

Data Report NBP1101

SEAFARERS

January 18, 2011 – February 15, 2011



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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 UDF format. It is readable by most modern computer platforms. We have gone to this format to make it easier to preserve file names and directory structures of data contributed by the science party.

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: NBP1101

File	Description
/	Root level directory
NBP1101.trk	Text file of cruise track (lat,lon)
NBP1101.mgd	Full Cruise MGD77 data file
NBP1101.gmt	GMT binary file of MGD77 data
INSTCOEF.TXT	Instrument Coefficient File
1101DATA.doc	Data Report NBP1101 (MS Word)
/plots	Cruise track plots
1101trak.ps	Cruise track plot (PostScript format)
1101trak.jpg	Cruise track plot (JPEG format)
/process	Processed data
1101JGOF.tar	JGOFS format data files
1101QC.tar	Daily RVDAS QC postscript plots
1101PCO2.tar	Merged pCO2 data files
1101MGD.tar	MGD Data
1101PROC.tar	Other processed data
/rvdas/nav	Navigation data
1101gyr1.tar	Gyro raw data
1101PCOD.tar	Trimble P-code raw data
1101seap.tar	Seapath data
1101adcp.tar	ADCP Data Sets
/rvdas/uw	Underway data
1101eng1.tar	Engineering aata
1101grv1.tar	Gravimeter raw data
1101hdas.tar	HydroDAS raw data
1101knud.tar	Knudsen raw data
1101mbdp.tar	Multibeam depth data
1101mtsg.tar	Micro TSG data
1101mwx1.tar	Meteorology raw data
1101pco2.tar	pCO2 raw data
1101pguv.tar	GUV raw data
1101rtmp.tar	Remote temperature data
1101svp1.tar	Sound velocity probe (in ADCP well)
1101oxyg.tar	Oxygen sensor
/Imagery	Satellite Imagery
1101Imag.tar	
/ocean	Ocean data
1101ctd.tar	CTD Data
1101xbt.tar	XBT Data
/science	Various science 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
```

Cruise Information

NBP1101 departed McMurdo Station Antarctica on January 18, 2011. Data collection began at that time. Data collection ended on February 15, 2011 when the ship returned to McMurdo Station. The data set consists of 1 DVD with the standard NBP data distribution plus various other cruise specific data. There is a separate two disk (DVD) set of sub bottom bathymetry data requested by one of the science team. The general distribution did not include the sub bottom data.

There was no gravity tie done in McMurdo at the January 16th port call. The USGS marker has apparently been destroyed, and doing a gravity tie on the ice pier is not recommended.

Cruise Track

The distribution DVD includes a GMT cruise track file (NBP1101.trk). It contains the longitude and latitude of the ship's position at one-minute intervals extracted from the NBP1101.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/1101Imag.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

The IT staff on the NBP create two processed data products for every 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/1101proc.tar. These files are not intended to be end-products. 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.

/science

The directory /science on the distribution disk is a collection of various computer files used by the science party. They include, data, calibration sheets, diagrams of moorings, and many other things. No attempt is made here to describe those files in any detail. They are mainly added for the convenience of the science party.

JGOFS

The JGOFS data set can be found on the distribution media in the file /process/1101jgof.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” 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	$\mu\text{Einsteins/meter}^2 \text{ sec}$
10	Sea surface temperature	$^{\circ}\text{C}$
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	$^{\circ}\text{C}$
17	Relative humidity	%
18	Barometric pressure	mBars
19	Sea surface fluorometry	$\mu\text{g/l}$ (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 NBP1101.mgd. The file NBP1101.gmt is created from the MGD77 dataset using the “mgd77togmt” utility. NBP1101.gmt can be used with the GMT plotting package.

The data used to produce the NBP1101.mgd file can be found on the distribution media in the file /process/1101proc.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	1 = 1 st or leading sensor

Col	Len	Type	Contents	Description, Possible Values, Notes
			field	2 = 2 nd 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 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 1101adcp.tar in the directory /rvdas/nav.

pCO₂

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 1101pco2.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/1101ctd.tar. The archive contains tar files 1101proc.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 1101xbt.tar in the /ocean directory.

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: NBP1101.mwx1.d330

- The CruiseID is the numeric name of the cruise, in this case, NBP1101.
- 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	knud	continuous	Varies	Knudsen 320B/R

*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
Oxygen	Oxyg	Continuous	10 sec	Oxygen Optode 3835

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 /rvdas/uw

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,-
0.4827508,282.9581,281.8823,1005.119

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. The 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)	

pCO₂ (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

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 24 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

Oxygen Data (oxyg)

Internal reference salinity is set to 34 ppt. For further information on this data, contact Sharon Stammerjohn, ssammer@ucsc.edu.

11+011:00:21:48.109 MEASUREMENT 3835 1424 Oxygen: 334.01
 Saturation: 90.71 Temperature: -0.78 DPhase: 37.65
 BPhase: 35.95 RPhase: 0.00 BAmp: 212.13 BPot:
 30.00 RAmp: 0.00 RawTem.: 788.05

Field	Data	Units
1	RVDAS time tag	
2-4	Measurement ID, Model Number, Serial Number	alphanumeric
5	Oxygen heading	text
6	Oxygen Reading	μ M
7	Saturation heading	text
8	Saturation Reading	%
9	Temperature heading	text
10	Water Temperature	°C
11	Dphase heading	text
12	Dphase	Raw numeric
13	Rphase heading	Text
14	Rphase	Raw numeric
15	Bamp heading	Text
16	Bamp	Raw numeric
17	Bpot heading	Text
18	Bpot	Raw numeric
19	Ramp heading	Text
20	Ramp	Raw numeric
21	RawTem heading	Text
22	RawTemp	V

Navigational Data /rvdas/nav

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 /process/**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 “mw1” file description. The calibration scale and probe offset dark are values taken from the PAR Cal Sheet.

```
par = raw data mV
calibration scale = 5.8644 V/(μEinstiens/cm2sec)
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 “mw1” file description.

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

Calculations (extracted from the C code):

```
/* Convert from mV to W/m^2 */
pspCalc = (psp * 1000 / pspCoeff);
```

PIR

Coefficient `pirCoeff` for this cruise can be found in the `instrument.coeff` file as the variable labeled `PIR1`. Variable `pir_thermo` is the raw data in mV, `pir_case` is the PIR case temperature in Kelvins and `pir_dome` is the PIR dome temperature in Kelvins, as described in the “`mw1`” 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/m2 */
```

```
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
019:05:22		Start logging, leave McMurdo
029:01:16		Turn off Knudsen while refueling at pier in McMurdo
029:10:15		Turn on Knudsen
045:23:53		Stop logging data

