Data Report NBP0901:

Amundsen Sea

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United States Antarctic Program

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Introduction

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

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

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

All the data has been 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: NBP0901 File		Description
/		Root level directory
	NBP0901.trk	Text file of cruise track (lat,lon)
	NBP0901.mgd	Full Cruise MGD77 data file
	NBP0901.gmt	GMT binary file of MGD77 data
	INSTCOEF.TXT	Instrument Coefficient File
	0901DATA.doc	Data Report NBP0901 (MS word)
	0901DATA.pdf	Data Report NBP0901 (pdf)
	0901MBRP.doc	Multibeam Report NBP0901
/plots		Cruise track plots
	0901_trk.ps	Cruise track plot (PostScript format)
	0901_trk.jpg	Cruise track plot (JPEG format)
/process		Processed data
	0901jgof.tar	JGOFS format data files
	0901qc.tar	Daily RVDAS QC postcript plots
	0901pco2.tar	Merged pCO2 data files
	0901mgd.tar	MGD Data
	0901proc.tar	Other processed data
/rvdas/nav		Navigation data
	0901gyr1.tar	Gyro raw data
	0901PCOD.tar	Trimble P-code raw data
	0901seap.tar	Seapath data
	0901adcp.tar	ADCP Data Sets
/rvdas/uw		Underway data
	0901ctdd.tar	CTD Depth
	0901eng1.tar	Engineering Data
	0901grv1.tar	Gravimeter raw data
	0901hdas.tar	HydroDAS raw data
	0901knud.tar	Knudsen raw data
	0901mbdp.tar	Multi-beam Depth
	0901mtsg.tar	Micro TSG data
	0901mwx1.tar	Meteorology raw data
	0901pco2.tar	pCO2 raw data
	0901pguv.tar	GUV raw data
	0901rtmp.tar	Remote temperature data
	0901svp1.tar	Sound velocity probe (in ADCP well)
/Imagery		Other Data, Files and Pictures
	0901Imag.tar	Satellite imagery
/ocean		Ocean Data
	0901ctd.tar	CTD data
	0901xbt.tar	XBT data
/science		Science drive data
	science.zip	Science drive 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

NBP0901 departed Punta Arenas, Chile on January 5, 2009 and spent roughly six weeks in the Amundsen Sea. Primary science questions focused on why ice shelves fringing the Antarctic coastline are rapidly melting, with secondary teams investigating questions about phytoplankton and sea ice dynamics in the Amundsen Sea. We returned to Punta Arenas on February 27, 2009. Science areas included Pine Island Bay and Pine Island Glacier front, the Thwaites Ice Tongue, and the Getz Ice Shelf and the continental shelf area of the Amundsen Sea.

Cruise Track

The distribution DVD includes a GMT cruise track file (NBP0901.trk). It contains the longitude and latitude of the ship's position at one-minute intervals extracted from the NBP0901.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/0901Imag.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/0901proc.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/0901jgof.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 NBP0901.mgd. The file NBP0901.gmt is created from the MGD77 dataset using the "mgd77togmt" utility. NBP0901.gmt can be used with the GMT plotting package.

The data used to produce the NBP0901.mgd file can be found on the distribution media in the file /process/0901proc.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, 1^{ST} sensor	In tenths of nanoteslas (gammas)
67-72	6	real	Magnetics total field, 2^{ND} 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 = 1^{st} or leading sensor 2 = 2^{nd} or trailing sensor 9 = Unspecified

Col	Len	Type	Contents	Description, Possible Values, Notes
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 10^{th} of mgals. Corrected for Eotvos, drift, tares
98-103	6	real	EOTVOS correction	In 10^{th} of mgals. E = 7.5 V cos phi sin alpha + 0.0042 V*V
104-108	5	real	Free-air anomaly	In 10^{th} of mgals G = observed G = theoretical
109-113	5	char	Seismic line number	Cross-reference for seismic data
114-119	6	char	Seismic shot-point number	
120	1	int	Quality code for navigation	5=Suspected, by the originating institution 6=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 0901adcp.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 0901pco2.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

Data acquired from conductivity, temperature and depth (CTD) casts has been placed in the tar file /ocean/0901ctd.tar. The archive contains ".gz" files of raw, processed and sv data with the file name beginning

`nbp0901XXX.yyy`

where XXX represents the cast number, and yyy is the data format.

XBT

Data acquired from expendable bathymetric temperature probes has been placed in the tar file /ocean/0901xbt.tar. The tar archive contains ".gz" files of the output files from the probe in the format

`T7_000XX.EDF`

where the first two digits indicate the probe type, the string after the underscore indicates the cast number, and the extension indicates the data format.

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: `NBP0901.mwx1.d330`

- The CruiseID is the numeric name of the cruise, in this case, NBP0901.
- 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	not collected	Varies	Simrad EK500 Sonar

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

**Primary underway bathymetry was switched from Knudsen to Bathy 2000 at 016:16:33.

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	

Bathy 2000 (bat1)

```
00+019:23:59:53.901 ;I04485.3ME -23.0, I00000.0,-99.9,0000@01/11/00,
23:59:52.08 PW2 PF1 SF1 PL3 MO4 SB3 PO0 TX1 TR: GM5 1500 06.7 -72.1
```

Field	Data	Format / Possible Values	Units
1	RVDAS time tag		
2	Flagged low frequency chn. depth w/ units	;FDDDDD.Dun where F = flag (V for valid, I for invalid), D=depth, un = units	meters
3	Low Frequency echo strength	EEE.EE	dB
4	Flagged high freq. chn. depth	not used	
5	High frequency echo strength	not used	
6	Signed heave data	SHHHH	cm
7	Date	mm/dd/yy	
8	Time	hh:mm:ss	
9	Transmit pulse window type	PW1=Rectangular PW2=Hamming PW3=Cosine PW4=Blackman	
10	Primary transmit frequency	PF1=3.5 kHz PF2=12.0 kHz	kHz
11	Parametric mode secondary	SF1=3.5 kHz	kHz

Field	Data	Format / Possible Values	Units
	frequency	SF2=12.0 kHz	
12	Pulse length	PL1=200usec PL2=500usec PL3=1msec PL4=2msec PL5=5msec PL6=10msec PL7=25msec If transmit mode is FM: PL1=25msec PL2=50msec PL3=100msec	
13	Operating mode	MO1=CW parametric MO2=CW MO3=FM parametric MO4=FM	
14	Frequency sweep bandwidth	SB1=1 kHz SB2=2 kHz SB3=5 kHz	kHz
15	Power level	PO1 = 0dB PO2 = -6dB PO3 = -12dB PO4 = -18dB PO5 = -24dB PO6 = -30dB PO6 = -30 dB PO7 = -36dB PO8 = -42dB	
16	Transmit mode	TX1=single ping active TX2=pinger listen TX3=multipinging TR TX4=multipinging TR TX5=multipinging TTRR TX6=multipinging TTTTRRRR TX7=multipinging TTTTTRRRRR	
17	Transmit Rate	TR3 = 4Hz TR4 = 2Hz TR5 = 1Hz TR6 = .5Hz TR7 = .33Hz TR8 = .25Hz TR9 = .20Hz TR: = .10Hz TR; = .05Hz	Hz
18	System gain mode	GM0=hydrographic AGC GM1 to GM9=hydrographic +3db to + 27db manual. GMA to GMD=hydrographic + 30db through + 60db manual GME to GMK=sub-bottom 1 through sub-bottom 7	
19	Speed of sound		m/sec
20	Depth of sonar window below sea-level		meters
21	Background noise level in fixed point reference		dB/V

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)

Field	Data	Units
1	LDTDS	
2	$EMDPT	
3	Center Beam Depth (corrected)	Meters

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

Field	Data	Conversion	Units
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
007:12:12		Departed Chilean EEZ at -55.3160, -79.1402– started loggers.
007:12:12	014:21:10	Fluorometry not valid. The fluorometer was not receiving sea water flow.
007:18:43		Reset sound speed velocity for Knudsen bathymetry sounder from 1450 to 1500 m/s.
011:16:50		Power reset to starboard anemometer.
014:18:53	014:20:50	PCOD data not logging. Serial cable from Trimble GPS was not communicating to DAS system.
014:21:37		Cleaned filters on TSG.
016:16:33		Changed bathymetry from Knudson (KND) to Bathy2000 (BAT)
017:12:15	017:12:18	Stopped bathymetry and ADCP for Autosub operations.
019:09:19	019:11:37	Interruption in underway TSG measurements.
019:20:05	020:05:35	Stopped bathymetry and ADCP for Autosub operations.
020:14:02	020:19:41	Stopped bathymetry and ADCP for Autosub operations.
021:21:17	022:07:35	Stopped bathymetry and ADCP for Autosub operations.
022:09:25	022:09:34	Stopped bathymetry and ADCP for Autosub operations.
022:15:35	022:19:35	Stopped bathymetry and ADCP for Autosub operations.
026:22:41	027:01:19	PCO2 system down.
027:21:26	028:10:32	Stopped bathymetry and ADCP for mooring setup operations.
034:00:40	034:03:30	Cleared ice from underway anemometer.
034:21:35	034:21:40	Stopped bathymetry and ADCP mooring setup operations.
038:23:59	039:03:20	Gap in PCOD data. The Trimble GPS lost connection with the GPS satellites.
040:18:52	040:19:24	ADCP was not updating.
048:13:05		Cleared ice from underway anemometer.
054:18:20	056:02:06	Gravimeter failed. Bad or no gravity data. Replaced instrument control system, and resumed logging. Note that all gravity data past this point is un-calibrated.
056:10:25		Entered Chilean EEZ at -54.15.9, -79.44.2– stopped loggers.

