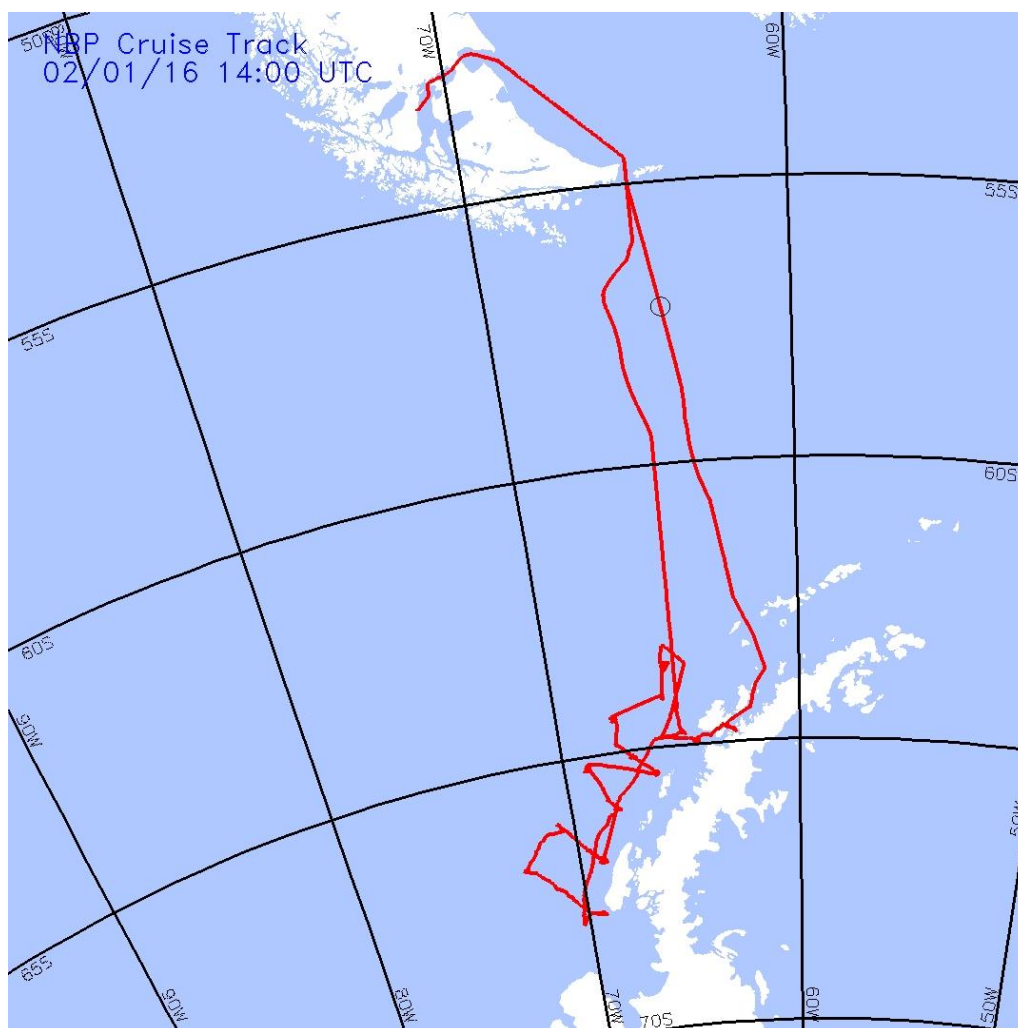


CRUISE NAME

# Data Report NBP16-01

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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All the data has been archived using 'tar' and compressed using 'gzip', identified by the '.tz' extension.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: NBP1601

File	Description
/	Root level directory
NBP1601.gmt	GMT binary file of MGD77 data
NBP1601.mgd	Full Cruise MGD77 data file
NBP1601.trk	Text file of cruise track
NBP1601DATA.docx	Data Report NBP1601 (MS Word)
NBP1601DATA.pdf	Data Report NBP1601 (PDF format)
INSTCOEF.TXT	Instrument Coefficient File
/process	Processed data
NBP1601JGOF.tz	JGOFs format data files
NBP1601MGD.tz	MGD Data
NBP1601PCO2.tz	Merged pCO <sub>2</sub> data files
NBP1601PROC.tz	Other processed data
NBP1601QC.tz	Daily RVDAS QC postscript plots
/rvdas/nav	Navigation data
NBP1601gyr1.tz	Gyro raw data
NBP1601s330.tz	Seapath 330 data
/rvdas/uw	Underway data
NBP1601bwnc.tz	Baltic winch data
NBP1601ctdd.tz	CTD depth data
NBP1601cwnc.tz	Waterfall winch data
NBP1601engl.tz	Engineering data
NBP1601grv1.tz	Gravimeter data
NBP1601hdas.tz	HydroDAS raw data
NBP1601knud.tz	Knudsen raw data
NBP1601mbdp.tz	Multi-beam depth
NBP1601mwx1.tz	Meteorology raw data
NBP1601pco2.tz	pCO <sub>2</sub> raw data
NBP1601pguv.tz	GUV raw data
NBP1601rtmp.tz	Remote Temperature data
NBP1601svp1.tz	Sound velocity probe (ADCP)
NBP1601tsg1.tz	Micro TSG1 data
NBP1601tsg2.tz	Micro TSG2 data
NBP1601twnc.tz	Trawl winch data
/Imagery	Satellite Imagery
NBP1601Imag.tz	Collection of Imagery Files
/ocean	Ocean data
NBP1601ctd.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 (NBP1601.trk). It contains the longitude and latitude at one-minute intervals extracted from the NBP1601.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 NBP1601proc.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](mailto:itvessel@usap.gov).

## JGOFS

The JGOFS data set can be found on the distribution media in the file /process/NBP1601JGOF.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	GMT Date	dd/mm/yy
02	GMT 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/meter <sup>2</sup>
10	Sea Surface Temperature	°C
11	Sea Surface Conductivity	siemens/meter
12	Sea Surface Salinity	PSU
13	Sea Depth (uncorrected, calc. sw sound 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/m <sup>2</sup>
22	PIR	W/m <sup>2</sup>

## 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 NBP1601.mgd. The file NBP1601.gmt is created from the MGD77 dataset using the “mgd77togmt” utility. NBP1601.gmt can be used with the GMT plotting package.

The data used to produce the NBP1601.mgd file can be found on the distribution media in the file /process/NBP1601proc.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 GMT when added; 0=GMT
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, 1 <sup>st</sup> sensor	In tenths of nanoteslas (gammas)
67-72	6	real	Magnetics total field, 2 <sup>nd</sup> sensor	In tenths of nanoteslas (gammas), for trailing sensor



Col	Len	Type	Contents	Description, Possible Values, Notes
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 = 1 <sup>st</sup> or leading sensor, 2 = 2 <sup>nd</sup> 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 10 <sup>th</sup> of mgals. Corrected for Eotvos, drift, tares
98-103	6	real	EOTVOS correction	In 10 <sup>th</sup> of mgals. $E = 7.5 V \cos \phi \sin \alpha + 0.0042 V^*V$
104-108	5	real	Free-air anomaly	In 10 <sup>th</sup> 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<sub>2</sub>

The NBP carries a pCO<sub>2</sub> measurement system from Lamont-Doherty Earth Observatory (LDEO). pCO<sub>2</sub> data is recorded by RVDAS and transmitted to LDEO at the end of each cruise. You will find pCO<sub>2</sub> data in a file named NBP1601pco2.tar in the /process directory, which contains the pCO<sub>2</sub> 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/NBP1601ctd.tar. The archive contains tar files NBP1601proc.tar.

### XBT

During the cruise, eXpendable BathyThermographs were used to obtain water column temperature profiles, providing corrections to the sound velocity profile for the multibeam system. The data files from these launches are included as NBP1601xbt.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:      NBP1601mwx1.d025

- The CruiseID is the numeric name of the cruise, in this case, NBP1601.
- 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 <sub>2</sub>	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	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 colon (:), equals (=), or ampersand (@). 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 pages 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<sub>2</sub> (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 <sub>2</sub> 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 <sup>3</sup> /min
7	pCO <sub>2</sub> Pressure	xxx.xx	μAtm
8	VCO <sub>2</sub> 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<sub>2</sub> time tag**

ttt = fractional time of day

**Flow Source**

Equil = pCO<sub>2</sub> 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 <sup>2</sup>
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 - <b>Rarely used*</b>	xx.xx	m
13	Transmissometer for Yo-Yo camera - <b>Rarely used*</b>	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*

### Seapath GPS (s330, seap)

The Seapath 330 outputs five NMEA standard strings – GPZDA, GPGGA, GPVTG, GPHDT, and GPRMC.

