OOI Southern Ocean

Data Report NBP17-09

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Table of Contents

Introduction

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

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

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

All the data has been archived using 'tar' and compressed using 'gzip', identified by the '.tz' extension.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

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

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

Distribution Contents at a Glance

Volume 1 of 1: NBP17-09

File	Description
/	Root level directory
NBP17-09.gmt	GMT binary file of MGD77 data
NBP17-09.mgd	Full Cruise MGD77 data file
NBP17-09.trk	Text file of cruise track
NBP1709DATA.docx	Data Report NBP17-09 (MS Word)
NBP1709DATA.pdf	Data Report NBP17-09 (PDF format)
INSTCOEF.TXT	Instrument Coefficient File
NBP1709map.pdf	Cruise Track Map
NBP1709-study-area.pdf	Cruise Track of the Study Area
/process	Processed data
NBP1709JGOF.tz	JGOFS format data files
NBP1709MGD.tz	MGD Data
NBP1709PCO2.tz	Merged pCO2 data files
NBP1709PROC.tz	Other processed data
NBP1709QC.tz	Daily RVDAS QC postcript plots
/rvdas/nav	Navigation data
NBP1709adcp.tz	ADCP Data Sets
NBP1709gyr1.tz	Gyro raw data
NBP1709s330.tz	Seapath 330 data
NBP1709seap.tz	Seapath 200 data
/rvdas/uw	Underway data
NBP1709bwnc.tz	Baltic winch data
NBP1709ctdd.tz	CTD depth data
NBP1709eng1.tz	Engineering data
NBP1709grv1.tz	Gravimeter data
NBP1709hdas.tz	HydroDAS raw data
NBP1709knud.tz	Knudsen raw data
NBP1709mbdp.tz	Multi-beam depth
NBP1709mwx1.tz	Meteorology raw data
NBP1709pco2.tz	pCO_2 raw data
NBP1709pguv.tz	GUV raw data
NBP1709rtmp.tz	Remote Temperature data
NBP1709tsg1.tz	Micro TSG1 data
NBP1709tsg2.tz	Micro TSG2 data
NBP1709twnc.tz	Trawl winch data
/ocean	Ocean data
NBP1709ctd.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 (NBP17-09.trk). It contains the longitude and latitude at one-minute intervals extracted from the NBP17-09.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 NBP1709proc.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/NBP17-09JGOF.tar. The archive contains one file produced for each day named jgDDD.dat.gz, where DDD is the year-day the data was acquired. The ".gz" extension indicates that the individual files are compressed before archiving. Each daily file consists of 22 columnar fields in text format as described in the table below. The JGOFS data set is created from calibrated data decimated at one-minute intervals. Several fields are derived measurements from more than a single raw input. For example, Course Made Good (CMG) and Speed Over Ground (SOG) are calculated from gyro and GPS inputs. Daily plots during the cruise are produced from the JGOFS data set. Note: Null, unused, or unknown fields are indicated as "NAN" as 9999 in the JGOFS data.

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

MGD77

The MGD77 data set is contained in a single file for the entire cruise. It can be found in the top level of the distribution data structure as NBP17-09.mgd. The file NBP17-09.gmt is created from the MGD77 dataset using the “mgd77togmt” utility. NBP17-09.gmt can be used with the GMT plotting package.

The data used to produce the NBP17-09.mgd file can be found on the distribution media in the file /process/NBP1709proc.tar. The data files in the archive contain a day’s data and follow the naming convention Dddd.fnl.tz, where ddd is the year-day. These files follow a space-delimited columnar format that may be more accessible for some purposes. They contain data at one-second intervals rather than one minute and are individually “gzipped” to save space. Below is a detailed description of the MGD77 data set format. The other files in the archive contain interim processing files and are included to simplify possible reprocessing of the data using the RVDAS NBP processing scripts.

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

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

Science of Opportunity

ADCP

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

A data feed is sent from the ADCP system to RVDAS whenever a reference layer is acquired. This feed contains east and north vectors for ship's speed, relative to the reference layer, and ship's heading. Collected files (one per day) are archived in NBP1709adcp.tar in the directory /rvdas/nav.

pCO_2

The NBP carries a pCO2 measurement system from Lamont-Doherty Earth Observatory (LDEO). pCO2 data is recorded by RVDAS and transmitted to LDEO at the end of each cruise. You will find pCO2 data in a file named NBP1709pco2.tar in the /process directory, which contains the pCO2 instrument's data merged with GPS, meteorological and other oceanographic measurements. For more information contact Colm Sweeney (csweeney@ldeo.columbia.edu).

Cruise Science

CTD

The CTD data has been placed in the tar file /ocean/NBP17-09ctd.tar. The archive contains tar files NBP17-09proc.tar.

XBT

During a cruise, eXpendable BathyThermographs (XBTs) may have been used to obtain water column temperature profiles, providing corrections to the sound velocity profile for the multibeam system. The data files from those launches would be included as NBP1709xbt.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: `NBP17-09mwx1.d025`

- The CruiseID is the numeric name of the cruise, in this case, NBP17-09.
- The ChannelID is a 4-character code representing the system being logged. An example is "mwx1," the designation for meteorology.
- DDD is the day of year the data was collected

Underway Sensors

Meteorology and Radiometry

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

Geophysics

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

Oceanography

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

Navigational Instruments

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

Data

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

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

where

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

All times are reported in UTC.

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

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

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

Underway Data */rvdas/uw*

Meteorology (mwx1)

MET

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

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

PUS

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

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

Status

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

SUS

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

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

Status

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

Knudsen (knud)

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

Gravimeter (grv1)

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

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

Error Flag

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

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

pCO_2 (pco2)

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

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

pCO_2 time tag

ttt = fractional time of day

Flow Source

Equil = pCO_2 Measurement

Micro TSG (tsg1, tsg2)

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

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

Remote Temperature (rtmp)

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

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

GUV (pguv)

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

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

Engineering (eng1)

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

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

Altimeter

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

Transmissometer

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

Hydro DAS (hdas)

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

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

Sea Water Valve

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

Winch (bwnc, cwnc, twnc)

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

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

Multibeam (mbdp)

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

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

Fluorometer (flr1)

```
17+241:00:00:22.630 99/99/99      99:99:99      695    83     538
```

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

Navigational Data */rvdas/nav*

GPS (s330, seap, PCOD)

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

GPZDA

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

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

GPGGA

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

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

Quality

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

GPVTG

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

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

Modes

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

GPRMC

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

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

GPHDT

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

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

GPGLL

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

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

Status

A = Data Valid, V = Data not valid

Modes

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

GPDTM

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

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

Datum Codes

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

PSXN 20

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

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

Qualities

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

PSXN 22

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

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

PSXN 23

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

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

Gyro Compass (gyr1)

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

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

ADCP Course (adcp)

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

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

Processed Data */process*

pCO_2 – Merged

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

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

pCO_2 time tag

ttt = fractional time of day

Flow Source

Equil = pCO_2 Measurement

Sea Water Valve

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

Calculations

PAR

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

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

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

PSP

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

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

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

PIR

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

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

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

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

Acquisition Problems and Events

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

Start	End	Description
330:06:13:55		Data collection begins. 53 20.745512 S; 080 25.807305 W
330:19:12	330:19:19	Data collection stopped to clear non-functional data logger on RVDAS that was disabling the serial feed for the Garmin/pcode GPS
332:16:28	332:16:30	Data collection interrupted for a Moxa restart to reset serial port for Baltic winch
333:21:35	333:21:58	Data collection interrupted to reset displays. RVDAS control were being run from a displayer due to the water damage to discovery during the open period
	341:00:03:59	Data collection ends. 53 12.278896 S; 080 28.489832 W

Appendix A: Sensors

NBP17-09 Sensors

Sensor	Manufacturer	Model	Serial No.	Last Cal Date	Comments
Meteorology and Radiometry					
Anemometer	RM Young	5106	WM128975	10/27/2011	ECO/Bridge
Anemometer, U/S	Gill Instruments	1390-PK-062	847014	9/29/2010	Starboard Side
Anemometer, U/S	Gill Instruments	1390-PK-062	924057	11/18/2009	Port Side
Barometer	RM Young	61201	01705	1/22/2016	
Barometer	Vaisala	PTB210B	M2750443	7/13/2016	
Humidity/Wet Temp	RM Young	41382LC	06733	10/6/2016	
PAR for Mast	Biosph. Inst.	QSR-2200	20531	3/8/2017	
PIR	Eppley	PIR	33023F3	10/19/2016	
PSP	Eppley	PSP	33090F3	10/18/2016	
GUV (Mast)	Biosph. Inst.	GUV-2511	25110203113	5/31/2017	