Appendix: Sensors and Calibrations

NBP0901 Shipboard Sensors:

Sensor	*Serial Number*	*Last Calibration Date*	*Comments*
Meteorology & Radiometers			
Port Anemometer (Gill Ultrasonic)	836076	5/15/2007	Installed 11/17/2008
Stbd Anemometer (Gill Ultrasonic)	836077	5/15/2007	Installed 11/17/2008
Bridge Anemometer	WM 45835	2/28/2007	Bridge (center)
Barometer	01705	12/1/2006	Installed 5/26/2008
Humidity/Wet Temp	06134	9/29/2006	Installed 5/26/2008
PIR	33023F3	6/20/2008	Installed 7/9/2008
PSP	33090F3	6/11/2008	Installed 7/9/2008
Mast PAR	6356	8/8/2007	Installed 8/28/2007
GUV (Mast)	25110203113	3/18/2008	Installed 3/18/2008
Underway			
Micro TSG	4549120-0226	1/12/2008	Installed 6/1/2008
Remote Temp (primary)	3849120-0178	1/12/2008	
Remote Temp	031267	4/12/2006	Installed 1/29/2007
Fluorometer	AFLD-011	5/31/2006	Installed 6/23/2007
Transmissometer	CST-557DR	12/20/2006	Installed 3/14/08

NBP0901 CTD Sensors:

Sensor	Serial Number	Last Calibration Date	Comments
CTD Fish	09P7536-0328	8/1/2008	
CTD Fish Pressure	53980	8/1/2008	
CTD Deck Unit	11P19858-0768	n/a	
Slip Ring Assembly	1.406	n/a	
Carousel Water Sampler	3211265-0066	n/a	
CTD Pump (Primary)	051646	4/17/2008	In House Cal
CTD Pump (Secondary)	051626	4/17/2008	In House Cal
Primary Conductivity Sensor	040926	8/21/2008	
Secondary Conductivity Sensor	041799	7/9/2007	
Primary Temperature Sensor	031457	6/18/2008	
Secondary Temperature Sensor	03P2299	6/18/2008	
Dissolved Oxygen	0161	6/19/2008	Used for casts 001-023, removed due to noisy signal
Dissolved Oxygen	0155	7/1/2008	
Dissolved Oxygen	0158	7/25/2008	Used on casts 024 -102, 104 - ?
Dissolved Oxygen	0139	2/5/2008	Used on cast 103
Fluorometer	AFLD-009	2/14/2008	
Transmissometer	CST-831DR	2/14/2008	
PAR	4469	2/1/2008	
Altimeter	42434	n/a	
Pinger 12khz	5518	n/a	In House Cal

Calibrations

The following pages are replicas of current calibration sheets for the sensors used during this cruise.

Gravity Tie Start (Punta Arenas)

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: **1/3/2009**
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. 9337-50
ISGN no. 51230N

	Value	Time (GMT)
Ship's meter before gravity tie (Gravity (cu))	8974.4	17:37
Ship's meter after gravity tie (Gravity (cu))	8974.6	18:38
Average	8974.5	
Ship Gravimeter's Calibration Constant	1.0046	
Corrected ship's meter (QC Grav (mgal))	9015.8	

	Value	Time (GMT)
Ship's meter before gravity tie (serial, RVDAS)	8974.5	17:37
Ship's meter after gravity tie (serial, RVDAS)	8974.6	18:38
Average (for comparison check only)	8974.6	

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	4913.36	17:51	53	January 3, 2009	
Pier measurement 2	4913.33	17:53	53	January 3, 2009	4962.82
Pier measurement 3	4913.35	17:54	53	January 3, 2009	
Average	4913.35				
Station measurement 1	4914.18	17:51	53	January 3, 2009	
Station measurement 2	4914.14	17:53	53	January 3, 2009	4963.64
Station measurement 3	4914.14	17:53	53	January 3, 2009	
Average	4914.15				
Pier measurement 4	4913.40	18:30	53	January 3, 2009	
Pier measurement 5	4913.45	18:31	53	January 3, 2009	4962.91
Pier measurement 6	4913.45	18:31	53	January 3, 2009	
Average	4913.43				

Gravity offset from last tie	972304.81
Drift since last tie	-0.50

OBS Differences	
Station to Pier (1, 2, & 3 averaged)	-0.81
Station to Pier (4, 5, & 6 averaged)	-0.73
Averaged Differences	-0.77
Gravity at pier	981320.05
Elevation of pier above gravimeter, meters	0.1
Earth differential gravity, mgal/meter	0.3
Gravity at ship's gravimeter	981320.09
Gravity Offset (for RVDAS)	972304.31

Comments

Gravity Tie performed by Greg Watson at pier in Punta Arenas and at port admin building.

Anemometer (Bridge)

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 potenbometer 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

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: 79261 Customer PO: RM35605-50
Test Date: 26 September 2007 Sales Order: 9248

Test Sensor:
Model: 61201 Serial Number: *BP00872*
Description: Barometric Pressure Sensor

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

Reference Pressure (hPa)	Voltage Output (millivolts)	Indicated (1) Pressure (hPa)
800.0	0	800.0
875.0	1251	875.1
950.0	2501	950.1
1025.0	3750	1025.0
1100.0	4997	1099.8

(1) Calculated from voltage output

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

Reference Instrument	Serial #	NIST Test Reference
Druck Pressure Controller Model DPI515	51500497	UKAS Lab 0221
Fluke Multimeter Model 8060A	4865407	234027

Tested By: E Chenning

METEOROLOGICAL INSTRUMENTS
Tel: 231-946-3980 Fax: 231-946-4772 Email: met.sales@youngusa.com Website: www.youngusa.com

Humidity Sensor

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

YOUNG

CALIBRATION REPORT
Relative Humidity Sensor

Customer: *Raytheon Technical Services Co LLC*

Test Number: 78223R
Test Date: 26 September 2007
Customer PO: RM35605-50
Sales Order: 9248

Test Sensor:
Model: 41372LC
Serial Number: 6733
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 (%)
10.3	6.0	12.2
30.3	8.8	29.9
50.3	12.0	50.0
70.2	15.1	69.2
89.6	17.9	85.8

(1) Calculated from voltage output

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

Reference Instrument	Serial #	NIST Test Reference
Vaisala Humidity Sensor Model 35AC	N475040	TN 266152
Fluke Multimeter Model 8060A	4865407	234027

Tested By: E Chrisman

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

Temperature Sensor

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

CALIBRATION REPORT
Temperature Sensor

Customer: *Raytheon Technical Services Co LLC*

Test Number: 78223 Customer PO: RM35605-50
Test Date: 26 September 2007 Sales Order: 9248

Test Sensor:
Model: 41372LC Serial Number: 6733
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	4.012	-49.93
0.03	12.005	0.03
49.99	19.998	49.98

(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	5006-118	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

METEOROLOGICAL INSTRUMENTS
Tel: 231-946-3980 Fax: 231-946-4772 Email: met.sales@youngusa.com Website: www.youngusa.com

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
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Since 1917

STANDARDIZATION OF EPPLEY PRECISION INFRARED RADIOMETER Model PIR

Serial Number: 33023F3

Resistance: 739 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 25 °C as measured by Standard Omega Temperature Probe, RTD#1.

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

3.90 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: Raytheon Technical Services
National Science Foundation
Port Hueneme, CA

Date of Test: June 13, 2008

In Charge of Test: R. T. Eppley

S.O. Number: 61667
Date: June 20, 2008

Reviewed by: Thomas J. Kuh

Remarks:

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: 33090F3

Resistance: 700 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:

8.06 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: Raytheon Technical Services
National Science Foundation
Port Hueneme, CA