Appendix: Sensors and Calibrations

NBP1101 Shipboard Sensors

<i>Sensor</i>	<i>Serial Number</i>	<i>Last Calibration</i>	<i>Comments</i>
Meteorology & Radiometers			
Bridge Anemometer (RMY)	WM 45835	2/28/07	
Port Anemometer (Gill Ultrasonic)	924057	11/18/2009	Installed 3/5/2010 There are no cal-sheets for this instrument.
Stbd Anemometer (Gill Ultrasonic)	847014	5/15/2007	Installed 11/17/2010 There are no cal-sheets for this instrument.
Barometer	01706	2/12/2010	Installed 11/15/2010
Humidity/Wet Temp	06134	3/05/2009	
PIR	33023F3	6/17/2009	Installed 10/12/10
PSP	33090F3	6/16/2009	Installed 10/12/10
Mast PAR	6356	7/20/2009	Installed 3/01/10
GUV (Mast)	25110203113	6/25/2009	
Underway			
TSG	4549120-0226	7/26/2009	Installed 10/10/10
Remote Temp (Primary)	3849120-0178	1/26/2010	Installed 10/10/10
Fluorometer	AFLT-009	5/14/2009	Installed 4/01/10
Transmissometer	CST-439DR	03/18/2010	Installed 11/30/10
Oxygen Optode 3835	1424	10/21/2010	Installed 11/30/10

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: 11/16/2010

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. 9337-50

ISGN no. 51230N

	Value	Time (GMT)
Ship's meter before gravity tie (Gravity (cu))	8979.0	19:12
Ship's meter after gravity tie (Gravity (cu))	8979.0	20:20
Average	8979.0	
Ship Gravimeter's Calibration Constant	1.0046	
Corrected ship's meter (QC Grav (mgal))	9020.3	

	Value	Time (GMT)
Ship's meter before gravity tie (serial, RVDAS)	8979.0	19:12
Ship's meter after gravity tie (serial, RVDAS)	8979.0	20:21
Average (for comparison check only)	8979.0	

Portable Gravimeter Interval Factor

1.01007 From Table 1 of Model G #807 Meter

Station	Value	Time (GMT)	Temp	Date	
Pier measurement 1	4915.87	19:37	54	November 16, 2010	OBS mgal, averaged
Pier measurement 2	4916.63	19:38	54	November 16, 2010	4965.62
Pier measurement 3	4915.85	19:39	54	November 16, 2010	
Average	4916.12				
Station measurement 1	4916.63	19:55	54	November 16, 2010	OBS mgal, averaged
Station measurement 2	4916.55	19:56	54	November 16, 2010	4966.06
Station measurement 3	4916.46	19:58	54	November 16, 2010	
Average	4916.55				
Pier measurement 4	4915.90	20:11	54	November 16, 2010	OBS mgal, averaged
Pier measurement 5	4915.84	20:12	54	November 16, 2010	4965.37
Pier measurement 6	4915.85	20:13	54	November 16, 2010	
Average	4915.86				

Gravity offset from last tie

972300.17

Drift since last tie

0.08

OBS Differences		Comments
Station to Pier (1, 2, & 3 averaged)	-0.43	Tie done by Barry Bjork. Very little heavy pier activity.
Station to Pier (4, 5, & 6 averaged)	-0.69	
Averaged Differences	-0.56	
Gravity at pier	981320.26	
Elevation of pier above gravimeter, meters	1.0	
Earth differential gravity, mgal/meter	0.3	
Gravity at ship's gravimeter	981320.56	
Gravity Offset (for RVDAS)	972300.25	

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

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
Livonia City, Michigan 48150 USA

CALIBRATION REPORT

Barometric Pressure Sensor

Customer: *Raytheon Technical Services Company LLC*

Test Number: 02121

Test Date: 12 February 2010

Customer PO: RR50590-01

Sales Order: C971

Test Sensor:	
Model: 01201	Serial Number: BP01706
Description: Barometric Pressure Sensor	

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

Reference Pressure (hPa)	Voltage Output (millivolts)	Indicated (1) Pressure (hPa)
800.0	0	800.0
875.0	1250	875.0
950.0	2500	950.0
1025.0	3749	1024.9
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:
Druck Pressure Controller Model DPI515
Fluke Multimeter Model 8090A

Serial # NIST Test Reference:
51500497 UKAS Lab 0221
4885407 234027

Tested By: *E. Chennery*

METEOROLOGICAL INSTRUMENTS
Tel: 231-945-3980 Fax: 231-240-4772 Email: met.sales@youngusa.com Website: youngusa.com

Mast Humidity Sensor

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: 92264R
 Test Date: 5 March 2009

Customer PO: RR44553-01
 Sales Order: 0282

Test Sensor:

Model: 41372LC Serial Number: 6134
 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	11.9
30.0	8.8	29.8
50.0	12.0	49.9
70.0	15.0	68.9
90.0	17.9	87.1

(1) Calculated from voltage output

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

Reference Instrument
 Vaisala Humidity Sensor Model 35AC
 Fluke Multimeter Model 8060A

Serial # NIST Test Reference
 N475040 TN 266152
 4865407 234027

Tested By: EChenning

Mast 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: 92264
Test Date: 26 February 2009

Customer PO: RR44553-01
Sales Order: 0282

Test Sensor:

Model: 41372LC Serial Number: 6134
Description: Temperature/Relative Humidity Sensor

Report of calibration comparison of test temperature sensor with National Institute of Standards and Technology traceable standard thermometers at three temperatures in the R.M. Young Company controlled temperature calibration bath facilities. Calibration accuracy $\pm 0.1^\circ$ Celsius.

Bath Temperature (degrees C)	Current Output (milliamps)	Indicated (1) Temperature (degrees C)
-50.18	3.973	-50.17
0.03	12.004	0.02
50.09	20.013	50.08

(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: ECherning

METEOROLOGICAL INSTRUMENTS

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

Mast PIR**THE EPPLEY LABORATORY, INC.**

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

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

Serial Number: 33023F3

Resistance: 738 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:

$$3.74 \times 10^{-6} \text{ volts/watts meter}^{-2}$$

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

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

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

Shipped to: Raytheon Technical Services
National Science Foundation
Port Hueneme, CA
S.O. Number: 62138
Date: June 25, 2009

Date of Test: June 17, 2009

In Charge of Test: *Debra L. Gentry*

Reviewed by: *Thomas D. Hark*

Remarks:

Mast PSP**THE EPPLEY LABORATORY, INC.**

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

**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 constant).

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

$$8.06 \times 10^{-6} \text{ volts/watts meter}^{-2}$$

The calculation of this constant is based on the fact that the relationship between radiation intensity and emf is rectilinear to intensities of 1400 watts meter⁻². This radiometer is linear to within $\pm 0.5\%$ 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/ft²-hr⁻¹ = 3.153 watts meter⁻²

Shipped to: Raytheon Technical Services
National Science Foundation
Port Hueneme, CA
S.O. Number: 62137
Date: June 25, 2009

Date of Test: June 16, 2009

In Charge of Test:

Debra L. Huntley

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/cm²sec

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/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.