Sensor	Manufacturer	Model	Serial No.	Last Cal Date	Comments
CTD					
SBE 11+ Deck Unit	Sea-Bird	11+	11P47914-0768	NA	
Conductivity	Sea-Bird	4 - 02/O	041314	12/1/2016	Primary
Conductivity	Sea-Bird	4C 6800m	041798	3/22/2016	Secondary
CTD Fish	Sea-Bird	SBE 9+	91480	1/19/2017	
CTD Pressure Sensor	Paroscientific	410K-105	53952	1/19/2017	
Dissolved Oxygen	Sea-Bird	SBE 43	0150	11/18/2016	Primary
Dissolved Oxygen	Sea-Bird	SBE 43	0155	11/18/2016	Secondary
CTD Pump	Sea-Bird	5T, PN 90543	055641 3.0K	1/3/2017	Primary
CTD Pump	Sea-Bird	5T, PN 90543	055643 3.0K	1/3/2017	Secondary
Fluorometer	WetLabs	FLRTD	FLRTD-1482	3/19/2016	
Temperature	Sea-Bird	3-02/F	031649	3/14/2016	Primary
Temperature	Sea-Bird	3plus 6800m	03P5730	2/26/2016	Secondary
Transmissometer	WET Labs	C-Star	CST-439DR	7/29/2016	

Sensor	Manufacturer	Model	Serial No.	Last Cal Date	Comments
Underway Seawater Sampling System					
Fluorometer	WetLabs	FLRTD	FLRTD-855	1/27/2016	
Transmissometer	WET Labs	C-Star	CST-1581DR	3/30/2016	
Micro-TSG	Sea-Bird	SBE 45	4549120-0226	2/19/2017	Primary
Micro-TSG	Sea-Bird	SBE 45	4566350-0389	10/5/2016	Secondary
Digital Remote Temp	Sea-Bird	SBE 38	3846730-0323	1/23/2016	

Appendix B: Calibration Sheets

Gravity

BGM3 ship-to-shore gravity tie report

AUKON/CHIN, vessel: R/V Palmer

Release Date: 2017/06/17 03:11:38 UTC

Sensor: S210
Software version: 1.2
Port/Pier/Berth: LYTTLETON PIER 7

Gravity station number	486732A CHRISTCHURCH
Station name	NEW ZEALAND NATIONAL GRAVITY BASE STATION
mGal at pier	980505.71
Tie start time UTC	2017/06/17 02:10:19.792
Samples used	3600
Land tie used	Yes
Water height to pier 1	12 ft 3 in
Water height to pier 2	12 ft 8 in
Water height to pier 3	12 ft 11 in
Average of filtered counts	25034.809182694
Filter length	181
Scale factor	4.994070552
NEW BIAS	**855481.29**

Table 1: Gravity tie information

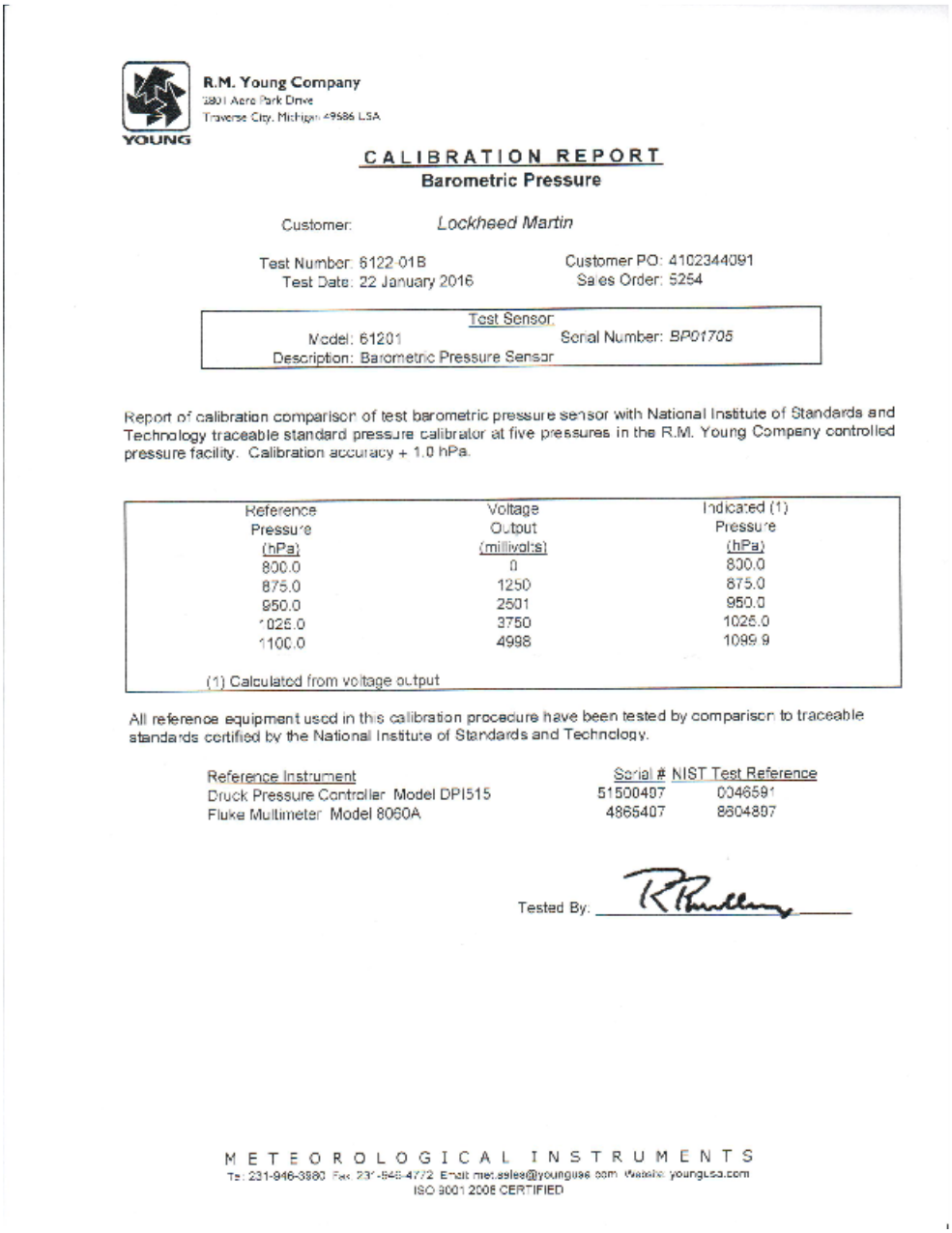
1

Meteorology

Anemometers

Cal sheet not required

Barometer 1



R.M. Young Company
3801 Aero Park Drive
Traverse City, Michigan 49686 USA

YOUNG

CALIBRATION REPORT
Barometric Pressure

Customer: *Lockheed Martin*

Test Number: 6122-01B
Test Date: 22 January 2016
Customer PO: 4102344091
Sales Order: 5254

Test Sensor:
Model: 61201
Serial Number: *BP01705*
Description: Barometric Pressure Sensor

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

Reference Pressure (hPa)	Voltage Output (millivolts)	Indicated (1) Pressure (hPa)
800.0	0	800.0
875.0	1250	875.0
950.0	2501	950.0
1025.0	3750	1025.0
1100.0	4998	1099.9

(1) Calculated from voltage output

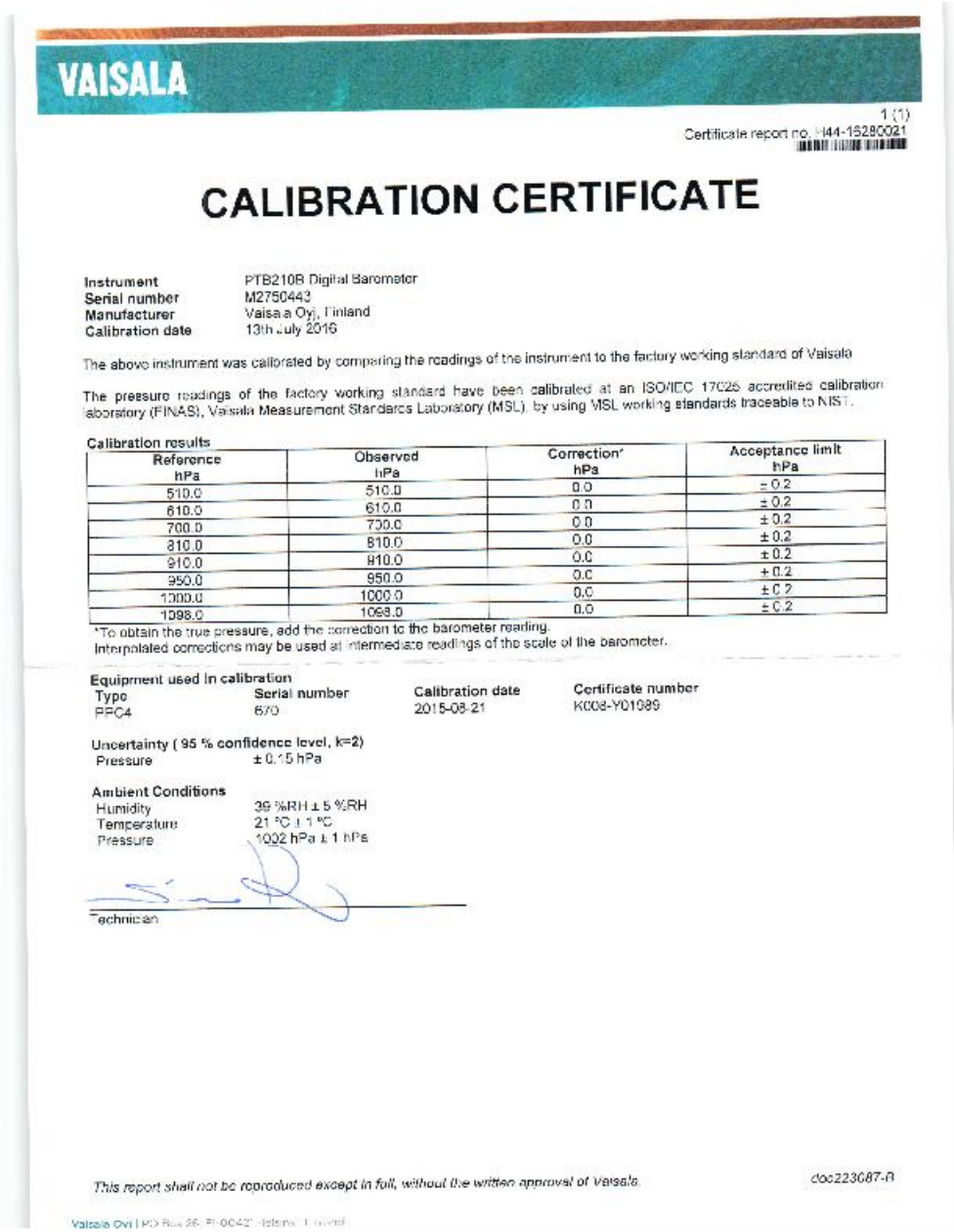
All reference equipment used in this calibration procedure have been tested by comparison to traceable standards certified by the National Institute of Standards and Technology.