Date of Test: June 11, 2008

In Charge of Test: R. T. Eppley

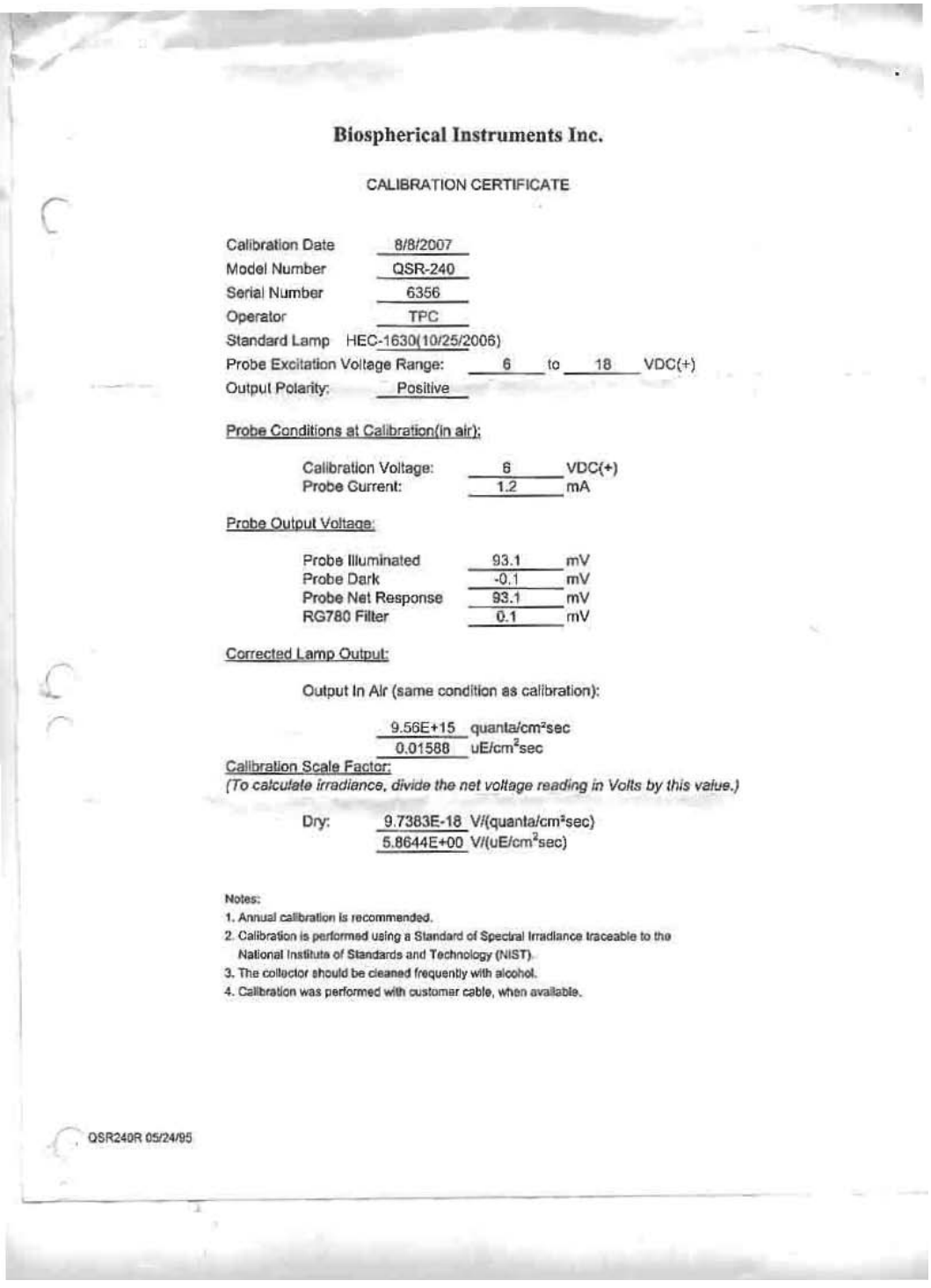
S.O. Number: 61666

Date: June 20, 2008

Reviewed by: Thomas J. Kuhn

Remarks:

PAR



Biospherical Instruments Inc.

CALIBRATION CERTIFICATE

Calibration Date 8/8/2007
Model Number QSR-240
Serial Number 6356
Operator TPC
Standard Lamp HEC-1630(10/25/2006)
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 93.1 mV
Probe Dark -0.1 mV
Probe Net Response 93.1 mV
RG780 Filter 0.1 mV

Corrected Lamp Output:

Output In Air (same condition as calibration):

9.56E+15 quanta/cm²sec
0.01588 uE/cm²sec

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

Dry: 9.7383E-18 V/(quanta/cm²sec)
5.8644E+00 V/(uE/cm²sec)

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

QSR240R 05/24/95

GUV

Biospherical Instruments Inc.

GUV-2511 Calibration Certificate

System Serial Number	25110203113	Date of Calibration	3/18/08
Calibration database	25110203113v4.mdb	Date of Certificate	3/18/2008
DASSN	0068	Standard of Spectral Irradiance	91537(10/25/06)
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	2.7010E-10	2.7551E-05	8.0491E-03	2.8497E+00	6.5000E-05	6.4000E-05	2.2300E-04	µW/(cm²nm)
Ed0340	6	340	2.2027E-10	2.2467E-05	6.5640E-03	2.3144E+00	3.7400E-04	3.7600E-04	1.1590E-03	µW/(cm²nm)
Ed0313	8	313	2.4100E-10	2.4539E-05	7.1692E-03	2.5594E+00	1.0000E-04	1.0000E-04	6.9100E-04	µW/(cm²nm)
Ed0305	10	305	1.6600E-11	1.6943E-06	4.9499E-04	1.5313E-01	4.1300E-04	4.0500E-04	-2.2080E-03	µW/(cm²nm)
Ed0380	12	380	7.0759E-11	7.2174E-06	2.1086E-03	7.0320E-01	1.1140E-03	1.1050E-03	-1.4780E-03	µW/(cm²nm)
Ed0395	18	395	3.4926E-10	3.5624E-05	1.0408E-02	3.3997E+00	1.3100E-04	1.3000E-04	2.2300E-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	1.9205E-05	1.9589E+00	5.7230E+02	2.0376E+05	8.8600E-04	8.7700E-04	-1.3030E-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

Calibration Data – Do Not Destroy

page 2 of 2

Micro-TSG Calibration Files

Temperature Sensor (Micro-TSG)

63

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: 0226
CALIBRATION DATE: 12-Jan-08

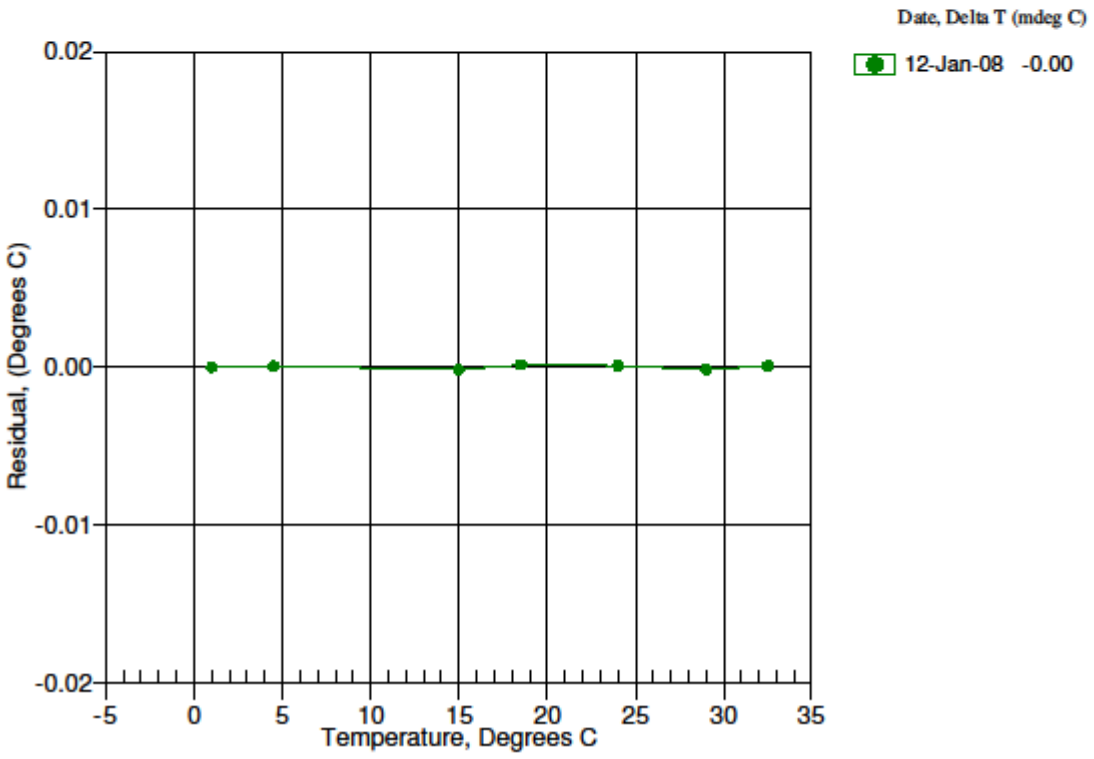
SBE 45 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

ITS-90 COEFFICIENTS
a0 = -6.625307e-005
a1 = 2.870318e-004
a2 = -3.279891e-006
a3 = 1.750784e-007

BATH TEMP (ITS-90)	INSTRUMENT OUTPUT	INST TEMP (ITS-90)	RESIDUAL (ITS-90)
1.0000	744351.4	1.0000	-0.0000
4.4999	636501.4	4.5000	0.0001
15.0000	405773.8	14.9998	-0.0002
18.5000	351383.7	18.5001	0.0001
24.0000	281927.0	24.0001	0.0001
29.0000	232171.7	28.9998	-0.0002
32.5000	203331.2	32.5001	0.0001

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

Residual = instrument temperature - bath temperature



Conductivity Sensor (Micro-TSG)

64

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: 0226
CALIBRATION DATE: 12-Jan-08

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

COEFFICIENTS:

g = -1.014919e+000	CPcor = -9.5700e-008
h = 1.569437e-001	CTcor = 3.2500e-006
i = -4.469846e-004	WBOTC = 9.8072e-007
j = 6.064779e-005	

