Data Report NBP1002

Western Antarctic Peninsula

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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 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, BathyW data, and raw ADCP data 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: NBP1002

File		**Description**
/		Root level directory
	NBP1002.trk	Text file of cruise track (lat,lon)
	NBP1002.mgd	Full Cruise MGD77 data file
	NBP1002.gmt	GMT binary file of MGD77 data
	INSTCOEF.TXT	Instrument Coefficient File
	1002DATA.doc	Data Report NBP1002 (MS Word)
	1002DATA.pdf	Data Report NBP1002 (pdf)
/plots		Cruise track plots
	1002_trak.ps	Cruise track plot (PostScript format)
	1002_trak.jpg	Cruise track plot (JPEG format)
/process		Processed data
	1002JGOF.tar	JGOFS format data files
	1002QC.tar	Daily RVDAS QC postcript plots
	1002PCO2.tar	Merged pCO2 data files
	1002MGD.tar	MGD Data
	1002PROC.tar	Other processed data
/rvdas/nav		Navigation data
	1002gyr1.tar	Gyro raw data
	1002pcod.tar	Trimble P-code raw data
	1002seap.tar	Seapath data
	1002adcp.tar	ADCP Data Sets
	1002sp1d.tar	Simrad data
/rvdas/uw		Underway data
	1002bat1.tar	Bathy data
	1002ctdd.tar	CTD depth data
	1002eng1.tar	Engineering aata
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	1002hdas.tar	HydroDAS raw data
	1002knud.tar	Knudsen raw data
	1002mtsg.tar	Micro TSG data
	1002mwx1.tar	Meteorology raw data
	1002pco2.tar	pCO2 raw data
	1002pguv.tar	GUV raw data
	1002rtmp.tar	Remote temperature data
	1002sim1.tar	Simrad EK500 data
	1002svp1.tar	Sound velocity probe (in ADCP well)
/EK500		Simrad EK500 data
/Imagery		Satellite Imagery
	1002Imag.tar	Satellite Imagery
/mocness		MOCNESS data
	1002moc.tar	MOCNESS data
/ocean		Ocean data

1002ctd.tar	CTD data
1002xbt.tar	XBT data

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 were created using the command,

```
tar cvf 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 ".gz" extension on the filename. These files can be decompressed after de-archiving, using the Unix command,

```
gunzip filename.gz
```

Distribution Contents

Cruise Information

NBP1002 departed Punta Arenas, Chile on March 16, 2009. There were unscheduled delays due to an earthquake in Chile. There was one scheduled stop at Palmer Station before arriving at Rothera. There were no major DAS problems during the cruise. The weather and the seas were occasionally uncooperative during the cruise. The basic objective was to continue a long-term ecology study along the Antarctic Peninsula. The NBP returned to Punta Arenas on December 19. 2009.

Cruise Track

The distribution DVD includes a GMT cruise track file (NBP1002.trk). It contains the longitude and latitude of the ship's position at one-minute intervals extracted from the NBP1002.gmt file.

JPEG and PostScript cruise track files have been produced and placed in the /plots directory.

Satellite Images

Satellite Images received for this cruise can be found in the file called /Imagery/1002Imag.tar collected and processed on the ship is in two further subdirectories, Ice and WX (weather). Files are named using the convention, ssss_fff_mmddyy_tttt_ww.gif where:

ssss_fff	= satellite and flight number
mm	= month
dd	= day
yy	= year
tttt	= time in hours and minutes (UTC)
ww	= optional field for identifying wavelength, such as vis (visible) or IR (infrared)

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 /process/1002proc.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/1002jgof.tar. The archive contains one file produced for each day named jgDDD.dat.gz, where DDD is the year-day the data was acquired. The ".gz" extension indicates that the individual files are compressed before archiving. Each daily file consists of 22 columnar fields in text format as described in the table below. The JGOFS data set is created from calibrated data decimated at one-minute intervals. Several fields are derived measurements from more than a single raw input. For example, Course Made Good (CMG) and Speed Over Ground (SOG) are calculated from gyro and GPS inputs. Daily plots during the cruise are produced from the JGOFS data set. Note: Null, unused, or unknown fields are indicated as "NAN" as 9999 in the JGOFS data.

Field	Data	Units
01	GMT date	dd/mm/yy
02	GMT time	hh:mm:ss
03	NGL latitude (negative is South)	tt.tttt
04	NGL 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	μEinsteins/meter^2 sec
10	Sea surface temperature	°C
11	Sea surface conductivity	siemens/meter
12	Sea surface salinity	PSU
13	Sea depth (uncorrected, calc. sw sound vel. 1500 m/s)	meters
14	True wind speed (max speed windbird)	meters/sec
15	True wind direction (max speed windbird)	degrees (azimuth)
16	Ambient air temperature	°C
17	Relative humidity	%
18	Barometric pressure	mBars
19	Sea surface fluorometry	μg/l (mg/m^3)
20	Transmissometry	%
21	PSP	W/m^2
22	PIR	W/m^2

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 NBP1002.mgd. The file NBP1002.gmt is created from the MGD77 dataset using the “mgd77togmt” utility. NBP1002.gmt can be used with the GMT plotting package.

The data used to produce the NBP1002.mgd file can be found on the distribution media in the file /process/1002proc.tar. The data files in the archive contain a day’s data and follow the naming convention Dddd.fnl.gz, 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 characters 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	+ = North - = South. (–9000000 to 9000000)
36-44	9	real	Longitude x 100000	+ = East - = 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	Bathymetry, 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	1 = 1st or leading sensor

Col	Len	Type	Contents	Description, Possible Values, Notes
			field	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 residuals are assumed to have been already corrected.
85-90	6	F6.0	Depth or altitude of magnetics sensor	(In meters) + = 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 1002adcp.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 1002pco2.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/1002ctd.tar. The archive contains tar files 1002proc.tar.

XBT

During the cruise, eXpendable BathyThermographs were used to obtain water column temperature profiles, providing corrections to the sound velocity profile for the multibeam system. The data files from these launches are included as 0806xbt.tar in the /ocean directory.

MOCNESS

Multiple Opening Closing Net Environmental Sensing System (MOCNESS). The mocness is a system of nets that can be opened and closed remotely from the deck. It is used to catch small marine organisms. All of the sensors on the Mocness are the same Seabird and Wetlabs sensors used on the CTD.

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: `NBP1002.mwx1.d330`

- The CruiseID is the numeric name of the cruise, in this case, NBP1002.
- 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	Channel ID	Collect. Status	Rate	Instrument
Air Temperature	mwx1	continuous	1 sec	R.M. Young 41372LC
Relative Humidity	mwx1	continuous	1 sec	R.M. Young 41372LC
Wind Speed/Direction	mwx1	continuous	1 sec	Gill 1390-PK-007
Barometer	mwx1	continuous	1 sec	R.M. Young 61201
PIR (LW radiation)	mwx1	continuous	1 sec	Eppley PIR
PSP (SW radiation)	mwx1	continuous	1 sec	Eppley PSP
PAR	mwx1	continuous	1 sec	BSI QSR-240
GUV	pguv	continuous	2 sec	BSI PUV-2511
PUV	pguv	not collected		BSI PUG-2500

Geophysics

Measurement	Channel ID	Collect. Status	Rate	Instrument
Gravimeter	grv1	continuous	10 sec*	LaCoste & Romberg
Magnetometer	mag1	not collected	15 sec	EG&G G-866
Bathymetry	bat1	continuous	Varies	ODEC Bathy 2000
Bathymetry	knud	continuous	Varies	Knudsen 320B/R
Bathymetry	sim1	partial collection	Varies	Simrad EK500 Sonar

*Data is output every second but it only changes every 10 seconds.

Oceanography

Measurement	Channel ID	Collect. Status	Rate	Instrument
Conductivity	mtsg	Continuous	6 sec	SeaBird SBE-45
Salinity	mtsg	Continuous	6 sec	Calc. from pri. temp
Sea Surface Temp	mtsg	Continuous	6 sec	SeaBird 3-01/S
Fluorometry	hdas	Continuous	2 sec	WET Lab AFL
Transmissometry	hdas	Continuous	2 sec	WET Lab C-Star
pCO_2	Pco2	Continuous	70 sec	(LDEO)
ADCP	adcp	Continuous	varies	RD Instruments

Navigational Instruments

Measurement	Channel ID	Collect. Status	Rate	Instrument
Trimble GPS	PCOD	Continuous	1 sec	Trimble 20636-00SM
Gyro	gyr1	Continuous	0.2 sec	Yokogawa Gyro
SeaPath	seap	Continuous	1 sec	SeaPath 200

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.

Underway Data

Each section below 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 directory on the distribution disc.

Sound Velocity Probe (svp1)

```
08+330:00:00:49.011  1519.35
```

Field	Data	Units
1	RVDAS Time tag	
2	Sound velocity in ADCP sonar well	m/s

Meteorology (mwx1)

```
There are 3 different data strings in the mwx1 data file:

MET

08+330:23:59:57.725 MET,12.1,-54,6.64,88.7,111.3374,0.02414567,-
0.4827508,282.9581,281.8823,1003.119

PUS

08+330:23:59:58.546 PUS,A,020,008.53,M,+337.12,+009.00,00,0F

SUS

08+330:23:59:58.779 SUS,A,017,008.76,M,+335.53,+006.35,00,02
```

MET string

Field	Data	Units
1	RVDAS time tag	
2	MET (string flag)	
3	Power Supply Voltage	V
4	Enclosure Relative Humidity	%
5	Air temperature	°C
6	Air Relative Humidity	%
7	PAR (photosynthetically available radiation)*	mV
8	PSP (short wave radiation)*	mV
9	PIR Thermopile (long wave radiation)*	mV
10	PIR Case Temperature	°Kelvin
11	PIR Dome Temperature	°Kelvin
12	Barometer	mBar

*See page 21 for calculations.

PUS string

Field	Data	Units
1	RVDAS time tag	
2	PUS (string flag)	
3	A (unit identification)	
4	Port Wind direction relative	deg
5	Port Wind speed relative	m/s
6	Units	
7	Sound Speed	m/s
8	Sonic Temperature	°C
9	Unit Status (00 or 60 are good, any other value indicates fault)	
10	Check Sum	

SUS string

Field	Data	Units
1	RVDAS time tag	
2	SUS (string flag)	
3	A (unit identification)	
4	Starboard Wind direction relative	deg
5	Starboard Wind speed relative	m/s
6	Units	
7	Sound Speed	m/s
8	Sonic Temperature	°C
9	Unit Status (00 or 60 are good, any other value indicates fault)	
10	Check Sum	

Knudsen (knud)

```
99+099:00:18:19.775 HF,305.2,LF,304.3
```

Field	Data	Units
1	RVDAS time tag	
2	HF = High frequency flag (12 kHz)	
3	High frequency depth	meters
4	LF = Low frequency flag (3.5 kHz)	
5	Low frequency depth	meters

Fluorometer (flr1)

This Fluorometer is not in use. Current Fluorometer goes to the hdas string.