Mast GUV

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)		TPC			
Microprocessor Tag Number		2		Operator							
Monochromatic Channels	Address	Wavelength [nm]	Responsivity [Amps per $\mu\text{W}/(\text{cm}^2\text{-nm})$]	ScaleSmall [Volts per $\mu\text{W}/(\text{cm}^2\text{-nm})$]	ScaleMedium [Volts per $\mu\text{W}/(\text{cm}^2\text{-nm})$]	ScaleLarge [Volts per $\mu\text{W}/(\text{cm}^2\text{-nm})$]	OffsetSmall [volts]	OffsetMedium [volts]	OffsetLarge [volts]	Measurement Units	
	E00320	2	320	2.6565E-10	2.7096E-05	7.9164E-03	2.8027E+00	7.3000E-05	7.1000E-05	3.4200E-04	$\mu\text{W}/(\text{cm}^2\text{-nm})$
	E00340	6	340	2.1645E-10	2.2078E-05	6.4502E-03	2.2743E+00	3.5400E-04	3.5800E-04	1.2200E-03	$\mu\text{W}/(\text{cm}^2\text{-nm})$
	E00313	8	313	2.2957E-10	2.3417E-05	6.8413E-03	2.4423E+00	6.5000E-05	6.3000E-05	6.7900E-04	$\mu\text{W}/(\text{cm}^2\text{-nm})$
	E00305	10	305	1.6588E-11	1.6919E-06	4.9431E-04	1.5292E-01	3.7700E-04	3.6900E-04	-2.2380E-03	$\mu\text{W}/(\text{cm}^2\text{-nm})$
	E00380	12	380	6.8861E-11	7.0238E-06	2.0521E-03	6.8434E-01	1.1490E-03	1.1430E-03	-1.3370E-03	$\mu\text{W}/(\text{cm}^2\text{-nm})$
	E00395	18	395	3.4619E-10	3.5311E-05	1.0316E-02	3.3698E+00	1.0600E-04	1.0400E-04	2.2100E-04	$\mu\text{W}/(\text{cm}^2\text{-nm})$
	Broadband Channels	Address	Wavelength [nm]	Responsivity [Amps per $\mu\text{E}/(\text{cm}^2\text{-s})$]	ScaleSmall [Volts per $\mu\text{E}/(\text{cm}^2\text{-s})$]	ScaleMedium [Volts per $\mu\text{E}/(\text{cm}^2\text{-s})$]	ScaleLarge [Volts per $\mu\text{E}/(\text{cm}^2\text{-s})$]	OffsetSmall [volts]	OffsetMedium [volts]	OffsetLarge [volts]	Measurement Units
		E00PAR	13	400-700	1.9164E-05	1.9547E+00	5.7109E+02	2.0333E+05	8.7700E-04	8.7100E-04	-1.2850E-03
	Auxiliary Channels	Address	Wavelength	Responsivity	ScaleS	ScaleM	ScaleL	OffsetS	OffsetM	OffsetL	Measurement Units
E00Gnd		0	0	1	1	1	0	0	0	V	
E00Temp		22	0	1	0.01	0.01	0	0	0	C	
E00Vin		27	0	1	-0.25	-0.25	-0.25	0	0	0	V

© Biospherical Instruments Inc., 5340 Riley Street, San Diego, California 92110 USA. Contact support@biospherical.com for more information.

Calibration Data – Do Not Destroy

page 2 of 2

Underway TSG Conductivity**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: 29-Jul-09SBE 45 CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Siemens/meter

COEFFICIENTS:

g = -1.015802e+000

CPcor = -9.5700e-008

h = 1.570346e-001

CTcor = 3.2500e-006

i = -4.241199e-004

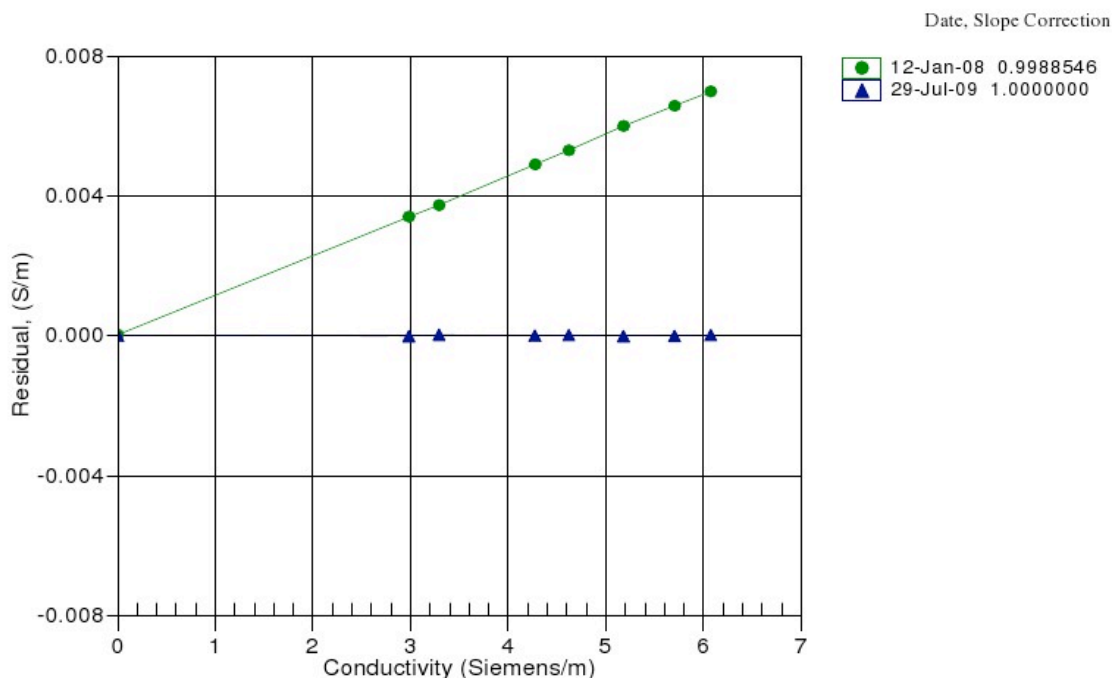
WBOTC = 9.8072e-007

j = 5.908119e-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	2548.99	0.00000	0.00000
1.0000	34.9069	2.98297	5056.42	2.98295	-0.00002
4.5000	34.8872	3.29075	5246.86	3.29077	0.00002
15.0000	34.8451	4.27477	5813.11	4.27477	-0.00000
18.5000	34.8362	4.62072	5999.21	4.62074	0.00001
24.0000	34.8265	5.17997	6288.06	5.17996	-0.00002
29.0000	34.8207	5.70296	6546.31	5.70295	-0.00001
32.5000	34.8182	6.07628	6724.38	6.07629	0.00001

 $f = \text{INST FREQ} * \text{sqrt}(1.0 + \text{WBOTC} * t) / 1000.0$ Conductivity = $(g + hf^2 + if^3 + jf^4) / (1 + \delta t + \epsilon p)$ Siemens/metert = temperature[°C]; p = pressure[decibars]; $\delta = \text{CTcor}$; $\epsilon = \text{CPcor}$;

Residual = instrument conductivity - bath conductivity



Underway TSG Temperature**SEA-BIRD ELECTRONICS, INC.**

1808 - 136th Place Northeast, Bellevue, Washington 98005 USA

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

Temperature Calibration Report

Customer:	Raytheon Polar Services Co.		
Job Number:	55214	Date of Report:	7/29/2009
Model Number:	SBE 45	Serial Number:	4549120-0226

Temperature sensors are normally calibrated 'as received', without adjustments, allowing a determination sensor drift. If the calibration identifies a problem, then a second calibration is performed after work is completed. The 'as received' calibration is not performed if the sensor is damaged or non-functional, or by customer request.

An 'as received' calibration certificate is provided, listing coefficients to convert sensor frequency to temperature. Users must choose whether the 'as received' calibration or the previous calibration better represents the sensor condition during deployment. In SEASOFT enter the chosen coefficients using the program SEACON. The coefficient 'offset' allows a small correction for drift between calibrations (consult the SEASOFT manual). Calibration coefficients obtained after a repair apply only to subsequent data.