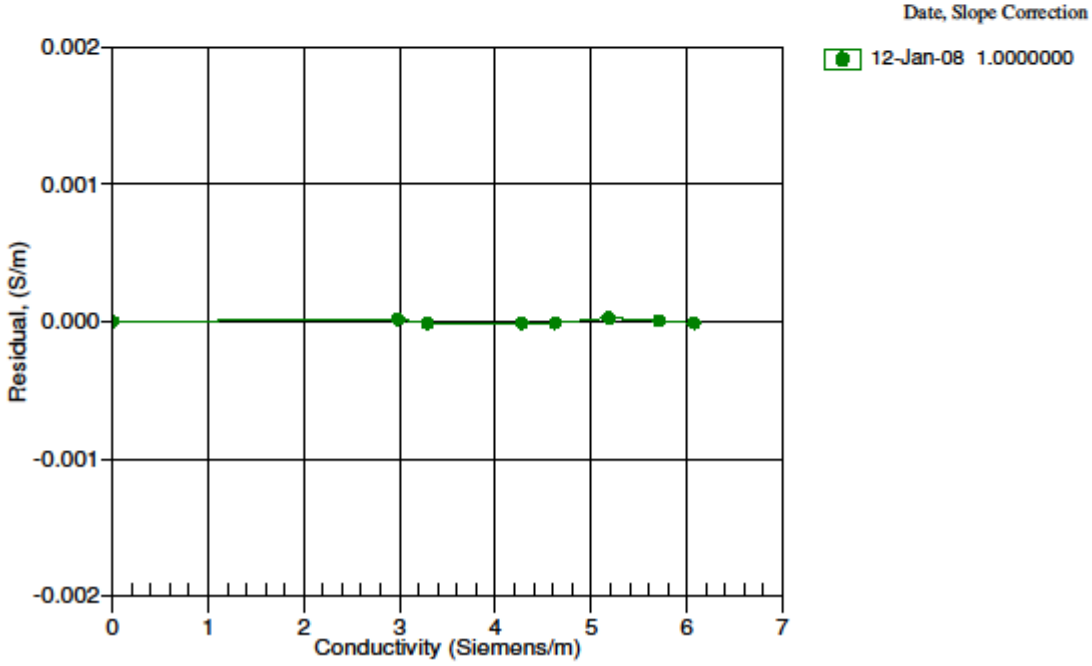
BATH TEMP (ITS-90)	BATH SAL (PSU)	BATH COND (Siemens/m)	INST FREQ (Hz)	INST COND (Siemens/m)	RESIDUAL (Siemens/m)
22.0000	0.0000	0.00000	2549.02	0.00000	0.00000
1.0000	34.9254	2.98440	5059.48	2.98442	0.00002
4.4999	34.9056	3.29231	5250.05	3.29229	-0.00001
15.0000	34.8618	4.27660	5816.78	4.27659	-0.00001
18.5000	34.8524	4.62264	6003.02	4.62263	-0.00001
24.0000	34.8419	5.18201	6292.11	5.18204	0.00003
29.0000	34.8360	5.70518	6550.56	5.70519	0.00001
32.5000	34.8334	6.07863	6728.76	6.07862	-0.00001

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

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

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

Residual = instrument conductivity - bath conductivity



Underway Temperature Sensor (Primary Remote)

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: 0178
CALIBRATION DATE: 07-Jan-08

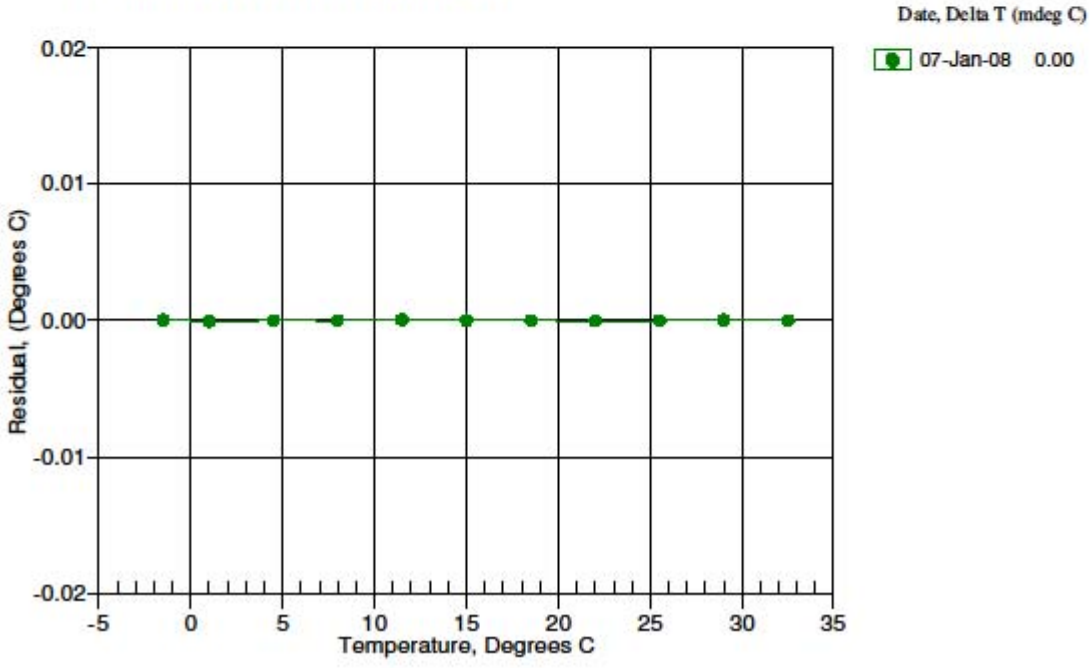
SBE 38 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

ITS-90 COEFFICIENTS
a0 = -4.331693e-005
a1 = 2.811171e-004
a2 = -2.677535e-006
a3 = 1.661218e-007

BATH TEMP (ITS-90)	INSTRUMENT OUTPUT	INST TEMP (ITS-90)	RESIDUAL (ITS-90)
-1.50010	750904.5	-1.50006	0.00004
0.99990	671271.1	0.99984	-0.00006
4.49990	575397.3	4.49989	-0.00001
7.99990	494813.7	7.99989	-0.00001
11.49990	426851.8	11.49995	0.00005
14.99990	369349.8	14.99992	0.00002
18.50000	320540.5	18.50001	0.00001
22.00000	278985.0	21.99995	-0.00005
25.49990	243497.2	25.49989	-0.00001
28.99990	213101.8	28.99992	0.00002
32.49990	186995.1	32.49990	0.00000

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 Temperature Sensor (Secondary Remote)

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: 1267
CALIBRATION DATE: 12-Apr-06

SBE3 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPRATURE SCALE

ITS-90 COEFFICIENTS

g = 4.76625066e-003
h = 6.64522185e-004
i = 2.84261863e-005
j = 2.62601374e-006
f0 = 1000.0

ITS-68 COEFFICIENTS

a = 3.68121498e-003
b = 5.89543636e-004
c = 1.47312260e-005
d = 2.62748536e-006
f0 = 5707.029

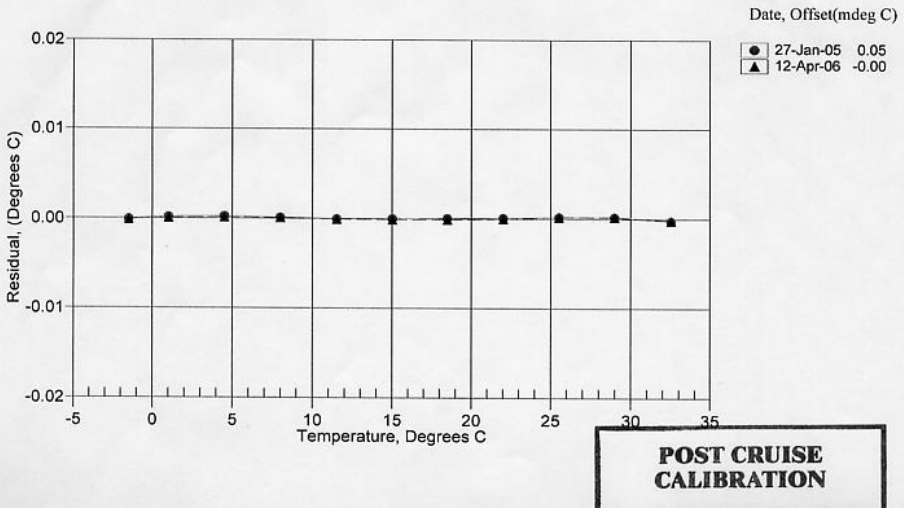
BATH TEMP (ITS-90)	INSTRUMENT FREQ (Hz)	INST TEMP (ITS-90)	RESIDUAL (ITS-90)
-1.5001	5707.029	-1.5002	-0.00010
1.0000	6042.027	1.0001	0.00005
4.4999	6534.652	4.5000	0.00014
7.9999	7055.608	8.0000	0.00007
11.4999	7605.659	11.4998	-0.00008
14.9999	8185.578	14.9998	-0.00014
18.4999	8796.088	18.4998	-0.00011
22.0000	9437.895	22.0000	-0.00003
25.4999	10111.624	25.5001	0.00019
28.9999	10817.898	29.0001	0.00019
32.4999	11557.257	32.4997	-0.00019

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 ITS-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

Underway fluorometer (Primary)

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 Transmissometer

PO Box 518
620 Applegate St.
Philomath, OR 97370

WET Labs
Western Environmental Technology Laboratories Inc.

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

C-Star Calibration and Repairs

Date	12/20/2006	Customer		Raytheon Polar Services	
Job #	021020	S/N#	CST-557DR	Work order	007

Repairs and Modifications:

Replaced bulkhead connector, 38 mm lens and o-rings. Baked to remove moisture. Recalibrated.

