (PSU); K = temperature (°K)
Oxsol(T,S) = oxygen saturation (ml/l); P = pressure (dbar)
Oxygen (ml/l) = Soc * (V + Voffset) * (1.0 + A * T + B * T^2 + C * T^3) * Oxsol(T,S) * exp(E * P / K)
Residual (ml/l) = instrument oxygen - bath oxygen



1

SEA-BIRD SCIENTIFIC
Sea-Bird Scientific
13431 NE 20th Street
Bellevue, WA 98005
USA

+1 425-643-9866
seabird@seabird.com
www.seabird.com

SENSOR SERIAL NUMBER: 0082
CALIBRATION DATE: 22-Aug-17

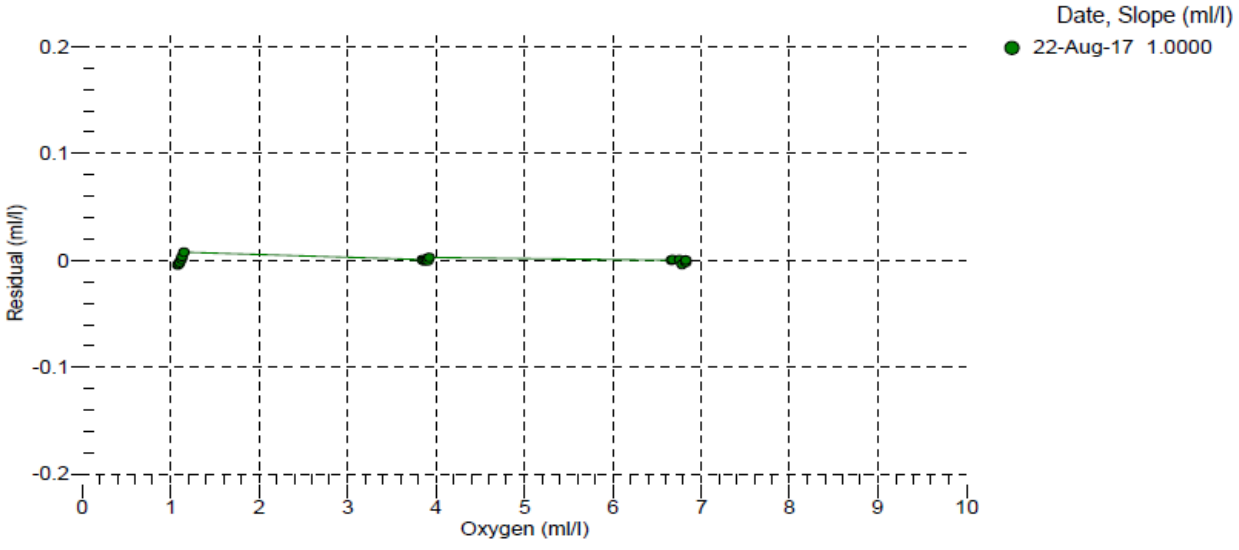
SBE 43 OXYGEN CALIBRATION DATA

COEFFICIENTS:
Soc = 0.4805
Voffset = -0.4953
Tau20 = 1.06
A = -3.1439e-003
B = 1.3533e-004
C = -2.2619e-006
E nominal = 0.036

NOMINAL DYNAMIC COEFFICIENTS
D1 = 1.92634e-4
D2 = -4.64803e-2
H1 = -3.300000e-2
H2 = 5.00000e+3
H3 = 1.45000e+3

BATH OXYGEN (ml/l)	BATH TEMPERATURE (° C)	BATH SALINITY (PSU)	INSTRUMENT OUTPUT (volts)	INSTRUMENT OXYGEN (ml/l)	RESIDUAL (ml/l)
1.08	2.00	0.00	0.729	1.08	-0.00
1.10	6.00	0.00	0.760	1.09	-0.00
1.11	12.00	0.00	0.807	1.10	-0.00
1.13	20.00	0.00	0.874	1.13	0.00
1.13	26.00	0.00	0.925	1.14	0.00
1.15	30.00	0.00	0.966	1.16	0.01
3.85	2.00	0.00	1.328	3.85	0.00
3.86	6.00	0.00	1.431	3.86	-0.00
3.88	12.00	0.00	1.590	3.88	0.00
3.90	26.00	0.00	1.970	3.90	0.00
3.91	20.00	0.00	1.809	3.91	-0.00
3.92	30.00	0.00	2.094	3.93	0.00
6.66	2.00	0.00	1.937	6.66	0.00
6.67	6.00	0.00	2.114	6.68	0.00
6.76	12.00	0.00	2.403	6.76	0.00
6.79	30.00	0.00	3.257	6.78	-0.00
6.82	20.00	0.00	2.788	6.82	-0.00
6.82	26.00	0.00	3.075	6.83	0.00

