NBP1610

Data Report NBP1610

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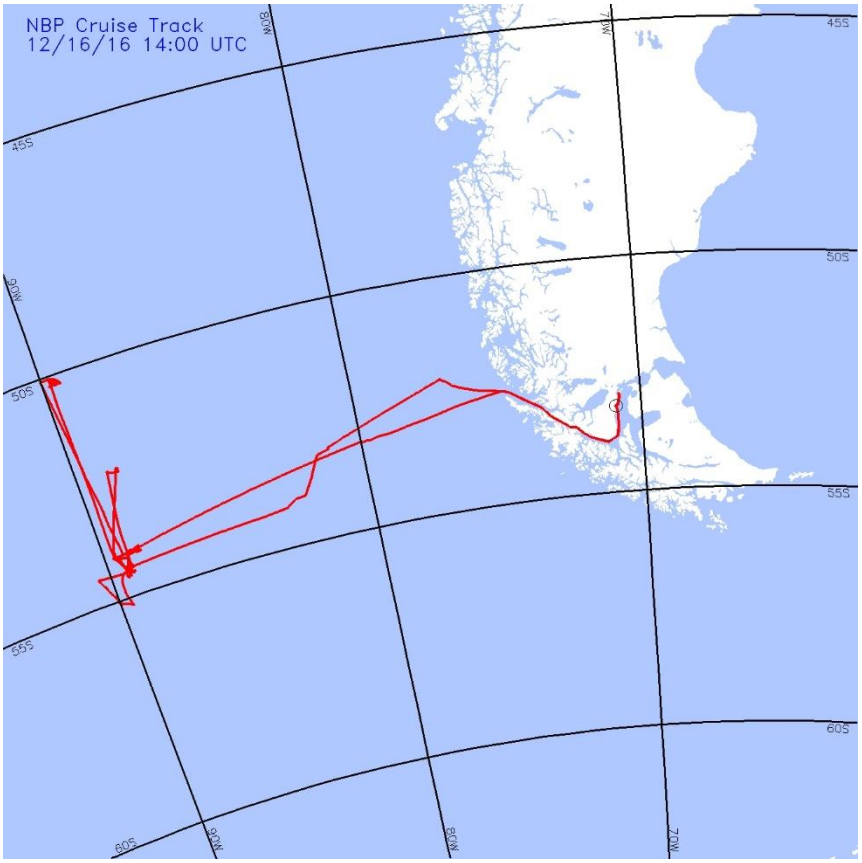

United States Antarctic Program

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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All the data has been archived using 'tar' and compressed using 'gzip', identified by the '.tz' extension.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: NBP1610

File	Description
/	Root level directory
NBP1610.gmt	GMT binary file of MGD77 data
NBP1610.mgd	Full Cruise MGD77 data file
NBP1610.trk	Text file of cruise track
1610DATA.docx	Data Report NBP1610 (MS Word)
1610DATA.pdf	Data Report NBP1610 (PDF format)
INSTCOEF.TXT	Instrument Coefficient File
/process	Processed data
1610JGOF.tz	JGOFS format data files
1610MGD.tz	MGD Data
1610PCO2.tz	Merged pCO2 data files
1610PROC.tz	Other processed data
1610QC.tz	Daily RVDAS QC postcript plots
/rvdas/nav	Navigation data
1610adcp.tz	ADCP Data Sets
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1610gyr1.tz	Gyro raw data
1610s330.tz	Seapath 330 data
1610seap.tz	Seapath 200 data
/rvdas/uw	Underway data
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1610ctdd.tz	CTD depth data
1610eng1.tz	Engineering data
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1610hdas.tz	HydroDAS raw data
1610knud.tz	Knudsen raw data
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1610mwx1.tz	Meteorology raw data
1610pco2.tz	pCO_2 raw data
1610pguv.tz	GUV raw data
1610rtmp.tz	Remote Temperature data
1610svp1.tz	Sound velocity probe (ADCP)
1610tsg1.tz	Micro TSG1 data
1610tsg2.tz	Micro TSG2 data
1610twnc.tz	Trawl winch data
/science	Cruise specific data
1610elog.tz	Elog data
/Imagery	Cruise Imagery
1610Imag.tz	Collection of Imagery Files
/ocean	Ocean data
1610ctd.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 (NBP1610.trk). It contains the longitude and latitude at one-minute intervals extracted from the NBP1610.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 1610proc.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/NBP1610JGOF.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 NBP1610.mgd. The file NBP1610.gmt is created from the MGD77 dataset using the “mgd77togmt” utility. NBP1610.gmt can be used with the GMT plotting package.

The data used to produce the NBP1610.mgd file can be found on the distribution media in the file /process/1610proc.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.

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 1610pco2.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/NBP1610ctd.tar. The archive contains tar files NBP1610proc.tar.

XBT

During a cruise, eXpendable BathyThermographs (XBTs) may have been used to obtain water column temperature profiles, providing corrections to the sound velocity profile for the multibeam system. The data files from those launches would be included as 1610xbt.tar in the /ocean directory. **No XBTs were collected on this cruise.**

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: `NBP1610mwx1.d025`

- The CruiseID is the numeric name of the cruise, in this case, NBP1610.
- 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

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

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
327:11:33		Data collection begins. -52 58.00868, -80 28.37447
	349:06:48	Data collection completes. -53 13.46293, -80 37.25885

Appendix A: Sensors

NBP1610 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	
Temperature / Humidity	RM Young 41372LC	06135	7/10/2015	
PIR	Eppley PIR	3284SF3	1/13/2016	
PSP	Eppley PSP	32850F3	1/15/2016	
PAR (Mast)	Biospherical Instruments QSR-240	6357	2/17/2015	
GUV (Mast)	Biospherical Instruments GUV-2511	25110203114	7/20/2016	

Sensor	Description	Serial	Last Cal Date	Comments
Underway Seawater Sampling System				
Micro-TSG	Sea-Bird SBE 45	4546167-0199	2/19/2016	Primary
Micro-TSG	Sea-Bird SBE 45	4549120-0226	5/27/2015	Secondary
Digital Remote Temp	Sea-Bird SBE 38	3850449-0389	6/8/2015	
Transmissometer	WetLabs C-Star	CST-889DR	7/6/2015	
Fluorometer	WetLabs AFLT	FLRTD-4158	10/23/2015	

Sensor	Description	Serial	Last Cal Date	Comments
CTD				
Altimeter	Valeport VA-500	51519	7/10/2015	
Carousel Water Sampler	Sea-Bird SBE 32	3270675-0925	NA	
SBE 11+ Deck Unit	Sea-Bird SBE 11+	11P19858-0490	NA	
Conductivity (Primary)	Sea-Bird 4C 6800m	041852	11/25/2015	
Conductivity (Secondary)	Sea-Bird 4C 6800m	044151	6/30/2015	
Transmissometer	WetLabs C-Star	CST-557DR	7/27/2015	
Fluorometer	WetLabs FLRTD	FLRTD-0397	2/23/2045	
CTD Fish	Sea-Bird SBE 9+	09P70675-1130	2/5/2016	
CTD Pressure Sensor	Sea-Bird SBE 9+	120089	1/27/2016	
Dissolved Oxygen	Sea-Bird SBE 43	0080	1/20/2016	Primary
Dissolved Oxygen	Sea-Bird SBE 43	0082	3/25/2016	Secondary
CTD Pump 1	Sea-Bird 5T, PN 90160	051646 3.0K	10/9/2014	Primary
CTD Pump 2	Sea-Bird 5T, PN 90543	055644 3.0K	10/9/2014	Secondary
Surface PAR	QSR-240	6357	2/17/2015	Fed to CTD, on Mast
PAR	Biospherical Instruments QSP-200L4S	4361	2/18/2015	
Temperature	Sea-Bird 03-02/F	031541	11/26/2015	Primary
Temperature	Sea-Bird 3F 6800m	03P5185	6/30/2015	Secondary
Transmissometer	WetLabs C-Star	CST-557DR	7/27/2015	

Appendix B: Calibration Sheets

Gravity

BGM3 ship-to-shore gravity tie report

S. Blackman / A. Scott, vessel: R/V Palmer

Release Date: 2016/10/18 19:52:08 UTC

Sensor: S210
Software version: 1.2
Port/Pier/Berth: Pratt Pier

Gravity station number	9337-50 (3)
Station name	Harbour Admin Bldg
mGal at pier	981320.82
Tie start time UTC	2016/10/18 19:10:36.961
Samples used	3600
Land tie used	Yes
Water height to pier 1	10 ft 6 in
Water height to pier 2	10 ft 9 in
Water height to pier 3	11 ft 0 in
Average of filtered counts	25195.216448472
Filter length	361
Scale factor	4.994070552
NEW BIAS	**855495.14**

Table 1: Gravity tie information

1

Meteorology

Anemometers

Cal sheet not required

Barometer

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

YOUNG

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

Temperature / Humidity

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

YOUNG

CALIBRATION REPORT
Temperature

Customer: *Lockheed Martin Corp*

Test Number: 5710-04T
Test Date: 10 July 2015

Customer PO: 4900063237
Sales Order: 4867

Test Sensor:
Model: 41372LC Serial Number: *TS06135*
Description: Temperature/Relative Humidity Sensor

Report of calibration comparison of test temperature sensor with National Institute of Standards and Technology traceable standard thermometers at three temperatures in the R.M. Young Company controlled temperature calibration bath facilities. Calibration accuracy ± 0.1° Celsius.

