Transit

Data Report NBP1504

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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 compressed using UNIX "gzip," identified by the ".gz" extension. It has been copied to the distribution media in the UNIX tar archive format, ".tar" extension. Tools are available on all platforms for uncompressing and de-archiving these formats: On Macintosh, use Stuffit Expander with DropStuff. On Windows operating systems use WinZip.

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: NBP1504

File	Description

/	*Root level directory*
NBP1504trk	*Text file of cruise track (*
NBP1504.mgd	*Full Cruise MGD77 data file*
NBP1504.gmt	*GMT binary file of MGD77 data*
INSTCOEF.TXT	*Instrument Coefficient File*
1504DATA.docx	*Data Report NBP1504 (MS Word)*
1504DATA.pdf	*Data Report NBP1504 (PDF format)*
/plots	*Cruise Tracks*
nbp1504-track.jpg	*jpeg format*
nbp1504-track.pdf	*pdf format*
nbp1504-track.ps	*postscript format*
/process	*Processed data*
1504JGOF.tz	*JGOFS format data files*
1504QC.tz	*Daily RVDAS QC postcript plots*
1504PCO2.tz	*Merged pCO2 data files*
1504MGD.tz	*MGD Data*
1504PROC.tz	*Other processed data*
/rvdas/nav	*Navigation data*
1504gyr1.tz	*Gyro raw data*
1504PCOD.tz	*Trimble P-code raw data*
1504seap.tz	*Seapath 200 data*
1504s330.tz	*Seapath 330 data*
/rvdas/uw	*Underway data*
1504flr1.tz	*Flourometer data*
1504eng1.tz	*Engineering data*
1504grv1.tz	*Gravimeter data*
1504hdas.tz	*HydroDAS raw data*
1504knud.tz	*Knudsen raw data*
1504mwx1.tz	*Meteorology raw data*
1504pco2.tz	*pCO_2 raw data*
1504pguv.tz	*GUV raw data*
1504rtmp.tz	*Remote Temperature data*
1504svp1.tz	*Sound velocity probe (ADCP)*
1504tsg1.tz	*Micro TSG1 data*
1504tsg2.tz	*Micro TSG2 data*
/Imagery	*Satellite Imagery*
1504Imagery.tz	*Collection of Imagery Files*

Extracting Data

The UNIX tar command has many options. It is often useful to know exactly how an archive was produced when expanding its contents. All archives are gzipped tar files and were created using the command,

```
tar -czvf archive_filename files_to_archive
```

To create a list of the files in the archive, use the UNIX command,

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

Where `contents.list` is the name of the file to create

To extract the files from the archive:

```
tar -xvf  archive_filename file(s)_to_extract
```

G-zipped files will have a ".tz" extension on the filename. ".tz" stands for tared and gziped. These files can be decompressed after de-archiving, using the UNIX command,

```
gunzip filename.tz
```

Distribution Contents

Cruise Track

The distribution DVD includes a GMT cruise track file (NBP1504.trk). It contains the longitude and latitude at one-minute intervals extracted from the NBP1504.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 1504proc.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/NBP1504JGOF.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.

```
03/04/15 00:00:00 -61.5761 131.9662 10.05 0.70 181.39 180.12 255.82 2.258 3.02 33.767 4560 10.39
277.03 0.82 90.94 975.47 0.92 86.83 46.89 274.17
```

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/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 NBP1504.mgd. The file NBP1504.gmt is created from the MGD77 dataset using the “mgd77togmt” utility. NBP1504.gmt can be used with the GMT plotting package.

The data used to produce the NBP1504.mgd file can be found on the distribution media in the file /process/1504proc.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, 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 10^{th} of mgals. Corrected for Eotvos, drift, tares
98-103	6	real	EOTVOS correction	In 10^{th} of mgals. E=7.5 V cos phi sin alpha + 0.0042 V*V
104-108	5	real	Free-air anomaly	In 10^{th} 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 = Suspeced, 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 1504pco2.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 (if any) has been placed in the tar file /ocean/NBP1504ctd.tar. The archive contains tar files NBP1504proc.tar. No CTDs were deployed on this cruise.

XBT

If during the cruise, eXpendable BathyThermographs were used to obtain water column temperature profiles, providing corrections to the sound velocity profile for the multibeam system, then the data files from these launches are included as 1504xbt.tar in the /ocean directory. No XBTs were deployed 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: `NBP1504mwx1.d025`

- The CruiseID is the numeric name of the cruise, in this case, NBP1504.
- 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
Magnetometer	mag1	Continuous	1/sec	Marine Magnetics – SeaSPY Overhauser
Bathymetry	knud	Continuous	varies	Knudsen Chirp
Bathymetry	sim1	Continuous	varies	Simrad EK60 Sonar
Bathymetry	mbdp	Continuous	varies	Simrad 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 FLRTD
pCO_2	pco2	Continuous	0.017/ sec	LDEO instrumentation
ADCP	adcp	Continuous	1/sec	UHDAS

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, GPS	PCOD	Continuous	1/sec	Trimble Centurion 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 : = @. 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

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*

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

Trimble P-Code GPS (PCOD)

The Trimble GPS, which formerly output Precise Position (*P-Code*) strings, but now only outputs Standard Position (*Civilian*) strings, outputs five NMEA data strings – GPZDA, GPGGA, GPVTG, GPRMC, and GPGLL.

GPZDA

```
15+051:21:02:04.507 $GPZDA,210204.39,20,02,2015,0,0,*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	(empty field)	x	Blank or 0
9	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,0,*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	North or South (for pervious)	x	E or W
8	GPS quality indicator*	x	0,1,2,3,4,5, or 6
9	Number of satellites in use	xx	00-99
10	HDOP	x.x	numeric

11	Antenna height	x.xx	m
12	M = Meters (for previous	x	M
13	Geoidal height	x.xx	m
14	M = Meters (for pervious)	x	M
15	Age of DGPS corrections	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,*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 pervious)	x	M
7	Speed over Ground	x.x	Knots
8	N = knots (for previous)	x	N
9	Speed over Ground	x.x	km/h
10	K = km per hour (for previous)	x	K
11	Checksum	xx	alphanumeric

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,*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)	E or W	E or W
14	Checksum	xx	alphanumeric

Statuses

A = Valid, N = invalid position

GPGLL