```
00+019:23:59:58.061 0  0818 ::  1/19/00 17:23:17 = 0.983  (RAW)   1.2 (C)
```

Field	Data	Units
1	RVDAS time tag	
2	Marker 0 to 8	
3	4-digit index	
4	Date	mm/dd/yy
5	Time	hh:mm:ss
6	Signal	
7	Signal units of measurement	
8	Cell temperature (if temperature compensation package is installed)	
9	Temperature units (if temperature compensation package is installed)	

pCO_2 (pco2)

```
00+021:23:59:43.190 2000021.99920 2382.4 984.2 30.73 50.8 345.9 334.1 -1.70
-68.046 -144.446 Equil
```

Field	Data	Units
1	RVDAS time tag	
2	pCO_2 time tag (decimal is fractional time of day)	yyyyddd.ttt
3	Raw voltage (IR)	mV
4	Cell temperature	°C
5	Barometer	MBar
6	Concentration	ppm
7	Equilibrated temperature	°C
8	pCO_2 pressure	microAtm
9	Flow rate	ml / min
10	Source ID #	1 or 2 digits
11	Valve position	1 or 2 digits
12	Flow source (Equil = pCO_2 measurement)	text

Simrad EM120 (mbdp)

```
09+282:10:53:38.318 $KGDPT,3945.60,7.29,1;12000.0*7c
```

Field	Data	Units
1	RVDAS time tag	
2	EM120 (string flag)	
3	Depth below keel	Meters
4	Keel depth	Meters
5		

Micro-TSG (mtsg)

```
08+330:23:59:40.894   5.9322,  3.34685,  34.0550, 1473.281
```

Field	Data	Units
1	RVDAS time tag	
2	Internal Temperature	°C
3	Conductivity	s/m
4	Salinity	PSU
5	Sound velocity	m/s

Gravimeter (grv1)

There are now two sets of fields output by the gravity meter. The data record is output once per second, and identified by “$DAT” in the id field. A summary of sensor environmental data is output every ten seconds, identified by “%ENV” in the id field.

Data record ($DAT):

05+194:00:00:27.995 $DAT,2005/ 7/13, 0: 7: 7.36,194, 9050.37, 9050.06, 5410.86, -0.00, -0.01, -0.02, 0.00, 0.00, 0.70, 0.19, -0.12, -0.25, 0.00, -69.45711315, -54.32181487, 0.000, 285.200,

Field	Data	Conversion	Units
1	RVDAS time tag		
2	Text string (id field)	$DAT for data record	
3	Date	YYYY/MM/DD	
4	Time	HH:MM:SS.SS	
5	Day of Year	DDD	
6	Gravity count	mgal = count x 1.0046 + offset	count
7	Spring Tension		CU
8	Beam Position	Volts x 750,000	
9	VCC		
10	AL		
11	AX		
12	VE		
13	AX2		
14	XACC2		
15	LACC2		
16	CROSS ACCEL		GAL
17	LONG ACCEL		GAL
18	EOTVOS CORR		MGAL
19	LONGITUDE		Degrees
20	LATITUDE		Degrees
21	HEADING		Degrees
22	VELOCITY		Knots

Environmental record ($ENV)

```
05+183:19:13:10.945 %ENV,2005/ 7/ 2,19:19:52.16,183,S-036/V1.5,    3.34,
47.19,   20.34,1.111840E-1,-0.57700,-0.10591, 0.40180, 2.55260, 0.43000,   1,
300
```

Field	Data	Conversion	Units
1	RVDAS time tag		
2	Text string (id field)	$ENV for environmental record	
3	Date	YYYY/MM/DD	
4	Time	HH:MM:SS.SS	
5	Day of Year	DDD	
6	Meter ID		
7	Meter Pressure		inch-Hg
8	Meter temp		°C
9	Ambient temp		°C
10	K-Factor		
11	VCC Coeff		
12	AL Coeff		
13	AX Coeff		
14	VE Coeff		
15	AX2 Coeff		
16	Serial Filter Length		Seconds
17	QC Filter Length		Seconds

Engineering (eng1)

```
08+330:23:59:50.899 12.25684 23.89813 0.4029922 0.2541656 233.4218 -
751.9 -8145.28 -1.386184 23.37653 23.37653 NAN
```

Field	Data	Units
1	RVDAS time tag	
2	Power Supply Voltage	V
3	Internal Case Temperature	°C
4	Pump #1 flow rate	L/min
5	Pump #2 flow rate	L/min
6	Pump #3 flow rate	L/min
7	Seismic air pressure	Lbs/sq-in
8	PIR case resistance (not currently hooked up, data is irrelevant)	Kohm
9	PIR case ratiometric output (not currently hooked up, data is irrelevant)	mV
10	Freezer #1 temperature	°C
11	Freezer #2 temperature	°C
12	Freezer #3 temperature	°C

*See page 25 for PIR calculations.

Hydro-DAS (hdas)

```
08+330:23:59:41.877 12.15836 14.22853 368.9655 4060.69 -1 65.5 65.5 80
57
```

Field	Data	Units
1	RVDAS time tag	
2	Supply voltage	V
3	Panel temperature	°C
4	Fluorometer	mV
5	Transmissometer	mV
6	Sea Water Valve (-1 = stern thruster valve, 0 = moon pool valve)	
7	Flow meter 1 frequency	Hz
8	Flow meter 2 frequency	Hz
9	Flow meter 3 frequency	Hz
10	Flow meter 4 frequency	Hz

GUV Data (pguv)

```
08+330:23:59:40.328 112508 235940 .000197 1.856E-1 1.116E0 4.987E-2 -
1.959E-4 1.637E0 4.153E-3 1.76E0 42.296 17.844
```

Field	Data	Units
1	RVDAS time tag	
2	Date	mmddyy
3	Time (UTC)	hhmmss
4	Ed0Gnd	V
5	Ed0320	uW (cm^2 nm)
6	Ed0340	uW (cm^2 nm)
7	Ed0313	uW (cm^2 nm)
8	Ed0305	uW (cm^2 nm)
9	Ed0380	uW (cm^2 nm)
10	Ed0PAR	uE (cm^2 nm)
11	Ed0395	uW (cm^2 nm)
12	Ed0Temp	°C
13	Ed0Vin	V

Remote Temperature (rtmp)

```
07+272:00:00:15.960 -1.7870
```

Field	Data	Units
1	RVDAS time tag	
2	Temperature at seawater intake	°C

Navigational Data

Seapath GPS (seap)

The Seapath GPS outputs the following data strings, four in NMEA format and two in proprietary PSXN format:

- GPZDA
- GPGGA
- GPVTG
- GPHDT
- PSXN, 20
- PSXN, 22
- PSXN, 23

GPZDA

```
02+253:00:00:00.772 $GPZDA,235947.70,09,09,2002,,*7F
```

Field	Data	Units
1	RVDAS time tag	
2	$GPZDA	
3	time	hhmmss.ss
4	Day	dd
5	Month	mm
6	Year	yyyy
7	(empty field)	
8	Checksum	

GPGGA

```
02+253:00:00:00.938
GPGGA,235947.70,6629.239059,S,06827.668899,W,1,07,1.0,11.81,M,,M,,*6F
```

Field	Data	Units
1	RVDAS time tag	
2	$GPGGA	
3	time	hhmmss.ss
4	Latitude	ddmm.mmmmmm
5	N or S for north or south latitude	
6	Longitude	ddmm.mmmmmm
7	E or W for east or west longitude	
8	GPS quality indicator, 0=invalid, 1=GPS SPS, 2=DGPS, 3=PPS, 4=RTK, 5=float RTK, 6=dead reckoning	
9	number of satellites in use (00-99)	
10	HDOP	x.x
9	height above ellipsoid in meters	m.mm
11	M	
12	(empty field)	
13	M	
14	age of DGPS corrections in seconds	s.s
15	DGPS reference station ID (0000-1023)	
16	Checksum	

GPVTG

```
02+253:00:00:00.940 $INVTG,19.96,T,,M,4.9,N,,K,A*39
```

Field	Data	Units
1	RVDAS time tag	
2	$GPVTG	
3	course over ground, degrees true	d.dd
4	T	
5	,	
6	M	
7	speed over ground in knots	k.k
8	N	
9	,	
10	K	
11	Mode	
12	Checksum	

GPHDT

```
02+253:00:00:00.941 $GPHDT,20.62,T*23
```

Field	Data	Units
1	RVDAS time tag	
2	$GPHDT	
3	Heading, degrees true	d.dd
4	T	
5	Checksum	

PSXN,20

```
02+253:00:00:00.942 $PSXN,20,0.43,0.43*39
```

Field	Data	Units
1	RVDAS time tag	
2	$PSXN	
3	20	
4	Horizontal position & velocity quality: 0=normal, 1=reduced performance, 2=invalid data	
5	Height & vertical velocity quality: 0=normal, 1=reduced performance, 2=invalid data	
6	Heading quality: 0=normal, 1=reduced performance, 2=invalid data	
7	Roll & pitch quality: 0=normal, 1=reduced performance, 2=invalid data	
8	Checksum	

PSXN,22

```
02+253:00:00:00.942 $PSXN,22,0.43,0.43*39
```

Field	Data	Units
1	RVDAS time tag	
2	$PSXN	
3	22	
4	gyro calibration value since system start-up in degrees	d.dd
5	short term gyro offset in degrees	d.dd
6	Checksum	

PSXN,23

```
02+253:00:00:02.933 $PSXN,23,0.47,0.57,20.62,0.03*0C
```

Field	Data	Units
1	RVDAS time tag	
2	$PSXN	
3	23	
4	roll in degrees, positive with port side up	d.dd
5	pitch in degrees, positive with bow up	d.dd
6	Heading, degrees true	d.dd
7	heave in meters, positive down	m.mm
8	Checksum	

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 three NMEA standard data strings:

- Position fix (GGA)
- Latitude / longitude (GLL),
- Track and ground speed (VTG)

GGA: GPS Position Fix – Geoid/Ellipsoid

```
01+319:00:04:11.193 $GPGGA,000410.312,6227.8068,S,06043.6738,W,1,06,1.0,
031.9,M,-017.4,M,,*49
```

Field	Data	Units
1	RVDAS Time tag	
2	$GPGGA	
3	UTC time at position	hhmmss.sss
4	Latitude	ddmm.mmm
5	North (N) or South (S)	
6	Longitude	ddmm.mmm
7	East (E) or West (W)	
8	GPS quality: 0 = Fix not available or invalid 1 = GPS, SPS mode, fix valid 2 = DGPS (differential GPS), SPS mode, fix valid 3 = P-CODE PPS mode, fix valid	
9	Number of GPS satellites used	
10	HDOP (horizontal dilution of precision)	
11	Antenna height	meters
12	M for meters	
13	Geoidal height	meters
14	M for meters	
15	Age of differential GPS data (no data in the sample string)	
16	Differential reference station ID (no data in the sample string)	
17	Checksum (no delimiter before this field)	

GLL: GPS Latitude/Longitude

```
01+319:00:04:11.272 $GPGLL,6227.8068,S,06043.6738,W,000410.312,A*32
```

Field	Data	Units
1	RVDAS Time tag	
2	$GPGLL	
3	Latitude	degrees
4	North or South	
5	Longitude	degrees
6	East or West	
7	UTC of position	hhmmss.sss
8	Status of data (A = valid)	
9	Checksum	

VTG: GPS Track and Ground Speed

```
01+319:00:04:11.273 $GPVTG,138.8,T,126.0,M,000.0,N,000.0,K*49
```

Field	Data	Units
1	RVDAS time tag	
2	$GPVTG	
3	Heading	degrees
4	Degrees true (T)	
5	Heading	degrees
6	Degrees magnetic (M)	
7	Ship speed	knots
8	N = knots	
9	Speed	km/hr
10	K = km per hour	
11	Checksum	

Gyro Compass (gyr1)

```
00+019:23:59:59.952 $HEHDT 25034,-020*73
```

Field	Data	Units
1	RVDAS time tag	
2	$HEHDT	
3	Heading, Degrees True	degrees
5	Checksum	

ADCP Course (adcp)

```
00+019:23:59:59.099 $PUHAW,UVH,-1.48,-0.51,250.6
```

Field	Data	Units
1	RVDAS time tag	
2	$PUHAW	
3	UVH (E-W, N-S, Heading)	
4	Ship Speed relative to reference layer, east vector	knots
5	Ship Speed relative to reference layer, north vector	knots
6	Ship heading	degrees

Processed Data

The processed data sets can be found in the /process directory and subdirectories. Note: many of the subdirectories contain intermediate datasets to facilitate further processing and are not intended to be end-products. Only the final product files and datasets are described below.

pCO2-merged