'AS RECEIVED CALIBRATION'☒ Performed ☐ Not Performed

Date: 7/29/2009

Drift since last cal: +0.00002 Degrees Celsius/year

Comments:

'CALIBRATION AFTER REPAIR'☐ Performed ☒ Not Performed

Date:

Drift since Last cal: Degrees Celsius/year

Comments:

Underway Remote Temperature

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

Temperature Calibration Report

Customer:	Raytheon Polar Services Co.		
Job Number:	57376	Date of Report:	1/26/2010
Model Number:	SBE 38	Serial Number:	3849120-0178

Temperature sensors are normally calibrated 'as received', without adjustments, allowing a determination sensor drift. If the calibration identifies a problem, then a second calibration is performed after work is completed. The 'as received' calibration is not performed if the sensor is damaged or non-functional, or by customer request.

An 'as received' calibration certificate is provided, listing coefficients to convert sensor frequency to temperature. Users must choose whether the 'as received' calibration or the previous calibration better represents the sensor condition during deployment. In SEASOFT enter the chosen coefficients using the program SEACON. The coefficient 'offset' allows a small correction for drift between calibrations (consult the SEASOFT manual). Calibration coefficients obtained after a repair apply only to subsequent data.

'AS RECEIVED CALIBRATION' ☒ Performed ☐ Not Performed
Date: 1/26/2010 Drift since last cal: +0.00016 Degrees Celsius/year
Comments:

'CALIBRATION AFTER REPAIR' ☐ Performed ☒ Not Performed
Date: Drift since Last cal: Degrees Celsius/year
Comments:

Underway Fluorometer

PO Box 518
620 Applegate St.
Philomath OR 97370



(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 R² (0–1.5 volts)
0.995 R² (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 determined by using the following equation:
 $SF = (25) / (CEV - \text{dark})$ 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/m³) can be derived by using the following equation: (µg/l) = (V_{measured} - dark) * SF

The relationship between fluorescence and chlorophyll-*a* concentrations in-situ is highly variable. The scale factor listed on this document was determined by using a mono-culture of phytoplankton (*Thalassiosira weissflogii*). The population was assumed to be reasonably healthy and the concentration was determined by using the absorption method. To accurately determine chlorophyll concentration using a fluorometer you must perform secondary measurements on the populations of interest. This is typically done using extraction based measurement techniques on discrete samples. For additional information on determination of chlorophyll concentration see [Standard Methods For The Examination Of Water And Wastewater] part 10200.11 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



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

C-Star Calibration

Date March 18, 2010 S/N# CST-439DR Pathlength 25 cm

	Analog meter
V_d	0.058 V
V_{air}	4.804 V
V_{ref}	4.702 V

Temperature of calibration water	22.7 °C
Ambient temperature during calibration	23.3 °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

Oxygen Sensor

AANDERAA DATA INSTRUMENTS

CALIBRATION CERTIFICATEForm No. 622, Dec 2005
Page 1 of 2Sensing Foil Batch No: 5009
Certificate No:Product: Oxygen Optode 3835
Serial No: 1424
Calibration Date: 21 October 2010

This is to certify that this product has been calibrated using the following instruments:

Calibration Bath model FNT
ASL Digital Thermometer model F250321-1-40
Serial: 6792/06**Parameter: Internal Temperature:****Calibration points and readings:**

Temperature (°C)	1.17	12.12	24.11	36.08
Reading (mV)	730.09	383.95	-11.29	-379.10

Giving these coefficients

Index	0	1	2	3
TempCoef	2.37613E01	-3.08128E-02	2.84735E-06	-4.15311E-09

Parameter: Oxygen:

	O2 Concentration	Air Saturation
Range:	0-500 μM ¹⁾	0 - 120%
Accuracy ¹⁾ :	< $\pm 8\mu\text{M}$ or $\pm 5\%$ (whichever is greater)	$\pm 5\%$
Resolution:	< 1 μM	< 0.4%
Settling Time (63%):	< 25 seconds	

Calibration points and readings²⁾:

	Air Saturated Water	Zero Solution (Na ₂ SO ₃)
Phase reading (°)	3.27669E+01	6.65595E+01
Temperature reading (°C)	9.90918E+00	2.04774E+01
Air Pressure (hPa)	9.76884E+02	

Giving these coefficients

Index	0	1	2	3
PhaseCoef	-4.44928E00	1.17131E00	0.00000E00	0.00000E00

¹⁾ Valid for 0 to 2000m (6562ft) depth, salinity 33 - 37ppt²⁾ The calibration is performed in fresh water and the salinity setting is set to: 0

AANDERAA DATA INSTRUMENTS AS

5851 BERGEN, NORWAY

Tel. +47 55 60 48 00

Fax. +47 55 60 48 01

E-mail: info@aadi.no

Web: http://www.aadi.no



AANDERAA DATA INSTRUMENTS

CALIBRATION CERTIFICATE

Form No. 622, Dec 2005
Page 2 of 2Sensing Foil Batch No: 5009
Certificate No:Product: Oxygen Optode 3835
Serial No: 1424
Calibration Date: 21 October 2010

SR10 Scaling Coefficients:

At the SR10 output the Oxygen Optode 3830 can give either absolute oxygen concentration in μM or air saturation in %. The setting of the internal property "Output"³⁾, controls the selection of the unit. The coefficients for converting SR10 raw data to engineering units are fixed.

Output = -1	Output = -2
A = 0	A = 0
B = 4.883E-01	B = 1.465E-01
C = 0	C = 0
D = 0	D = 0
Oxygen (μM) = A + BN + CN2 + DN3	Oxygen (%) = A + BN + CN2 + DN3

³⁾ The default output setting is set to -1

Date: 22 October 2010

Sign:

Tor-Ove Kvalvaag, Calibration Engineer

AANDERAA DATA INSTRUMENTS AS

5851 BERGEN, NORWAY

Tel. +47 55 60 48 00

Fax. +47 55 60 48 01

E-mail: info@aadi.noWeb: <http://www.aadi.no>



AANDERAA DATA INSTRUMENTS

CALIBRATION CERTIFICATE

Form No. 621, Dec 2005

Certificate No: 3853_5009_40331
Batch No: 5009

Product: O2 Sensing Foil PSt3 3853
Calibration Date: 2 June 2010

Calibration points and phase readings (degrees)

Temperature (°C)		3.97	10.93	20.15	29.32	38.39
Pressure (hPa)		977.00	977.00	977.00	977.00	977.00
O2 in % of O2+N2	0.00	73.18	72.63	71.62	70.72	69.77
	1.00	68.01	67.02	65.42	63.92	62.31
	2.00	64.39	63.16	61.20	59.44	57.57
	5.00	55.80	54.16	51.76	49.56	47.45
	10.00	46.27	44.47	41.97	39.75	37.69
	20.90	35.09	33.38	31.14	29.24	27.56
	30.00	29.85	28.30	26.31	24.64	23.19

Giving these coefficients ¹⁾

Index	0	1	2	3
C0 Coefficient	4.53793E+03	-1.62595E+02	3.29574E+00	-2.79285E-02
C1 Coefficient	-2.50953E+02	8.02322E+00	-1.58398E-01	1.31141E-03
C2 Coefficient	5.66417E+00	-1.59647E-01	3.07910E-03	-2.46265E-05
C3 Coefficient	-5.99449E-02	1.48326E-03	-2.82110E-05	2.15156E-07
C4 Coefficient	2.43614E-04	-5.26759E-06	1.00064E-07	-7.14320E-10

¹⁾ Ask for Form No 621S when this O2 Sensing Foil is used in Oxygen Sensor 3830 with Serial Numbers lower than 184.