```
15+051:21:02:21.674 $GPGLL,7712.9783,S,16741.2521,W,210220.627,A*3C
```

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	hhmmss.sss	UTC
8	Status	x	A or N
9	Checksum	xx	alphanumeric

Statuses

A = Valid, N = invalid position

Gyro Compass (gyr1)

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

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

ADCP Course (adcp) [Data collection OFFLINE for NBP1504]

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

Field	Data	Format	Unit
1	RVDAS time tag		
2	$PUHAW		

3	UVH		
4	Ship Speed relative to reference layer, east vector	x.xx	knots
5	Ship Speed relative to reference layer, north vector	x.xx	knots
6	Ship heading	x.xx	degrees

Processed Data /process/

pCO_2 – Merged

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

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

25	TSG2 Temperature	x.xx	C
26	TSG2 Salinity	xx.xx	PSU
27	TSG1 Temperature	x.xx	C
28	Sea Water Valve*	x	-1 or 0

pCO_2 time tag

ttt = fractional time of day

Flow Source

Equil = pCO_2 Measurement

Sea Water Valve

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

Calculations

PAR

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

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

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

PSP

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

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

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

PIR

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

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

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

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

Acquisition Problems and Events

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

Start	End	Description
		ADCP NBP150 is no longer operation, no ADCP data collected over RVDAS system.
132:03:36		Data collection begins. -52 50.308054, 176 29.158497
	148 10:23:32	Data collection ends. -41 38.038504, -78 37.351845

Appendix A: Sensors

NBP1504 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	01706	4/10/2014	
Temperature / Humidity	RM Young 41372LC	06720	6/3/2014	
PIR	Eppley PIR	32845F3	7/18/2013	
PSP	Eppley PSP	32850F3	8/7/2013	
PAR (Mast)	Biospherical Instruments QSR-240	6356	2/3/2014	
GUV (Mast)	Biospherical Instruments GUV-2511	25110203113	2/5/2014	

Sensor	Description	Serial	Last Cal Date	Comments
Underway Seawater Sampling System				
Micro-TSG	Sea-Bird SBE 45	4546167-0199	11/2/2013	
Micro-TSG	Sea-Bird SBE 45	4566350-0389	5/29/2014	
Digital Remote Temp	Sea-Bird SBE 38	3846730-0323	6/25/2013	
Transmissometer	WetLabs C-Star	CST-892DR	4/29/2014	
Fluorometer	WetLabs FLRTD	FLRTD-855	3/26/2014	

Sensor	Description	Serial	Last Cal Date	Comments
CTD				
Altimeter	Teledyne Benthos PSA-916	49432	NA	
Bottom Contact Switch	Sea-Bird	# 3	NA	
Carousel Water Sampler	Sea-Bird SBE 32	3270675-0925	NA	
Deck Unit	Sea-Bird SBE 11+	11P19858-0490	NA	

Dissolved Oxygen	Sea-Bird SBE 43	0152	7/11/2014	
Dissolved Oxygen	Sea-Bird SBE 43	2267	10/15/2014	
Conductivity	Sea-Bird 4M 6800m	042513	7/16/2014	
Conductivity	Sea-Bird 4M 6800m	044151	3/7/2014	
Fish	Sea-Bird SBE 9+	09P78915-1190	6/9/2014	
PAR	Biospherical Instruments QSP-200L4S	4469	2/3/2014	
Pressure Sensor	Sea-Bird SBE 9+	130016	6/9/2014	
Pump	Sea-Bird 5T, PN 90160	051646 3.0K	8/10/2014	
Pump	Sea-Bird 5T, PN 90543	055641 3.0K	3/31/2014	
Temperature	Sea-Bird 3+ 6800M	03P2438	1/7/2014	
Temperature	Sea-Bird 3F 6800M	03P5185	1/4/2014	
Transmissometer	WetLabs C-Star	CST-889DR	9/5/2013	

Appendix B: Calibration Sheets

Gravity

BGM3 ship-to-shore gravity tie report

S. Suman, vessel: R/V Palmer

Release Date: 2015/03/23 05:54:11 UTC

Sensor: S210
Software version: 1.2
Port/Pier/Berth: Macquarie Pier, Hobart, Tasmania

Gravity station number	lt_S210_20150322_040325
Station name	Macquarie Pier 220-230 bollard
mGal at pier	980438.04
Tie start time UTC	2015/03/23 04:53:37.914
Samples used	3600
Land tie used	Yes
Water height to pier 1	2 ft 9 in
Water height to pier 2	2 ft 1 in
Water height to pier 3	2 ft 4 in
Average of filtered counts	25022.726614333
Filter length	361
Scale factor	4.994070552
NEW BIAS	**855473**

Table 1: Gravity tie information

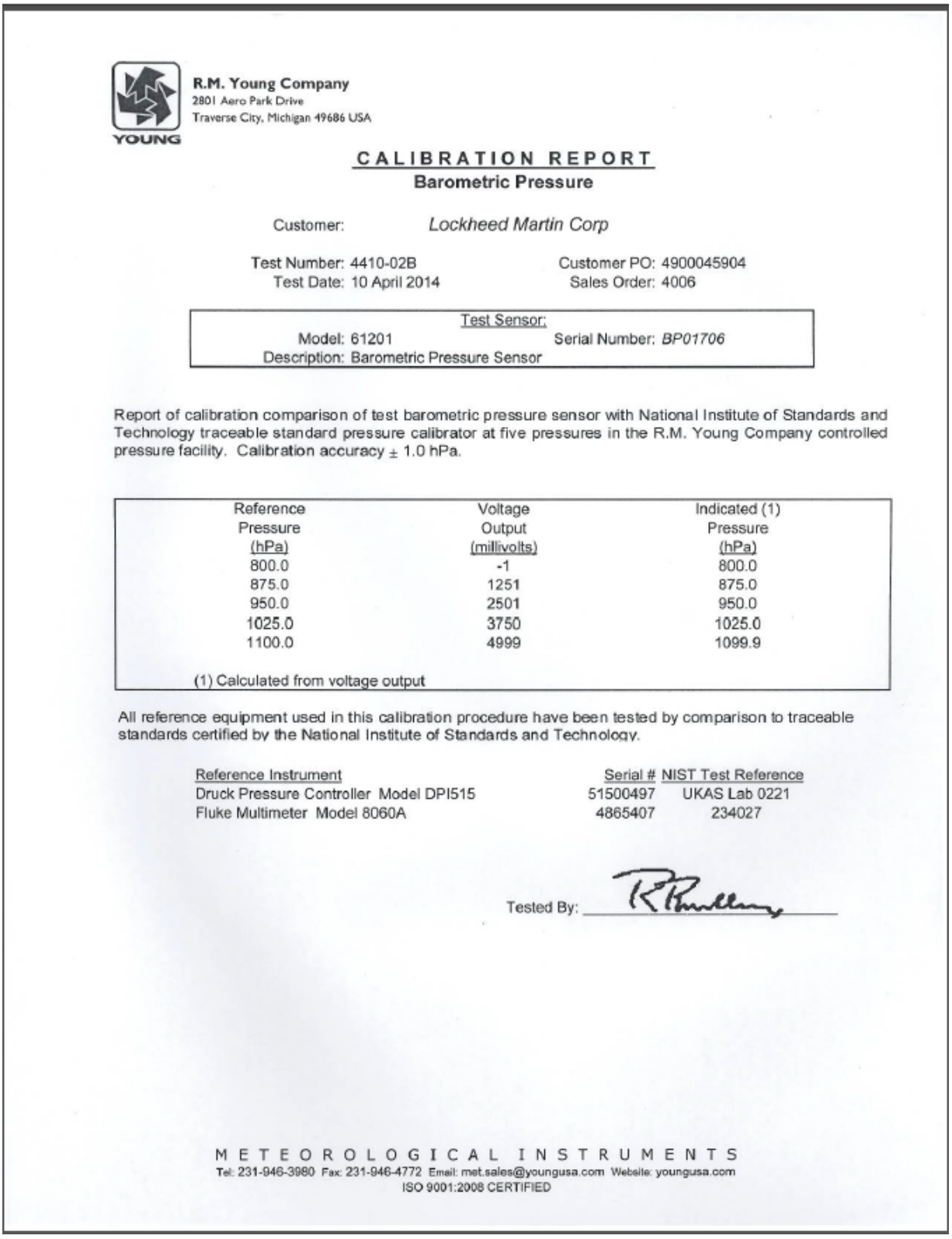
1

Meteorology

Anemometer(s)

No Calibration 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: 4410-02B
Test Date: 10 April 2014
Customer PO: 4900045904
Sales Order: 4006

Test Sensor:
Model: 61201
Serial Number: *BP01706*
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	-1	800.0
875.0	1251	875.0
950.0	2501	950.0
1025.0	3750	1025.0
1100.0	4999	1099.9

(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	UKAS Lab 0221
Fluke Multimeter Model 8060A	4865407	234027

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: 5120-07T
Test Date: 20 January 2015
Customer PO: 4101741493
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 ± 0.1° 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	Serial #	NIST Test Reference
Brooklyn Thermometer Model 43-FC	3006-1 0	W204690
Brooklyn Thermometer Model 22332-D5-FC	25071	W204691
Brooklyn Thermometer Mode 2X400-D7-FC	77532	W204692
Keithley Multimeter Model 191	15232	71248 5

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