Bath Temperature (degrees C)	Current Output (milliamps)	Indicated (1) Temperature (degrees C)
-49.85	4.023	-49.66
-0.01	11.995	-0.03
49.97	19.993	49.96

(1) Calculated from current 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
Brooklyn Thermometer Model 43-FC	3006-118	W204690
Brooklyn Thermometer Model 22332-D5-FC	25071	W204691
Brooklyn Thermometer Model 2X100-D7-FC	77532	W204692
Keithley Multimeter Model 19[illegible]	15232	8604897

Tested By: [signature]

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

PIR

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

YOUNG

CALIBRATION REPORT
Temperature

Customer: *Lockheed Martin Corp*

Test Number: 5710-04T
Test Date: 10 July 2015

Customer PO: 4900063237
Sales Order: 4867

Test Sensor:
Model: 41372LC Serial Number: *TS06135*
Description: Temperature/Relative Humidity Sensor

Report of calibration comparison of test temperature sensor with National Institute of Standards and Technology traceable standard thermometers at three temperatures in the R.M. Young Company controlled temperature calibration bath facilities. Calibration accuracy ± 0.1° Celsius.

Bath Temperature (degrees C)	Current Output (milliamps)	Indicated (1) Temperature (degrees C)
-49.85	4.023	-49.86
-0.01	11.995	-0.03
49.97	19.993	49.96

(1) Calculated from current 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
Brooklyn Thermometer Model 43-FC	3006-118	W204690
Brooklyn Thermometer Model 22332-D5-FC	25071	W204691
Brooklyn Thermometer Model 2X100-D7-FC	77532	W204692
Keithley Multimeter Model 19[illegible]	15232	8604897

Tested By: [signature]

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

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:** **$S = 6.91\ \mu V / Wm^{-2}$** Uncertainty: $U_{95} = \pm 0.91\%$ (95% confidence level, k=2) Resistance: 706 Ω at 23°C
	Date of Test: January 15, 2016
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 Eleventh International Pyrheliometric Comparisons (IPC XI) at Davos, Switzerland in September-October 2010. 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 Port Hueneme, CA
Signatures:	In Charge of Test: Reviewed by:
Eppley SO:	64614
Date of Certificate:	January 15, 2016
Remarks:	Sensitivity before Repainting Element = 7.62 $\mu V / Wm^{-2}$

End of Report

PAR (Mast)

Biospherical Instruments Inc.

CALIBRATION CERTIFICATE

Calibration Date	2/17/2015			
Model Number	QSR240			
Serial Number	6357			
Operator	TPC			
Standard Lamp	V-033(3/7/12)			
Probe Excitation Voltage Range:	6	to	18	VDC(+)
Output Polarity:	Positive			

Probe Conditions at Calibration(in air):

Calibration Voltage:	6	VDC(+)
Probe Current:	7.2	mA

Probe Output Voltage:

Probe Illuminated	97.3	mV
Probe Dark	1.0	mV
Probe Net Response	96.3	mV
RG780	1.1	mV

Corrected Lamp Output:

Output In Air (same condition as calibration):

9.342E+15	quanta/cm²sec
155.13384	uE/m²sec

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

Dry:	1.0304E-17	V/(quanta/cm²sec)
	6.2054E-04	V/(uE/m²sec)

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.

GUV-2511 Calibration Certificate

System Serial Number	25110203114	Date of Calibration	8/3/2016
Calibration database	25110203114v9.mdb	Date of Certificate	8/4/2016
DASSN	0069	Standard of Spectral Irradiance	91453(7/20/16)
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	2.3369E-10	2.3836E-05	6.9638E-03	2.1979E+00	3.4492E-05	3.2554E-05	5.6504E-04	µW/(cm²nm)
Ed0340	6	340	1.8327E-10	1.8693E-05	5.4614E-03	1.8735E+00	4.2136E-05	4.1875E-05	7.6934E-04	µW/(cm²nm)
Ed0313	8	313	2.0456E-10	2.0865E-05	6.0958E-03	2.1398E+00	9.1228E-04	9.0624E-04	-1.2773E-03	µW/(cm²nm)
Ed0305	10	305	1.1339E-11	1.1565E-06	3.3789E-04	1.1614E-01	3.5080E-04	3.5087E-04	1.1382E-03	µW/(cm²nm)
Ed0380	12	380	8.1708E-11	8.3342E-06	2.4349E-03	7.8097E-01	2.8388E-04	2.7513E-04	-3.8577E-05	µW/(cm²nm)
Ed0395	18	395	2.8750E-10	2.9325E-05	8.5676E-03	2.7082E+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	1.7117E-05	1.7459E+00	5.1009E+02	1.8027E+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, Washington 98005 USA
Phone: (425) 643-9866 Fax: (425) 643-9954 www.seabird.com

Conductivity Calibration Report

Customer:	Lockheed Martin Antarctic Support		
Job Number:	86705	Date of Report:	2/22/2016
Model Number	SBE 45	Serial Number:	4546167-0199

Conductivity sensors are normally calibrated 'as received', without cleaning or adjustments, allowing a determination of sensor drift. If the calibration identifies a problem or indicates cell cleaning is necessary, then a second calibration is performed after work is completed. The 'as received' calibration is not performed if the sensor is damaged or non-functional, or by customer request.

An 'as received' calibration certificate is provided, listing the coefficients used to convert sensor frequency to conductivity. Users must choose whether the 'as received' calibration or the previous calibration better represents the sensor condition during deployment. In SEASOFT enter the chosen coefficients. The coefficient 'slope' allows small corrections for drift between calibrations (consult the SEASOFT manual). Calibration coefficients obtained after a repair or cleaning apply only to subsequent data.

'AS RECEIVED CALIBRATION' ☑ Performed ☐ Not Performed

Date: 1/29/2016 Drift since last cal: -0.00160 PSU/month

Comments:

'CALIBRATION AFTER REPAIR' ☑ Performed ☐ Not Performed

Date: 2/19/2016 Drift since Last cal: N/A PSU/month

Comments:
The conductivity cell was replaced.

**Measured at 3.0 S/m*

Cell cleaning and electrode replatinizing tend to 'reset' the conductivity sensor to its original condition. Lack of drift in post-cleaning-calibration indicates geometric stability of the cell and electrical stability of the sensor circuit.

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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: 0199
CALIBRATION DATE: 19-Feb-16

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

COEFFICIENTS:

g = -9.839079e-001	CPcor = -9.5700e-008
h = 1.397390e-001	CTcor = 3.2500e-006
i = -3.278767e-005	WBOTC = -1.0552e-005
j = 2.412783e-005	

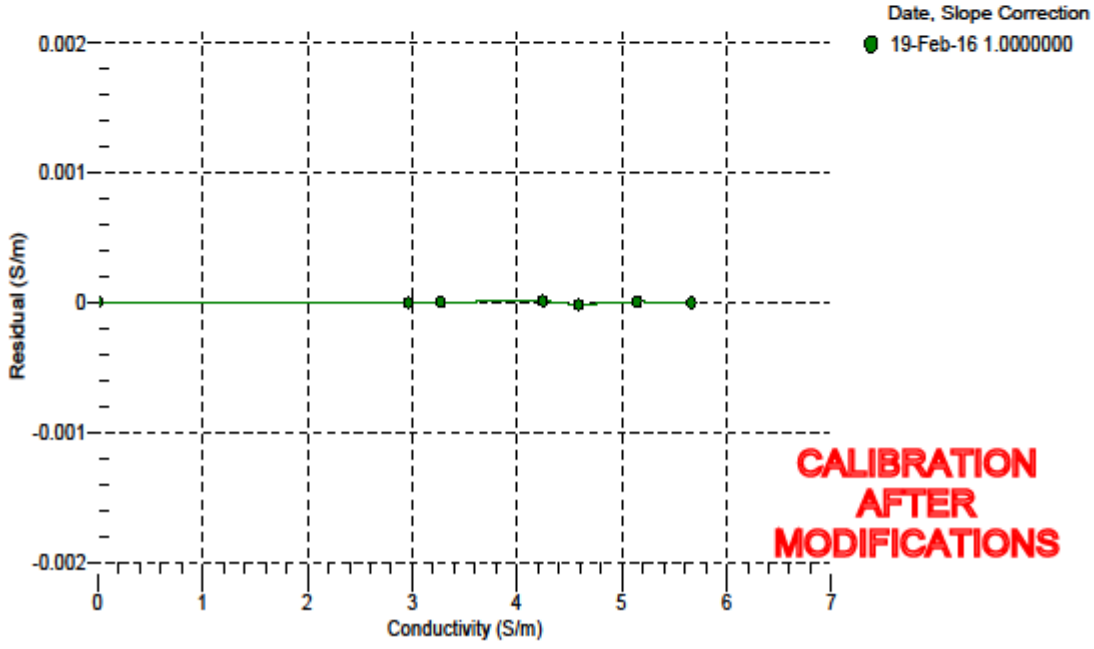
BATH TEMP (° C)	BATH SAL (PSU)	BATH COND (S/m)	INSTRUMENT OUTPUT (Hz)	INSTRUMENT COND (S/m)	RESIDUAL (S/m)
22.0000	0.0000	0.00000	2653.02	0.00000	0.00000
1.0000	34.6481	2.96295	5305.01	2.96295	-0.00000
4.5000	34.6281	3.26871	5505.90	3.26871	0.00000
15.0000	34.5846	4.24619	6103.19	4.24620	0.00001
18.5000	34.5748	4.58978	6299.43	4.58976	-0.00002
24.0000	34.5639	5.14521	6604.13	5.14522	0.00001
29.0000	34.5571	5.66462	6876.55	5.66462	-0.00000
32.5000	34.5537	6.03536	7064.36	6.03527	-0.00009

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 St. Bellevue, Washington 98005 USA
Phone: (425) 643-9866 Fax: (425) 643-9954 www.seabird.com

Temperature Calibration Report

Customer:	Lockheed Martin Antarctic Support		
Job Number:	86705	Date of Report:	2/22/2016
Model Number	SBE 45	Serial Number:	4546167-0199

Temperature sensors are normally calibrated 'as received', without adjustments, allowing a determination sensor drift. If the calibration identifies a problem, then a second calibration is performed after work is completed. The 'as received' calibration is not performed if the sensor is damaged or non-functional, or by customer request.