V = instrument output (volts); T = temperature (°C); S = salinity (PSU); K = temperature (°K)
Oxsol(T,S) = oxygen saturation (ml/l); P = pressure (dbar)
$Oxygen\ (ml/l) = Soc * (V + Voffset) * (1.0 + A * T + B * T^2 + C * T^3) * Oxsol(T,S) * \exp(E * P / K)$
Residual (ml/l) = instrument oxygen - bath oxygen



1

Dissolved Oxygen (secondary)

SEA-BIRD SCIENTIFIC
Sea-Bird Scientific
13431 NE 20th Street
Bellevue, WA 98005
USA

+1 425-643-9866
seabird@seabird.com
www.seabird.com

SENSOR SERIAL NUMBER: 0152
CALIBRATION DATE: 01-Aug-17

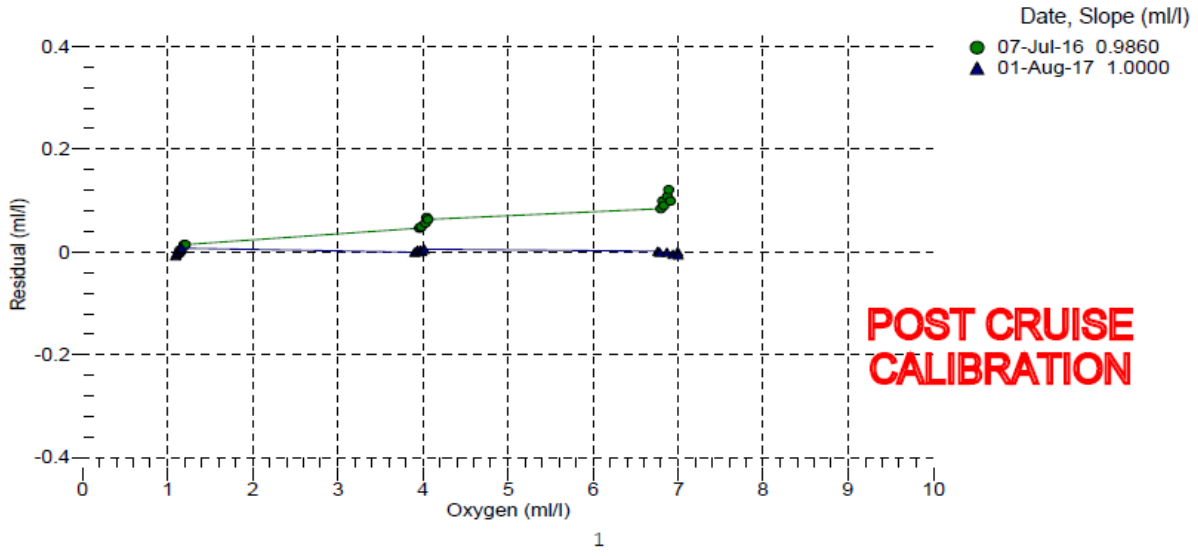
SBE 43 OXYGEN CALIBRATION DATA

COEFFICIENTS:
Soc = 0.4401
Voffset = -0.4941
Tau20 = 1.07
A = -4.0723e-003
B = 2.2936e-004
C = -3.5396e-006
E nominal = 0.036

NOMINAL DYNAMIC COEFFICIENTS
D1 = 1.92634e-4
D2 = -4.64803e-2
H1 = -3.300000e-2
H2 = 5.00000e+3
H3 = 1.45000e+3

BATH OXYGEN (ml/l)	BATH TEMPERATURE (° C)	BATH SALINITY (PSU)	INSTRUMENT OUTPUT (volts)	INSTRUMENT OXYGEN (ml/l)	RESIDUAL (ml/l)
1.09	2.00	0.00	0.751	1.09	-0.01
1.10	6.00	0.00	0.785	1.10	-0.00
1.12	12.00	0.00	0.838	1.11	-0.00
1.13	20.00	0.00	0.907	1.14	0.00
1.15	26.00	0.00	0.963	1.16	0.00
1.16	30.00	0.00	1.003	1.17	0.01
3.91	2.00	0.00	1.418	3.91	-0.00
3.92	6.00	0.00	1.535	3.92	0.00
3.94	12.00	0.00	1.710	3.95	0.00
3.97	20.00	0.00	1.940	3.98	0.00
3.99	26.00	0.00	2.113	3.99	0.00
4.01	30.00	0.00	2.241	4.02	0.01
6.76	2.00	0.00	2.093	6.76	0.00
6.79	6.00	0.00	2.295	6.79	-0.00
6.87	12.00	0.00	2.611	6.87	-0.00
6.94	20.00	0.00	3.017	6.94	-0.00
6.99	26.00	0.00	3.330	6.99	0.00
7.00	30.00	0.00	3.534	6.99	-0.01