YOUNG

CALIBRATION REPORT
Relative Humidity

Customer *Lockheed Martin Corp*

Test Number: 5120-07R
Test Date: 20 January 2015

Customer PO: 4101741493
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 ± 2.0 %.

Reference Humidity (%)	Current Output (milliamps)	Indicated (1) Humidity (%)
10.1	8.0	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	Serial #	NIST Test Reference
Vaisala Humidity Sensor Model 35AC	N475040	TN 266152
Agilent Multimeter Model 34405A	MY53020093	7124815

Tested By: R Rudloff

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

PIR

EPLAB

THE EPPLEY LABORATORY, INC.

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

STANDARDIZATION OF EPPLEY PRECISION INFRARED RADIOMETER Model PIR

Serial Number: 32845F3

Resistance: 712 Ω 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^{-2} and an average ambient temperature of 30°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:

4.08×10^{-6} 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^{-2}. This radiometer is linear to within ±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: LMP4 ISGS N.S.F.
Port Hueneme, CA

S.O. Number: 63850
Date: July 18, 2013

Remarks:

Date of Test: July 17, 2013

In Charge of Test: Debra L. Gentry

Reviewed by: Thomas J. Kucik

PSP

EPLAB

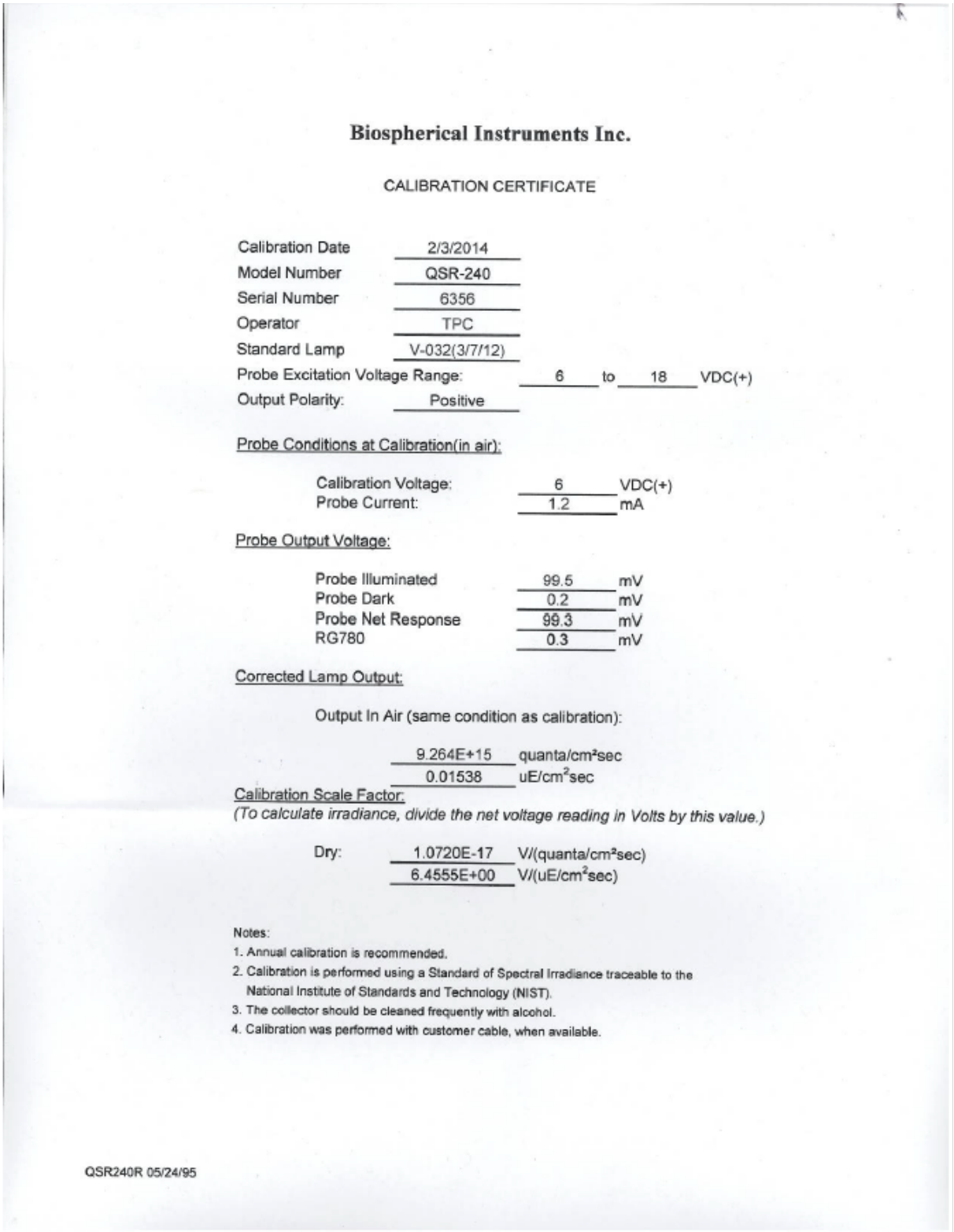
THE EPPLEY LABORATORY, INC.

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 Precision Spectral Pyranometer, Model PSP, Serial Number 21231F3
Results:	**Sensitivity:** **S = 7.68 µV / Wm^{-2}**
	Uncertainty: U_{95} = ±0.91% (95% confidence level, k=2)
	Resistance: 706 Ω at 23°C
	Date of Test: August 7, 2013
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:	LMP4 ISGS Port Hueneme, CA
Signatures:	D. GIENTY — In Charge of Test:
	Thomas D Kuh — Reviewed by:
Eppley SO	63884
Date of Certificate	August 15, 2013
Remarks:	

PAR (Mast)



Biospherical Instruments Inc.

CALIBRATION CERTIFICATE

Calibration Date	2/3/2014
Model Number	QSR-240
Serial Number	6356
Operator	TPC
Standard Lamp	V-032(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:	1.2 mA

Probe Output Voltage:

Probe Illuminated	99.5 mV
Probe Dark	0.2 mV
Probe Net Response	99.3 mV
RG780	0.3 mV

Corrected Lamp Output:

Output In Air (same condition as calibration):

9.264E+15	quanta/cm²sec
0.01538	uE/cm²sec

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

Dry: 1.0720E-17	V/(quanta/cm²sec)
6.4555E+00	V/(uE/cm²sec)

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

QSR240R 05/24/95

GUV (Mast)

Biospherical Instruments Inc.

System Calibration Certificate

THE INSTRUMENTS REFERENCED BELOW WERE FACTORY TESTED AND CALIBRATED BY

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

Instruments: GUV-2511 No 25110203113

Optical Calibrations:

NIST Traceability. For wavelengths longer than 313 nm, the specific instruments cited here were calibrated using a 1000W FEL #V-034 (3/7/12) following procedures and standards traceable to NIST Standard of Spectral Irradiance **F-616**. Traceability paths and all procedures for all calibrated lamps and associated apparatus (shunts, power supplies, DMMs, etc) are maintained following calibration methodologies per National Bureau of Standards (US) (NBS) Special Publication 250-20 Spectral Irradiance Calibrations (1987) and NBS Publication 594–13 Optical Radiation Measurements: The 1973 Scale of Spectral Irradiance (1977).

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

Note that this certificate contains a subset of the information delivered in the calibration database **25110203113v7.mdb**. This database is required for operation of this system using Biospherical Instruments Inc.'s Logger® software.

Biospherical Instruments Inc.

GUV-2511 Calibration Certificate

System Serial Number	25110203113	Date of Calibration	2/5/2014
Calibration database	25110203113v7.mdb	Date of Certificate	2/5/2014
DASSN	0068	Standard of Spectral Irradiance	V-034(3/7/12)
Microprocessor Tag Number	2	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	2.6356E-10	2.6883E-05	7.8542E-03	2.7807E+00	-6.0000E-06	-9.0000E-06	1.7200E-04	μW/(cm²nm)
Ed0340	6	340	2.1334E-10	2.1761E-05	6.3577E-03	2.2417E+00	3.0500E-04	3.0500E-04	1.1770E-03	μW/(cm²nm)
Ed0313	8	313	2.5014E-10	2.5515E-05	7.4543E-03	2.6611E+00	6.3000E-05	6.5000E-05	7.6700E-04	μW/(cm²nm)
Ed0305	10	305	1.6730E-11	1.7064E-06	4.9855E-04	1.5423E-01	3.5000E-04	3.3900E-04	-2.2550E-03	μW/(cm²nm)
Ed0380	12	380	6.5920E-11	6.7239E-06	1.9644E-03	6.5511E-01	1.0890E-03	1.0750E-03	-1.4790E-03	μW/(cm²nm)
Ed0395	18	395	3.4630E-10	3.5323E-05	1.0320E-02	3.3709E+00	6.8000E-05	6.3000E-05	2.1600E-04	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	1.8985E-05	1.9365E+00	5.6576E+02	2.0143E+05	8.5300E-04	8.4400E-04	-1.3230E-03	μE/(cm²sec)

Auxiliary Channels	Address	Wavelength	Responsivity	ScaleS	ScaleM	ScaleL	OffsetS	OffsetM	OffsetL	Measurement Units
Ed0Gnd	0	0	1	1.00	1.00	1.00	0	0	0	V
Ed0Temp	22	0	1	0.01	0.01	0.01	0	0	0	C
Ed0Vin	27	0	1	-0.25	-0.25	-0.25	0	0	0	V

Calibration Data – Do Not Destroy

page 2 of 2

Underway Seawater Sampling System

Micro-TSG 1

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

SENSOR SERIAL NUMBER: 0389
CALIBRATION DATE: 29-May-14

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

COEFFICIENTS:

```
g = -9.972006e-001          CPcor = -9.5700e-008
h =  1.453197e-001          CTcor =  3.2500e-006
i = -3.532467e-004          WBOTC =  1.2700e-007
j =  4.851413e-005
```

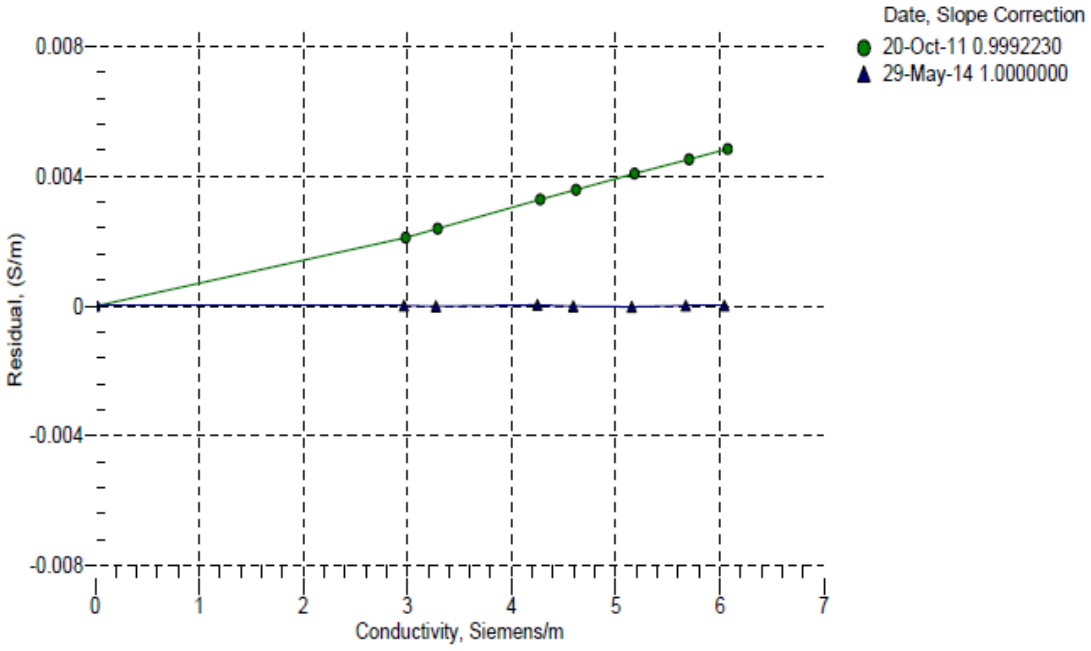
BATH TEMP (ITS-90)	BATH SAL (PSU)	BATH COND (Siemens/m)	INST FREQ (Hz)	INST COND (Siemens/m)	RESIDUAL (Siemens/m)
22.0000	0.0000	0.00000	2624.92	0.00000	0.00000
0.9998	34.6961	2.96665	5232.10	2.96665	0.00000
4.5057	34.6762	3.27332	5430.12	3.27330	-0.00001
15.0000	34.6345	4.25166	6017.72	4.25170	0.00003
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 = INST FREQ * sqrt(1.0 + WBOTC * t) / 1000.0

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

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

Residual = instrument conductivity - bath conductivity



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-14

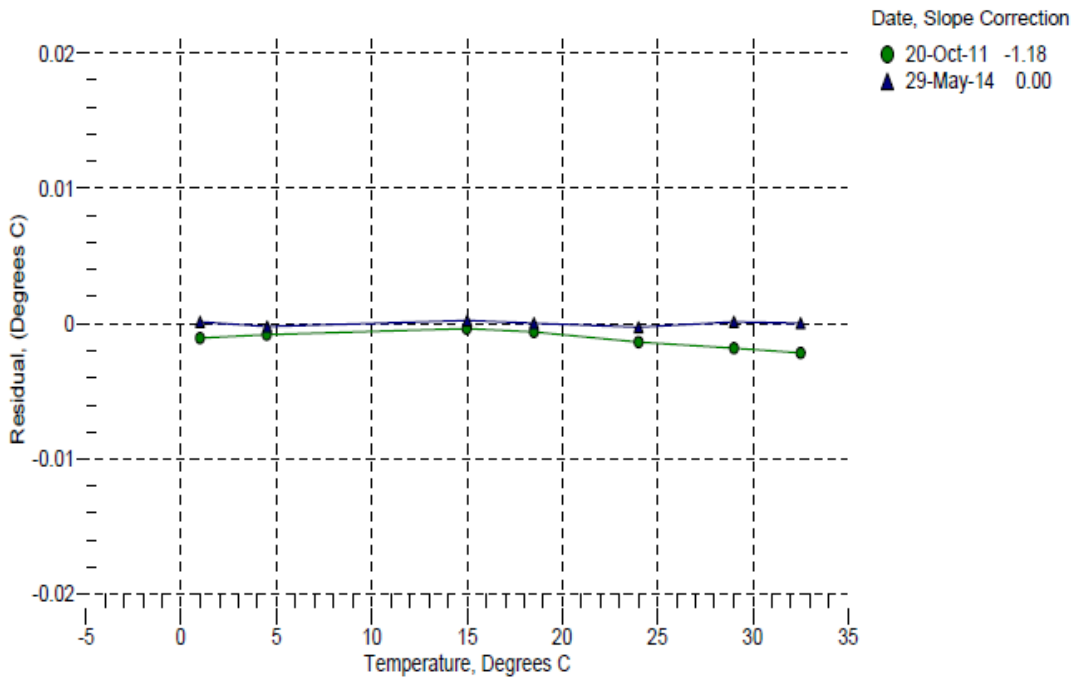
SBE 45 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

COEFFICIENTS:

a0 = -3.970068e-006
a1 = 2.742995e-004
a2 = -2.529944e-006
a3 = 1.515249e-007

BATH TEMP (ITS-90)	INSTRUMENT OUTPUT	INST TEMP (ITS-90)	RESIDUAL (ITS-90)
0.9998	828477.2	0.9999	0.0001
4.5057	706509.0	4.5055	-0.0002
15.0000	447322.3	15.0002	0.0002
18.5010	386479.8	18.5010	0.0000
24.0071	308941.3	24.0068	-0.0003
29.0000	253708.3	29.0001	0.0001
32.5000	221731.4	32.5000	0.0000

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



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: 0199
CALIBRATION DATE: 02-Nov-13

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

COEFFICIENTS:

```
g = -1.002257e+000          CPcor = -9.5700e-008
h =  1.426088e-001          CTcor =  3.2500e-006
i = -1.618469e-004          WBOTC = -1.0552e-005
j =  3.383846e-005
```

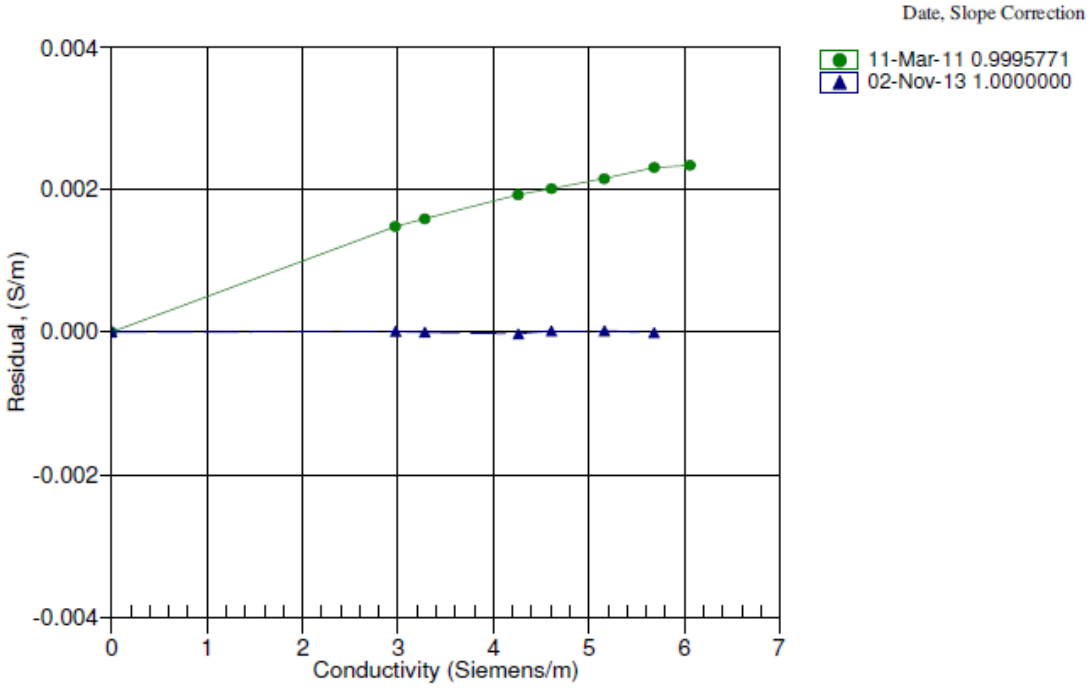
BATH TEMP (ITS-90)	BATH SAL (PSU)	BATH COND (Siemens/m)	INST FREO (Hz)	INST COND (Siemens/m)	RESIDUAL (Siemens/m)
22.0000	0.0000	0.00000	2653.13	0.00000	0.00000
1.0000	34.7663	2.97210	5277.51	2.97211	0.00001
4.5000	34.7462	3.27876	5476.68	3.27876	-0.00000
15.0000	34.7026	4.25914	6069.01	4.25911	-0.00003
18.5000	34.6921	4.60367	6263.64	4.60368	0.00001
24.0000	34.6804	5.16064	6565.79	5.16066	0.00002
29.0000	34.6720	5.68134	6835.87	5.68133	-0.00001

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

Conductivity = $(g + hf^2 + if^3 + jf^4) / (1 + \delta t + \varepsilon p)$ Siemens/meter

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

Residual = instrument conductivity - bath conductivity



Sea-Bird Electronics, Inc.
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: 02-Nov-13

SBE 45 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

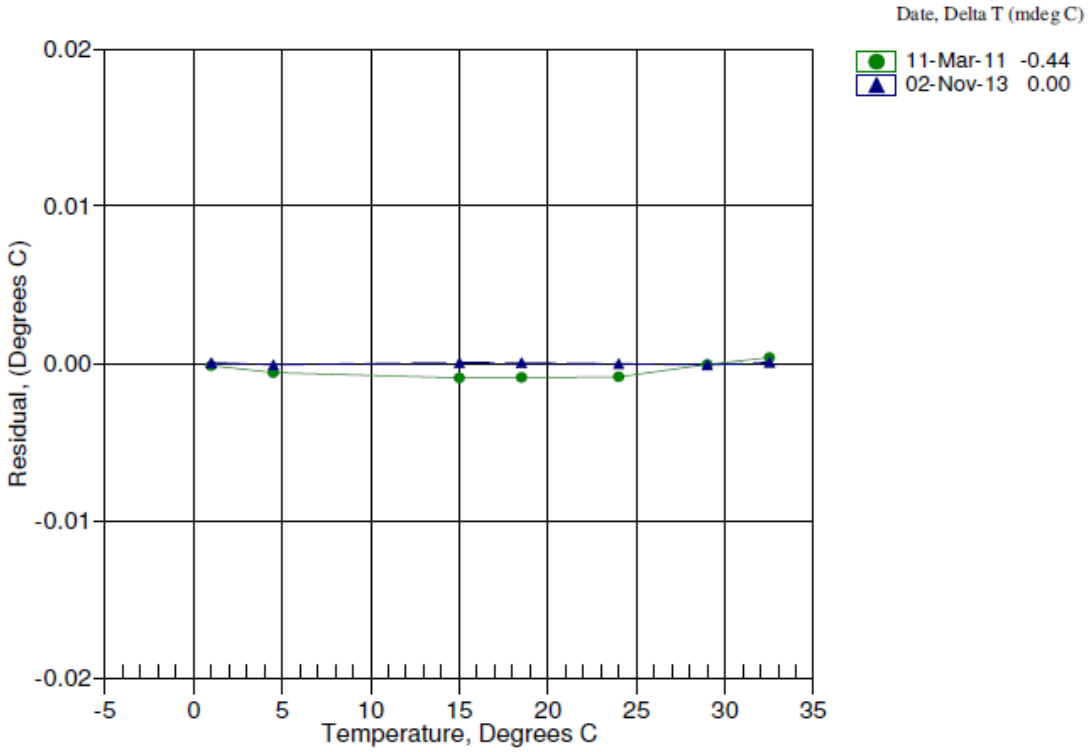
ITS-90 COEFFICIENTS

a0 = 1.853068e-005
a1 = 2.716266e-004
a2 = -2.093146e-006
a3 = 1.483856e-007

BATH TEMP (ITS-90)	INSTRUMENT OUTPUT	INST TEMP (ITS-90)	RESIDUAL (ITS-90)
1.0000	678395.6	1.0000	0.0000
4.5000	580509.7	4.4999	-0.0001
15.0000	370800.2	15.0001	0.0001
18.5000	321296.5	18.5000	0.0000
24.0000	258018.8	24.0000	-0.0000
29.0000	212643.2	28.9999	-0.0001
32.5000	186322.1	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



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:	74186	Date of Report:	6/25/2013
Model Number	SBE 38	Serial Number:	3846167-0323

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: 6/18/2013 **Drift since last cal:** -0.00019 **Degrees Celsius/year**

Comments:

'FINAL CALIBRATION' ☑ Performed ☐ Not Performed

Date: 6/25/2013 **Drift since 18 May 10** -0.00019 **Degrees Celsius/year**

Comments:
Added wet-pluggable type connector.

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: 0323
CALIBRATION DATE: 25-Jun-13

SBE 38 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

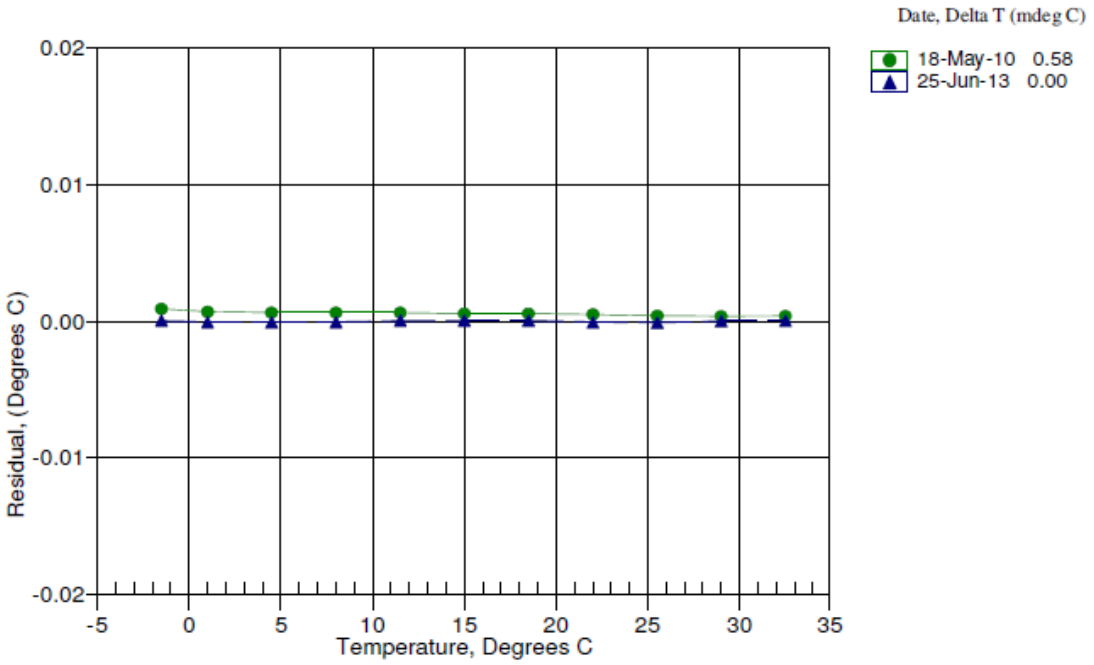
ITS-90 COEFFICIENTS

a0 = 2.640178e-006
a1 = 2.777731e-004
a2 = -2.536115e-006
a3 = 1.619290e-007

BATH TEMP (ITS-90)	INSTRUMENT OUTPUT	INST TEMP (ITS-90)	RESIDUAL (ITS-90)
-1.50000	711105.7	-1.49995	0.00005
1.00000	635152.2	0.99996	-0.00004
4.50000	543801.8	4.49995	-0.00005
8.00000	467106.8	7.99996	-0.00004
11.50000	402497.3	11.50005	0.00005
15.00000	347892.2	15.00006	0.00006
18.50000	301593.7	18.50006	0.00006
22.00000	262217.2	21.99995	-0.00005
25.50000	228624.6	25.49990	-0.00010
29.00010	199880.5	29.00012	0.00002