```
00+346:23:58:20.672 2000346.9991 2398.4 1008.4 0.01 45.4 350.3 342.6 15.77
Equil -43.6826 173.1997 15.51 33.90 0.33 5.28 9.05 1007.57 40.0 14.87 182.44 -1
```

Field	Data	Units
1	RVDAS time tag	
2	pCO_2 time tag (decimal is fractional time of day)	yyyyddd.ttt
3	Raw voltage (IR)	mV
4	Cell temperature	°C
5	Barometer	MBar
6	Concentration	ppm
7	Equilibrated temperature	°C
8	pCO_2 pressure	microAtm
9	Flow rate	ml / min
10	Source ID #	1 or 2 digits
11	Valve position	1 or 2 digits
12	Flow source (Equil = pCO_2 measurement)	text
13	RVDAS latitude	degrees
14	RVDAS longitude	degrees
15	TSG external temperature	°C
16	TSG salinity	PSU
17	TSG fluorometry	V
18	RVDAS true wind speed	m/s
19	RVDAS true wind direction	degrees
20	Barometric Pressure	mBars
21	Uncontaminated seawater pump flow rate	l/min
22	Speed over ground	knots
23	Course made good	degrees
24	Input Source	-1 stem Thurston; 0 moonpool

Calculations

The file `instrument.coeff` located in the `/` directory contains the calibration factors for shipboard instruments. This was the file used by the RVDAS processing software.

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
077:00:00:00		68° West – started loggers
077:22:06:00		Left Argentinean EEZ (-58.801666S, -63.753333W)
119:11:44:00		Entered Argentinean EEZ (-57.93333, -61.81833)
120:22:56:00		68° West – stopped loggers

The data for day 076 is in the distribution, but was not processed.

Appendix: Sensors and Calibrations

Calibrations

The following pages contain current calibration sheets for the sensors used during this cruise.

Gravity Tie

Gravity Tie Spreadsheet

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

Date: 3/8/2010
Location: Punta Arenas, Chile
Station: Harbour Admin. Bldg.
Latitude: 53 09 S
Longitude: 070 55 W
Elevation:
Gravity: 981320.82

Reference Code Numbers:
Station no. 9537-50
ISGN no. 51230N

	Value	Time (GMT)
Ship's meter before gravity tie (Gravity (cu))	8979.1	11 58
Ship's meter after gravity tie (Gravity (cu))	8979.2	13 50
Average	8979.2	
Ship Gravimeter's Calibration Constant	1.0046	
Corrected ship's meter (QC Grav (mgal))	9020.5	

	Value	Time (GMT)
Ship's meter before gravity tie (serial, RVDAS)	8979.1	11 59
Ship's meter after gravity tie (serial, RVDAS)	8979.1	13 51
Average (for comparison check only)	8979.1	

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

Station	Value	Time (GMT)	Temp	Date	OBS mgal, averaged
Pier measurement 1	4914.75	12 24	54	March 8, 2010	
Pier measurement 2	4914.77	12 26	54	March 8, 2010	4964.25
Pier measurement 3	4914.75	12 27	54	March 8, 2010	
Average	4914.76				
Station measurement 1	4915.52	13 00	54	March 8, 2010	
Station measurement 2	4915.51	13 04	54	March 8, 2010	4965.01
Station measurement 3	4915.51	13 03	54	March 8, 2010	
Average	4915.51				
Pier measurement 4	4914.72	13 24	54	March 8, 2010	
Pier measurement 5	4914.76	13 25	54	March 8, 2010	4964.23
Pier measurement 6	4914.75	13 27	54	March 8, 2010	
Average	4914.74				

Gravity offset from last tie 972299.85
Drift since last tie -0.05

OBS Differences

Station to Pier (1, 2, & 3 averaged)	-0.76
Station to Pier (4, 5, & 6 averaged)	-0.78
Averaged Differences	-0.77
Gravity at pier	981320.05
Elevation of pier above gravimeter, meters	0.7
Earth differential gravity, mgal/meter	0.3
Gravity at ship's gravimeter	981320.26
Gravity Offset (for RVDAS)	972299.80

Comments

Gravity Tie Performed by Sheldon Blackman. Conditions were very good, with very little dock activity. The drift was very low considering the amount of ice breaking and rough sea activity during the cruise (NBP10-01).

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

Meteorology & Radiometers Shipboard Sensors

Sensor	Serial Number	Last Calibration Date	Comments
Port Anemometer (Gill Ultrasonic)	836076	5/15/2007	Installed 12/13/2008
Starboard Anemometer (Gill Ultrasonic)	836077	5/15/2007	Installed 11/17/2008
Bridge Anemometer	WM 45835	2/28/2007	Bridge (center)
Mast Barometer	BP01705	3/5/2009	Installed 12/19/2009
Mast Humidity	6135	7/30/2008	Installed 10/7/2009
Mast Temperature	6135	7/30/2008	Installed 10/7/2009
Mast PIR	32845F3	10/14/2008	Installed 10/15/2009
Mast PSP	32850F3	10/14/2008	Installed 10/15/2009
Mast PAR	6356	7/20/2009	Installed 3/1/2010
Mast GUV	25110203113	6/25/09	Installed 3/1/2010

Bridge Anemometer

RM Young Anemometer Calibration, Model 05106

S/N: 45835 **Date:** 28-Feb-07 **Cal'd By:** George Aukon

Clockwise Cal Motor RPM	Calculated Windspeed m/s	Measured Windspeed m/s	Delta m/s	Knots
0	0.00	0.00	0.00	0.0
200	0.98	0.90	0.08	1.9
500	2.45	2.40	0.05	4.8
1000	4.90	4.80	0.10	9.5
1500	7.35	7.30	0.05	14.3
2000	9.80	9.80	0.00	19.0
3000	14.70	14.60	0.10	28.6
4000	19.60	19.50	0.10	38.1
5000	24.50	24.30	0.20	47.6
6000	29.40	29.20	0.20	57.1
7000	34.30	34.10	0.20	66.6
8000	39.20	39.00	0.20	76.2
9000	44.10	43.90	0.20	85.7
10000	49.00	48.80	0.20	95.2
12000	58.80	58.60	0.20	114.2

Direction	Measured Direction	Delta Direction
0	359	0
30	29	1
60	59	1
90	89	1
120	119	1
150	148	2
180	179	1
210	210	0
240	240	0
270	270	0
300	301	-1
330	331	-1
0	1	-1

Note: Delta direction should not exceed + or - 3 degrees.

Counter Clockwise Cal Motor RPM	Calculated Windspeed m/s	Measured Windspeed m/s	Delta m/s
0	0.00	0.00	0.00
200	0.98	1.00	-0.02
500	2.45	2.50	-0.05
1000	4.90	4.90	0.00
1500	7.35	7.40	-0.05
2000	9.80	9.80	0.00
3000	14.70	14.80	-0.10
4000	19.60	19.80	-0.20
5000	24.50	24.60	-0.10
6000	29.40	29.50	-0.10
7000	34.30	34.50	-0.20
8000	39.20	39.40	-0.20
9000	44.10	44.40	-0.30
10000	49.00	49.30	-0.30
12000	58.80	59.60	-0.80

Caution: Do Not exceed 12000 rpm during Wind Speed test.

Wind Speed Threshold < 2.9 gm?	yes
Wind Direction Threshold < 30 gm?	yes

Additional Comments

Potentiometer and potentiometer coupling were replaced , vertical shaft bearings were cleaned and lubricated.

Note: Delta Windspeed should not exceed + or - 0.3 m/s for 0 - 5000 rpm

Mast Barometer

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

CALIBRATION REPORT
Barometric Pressure Sensor

Customer: *Raytheon Technical Services Co LLC*

Test Number: 93052
Test Date: 5 March 2009
Customer PO: RR44553-01
Sales Order: 0282

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	1	800.1
875.0	1251	875.1
950.0	2501	950.1
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	51500497	UKAS Lab 0221
Fluke Multimeter Model 8060A	4865407	234027

Tested By: [signature]