An 'as received' calibration certificate is provided, listing coefficients to convert sensor frequency to temperature. Users must choose whether the 'as received' calibration or the previous calibration better represents the sensor condition during deployment. In SEASOFT enter the chosen coefficients. The coefficient 'offset' allows a small correction for drift between calibrations (consult the SEASOFT manual). Calibration coefficients obtained after a repair apply only to subsequent data.

'AS RECEIVED CALIBRATION' ☑ Performed ☐ Not Performed

Date: 1/29/2016 **Drift since last cal:** -0.00074 **Degrees Celsius/year**

Comments:

'FINAL CALIBRATION' ☑ Performed ☐ Not Performed

Date: 2/19/2016 **Drift since 02 Nov 13** -0.00079 **Degrees Celsius/year**

Comments:

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SENSOR SERIAL NUMBER: 0199
CALIBRATION DATE: 19-Feb-16

SBE 45 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

COEFFICIENTS:

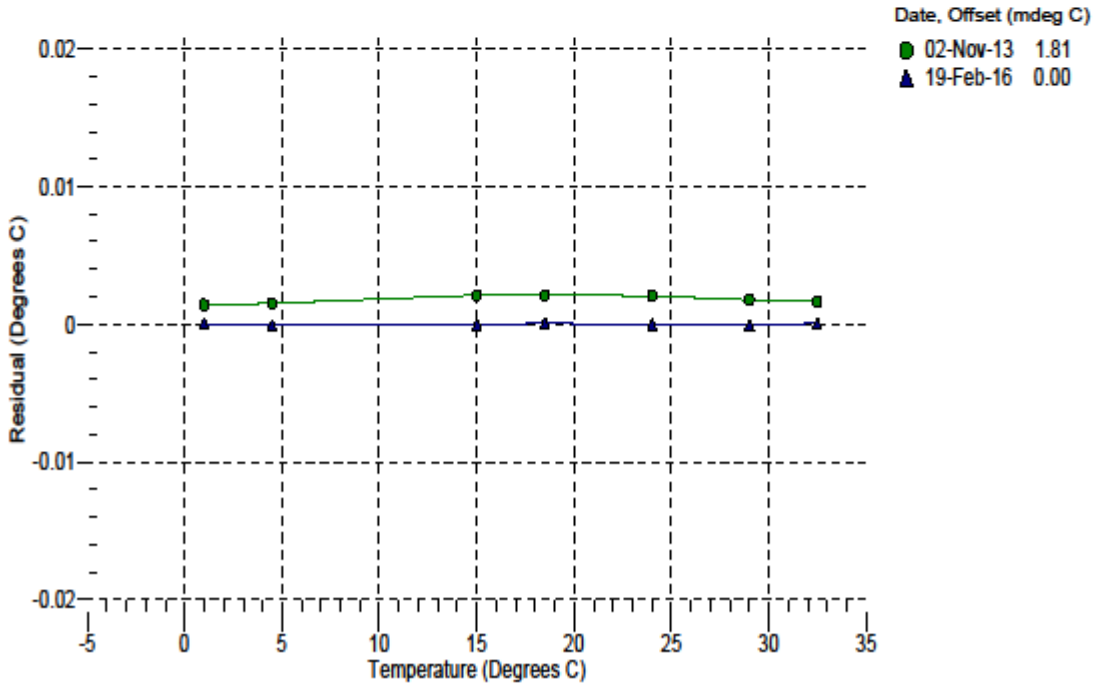
a0 = 3.346026e-005
a1 = 2.683251e-004
a2 = -1.851289e-006
a3 = 1.425108e-007

BATH TEMP (° C)	INSTRUMENT OUTPUT (counts)	INST TEMP (° C)	RESIDUAL (° C)
1.0000	678437.9	1.0000	0.0000
4.5000	580549.3	4.4999	-0.0001
15.0000	370832.4	15.0000	-0.0000
18.5000	321323.4	18.5001	0.0001
24.0000	258039.6	24.0000	-0.0000
29.0000	212658.3	28.9999	-0.0001
32.5000	186333.4	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



Micro-TSG2

SEA-BIRD ELECTRONICS, INC.
13431 NE 20th Street Bellevue, Washington 98005 USA
Phone: (425) 643-9866 Fax: (425) 643-9954 www.seabird.com

Conductivity Calibration Report

Customer:	Lockheed Martin Antarctic Support		
Job Number:	84353	**Date of Report:**	5/28/2015
Model Number	SBE 45	**Serial Number:**	4549120-0226

Conductivity sensors are normally calibrated 'as received', without cleaning or adjustments, allowing a determination of sensor drift. If the calibration identifies a problem or indicates cell cleaning is necessary, then a second calibration is performed after work is completed. The 'as received' calibration is not performed if the sensor is damaged or non-functional, or by customer request.

An 'as received' calibration certificate is provided, listing the coefficients used to convert sensor frequency to conductivity. Users must choose whether the 'as received' calibration or the previous calibration better represents the sensor condition during deployment. In SEASOFT enter the chosen coefficients. The coefficient 'slope' allows small corrections for drift between calibrations (consult the SEASOFT manual). Calibration coefficients obtained after a repair or cleaning apply only to subsequent data.

'AS RECEIVED CALIBRATION' ☑ **Performed** ☐ **Not Performed**

Date: 5/27/2015 **Drift since last cal:** +0.00020 **PSU/month***

Comments:

'CALIBRATION AFTER CLEANING & REPLATINIZING' ☐ **Performed** ☑ **Not Performed**

Date: **Drift since Last cal:** **PSU/month***

Comments:

**Measured at 3.0 S/m*

Cell cleaning and electrode replatinizing tend to 'reset' the conductivity sensor to its original condition. Lack of drift in post-cleaning-calibration indicates geometric stability of the cell and electrical stability of the sensor circuit.

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SENSOR SERIAL NUMBER: 0226
CALIBRATION DATE: 27-May-15

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

COEFFICIENTS:

g = -1.021321e+000	CPcor = -9.5700e-008
h = 1.582719e-001	CTcor = 3.2500e-006
i = -6.715649e-004	WBOTC = 9.8072e-007
j = 7.382137e-005	

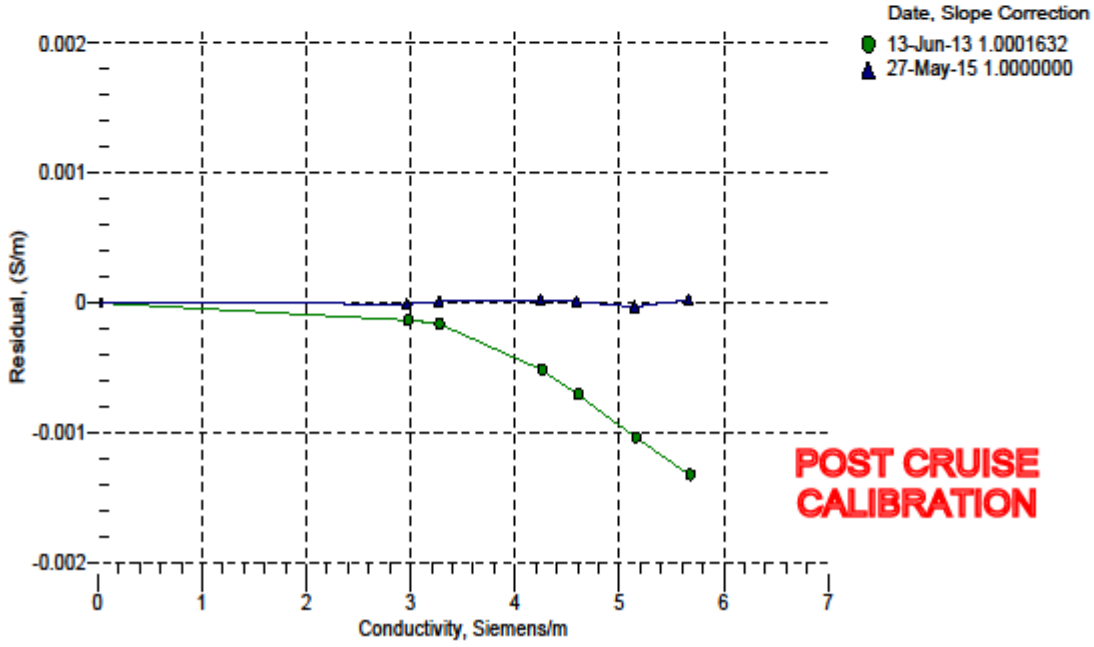
BATH TEMP (ITS-90)	BATH SAL (PSU)	BATH COND (Siemens/m)	INST FREQ (Hz)	INST COND (Siemens/m)	RESIDUAL (Siemens/m)
22.0000	0.0000	0.00000	2550.19	0.00000	0.00000
1.0000	34.6425	2.96252	5041.15	2.96251	-0.00001
4.5000	34.6230	3.26828	5230.78	3.26829	0.00001
14.9999	34.5803	4.24570	5794.74	4.24572	0.00002
18.5000	34.5708	4.58930	5980.08	4.58931	0.00001
23.9999	34.5602	5.14471	6267.76	5.14468	-0.00003
29.0000	34.5538	5.66414	6525.02	5.66416	0.00002
32.5000	34.5494	6.03469	6702.40	6.03495	0.00026

f = INST FREQ * sqrt(1.0 + WBOTC * t) / 1000.0

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

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

Residual = instrument conductivity - bath conductivity



SEA-BIRD ELECTRONICS, INC.
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Temperature Calibration Report

Customer:	Lockheed Martin Antarctic Support		
Job Number:	84353	Date of Report:	5/28/2015
Model Number	SBE 45	Serial Number:	4549120-0226

Temperature sensors are normally calibrated 'as received', without adjustments, allowing a determination sensor drift. If the calibration identifies a problem, then a second calibration is performed after work is completed. The 'as received' calibration is not performed if the sensor is damaged or non-functional, or by customer request.