Reference Instrument	Serial #	NIST Test Reference
Druck Pressure Controller Model DPI515	51500407	0046591
Fluke Multimeter Model 8060A	4865407	8804897

Tested By: _____

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

Barometer 2



VAISALA

1 (1)
Certificate report no. H44-16280021

CALIBRATION CERTIFICATE

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

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

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

Calibration results

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

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

Equipment used in calibration

Type	Serial number	Calibration date	Certificate number
PPC4	670	2015-08-21	K008-Y01089

Uncertainty (95 % confidence level, k=2)
Pressure ± 0.15 hPa

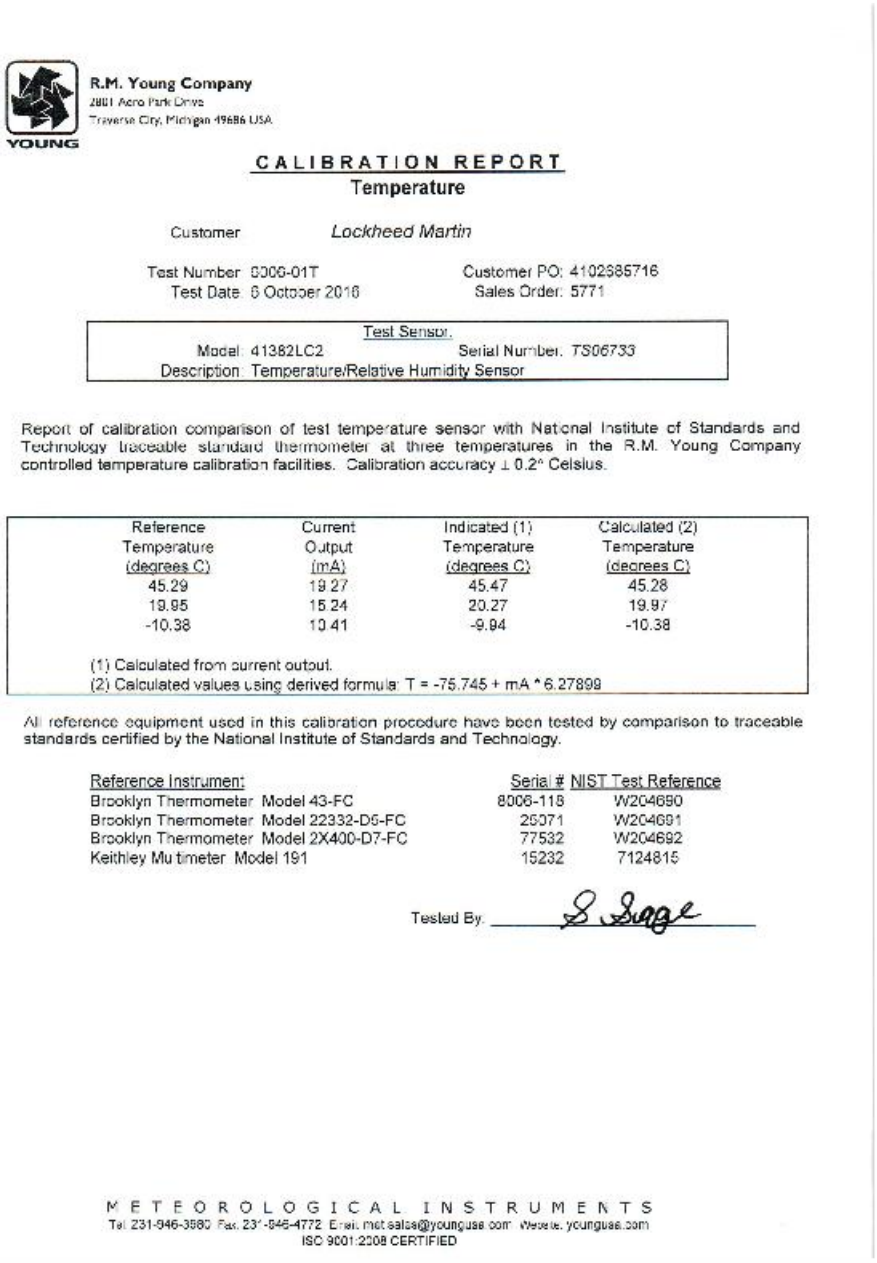
Ambient Conditions
Humidity 39 %RH ± 5 %RH
Temperature 21 °C ± 1 °C
Pressure 1002 hPa ± 1 hPa

Technician

This report shall not be reproduced except in full, without the written approval of Vaisala. doc223087-B

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

Temperature / Humidity



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

YOUNG

CALIBRATION REPORT
Temperature

Customer *Lockheed Martin*

Test Number: 8006-01T
Test Date: 6 October 2016
Customer PO: 4102585716
Sales Order: 5771

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

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

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

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

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

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

Tested By: S Sage

METEOROLOGICAL INSTRUMENTS
Tel: 231-946-3980 Fax: 231-946-4772 Email: mot.sales@younguse.com Website: younguse.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*

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

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

Report of calibration comparison of test 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	5.7	10.8
30.1	8.9	30.9
50.0	12.3	51.6
70.0	15.4	71.3
90.1	18.6	91.1

(1) Calculated from voltage output

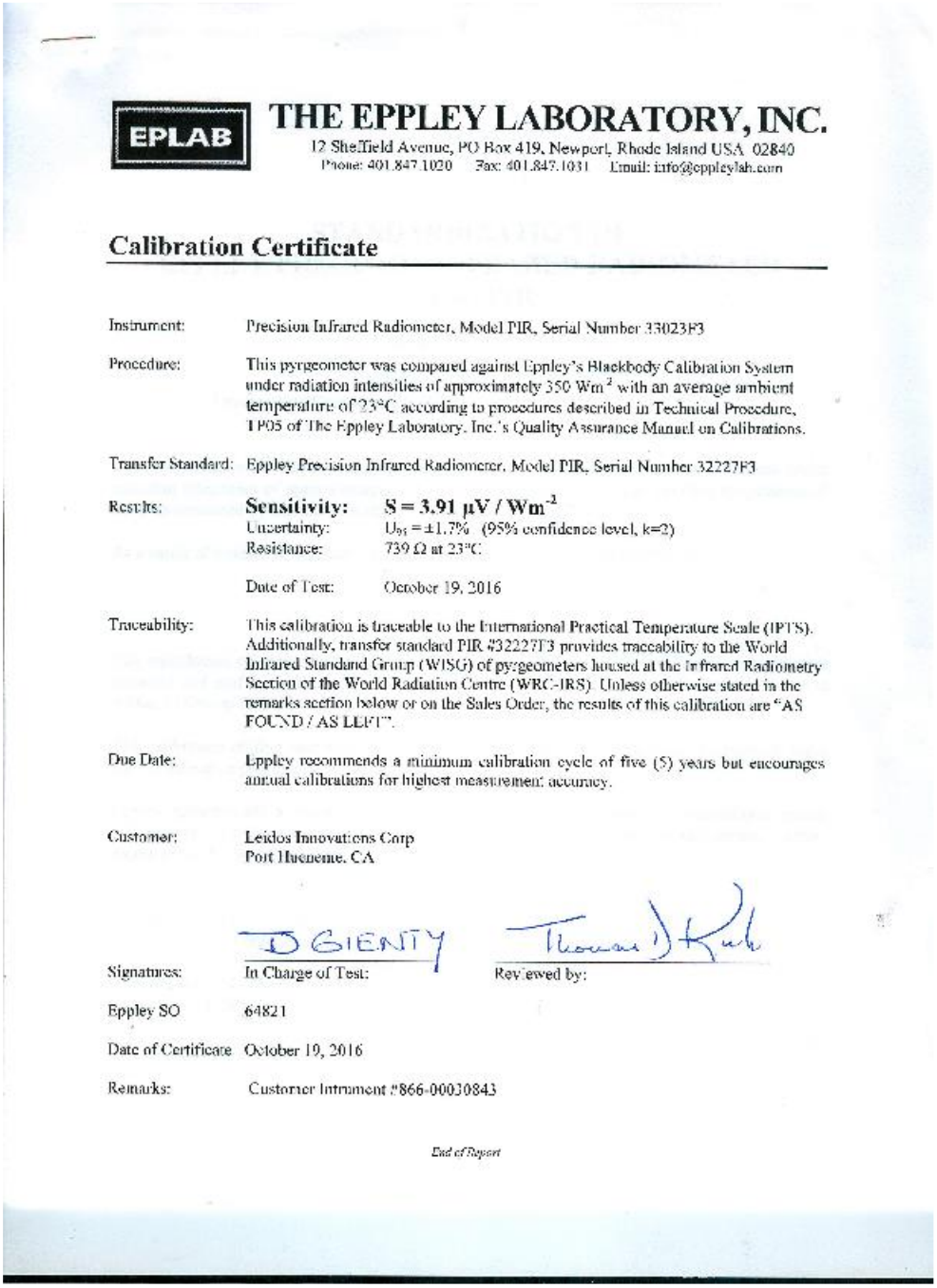
All reference equipment used in this calibration procedure have been tested by comparison to traceable standards certified by the National Institute of Standards and Technology.