Comments:

- Shake-tested unit
- Pressure-tested unit
- Noise test: 1 sample/sec for 60 sec
- Stability test: 1 sample/min for 12 hrs
- Performed water calibration
- Temperature test, 27–2 °C
- Updated unit's calibration sheet

cstarwkbkf1.xls Revision F 6/12/03

PO Box 518
620 Applegate St.
Philomath, OR 97370

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

C-Star Calibration

Date	December 20, 2006	Customer	Raytheon Polar Services	Work order	007
Job #	021020	S/N#	CST-557DR	Pathlength	25 cm

	Analog meter
V_d	**0.056 V**
V_{air}	**4.800 V**
V_{ref}	**4.770 V**

Temperature of calibration water	18.0 °C
Ambient temperature during calibration	22.6 °C

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

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

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

V_d Meter output with the beam blocked. This is the offset.
V_{air} Meter output in air with a clear beam path.
V_{ref} Meter output with clean water in the path.
Temperature of calibration water: temperature of clean water used to obtain V_{ref}.
Ambient temperature: meter temperature in air during the calibration.
V_{sig} Measured signal output of meter.

cstarwkbkf1.xls Revision F 1/17/05

CTD Pressure Sensor (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: 0328
CALIBRATION DATE: 01-Aug-07

SBE9plus PRESSURE CALIBRATION DATA
10000 psia S/N 53980

DIGIQUARTZ COEFFICIENTS:

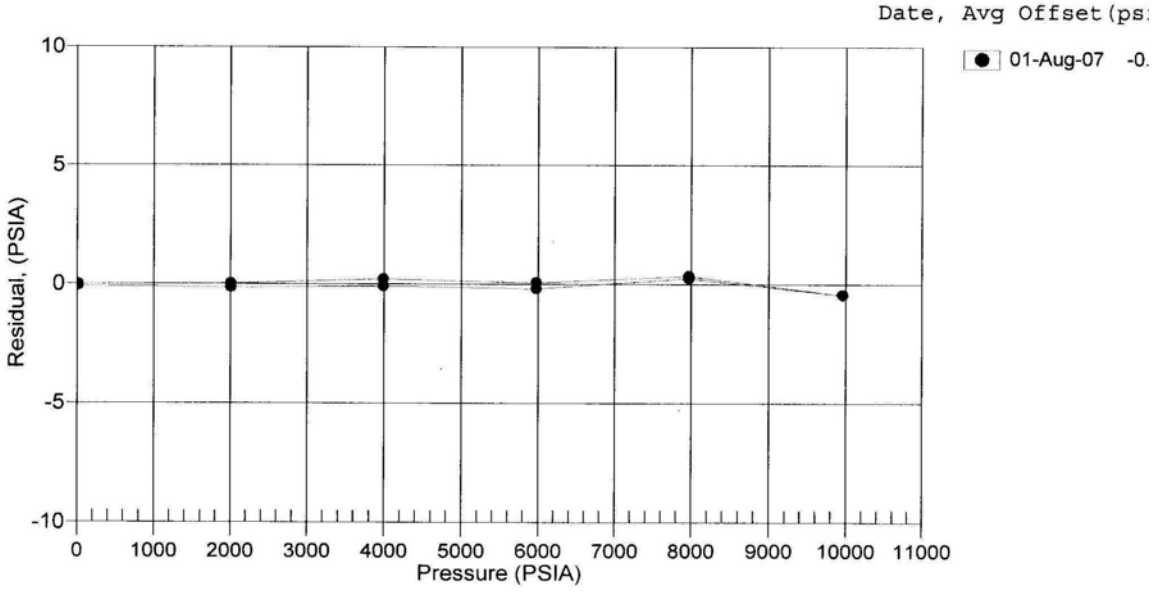
C1 = -5.847002e+004
C2 = 6.910390e-001
C3 = 1.753360e-002
D1 = 4.241600e-002
D2 = 0.000000e+000
T1 = 3.026040e+001
T2 = -1.938830e-004
T3 = 4.330190e-006
T4 = 2.020250e-009
T5 = 0.000000e+000

AD590M, AD590B, SLOPE AND OFFSET:

AD590M = 1.13300e-002
AD590B = -8.47592e+000
Slope = 0.99999
Offset = -0.8347 (dbars)

PRESSURE (PSIA)	INST OUTPUT(Hz)	INST TEMP(C)	INST OUTPUT (PSIA)	CORRECTED INST OUTPUT (PSIA)	RESIDUAL (PSIA)
14.647	33053.30	22.4	15.793	14.583	-0.064
2001.665	33609.50	22.7	2002.748	2001.525	-0.140
3988.943	34155.20	22.7	3990.098	3988.862	-0.081
5976.002	34690.70	22.8	5977.067	5975.820	-0.182
7962.994	35216.70	22.8	7964.504	7963.244	0.250
9950.680	35733.40	22.9	9951.508	9950.236	-0.444
7962.873	35216.70	23.0	7964.485	7963.225	0.352
5975.724	34690.70	23.0	5977.040	5975.792	0.068
3988.622	34155.20	23.1	3990.073	3988.837	0.215
2001.487	33609.50	23.2	2002.738	2001.515	0.028
14.639	33053.30	23.9	15.848	14.638	-0.001

Residual = corrected instrument pressure - reference pressure



CTD Primary Pump

NBP-Bird Electronics, Inc

53° 10'S, 70° 50'W, Punta Arenas, Chile
Phone: (808)434-9769, (808)659-5076 Fax: 011-870-336-661-014
Email: et@NBP.usap.gov

SBE 5+ Pump Service & Calibration 4/17/08

S/N 051646

_X_ Check all O-rings, lubricate and install new O-rings if required

_X_ Check Thrust Washers, replace if necessary

_X_ Remove and clean impeller – reinstall

_X_ Tune R11 as necessary for RPM adjustment

_X_ Seal and purge with Nitrogen

Technician: VS

Location: NBP

CTD Secondary Pump

NBP-Bird Electronics, Inc

53° 10'S, 70° 50'W, Punta Arenas, Chile
Phone: (808)434-9769, (808)659-5076 Fax: 011-870-336-661-014
Email: et@NBP.usap.gov

SBE 5+ Pump Service & Calibration 4/17/08

S/N 051626

_X_ Check all O-rings, lubricate and install new O-rings if required

_X_ Check Thrust Washers, replace if necessary

_X_ Remove and clean impeller – reinstall

_X_ Tune R11 as necessary for RPM adjustment

_X_ Seal and purge with Nitrogen

Technician: VS

Location: NBP

CTD Primary Conductivity Sensor

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: 0926
CALIBRATION DATE: 21-Aug-08

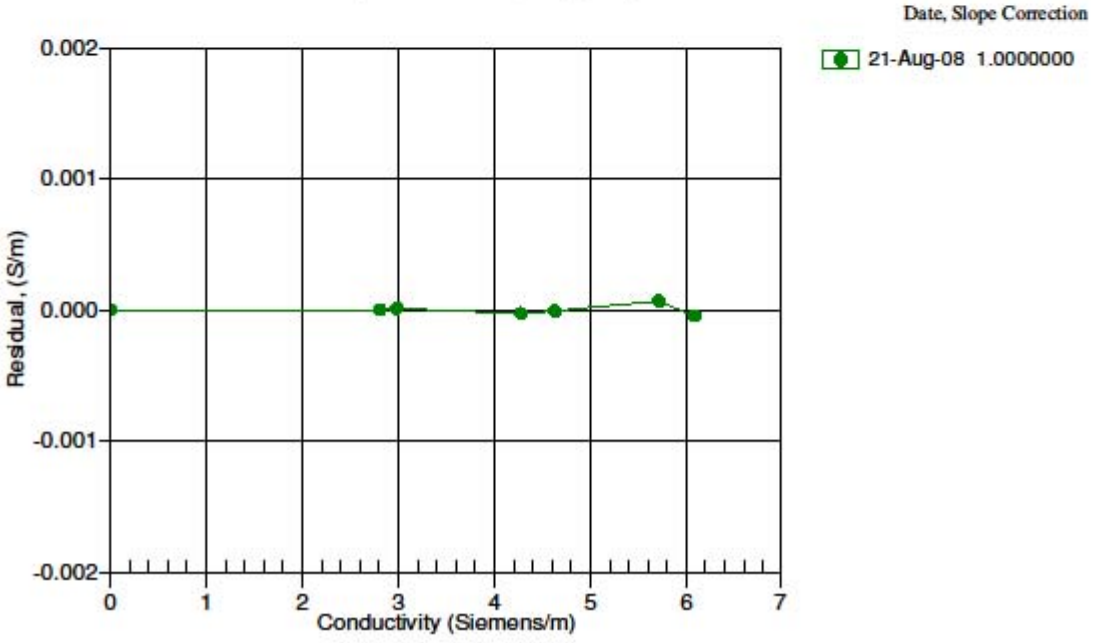
SBE4 CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Seimens/meter

GHIJ COEFFICIENTS
g = -4.06439311e+000
h = 5.32197873e-001
i = -5.33792245e-004
j = 5.48290356e-005
CPcor = -9.5700e-008 (nominal)
CTcor = 3.2500e-006 (nominal)