An 'as received' calibration certificate is provided, listing coefficients to convert sensor frequency to temperature. Users must choose whether the 'as received' calibration or the previous calibration better represents the sensor condition during deployment. In SEASOFT enter the chosen coefficients. The coefficient 'offset' allows a small correction for drift between calibrations (consult the SEASOFT manual). Calibration coefficients obtained after a repair apply only to subsequent data.

'AS RECEIVED CALIBRATION' ☑ Performed ☐ Not Performed

Date: 5/27/2015 Drift since last cal: -0.00011 Degrees Celsius/year

Comments:

'CALIBRATION AFTER REPAIR' ☐ Performed ☑ Not Performed

Date: Drift since Last cal: Degrees Celsius/year

Comments:

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SENSOR SERIAL NUMBER: 0226
CALIBRATION DATE: 27-May-15

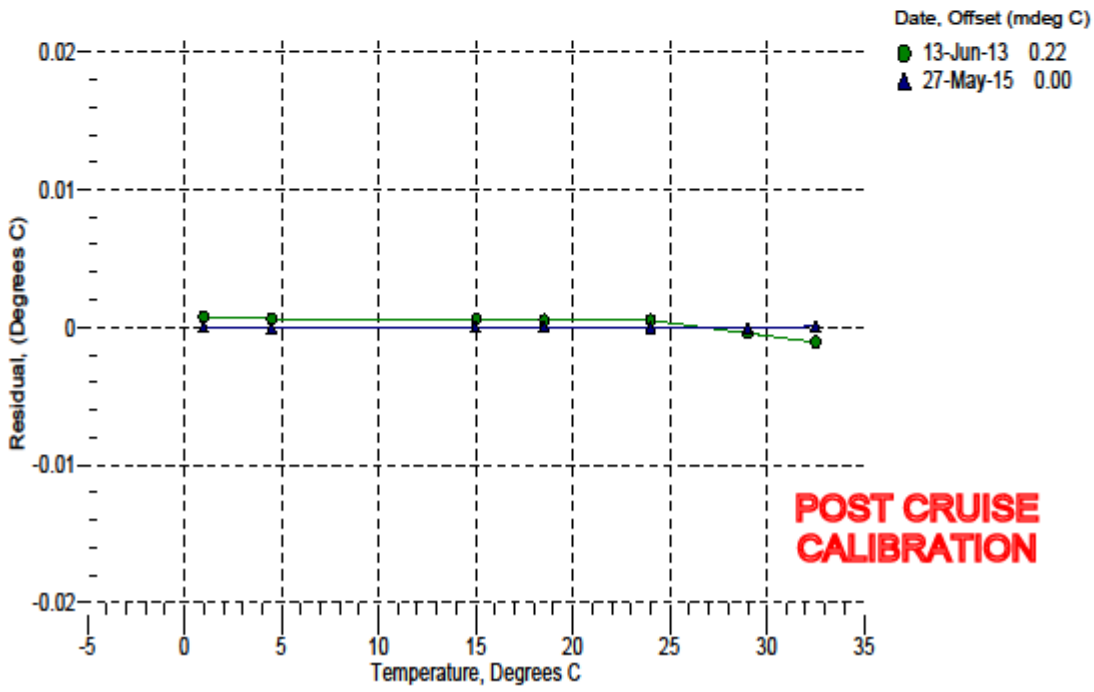
SBE 45 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

COEFFICIENTS:

a0 = -3.113213e-005
a1 = 2.790781e-004
a2 = -2.680662e-006
a3 = 1.600572e-007

BATH TEMP (ITS-90)	INSTRUMENT OUTPUT	INST TEMP (ITS-90)	RESIDUAL (ITS-90)
1.0000	744351.6	1.0000	0.0000
4.5000	636509.1	4.4999	-0.0001
14.9999	405784.5	14.9999	0.0000
18.5000	351396.6	18.5000	0.0000
23.9999	281937.8	23.9999	-0.0000
29.0000	232175.4	28.9999	-0.0001
32.5000	203332.0	32.5001	0.0001

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



Digital Remote Temp

SEA-BIRD ELECTRONICS, INC.
13431 NE 20th St. Bellevue, Washington 98005 USA
Phone: (425) 643-9866 Fax: (425) 643-9954 www.seabird.com

Temperature Calibration Report

Customer:	Lockheed Martin Antarctic Support		
Job Number:	84324	**Date of Report:**	6/8/2015
Model Number	SBE 38	**Serial Number:**	3850449-0389

Temperature sensors are normally calibrated 'as received', without adjustments, allowing a determination sensor drift. If the calibration identifies a problem, then a second calibration is performed after work is completed. The 'as received' calibration is not performed if the sensor is damaged or non-functional, or by customer request.

An 'as received' calibration certificate is provided, listing coefficients to convert sensor frequency to temperature. Users must choose whether the 'as received' calibration or the previous calibration better represents the sensor condition during deployment. In SEASOFT enter the chosen coefficients. The coefficient 'offset' allows a small correction for drift between calibrations (consult the SEASOFT manual). Calibration coefficients obtained after a repair apply only to subsequent data.

'AS RECEIVED CALIBRATION' ☑ Performed ☐ Not Performed

Date: 6/8/2015 Drift since last cal: +0.00071 Degrees Celsius/year

Comments:
The connector was upgraded.

'CALIBRATION AFTER REPAIR' ☐ Performed ☑ Not Performed

Date: Drift since Last cal: Degrees Celsius/year

Comments:

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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: 0389
CALIBRATION DATE: 08-Jun-15

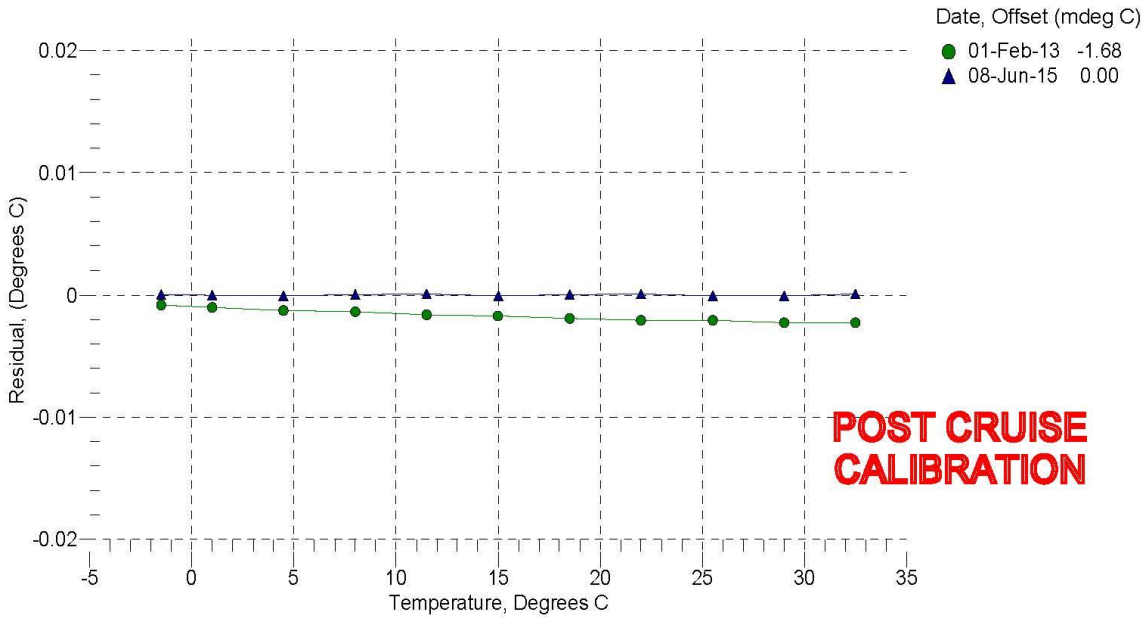
SBE 38 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