Reference Instrument	Serial #	NIST Test Reference
Vaisala Humidity Sensor Model 35AC	N4750040	TN 266152
Fluke Multimeter Model 8060A	4865407	8604897

Tested By: S Sage

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

PIR



EPLAB

THE EPPLEY LABORATORY, INC.

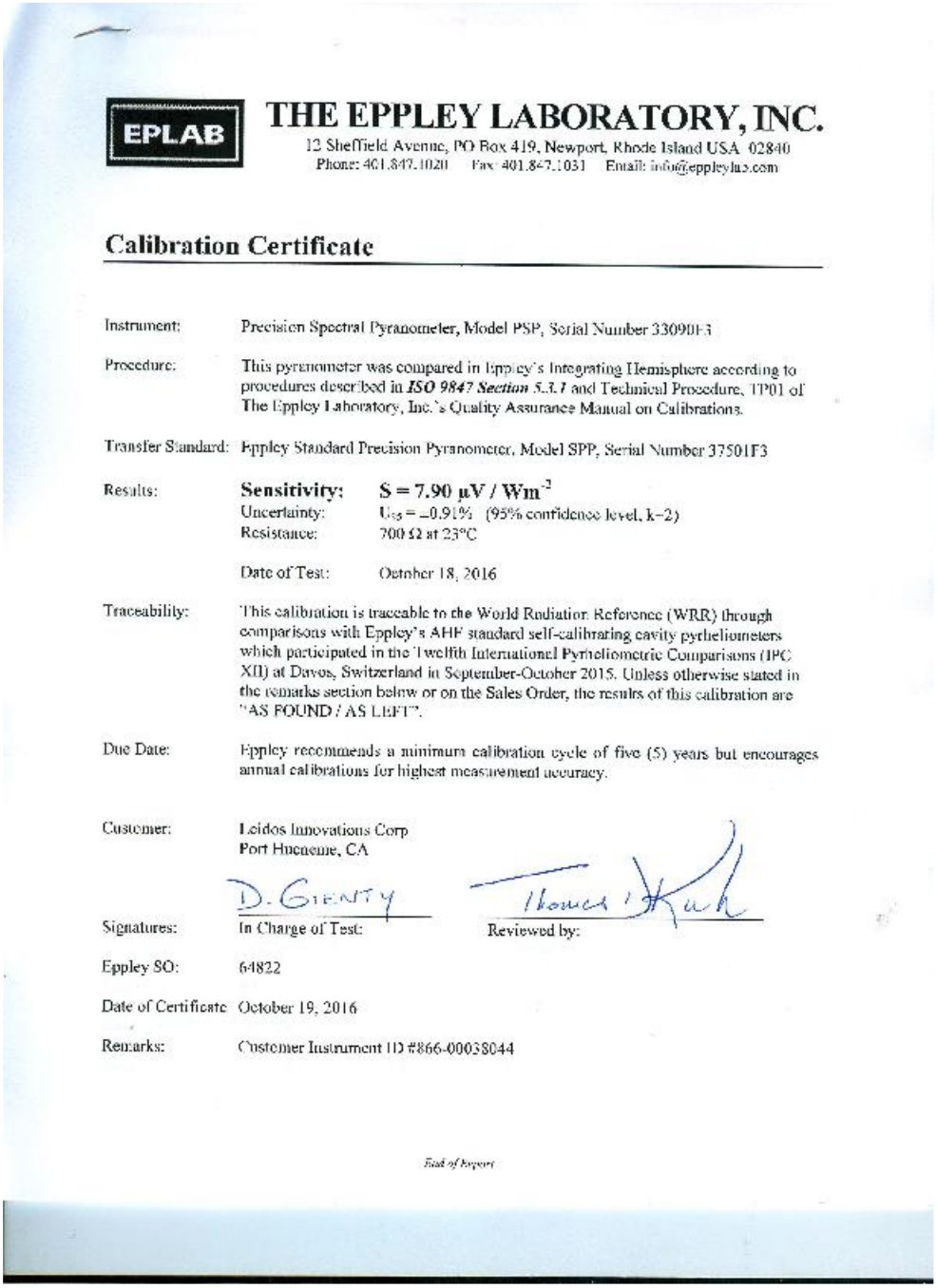
12 Sheffield Avenue, PO Box 419, Newport, Rhode Island USA 02840
Phone: 401.847.1020 Fax: 401.847.1031 Email: info@eppleylab.com

Calibration Certificate

Instrument:	Precision Infrared Radiometer, Model PIR, Serial Number 33023F3
Procedure:	This pyrgeometer was compared against Eppley's Blackbody Calibration System under radiation intensities of approximately 350 Wm^{-2} with an average ambient temperature of 23°C according to procedures described in Technical Procedure, TP05 of The Eppley Laboratory, Inc.'s Quality Assurance Manual on Calibrations.
Transfer Standard:	Eppley Precision Infrared Radiometer, Model PIR, Serial Number 32227F3
Results:	**Sensitivity:** **$S = 3.91\ \mu V / Wm^{-2}$** Uncertainty: $U_{95} = \pm 1.7\%$ (95% confidence level, k=2) Resistance: 739 Ω at 23°C
	Date of Test: October 19, 2016
Traceability:	This calibration is traceable to the International Practical Temperature Scale (IPTS). Additionally, transfer standard PIR #32227F3 provides traceability to the World Infrared Standard Group (WISG) of pyrgeometers housed at the Infrared Radiometry Section of the World Radiation Centre (WRC-IRS). Unless otherwise stated in the remarks section below or on the Sales Order, the results of this calibration are "AS FOUND / AS LEFT".
Due Date:	Eppley recommends a minimum calibration cycle of five (5) years but encourages annual calibrations for highest measurement accuracy.
Customer:	Leidos Innovations Corp Port Hueneme, CA
Signatures:	In Charge of Test: D GIENTY Reviewed by: Thomas J Kirk
Eppley SO	64821
Date of Certificate	October 19, 2016
Remarks:	Customer Instrument #866-00030843

End of Report

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 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 Standard Precision Pyranometer, Model SPP, Serial Number 37501F3
Results:	**Sensitivity:** **S = 7.90 µV / Wm^{-2}** Uncertainty: U_{95} = ±0.91% (95% confidence level, k=2) Resistance: 700 Ω at 23°C
	Date of Test: October 18, 2016
Traceability:	This calibration is traceable to the World Radiation Reference (WRR) through comparisons with Eppley's AHF standard self-calibrating cavity pyrheliometers which participated in the Twelfth International Pyrheliometric Comparisons (IPC XII) at Davos, Switzerland in September-October 2015. Unless otherwise stated in the remarks section below or on the Sales Order, the results of this calibration are "AS FOUND / AS LEFT".
Due Date:	Eppley recommends a minimum calibration cycle of five (5) years but encourages annual calibrations for highest measurement accuracy.
Customer:	Leidos Innovations Corp Port Hueneme, CA
Signatures:	D. Gienty — In Charge of Test:
	Reviewed by:
Eppley SO:	64822
Date of Certificate	October 19, 2016
Remarks:	Customer Instrument ID #866-00038044

End of Report

PAR (Mast)

Biospherical Instruments Inc.