Mast Humidity Sensor

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

CALIBRATION REPORT
Relative Humidity Sensor

Customer: *Raytheon Technical Services Co LLC*

Test Number: 87910R
Test Date: 31 July 2008

Customer PO: RR41221-01
Sales Order: 9867

Test Sensor:
Model: 41372LC Serial Number: *6135*
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 (%)
10.0	5.9	11.6
30.0	8.8	30.0
50.0	12.1	50.7
70	15.1	69.6
90	18.0	87.2

(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
Fluke Multimeter Model 8060A	4865407	234027

Tested By: E Chenming

Mast Temperature Sensor

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

YOUNG

CALIBRATION REPORT
Temperature Sensor

Customer: *Raytheon Technical Services Co LLC*

Test Number: 87910
Test Date: 30 July 2008

Customer PO: RR41221-01
Sales Order: 9867

Test Sensor:
Model: 41372LC Serial Number: *6135*
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)
-49.93	4.009	-49.94
0.03	12.006	0.04
49.92	19.986	49.91

(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	8006-118	204365
Brooklyn Thermometer Model 22332-D5-FC	25071	249763
Brooklyn Thermometer Model 2X400-D7-FC	77532	228060
Keithley Multimeter Model 191	15232	234027

Tested By: E Chenney

Mast PIR

THE EPPLEY LABORATORY, INC.

12 Sheffield Ave., P.O. Box 419, Newport, RI 02840 USA

Telephone: 401-847-1020 Fax: 401-847-1031

Email: info@eppleylab.com Internet: www.eppleylab.com

EPLAB

Scientific Instruments for Precision Measurements Since 1917

STANDARDIZATION OF EPPLEY PRECISION INFRARED RADIOMETER Model PIR

Serial Number: 32845F3

Resistance: 713 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 24 °C as measured by Standard Omega Temperature Probe, RTD#1.

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

4.15 x 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: National Science Foundation
Port Hueneme, CA

S.O. Number: 61816

Date: October 14, 2008

Date of Test: Sept. 30, 2008

In Charge of Test: B Eppman

Reviewed by:

Remarks:

Mast PSP

THE EPPLEY LABORATORY, INC.
12 Sheffield Ave., P.O. Box 419, Newport, RI 02840 USA
Telephone: 401-847-1020 Fax: 401-847-1031
Email: info@eppleylab.com Internet: www.eppleylab.com

EPLAB
Scientific Instruments for Precision Measurements Since 1917

STANDARDIZATION OF EPPLEY PRECISION SPECTRAL PYRANOMETER Model PSP

Serial Number: 32850F3

Resistance: 706 Ω at 23 °C
Temperature Compensation Range: −20 to +40 °C

This radiometer has been compared with Standard Precision Spectral Pyranometer, Serial Number 21231F3 in Eppley's Integrating Hemisphere under radiation intensities of approximately 700 watts meter^{-2} (roughly one half a solar conatant).

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

7.89 x 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 1400 watts meter^{-2}. This radiometer is linear to within ± 0.5% up to this intensity.

The calibration of this instrument is traceable to standard self-calibrating cavity pyrheliometers in terms of the Systems Internationale des Unites (SI units), which participated in the Tenth International Pyrheliometric Comparisons (IPC X) at Davos, Switzerland in September-October 2005.

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".

Useful conversion facts: 1 cal cm^{-2} min^{-1} = 697.3 watts meter^{-2}
1 BTU/ft^{2}-hr^{-1} = 3.153 watts meter^{-2}

Shipped to: National Science Foundation
Port Hueneme, CA

Date of Test: Sept. 24, 2008

In Charge of Test: R. Eggeman

S.O. Number: 61817
Date: Oct. 14, 2008

Reviewed by: Thomas D Kirk

Remarks:

Mast PAR

Biospherical Instruments Inc.

CALIBRATION CERTIFICATE

Calibration Date	7/20/2009
Model Number	QSR240
Serial Number	6356
Operator	TPC
Standard Lamp	GS-1019(8/28/08)

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	90.9	mV
Probe Dark	0.1	mV
Probe Net Response	90.8	mV
RG780	0.3	mV

Corrected Lamp Output:

Output In Air (same condition as calibration):

9.088E+15	quanta/cm²sec
0.01509	uE/cm^{2}sec

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

Dry:	9.9899E-18	V/(quanta/cm²sec)
	6.0159E+00	V/(uE/cm^{2}sec)

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

Mast GUV

Biospherical Instruments Inc.

GUV-2511 Calibration Certificate

System Serial Number	25110203113	Date of Calibration	6/25/09
Calibration database	25110203113v5.mdb	Date of Certificate	6/25/2009
DASSN	0068	Standard of Spectral Irradiance	GS-1019(8/28/08)
Microprocessor Tag Number	2	Operator	TPC

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	2.6565E-10	2.7096E-05	7.9164E-03	2.8027E+00	7.3000E-05	7.1000E-05	3.4200E-04	μW/(cm²nm)
Ed0340	6	340	2.1645E-10	2.2078E-05	6.4502E-03	2.2743E+00	3.5400E-04	3.5800E-04	1.2200E-03	μW/(cm²nm)
Ed0313	8	313	2.2957E-10	2.3417E-05	6.8413E-03	2.4423E+00	6.5000E-05	6.3000E-05	6.7900E-04	μW/(cm²nm)
Ed0305	10	305	1.6588E-11	1.6919E-06	4.9431E-04	1.5292E-01	3.7700E-04	3.6900E-04	-2.2380E-03	μW/(cm²nm)
Ed0380	12	380	6.8861E-11	7.0238E-06	2.0521E-03	6.8434E-01	1.1490E-03	1.1430E-03	-1.3370E-03	μW/(cm²nm)
Ed0395	18	395	3.4619E-10	3.5311E-05	1.0316E-02	3.3698E+00	1.0600E-04	1.0400E-04	2.2100E-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	1.9164E-05	1.9547E+00	5.7109E+02	2.0333E+05	8.7700E-04	8.7100E-04	-1.2850E-03	μE/(cm²sec)

Auxilliary Channels	Address	Wavelength	Responsivity	ScaleS	ScaleM	ScaleL	OffsetS	OffsetM	OffsetL	Measurement Units
Ed0Gnd	0	0	1	1	1	1	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

Underway Sensors

Sensor	Serial Number	Last Calibration Date	Comments
Flourometer (Primary)	AFLD-011	10/29/2008	Installed 1/1/2010
Flourometer (Secondary)	AFLD-009	5/14/2009	Installed 4/1/2010
Remote Temperature	3850449-0389	6/6/2008	Installed 3/1/2010
Transmissometer	CST-397DR	8/7/2008	Installed 1/4/2010
TSG Conductivity	4550449-0242	3/31/2008	Installed 4/1/2009
TSG Temperature	4550449-0242	3/31/2008	Installed 4/1/2009

Underway Fluorometer (Primary)

CTD

PO Box 518
620 Applegate St.
Philomath OR 97370

WET Labs

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

Chlorophyll Fluorometer Characterization .

Date:	10/29/08
Serial #:	AFLD-011
Job#:	0011007
Tech:	K.C

Dark Counts	0.183 volts
CEV	2.902 volts
SF	8.6598
FSV	5.36 volts
Linearity:	0.999 R^2 (0–1.5 volts) 0.995 R^2 (0– 5.45 volts)

Notes:

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