V = instrument output (volts); T = temperature (°C); S = salinity (PSU); K = temperature (°K)
Oxsol(T,S) = oxygen saturation (ml/l); P = pressure (dbar)
$Oxygen\ (ml/l) = Soc * (V + Voffset) * (1.0 + A * T + B * T^2 + C * T^3) * Oxsol(T,S) * \exp(E * P / K)$
Residual (ml/l) = instrument oxygen - bath oxygen



1

Fluorometer

PO Box 518
620 Applegate St.
Philomath, OR 97370

(541) 929-5650
Fax (541) 929-5277
www.wetlabs.com

ECO Chlorophyll Fluorometer Characterization Sheet

Date: 5/16/2018 S/N: FLRTD-855

Chlorophyll concentration expressed in µg/l can be derived using the equation:

CHL (µg/l) = Scale Factor * (Output - Dark Counts)

	Analog Range 1	Analog Range 2	Analog Range 4 (default)		Digital	
Dark Counts	0.113	0.070	0.049	V	71	counts
Scale Factor (SF)	7	14	29	µg/l/V	0.0079	µg/l/count
Maximum Output	4.98	4.98	4.98	V	16326	counts
Resolution	0.6	0.6	0.6	mV	1.0	counts

Ambient temperature during characterization 22.0 °C

Analog Range: 1 (most sensitive, 0–4,000 counts), 2 (midrange, 0–8,000 counts), 4 (entire range, 0–16,000 counts).

Dark Counts: Signal output of the meter in clean water with black tape over detector.

SF: Determined using the following equation: SF = x ÷ (output - dark counts), where x is the concentration of the solution used during instrument characterization. SF is used to derive instrument output concentration from the raw signal output of the fluorometer.

Maximum Output: Maximum signal output the fluorometer is capable of.

Resolution: Standard deviation of 1 minute of collected data.

The relationship between fluorescence and chlorophyll-a concentrations *in-situ* is highly variable. The scale factor listed on this document was determined using a mono-culture of phytoplankton (*Thalassiosira weissflogii*). The population was assumed to be reasonably healthy and the concentration was determined by using the absorption method. To accurately determine chlorophyll concentration using a fluorometer, you must perform secondary measurements on the populations of interest. This is typically done using extraction-based measurement techniques on discrete samples. For additional information on determining chlorophyll concentration see "Standard Methods for the Examination of Water and Wastewater" part 10200 H, published jointly by the American Public Health Association, American Water Works Association, and the Water Environment Federation.

FLRTD-855 Revision J 3/17/08

PO Box 518
620 Applegate St.
Philomath OR 97370

SEA-BIRD SCIENTIFIC

(541) 929-5650
Fax (541) 929-5277
www.seabird.com

ECO Calibration and Repairs

Diagnosis: Evaluated instrument FLRTD-855 and found no problems.

Repairs and Modifications: Standard service performed.

Comments: New Device file and characterization sheets included.

ECO Standard Service:

The instrument bulkhead connector, pressure housing and window\optics are inspected for damage. Instrument is checked to determine proper functionality. Incoming settings and memory are collected if incoming condition allows.

A pre-service characterization is performed. Data is analyzed and Instrument is rescaled, if applicable.

The head is inspected for cracks in detector and motor bores. Case seals, shaft, shaft seal, faceplate, wiper, desiccant pack and batteries (if equipped) are replaced. Noise, stability, and live pressure test is performed.

Final calibration and characterization is completed. Including calibration of thermistor and pressure sensor, if equipped. A device file, repair sheet, and new characterization sheets are provided to customer via hard copy and CD.