CALIBRATION CERTIFICATE

Calibration Date	3/8/2017			
Model Number	QSR2200			
Serial Number	20531			
Operator	TPC			
Standard Lamp	91453(7/20/16)			
Probe Excitation Voltage Range:	6	to	18	VDC(+)
Output Polarity:	POSITIVE			

Probe Conditions at Calibration(in air):

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

Probe Output Voltage:

Probe Illuminated	90.1	mV
Probe Dark	1.0	mV
Probe Net Response	89.1	mV
RG780	1.1	mV

Corrected Lamp Output

Output in Air (same condition as calibration):

8.379E+15	quanta/cm²sec
0.013914	uE/cm²sec

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

Dry:	1.0633E-17	V/(quanta/cm²sec)
	6.4030E+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

[Insert Page Break]

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-039 (7/20/16) 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 **25110203113v9.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	5/31/2017
Calibration database	25110203113v9.mdb	Date of Certificate	5/31/2017
DASSN	0068	Standard of Spectral Irradiance	V-039(7/20/16)
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	2.5669E-10	2.6182E-05	7.6493E-03	2.7081E+00	8.7011E-05	8.5714E-05	4.3851E-04	µW/(cm²nm)
Ed0340	6	340	2.0781E-10	2.1196E-05	6.1927E-03	2.1835E+00	3.7847E-04	3.8104E-04	1.3278E-03	µW/(cm²nm)
Ed0313	8	313	2.2231E-10	2.2675E-05	6.6247E-03	2.3650E+00	3.5302E-05	3.7066E-05	6.5847E-04	µW/(cm²nm)
Ed0305	10	305	1.6361E-11	1.6688E-06	4.8755E-04	1.5082E-01	4.6550E-04	4.5669E-04	-2.1536E-03	µW/(cm²nm)
Ed0380	12	380	6.2595E-11	6.3847E-06	1.8653E-03	6.2206E-01	1.0328E-03	1.0241E-03	-1.5881E-03	µW/(cm²nm)
Ed0395	18	395	3.3548E-10	3.4219E-05	9.9974E-03	3.2656E+00	9.7613E-05	9.8620E-05	2.5961E-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	1.8717E-05	1.9091E+00	5.5776E+02	1.9859E+05	9.0359E-04	8.9635E-04	-1.2834E-03	µE/(cm²sec)

Auxilliary 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: 0226
CALIBRATION DATE: 19-Feb-17

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

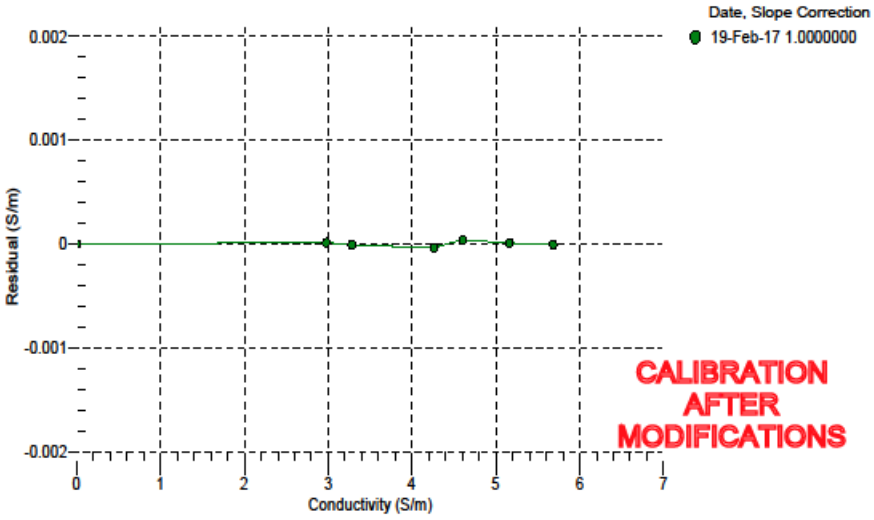
COEFFICIENTS:

g = -1.013733e+000
h = 1.569130e-001
i = -5.222989e-004
j = 6.723089e-005

CPcor = -9.5700e-008
CTcor = 3.2500e-006
WBOTC = 9.8072e-007

BATH TEMP (° C)	BATH SAL (PSU)	BATH COND (S/m)	INSTRUMENT OUTPUT (Hz)	INSTRUMENT COND (S/m)	RESIDUAL (S/m)
22.0000	0.0000	0.00000	2548.99	0.00000	0.00000
1.0000	34.7782	2.97302	5055.47	2.97303	0.00001
4.4999	34.7582	3.27977	5245.81	3.27976	-0.00001
15.0001	34.7152	4.26053	5811.87	4.26049	-0.00004
18.5000	34.7063	4.60535	5997.94	4.60538	0.00004
24.0000	34.6972	5.16286	6286.70	5.16287	0.00001
29.0000	34.6931	5.68441	6544.93	5.68440	-0.00001
32.5000	34.6918	6.05673	6722.93	6.05661	-0.00012

f = Instrument Output(Hz) * sqrt(1.0 + WBOTC * t) / 1000.0
t = temperature (°C); p = pressure (decibars); δ = CTcor; ε = CPcor;
Conductivity (S/m) = $(g + h * f^2 + i * f^3 + j * f^4) / 10 (1 + \delta * t + \varepsilon * p)$
Residual (Siemens/meter) = instrument conductivity - bath conductivity



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

SENSOR SERIAL NUMBER: 0226
CALIBRATION DATE: 19-Feb-17

SBE 45 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

COEFFICIENTS:

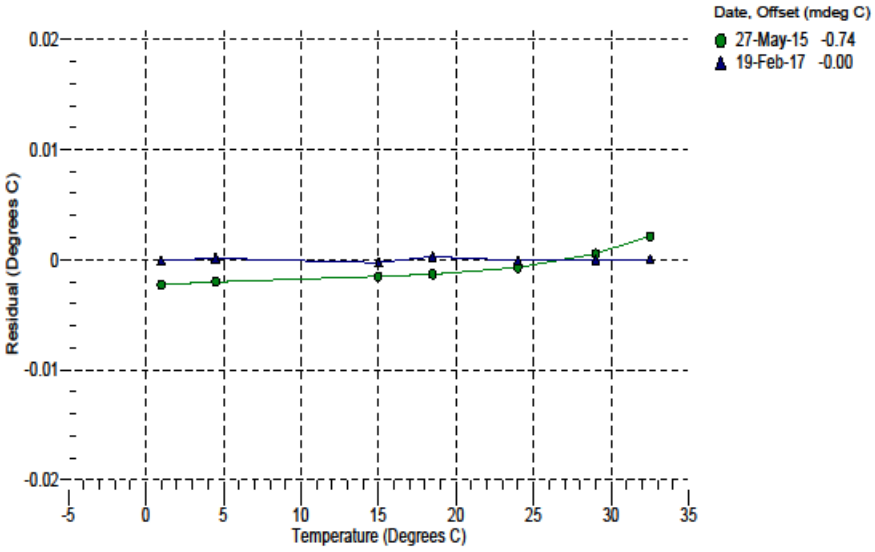
a0 = -1.625436e-004
a1 = 3.092515e-004
a2 = -4.990410e-006
a3 = 2.190124e-007

BATH TEMP (° C)	INSTRUMENT OUTPUT (counts)	INST TEMP (° C)	RESIDUAL (° C)
1.0000	744277.3	0.9999	-0.0001
4.4999	636452.3	4.5000	0.0001
15.0001	405760.1	14.9998	-0.0003
18.5000	351373.2	18.5003	0.0003
24.0000	281929.6	23.9999	-0.0001
29.0000	232180.3	29.0000	-0.0000
32.5000	203348.2	32.5000	0.0000

n = Instrument Output (counts)

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

Residual (°C) = instrument temperature - bath temperature



Micro-TSG2

Sea-Bird 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: 05-Oct-16

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

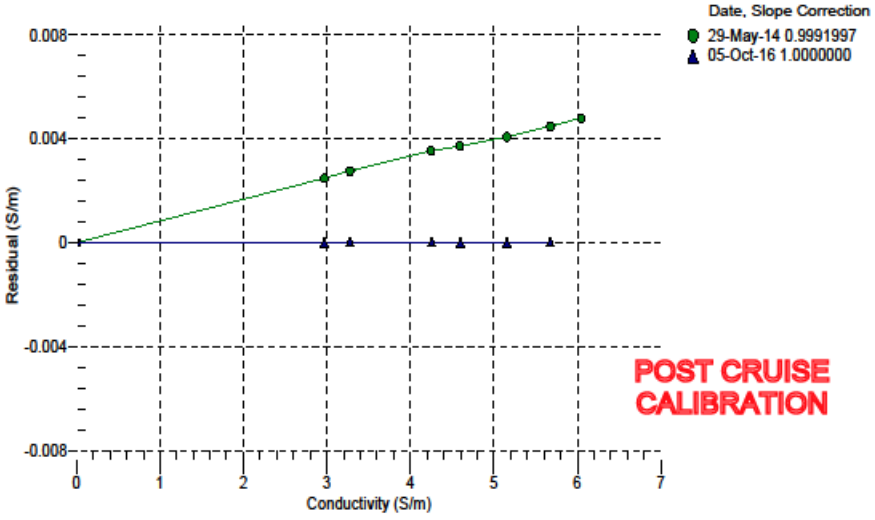
COEFFICIENTS:

g = -1.011215e+000
h = 1.476175e-001
i = -8.280491e-004
j = 7.730207e-005

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

BATH TEMP (° C)	BATH SAL (PSU)	BATH COND (S/m)	INSTRUMENT OUTPUT (Hz)	INSTRUMENT COND (S/m)	RESIDUAL (S/m)
22.0000	0.0000	0.00000	2631.99	0.00000	0.00000
1.0000	34.7178	2.96835	5231.58	2.96833	-0.00002
4.5000	34.6978	3.27464	5429.24	3.27466	0.00002
14.9999	34.6545	4.25385	6016.97	4.25386	0.00001
18.5000	34.6448	4.59807	6210.08	4.59806	-0.00001
24.0000	34.6345	5.15456	6509.85	5.15455	-0.00002
29.0000	34.6289	5.67507	6777.88	5.67508	0.00001
32.5000	34.6261	6.04656	6962.65	6.04663	0.00007

f = Instrument Output(Hz) * sqrt(1.0 + WBOTC * t) / 1000.0
t = temperature (°C); p = pressure (decibars); δ = CTcor; ε = CPcor;
Conductivity (S/m) = $(g + h * f^2 + i * f^3 + j * f^4) / 10 (1 + \delta * t + \varepsilon * p)$
Residual (Siemens/meter) = instrument conductivity - bath conductivity