32.49990	175219.4	32.49993	0.00003

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

Residual = instrument temperature - bath temperature



Transmissometer

PO Box 518
620 Applegate St.
Philomath, OR 97370

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

WET Labs

C-Star Calibration

Date 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
www.wetlabs.com

WET Labs

ECO Chlorophyll Fluorometer Characterization Sheet

Date: 3/26/2014 S/N: FLRTD-855

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

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

	Analog Range 1	Analog Range 2	Analog Range 4 (default)		Digital	
Dark Counts	0.116	0.073	0.050	V	71	counts
Scale Factor (SF)	6	13	26	µg/l/V	0.0078	µg/l/count
Maximum Output	4.97	4.97	4.97	V	16326	counts
Resolution	0.8	0.8	0.8	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-855 Revision J 3/17/08

CTD

Conductivity

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:	78995	Date of Report:	7/17/2014
Model Number	SBE 04M	Serial Number:	042513

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: 7/9/2014 **Drift since last cal:** 0.0000 **PSU/month**

Comments:

'FINAL CALIBRATION' ☑ Performed ☐ Not Performed

Date: 7/16/2014 **Drift since 26 Jun 13** -0.00010 **PSU/month**

Comments:
The connector was upgraded to wet-pluggable style.

**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.

Conductivity

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:	77298	Date of Report:	3/7/2014
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: 3/7/2014 **Drift since last cal:** -0.00030 **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.

Fish

SEA-BIRD ELECTRONICS, INC.
13431 NE 20th 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^2
D1	0.035242	
D2	0.0	
T1	***30.1865***	***µsec***
T2	***-5.300152e-04***	***µsec/deg C***
T3	4.0491e-06	µsec/deg C^2
T4	3.10496e-09	µsec/deg C^3
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.

Pressure Sensor

Sea-Bird Electronics, Inc.
13431 NE 20th St. Bellevue, Washington 98005 USA
Website: http://www.seabird.com

Phone: (425) 643-9866
FAX: (425) 643-9954
Email: seabird@seabird.com

SBE Pressure Test Certificate

Test Date: 6/2/2014 Description SBE-9plus CTD

SBE Sensor Information:

Model Number: 09
Serial Number: 1190

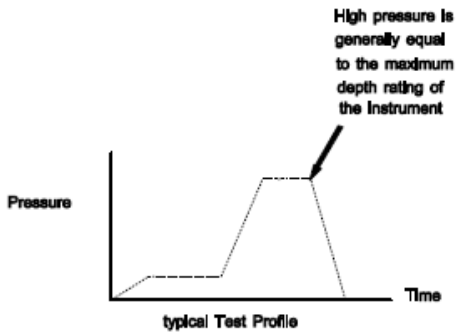
Pressure Test Protocol:

Low Pressure Test: 40 PSI Held For 15 Minutes

High Pressure Test: 10000 PSI Held For 15 Minutes

Passed Test: ☑

Tested By: nd



Dissolved Oxygen

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: 0152
CALIBRATION DATE: 05-Jan-14

SBE 43 OXYGEN CALIBRATION DATA

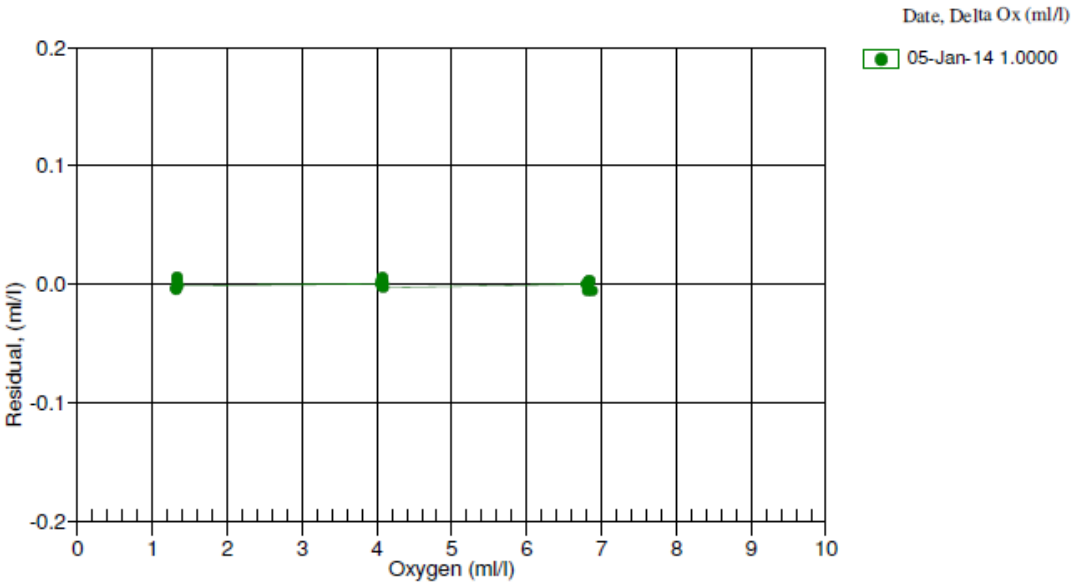
COEFFICIENTS
Soc = 0.4378
Voffset = -0.4894
Tau20 = 1.10