Date: 11/4/2010

Sign:

Tor-Ove Kvalvaag, Calibration Engineer

AANDERAA DATA INSTRUMENTS AS

5851 BERGEN, NORWAY

Tel. +47 55 60 48 00

Fax. +47 55 60 48 01

E-mail: info@aadi.no

Web: <http://www.aadi.no>

CTD Sensors

Sensor	Serial Number	Last Calibration Date	Comments
CTD Fish	094857-0919	09/23/10	Installed 11/22/10
CTD Fish Pressure	110538	04/01/10	Installed 11/22/10
CTD Deck Unit	11P19858-0768	N/A	Installed 11/08/07
Slip-Ring Assembly	1.406	N/A	Installed 03/27/04
Carousel Water Sampler	3211265-0066	N/A	Installed 11/18/06
Pump (primary)	051256	8/18/2010	Installed 01/20/11
Pump (secondary)	051646	N/A	Installed 11/22/10
Temperature (primary)	03P2168	08/25/2010	Installed 01/20/11
Temperature (secondary)	03P2186	05/14/2010	Installed 01/20/11
Conductivity (primary)	042067	08/24/2010	Installed 01/20/11
Conductivity (secondary)	041798	05/14/2010	Installed 01/20/11
Dissolved Oxygen (primary)	430080	08/19/2010	Installed 01/20/11
Dissolved Oxygen (secondary)	430082	08/19/2010	Installed 01/20/11
PAR	4469	04/22/2009	Installed 01/20/11
Fluorometer	FLRTD-855	09/22/2010	Installed 01/20/11
Transmissometer	CST-831DR	06/28/2010	Installed 01/20/11
Altimeter	42434	N/A	Installed 10/18/10
Bottom Contact Switch	# 1	N/A	Installed 11/22/10

CTD Fish pressure**SEA-BIRD ELECTRONICS, INC.**

13431 NE 20th Street, Bellevue, Washington, 98005-2010 USA

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

SENSOR SERIAL NUMBER: 0919
CALIBRATION DATE: 23-Sep-10SBE9plus PRESSURE CALIBRATION DATA
10000 psia S/N 110538

DIGIQUARTZ COEFFICIENTS:

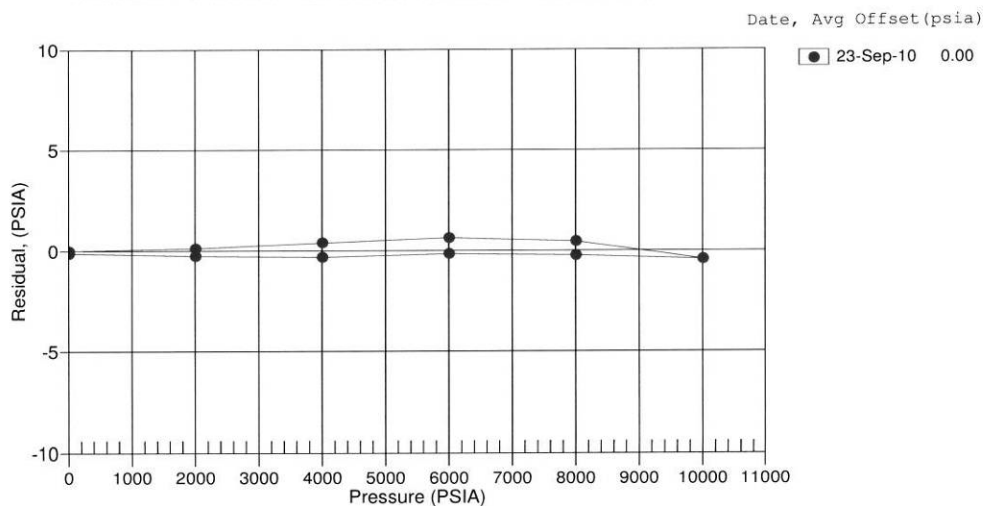
C1 = -4.555149e+004
 C2 = 1.898470e-001
 C3 = 1.479120e-002
 D1 = 3.202800e-002
 D2 = 0.000000e+000
 T1 = 2.996325e+001
 T2 = -2.339450e-004
 T3 = 4.373540e-006
 T4 = 2.520670e-009
 T5 = 0.000000e+000

AD590M, AD590B, SLOPE AND OFFSET:

AD590M = 1.28040e-002
 AD590B = -8.97842e+000
 Slope = 1.00008
 Offset = -2.2397 (dbars)

PRESSURE (PSIA)	INST OUTPUT(Hz)	INST TEMP(C)	INST OUTPUT (PSIA)	CORRECTED INST OUTPUT (PSIA)	RESIDUAL (PSIA)
14.583	33383.99	20.8	17.701	14.453	-0.130
2014.793	34107.83	20.9	2017.610	2014.531	-0.262
4014.932	34814.68	21.0	4017.509	4014.599	-0.334
6014.946	35505.58	21.0	6017.526	6014.785	-0.161
8014.801	36181.31	21.1	8017.133	8014.561	-0.240
10014.824	36842.86	21.1	10016.794	10014.391	-0.433
8014.802	36181.55	21.2	8017.821	8015.249	0.446
6014.724	35505.79	21.2	6018.092	6015.352	0.628
4014.787	34814.90	21.3	4018.080	4015.170	0.383
2014.844	34108.01	21.3	2018.032	2014.953	0.109
14.584	33384.07	21.4	17.829	14.581	-0.003

Residual = corrected instrument pressure - reference pressure



CTD Pump (primary)**SEA-BIRD ELECTRONICS, INC.**

13431 NE 20th St. Bellevue, Washington 98005 USA

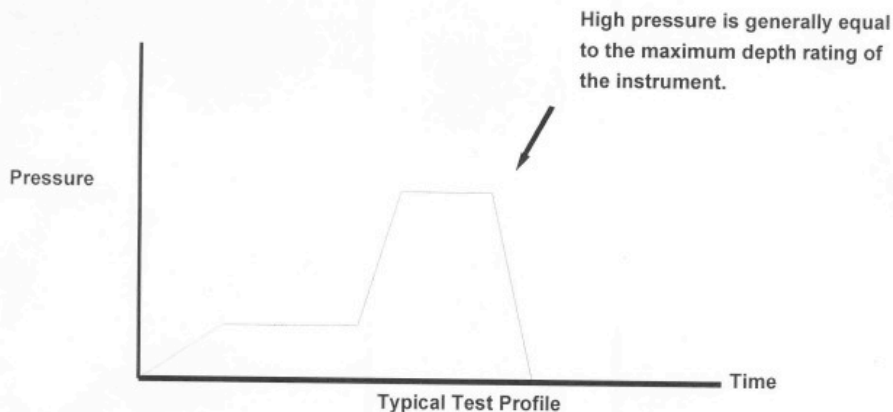
Phone: (425) 643-9866 Fax: (425) 643-9954 www.seabird.com

Pressure Test CertificateCustomer Raytheon Polar Services Co.Job Number 60764Date 8/18/2010Technician BLTSerial Number 051265

CTD Pump

Low Pressure (PSI) 50 PSITime (Minutes) 15 MinutesHigh Pressure (PSI) 10000 PSITime (Minutes) 30 MinutesPass ☒Fail ☐Comments

Replaced the main piston "O"-Rings.