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

SENSOR SERIAL NUMBER: 0389
CALIBRATION DATE: 05-Oct-16

SBE 45 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

COEFFICIENTS:

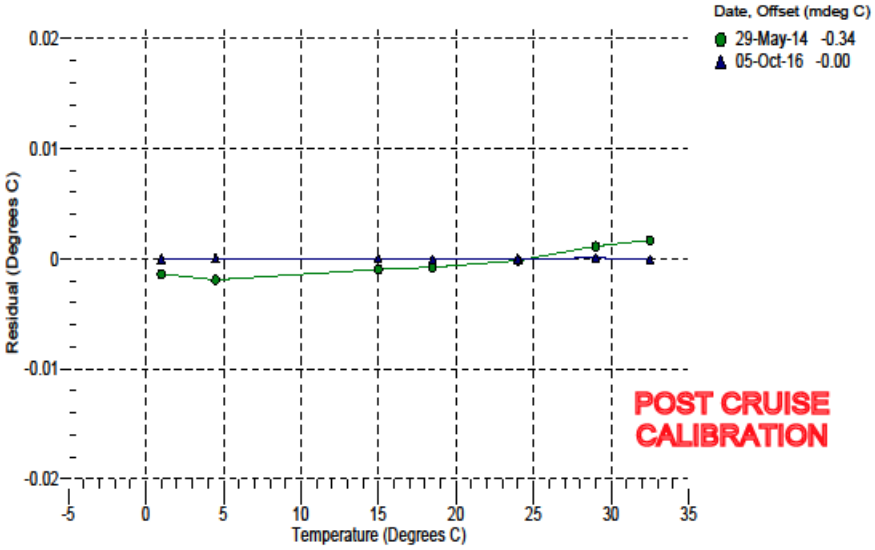
a0 = 3.090837e-005
a1 = 2.658070e-004
a2 = -1.844963e-006
a3 = 1.332162e-007

BATH TEMP (° C)	INSTRUMENT OUTPUT (counts)	INST TEMP (° C)	RESIDUAL (° C)
1.0000	828418.5	1.0000	-0.0000
4.5000	706628.0	4.5000	0.0000
14.9999	447305.9	14.9999	0.0000
18.5000	386484.7	18.4999	-0.0001
24.0000	309027.4	24.0000	-0.0000
29.0000	253718.2	29.0001	0.0001
32.5000	221745.8	32.4999	-0.0001

n = Instrument Output (counts)

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

Residual (°C) = instrument temperature - bath temperature



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: 0323
CALIBRATION DATE: 23-Jan-16

SBE 38 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

COEFFICIENTS:

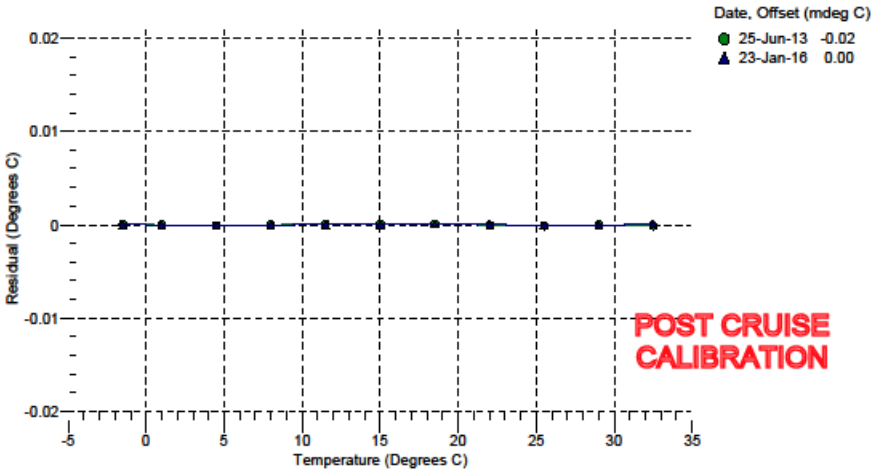
a0 = 1.374421e-005
a1 = 2.751852e-004
a2 = -2.335169e-006
a3 = 1.567304e-007

BATH TEMP (° C)	INSTRUMENT OUTPUT (counts)	INST TEMP (° C)	RESIDUAL (° C)
-1.5000	711106.6	-1.5000	0.0000
1.0000	635152.2	1.0000	-0.0000
4.5000	543801.6	4.4999	-0.0001
8.0000	467106.4	8.0000	-0.0000
11.5000	402497.5	11.5000	0.0000
15.0000	347892.6	15.0000	0.0000
18.5000	301594.1	18.5001	0.0001
22.0000	262216.7	22.0000	0.0000
25.4999	228625.3	25.4998	-0.0001
29.0002	199879.9	29.0001	-0.0001
32.5000	175217.4	32.5001	0.0001

n = Instrument Output (counts)

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

Residual (°C) = instrument temperature - bath temperature



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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 3.30.16 S/N# CST-1581DR Pathlength 25cm

	Analog output	Digital output	
V_d	0.004 V	0 counts	
V_{air}	4.806 V	15795 counts	
V_{ref}	4.699 V	15445 counts	
Temperature of calibration water			20.5 °C
Ambient temperature during calibration			22.5 °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 L 6/9/09

[Insert Page Break]

Fluorometer

PO Box 518
620 Applegate St.
Philomath, OR 97370

WET Labs

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

ECO Chlorophyll Fluorometer Characterization Sheet

Date: 1/27/2016 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	0.117	0.072	0.050 V	72 counts
Scale Factor (SF)	8	15	30 µg/l/V	0.0092 µg/l/count
Maximum Output	4.98	4.98	4.98 V	16326 counts
Resolution	0.6	0.6	0.6 mV	1.0 counts

Ambient temperature during characterization 22.3 °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

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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: 1314
CALIBRATION DATE: 01-Dec-16

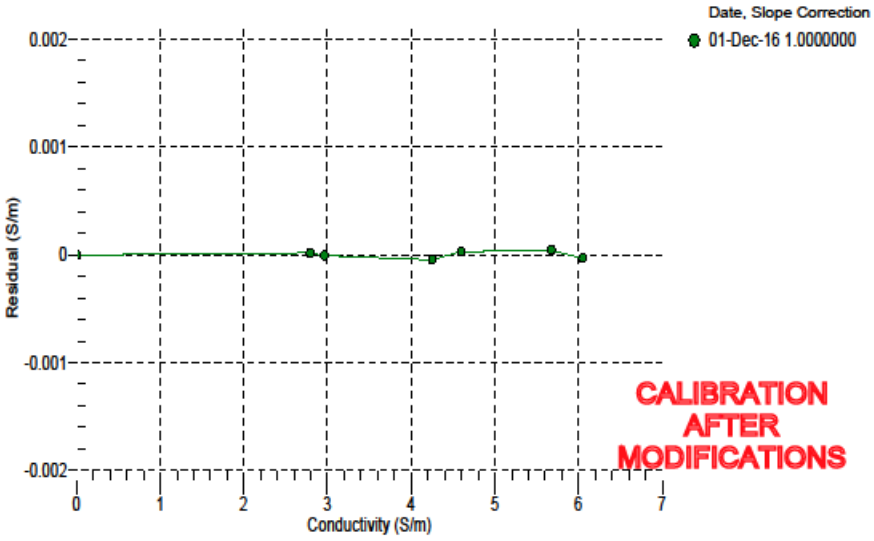
SBE 4 CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Siemens/meter

COEFFICIENTS:

```
g =  -3.96047725e+000          CPcor = -9.5700e-008 (nominal)
h =   4.57902311e-001          CTcor =  3.2500e-006 (nominal)
i =  -8.86036213e-005
j =   2.95672674e-005
```

BATH TEMP (° C)	BATH SAL (PSU)	BATH COND (S/m)	INSTRUMENT OUTPUT (kHz)	INSTRUMENT COND (S/m)	RESIDUAL (S/m)
0.0000	0.0000	0.00000	2.94096	0.00000	0.00000
-1.0000	34.6325	2.79115	8.33098	2.79116	0.00002
1.0000	34.6329	2.96178	8.55024	2.96177	-0.00001
15.0000	34.6325	4.25145	10.05167	4.25140	-0.00005
18.5000	34.6312	4.59646	10.41610	4.59648	0.00003
29.0001	34.6295	5.67517	11.47918	5.67521	0.00004
32.5001	34.6234	6.04616	11.82206	6.04612	-0.00003

f = Instrument Output (kHz)
t = temperature (°C); p = pressure (decibars); δ = CTcor; ε = CPcor;
Conductivity (S/m) = $(g + h * f^2 + i * f^3 + j * f^4) / 10 (1 + \delta * t + \varepsilon * p)$
Residual (Siemens/meter) = instrument conductivity - bath conductivity