CEV is the chlorophyll equivalent voltage. This value is the signal output of the fluorometer when using a fluorescent proxy that has been determined to be approximately equivalent to **25 µg/l** of a *Thalassiosira weissflogii* phytoplankton culture.

SF is the scale factor used to derive chlorophyll concentration from the signal voltage output of the fluorometer. The scale factor is determine by using the following equation: SF = (25) / (CEV – dark) e.g.(25 / (2.865 – 0.238) = 9.516)

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

Chlorophyll concentration expressed in µg/l (mg/m^3) can be derived by using the following equation: (µg/l) = (Vmeasured -dark) * SF

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

Underway Fluorometer (Secondary)

PO Box 518
620 Applegate St.
Philomath OR 97370

WET Labs

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

Chlorophyll Fluorometer Characterization .

Date:	**05/14/2009**
Serial #:	AFLT-009
Job#:	006066
Tech:	DCM

Dark Counts	**0.189 volts**
CEV	**2.708 volts**
SF	**9.924**
FSV	**5.31 volts**
Linearity:	**0.999 R^2 (0–1.5 volts)**
	0.995 R^2 (0 5.45 volts)

Notes:

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

CEV is the chlorophyll equivalent voltage. This value is the signal output of the fluorometer when using a fluorescent proxy that has been determined to be approximately equivalent to **25 µg/l** of a *Thalassiosira weissflogii* phytoplankton culture.

SF is the scale factor used to derive chlorophyll concentration from the signal voltage output of the fluorometer. The scale factor is determine by using the following equation: SF = (25) / (CEV – dark) e.g.(25 / (2.865 – 0.238) = 9.516)

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

Chlorophyll concentration expressed in µg/l (mg/m^3) can be derived by using the following equation: (µg/l) = (Vmeasured -dark) * SF

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

Underway Remote Temperature

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SEA-BIRD ELECTRONICS, INC.

1808 136th Place N.E., Bellevue, Washington, 98005 USA
Phone: (425) 643 - 9866 Fax (425) 643 - 9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 0389
CALIBRATION DATE: 06-Jun-08

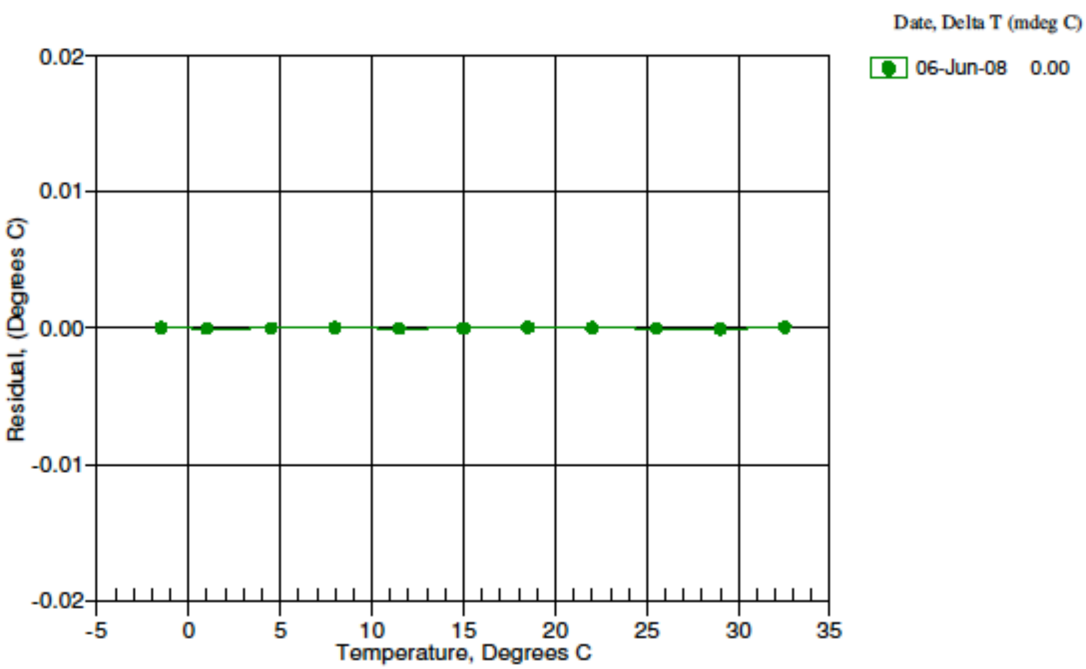
SBE 38 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

ITS-90 COEFFICIENTS
a0 = 5.665621e-005
a1 = 2.720183e-004
a2 = -2.302051e-006
a3 = 1.478988e-007

BATH TEMP (ITS-90)	INSTRUMENT OUTPUT	INST TEMP (ITS-90)	RESIDUAL (ITS-90)
-1.50010	749675.6	-1.50007	0.00003
0.99990	667866.6	0.99986	-0.00004
4.49990	569784.5	4.49990	-0.00000
7.99990	487738.4	7.99992	0.00002
11.50000	418866.9	11.49996	-0.00004
14.99990	360860.1	14.99992	0.00002
18.49990	311841.2	18.49995	0.00005
21.99990	270286.7	21.99992	0.00002
25.49990	234949.8	25.49987	-0.00003
29.00000	204808.3	28.99992	-0.00008
32.49990	179023.6	32.49995	0.00005

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

Residual = instrument temperature - bath temperature



Underway Transmissometer

PO Box 518
620 Applegate St.
Philomath, OR 97370

WET Labs

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

C-Star Calibration

Date August 7, 2008 S/N# CST-397DR Pathlength 25 cm

	Analog meter
V_d	0.061 V
V_{air}	4.842 V
V_{ref}	4.733 V

Temperature of calibration water	23.2 °C
Ambient temperature during calibration	21.5 °C

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

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 I 4/17/08

Underway TSG Conductivity

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SEA-BIRD ELECTRONICS, INC.
1808 136th Place N.E., Bellevue, Washington, 98005 USA
Phone: (425) 643 - 9866 Fax (425) 643 - 9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 0242
CALIBRATION DATE: 31-Mar-08

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

COEFFICIENTS:

g = -9.980367e-001
h = 1.523293e-001
i = -4.438334e-004
j = 5.882995e-005

CPcor = -9.5700e-008
CTcor = 3.2500e-006
WBOTC = 0.0000e+000

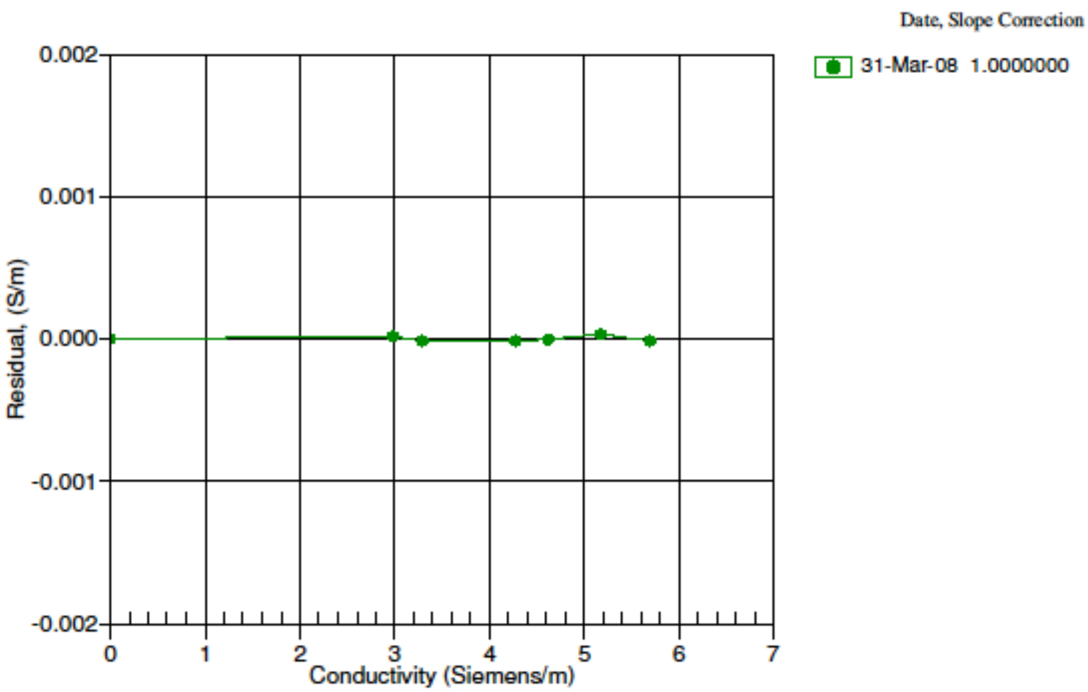
BATH TEMP (ITS-90)	BATH SAL (PSU)	BATH COND (Siemens/m)	INST FREQ (Hz)	INST COND (Siemens/m)	RESIDUAL (Siemens/m)
22.0000	0.0000	0.00000	2565.99	0.00000	0.00000
1.0000	34.8739	2.98042	5122.83	2.98043	0.00002
4.5000	34.8542	3.28795	5316.56	3.28793	-0.00001
15.0000	34.8112	4.27105	5892.53	4.27104	-0.00001
18.5000	34.8020	4.61668	6081.77	4.61667	-0.00001
24.0000	34.7913	5.17532	6375.44	5.17535	0.00003
29.0000	34.7843	5.69767	6637.87	5.69765	-0.00002

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



Underway TSG Temperature

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SEA-BIRD ELECTRONICS, INC.

1808 136th Place N.E., Bellevue, Washington, 98005 USA
Phone: (425) 643 - 9866 Fax (425) 643 - 9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 0242
CALIBRATION DATE: 31-Mar-08

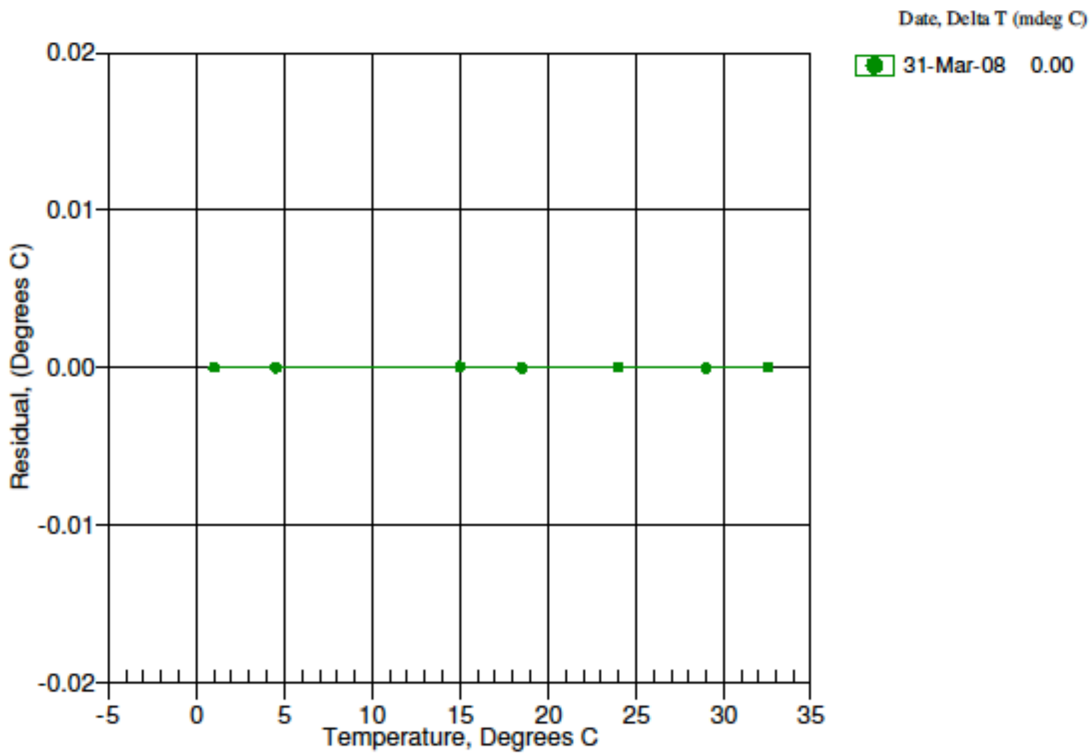
SBE 45 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

ITS-90 COEFFICIENTS
a0 = -3.912618e-006
a1 = 2.847375e-004
a2 = -3.193105e-006
a3 = 1.720429e-007

BATH TEMP (ITS-90)	INSTRUMENT OUTPUT	INST TEMP (ITS-90)	RESIDUAL (ITS-90)
1.0000	649832.1	1.0000	0.0000
4.5000	554895.8	4.5000	-0.0000
15.0000	352330.7	15.0000	0.0000
18.5000	304721.7	18.5000	-0.0000
24.0000	244015.9	24.0000	0.0000
29.0000	200610.7	29.0000	-0.0000
32.5000	175490.5	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



CTD Sensors

Sensor	Serial Number	Last Calibration Date	Comments
CTD Fish	377	11/4/2008	
CTD Fluorometer	FLRTD-867	5/29/2009	
CTD PAR	4469	4/22/2009	
CTD Conductivity (Primary)	042069	7/16/2009	
CTD Conductivity (Secondary)	042513	2/5/2009	
CTD Oxygen (Primary)	0152	8/8/2009	
CTD Oxygen (Secondary)	0158	4/22/2009	
CTD Temperature (Primary)	1238	2/5/2009	
CTD Temperature (Secondary)	1649	2/5/2009	
CTD Transmissometer	CST-891DR	9/30/2009	

CTD Fish

SEA-BIRD ELECTRONICS, INC.

1808 136th Place N.E., Bellevue, Washington, 98005 USA
Phone: (425) 643 - 9866 Fax (425) 643 - 9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 0377
CALIBRATION DATE: 04-Nov-08

SBE9plus PRESSURE CALIBRATION DATA
10000 psia S/N 58949

DIGIQUARTZ COEFFICIENTS:

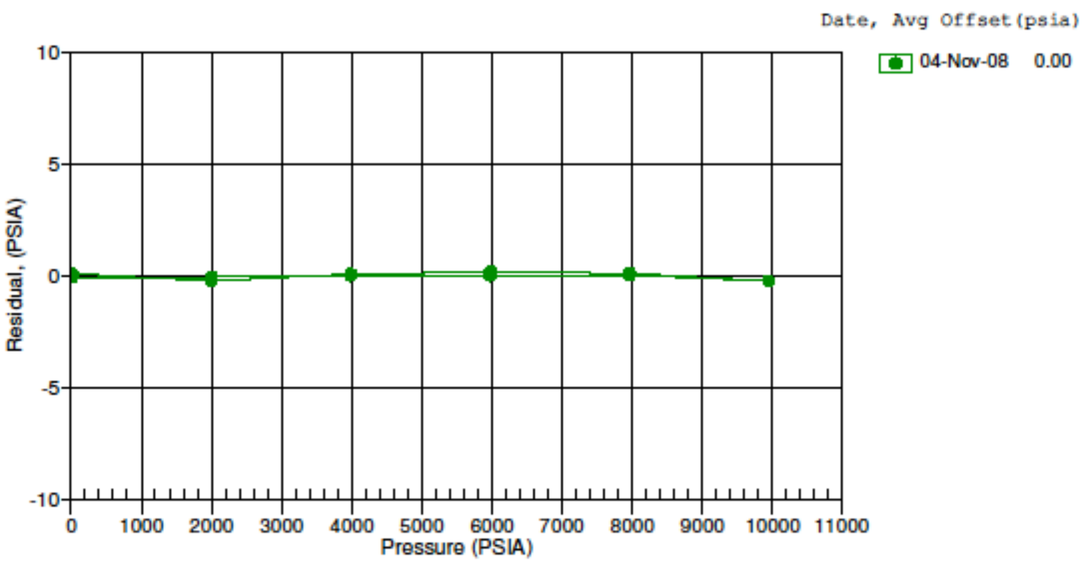
```
C1 =  -4.840395e+004
C2 =  -2.017057e-003
C3 =   1.464810e-002
D1 =   3.990600e-002
D2 =   0.000000e+000
T1 =   2.998386e+001
T2 =  -2.560542e-004
T3 =   3.869120e-006
T4 =   2.452640e-009
T5 =   0.000000e+000
```

AD590M, AD590B, SLOPE AND OFFSET:

```
AD590M =   1.14600e-002
AD590B =  -8.45734e+000
Slope =    0.99993
Offset =   0.3479 (dbars)
```

PRESSURE (PSIA)	INST OUTPUT(Hz)	INST TEMP(C)	INST OUTPUT (PSIA)	CORRECTED INST OUTPUT (PSIA)	RESIDUAL (PSIA)
14.481	33360.00	19.3	14.073	14.577	0.096
2001.608	34036.60	19.4	2001.032	2001.389	-0.219
3988.829	34698.10	19.4	3988.692	3988.901	0.072
5975.782	35345.00	19.5	5975.900	5975.961	0.179
7961.793	35977.90	19.5	7961.992	7961.906	0.113
9949.713	36598.40	19.5	9949.725	9949.491	-0.222
7962.802	35978.20	19.5	7962.922	7962.835	0.033
5975.849	35345.00	19.7	5975.808	5975.869	0.020
3988.776	34698.10	19.7	3988.589	3988.798	0.022
2001.616	34036.70	19.7	2001.214	2001.571	-0.045
14.489	33360.00	19.7	13.933	14.438	-0.051

Residual = corrected instrument pressure - reference pressure



CTD Fluorometer

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Philomath, OR 97370

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www.wetlabs.com

WET Labs

ECO Chlorophyll Fluorometer Characterization Sheet

Date: 5/29/2009 S/N: FLRTD-867

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	0.087	0.055	0.037	V	55	counts
Scale Factor (SF)	6	13	25	µg/l/V	0.0077	µg/l/count
Maximum Output	4.90	4.90	4.90	V	16326	counts
Resolution	0.9	0.9	0.9	mV	1.0	counts

Ambient temperature during characterization 0.0 °C

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

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

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

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

Resolution: Standard deviation of 1 minute of collected data.

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

FLRTD-867_workbookj1.xls Revision J 3/17/08

CTD PAR

Biospherical Instruments Inc

CALIBRATION CERTIFICATE

UNDERWATER PAR SENSOR WITH LOG AMPLIFIER

PAR 4469

Calibration Date: 04/22/09 **Job No.:** R-10265
Model Number: QSP-200L
Serial Number: 4469
Operator: TPC
Standard Lamp: GS-1019 (8/28/08)
Operating Voltage Range: 6 to 15 VDC (+)

Note: The QSP-200 uses a log amplifier to measure the detector signal current with V = log I (Amps) / IRef
To calculate irradiance, use this formula:

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

With the appropriate (solar corrected) Irradiance Calibration Factor:

Dry Calibration Factor:	**6.59E+12**	**quanta/cm²·sec/"amps"**	**1.09E-05**	**µEinsteins/cm²·sec/"amps"**
Wet Calibration Factor:	**1.11E+13**	**quanta/cm²·sec/"amps"**	**1.84E-05**	**µEinsteins/cm²·sec/"amps"**

Sensor Test Data and Results[4]

Sensor Supply Current (Dark):	53.3	mA		
Supply Voltage:	6	Volts		
Lamp Integrated PAR Irradiance:	9.09E+15	quanta/cm²·sec	0.01509	µEinsteins/cm²sec
SC3 Immersion Coefficient:	0.594	Scalar Correction: 1	PAR Solar Correction:	1.0000

Nominal Filter OD	Calibrated Trans.	Sensor Voltage	Measured Trans.		Measured Signal (Amps)	Estimated Signal (Amps)	Calc. Output (Volts)	Error (Volts)	Error (%)	Test Irrad. (quanta/ cm² sec)
No Filter	100.00%	3.140	100.00%		1.38E-07	1.38E-07	3.140	0.000	0.0	9.09E+15
0.3	36.10%	2.698	36.07%		4.98E-08	4.98E-08	2.699	0.001	0.1	3.28E+15
0.5	27.60%	2.584	27.72%		3.83E-08	3.81E-08	2.582	-0.002	-0.5	2.52E+15
1	9.27%	2.121	9.48%		1.31E-08	1.28E-08	2.112	-0.009	-2.2	8.62E+14
2	1.11%	1.239	1.16%		1.60E-09	1.53E-09	1.223	-0.016	-4.0	1.05E+14
3	0.05%	0.392	0.08%		1.08E-10	7.37E-11	0.326	-0.065	-31.9	7.13E+12

Dark Before: 0.140 Volts
Light - No Filter Hldr.: 3.140 Volts I_{Ref} = 1.00E-10 Amps
Dark After - NFH: 0.141 Volts I_{Dark} = 1.38E-10 Amps RG780 0.607
Average Dark 0.141 Volts $10^{V_{Dark}}$ = 1.381974 Amps

Notes:
1. Annual calibration is recommended.
2. There is increasing error associated with readings below zero.
3. The collector should be cleaned frequently with alcohol.
4) This section is for internal use and for more advanced analysis.

QSP-200L.QSP2300(2006-) .xls

CTD Conductivity (Primary)

SEA-BIRD ELECTRONICS, INC.
1808 - 136th Place Northeast, Bellevue, Washington 98005 USA
Phone: (425) 643-9866 Fax: (425) 643-9954 www.seabird.com

Conductivity Calibration Report

Customer:	Raytheon Polar Services Co.		
Job Number:	55215	**Date of Report:**	7/16/2009
Model Number:	SBE 04	**Serial Number:**	042069

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 using the program SEACON. 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: 7/16/2009 **Drift since last cal:** +0.00010 **PSU/month***

Comments:

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

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

Comments:

**Measured at 3.0 S/m*

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

CTD Conductivity (Secondary)

SEA-BIRD ELECTRONICS, INC.
1808 - 136th Place Northeast, Bellevue, Washington 98005 USA
Phone: (425) 643-9866 Fax: (425) 643-9954 www.seabird.com

Conductivity Calibration Report

Customer:	Raytheon Polar Services Co.		
Job Number:	53449	**Date of Report:**	2/5/2009
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 using the program SEACON. 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: 2/5/2009 **Drift since last cal:** 0.0000 **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.

CTD Oxygen (Primary)

SEA-BIRD ELECTRONICS, INC.
1808 136th Place N.E., Bellevue, Washington, 98005 USA
Phone: (425) 643 - 9866 Fax (425) 643 - 9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 0152
CALIBRATION DATE: 08-Aug-09p

SBE 43 OXYGEN CALIBRATION DATA

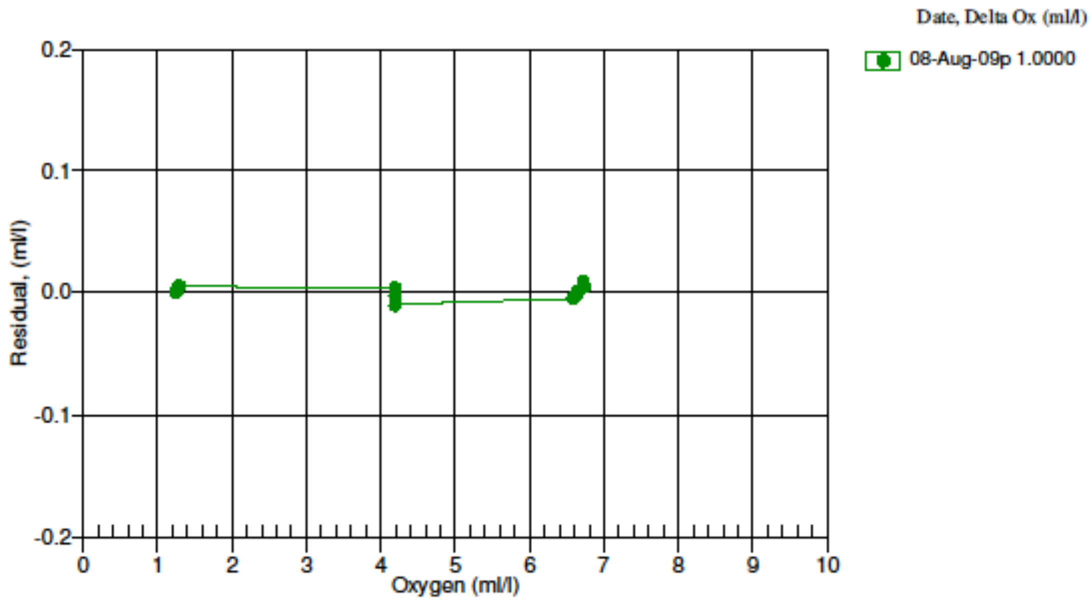
COEFFICIENTS
Soc = 0.5365
Voffset = -0.4992
Tau20 = 1.47

A = -8.7107e-003
B = 4.7080e-004
C = -5.8467e-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)
1.25	2.00	0.00	0.744	1.25	0.00
1.26	6.00	0.00	0.779	1.26	0.00
1.26	12.00	0.01	0.826	1.26	0.00
1.27	20.00	0.01	0.885	1.27	0.00
1.28	26.00	0.01	0.925	1.28	0.01
1.28	30.00	0.01	0.952	1.29	0.01
4.19	26.00	0.01	1.890	4.19	0.00
4.19	2.00	0.00	1.317	4.18	-0.01
4.19	20.00	0.01	1.767	4.19	-0.00
4.19	30.00	0.01	1.971	4.19	0.00
4.19	6.00	0.00	1.428	4.18	-0.01
4.19	12.00	0.01	1.584	4.18	-0.01
6.58	30.00	0.02	2.807	6.58	-0.00
6.63	26.00	0.01	2.698	6.63	-0.00
6.65	20.00	0.01	2.513	6.65	0.00
6.68	12.00	0.01	2.232	6.68	0.00
6.71	6.00	0.00	1.993	6.72	0.01
6.74	2.00	0.00	1.819	6.75	0.00

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



CTD Oxygen (Secondary)

SEA-BIRD ELECTRONICS, INC.

1808 136th Place N.E., Bellevue, Washington, 98005 USA
Phone: (425) 643 - 9866 Fax (425) 643 - 9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 0158
CALIBRATION DATE: 22-Apr-09p