COEFFICIENTS:

a0 = 5.529089e-005
a1 = 2.722899e-004
a2 = -2.318547e-006
a3 = 1.481909e-007

BATH TEMP (ITS-90)	INSTRUMENT OUTPUT	INST TEMP (ITS-90)	RESIDUAL (ITS-90)
-1.5000	749636.8	-1.5000	0.0000
0.9999	667830.2	0.9999	-0.0000
4.5000	569749.8	4.4999	-0.0001
8.0000	487704.3	8.0000	0.0000
11.4999	418836.7	11.5000	0.0001
15.0000	360832.6	14.9999	-0.0001
18.4999	311816.7	18.4999	0.0000
21.9999	270263.8	22.0000	0.0001
25.5000	234929.8	25.4999	-0.0001
29.0000	204791.1	28.9999	-0.0001
32.4999	179008.3	32.5000	0.0001

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



Transmissometer

PO Box 518
620 Applegate St.
Philomath, OR 97370

WET Labs

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

C-Star Calibration

Date 7.6.15 S/N# CST-889DR Pathlength 25cm

	Analog output	
V_d	0.058 V	
V_{air}	4.729 V	
V_{ref}	4.622 V	
Temperature of calibration water		24.1 ℃
Ambient temperature during calibration		22.5 ℃

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

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

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

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

Fluorometer

PO Box 518
620 Applegate St.
Philomath, OR 97370

WET Labs

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

ECO Chlorophyll Fluorometer Characterization Sheet

Date: 10/23/2015 S/N: FLRTD-4158

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	0.060	0.035	0.022 V	42 counts
Scale Factor (SF)	6	12	25 µg/l/V	0.0076 µg/l/count
Maximum Output	5.01	5.01	5.01 V	16380 counts
Resolution	0.8	0.8	0.8 mV	1.0 counts

Ambient temperature during characterization 21.3 °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-4158.xls Revision J 3/17/08

CTD

Altimeter

Instrument Serial Number	51519
Sensor Type	500kHz Neptune
Altimeter Range (m)	100m
Certificate Number	49382

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	1484.385

Input SOS value to the altimeter using: #830;1484.3850

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	1.021	-0.021

Stage 4: Enter the Offset Correction
#828;-0.0210

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	0	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

Conductivity (primary)

SEA-BIRD ELECTRONICS, INC.
13431 NE 20th Street Bellevue, Washington 98005 USA
Phone: (425) 643-9866 Fax: (425) 643-9954 www.seabird.com

Conductivity Calibration Report

Customer:	Lockheed Martin Antarctic Support		
Job Number:	87035	**Date of Report:**	11/25/2015
Model Number	SBE 04C	**Serial Number:**	041852

Conductivity sensors are normally calibrated 'as received', without cleaning or adjustments, allowing a determination of sensor drift. If the calibration identifies a problem or indicates cell cleaning is necessary, then a second calibration is performed after work is completed. The 'as received' calibration is not performed if the sensor is damaged or non-functional, or by customer request.

An 'as received' calibration certificate is provided, listing the coefficients used to convert sensor frequency to conductivity. Users must choose whether the 'as received' calibration or the previous calibration better represents the sensor condition during deployment. In SEASOFT enter the chosen coefficients. The coefficient 'slope' allows small corrections for drift between calibrations (consult the SEASOFT manual). Calibration coefficients obtained after a repair or cleaning apply only to subsequent data.

'AS RECEIVED CALIBRATION' ☑ **Performed** ☐ **Not Performed**

Date: 11/25/2015 **Drift since last cal:** -0.00010 **PSU/month**

Comments:

'CALIBRATION AFTER CLEANING & REPLATINIZING' ☐ **Performed** ☑ **Not Performed**

Date: **Drift since Last cal:** **PSU/month**

Comments:

‡Measured at 3.0 S/m

Cell cleaning and electrode replatinizing tend to 'reset' the conductivity sensor to its original condition. Lack of drift in post-cleaning-calibration indicates geometric stability of the cell and electrical stability of the sensor circuit.

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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: 1852
CALIBRATION DATE: 25-Nov-15

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

COEFFICIENTS:

```
g =  -3.96259528e+000          CPcor = -9.5700e-008 (nominal)
h =   5.06259868e-001          CTcor =  3.2500e-006 (nominal)
i =  -6.49946649e-004
j =   5.90363829e-005
```

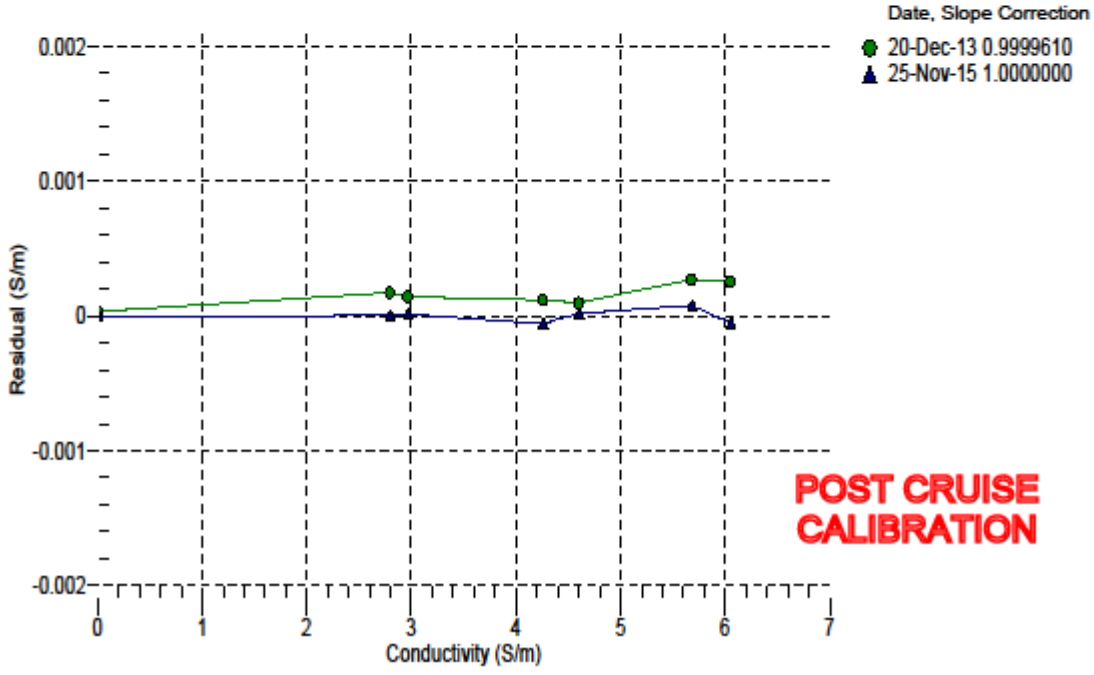
BATH TEMP (° C)	BATH SAL (PSU)	BATH COND (S/m)	INSTRUMENT OUTPUT (kHz)	INSTRUMENT COND (S/m)	RESIDUAL (S/m)
0.0000	0.0000	0.00000	2.80147	0.00000	0.00000
-1.0001	34.7153	2.79719	7.95352	2.79719	0.00000
0.9999	34.7149	2.96811	8.16312	2.96813	0.00001
14.9999	34.7153	4.26052	9.59857	4.26046	-0.00006
18.4999	34.7151	4.60638	9.94703	4.60640	0.00002
28.9999	34.7121	5.68716	10.96281	5.68724	0.00008
32.5000	34.7020	6.05831	11.28980	6.05825	-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, Washington 98005 USA
Phone: (425) 643-9866 Fax: (425) 643-9954 www.seabird.com

Conductivity Calibration Report

Customer:	Lockheed Martin Antarctic Support		
Job Number:	84671	**Date of Report:**	6/30/2015
Model Number	SBE 04c	**Serial Number:**	044151

Conductivity sensors are normally calibrated 'as received', without cleaning or adjustments, allowing a determination of sensor drift. If the calibration identifies a problem or indicates cell cleaning is necessary, then a second calibration is performed after work is completed. The 'as received' calibration is not performed if the sensor is damaged or non-functional, or by customer request.

An 'as received' calibration certificate is provided, listing the coefficients used to convert sensor frequency to conductivity. Users must choose whether the 'as received' calibration or the previous calibration better represents the sensor condition during deployment. In SEASOFT enter the chosen coefficients. The coefficient 'slope' allows small corrections for drift between calibrations (consult the SEASOFT manual). Calibration coefficients obtained after a repair or cleaning apply only to subsequent data.

'AS RECEIVED CALIBRATION' ☑ **Performed** ☐ **Not Performed**

Date: 6/30/2015 **Drift since last cal:** -0.00050 **PSU/month***

Comments:

'CALIBRATION AFTER CLEANING & REPLATINIZING' ☐ **Performed** ☑ **Not Performed**

Date: **Drift since Last cal:** **PSU/month***

Comments:

**Measured at 3.0 S/m*

Cell cleaning and electrode replatinizing tend to 'reset' the conductivity sensor to its original condition. Lack of drift in post-cleaning-calibration indicates geometric stability of the cell and electrical stability of the sensor circuit.