ABCDM COEFFICIENTS
a = 1.86968737e-006
b = 5.30396635e-001
c = -4.05877440e+000
d = -8.20653592e-005
m = 5.0
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	2.76626	0.00000	0.00000
-1.0001	34.8793	2.80917	7.77921	2.80917	0.00000
0.9999	34.8796	2.98085	7.98370	2.98086	0.00001
14.9999	34.8813	4.27873	9.38444	4.27871	-0.00003
18.4999	34.8820	4.62613	9.72462	4.62612	-0.00001
28.9999	34.8813	5.71175	10.71671	5.71182	0.00007
32.4999	34.8769	6.08535	11.03684	6.08530	-0.00004

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



CTD Primary Conductivity Sensor

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: 1799
CALIBRATION DATE: 09-Jul-08

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

GHIJ COEFFICIENTS
g = -4.14580451e+000
h = 5.02758755e-001
i = -7.10244651e-004
j = 5.95755254e-005
CPcor = -9.5700e-008 (nominal)
CTcor = 3.2500e-006 (nominal)

ABCDM COEFFICIENTS
a = 4.36743043e-007
b = 5.00122905e-001
c = -4.13657615e+000
d = -8.10746201e-005
m = 5.5
CPcor = -9.5700e-008 (nominal)

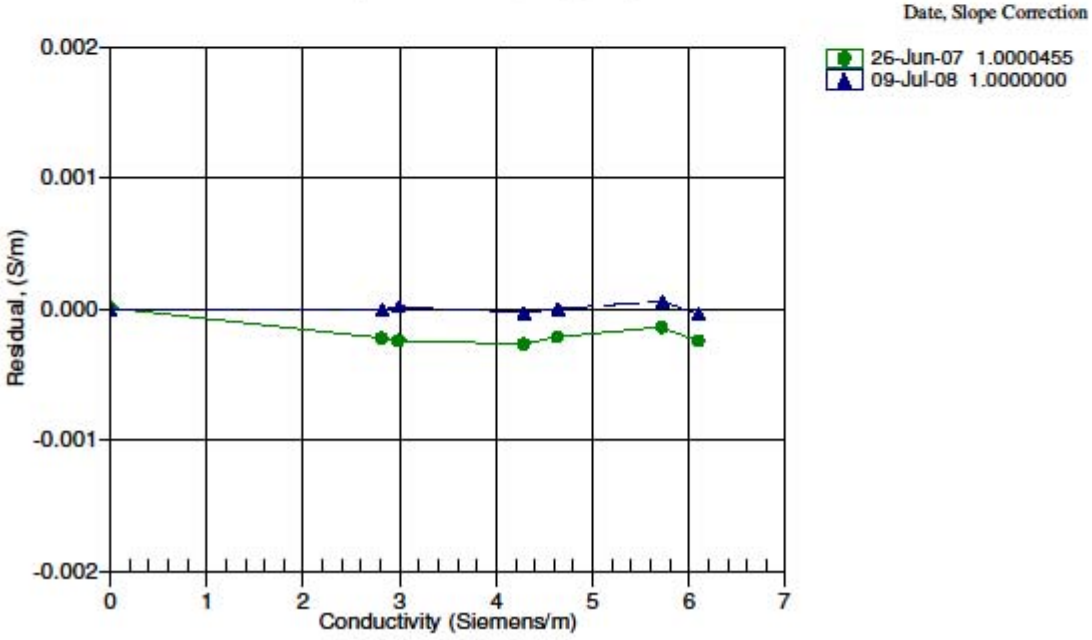
BATH TEMP (ITS-90)	BATH SAL (PSU)	BATH COND (Siemens/m)	INST FREQ (kHz)	INST COND (Siemens/m)	RESIDUAL (Siemens/m)
0.0000	0.0000	0.00000	2.87604	0.00000	0.00000
-0.9253	34.9561	2.82114	8.03729	2.82113	-0.00001
1.0564	34.9561	2.99168	8.24598	2.99170	0.00002
14.9999	34.9577	4.28711	9.68309	4.28708	-0.00003
18.4999	34.9578	4.63510	10.03349	4.63510	-0.00000
29.0000	34.9557	5.72257	11.05532	5.72263	0.00006
32.4999	34.9487	6.09645	11.38472	6.09641	-0.00004

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



CTD Primary Temperature Sensor

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: 18-Jun-08

SBE3 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

ITS-90 COEFFICIENTS
g = 4.82780686e-003
h = 6.69678772e-004
i = 2.48639492e-005
j = 1.92287613e-006
f0 = 1000.0

IPTS-68 COEFFICIENTS
a = 3.68121501e-003
b = 5.98496911e-004
c = 1.44059076e-005
d = 1.92424690e-006
f0 = 6156.904

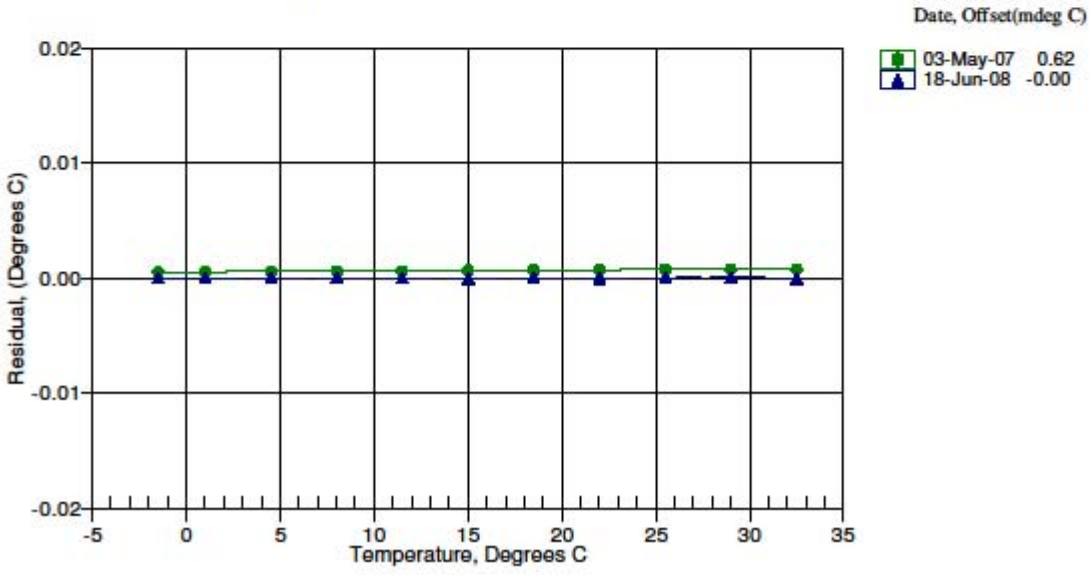
BATH TEMP (ITS-90)	INSTRUMENT FREQ (Hz)	INST TEMP (ITS-90)	RESIDUAL (ITS-90)
-1.5002	6156.904	-1.5002	0.00000
0.9998	6512.687	0.9998	-0.00001
4.4998	7035.326	4.4998	0.00001
7.9998	7587.307	7.9998	-0.00001
11.4998	8169.422	11.4998	0.00002
14.9998	8782.410	14.9998	-0.00001
18.4998	9427.018	18.4998	0.00000
21.9998	10103.939	21.9998	-0.00003
25.4998	10813.872	25.4998	0.00000
28.9998	11557.463	28.9998	0.00004
32.4998	12335.311	32.4998	-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 Secondary Temperature Sensor

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: 2299
CALIBRATION DATE: 18-Jun-08

SBE3 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

ITS-90 COEFFICIENTS

g = 4.33160494e-003
h = 6.43031435e-004
i = 2.30395794e-005
j = 2.16539855e-006
f0 = 1000.0

IPTS-68 COEFFICIENTS

a = 3.68121491e-003
b = 6.02058537e-004
c = 1.62666005e-005
d = 2.16695138e-006
f0 = 2848.674

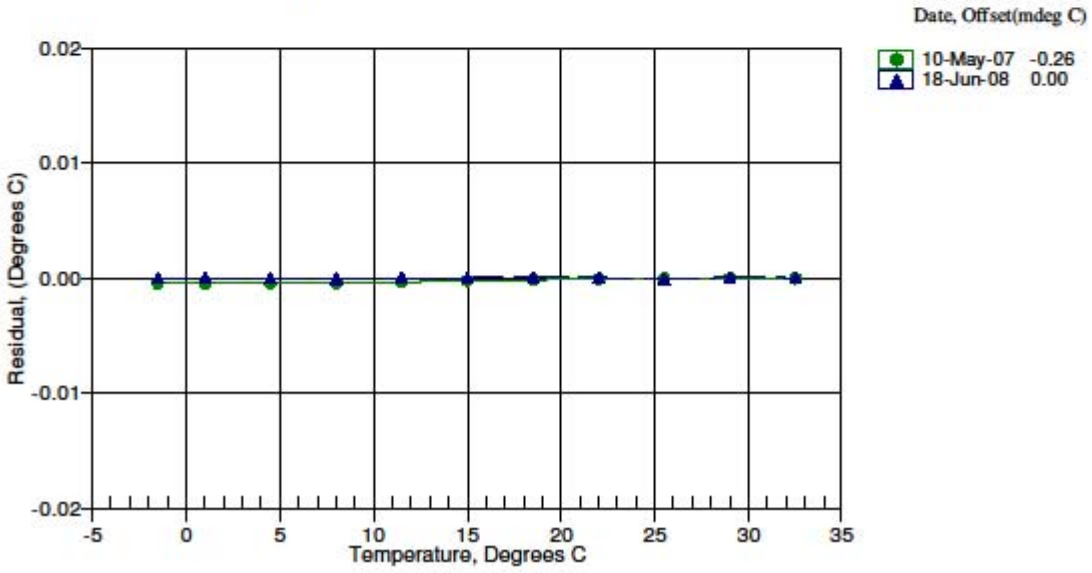
BATH TEMP (ITS-90)	INSTRUMENT FREQ (Hz)	INST TEMP (ITS-90)	RESIDUAL (ITS-90)
-1.5002	2848.674	-1.5002	0.00001
0.9998	3012.312	0.9998	-0.00001
4.4998	3252.693	4.4998	0.00001
7.9998	3506.572	7.9998	-0.00003
11.4998	3774.324	11.4998	0.00000
14.9998	4056.294	14.9998	-0.00000
18.4998	4352.835	18.4999	0.00007
21.9998	4664.263	21.9998	0.00002
25.4998	4990.900	25.4997	-0.00011
28.9998	5333.089	28.9998	0.00004
32.4998	5691.082	32.4998	0.00001