A = -2.9087e-003
B = 1.6797e-004
C = -2.7053e-006
E nominal = 0.036

NOMINAL DYNAMIC COEFFICIENTS
D1 = 1.92634e-4 H1 = -3.30000e-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)
1.31	6.00	0.00	0.837	1.31	-0.00
1.32	2.00	0.00	0.801	1.31	-0.00
1.33	26.00	0.00	1.032	1.34	0.00
1.33	30.00	0.00	1.073	1.34	0.01
1.34	20.00	0.00	0.976	1.34	0.00
1.34	12.00	0.00	0.902	1.34	-0.00
4.05	2.00	0.00	1.450	4.05	0.00
4.06	6.00	0.00	1.567	4.06	0.00
4.08	26.00	0.00	2.147	4.08	0.01
4.08	30.00	0.00	2.267	4.08	0.00
4.08	12.00	0.00	1.745	4.08	0.00
4.08	20.00	0.00	1.972	4.08	-0.00
6.79	2.00	0.00	2.101	6.79	0.00
6.81	30.00	0.00	3.456	6.81	-0.01
6.81	6.00	0.00	2.298	6.81	-0.00
6.83	12.00	0.00	2.591	6.83	0.00
6.84	26.00	0.00	3.269	6.84	0.00
6.87	20.00	0.00	2.986	6.87	-0.01

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

V = voltage output from SBE43, T = temperature [deg C], S = salinity [PSU], K = temperature [Kelvin]
OxSol(T,S) = oxygen saturation [ml/l], P = pressure [dbar], Residual = instrument oxygen - bath oxygen



Dissolved Oxygen

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: 2267
CALIBRATION DATE: 15-Oct-14

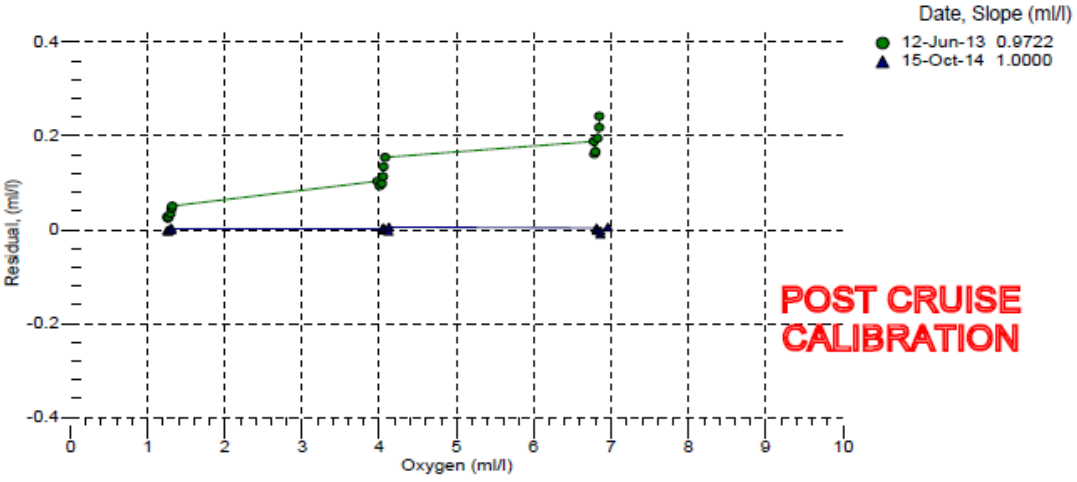
SBE 43 OXYGEN CALIBRATION DATA

COEFFICIENTS:
Soc = 0.5022
Voffset = -0.5217
Tau20 = 1.33
A = -3.9990e-003
B = 2.2855e-004
C = -4.1463e-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 OX (ml/l)	BATH TEMP (ITS-90)	BATH SAL (PSU)	INSTRUMENT OUTPUT (VOLTS)	INSTRUMENT OXYGEN (ml/l)	RESIDUAL (ml/l)
1.26	2.00	0.00	0.782	1.26	-0.00
1.26	6.00	0.00	0.815	1.26	-0.00
1.27	12.00	0.00	0.865	1.27	-0.00
1.29	20.00	0.00	0.934	1.29	-0.00
1.31	26.00	0.00	0.992	1.31	0.00
1.31	30.00	0.00	1.028	1.31	0.00
4.04	12.00	0.00	1.612	4.04	0.00
4.04	2.00	0.00	1.361	4.05	0.00
4.05	6.00	0.00	1.463	4.05	-0.00
4.06	20.00	0.00	1.823	4.07	0.00
4.11	30.00	0.00	2.111	4.11	-0.00
4.12	26.00	0.00	2.002	4.13	0.01
6.81	12.00	0.00	2.362	6.82	0.00
6.82	6.00	0.00	2.107	6.82	0.00
6.82	30.00	0.00	3.156	6.81	-0.00
6.86	20.00	0.00	2.712	6.85	-0.01
6.86	2.00	0.00	1.943	6.86	-0.00
6.96	26.00	0.00	3.019	6.96	0.01

Oxygen (ml/l) = Soc * (V + Voffset) * (1.0 + A * T + B * T^2 + C * T^3) * 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



Temperature

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:	74718	Date of Report:	1/7/2014
Model Number:	SBE 03Plus	Serial Number:	03P2438

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: 12/12/2013 **Drift since last cal:** +0.00019 **Degrees Celsius/year**

Comments:

'FINAL CALIBRATION' ☑ Performed ☐ Not Performed

Date: 1/7/2014 **Drift since 22 Aug 12** +0.00108 **Degrees Celsius/year**

Comments:
The connector was upgraded to wet-pluggable type.

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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: 2438