The Seapath 200 outputs four NMEA standard strings – GPZDA, GPGGA, GPVTG, and GPHDT. Both GPS's output three PSXN proprietary strings – PSXN 20, PSXN 22, and PSXN 23.

#### 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

**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<sub>2</sub> – 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 <sub>2</sub> 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 <sup>3</sup> /min
7	pCO <sub>2</sub> Pressure	xxx.xx	µAtm
8	VCO <sub>2</sub> 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 <sup>3</sup>
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 <sub>2</sub> O 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<sub>2</sub> time tag**

ttt = fractional time of day

**Flow Source**Equil = pCO<sub>2</sub> Measurement**Sea Water Valve**

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

**Calculations****PAR**

Coefficients parcl 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 “mw1” 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)
parcl = 1 / scale = .17
probe offset dark = -.1 mV
parcv = dark x 1000 mV/V = -0.0001 V
((par / 1000 mV/V) - parcv) x parcl 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) * parcl * 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 “mw1” 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<sup>-6</sup> V/(W/m<sup>2</sup>)

pir\_thermo / (scale x 1000 mV/V) = W/m<sup>2</sup>

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))
```

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 yy+ddd:hh:mm:ss where yy is year, ddd is year-day, hh is hour, mm is minute, and ss is second. Times are reported in UTC.

[illegible]



## Appendix A: Sensors

### NBP1601 Sensors

Sensor	Description	Serial	Last Cal Date	Comments
<b>Meteorology and Radiometry</b>				
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	5/29/2015	
Temperature / Humidity	RM Young 41372LC	06134	1/20/2015	
PIR	Eppley PIR	33023F3	6/12/2014	
PSP	Eppley PSP	33090F3	6/11/2014	
PAR (Mast)	Biospherical Instruments QSR-240	6357	2/17/2015	
GUV (Mast)	Biospherical Instruments GUV-2511	25110203114	2/10/2015	

Sensor	Description	Serial	Last Cal Date	Comments
<b>Underway Seawater Sampling System</b>				
Micro-TSG	Sea-Bird SBE 45	4550449-0242	12/20/2014	
Micro-TSG	Sea-Bird SBE 45	4566350-0389	5/29/2014	
Digital Remote Temp	Sea-Bird SBE 38	3849120-0178	10/31/2014	
Transmissometer	WetLabs C-Star	CST-892DR	4/29/2014	
Fluorometer	WetLabs AFLT	AFLD-011	6/26/2015	

Sensor	Description	Serial	Last Cal Date	Comments
<b>CTD</b>				
Altimeter	Teledyne Benthos PSA-916	49432	NA	
Bottom Contact Switch	Sea-Bird	# 3	NA	
Carousel Water Sampler	Sea-Bird SBE 32	3270675-0925	NA	
SBE 11+ Deck Unit	Sea-Bird SBE 11+	11P19858-0490	NA	
Conductivity	Sea-Bird 4 – 02/O	041143	02/20/2015	
Conductivity	Sea-Bird 4C 6800m	041789	07/17/2014	
CTD Fish	Sea-Bird SBE 9+	09P78915-1190	06/09/2014	
CTD Pressure Sensor	Sea-Bird SBE 9+	130016	06/09/2014	
Dissolved Oxygen	Sea-Bird SBE 43	0139	03/25/2015	Primary
Dissolved Oxygen	Sea-Bird SBE 43	0082	03/25/2015	Secondary
CTD Pump	Sea-Bird 5T, PN 90543	055641 3.0K	03/31/2014	Primary
CTD Pump	Sea-Bird 5T, PN 90160	051644 3.0K	08/10/2014	Secondary
Fluorometer	WetLabs FLRTD	FLRTD-0397	02/23/2045	
Surface PAR	QSR-240	6357	2/17/2015	Fed to CTD, on Mast
PAR	Biospherical Instruments QSP-200L4S	4469	02/03/2014	
Temperature	Sea-Bird 3plus 6800M	03P5730	03/17/2015	Primary
Temperature	Sea-Bird 3-02/F	031649	02/20/2015	Secondary

## Appendix B: Calibration Sheets

### Gravity

#### 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: **12/5/2015** Reference Code Numbers:  
 Location: Punta Arenas, Chile Station no. 9337-50  
 Station: Harbour Admin. Bldg. ISGN no. 51230N  
 Latitude: 53 09 S  
 Longitude: 070 55 W  
 Elevation:  
 Gravity: 981320.82

	Value	Time (GMT)
Ship's meter before gravity tie (Filt Counts)	25197.54	15:58
Ship's meter after gravity tie (Filt Counts)	25197.46	16:57
Average	25197.50	
Ship Gravimeter's Calibration Constant	4.99407055	
Corrected ship's meter ( QC Grav (mgal) )	125838.09	

	Value	Time (GMT)
Ship's meter before gravity tie (serial, RVDAS)	981316.4	15:59
Ship's meter after gravity tie (serial, RVDAS)	981316.4	16:57
Average (for comparison check only)	981316.4	

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	4919.62	16:12	53	December 5, 2015	
Pier measurement 2	4919.66	16:15	53	December 5, 2015	4969.18
Pier measurement 3	4919.64	16:16	53	December 5, 2015	
Average	4919.64				
Station measurement 1	4920.40	16:36	53	December 5, 2015	
Station measurement 2	4920.37	16:39	53	December 5, 2015	4969.94
Station measurement 3	4920.40	16:40	53	December 5, 2015	
Average	4920.39				
Pier measurement 4	4919.83	16:48	53	December 5, 2015	
Pier measurement 5	4919.82	16:52	53	December 5, 2015	4969.38
Pier measurement 6	4919.87	16:53	53	December 5, 2015	
Average	4919.84				