Tuesday, September 21, 2010

Page 1 of 1

CTD Temperature (Primary)**SEA-BIRD ELECTRONICS, INC.**

13431 NE 20th Street, Bellevue, Washington, 98005-2010 USA

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

SENSOR SERIAL NUMBER: 2168
CALIBRATION DATE: 25-Aug-10SBE3 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

ITS-90 COEFFICIENTS

$g = 4.35074487e-003$
 $h = 6.43617720e-004$
 $i = 2.32169072e-005$
 $j = 2.16604066e-006$
 $f_0 = 1000.0$

IPTS-68 COEFFICIENTS

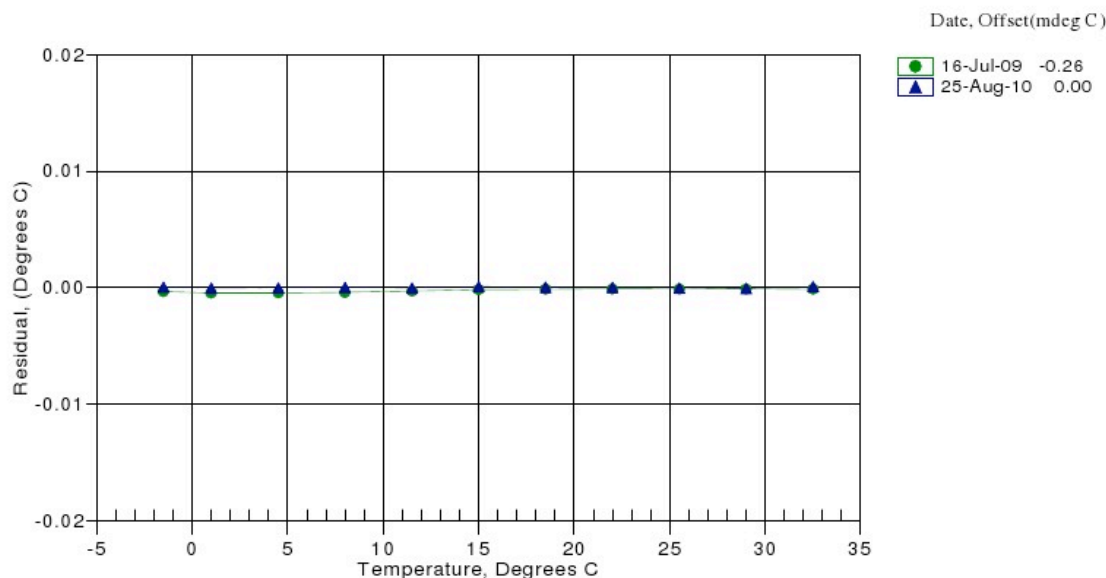
$a = 3.68121031e-003$
 $b = 6.01260029e-004$
 $c = 1.62396002e-005$
 $d = 2.16759037e-006$
 $f_0 = 2938.728$

BATH TEMP (ITS-90)	INSTRUMENT FREQ (Hz)	INST TEMP (ITS-90)	RESIDUAL (ITS-90)
-1.4999	2938.728	-1.4999	0.00005
1.0001	3107.763	1.0000	-0.00006
4.5001	3356.106	4.5001	-0.00001
8.0001	3618.424	8.0001	0.00000
11.5001	3895.094	11.5001	-0.00003
15.0000	4186.491	15.0001	0.00007
18.5000	4492.964	18.5000	0.00002
22.0000	4814.867	22.0000	0.00000
25.5000	5152.529	25.5000	-0.00002
29.0001	5506.278	29.0000	-0.00009
32.5000	5876.419	32.5001	0.00007

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

$$\text{Temperature IPTS-68} = 1/[a + b[\ln(f_0/f)] + c[\ln^2(f_0/f)] + d[\ln^3(f_0/f)]] - 273.15 \text{ (}^\circ\text{C)}$$
Following the recommendation of JPOTS: T_{68} is assumed to be $1.00024 \times T_{90}$ (-2 to 35 $^\circ\text{C}$)

Residual = instrument temperature - bath temperature



CTD Temperature (Secondary)**SEA-BIRD ELECTRONICS, INC.**

13431 NE 20th Street, Bellevue, Washington, 98005-2010 USA

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

SENSOR SERIAL NUMBER: 2186
CALIBRATION DATE: 14-May-10SBE3 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

ITS-90 COEFFICIENTS

$g = 4.34011789 \times 10^{-3}$
 $h = 6.44460535 \times 10^{-4}$
 $i = 2.30790756 \times 10^{-5}$
 $j = 2.14929053 \times 10^{-6}$
 $f_0 = 1000.0$

IPTS-68 COEFFICIENTS

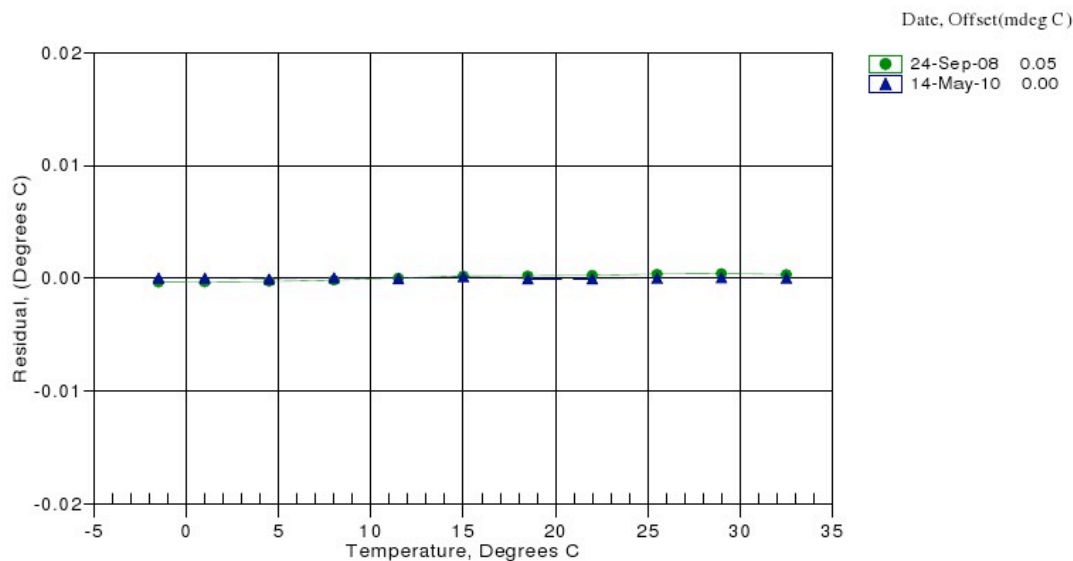
$a = 3.68121198 \times 10^{-3}$
 $b = 6.02969569 \times 10^{-4}$
 $c = 1.62810398 \times 10^{-5}$
 $d = 2.15084434 \times 10^{-6}$
 $f_0 = 2882.325$