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 Dissolved Oxygen Sensor (Casts 001 – 023)

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: 0161
CALIBRATION DATE: 19-Jun-08p

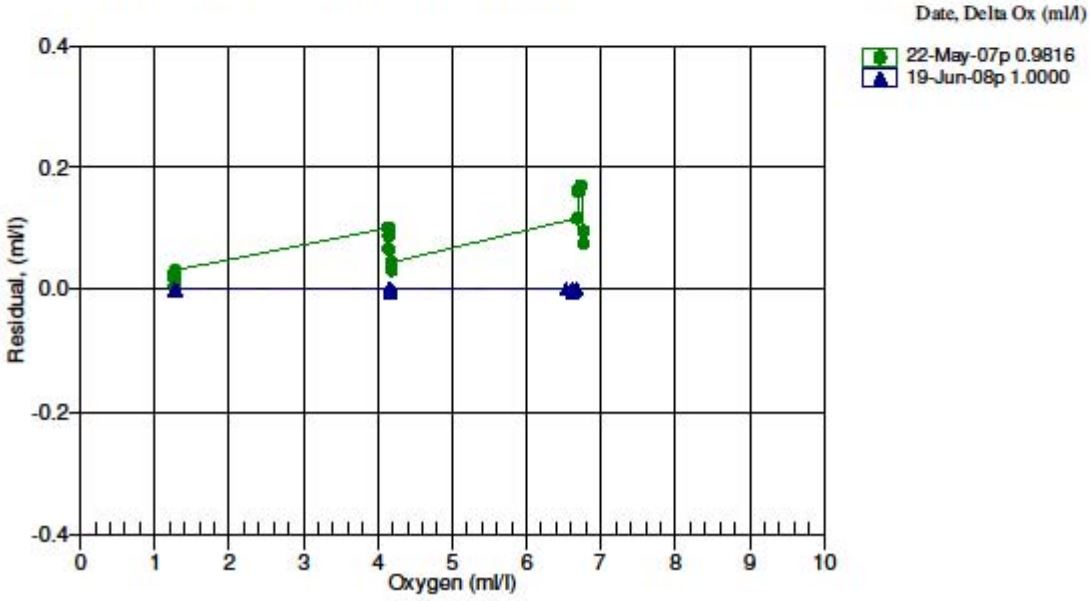
SBE 43 OXYGEN CALIBRATION DATA

COEFFICIENTS
Soc = 0.3616
Voffset = -0.5011
Tau20 = 1.44

A = -8.7273e-003
B = 4.7173e-004
C = -5.2708e-006
E nominal = 0.036

BATH OX (ml/l)	BATH TEMP ITS-90	BATH SAL PSU	INSTRUMENT OUTPUT(VOLTS)	INSTRUMENT OXYGEN(ml/l)	RESIDUAL (ml/l)
1.26	12.00	0.01	0.986	1.26	-0.00
1.26	2.00	0.00	0.868	1.26	0.00
1.27	6.00	0.00	0.918	1.27	0.00
1.27	20.00	0.01	1.070	1.27	-0.00
1.27	26.00	0.01	1.121	1.27	-0.00
1.29	30.00	0.01	1.162	1.29	-0.00
4.16	20.00	0.01	2.362	4.16	0.00
4.16	12.00	0.01	2.101	4.16	0.00
4.17	26.00	0.01	2.533	4.17	0.00
4.17	6.00	0.00	1.874	4.16	-0.00
4.17	2.00	0.00	1.712	4.17	-0.00
4.18	30.00	0.01	2.645	4.18	-0.00
6.52	30.00	0.01	3.845	6.53	0.00
6.61	20.00	0.01	3.460	6.62	0.00
6.62	26.00	0.01	3.728	6.62	-0.00
6.65	12.00	0.01	3.057	6.65	-0.00
6.67	2.00	0.00	2.438	6.67	0.00
6.68	6.00	0.00	2.703	6.68	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 Dissolved Oxygen Sensor

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: 0155
CALIBRATION DATE: 01-Jul-08p

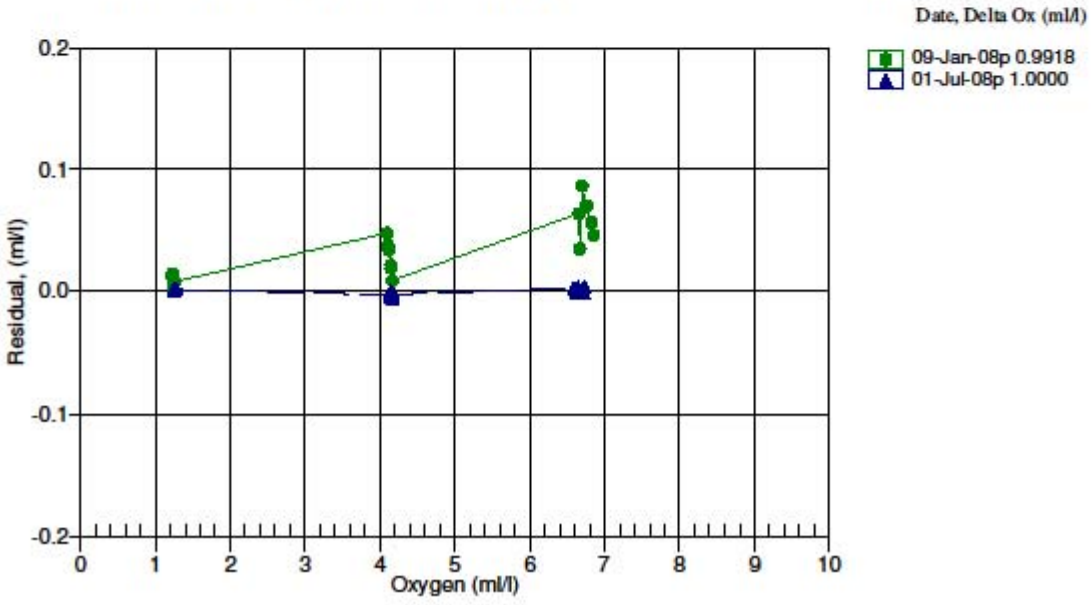
SBE 43 OXYGEN CALIBRATION DATA

COEFFICIENTS
Soc = 0.3457
Voffset = -0.4831
Tau20 = 1.11

A = -8.5822e-004
B = 1.6433e-004
C = -2.5166e-006
E nominal = 0.036

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	0.854	1.24	0.00
1.25	12.00	0.01	0.958	1.25	0.00
1.25	6.00	0.01	0.898	1.25	0.00
1.25	20.00	0.01	1.037	1.25	0.00
1.26	26.00	0.01	1.098	1.26	0.00
1.28	30.00	0.02	1.146	1.28	0.00
4.13	20.00	0.01	2.307	4.12	-0.00
4.14	26.00	0.01	2.498	4.13	-0.00
4.15	12.00	0.01	2.060	4.15	0.00
4.16	2.00	0.00	1.726	4.16	-0.01
4.16	6.00	0.01	1.865	4.16	-0.00
4.17	30.00	0.02	2.644	4.16	-0.00
6.59	30.00	0.02	3.901	6.59	0.00
6.61	26.00	0.01	3.709	6.61	-0.00
6.64	20.00	0.01	3.421	6.64	0.00
6.68	12.00	0.01	3.021	6.68	0.00
6.72	6.00	0.01	2.715	6.72	-0.00
6.72	2.00	0.00	2.497	6.73	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 Dissolved Oxygen Sensor (casts 025 -102, 104 - 160)