Date of last tie **9/1/2015**  
 Gravity Bias from last tie **855480.71**  
 Drift since last tie **1.81**  
 Drift RATE since last tie **0.58**

#### OBS Differences

Station to Pier (1, 2, & 3 averaged)	-0.76
Station to Pier (4, 5, & 6 averaged)	-0.56
Averaged Differences	-0.66
Gravity at pier	981320.16
Elevation of pier above gravimeter, meters	1.5
Earth differential gravity, mgal/meter	0.3
Gravity at ship's gravimeter	981320.61
Gravity Bias (Offset for RVDAS)	855482.52

#### Comments

Gravity Land Tie done by Barry Bjork and Sheldon Blackman. Conditions excellent. **However, we had a difficult time with doing the tie in the gravimeter laptop utilizing 3 consecutive changes in sealevel. Therefore we used the Bias from this sheet instead.**

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

## Meteorology

### Anemometer

No Calibration Needed

## Barometer



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



**CALIBRATION REPORT**  
**Barometric Pressure**

Customer: *Lockheed Martin Maritime Systems & Sensors*

Test Number: 2060-01B

Customer PO: 4900027957

Test Date: 29 November 2012

Sales Order: 2973

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  $\pm 1.0$  hPa.

Reference Pressure (hPa)	Voltage Output (millivolts)	Indicated (1) Pressure (hPa)
800.0	-1	800.0
875.0	1251	875.0
950.0	2501	950.0
1025.0	3749	1024.9
1100.0	4996	1099.7

(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

Druck Pressure Controller Model DPI515  
Fluke Multimeter Model 8060A

Serial # NIST Test Reference

51500497 UKAS Lab 0221  
4865407 234027

Tested By:

*EChen*

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

**CALIBRATION REPORT**  
**Temperature**

Customer: *Lockheed Martin Corp*

Test Number: 5120-07T

Customer PO: 4101741493

Test Date: 20 January 2015

Sales Order: 4554

Test Sensor:

Model: 41372LC

Serial Number: TS06134

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  $\pm 0.1^\circ$  Celsius.

Bath Temperature (degrees C)	Current Output (milliamps)	Indicated (1) Temperature (degrees C)
-49.85	4.029	-49.82
-0.01	11.997	-0.02
49.94	19.990	49.94

(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

Brooklyn Thermometer Model 43-FC  
Brooklyn Thermometer Model 22332-D5-FC  
Brooklyn Thermometer Model 2X400-D7-FC  
Keithley Multimeter Model 191

Serial # NIST Test Reference

3006-118 W204690  
25071 W204691  
77532 W204692  
15232 7124815

Tested By: 

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



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

**CALIBRATION REPORT**  
**Relative Humidity**

Customer: *Lockheed Martin Corp*

Test Number: 5120-07R

Customer PO: 4101741493

Test Date: 20 January 2015

Sales Order: 4554

Test Sensor:

Model: 41372LC

Serial Number: *TS06134*

Description: Temperature/Relative Humidity Sensor

Report of calibration comparison of test relative humidity sensor with National Institute of Standards and Technology traceable standard relative humidity sensor at five humidity levels in the R.M. Young Company controlled humidity chamber facility. Calibration accuracy  $\pm 2.0$  %.

Reference Humidity (%)	Current Output (milliamps)	Indicated (1) Humidity (%)
10.1	6.0	12.4
30.0	9.0	31.1
50.0	12.4	52.3
70.0	15.4	71.5
90.0	18.2	88.6

(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

Vaisala Humidity Sensor Model 35AC  
Agilent Multimeter Model 34405A

Serial # NIST Test Reference

N475040 TN 266152  
MY53020093 7124815

Tested By: *R. Palmer*

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





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

### CALIBRATION REPORT

#### Temperature

Customer: *Lockheed Martin Corp*

Test Number: 4307-01T  
Test Date: 7 March 2014

Customer PO: 4900045732  
Sales Order: 3919

Test Sensor:

Model: 41372LC      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 thermometers at three temperatures in the R.M. Young Company controlled temperature calibration bath facilities. Calibration accuracy  $\pm 0.1^\circ$  Celsius.

Bath Temperature (degrees C)	Current Output (milliamps)	Indicated (1) Temperature (degrees C)
-49.85	4.015	-49.91
-0.01	11.992	-0.05
50.10	20.016	50.10

(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 2X400-D7-FC	77532	W204692
Keithley Multimeter Model 191	15232	4200646497

Tested By: *R. Thullen*

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



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

**CALIBRATION REPORT**  
**Relative Humidity**

Customer: *Lockheed Martin Corp*

Test Number: 4307-01R  
Test Date: 7 March 2014

Customer PO: 4900045732  
Sales Order: 3919

Test Sensor:

Model: 41372LC      Serial Number: TS06733  
Description: Temperature/Relative Humidity Sensor