Pressure Sensor

Sea-Bird Scientific
13431 NE 20th Street
Bellevue, WA 98005
USA

+1 425-643-9866
seabird@seabird.com
www.seabird.com

SENSOR SERIAL NUMBER: 1130
CALIBRATION DATE: 23-Apr-18

SBE 9plus PRESSURE CALIBRATION DATA
10000 psia S/N 120089

DIGIQUARTZ COEFFICIENTS:

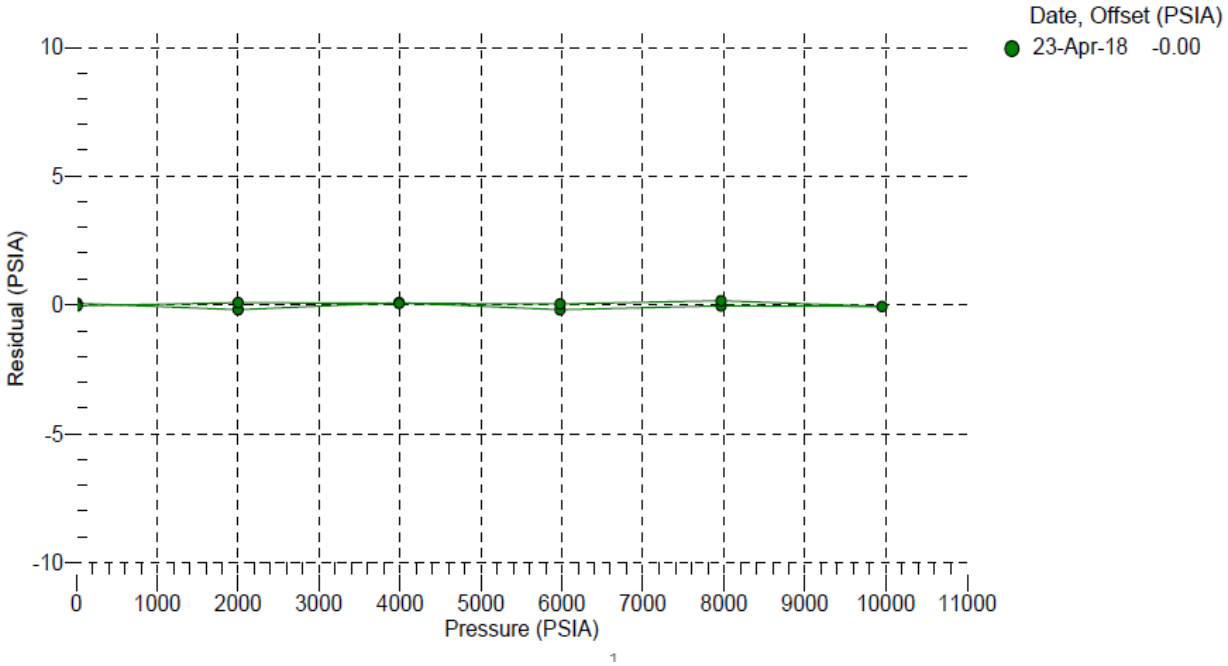
C1 =	-4.230776e+004
C2 =	1.490078e-001
C3 =	1.507500e-002
D1 =	3.473000e-002
D2 =	0.000000e+000
T1 =	3.002251e+001
T2 =	-2.774200e-004
T3 =	4.796030e-006
T4 =	1.754420e-009
T5 =	0.000000e+000

AD590M, AD590B, SLOPE AND OFFSET:

AD590M =	1.28100e-002
AD590B =	-8.83931e+000
Slope =	1.00002
Offset =	0.0671 (dbars)

PRESSURE (PSIA)	INSTRUMENT OUTPUT (Hz)	INSTRUMENT TEMPERATURE (°C)	INSTRUMENT PRESSURE (PSIA)	CORRECTED PRESSURE (PSIA)	RESIDUAL (PSIA)
14.773	33318.30	21.8	14.731	14.828	0.055
2001.291	34090.10	21.8	2000.973	2001.116	-0.175
3988.404	34842.80	21.9	3988.299	3988.486	0.082
5975.389	35577.00	21.9	5974.980	5975.212	-0.177
7962.053	36294.10	21.9	7961.729	7962.007	-0.046
9950.019	36995.50	22.0	9949.640	9949.963	-0.056
7962.381	36294.30	22.0	7962.271	7962.548	0.167
5975.403	35577.10	22.0	5975.213	5975.446	0.043
3988.370	34842.80	22.0	3988.249	3988.437	0.067
2001.246	34090.20	22.1	2001.179	2001.322	0.076
14.766	33318.30	22.3	14.632	14.730	-0.036

Residual (PSIA) = corrected instrument pressure - reference pressure



PAR

Calibration Date: 12/12/16 **Job No.:** R12817
Model Number: QSP2350
Serial Number: 70555
Operator: TPC
Standard Lamp: 91453(7/20/16)
Operating Voltage Range: 6 to 15 VDC (+)

Note: The QSP2350 output is a voltage that is proportional to the log of the incident irradiance.
To calculate irradiance, use this formula:
Irradiance = Calibration factor * (10^Light Signal Voltage - 10^Dark Voltage)