Conductivity (secondary)

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

SENSOR SERIAL NUMBER: 1798
CALIBRATION DATE: 22-Mar-16

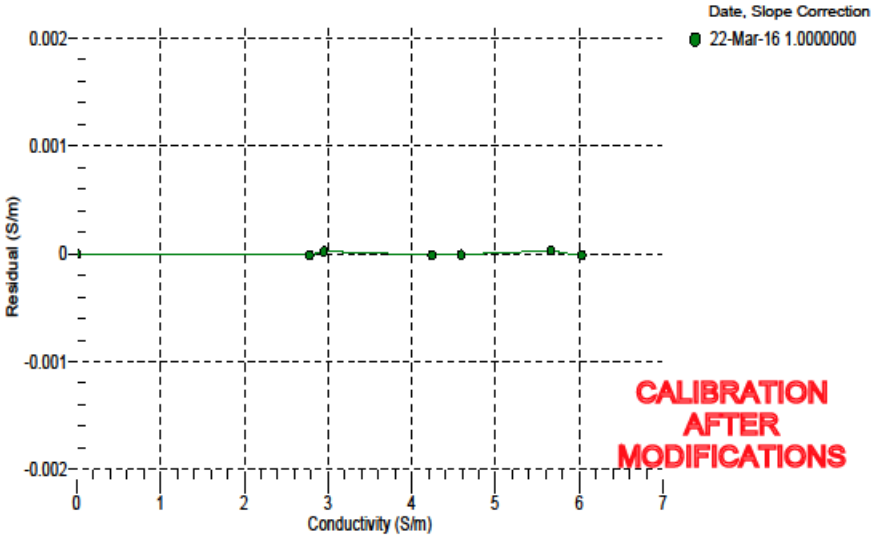
SBE 4 CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Siemens/meter

COEFFICIENTS:

```
g =  -9.79125732e+000          CPcor = -9.5700e-008 (nominal)
h =   1.26410805e+000          CTcor =  3.2500e-006 (nominal)
i =   1.34277903e-004
j =   4.48411138e-005
```

BATH TEMP (° C)	BATH SAL (PSU)	BATH COND (S/m)	INSTRUMENT OUTPUT (kHz)	INSTRUMENT COND (S/m)	RESIDUAL (S/m)
0.0000	0.0000	0.00000	2.78230	0.00000	0.00000
-1.0000	34.5316	2.78377	5.45147	2.78376	-0.00001
1.0000	34.5320	2.95397	5.57326	2.95399	0.00002
15.0000	34.5334	4.24056	6.41909	4.24055	-0.00001
18.5000	34.5333	4.58486	6.62706	4.58485	-0.00001
29.0001	34.5313	5.66088	7.23837	5.66090	0.00003
32.4999	34.5234	6.03065	7.43674	6.03064	-0.00002

f = Instrument Output (kHz)
t = temperature (°C); p = pressure (decibars); δ = CTcor; ε = CPcor;
Conductivity (S/m) = $(g + h * f^2 + i * f^3 + j * f^4) / 10 (1 + \delta * t + \varepsilon * p)$
Residual (Siemens/meter) = instrument conductivity - bath conductivity



Fluorometer

PO Box 518
620 Applegate St.
Philomath, OR 97370

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

ECO Chlorophyll Fluorometer Characterization Sheet

Date: 3/19/2016 S/N: FLRTD-1482

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	0.066	0.035	0.020 V	50 counts
Scale Factor (SF)	6	12	25 µg/l/V	0.0075 µg/l/count
Maximum Output	4.99	4.99	4.99 V	16380 counts
Resolution	0.5	0.5	0.5 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-1482 Revision J 3/17/08

Pressure Sensor

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

SENSOR SERIAL NUMBER: 1480
CALIBRATION DATE: 19-Jan-17

SBE 9plus PRESSURE CALIBRATION DATA
10000 psia S/N 53952

DIGIQUARTZ COEFFICIENTS:

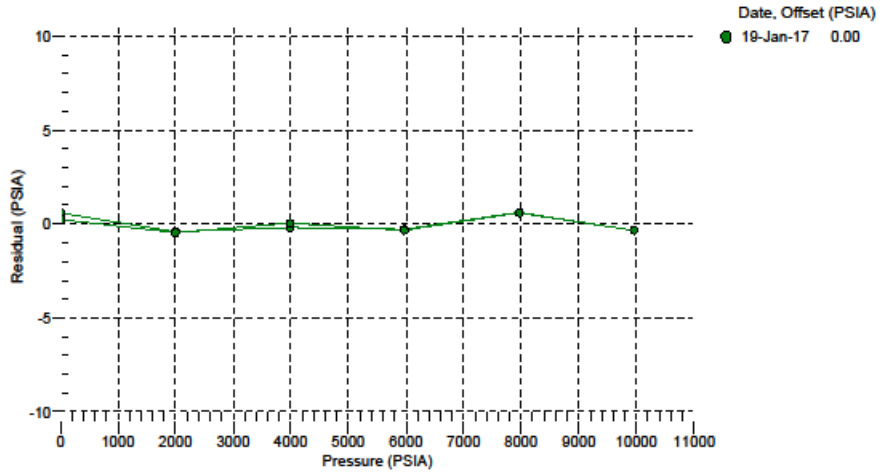
C1 =	-5.561704e+004
C2 =	4.302402e-001
C3 =	1.582810e-002
D1 =	4.708200e-002
D2 =	0.000000e+000
T1 =	3.029296e+001
T2 =	-2.122954e-004
T3 =	4.352450e-006
T4 =	2.626550e-009
T5 =	0.000000e+000

AD590M, AD590B, SLOPE AND OFFSET:

AD590M =	1.16300e-002
AD590B =	-8.63457e+000
Slope =	1.00003
Offset =	-3.0883 (dbars)

PRESSURE (PSIA)	INSTRUMENT OUTPUT (Hz)	INSTRUMENT TEMPERATURE (°C)	INSTRUMENT PRESSURE (PSIA)	CORRECTED PRESSURE (PSIA)	RESIDUAL (PSIA)
14.368	33019.50	21.9	19.428	14.949	0.581
2001.245	33602.80	22.0	2005.236	2000.825	-0.420
3988.124	34174.60	22.1	3992.274	3987.932	-0.192
5975.189	34735.10	22.1	5979.167	5974.893	-0.296
7962.358	35285.20	22.1	7967.167	7962.961	0.603
9949.890	35824.70	22.2	9953.696	9949.559	-0.331
7962.375	35285.20	22.2	7967.156	7962.951	0.576
5975.203	34735.10	22.2	5979.148	5974.874	-0.329
3988.221	34174.70	22.2	3992.602	3988.260	0.039
2001.256	33602.80	22.3	2005.213	2000.802	-0.454
14.365	33019.40	22.3	19.069	14.590	0.225

Residual (PSIA) = corrected instrument pressure - reference pressure



Dissolved Oxygen (primary)

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

SENSOR SERIAL NUMBER: 0150
CALIBRATION DATE: 18-Nov-16

SBE 43 OXYGEN CALIBRATION DATA

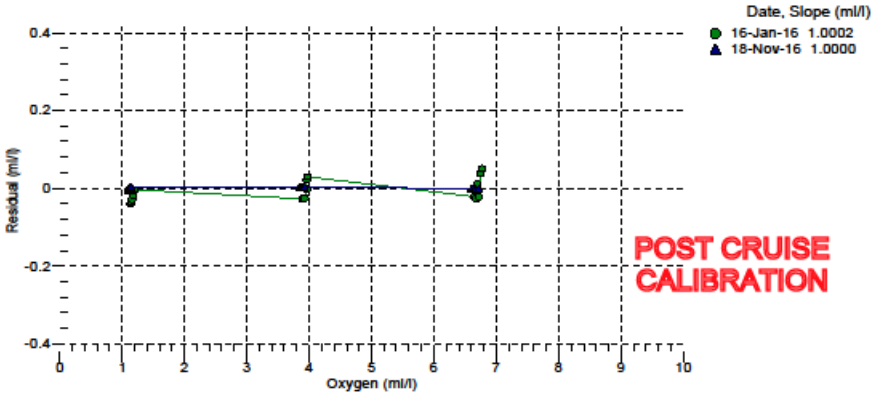
COEFFICIENTS:
Soc = 0.4594
Voffset = -0.4992
Tau20 = 1.65

A = -5.1283e-003
B = 2.7364e-004
C = -3.5992e-006
E nominal = 0.036

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

BATH OXYGEN (ml/l)	BATH TEMPERATURE (° C)	BATH SALINITY (PSU)	INSTRUMENT OUTPUT (volts)	INSTRUMENT OXYGEN (ml/l)	RESIDUAL (ml/l)
1.10	12.00	0.00	0.827	1.10	-0.00
1.11	2.00	0.00	0.750	1.10	-0.00
1.11	6.00	0.00	0.781	1.10	-0.00
1.12	20.00	0.00	0.891	1.12	0.00
1.14	26.00	0.00	0.942	1.14	0.00
1.14	30.00	0.00	0.974	1.15	0.00
3.85	2.00	0.00	1.374	3.85	0.00
3.88	12.00	0.00	1.651	3.88	0.00
3.88	6.00	0.00	1.490	3.88	0.00
3.90	20.00	0.00	1.862	3.90	0.00
3.92	26.00	0.00	2.021	3.92	0.00
3.92	30.00	0.00	2.122	3.92	0.00
6.60	6.00	0.00	2.185	6.60	-0.00
6.61	2.00	0.00	1.999	6.61	-0.00
6.62	12.00	0.00	2.465	6.62	0.00
6.66	30.00	0.00	3.251	6.66	-0.00
6.66	20.00	0.00	2.828	6.66	-0.00
6.71	26.00	0.00	3.103	6.71	-0.00