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: 4151
CALIBRATION DATE: 30-Jun-15

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

COEFFICIENTS:

```
g =  -1.02559095e+001
h =   1.45362257e+000
i =  -1.03075549e-003
j =   1.40752515e-004

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

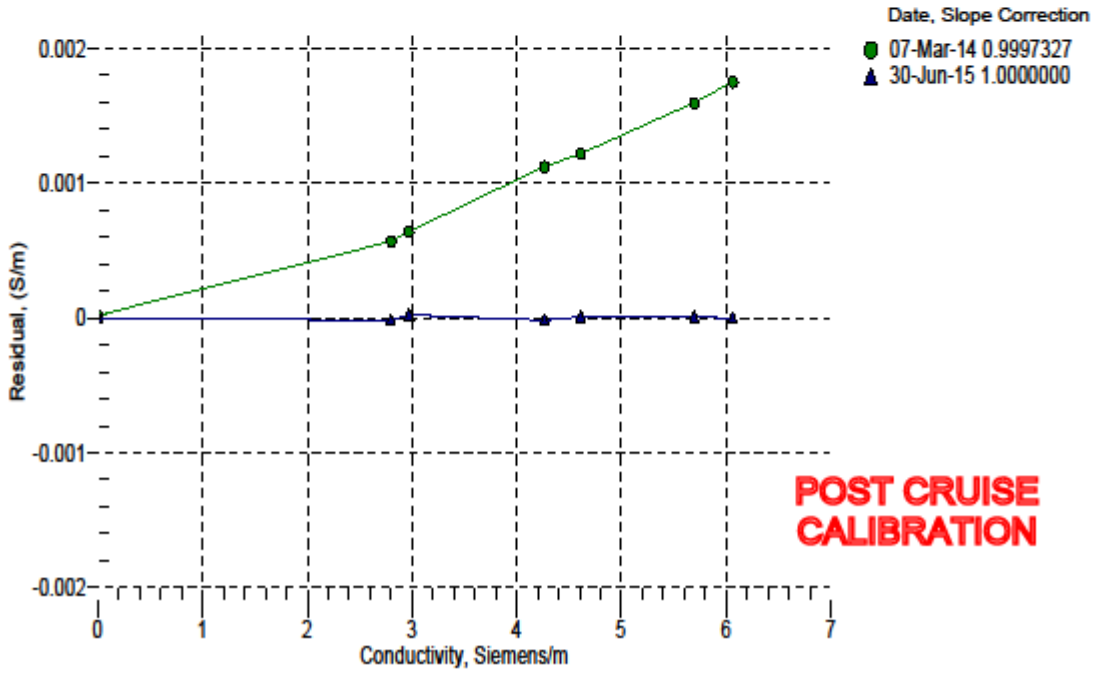
BATH TEMP (ITS-90)	BATH SAL (PSU)	BATH COND (Siemens/m)	INST FREQ (kHz)	INST COND (Siemens/m)	RESIDUAL (Siemens/m)
0.0000	0.0000	0.00000	2.65780	0.00000	0.00000
-1.0000	34.7537	2.80000	5.13285	2.79999	-0.00002
0.9999	34.7547	2.97119	5.24639	2.97121	0.00002
14.9999	34.7569	4.26509	6.03533	4.26507	-0.00002
18.5000	34.7566	4.61130	6.22943	4.61131	0.00001
29.0000	34.7541	5.69328	6.80009	5.69328	0.00001
32.5000	34.7461	6.06513	6.98536	6.06513	-0.00000

f = INST FREQ / 1000.0

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

t = temperatur e[°C)]; p = pressure[decibars]; δ = CTcor; ε = CPcor;

Residual = instrument conductivity - bath conductivity



Fluorometer

PO Box 518
620 Applegate St.
Philomath, OR 97370

WET Labs

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

ECO Chlorophyll Fluorometer Characterization Sheet

Date: 2/23/2015 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	0.107	0.065	0.044	V	67 counts
Scale Factor (SF)	6	13	26	µg/l/V	0.0078 µg/l/count
Maximum Output	4.97	4.97	4.97	V	16330 counts
Resolution	0.7	0.7	0.7	mV	1.0 counts

Ambient temperature during characterization 22.3 °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

PAR

Biospherical Instruments Inc

CALIBRATION CERTIFICATE

UNDERWATER PAR SENSOR WITH LOG AMPLIFIER

Calibration Date: 02/18/15 **Job No.:** R12168
Model Number: QSP200L4S
Serial Number: 4361
Operator: TPC
Standard Lamp: V-033(3/7/12)
Operating Voltage Range: 6 to 15 VDC (+)

Note: The QSP200L4S uses a log amplifier to measure the detector signal current with V = log I (Amps) / IRef
To calculate irradiance, use this formula:

Irradiance = Calibration factor * (10^Light Signal Voltage - 10^Dark Voltage)

With the appropriate (solar corrected) Irradiance Calibration Factor:

Dry Calibration Factor:	**1.16E+13**	**quanta/cm²·sec/"amps"**	**1.93E-05**	**µEinsteins/cm²·sec/"amps"**
Wet Calibration Factor:	**2.05E+13**	**quanta/cm²·sec/"amps"**	**3.40E-05**	**µEinsteins/cm²·sec/"amps"**

Sensor Test Data and Results[4)]

Sensor Supply Current (Dark):	75.5	mA			
Supply Voltage:	6	Volts			
Lamp Integrated PAR Irradiance:	9.34E+15	quanta/cm²·sec	0.01551	µEinsteins/cm²sec	
SC3 Immersion Coefficient:	0.5664	Scalar Correction:	1	PAR Solar Correction:	1.0000

Nominal Filter OD	Calibrated Trans.	Sensor Voltage	Measured Trans.	Measured Signal (Amps)	Estimated Signal (Amps)	Calc. Output (Volts)	Error (Volts)	Error (%)	Test Irrad. (quanta/ cm²·sec)
No Filter	100.00%	2.907	100.00%	8.07E-08	8.07E-08	2.908	0.001	0.0	9.34E+15
0.3	36.10%	2.466	36.09%	2.91E-08	2.91E-08	2.467	0.001	0.0	3.37E+15
0.5	27.60%	2.351	27.65%	2.23E-08	2.23E-08	2.351	0.000	-0.2	2.58E+15
1	9.27%	1.881	9.25%	7.46E-09	7.48E-09	1.883	0.002	0.2	8.64E+14
2	1.11%	1.013	1.09%	8.79E-10	8.96E-10	1.021	0.008	2.0	1.02E+14
3	0.05%	0.322	0.07%	5.76E-11	4.31E-11	0.291	-0.031	-25.2	6.67E+12

Dark Before: 0.183 Volts
Light - No Filter Hldr.: 2.908 Volts
Dark After - NFH: 0.183 Volts
Average Dark 0.183 Volts

I_{Ref} = 1.00E-10 Amps
I_{Dark} = 1.52E-10 Amps
10^{VDark} = 1.524053 Amps

RG780 0.22

Notes:
1. Annual calibration is recommended.
2. The collector should be cleaned frequently with alcohol.
4) This section is for internal use and for more advanced analysis.

QSP200L-QSP2300 (4-2013-).xls

Pressure Sensor

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: 1130
CALIBRATION DATE: 27-Jan-16

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

DIGIQUARTZ COEFFICIENTS:

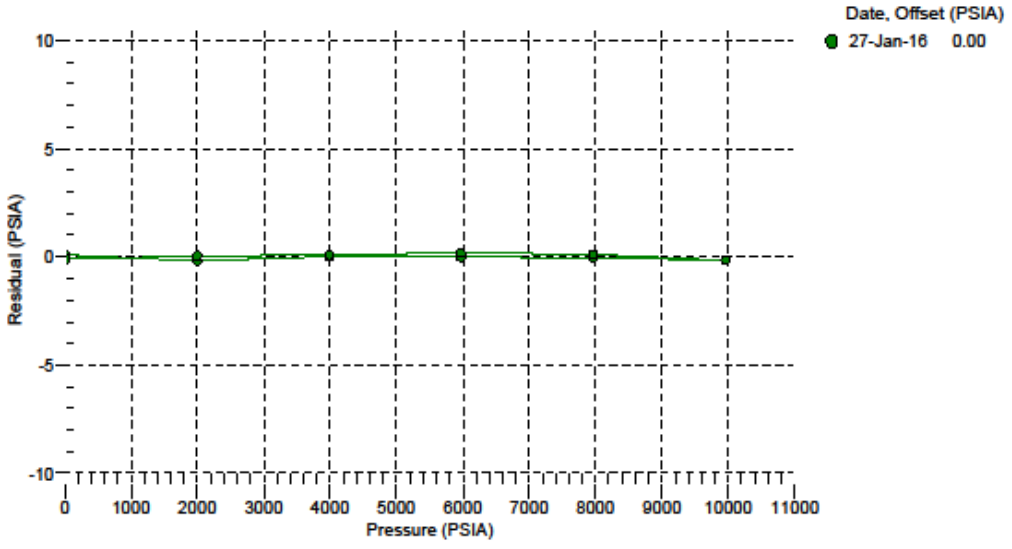
C1 =	-4.230776e+004
C2 =	1.490078e-001
C3 =	1.507500e-002
D1 =	3.473000e-002
D2 =	0.000000e+000
T1 =	3.002251e+001
T2 =	-2.774200e-004
T3 =	4.796030e-006
T4 =	1.754420e-009
T5 =	0.000000e+000

AD590M, AD590B, SLOPE AND OFFSET:

AD590M =	1.28100e-002
AD590B =	-8.83931e+000
Slope =	1.00002
Offset =	-0.1324 (dbars)

PRESSURE (PSIA)	INSTRUMENT OUTPUT (Hz)	INSTRUMENT TEMPERATURE (°C)	INSTRUMENT PRESSURE (PSIA)	CORRECTED PRESSURE (PSIA)	RESIDUAL (PSIA)
14.685	33318.40	21.9	14.957	14.765	0.080
2001.213	34090.20	22.1	2001.179	2001.033	-0.180
3988.132	34842.80	22.1	3988.234	3988.135	0.003
5975.146	35577.10	22.1	5975.181	5975.128	-0.018
7962.515	36294.40	22.2	7962.476	7962.469	-0.046