SBE 43 OXYGEN CALIBRATION DATA

COEFFICIENTS

Soc = 0.4925
Voffset = -0.5035
Tau20 = 0.93

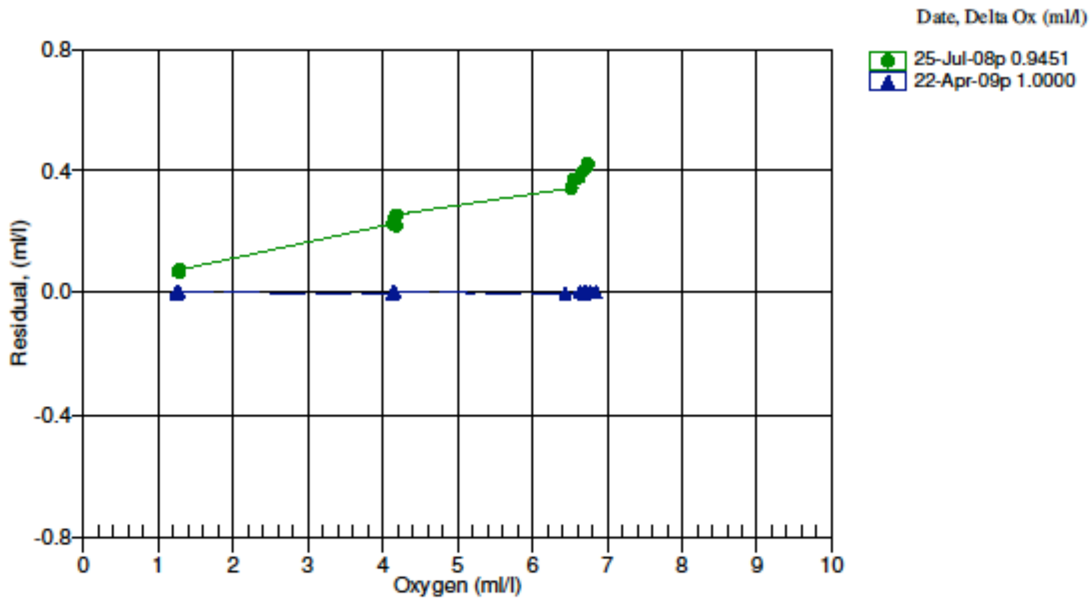
A = -6.5921e-003
B = 3.8339e-004
C = -4.6587e-006
E nominal = 0.036

NOMINAL DYNAMIC COEFFICIENTS

D1 = 1.92634e-4
D2 = -4.64803e-2
H1 = -3.30000e-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)
1.24	2.00	0.00	0.766	1.24	0.00
1.25	6.00	0.01	0.803	1.25	0.00
1.25	12.00	0.01	0.853	1.26	0.00
1.26	20.00	0.01	0.914	1.27	0.00
1.27	26.00	0.01	0.956	1.27	0.00
1.27	30.00	0.02	0.984	1.28	0.00
4.13	2.00	0.00	1.379	4.13	-0.01
4.14	12.00	0.01	1.652	4.13	-0.01
4.14	6.00	0.01	1.493	4.13	-0.01
4.14	20.00	0.01	1.845	4.14	-0.00
4.14	26.00	0.01	1.977	4.14	0.00
4.16	30.00	0.02	2.067	4.16	0.00
6.44	30.00	0.02	2.921	6.43	-0.00
6.63	26.00	0.01	2.861	6.63	0.00
6.69	20.00	0.01	2.672	6.69	-0.00
6.71	12.00	0.01	2.370	6.71	0.00
6.77	6.00	0.01	2.126	6.77	0.00
6.85	2.00	0.00	1.958	6.85	0.00

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



CTD Temperature (Primary)

SEA-BIRD ELECTRONICS, INC.
1808 136th Place N.E., Bellevue, Washington, 98005 USA
Phone: (425) 643 - 9866 Fax (425) 643 - 9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 1238
CALIBRATION DATE: 05-Feb-09

SBE3 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

ITS-90 COEFFICIENTS
g = 4.82517054e-003
h = 6.71363601e-004
i = 2.59913689e-005
j = 2.10021219e-006
f0 = 1000.0

IPTS-68 COEFFICIENTS
a = 3.68121338e-003
b = 5.97988720e-004
c = 1.45983757e-005
d = 2.10162121e-006
f0 = 6125.700

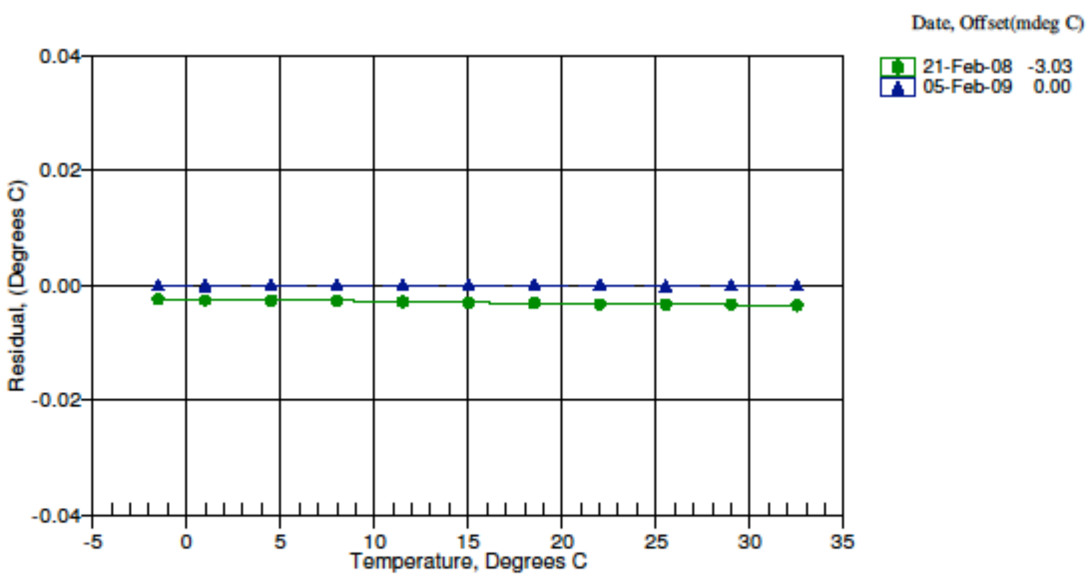
BATH TEMP (ITS-90)	INSTRUMENT FREQ (Hz)	INST TEMP (ITS-90)	RESIDUAL (ITS-90)
-1.5001	6125.700	-1.5001	0.00002
0.9999	6479.991	0.9999	-0.00002
4.4999	7000.496	4.4999	-0.00001
7.9999	7550.289	7.9999	-0.00001
11.4999	8130.146	11.4999	-0.00000
14.9999	8740.824	14.9999	0.00003
18.4999	9383.039	18.4999	0.00003
21.9999	10057.497	21.9999	0.00001
25.5000	10764.881	25.4999	-0.00008
28.9999	11505.829	28.9999	0.00002
32.4999	12280.963	32.4999	0.00002

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

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



CTD Temperature (Secondary)

SEA-BIRD ELECTRONICS, INC.
1808 136th Place N.E., Bellevue, Washington, 98005 USA
Phone: (425) 643 - 9866 Fax (425) 643 - 9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 1649
CALIBRATION DATE: 05-Feb-09

SBE3 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

ITS-90 COEFFICIENTS
g = 4.80716800e-003
h = 6.65138872e-004
i = 2.18651982e-005
j = 1.47887591e-006
f0 = 1000.0

IPTS-68 COEFFICIENTS
a = 3.68120750e-003
b = 6.01364454e-004
c = 1.39732107e-005
d = 1.48016531e-006
f0 = 5959.074

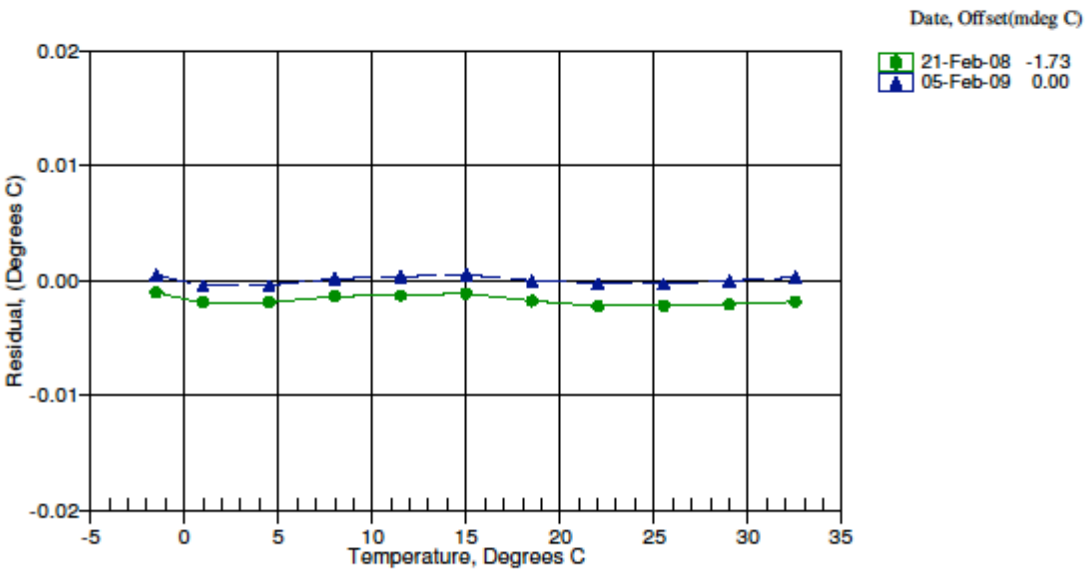
BATH TEMP (ITS-90)	INSTRUMENT FREQ (Hz)	INST TEMP (ITS-90)	RESIDUAL (ITS-90)
-1.5001	5959.074	-1.4996	0.00046
0.9999	6301.587	0.9994	-0.00049
4.4999	6804.702	4.4995	-0.00044
7.9999	7335.896	8.0000	0.00012
11.4999	7895.775	11.5002	0.00032
14.9999	8485.105	15.0004	0.00048
18.4999	9104.466	18.4999	-0.00004
21.9999	9754.699	21.9996	-0.00027
25.5000	10436.462	25.4997	-0.00033
28.9999	11150.362	28.9998	-0.00006
32.4999	11897.008	32.5001	0.00024

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



CTD Transmissometer

PO Box 518
620 Applegate St.
Philomath, OR 97370

WET Labs

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

C-Star Calibration

Date September 30, 2009 S/N# CST-891DR Pathlength 25 cm

	Analog meter
V_d	0.058 V
V_{air}	4.828 V
V_{ref}	4.725 V

Temperature of calibration water	21.1 °C
Ambient temperature during calibration	22.9 °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

MOCNESS Sensors

Sensor	Serial Number	Last Calibration Date	Comments
MOC1 Temperature	2168	7/16/2009	Installed 4/23/2010
MOC10 Temperature	1457	5/17/2009	Installed 4/17/2010
MOC Conductivity (Primary)	0924	3/4/2009	
MOC Conductivity (Secondary)	1431	7/16/2009	
MOC Fluorometer	FLRTD-855	7/30/2009	
MOC Temperature (Primary)	1497	7/15/2009	Installed 4/17/2010
MOC Temperature (Secondary)	4080	7/15/2009	Installed 4/17/2010

MOC1 Temperature

SEA-BIRD ELECTRONICS, INC.
1808 136th Place N.E., Bellevue, Washington, 98005 USA
Phone: (425) 643 - 9866 Fax (425) 643 - 9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 2168
CALIBRATION DATE: 16-Jul-09

SBE3 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

ITS-90 COEFFICIENTS
g = 4.35097705e-003
h = 6.44151925e-004
i = 2.36080556e-005
j = 2.25874390e-006
f0 = 1000.0

IPTS-68 COEFFICIENTS
a = 3.68121322e-003
b = 6.01274555e-004
c = 1.63310636e-005
d = 2.26031285e-006
f0 = 2938.688

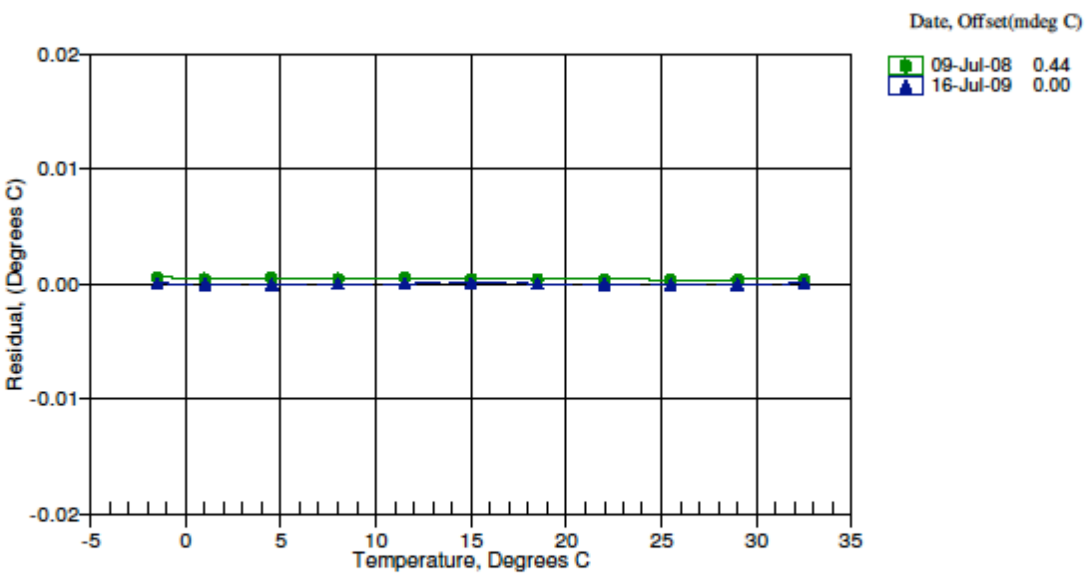
BATH TEMP (ITS-90)	INSTRUMENT FREQ (Hz)	INST TEMP (ITS-90)	RESIDUAL (ITS-90)
-1.5001	2938.688	-1.5001	0.00003
0.9999	3107.721	0.9999	-0.00003
4.4999	3356.058	4.4999	-0.00003
7.9999	3618.377	7.9999	-0.00000
11.4999	3895.054	11.4999	0.00001
14.9999	4186.460	15.0000	0.00005
18.4999	4492.940	18.4999	0.00001
21.9999	4814.846	21.9999	-0.00002
25.4999	5152.512	25.4999	-0.00003
28.9999	5506.254	28.9999	-0.00003
32.4999	5876.384	32.4999	0.00003

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



MOC10 Temperature

SEA-BIRD ELECTRONICS, INC.

1808 136th Place N.E., Bellevue, Washington, 98005 USA
Phone: (425) 643 - 9866 Fax (425) 643 - 9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 1457
CALIBRATION DATE: 14-May-09

SBE3 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

ITS-90 COEFFICIENTS	IPTS-68 COEFFICIENTS
g = 4.82887959e-003	a = 3.68121335e-003
h = 6.71173750e-004	b = 5.98531721e-004
i = 2.55460076e-005	c = 1.45274954e-005
j = 2.02568132e-006	d = 2.02707547e-006
f0 = 1000.0	f0 = 6156.833

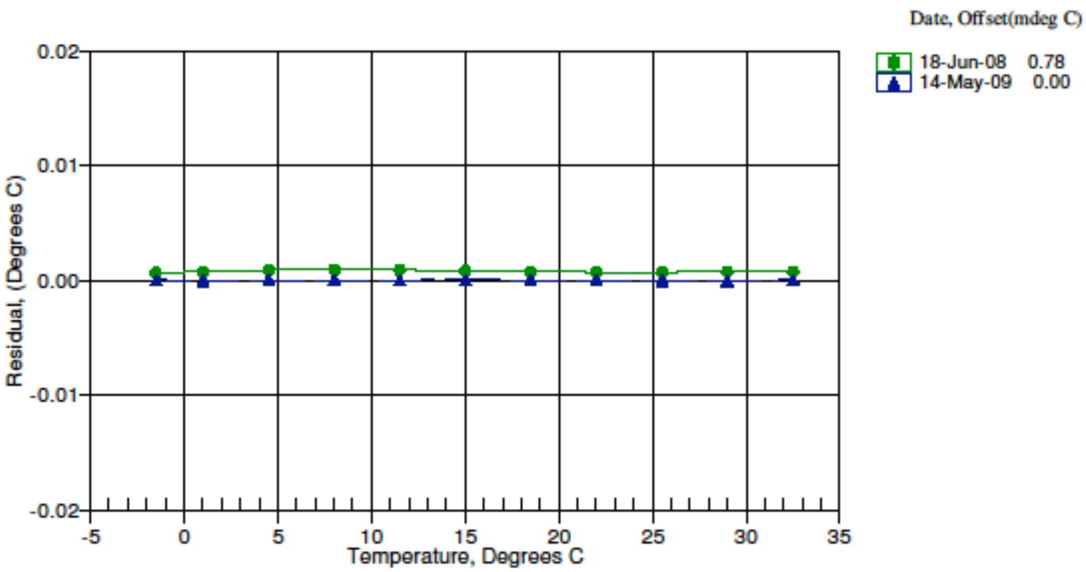
BATH TEMP (ITS-90)	INSTRUMENT FREQ (Hz)	INST TEMP (ITS-90)	RESIDUAL (ITS-90)
-1.5001	6156.833	-1.5001	0.00002
0.9999	6512.588	0.9999	-0.00003
4.4999	7035.205	4.4999	-0.00001
7.9999	7587.178	7.9999	-0.00000
11.4999	8169.287	11.4999	0.00001
14.9999	8782.283	14.9999	0.00002
18.4999	9426.890	18.4999	0.00000
21.9999	10103.823	21.9999	0.00001
25.4999	10813.744	25.4999	-0.00002
28.9999	11557.313	28.9999	-0.00004
32.4999	12335.169	32.4999	0.00003

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



MOC Conductivity (Primary)

SEA-BIRD ELECTRONICS, INC.

1808 136th Place N.E., Bellevue, Washington, 98005 USA

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

SENSOR SERIAL NUMBER: 0924
CALIBRATION DATE: 04-Mar-09

SBE4 CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Seimens/meter

GHIJ COEFFICIENTS