CALIBRATION DATE: 07-Jan-14

SBE3 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

ITS-90 COEFFICIENTS

g = 4.31118159e-003
h = 6.41557351e-004
i = 2.27593316e-005
j = 2.12780590e-006
f0 = 1000.0

IPTS-68 COEFFICIENTS

a = 3.68121215e-003
b = 6.02077452e-004
c = 1.63075948e-005
d = 2.12935680e-006
f0 = 2759.436

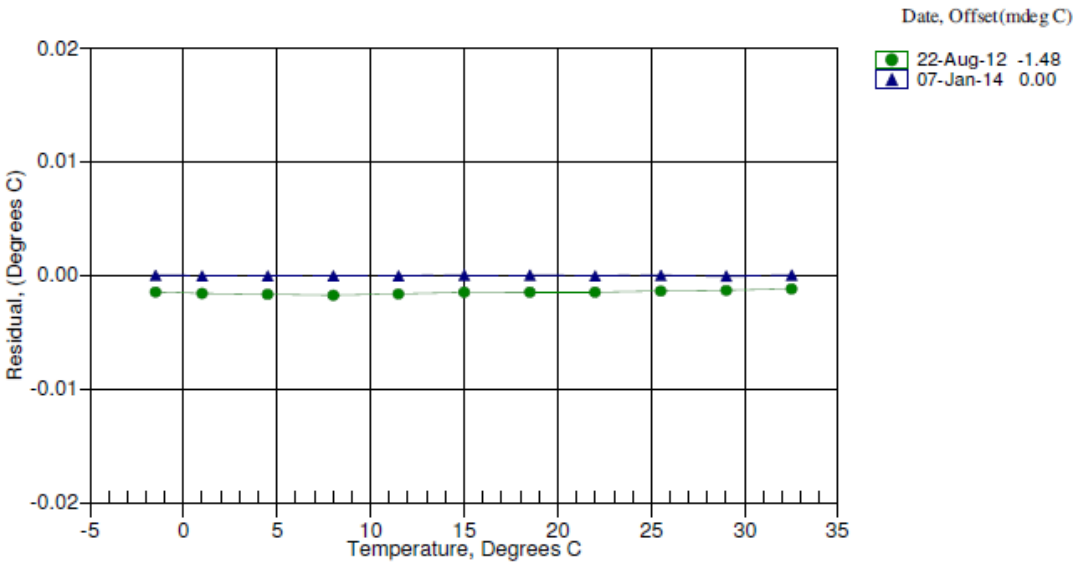
BATH TEMP (ITS-90)	INSTRUMENT FREQ (Hz)	INST TEMP (ITS-90)	RESIDUAL (ITS-90)
-1.5000	2759.436	-1.5000	0.00001
1.0000	2917.943	1.0000	-0.00001
4.5000	3150.787	4.5000	-0.00001
8.0000	3396.715	8.0000	-0.00000
11.5000	3656.079	11.5000	-0.00000
15.0000	3929.226	15.0000	0.00002
18.5000	4216.487	18.5000	0.00003
22.0000	4518.183	22.0000	-0.00001
25.5000	4834.634	25.5000	0.00000
29.0001	5166.139	29.0000	-0.00006
32.5000	5512.979	32.5000	0.00004

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)

Temperature IPTS-68 = $1/\{a + b[ln(f_0/f)] + c[ln^2(f_0/f)] + d[ln^3(f_0/f)]\} - 273.15$ (°C)

Following the recommendation of JPOTS: T_{68} is assumed to be 1.00024 * T_{90} (-2 to 35 °C)

Residual = instrument temperature - bath temperature



Temperature

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: 04-Jan-14

SBE3 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

ITS-90 COEFFICIENTS

g = 4.35781029e-003
h = 6.34972501e-004
i = 2.14137327e-005
j = 1.94871487e-006
f0 = 1000.0

IPTS-68 COEFFICIENTS

a = 3.68121254e-003
b = 5.95007463e-004
c = 1.49954616e-005
d = 1.95012647e-006
f0 = 3011.496

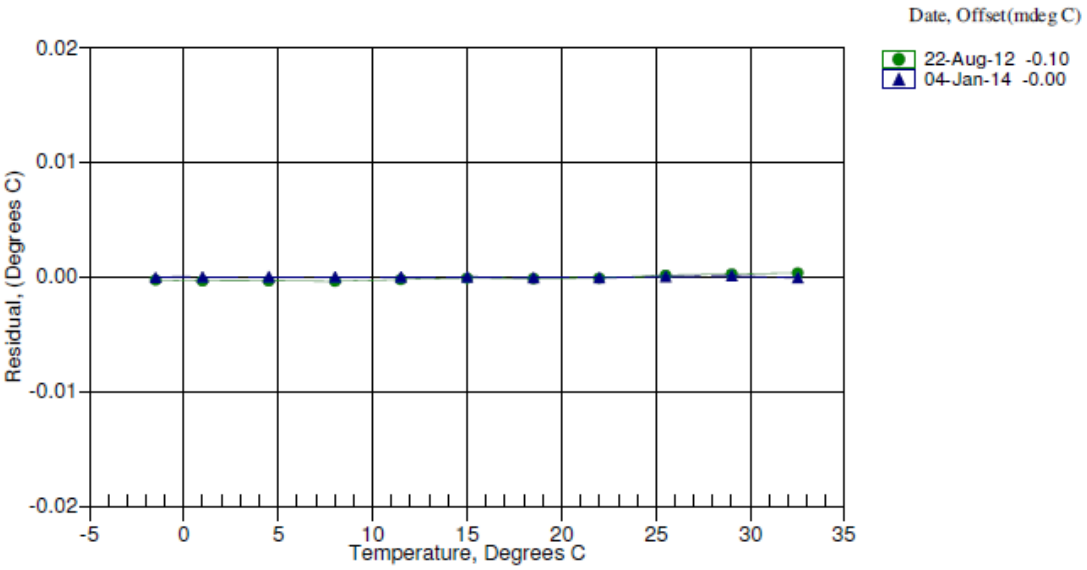
BATH TEMP (ITS-90)	INSTRUMENT FREQ (Hz)	INST TEMP (ITS-90)	RESIDUAL (ITS-90)
-1.5000	3011.496	-1.5000	-0.00002
1.0000	3186.583	1.0000	0.00001
4.5000	3443.927	4.5000	0.00003
8.0000	3715.900	8.0000	0.00000
11.5000	4002.910	11.5000	0.00001
15.0000	4305.346	15.0000	0.00001
18.5000	4623.583	18.4999	-0.00006
22.0000	4958.002	21.9999	-0.00006
25.5000	5308.966	25.5001	0.00006
29.0000	5676.798	29.0001	0.00010
32.5001	6061.822	32.5000	-0.00008

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)

Temperature IPTS-68 = $1/[a + b[ln(f_0/f)] + c[ln^2(f_0/f)] + d[ln^3(f_0/f)]] - 273.15$ (°C)

Following the recommendation of JPOTS: T_{68} is assumed to be 1.00024 * T_{90} (-2 to 35 °C)

Residual = instrument temperature - bath temperature



Transmissometer

PO Box 518
620 Applegate St.
Philomath, OR 97370

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

WET Labs

C-Star Calibration

Date September 5, 2013 S/N# CST-889DR Pathlength 25cm

	Analog output
V_d	0.060 V
V_{air}	4.726 V
V_{ref}	4.624 V

Temperature of calibration water	23.1 °C
Ambient temperature during calibration	21.2 °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