9949.743	36995.50	22.2	9949.539	9949.580	-0.163
7962.054	36294.30	22.2	7962.180	7962.174	0.120
5973.248	35576.50	22.3	5973.478	5973.425	0.177
3987.987	34842.80	22.3	3988.175	3988.075	0.088
2001.193	34090.30	22.3	2001.379	2001.234	0.041
14.672	33318.40	23.1	14.763	14.571	-0.101

Residual (PSIA) = corrected instrument pressure - reference pressure



Dissolved Oxygen (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: 0080
CALIBRATION DATE: 20-Jan-16

SBE 43 OXYGEN CALIBRATION DATA

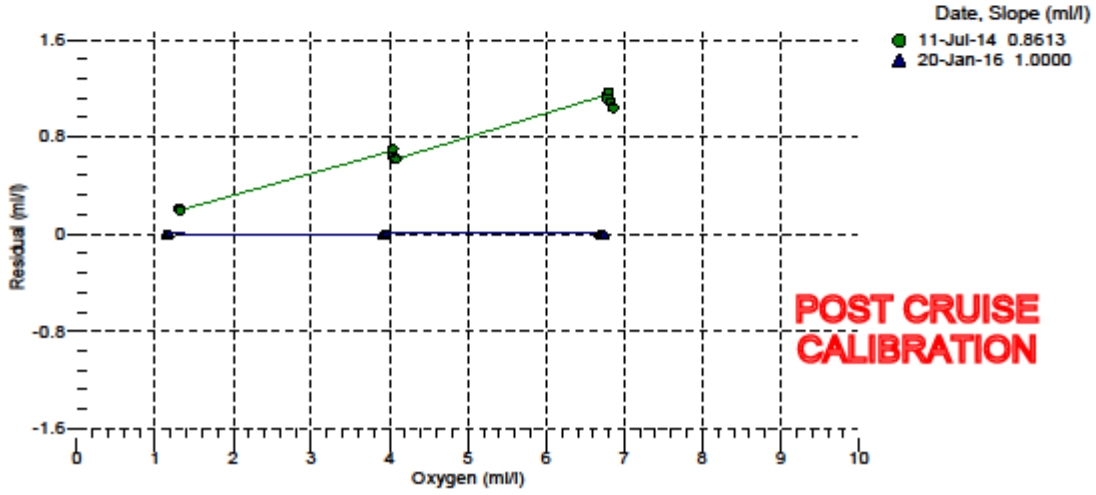
COEFFICIENTS:
Soc = 0.5835
Voffset = -0.5112
Tau20 = 1.45

A = -3.9682e-003
B = 1.6634e-004
C = -2.5707e-006
E nominal = 0.036

NOMINAL DYNAMIC COEFFICIENTS
D1 = 1.92634e-4 H1 = -3.300000e-2
D2 = -4.64803e-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)
1.14	12.00	0.00	0.778	1.14	-0.00
1.15	2.00	0.00	0.716	1.15	-0.00
1.15	6.00	0.00	0.742	1.15	-0.00
1.17	20.00	0.00	0.838	1.17	0.00
1.17	26.00	0.00	0.879	1.17	0.00
1.18	30.00	0.00	0.910	1.18	0.00
3.92	2.00	0.00	1.209	3.91	-0.00
3.92	12.00	0.00	1.429	3.92	0.00
3.92	6.00	0.00	1.298	3.92	-0.00
3.95	30.00	0.00	1.841	3.94	-0.00
3.95	20.00	0.00	1.613	3.95	-0.00
3.96	26.00	0.00	1.751	3.96	0.00
6.68	2.00	0.00	1.704	6.69	0.00
6.69	30.00	0.00	2.767	6.69	-0.00
6.72	6.00	0.00	1.858	6.72	0.00
6.72	20.00	0.00	2.382	6.71	-0.00
6.74	26.00	0.00	2.622	6.74	0.00
6.74	12.00	0.00	2.087	6.74	-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



Dissolved Oxygen (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: 0082
CALIBRATION DATE: 15-Mar-16

SBE 43 OXYGEN CALIBRATION DATA

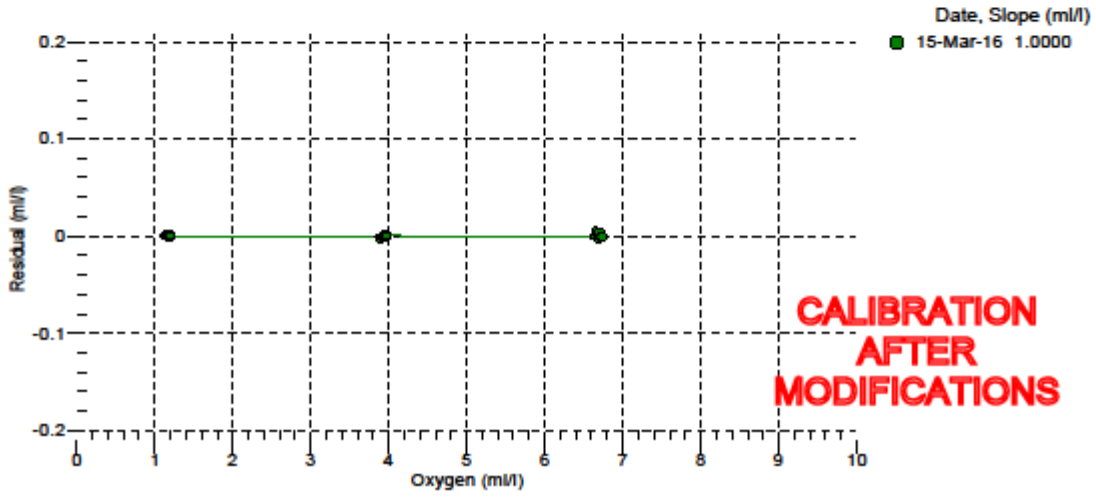
COEFFICIENTS:
Soc = 0.3539
Voffset = -0.6976
Tau20 = 1.50

A = -3.3092e-003
B = 1.2261e-004
C = -2.3444e-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)
1.14	2.00	0.00	1.031	1.14	0.00
1.15	6.00	0.00	1.076	1.15	0.00
1.17	12.00	0.00	1.147	1.17	0.00
1.18	20.00	0.00	1.240	1.18	-0.00
1.19	30.00	0.00	1.371	1.19	0.00
1.19	26.00	0.00	1.319	1.19	0.00
3.89	2.00	0.00	1.839	3.89	-0.00
3.90	6.00	0.00	1.981	3.89	-0.00
3.92	12.00	0.00	2.206	3.92	-0.00
3.94	20.00	0.00	2.510	3.94	-0.00
3.96	30.00	0.00	2.929	3.96	0.00
3.96	26.00	0.00	2.760	3.96	0.00
6.65	2.00	0.00	2.650	6.65	-0.00
6.66	6.00	0.00	2.895	6.67	0.00
6.69	12.00	0.00	3.269	6.69	-0.00
6.71	20.00	0.00	3.788	6.71	0.00
6.73	30.00	0.00	4.487	6.72	-0.00
6.73	26.00	0.00	4.201	6.73	-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



Pump (primary)

SEA-BIRD ELECTRONICS, INC.
13431 NE 20th St. Bellevue, Washington 98005 USA
Phone: (425) 643-9866 Fax: (425) 643-9954 www.seabird.com

Service Report

RMA Number: 78995

Customer Information:

Company	Lockheed Martin Antarctic Support	Date	10/9/2014
Contact	Dave Morehouse		
PO Number	4900050723		

Serial Number	051646
Model Number	SBE 05T

Services Requested:

1. Evaluate/Repair Instrumentation.
2. Replace standard impulse connector(s) with NEW wet-pluggable connector(s).

Problems Found:

1. Pumped is fixed. Replaced Q1,Q2,Q3,U1,C4,C2 and R11

Services Performed:

1. Performed initial diagnostic evaluation.
2. Installed NEW two pin wet-pluggable bulkhead connector(s).
3. Performed internal inspection and O-ring and thrust washer replacements.
4. Performed hydrostatic pressure test.

Special Notes:

Thursday, October 09, 2014 Page 7 of 11

Pump (secondary)

SEA-BIRD ELECTRONICS, INC.
13431 NE 20th St. Bellevue, Washington 98005 USA
Phone: (425) 643-9866 Fax: (425) 643-9954 www.seabird.com

Service Report

RMA Number: 78995

Customer Information:

Company	Lockheed Martin Antarctic Support	Date	10/9/2014
Contact	Dave Morehouse		
PO Number	4900050723		

Serial Number	055644
Model Number	SBE 05T

Services Requested:

1. Evaluate/Repair Instrumentation.
2. Replace standard impulse connector(s) with NEW wet-pluggable connector(s).

Problems Found:

Services Performed:

1. Performed initial diagnostic evaluation.
2. Installed NEW two pin wet-pluggable bulkhead connector(s).
3. Performed internal inspection and O-ring and thrust washer replacements.
4. Performed hydrostatic pressure test.

Special Notes:

Thursday, October 09, 2014 Page 8 of 11

Temperature (primary)

SEA-BIRD ELECTRONICS, INC.
13431 NE 20th St. Bellevue, Washington 98005 USA
Phone: (425) 643-9866 Fax: (425) 643-9954 www.seabird.com

Temperature Calibration Report

Customer:	Lockheed Martin Antarctic Support		
Job Number:	87035	**Date of Report:**	11/30/2015
Model Number	SBE 03-02/F	**Serial Number:**	031541