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: 25-Jul-08p

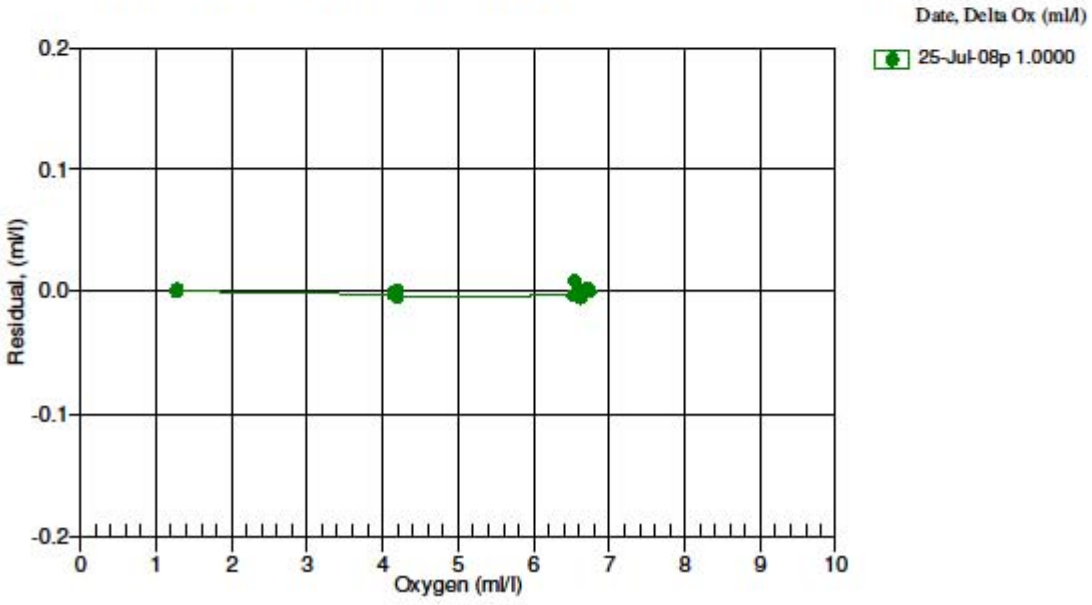
SBE 43 OXYGEN CALIBRATION DATA

COEFFICIENTS
Soc = 0.4625
Voffset = -0.5023
Tau20 = 0.78

A = -5.8810e-003
B = 3.4575e-004
C = -3.7844e-006
E nominal = 0.036

BATH OX (ml/l)	BATH TEMP ITS-90	BATH SAL PSU	INSTRUMENT OUTPUT(VOLTS)	INSTRUMENT OXYGEN(ml/l)	RESIDUAL (ml/l)
1.27	26.00	0.02	0.980	1.27	0.00
1.27	20.00	0.01	0.939	1.27	-0.00
1.28	12.00	0.01	0.880	1.28	0.00
1.28	2.00	0.00	0.792	1.28	0.00
1.28	30.00	0.02	1.012	1.29	0.00
1.29	6.00	0.01	0.829	1.29	0.00
4.13	26.00	0.02	2.054	4.13	-0.00
4.15	20.00	0.01	1.925	4.15	-0.00
4.16	12.00	0.01	1.728	4.16	-0.00
4.18	6.00	0.01	1.566	4.18	0.00
4.18	30.00	0.02	2.159	4.18	-0.00
4.19	2.00	0.00	1.448	4.19	-0.00
6.52	30.00	0.02	3.083	6.52	-0.00
6.55	26.00	0.02	2.963	6.55	0.01
6.62	20.00	0.01	2.773	6.62	-0.01
6.66	12.00	0.01	2.467	6.67	0.00
6.72	6.00	0.01	2.212	6.72	0.00
6.75	2.00	0.00	2.025	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 Dissolved Oxygen Sensor (Cast 103)

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: 0139
CALIBRATION DATE: 05-Feb-08p

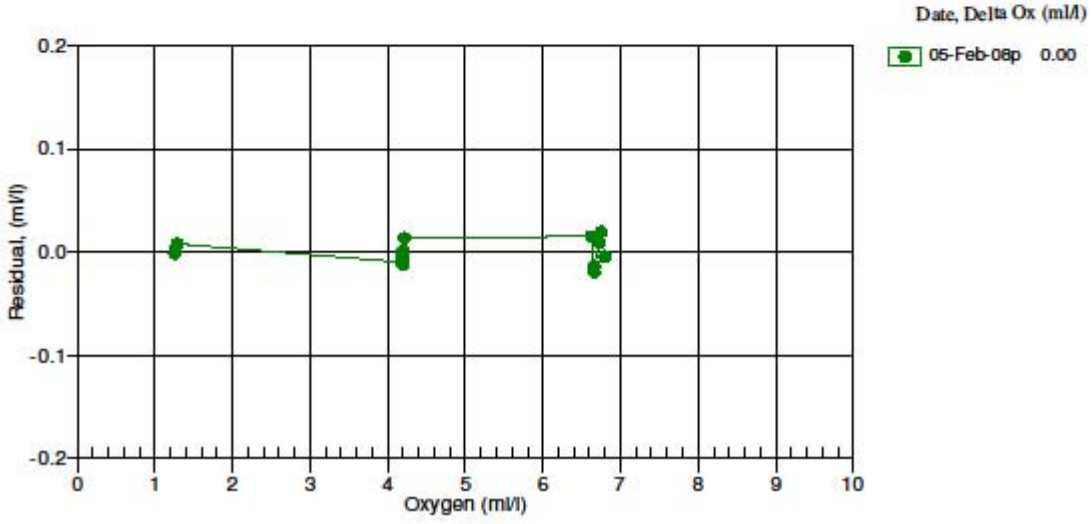
SBE 43 OXYGEN CALIBRATION DATA

COEFFICIENTS
Soc = 0.3661
Boc = 0.0000
Voffset = -0.5984

TCor = 0.0005
PCor = 1.350e-04

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	0.952	1.25	-0.00
1.26	6.00	0.00	0.993	1.26	0.00
1.26	12.00	0.01	1.053	1.26	0.00
1.26	20.00	0.01	1.135	1.26	-0.00
1.27	26.00	0.01	1.203	1.27	0.00
1.28	30.00	0.01	1.257	1.29	0.01
4.17	20.00	0.01	2.368	4.16	-0.01
4.18	26.00	0.01	2.585	4.18	-0.01
4.19	12.00	0.01	2.107	4.19	0.00
4.20	6.00	0.00	1.913	4.20	0.00
4.20	2.00	0.00	1.782	4.19	-0.01
4.21	30.00	0.01	2.753	4.23	0.01
6.62	30.00	0.01	3.979	6.64	0.02
6.66	20.00	0.01	3.425	6.64	-0.02
6.66	26.00	0.01	3.761	6.65	-0.01
6.73	12.00	0.01	3.025	6.74	0.01
6.75	6.00	0.00	2.717	6.77	0.02
6.80	2.00	0.00	2.515	6.79	-0.00

oxygen (ml/l) = (Soc * (V + Voffset)) * exp(Tcor * T) * Oxsat(T,S) * exp(Pcor * P)
V = voltage output from SBE43, T = temperature [deg C], S = salinity [PSU]
Oxsat(T,S) = oxygen saturation [ml/l], P = pressure [dbar], Residual = instrument oxygen - bath oxygen



CTD Fluorometer

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:	02/14/08
Serial #:	AFLD-009
Job#:	0009009
Tech:	K C

Dark Counts	0.184 volts
CEV	2.557 volts
SF	8.470
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.

CTD Transmissometer

PO Box 518
620 Applegate St.
Philomath, OR 97370

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

WET Labs

C-Star Calibration

Date April 9, 2008 S/N# CST-831 Pathlength 25 cm

	Analog meter
V_d	0.061 V
V_{air}	4.838 V
V_{ref}	4.767 V

Temperature of calibration water	22.9 °C
Ambient temperature during calibration	26.0 °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 H 10/3/07

CTD PAR

Biospherical Instruments Inc

CALIBRATION CERTIFICATE

UNDERWATER PAR SENSOR WITH LOG AMPLIFIER

Calibration Date: 02/01/08 **Job No.:** R-9814
Model Number: QSP-200L
Serial Number: 4469
Operator: TPC
Standard Lamp: 91537(10/25/06)
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:	**7.11E+12**	**quanta/cm²·sec/"amps"**	**1.18E-05**	**µEinsteins/cm²·sec/"amps"**
Wet Calibration Factor:	**1.20E+13**	**quanta/cm²·sec/"amps"**	**1.99E-05**	**µEinsteins/cm²·sec/"amps"**

Sensor Test Data and Results[4]

Sensor Supply Current (Dark):	64.3	mA			
Supply Voltage:	6	Volts			
Lamp Integrated PAR Irradiance:	8.83E+15	quanta/cm²·sec	0.01467	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%	3.095	100.00%	1.24E-07	1.24E-07	3.095	0.000	0.0	8.83E+15
0.3	36.10%	2.654	36.14%	4.50E-08	4.49E-08	2.654	0.000	-0.1	3.19E+15
0.5	27.60%	2.540	27.79%	3.46E-08	3.43E-08	2.538	-0.003	-0.7	2.46E+15
1	9.27%	2.079	9.53%	1.19E-08	1.15E-08	2.067	-0.012	-2.8	8.42E+14
2	1.11%	1.196	1.15%	1.43E-09	1.38E-09	1.182	-0.014	-3.7	1.02E+14
3	0.05%	0.371	0.06%	9.68E-11	6.65E-11	0.311	-0.060	-31.4	6.87E+12

Dark Before: 0.138 Volts
Light - No Filter Hldr.: 3.095 Volts
Dark After - NFH: 0.142 Volts
Average Dark 0.140 Volts

I_{Ref} = 1.00E-10 Amps
I_{Dark} = 1.38E-10 Amps
10^{VDark} = 1.380225 Amps

RG780 0.5-11

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

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