Dry Calibration Factor: 2.72E+12 quanta/cm²·sec per volt 4.52E-06 µEinsteins/cm²·sec per volt
Wet Calibration Factor: 4.81E+12 quanta/cm²·sec per volt 7.99E-06 µEinsteins/cm²·sec per volt

Sensor Test Data and Results[2)]

Sensor Supply Current (Dark): 3.4 mA
Supply Voltage: 6 Volts
Lamp Integrated PAR Irradiance: 8.38E+15 quanta/cm²·sec 0.01391 µEinsteins/cm²sec
Immersion Coefficient: 0.566

Nominal Filter OD	Expected Transmission	Calibrated Trans.	Sensor Voltage	Expected Voltage	Voltage % Error	Measured Trans.	Transmission Error (%)	Test Irrad. (quanta/ cm²·sec)
No Filter	100%	100.00%	3.488	3.488	0%	100.00%	0.0	8.38E+15
0.3	50%	36.10%	3.046	3.046	0%	36.11%	0.0	3.03E+15
0.5	32%	27.60%	2.933	2.929	0%	27.86%	-0.9	2.33E+15
1	10%	9.27%	2.465	2.455	0%	9.45%	-1.9	7.92E+14
2	1%	1.11%	1.551	1.533	1%	1.12%	-1.2	9.42E+13
3	0.10%	0.05%	0.396	0.216	46%	0.05%	12.3	4.06E+12
RG780	0.00%	0.00%	0.011	0.011	-3%	0.00%	-100.0	6.99E+10

Dark Before: 0.011 Volts
Light - No Filter Hldr.: 3.488 Volts
Dark After - NFH: 0.012 Volts
Average Dark 0.0114 Volts

Notes:
1. Annual calibration is recommended.
2) This section is for internal use and for more advanced analysis.

Surface PAR

Biospherical Instruments Inc.

CALIBRATION CERTIFICATE

Calibration Date	3/8/2017			
Model Number	QSR2200			
Serial Number	20546			
Operator	TPC			
Standard Lamp	91453(7/20/16)			
Probe Excitation Voltage Range:	6	to	18	VDC(+)
Output Polarity:	POSITIVE			

Probe Conditions at Calibration(in air):

Calibration Voltage:	6	VDC(+)
Probe Current:	4.0	mA

Probe Output Voltage:

Probe Illuminated	88.8	mV
Probe Dark	1.0	mV
Probe Net Response	87.8	mV
RG780	1.1	mV

Corrected Lamp Output:

Output In Air (same condition as calibration):

8.379E+15	quanta/cm²sec
0.013914	uE/cm²sec

Calibration Scale Factor:
(To calculate irradiance, divide the net voltage reading in Volts by this value.)

Dry:	1.0481E-17	V/(quanta/cm²sec)
	6.3114E+00	V/(uE/cm²sec)

Notes:
1. Annual calibration is recommended.
2. Calibration is performed using a Standard of Spectral Irradiance traceable to the National Institute of Standards and Technology (NIST).
3. The collector should be cleaned frequently with alcohol.
4. Calibration was performed with customer cable, when available.

QSR240R 05/24/95

Pump (primary)

SEA-BIRD SCIENTIFIC
Sea-Bird Scientific
13431 NE 20th Street
Bellevue, WA 98005
USA

+1 425-643-9866
seabird@seabird.com
www.seabird.com

Pressure Test Certificate

Test Date: **2017-08-02**

Description: **SBE-5T Submersible Pump**

Sensor Information:

Model Number: **SBE-5T**

Serial Number: **05T-1626**

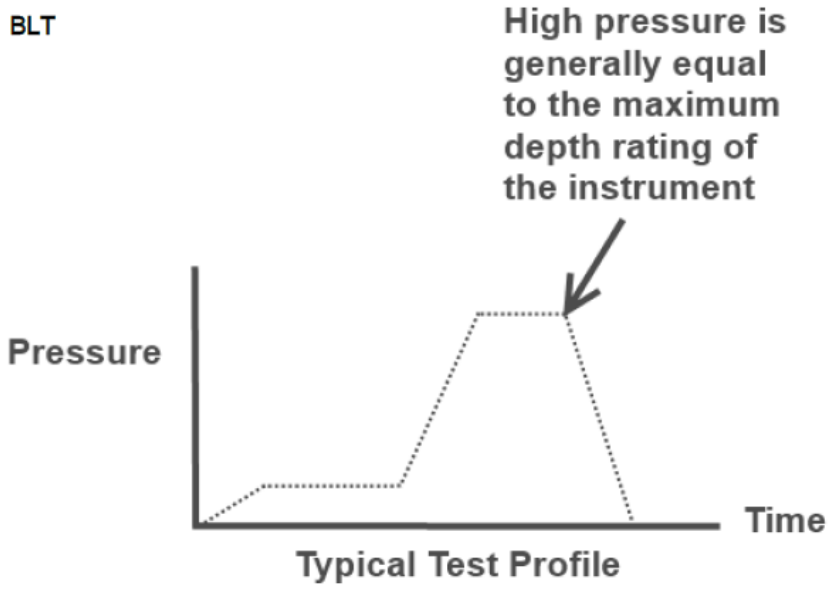
Replaced the main piston "O"-Rings.