Temperature sensors are normally calibrated 'as received', without adjustments, allowing a determination sensor drift. If the calibration identifies a problem, then a second calibration is performed after work is completed. The 'as received' calibration is not performed if the sensor is damaged or non-functional, or by customer request.

An 'as received' calibration certificate is provided, listing coefficients to convert sensor frequency to temperature. Users must choose whether the 'as received' calibration or the previous calibration better represents the sensor condition during deployment. In SEASOFT enter the chosen coefficients. The coefficient 'offset' allows a small correction for drift between calibrations (consult the SEASOFT manual). Calibration coefficients obtained after a repair apply only to subsequent data.

'AS RECEIVED CALIBRATION' ☑ Performed ☐ Not Performed

Date: 11/26/2015 **Drift since last cal:** -0.00043 **Degrees Celsius/year**

Comments:

'CALIBRATION AFTER REPAIR' ☐ Performed ☑ Not Performed

Date: **Drift since Last cal:** **Degrees Celsius/year**

Comments:

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: 1541
CALIBRATION DATE: 26-Nov-15

SBE 3 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

COEFFICIENTS:

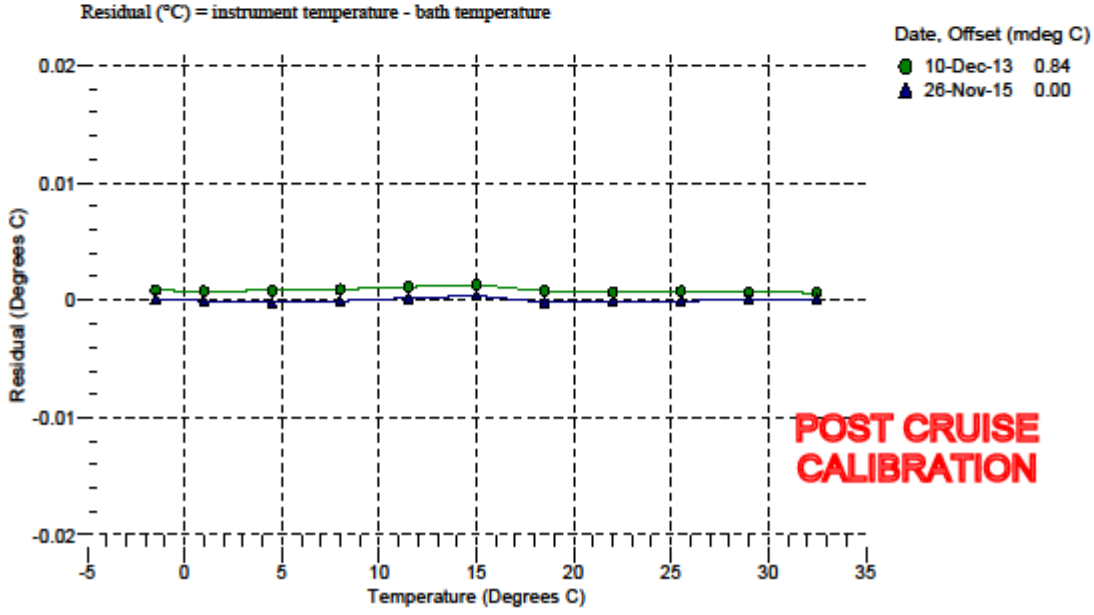
g = 4.82596096e-003
h = 6.66344550e-004
i = 2.43252369e-005
j = 1.86579435e-006
f0 = 1000.0

BATH TEMP (° C)	INSTRUMENT OUTPUT (Hz)	INST TEMP (° C)	RESIDUAL (° C)
-1.5000	6185.690	-1.4999	0.00012
1.0000	6544.384	0.9999	-0.00006
4.5000	7071.412	4.4998	-0.00021
8.0000	7628.204	7.9999	-0.00007
11.5000	8215.532	11.5002	0.00016
15.0000	8834.145	15.0004	0.00036
18.5000	9484.665	18.4999	-0.00015
22.0000	10168.038	21.9999	-0.00015
25.5000	10884.883	25.4999	-0.00007
29.0000	11635.859	29.0000	0.00000
32.5000	12421.607	32.5001	0.00007

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 St. Bellevue, Washington 98005 USA
Phone: (425) 643-9866 Fax: (425) 643-9954 www.seabird.com

Temperature Calibration Report

Customer:	Lockheed Martin Antarctic Support		
Job Number:	84671	**Date of Report:**	6/30/2015
Model Number	SBE 03F	**Serial Number:**	035185

Temperature sensors are normally calibrated 'as received', without adjustments, allowing a determination sensor drift. If the calibration identifies a problem, then a second calibration is performed after work is completed. The 'as received' calibration is not performed if the sensor is damaged or non-functional, or by customer request.

An 'as received' calibration certificate is provided, listing coefficients to convert sensor frequency to temperature. Users must choose whether the 'as received' calibration or the previous calibration better represents the sensor condition during deployment. In SEASOFT enter the chosen coefficients. The coefficient 'offset' allows a small correction for drift between calibrations (consult the SEASOFT manual). Calibration coefficients obtained after a repair apply only to subsequent data.

'AS RECEIVED CALIBRATION' ☑ Performed ☐ Not Performed

Date: 6/30/2015 **Drift since last cal:** -0.00028 **Degrees Celsius/year**

Comments:

'CALIBRATION AFTER REPAIR' ☐ Performed ☑ Not Performed

Date: **Drift since Last cal:** **Degrees Celsius/year**

Comments:

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: 5185
CALIBRATION DATE: 30-Jun-15

SBE 3 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

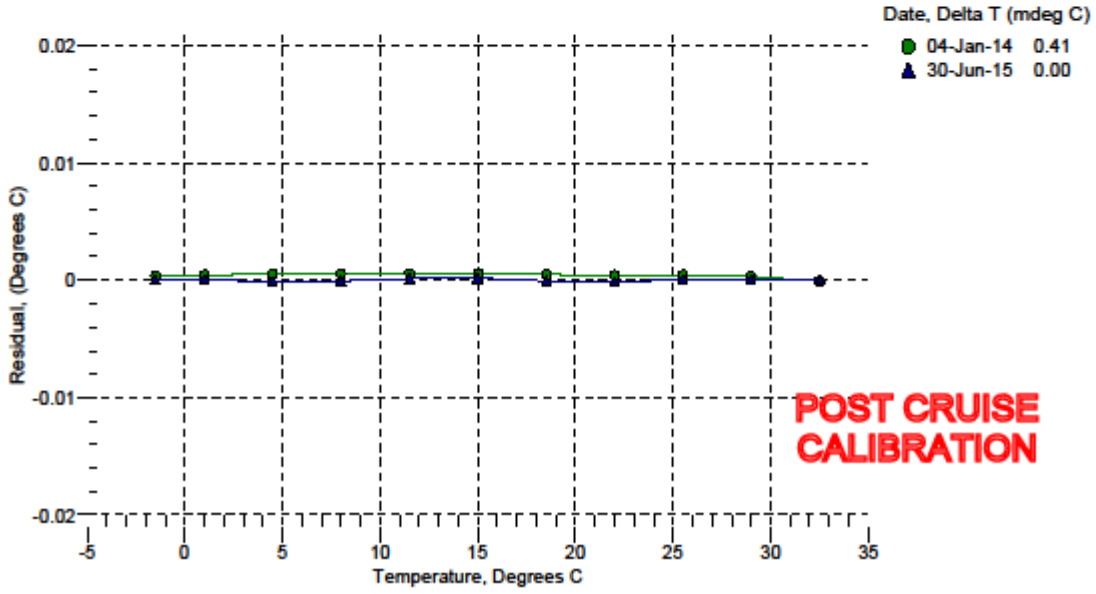
ITS-90 COEFFICIENTS:

g = 4.35773058e-003
h = 6.34779409e-004
i = 2.12499197e-005
j = 1.90362741e-006
f0 = 1000.0

BATH TEMP (ITS-90)	INSTRUMENT FREQ (Hz)	INST TEMP (ITS-90)	RESIDUAL (ITS-90)
-1.5000	3011.472	-1.5000	0.00004
0.9999	3186.545	0.9999	0.00001
4.5000	3443.880	4.4999	-0.00012
8.0000	3715.854	7.9999	-0.00006
11.4999	4002.865	11.5000	0.00012
14.9999	4305.303	15.0001	0.00017
18.5000	4623.531	18.4999	-0.00009
22.0000	4957.950	21.9999	-0.00012
25.5000	5308.924	25.5000	0.00002
29.0000	5676.765	29.0000	0.00001
32.4999	6061.812	32.4999	0.00002

Temperature ITS-90 = $1/\{ g + h[ln(f_0/f)] + i[ln^2(f_0/f)] + j[ln^3(f_0/f)]\} - 273.15$ (°C)

Residual = instrument temperature - bath temperature



Transmissometer

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WET Labs

C-Star Calibration

Date 7.27.15 S/N# CST-557DR Pathlength 25cm

	Analog output	Digital output
V_d	0.007 V	0 counts
V_{air}	4.766 V	15628 counts
V_{ref}	4.700 V	15410 counts

Temperature of calibration water	23.1 ℃
Ambient temperature during calibration	22.9 ℃

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.

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