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



Dissolved Oxygen (secondary)

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

SENSOR SERIAL NUMBER: 0150
CALIBRATION DATE: 18-Nov-16

SBE 43 OXYGEN CALIBRATION DATA

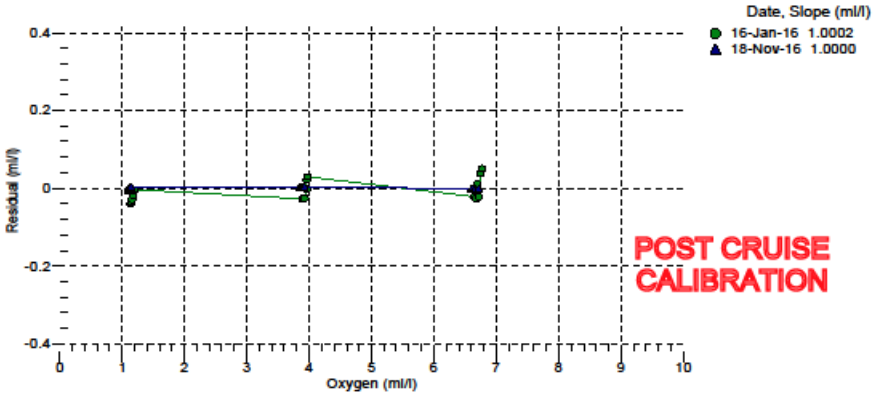
COEFFICIENTS:
Soc = 0.4594
Voffset = -0.4992
Tau20 = 1.65

A = -5.1283e-003
B = 2.7364e-004
C = -3.5992e-006
E nominal = 0.036

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

BATH OXYGEN (ml/l)	BATH TEMPERATURE (° C)	BATH SALINITY (PSU)	INSTRUMENT OUTPUT (volts)	INSTRUMENT OXYGEN (ml/l)	RESIDUAL (ml/l)
1.10	12.00	0.00	0.827	1.10	-0.00
1.11	2.00	0.00	0.750	1.10	-0.00
1.11	6.00	0.00	0.781	1.10	-0.00
1.12	20.00	0.00	0.891	1.12	0.00
1.14	26.00	0.00	0.942	1.14	0.00
1.14	30.00	0.00	0.974	1.15	0.00
3.85	2.00	0.00	1.374	3.85	0.00
3.88	12.00	0.00	1.651	3.88	0.00
3.88	6.00	0.00	1.490	3.88	0.00
3.90	20.00	0.00	1.862	3.90	0.00
3.92	26.00	0.00	2.021	3.92	0.00
3.92	30.00	0.00	2.122	3.92	0.00
6.60	6.00	0.00	2.185	6.60	-0.00
6.61	2.00	0.00	1.999	6.61	-0.00
6.62	12.00	0.00	2.465	6.62	0.00
6.66	30.00	0.00	3.251	6.66	-0.00
6.66	20.00	0.00	2.828	6.66	-0.00
6.71	26.00	0.00	3.103	6.71	-0.00

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



Pump (primary)

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

Service Report

RMA Number 77298

Customer Information:

Company	Lockheed Martin Antarctic Support	Date	3/31/2014
Contact	Dave Morehouse		
PO Number	4900044522		

Serial Number	055641
Model Number	SBE 05T

Services Requested:

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

Problems Found:

Services Performed:

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

Special Notes:

Monday, March 31, 2014 Page 4 of 5

Pump (secondary)

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

Service Report

RMA Number: 77298

Customer Information:

Company	Lockheed Martin Antarctic Support	Date	3/31/2014
Contact	Dave Morehouse		
PO Number	4900044522		

Serial Number	055643
Model Number	SBE 05T

Services Requested:

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

Problems Found:

Services Performed:

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

Special Notes:

Monday, March 31, 2014 Page 5 of 5

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: 1649
CALIBRATION DATE: 14-Mar-16

SBE 3 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

COEFFICIENTS:

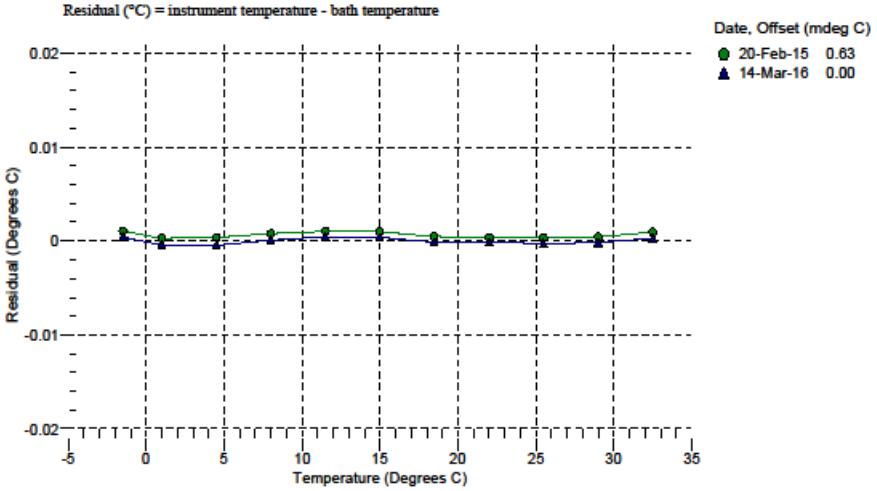
g = 4.80855419e-003
h = 6.67083809e-004
i = 2.27462895e-005
j = 1.61035917e-006
f0 = 1000.0

BATH TEMP (° C)	INSTRUMENT OUTPUT (Hz)	INST TEMP (° C)	RESIDUAL (° C)
-1.5000	5958.826	-1.4996	0.00042
1.0000	6301.309	0.9996	-0.00043
4.5000	6804.364	4.4995	-0.00047
8.0000	7335.524	8.0001	0.00010
11.5000	7895.401	11.5004	0.00043
15.0000	8484.680	15.0004	0.00037
18.5000	9104.035	18.4999	-0.00013
22.0000	9754.306	21.9999	-0.00013
25.5000	10436.029	25.4997	-0.00026
29.0000	11149.901	28.9998	-0.00017
32.5000	11896.554	32.5003	0.00027

f = Instrument Output (Hz)

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

Residual (°C) = instrument temperature - bath temperature



Temperature (Secondary)

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

SENSOR SERIAL NUMBER: 5730
CALIBRATION DATE: 26-Feb-16

SBE 3 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

COEFFICIENTS:

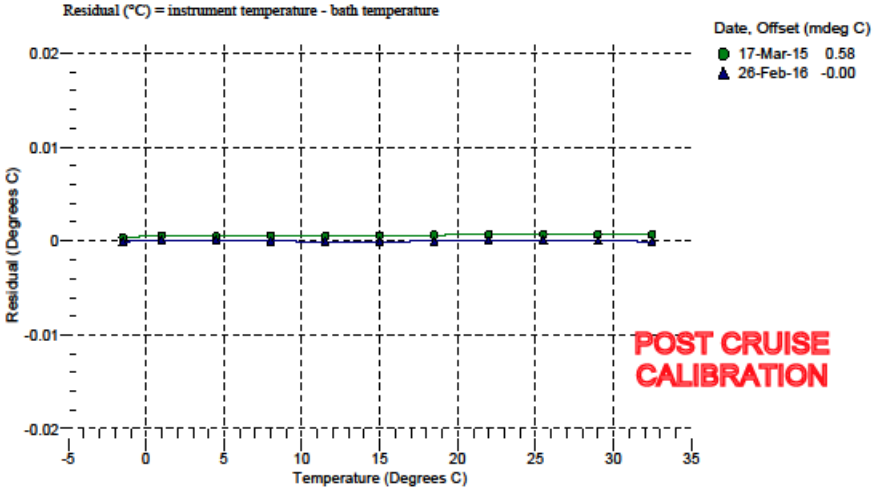
g = 4.35194524e-003
h = 6.29868351e-004
i = 1.97821726e-005
j = 1.44030219e-006
f0 = 1000.0

BATH TEMP (° C)	INSTRUMENT OUTPUT (Hz)	INST TEMP (° C)	RESIDUAL (° C)
-1.5000	3003.663	-1.5001	-0.00008
1.0000	3179.306	1.0001	0.00009
4.5000	3437.566	4.5001	0.00006
8.0000	3710.656	8.0000	-0.00001
11.5000	3999.011	11.4999	-0.00005
15.0000	4303.052	14.9999	-0.00005
18.5000	4623.188	18.5000	-0.00004
22.0000	4959.824	22.0000	0.00004
25.5000	5313.340	25.5001	0.00007
29.0000	5684.113	29.0000	0.00003
32.5000	6072.511	32.4999	-0.00006

f = Instrument Output (Hz)

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

Residual (°C) = instrument temperature - bath temperature



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

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