Report of calibration comparison of test relative humidity sensor with National Institute of Standards and Technology traceable standard relative humidity sensor at five humidity levels in the R.M. Young Company controlled humidity chamber facility. Calibration accuracy  $\pm 2.0$  %.

Reference Humidity (%)	Current Output (milliamps)	Indicated (1) Humidity (%)
10.1	5.9	11.9
30.1	8.8	30.0
50.0	12.1	50.4
70.2	15.2	70.1
89.9	18.0	87.3

(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  
Vaisala Humidity Sensor Model 35AC  
Agilent Multimeter Model 34405A

Serial # NIST Test Reference  
N475040      TN 266152  
MY53020093      4200646497

Tested By: \_\_\_\_\_

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





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

## CALIBRATION REPORT

### Temperature

Customer: *Lockheed Martin Corp*

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

Customer PO: 49000063237  
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  $\pm 0.1^\circ$  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

Brooklyn Thermometer Model 43-FC  
Brooklyn Thermometer Model 22332-D5-FC  
Brooklyn Thermometer Model 2X400-D7-FC  
Keithley Multimeter Model 191

#### Serial # NIST Test Reference

3006-118      W204690  
25071      W204691  
77532      W204692  
15232      8604897

Tested By: \_\_\_\_\_

M E T E O R O L O G I C A L   I N S T R U M E N T S  
Tel: 231-946-3980 Fax: 231-946-4772 Email: met.sales@youngusa.com Website: youngusa.com  
ISO 9001:2008 CERTIFIED



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

## CALIBRATION REPORT

### Relative Humidity

Customer: *Lockheed Martin Corp*

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

Customer PO: 49000063237  
Sales Order: 4867

#### Test Sensor:

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

Report of calibration comparison of test relative humidity sensor with National Institute of Standards and Technology traceable standard relative humidity sensor at five humidity levels in the R.M. Young Company controlled humidity chamber facility. Calibration accuracy  $\pm 2.0\%$ .

Reference Humidity (%)	Current Output (milliamps)	Indicated (1) Humidity (%)
10.0	6.1	12.8
30.0	9.1	31.6
50.0	12.4	52.6
70.0	15.4	71.3
90.0	18.0	87.7

(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

Vaisala Humidity Sensor Model 35AC  
Agilent Multimeter Model 34405A

#### Serial # NIST Test Reference

N475040      TN 266152  
MY53020093      8604897

Tested By: \_\_\_\_\_

M E T E O R O L O G I C A L I N S T R U M E N T S  
Tel: 231-946-3980 Fax: 231-946-4772 Email: met.sales@youngusa.com Website: youngusa.com  
ISO 9001:2008 CERTIFIED

PIR

**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

**STANDARDIZATION OF  
EPPLEY PRECISION INFRARED RADIOMETER  
Model PIR**

Serial Number: 33023F3

Resistance: 739  $\Omega$  at 23°C

Temperature Compensation Range: -20° to +40°C

This pyrgeometer has been compared against Eppley's Blackbody Calibration System under radiation intensities of approximately 200 watts meter<sup>-2</sup> and an average ambient temperature of 24°C as measured by Standard Omega Temperature Probe, RTD#1.

As a result of a series of comparisons, it has been found to have a sensitivity of:

$$3.82 \times 10^{-6} \text{ volts/watts meter}^{-2}$$

The calculation of this constant is based on the fact that the relationship between radiation intensity and emf is rectilinear to intensities of 700 watts meter<sup>-2</sup>. This radiometer is linear to within  $\pm 1.0\%$  up to this intensity.

The calibration of this instrument is traceable to the International Practical Temperature Scale (IPTS) through a precision low-temperature blackbody.

Eppley recommends a minimum calibration cycle of five (5) years but encourages annual calibrations for highest measurement accuracy. Unless otherwise stated in the remarks section below or on the Sales Order, the results are "AS FOUND / AS LEFT".

Shipped to: NSF/Lockheed Martin  
Port Hueneme, CA

S.O. Number: 64124  
Date: June 12, 2014

Date of Test: June 11, 2014

In Charge of Test:

Reviewed by:

Remarks:

*End of Report*

PSP

**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 33090F3

**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 Precision Spectral Pyranometer, Model PSP, Serial Number 18851F3

**Results:**  
**Sensitivity:**  $S = 7.90 \mu V / W m^{-2}$   
**Uncertainty:**  $U_{95} = \pm 0.91\%$  (95% confidence level,  $k=2$ )  
**Resistance:**  $700 \Omega$  at  $23^{\circ}C$   
**Date of Test:** June 23, 2014

**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:**  
*Debra L. Lundy*  
In Charge of Test: \_\_\_\_\_  
*Thomas D. Kirk*  
Reviewed by: \_\_\_\_\_

**Eppley SO:** 64130

**Date of Certificate:** June 23, 2014

**Remarks:** Sensitivity before Repainting Element =  $7.86 \mu V / W m^{-2}$

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/cm<sup>2</sup>sec  
155.13384 uE/m<sup>2</sup>sec

Calibration Scale Factor:

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

Dry: 1.0304E-17 V/(quanta/cm<sup>2</sup>sec)  
6.2054E-04 V/(uE/m<sup>2</sup>sec)

## 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)

**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-035(3/7/12) 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  $\pm 10\%$  for solar zenith angles smaller than  $75^\circ$ . 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 25110203114v8.mdb. This database is required for operation of this system using Biospherical Instruments Inc.'s Logger® software.

## 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: 0389  
CALIBRATION DATE: 29-May-14SBE 45 CONDUCTIVITY CALIBRATION DATA  
PSS 1978: C(35,15,0) = 4.2914 Siemens/meter

## COEFFICIENTS:

g = -9.972006e-001  
h = 1.453197e-001  
i = -3.532467e-004  
j = 4.851413e-005

CPcor = -9.5700e-008  
CTcor = 3.2500e-006  
WBOTC = 1.2700e-007

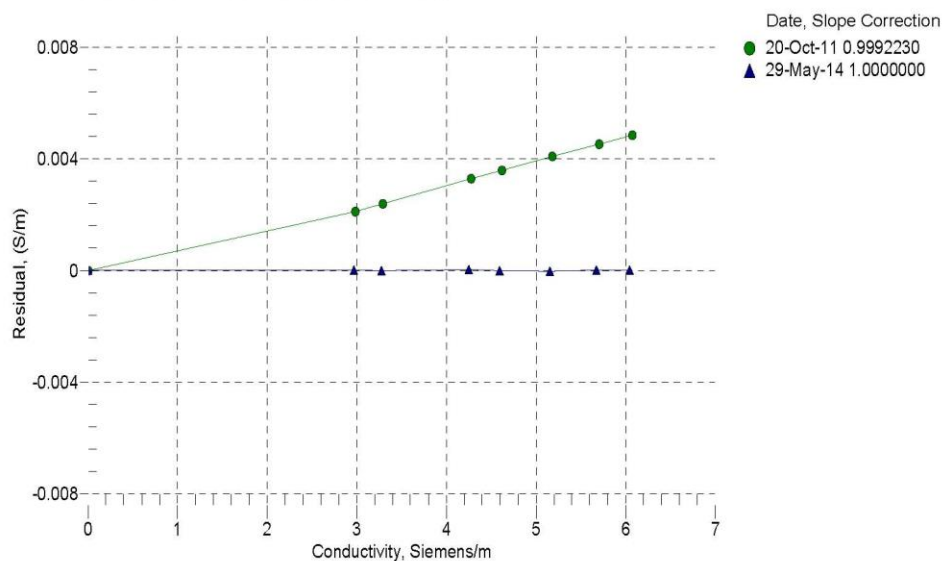
BATH TEMP (ITS-90)	BATH SAL (PSU)	BATH COND (Siemens/m)	INST FREQ (Hz)	INST COND (Siemens/m)	RESIDUAL (Siemens/m)
22.0000	0.0000	0.00000	2624.92	0.00000	0.00000
0.9998	34.6961	2.96665	5232.10	2.96665	0.00000
4.5057	34.6762	3.27332	5430.12	3.27330	-0.00001
15.0000	34.6345	4.25166	6017.72	4.25170	0.00003
18.5010	34.6261	4.59595	6210.96	4.59595	-0.00000
24.0071	34.6168	5.15295	6511.14	5.15292	-0.00003
29.0000	34.6116	5.67255	6778.86	5.67255	0.00000
32.5000	34.6081	6.04378	6963.60	6.04378	0.00001

$$f = \text{INST FREQ} * \sqrt{1.0 + \text{WBOTC} * t} / 1000.0$$

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

$$t = \text{temperature} [^{\circ}\text{C}]; p = \text{pressure} [\text{decibars}]; \delta = \text{CTcor}; \epsilon = \text{CPcor};$$

$$\text{Residual} = \text{instrument conductivity} - \text{bath conductivity}$$



## Micro-TSG2

## 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: 20-Dec-14SBE 45 CONDUCTIVITY CALIBRATION DATA  
PSS 1978: C(35,15,0) = 4.2914 Siemens/meter

## COEFFICIENTS:

g = -9.971074e-001  
h = 1.520779e-001  
i = -3.950938e-004  
j = 5.484363e-005CPcor = -9.5700e-008  
CTcor = 3.2500e-006  
WBOTC = -0.0000e+000

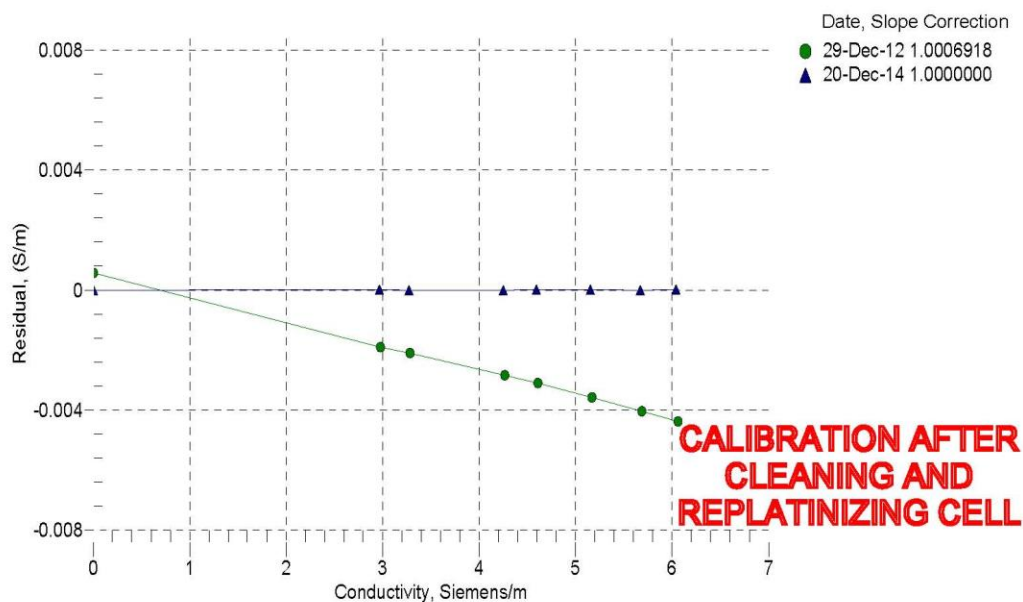
BATH TEMP (ITS-90)	BATH SAL (PSU)	BATH COND (Siemens/m)	INST FREQ (Hz)	INST COND (Siemens/m)	RESIDUAL (Siemens/m)
22.0000	0.0000	0.00000	2566.09	0.00000	0.00000
1.0000	34.6921	2.96636	5114.98	2.96636	0.00000
4.5000	34.6725	3.27249	5308.26	3.27249	-0.00001
15.0000	34.6299	4.25116	5882.92	4.25115	-0.00001
18.5000	34.6209	4.59524	6071.75	4.59525	0.00001
24.0000	34.6113	5.15149	6364.85	5.15149	0.00000
29.0000	34.6062	5.67177	6626.90	5.67176	-0.00000
32.5000	34.6038	6.04311	6807.56	6.04311	0.00000

$$f = \text{INST FREQ} * \text{sqrt}(1.0 + \text{WBOTC} * t) / 1000.0$$

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

t = temperature[°C]; p = pressure[decibars];  $\delta$  = CTcor;  $\epsilon$  = CPcor;

Residual = instrument conductivity - bath conductivity





## 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: 31-Oct-14SBE 38 TEMPERATURE CALIBRATION DATA  
ITS-90 TEMPERATURE SCALE

## COEFFICIENTS:

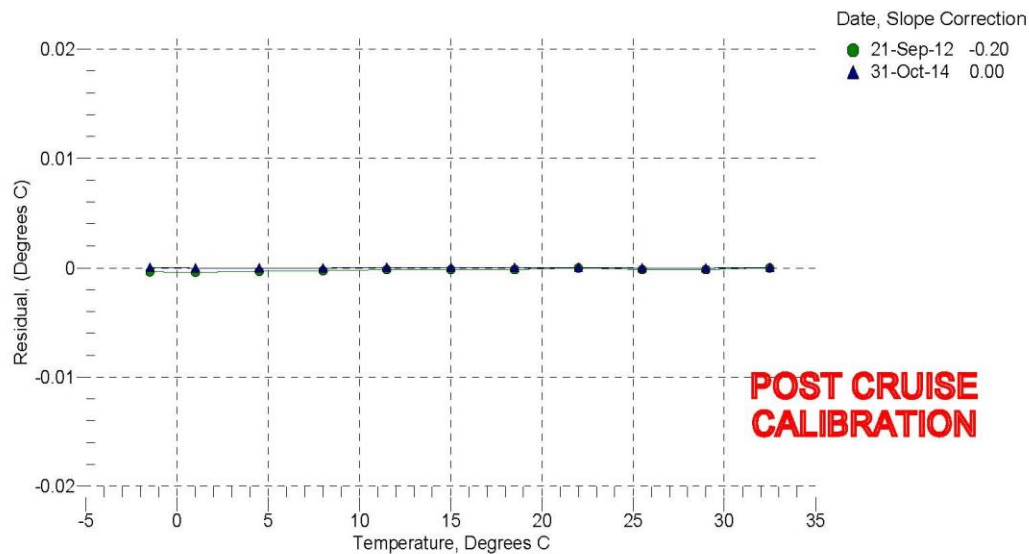
$a_0 = -4.694187e-005$   
 $a_1 = 2.820030e-004$   
 $a_2 = -2.750070e-006$   
 $a_3 = 1.681123e-007$

BATH TEMP (ITS-90)	INSTRUMENT OUTPUT	INST TEMP (ITS-90)	RESIDUAL (ITS-90)
-1.5000	750866.0	-1.5000	0.0000
1.0000	671239.5	1.0000	-0.0000
4.5000	575375.4	4.5000	-0.0000
8.0000	494797.7	8.0000	-0.0000
11.5000	426839.8	11.5000	0.0000
15.0000	369340.5	15.0000	0.0000
18.5000	320535.0	18.5000	0.0000
22.0000	278980.5	22.0000	0.0000
25.5000	243493.8	25.5000	-0.0000
29.0000	213099.6	29.0000	-0.0000
32.5000	186992.8	32.5000	0.0000

$$\text{Temperature ITS-90} = 1/\{a_0 + a_1[\ln(n)] + a_2[\ln^2(n)] + a_3[\ln^3(n)]\} - 273.15 (^{\circ}\text{C})$$

Residual = instrument temperature - bath temperature

n = instrument output



## Transmissometer

PO Box 518  
620 Applegate St.  
Philomath, OR 97370



(541) 929-5650  
Fax (541) 929-5277  
[www.wetlabs.com](http://www.wetlabs.com)

## C-Star Calibration

Date **April 29, 2014** S/N# **CST-892DR** Pathlength **25cm**

## Analog output

$V_d$  **0.059 V**  
 $V_{air}$  **4.816 V**  
 $V_{ref}$  **4.712 V**

Temperature of calibration water **20.4 °C**  
Ambient temperature during calibration **19.4 °C**

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



(541) 929-5650  
Fax (541) 929-5277  
<http://www.wetlabs.com>

## Chlorophyll Fluorometer Characterization . Uranine Proxy

**Date:** 6/26/15  
**Serial #:** AFLD-011  
**Tech:** KM

**Dark Counts** 0.0650 volts  
**CEV** .920 volts  
**SF** 27.2865

**FSV** 5.367 volts

**Linearity:** 0.999 R<sup>2</sup> (0–1.5 volts)  
0.995 R<sup>2</sup> (0– 5.45 volts)

## Notes:

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