Pressure Test Protocol:

Low Pressure Test: **50**	PSI	Held For: **15**	Minutes	
High Pressure Test: **10000**	PSI	Held For: **30**	Minutes	

Passed Test: **True**

Tested By: **BLT**



Typical Test Profile

Pump (secondary)

SEA-BIRD SCIENTIFIC
Sea-Bird Scientific
13431 NE 20th Street
Bellevue, WA 98005
USA

+1 425-643-9866
seabird@seabird.com
www.seabird.com

Pressure Test Certificate

Test Date: **2017-08-02**

Description: **SBE-5T Submersible Pump**

Sensor Information:

Model Number: **SBE-5T**

Serial Number: **05T-1627**

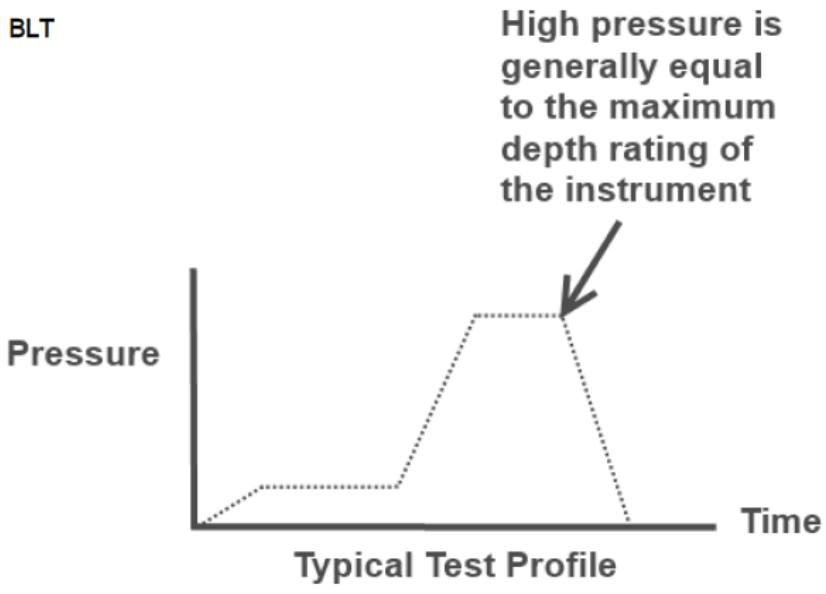
Replaced the main piston "O"-Rings.

Pressure Test Protocol:

Low Pressure Test: **50**	PSI	Held For: **15**	Minutes
High Pressure Test: **10000**	PSI	Held For: **30**	Minutes

Passed Test: **True**

Tested By: **BLT**



Typical Test Profile

Temperature (primary)

Sea-Bird Electronics, Inc.
13431 NE 20th Street, Bellevue, WA 98005-2010 USA
Phone: (+1) 425-643-9866 Fax (+1) 425-643-9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 1238
CALIBRATION DATE: 08-Jul-16

SBE 3 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

COEFFICIENTS:

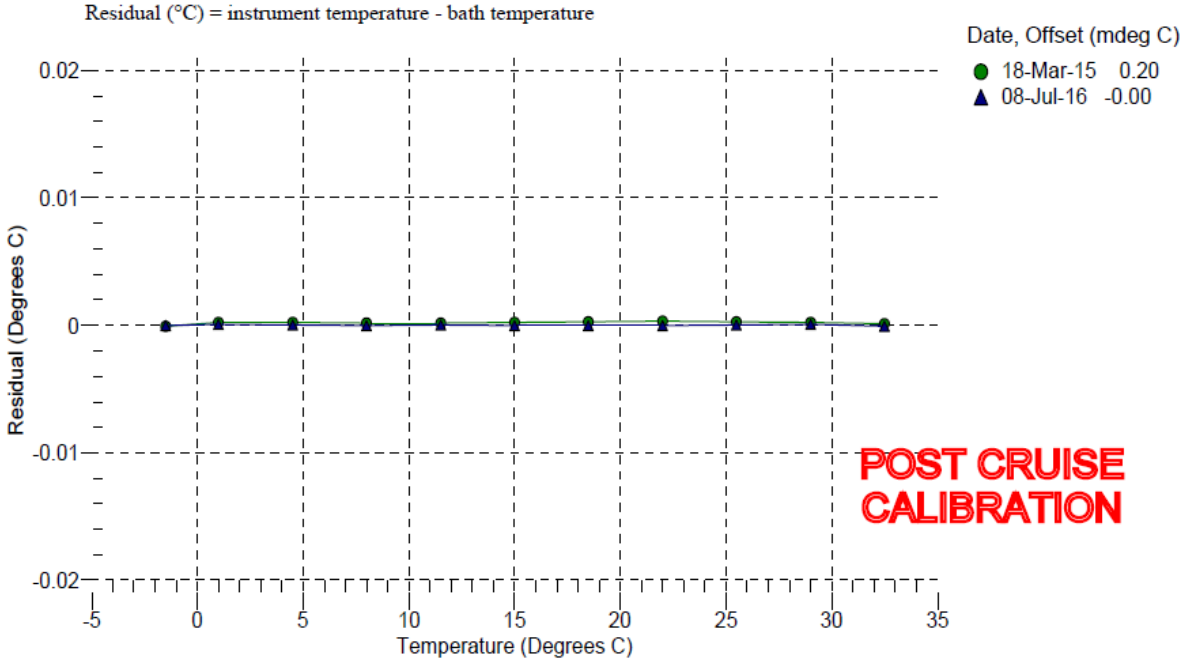
```
g =  4.78524686e-003
h =  6.53727398e-004
i =  2.17563983e-005
j =  1.45067186e-006
f0 =  1000.0
```

BATH TEMP (° C)	INSTRUMENT OUTPUT (Hz)	INST TEMP (° C)	RESIDUAL (° C)
-1.5000	5941.481	-1.5000	-0.00005
1.0000	6289.828	1.0001	0.00006
4.5000	6802.007	4.5000	0.00002
8.0000	7343.561	8.0000	-0.00001
11.5000	7915.327	11.5000	0.00000
15.0000	8518.104	15.0000	-0.00004
18.5000	9152.707	18.5000	-0.00002
22.0000	9819.893	22.0000	-0.00001
25.5000	10520.425	25.5000	0.00003
29.0000	11255.024	29.0001	0.00008
32.5000	12024.352	32.4999	-0.00006

f = Instrument Output (Hz)

Temperature ITS-90 (°C) = $1/\{g + h[ln(f0 / f)] + i[ln^2(f0 / f)] + j[ln^3(f0 / f)]\} - 273.15$

Residual (°C) = instrument temperature - bath temperature



Temperature (Secondary)

Sea-Bird Electronics, Inc.
13431 NE 20th Street, Bellevue, WA 98005-2010 USA
Phone: (+1) 425-643-9866 Fax (+1) 425-643-9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 1457
CALIBRATION DATE: 12-Jul-16

SBE 3 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

COEFFICIENTS:

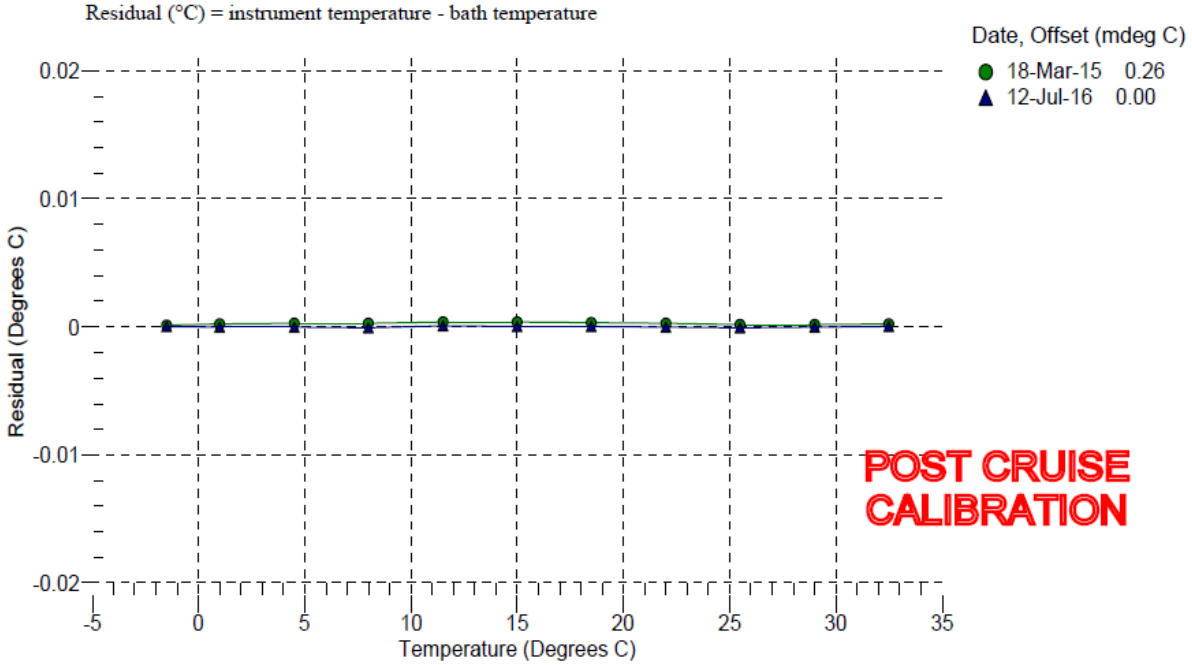
```
g =  4.82829114e-003
h =  6.70332317e-004
i =  2.51350390e-005
j =  1.96079570e-006
f0 =  1000.0
```

BATH TEMP (° C)	INSTRUMENT OUTPUT (Hz)	INST TEMP (° C)	RESIDUAL (° C)
-1.5000	6156.569	-1.5000	0.00003
1.0000	6512.298	1.0000	-0.00003
4.5000	7034.875	4.5000	-0.00000
8.0000	7586.787	7.9999	-0.00007
11.5000	8168.856	11.5001	0.00005
15.0000	8781.785	15.0000	0.00004
18.5000	9426.329	18.5000	0.00003
22.0000	10103.184	22.0000	-0.00001
25.5000	10813.035	25.4999	-0.00005
29.0000	11556.549	29.0000	-0.00004
32.5000	12334.357	32.5000	0.00005

f = Instrument Output (Hz)

Temperature ITS-90 (°C) = $1/\{g + h[ln(f0 / f)] + i[ln^2(f0 / f)] + j[ln^3(f0 / f)]\} - 273.15$

Residual (°C) = instrument temperature - bath temperature



Transmissometer

PO Box 518
620 Applegate St.
Philomath, OR 97370

(541) 929-5650
Fax (541) 929-5277
www.wetlabs.com

WET Labs

C-Star Calibration

Date 11.10.16 S/N# CST-892DR Pathlength 25 cm

	Analog output
V_d	0.058 V
V_{air}	4.761 V
V_{ref}	4.662 V

Temperature of calibration water	23.5 ℃
Ambient temperature during calibration	24.7 ℃

Relationship of transmittance (Tr) to beam attenuation coefficient (c), and pathlength (x, in meters): $\mathbf{Tr = e^{-cx}}$

To determine beam transmittance: $\mathbf{Tr = (V_{sig} - V_{dark}) / (V_{ref} - V_{dark})}$

To determine beam attenuation coefficient: $\mathbf{c = -1/x * ln\ (Tr)}$

V_d Meter output with the beam blocked. This is the offset.
V_{air} Meter output in air with a clear beam path.
V_{ref} Meter output with clean water in the path.
Temperature of calibration water: temperature of clean water used to obtain V_{ref}.
Ambient temperature: meter temperature in air during the calibration.
V_{sig} Measured signal output of meter.

Revision M 7/26/11

PO Box 518
620 Applegate St.
Philomath, OR 97370

(541) 929-5650
Fax (541) 929-5277
www.wetlabs.com

C-Star Repairs

Date 11/3/2016 Customer Leidos Innovations Corp

S/N# **CST-892DR** Repair Order 32169

Standard Service (Analog)

- Replaced cover plate seal
- Checked optics alignment
- Performed noise test: 1 sample/sec for 60 sec
- Performed stability test: 1 sample/min for 12 hrs
- Performed temperature test
- Performed water calibration
- Shake-tested unit
- Pressure-tested unit
- Updated unit's calibration sheet

Additional Repairs

Replaced TX Pressure Window. (Scratched)
Replaced RX Pressure Window. (Scratched)

Comments

The RX and TX Mounts have excess leeching on the annodization dye. Even so, the inside of the instrument looks to be in good shape. The electronics are corrosion free. The Service Department recommends the customer return the instrument to WETLabs within a year's time for evaluation or replacment.