BATH TEMP (ITS-90)	INSTRUMENT FREQ (Hz)	INST TEMP (ITS-90)	RESIDUAL (ITS-90)
-1.5000	2882.325	-1.5000	0.00002
1.0000	3047.637	1.0000	-0.00001
4.5000	3290.446	4.4999	-0.00008
8.0000	3546.877	8.0000	0.00005
11.5000	3817.268	11.5000	-0.00002
15.0000	4102.004	15.0001	0.00012
18.5000	4401.387	18.4999	-0.00006
21.9999	4715.782	21.9998	-0.00006
25.5000	5045.530	25.5000	0.00000
28.9999	5390.894	28.9999	0.00004
32.5000	5752.203	32.5000	-0.00001

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

$$\text{Temperature IPTS-68} = 1/[a + b[\ln(f_0/f)] + c[\ln^2(f_0/f)] + d[\ln^3(f_0/f)]] - 273.15 \text{ (}^\circ\text{C)}$$
Following the recommendation of JPOTS: T_{68} is assumed to be $1.00024 \times T_{90}$ (-2 to 35 $^\circ\text{C}$)

Residual = instrument temperature - bath temperature



CTD Conductivity (Primary)**SEA-BIRD ELECTRONICS, INC.**

13431 NE 20th Street, Bellevue, Washington, 98005-2010 USA

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

SENSOR SERIAL NUMBER: 2067
CALIBRATION DATE: 24-Aug-10SBE4 CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Siemens/meter

GHJ COEFFICIENTS

$g = -1.01988362 \times 10^{-1}$
 $h = 1.43690937 \times 10^{-1}$
 $i = -4.11107538 \times 10^{-3}$
 $j = 3.73335698 \times 10^{-4}$
 $CP_{cor} = -9.5700 \times 10^{-8}$ (nominal)
 $CT_{cor} = 3.2500 \times 10^{-6}$ (nominal)

ABCDM COEFFICIENTS

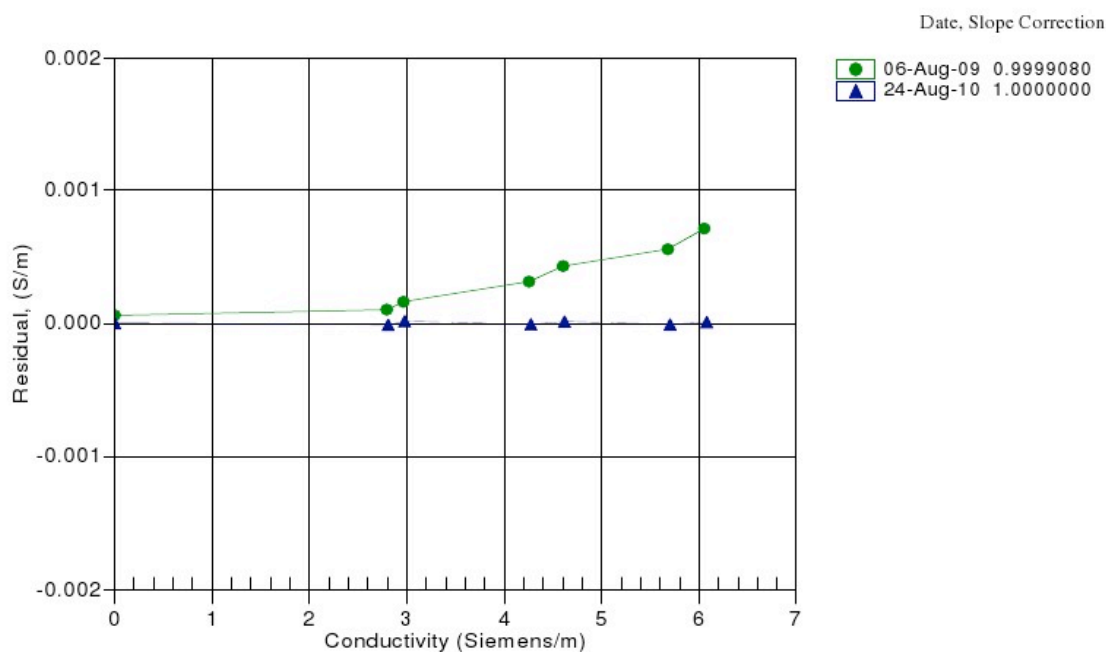
$a = 3.76069224 \times 10^{-9}$
 $b = 1.42426479 \times 10^{-1}$
 $c = -1.01668319 \times 10^{-1}$
 $d = -6.16148601 \times 10^{-5}$
 $m = 8.6$
 $CP_{cor} = -9.5700 \times 10^{-8}$ (nominal)

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	2.67191	0.00000	0.00000
-1.0000	34.8168	2.80461	5.17943	2.80460	-0.00001
1.0000	34.8171	2.97603	5.29431	2.97604	0.00001
15.0000	34.8186	4.27187	6.09243	4.27186	-0.00001
18.5000	34.8181	4.61858	6.28868	4.61859	0.00001
29.0000	34.8170	5.70242	6.86552	5.70241	-0.00001
32.5000	34.8107	6.07512	7.05282	6.07513	0.00001

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

$$\text{Conductivity} = (af^m + bf^2 + c + dt) / [10(1 + \epsilon p)] \text{ Siemens/meter}$$

$$t = \text{temperature}[^\circ\text{C}]; p = \text{pressure}[\text{decibars}]; \delta = CT_{cor}; \epsilon = CP_{cor};$$

$$\text{Residual} = (\text{instrument conductivity} - \text{bath conductivity}) \text{ using } g, h, i, j \text{ coefficients}$$


CTD Conductivity (Secondary)**SEA-BIRD ELECTRONICS, INC.**

13431 NE 20th Street, Bellevue, Washington, 98005-2010 USA

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

SENSOR SERIAL NUMBER: 1798
CALIBRATION DATE: 14-May-10SBE4 CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Siemens/meter

GHJ COEFFICIENTS

$g = -4.11966650e+000$
 $h = 4.81045717e-001$
 $i = -4.26926896e-004$
 $j = 4.66948716e-005$
 $CP_{cor} = -9.5700e-008$ (nominal)
 $CT_{cor} = 3.2500e-006$ (nominal)