**CEV** is the chlorophyll equivalent voltage. This value is the signal output of the fluorometer when using a fluorescent proxy that has been determined to be approximately equivalent to **23.33 µg/l** of a *Thalassiosira weissflogii* phytoplankton culture.

**SF** is the scale factor used to derive chlorophyll concentration from the signal voltage output of the fluorometer. The scale factor is determined by using the following equation:  
 $SF = (23.33) / (CEV - \text{dark})$  e.g.  $(23.33 / (.920 - 0.0650)) = 27.2865$

**FSV** is the maximum signal voltage output that the fluorometer is capable of.

Chlorophyll concentration expressed in µg/l (mg/m<sup>3</sup>) can be derived by using the following equation: (µg/l) = (V<sub>measured</sub> - dark) \* SF

The relationship between fluorescence and chlorophyll-*a* concentrations in-situ is highly variable. The scale factor listed on this document was determined by 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 determination of chlorophyll concentration see [ Standard Methods For The Examination Of Water And Wastewater] part 10200 H published jointly by: American Public Health Association, American Water Works Association and Water Environment Federation.

## CTD

## 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: 1143  
CALIBRATION DATE: 20-Feb-15SBE 4 CONDUCTIVITY CALIBRATION DATA  
PSS 1978: C(35,15,0) = 4.2914 Siemens/meter

## COEFFICIENTS:

g = -3.93961350e+000  
h = 5.03101997e-001  
i = 1.35579103e-005  
j = 2.55829144e-005CPcor = -9.5700e-008 (nominal)  
CTcor = 3.2500e-006 (nominal)

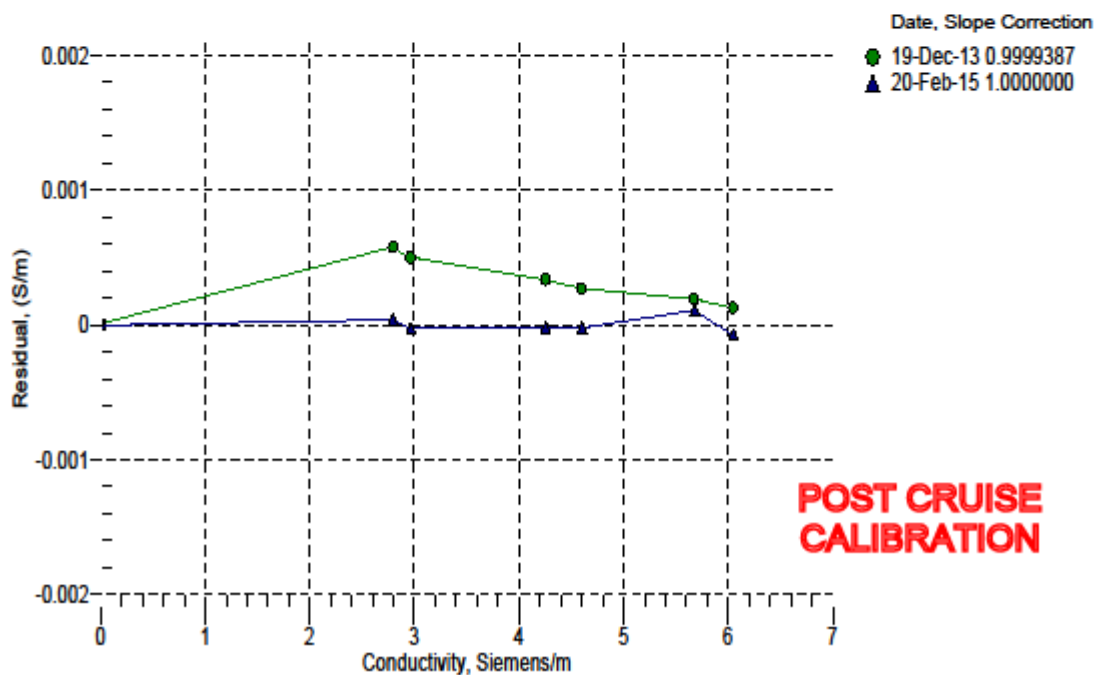
BATH TEMP (ITS-90)	BATH SAL (PSU)	BATH COND (Siemens/m)	INST FREQ (kHz)	INST COND (Siemens/m)	RESIDUAL (Siemens/m)
0.0000	0.0000	0.00000	2.79766	0.00000	0.00000
-1.0000	34.6810	2.79469	7.94758	2.79473	0.00004
1.0000	34.6821	2.96558	8.15700	2.96556	-0.00003
15.0000	34.6831	4.25700	9.59142	4.25698	-0.00002
18.5000	34.6834	4.60264	9.93972	4.60261	-0.00002
29.0001	34.6817	5.68276	10.95581	5.68287	0.00011
32.5000	34.6744	6.05404	11.28332	6.05397	-0.00007

$$f = \text{INST FREQ} / 1000.0$$

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

t = temperature[°C]; p = pressure[decibars];  $\delta$  = CTcor;  $\epsilon$  = CPcor;

Residual = 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: 1798  
CALIBRATION DATE: 17-Jul-14SBE 4 CONDUCTIVITY CALIBRATION DATA  
PSS 1978: C(35,15,0) = 4.2914 Siemens/meter

## COEFFICIENTS:

g = -3.93288929e+000  
h = 4.59853839e-001  
i = -7.27510146e-004  
j = 5.68537961e-005CPcor = -9.5700e-008 (nominal)  
CTcor = 3.2500e-006 (nominal)

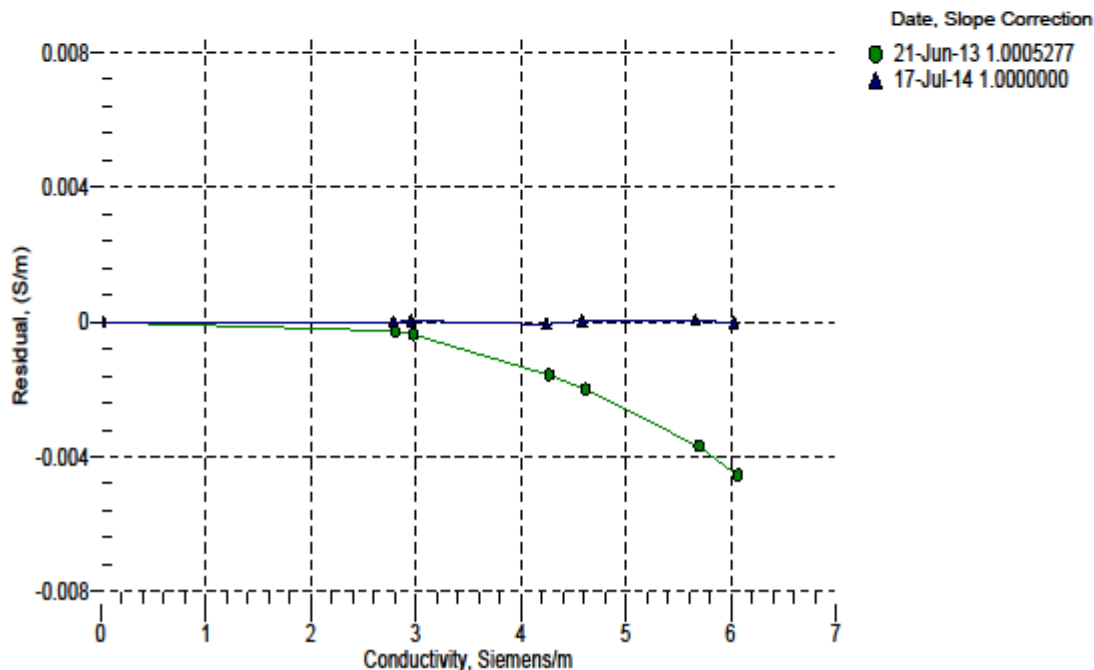
BATH TEMP (ITS-90)	BATH SAL (PSU)	BATH COND (Siemens/m)	INST FREQ (kHz)	INST COND (Siemens/m)	RESIDUAL (Siemens/m)
0.0000	0.0000	0.00000	2.92970	0.00000	0.00000
-1.0000	34.5587	2.78575	8.33369	2.78574	-0.00001
1.0000	34.5589	2.95605	8.55359	2.95608	0.00003
15.0000	34.5590	4.24338	10.05865	4.24330	-0.00007
18.5000	34.5580	4.58779	10.42390	4.58782	0.00004
29.0000	34.5572	5.66464	11.48885	5.66469	0.00005
32.5000	34.5510	6.03494	11.83211	6.03490	-0.00004

f = INST FREQ / 1000.0

Conductivity = (g + h \* f + i \* f<sup>2</sup> + j \* f<sup>3</sup>) / (1 + δ \* t + ε \* p) Siemens / meter

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

Residual = instrument conductivity - bath conductivity



## 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: 0139  
CALIBRATION DATE: 25-Mar-15

## SBE 43 OXYGEN CALIBRATION DATA

COEFFICIENTS: A = -3.2599e-003  
Soc = 0.4454 B = 1.8886e-004  
Voffset = -0.5633 C = -2.3727e-008  
Tau20 = 1.66 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

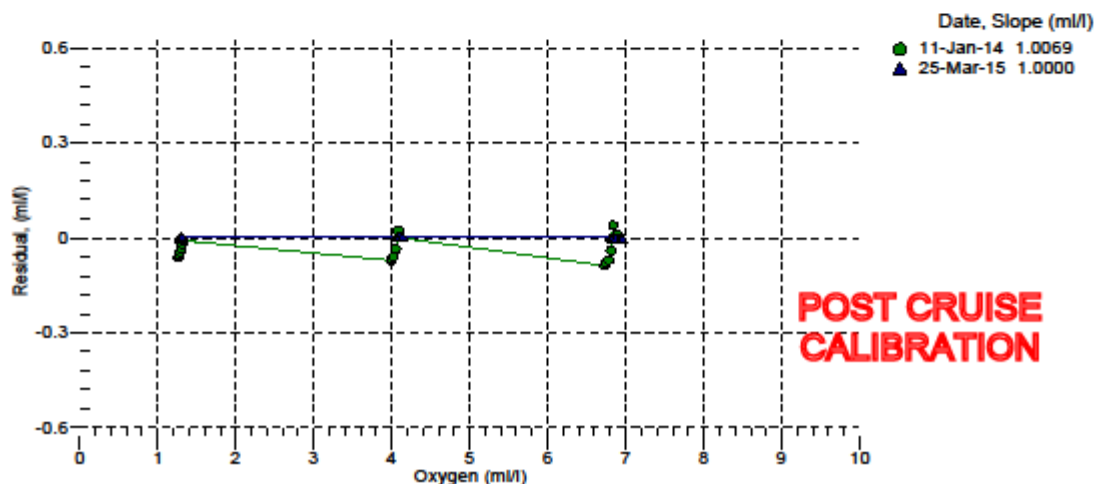
BATH OX (ml/l)	BATH TEMP (ITS-90)	BATH SAL (PSU)	INSTRUMENT OUTPUT (VOLTS)	INSTRUMENT OXYGEN (ml/l)	RESIDUAL (ml/l)
1.27	2.00	0.00	0.860	1.27	-0.00
1.28	6.00	0.00	0.896	1.27	-0.00
1.29	12.00	0.00	0.954	1.29	-0.00
1.30	26.00	0.00	1.077	1.30	0.00
1.30	30.00	0.00	1.113	1.31	0.00
1.31	20.00	0.00	1.031	1.31	0.00
4.06	12.00	0.00	1.792	4.06	0.00
4.07	20.00	0.00	2.013	4.07	0.00
4.07	6.00	0.00	1.628	4.07	0.00
4.08	2.00	0.00	1.515	4.08	0.00
4.11	26.00	0.00	2.186	4.11	0.00
4.14	30.00	0.00	2.308	4.14	0.00
6.81	6.00	0.00	2.342	6.81	0.00
6.83	2.00	0.00	2.157	6.83	-0.00
6.84	12.00	0.00	2.634	6.84	-0.00
6.87	20.00	0.00	3.010	6.87	-0.00
6.94	26.00	0.00	3.302	6.93	-0.00
6.96	30.00	0.00	3.492	6.96	-0.00

$$\text{Oxygen (ml/l)} = \text{Soc} * (V + \text{Voffset}) * (1.0 + A * T + B * T^2 + C * T^3) * \text{OxSol}(T, S) * \exp(E * P / K)$$

V = voltage output from SBE43, T = temperature [deg C], S = salinity [PSU], K = temperature [deg K]

OxSol(T,S) = oxygen saturation [ml/l], P = pressure [dbar]

Residual = 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: 25-Mar-15

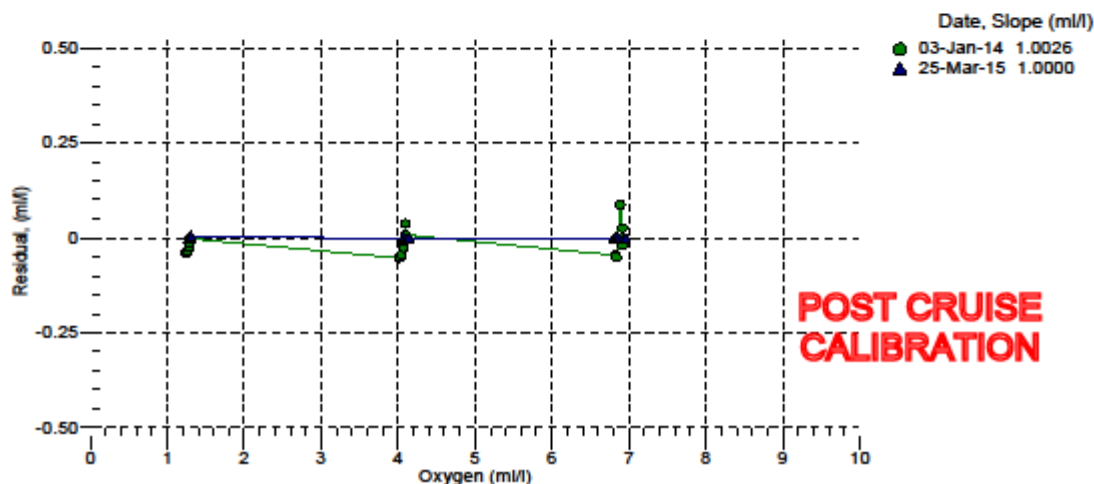
## SBE 43 OXYGEN CALIBRATION DATA

COEFFICIENTS: A = -3.8944e-003  
Soc = 0.4239 B = 1.3315e-004  
Voffset = -0.7060 C = -1.9051e-008  