```
g =  -3.98675184e+000
h =   5.33619745e-001
i =  -5.96974198e-004
j =   6.00348589e-005
CPcor = -9.5700e-008 (nominal)
CTcor =  3.2500e-006 (nominal)
```

ABCDM COEFFICIENTS

```
a =   1.54707670e-006
b =   5.31624640e-001
c =  -3.98082768e+000
d =  -8.61976856e-005
m =   5.1
CPcor = -9.5700e-008 (nominal)
```

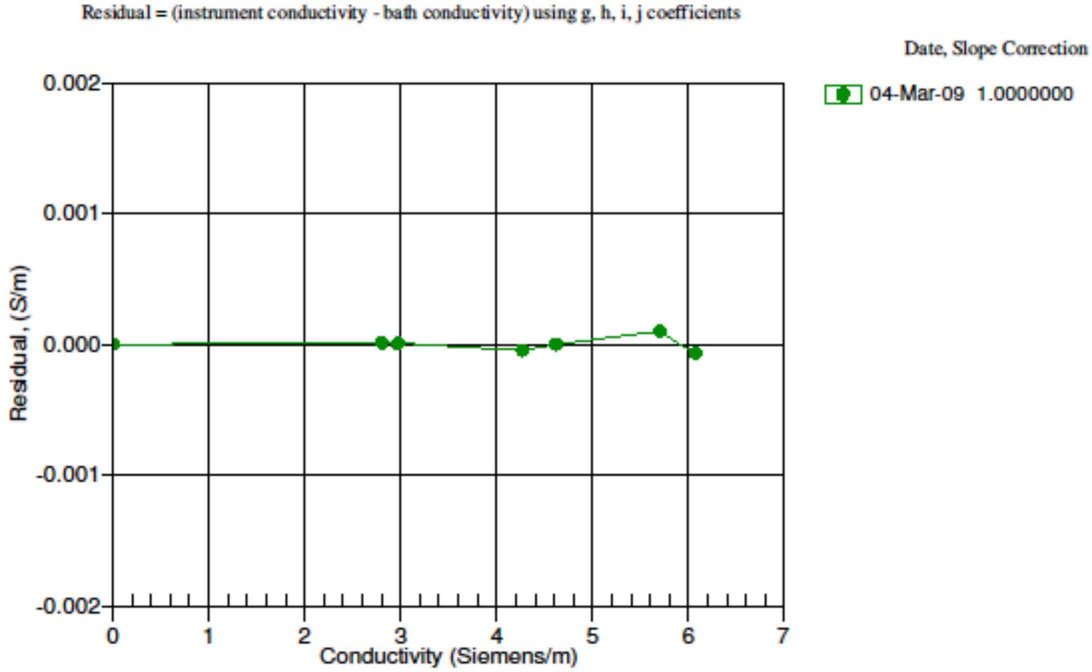
BATH TEMP (ITS-90)	BATH SAL (PSU)	BATH COND (Siemens/m)	INST FREQ (kHz)	INST COND (Siemens/m)	RESIDUAL (Siemens/m)
0.0000	0.0000	0.00000	2.73637	0.00000	0.00000
-1.0000	34.7922	2.80282	7.75310	2.80283	0.00001
1.0016	34.7926	2.97427	7.95749	2.97428	0.00001
15.0000	34.7935	4.26911	9.35581	4.26907	-0.00005
18.5000	34.7934	4.61566	9.69531	4.61566	-0.00000
29.0000	34.7900	5.69850	10.68507	5.69860	0.00010
32.5000	34.7824	6.07075	11.00402	6.07068	-0.00007

Conductivity = $(g + hf^2 + if^3 + jf^4) / 10(1 + \delta t + \varepsilon p)$ Siemens/meter

Conductivity = $(af^m + bf^2 + c + dt) / [10 (1 + \varepsilon p)$ Siemens/meter

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

Residual = (instrument conductivity - bath conductivity) using g, h, i, j coefficients



MOC Conductivity (Secondary)

SEA-BIRD ELECTRONICS, INC.

1808 136th Place N.E., Bellevue, Washington, 98005 USA
Phone: (425) 643 - 9866 Fax (425) 643 - 9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 1431
CALIBRATION DATE: 16-Jul-09

SBE4 CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Seimens/meter

GHIJ COEFFICIENTS
g = -4.25184463e+000
h = 5.51861327e-001
i = -2.16164558e-004
j = 4.10374206e-005
CPcor = -9.5700e-008 (nominal)
CTcor = 3.2500e-006 (nominal)

ABCDM COEFFICIENTS
a = 9.89960996e-006
b = 5.51283675e-001
c = -4.25058407e+000
d = -8.94310168e-005
m = 4.4
CPcor = -9.5700e-008 (nominal)

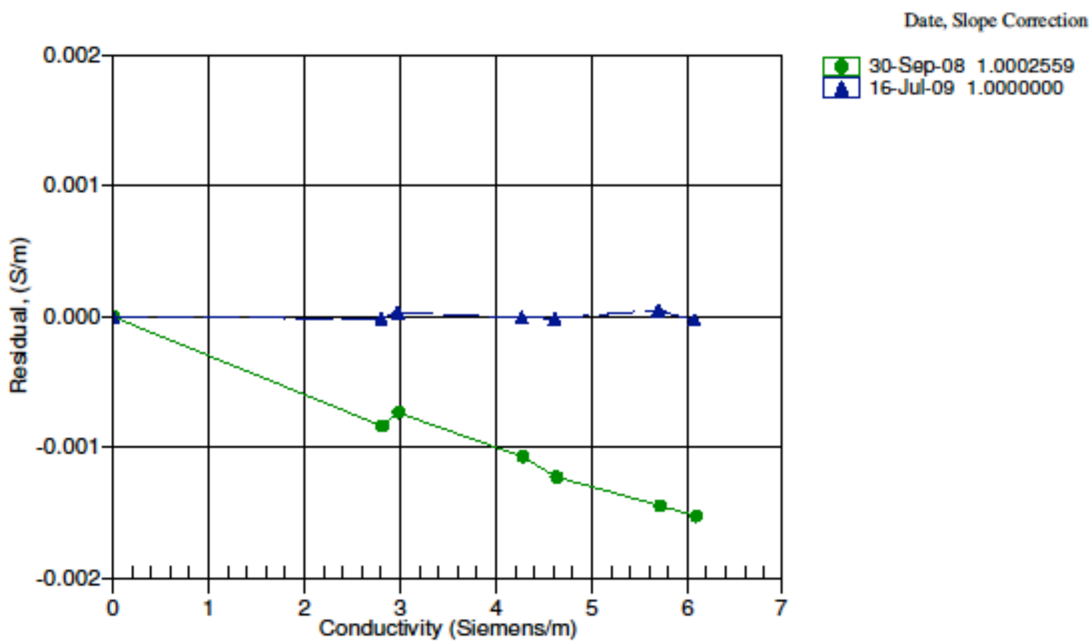
BATH TEMP (ITS-90)	BATH SAL (PSU)	BATH COND (Siemens/m)	INST FREQ (kHz)	INST COND (Siemens/m)	RESIDUAL (Siemens/m)
0.0000	0.0000	0.00000	2.77642	0.00000	0.00000
-1.0000	34.7598	2.80045	7.64008	2.80043	-0.00002
1.0000	34.7599	2.97160	7.83965	2.97163	0.00003
15.0000	34.7610	4.26555	9.20724	4.26554	-0.00001
18.5000	34.7611	4.61184	9.53951	4.61182	-0.00002
29.0000	34.7594	5.69405	10.50912	5.69409	0.00005
32.4999	34.7538	6.06631	10.82205	6.06628	-0.00003

Conductivity = $(g + hf^2 + if^3 + jf^4)/10(1 + \delta t + \varepsilon p)$ Siemens/meter

Conductivity = $(af^m + bf^2 + c + dt) / [10 (1 + \varepsilon p)$ Siemens/meter

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

Residual = (instrument conductivity - bath conductivity) using g, h, i, j coefficients



MOC 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: 7/30/2009 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	0.108	0.068	0.048	V	65	counts
Scale Factor (SF)	6	13	25	µg/l/V	0.0077	µg/l/count
Maximum Output	4.97	4.97	4.97	V	16326	counts
Resolution	0.7	0.7	0.7	mV	1.0	counts

Ambient temperature during characterization 23.2 °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_workbookj1.xls Revision J 3/17/08

MOC Temperature (Primary)

SEA-BIRD ELECTRONICS, INC.

1808 136th Place N.E., Bellevue, Washington, 98005 USA
Phone: (425) 643 - 9866 Fax (425) 643 - 9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 1497
CALIBRATION DATE: 15-Jul-09

SBE3 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

ITS-90 COEFFICIENTS
g = 4.73782197e-003
h = 6.69068410e-004
i = 2.85998185e-005
j = 2.63506700e-006
f0 = 1000.0

IPTS-68 COEFFICIENTS
a = 3.68121496e-003
b = 5.95387783e-004
c = 1.53352351e-005
d = 2.63659616e-006
f0 = 5372.795

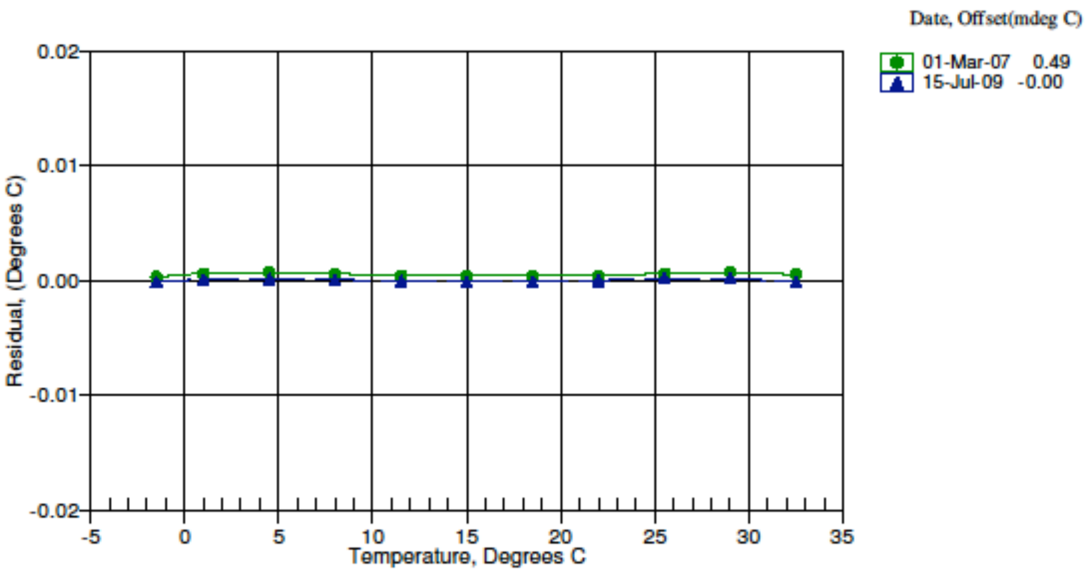
BATH TEMP (ITS-90)	INSTRUMENT FREQ (Hz)	INST TEMP (ITS-90)	RESIDUAL (ITS-90)
-1.5001	5372.795	-1.5002	-0.00010
0.9999	5684.988	1.0000	0.00006
4.4999	6143.834	4.5000	0.00012
7.9999	6628.735	7.9999	0.00004
11.4999	7140.400	11.4998	-0.00007
14.9999	7679.520	14.9998	-0.00010
18.4999	8246.736	18.4998	-0.00010
21.9999	8842.684	21.9999	-0.00001
25.4999	9467.960	25.5000	0.00015
28.9999	10123.099	29.0001	0.00018
32.4999	10808.588	32.4997	-0.00017

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



MOC Temperature (Secondary)

SEA-BIRD ELECTRONICS, INC.

1808 136th Place N.E., Bellevue, Washington, 98005 USA
Phone: (425) 643 - 9866 Fax (425) 643 - 9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 4080
CALIBRATION DATE: 15-Jul-09

SBE3 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

ITS-90 COEFFICIENTS
g = 4.38316091e-003
h = 6.44857226e-004
i = 2.22639857e-005
j = 1.73250478e-006
f0 = 1000.0

IPTS-68 COEFFICIENTS
a = 3.68121375e-003
b = 6.01367242e-004
c = 1.64253661e-005
d = 1.73400881e-006
f0 = 3091.501

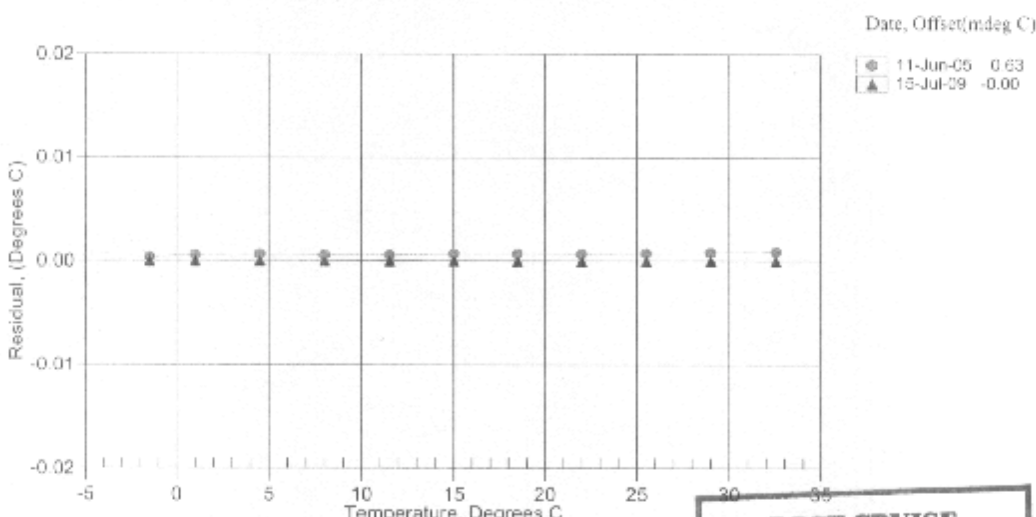
BATH TEMP (ITS-90)	INSTRUMENT FREQ (Hz)	INST TEMP (ITS-90)	RESIDUAL (ITS-90)
-1.5001	3091.501	-1.5001	-0.00001
0.9999	3269.303	0.9999	-0.00000
4.4999	3530.525	4.4999	0.00001
7.9999	3806.472	7.9999	0.00001
11.4999	4097.552	11.4999	-0.00002
14.9999	4404.175	14.9999	0.00001
18.4999	4726.720	18.4999	-0.00002
21.9999	5065.577	21.9999	-0.00000
25.4999	5421.111	25.4999	0.00001
28.9999	5793.679	28.9999	0.00003
32.4999	6183.620	32.4999	-0.00002

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

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



POST CRUISE CALIBRATION