Tau20 = 1.56 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 OX (ml/l)	BATH TEMP (ITS-90)	BATH SAL (PSU)	INSTRUMENT OUTPUT (VOLTS)	INSTRUMENT OXYGEN (ml/l)	RESIDUAL (ml/l)
1.27	2.00	0.00	1.018	1.27	-0.00
1.28	6.00	0.00	1.057	1.27	-0.00
1.29	12.00	0.00	1.123	1.29	-0.00
1.30	26.00	0.00	1.272	1.30	0.00
1.30	30.00	0.00	1.319	1.31	0.01
1.31	20.00	0.00	1.213	1.31	0.00
4.06	12.00	0.00	2.016	4.06	-0.00
4.07	20.00	0.00	2.277	4.07	-0.00
4.07	6.00	0.00	1.831	4.08	0.00
4.08	2.00	0.00	1.708	4.08	0.00
4.11	26.00	0.00	2.492	4.11	0.00
4.14	30.00	0.00	2.646	4.14	-0.00
6.81	6.00	0.00	2.585	6.81	-0.00
6.83	2.00	0.00	2.382	6.83	-0.00
6.84	12.00	0.00	2.915	6.85	0.00
6.87	20.00	0.00	3.360	6.87	-0.00
6.94	26.00	0.00	3.724	6.94	0.00
6.96	30.00	0.00	3.967	6.96	-0.00

Oxygen (ml/l) = Soc \* (V + Voffset) \* (1.0 + A \* T + B \* T<sup>2</sup> + C \* T<sup>3</sup>) \* OxSol(T,S) \* exp(E \* P / K)  
V = voltage output from SBE43, T = temperature [deg C], S = salinity [PSU], K = temperature [deg K]  
OxSol(T,S) = oxygen saturation [ml/l], P = pressure [dbar]  
Residual = instrument oxygen - bath oxygen



## Fluorometer

PO Box 518  
620 Applegate St.  
Philomath, OR 97370



(541) 929-5650  
Fax (541) 929-5277  
[www.wetlabs.com](http://www.wetlabs.com)

## ECO Chlorophyll Fluorometer Characterization Sheet

Date: 2/23/2015

S/N: FLRTD-397

Chlorophyll concentration expressed in  $\mu\text{g/l}$  can be derived using the equation:

$$\text{CHL } (\mu\text{g/l}) = \text{Scale Factor} * (\text{Output} - \text{Dark Counts})$$

	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)	8	13	28 $\mu\text{g/V}$	0.0078 $\mu\text{g/l/count}$
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:  $\text{SF} = x \div (\text{output} - \text{dark counts})$ , 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

<b>Calibration Date:</b> 02/03/14				<b>Job No.:</b> R-11319					
<b>Model Number:</b> QSP200L4S									
<b>Serial Number:</b> 4469									
<b>Operator:</b> TPC									
<b>Standard Lamp:</b> V-032(3/7/12)									
<b>Operating Voltage Range:</b> 6 to 15 VDC (+)									
Note: The QSP200L4S uses a log amplifier to measure the detector signal current with $V = \log I (\text{Amps}) / I_{\text{Ref}}$ To calculate irradiance, use this formula:									
<b>Irradiance = Calibration factor * (10<sup>A</sup>Light Signal Voltage - 10<sup>A</sup>Dark Voltage)</b>									
With the appropriate (solar corrected) Irradiance Calibration Factor:									
<b>Dry Calibration Factor:</b> 4.74E+12 quanta/cm <sup>2</sup> ·sec/"amps"				7.87E-06 $\mu$ Einsteins/cm <sup>2</sup> ·sec/"amps"					
<b>Wet Calibration Factor:</b> 8.37E+12 quanta/cm <sup>2</sup> ·sec/"amps"				1.39E-05 $\mu$ Einsteins/cm <sup>2</sup> ·sec/"amps"					
<b>Sensor Test Data and Results<sup>4)</sup></b>									
<b>Sensor Supply Current (Dark):</b>		60.9	mA						
<b>Supply Voltage:</b>		6	Volts						
<b>Lamp Integrated PAR Irradiance:</b>		9.26E+15	quanta/cm <sup>2</sup> ·sec	0.01538	$\mu$ Einsteins/cm <sup>2</sup> ·sec				
<b>SC3 Immersion Coefficient:</b>		0.5664	<b>Scalar Correction:</b>		1	<b>PAR Solar Correction:</b> 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/cm <sup>2</sup> ·sec)
No Filter	100.00%	3.292	100.00%	1.98E-07	1.98E-07	3.292	0.000	0.0	9.26E+15
0.3	36.10%	2.849	36.05%	7.05E-08	7.06E-08	2.850	0.001	0.1	3.34E+15
0.5	27.60%	2.728	27.25%	5.33E-08	5.40E-08	2.734	0.006	1.3	2.52E+15
1	9.27%	2.270	9.45%	1.65E-08	1.81E-08	2.262	-0.008	-1.9	8.76E+14
2	1.11%	1.373	1.14%	2.22E-09	2.17E-09	1.364	-0.009	-2.3	1.05E+14
3	0.05%	0.458	0.08%	1.49E-10	1.04E-10	0.385	-0.073	-30.0	7.06E+12
<b>Dark Before:</b>		0.140	Volts						
<b>Light - No Filter Hldr.:</b>		3.291	Volts	$I_{\text{Ref}} = 1.00\text{E-}10$ Amps					
<b>Dark After - NFH:</b>		0.140	Volts	$I_{\text{Dark}} = 1.38\text{E-}10$ Amps		RG780		1.01	
<b>Average Dark:</b>		0.140	Volts	$10^{I_{\text{Dark}}} = 1.380088$ Amps					
<b>Notes:</b> 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-QSP230C (4-2013- ) xls

## Pressure Sensor



**SEA-BIRD ELECTRONICS, INC.**  
 13431 NE 20<sup>th</sup> St, Bellevue Washington 98005 USA  
 Phone: (425) 643-9866 Fax: (425) 643-9954 Email: seabird@seabird.com

**Digiquartz Pressure Calibration dP/dT Corrected Coefficients**  
*(Changed coefficients are posted in italics)*

Pressure Transducer Serial Number: 130016  
 Original Calibration Date: 2013-12-23  
 Date of Correction: 2014-06-09  
 Installed in: SBE 9Plus S/N 1190

**PRESSURE COEFFICIENTS**

*C1*   *-40856.42*                      *psia*  
*C2*   *-6.8584644e-01*            *psia/deg C*  
*C3*   *1.2613e-02*                   *psia/deg C<sup>2</sup>*

D1   0.035242  
 D2   0.0

*T1*   *30.1865*                        *μsec*  
*T2*   *-5.300152e-04*                *μsec/deg C*  
*T3*   *4.0491e-06*                    *μsec/deg C<sup>2</sup>*  
*T4*   *3.10496e-09*                *μsec/deg C<sup>3</sup>*  
*T5*   *0e+00*

AD590M = 0.0128082  
 AD590B = -8.80033622  
 Slope = 1.0  
 Offset = 0.0

Corrected at Sea-Bird Electronics as per Paroscientific Calibration and Sea-Bird Electronics dP/dT tests. The original calibration from Paroscientific assumes an operating temperature range of 0 to 125 degrees C. dP/dT correction adjusts this operating range to a nominal range of 0 to 22 degrees C. This increases the accuracy of the transducer in this temperature range.

NOTE: Original coefficients from Paroscientific are attached to this form for informational purposes and should not be used.

CALIBRATION COEFFICIENTS		SERIAL NO : 130016	
PRESSURE TRANSDUCER		DATE : 12-20-2013	
MODEL :	PRESSURE RANGE :	TEMP. RANGE :	PORT :
410K-134	0 to 10000 psia	0 to 125 deg C	

**TEMPERATURE COEFFICIENTS**

X = temperature period  
( $\mu\text{sec}$ )

$$U = X - U_0$$

Temperature : (deg C)

$$\text{Temp} = Y_1 U + Y_2 U^2 + Y_3 U^3$$

$U_0$	5.826575	$\mu\text{sec}$
$Y_1$	-3904.181	deg C/ $\mu\text{sec}$
$Y_2$	-9965.538	deg C/ $\mu\text{sec}^2$
$Y_3$	0	

**PRESSURE COEFFICIENTS**

T = pressure period  
( $\mu\text{sec}$ )

$$C = C_1 + C_2 U + C_3 U^2$$

$$D = D_1 + D_2 U$$

$$T_0 = T_1 + T_2 U + T_3 U^2 + T_4 U^3 + T_5 U^4$$

Pressure : (psia)

$$P = C \left(1 - \frac{T_0^2}{T^2}\right) \left(1 - D \left(1 - \frac{T_0^2}{T^2}\right)\right)$$

$C_1$	-40855.91	psia
$C_2$	2012.569	psia/ $\mu\text{sec}$
$C_3$	149152.2	psia/ $\mu\text{sec}^2$

$D_1$	0.035227
$D_2$	0

$T_1$	30.18714	$\mu\text{sec}$
$T_2$	2.054575	$\mu\text{sec}/\mu\text{sec}$
$T_3$	66.67620	$\mu\text{sec}/\mu\text{sec}^2$
$T_4$	161.0770	$\mu\text{sec}/\mu\text{sec}^3$
$T_5$	0	

(12-20-2013)

**PAROSCIENTIFIC, INC.**  
4500 148th AVENUE N.E.  
REDMOND, WA. 98052

CUSTOMER : SEABIRD ELECTRONICS, INC.

SALES ORDER : 31634

PREPARED BY : RM



<b>CALIBRATION COEFFICIENTS</b>		<b>SERIAL NO : 130016</b>	
<b>PRESSURE TRANSDUCER</b>		<b>DATE : 12-20-2013</b>	
<b>MODEL :</b> 410K-134	<b>PRESSURE RANGE :</b> 0 to 10000 psia	<b>TEMP. RANGE :</b> 0 to 125 deg C	<b>PORT :</b>

**PRESSURE COEFFICIENTS AT FIXED TEMPERATURE**

(only valid at specified temperature)

T = pressure period (μsec)

Pressure equation : (psia)

$$P = C \left( 1 - \frac{T_0^2}{T^2} \right) \left( 1 - D \left( 1 - \frac{T_0^2}{T^2} \right) \right)$$

Temperature: 21.0 C

C (psia)	-40862.45				
D	0.035227				
T <sub>0</sub> (μsec)	30.17789				

(12-20-2013)

**PAROSCIENTIFIC, INC.**4500 148th AVENUE N.E.  
REDMOND, WA. 98052**CUSTOMER : SEABIRD ELECTRONICS, INC.****SALES ORDER : 31634****PREPARED BY : RM**

## 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: 5730  
CALIBRATION DATE: 17-Mar-15SBE 3 TEMPERATURE CALIBRATION DATA  
ITS-90 TEMPERATURE SCALE

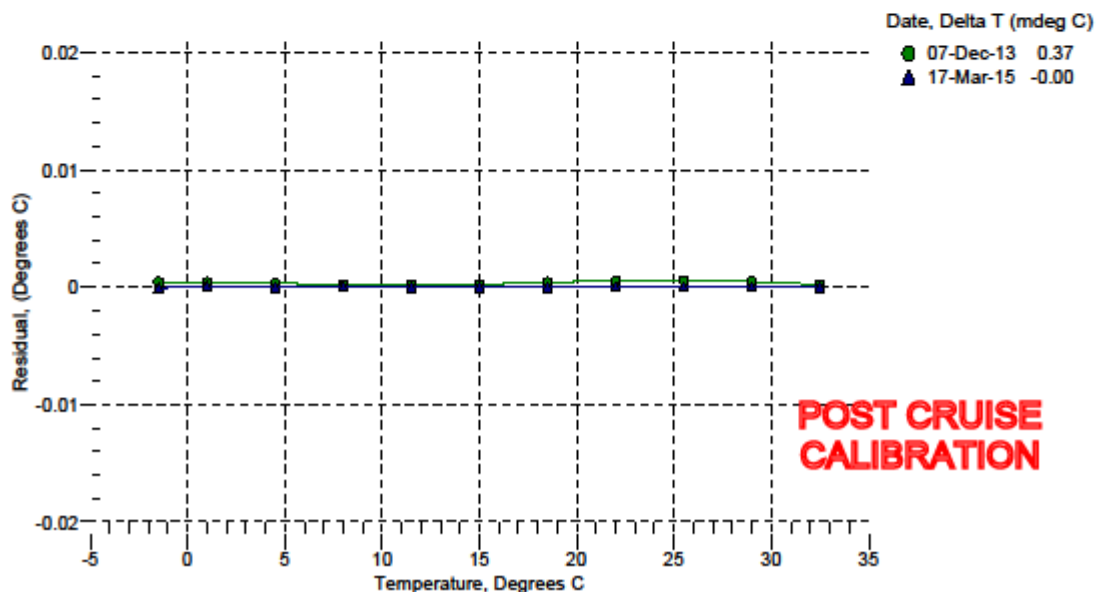
## ITS-90 COEFFICIENTS:

$g = 4.35191731e-003$   
 $h = 6.29805645e-004$   
 $i = 1.97444686e-005$   
 $j = 1.43261949e-006$   
 $f_0 = 1000.0$

BATH TEMP (ITS-90)	INSTRUMENT FREQ (Hz)	INST TEMP (ITS-90)	RESIDUAL (ITS-90)
-1.5000	3003.693	-1.5001	-0.00006
0.9999	3179.332	1.0000	0.00009
4.5000	3437.598	4.5000	-0.00001
7.9999	3710.693	7.9999	0.00001
11.4999	3999.052	11.4999	-0.00004
14.9999	4303.099	14.9999	-0.00002
18.5000	4623.248	18.5000	-0.00002
22.0000	4959.885	22.0000	0.00002
25.5000	5313.406	25.5000	0.00004
29.0000	5684.184	29.0000	0.00000
32.4999	6072.584	32.4999	-0.00002

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

Residual = 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: 1649  
CALIBRATION DATE: 20-Feb-15SBE 3 TEMPERATURE CALIBRATION DATA  
ITS-90 TEMPERATURE SCALE

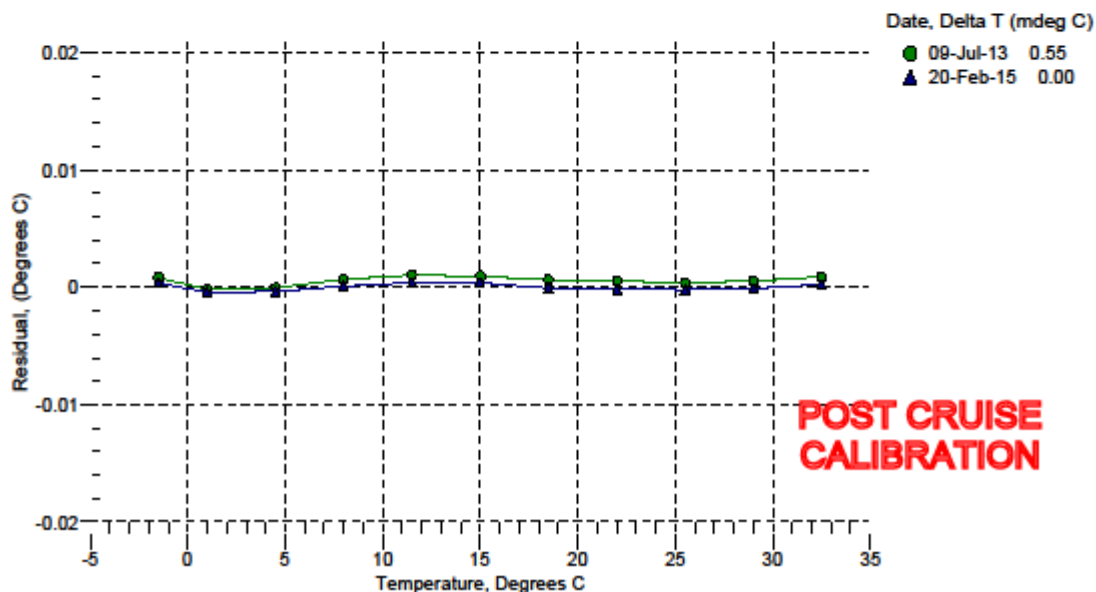
## ITS-90 COEFFICIENTS:

$g = 4.80781420e-003$   
 $h = 6.65997173e-004$   
 $i = 2.22259275e-005$   
 $j = 1.52821861e-006$   
 $f_0 = 1000.0$

BATH TEMP (ITS-90)	INSTRUMENT FREQ (Hz)	INST TEMP (ITS-90)	RESIDUAL (ITS-90)
-1.5000	5958.910	-1.4996	0.00040
1.0000	6301.407	0.9996	-0.00043
4.5000	6804.487	4.4996	-0.00037
8.0000	7335.629	8.0001	0.00006
11.4999	7895.486	11.5003	0.00038
14.9999	8484.765	15.0003	0.00035
18.5000	9104.144	18.4999	-0.00009
22.0000	9754.398	21.9998	-0.00017
25.5000	10436.142	25.4998	-0.00022
29.0000	11150.029	28.9999	-0.00013
32.4999	11896.671	32.5001	0.00023

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

Residual = instrument temperature - bath temperature



## Transmissometer

PO Box 518 620 Applegate St. Philomath, OR 97370	<b>WET Labs</b>	(541) 929-5850 Fax (541) 929-5277 <a href="http://www.wetlabs.com">www.wetlabs.com</a>
<b>C-Star Calibration</b>		
Date <b>May 23, 2014</b>	S/N# <b>CST-439DR</b>	Pathlength <b>25cm</b>
<b>Analog output</b>		
$V_d$	<b>0.058 V</b>	
$V_{air}$	<b>4.773 V</b>	
$V_{ref}$	<b>4.674 V</b>	
Temperature of calibration water	<b>23.4 °C</b>	
Ambient temperature during calibration	<b>21.9 °C</b>	
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