ABCDM COEFFICIENTS

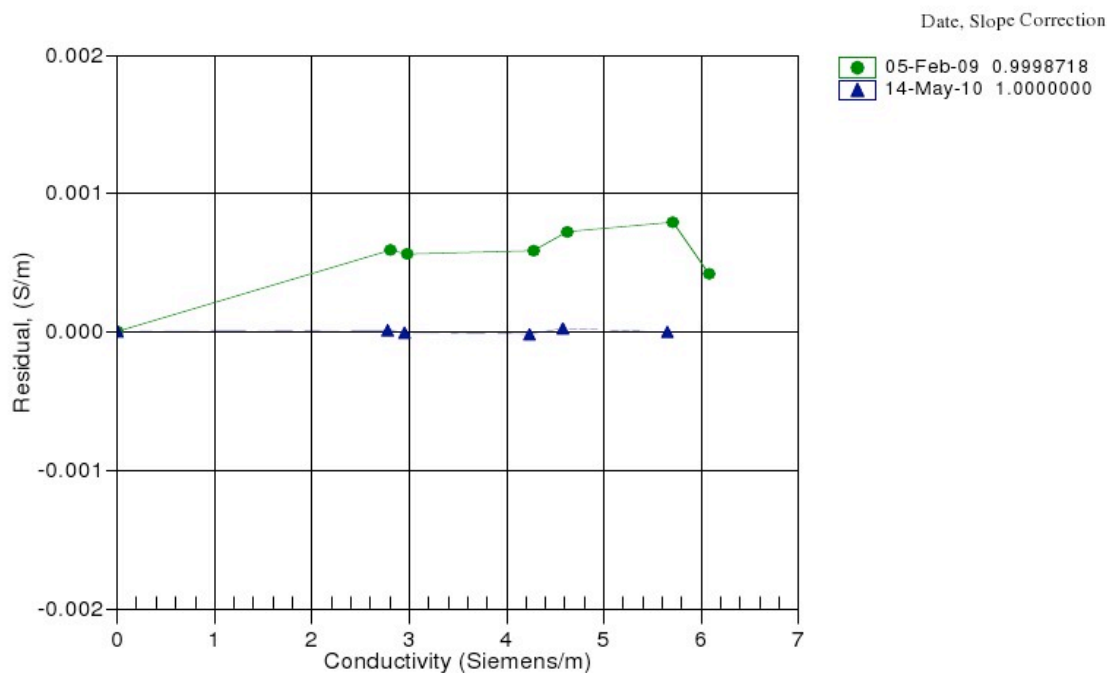
$a = 1.69827089e-006$
 $b = 4.79696645e-001$
 $c = -4.11590036e+000$
 $d = -9.81195373e-005$
 $m = 5.0$
 $CP_{cor} = -9.5700e-008$ (nominal)

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	2.92902	0.00000	0.00000
-1.0000	34.4742	2.77957	8.14850	2.77958	0.00001
1.0000	34.4746	2.94952	8.36201	2.94952	-0.00001
15.0000	34.4746	4.23411	9.82466	4.23409	-0.00002
18.4999	34.4748	4.57792	10.17988	4.57794	0.00002
28.9999	34.4730	5.65237	11.21574	5.65237	-0.00000

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

$$\text{Conductivity} = (af^m + bf^2 + c + dt) / [10(1 + \epsilon p)] \text{ Siemens/meter}$$
 $t = \text{temperature}[^\circ\text{C}]; p = \text{pressure}[\text{decibars}]; \delta = CT_{cor}; \epsilon = CP_{cor};$

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



CTD Dissolved Oxygen (Primary)**SEA-BIRD ELECTRONICS, INC.**

13431 NE 20th Street, Bellevue, Washington, 98005-2010 USA

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

SENSOR SERIAL NUMBER: 0080
CALIBRATION DATE: 19-Aug-10p

SBE 43 OXYGEN CALIBRATION DATA

COEFFICIENTS

Soc = 0.4008

Voffset = -0.5204

Tau20 = 0.93

A = -9.3762e-003

B = 4.3145e-004

C = -4.1361e-006

E nominal = 0.036

NOMINAL DYNAMIC COEFFICIENTS

D1 = 1.92634e-4 H1 = -3.30000e-2

D2 = -4.64803e-2 H2 = 5.00000e+3

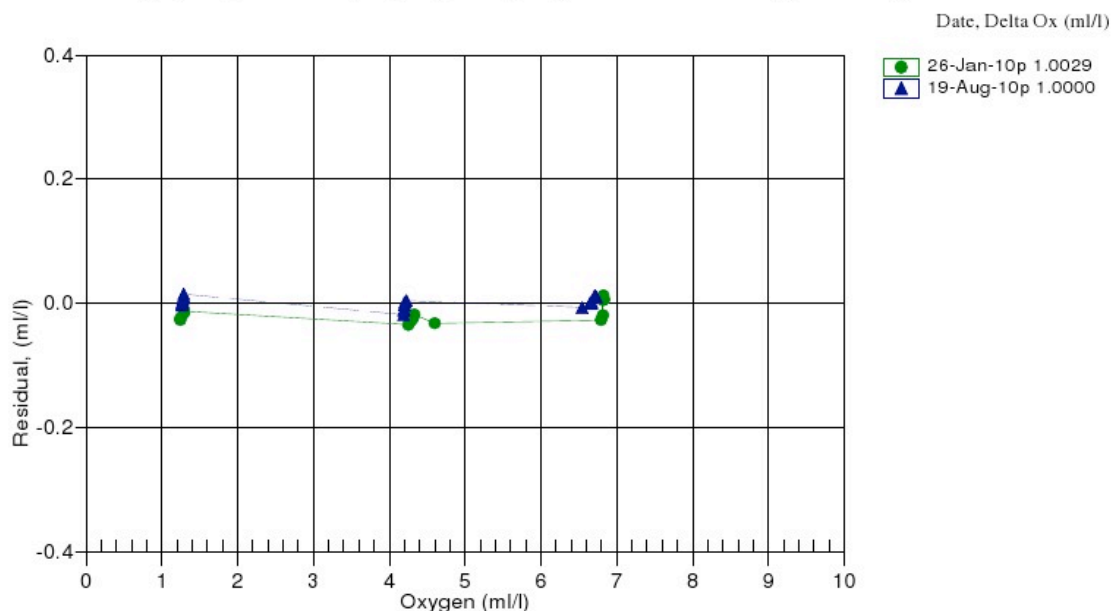
H3 = 1.45000e+3

BATH OX (ml/l)	BATH TEMP ITS-90	BATH SAL PSU	INSTRUMENT OUTPUT(VOLTS)	INSTRUMENT OXYGEN(ml/l)	RESIDUAL (ml/l)
1.26	2.00	0.01	0.851	1.26	-0.00
1.27	6.00	0.02	0.900	1.27	-0.00
1.27	12.00	0.02	0.968	1.28	0.00
1.28	20.00	0.02	1.051	1.29	0.01
1.29	26.00	0.02	1.105	1.30	0.01
1.29	30.00	0.02	1.138	1.30	0.01
4.19	2.00	0.01	1.614	4.17	-0.02
4.19	6.00	0.02	1.769	4.18	-0.01
4.20	12.00	0.02	1.990	4.18	-0.01
4.20	20.00	0.02	2.250	4.20	-0.00
4.21	26.00	0.02	2.417	4.21	0.00
4.23	30.00	0.02	2.525	4.23	0.00
6.55	30.00	0.02	3.620	6.54	-0.01
6.65	20.00	0.02	3.260	6.65	0.00
6.67	26.00	0.02	3.526	6.67	-0.00
6.67	12.00	0.02	2.863	6.67	0.00
6.71	6.00	0.02	2.530	6.72	0.01
6.73	2.00	0.01	2.288	6.74	0.01

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

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 (Secondary)**SEA-BIRD ELECTRONICS, INC.**

13431 NE 20th Street, Bellevue, Washington, 98005-2010 USA

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

SENSOR SERIAL NUMBER: 0082
CALIBRATION DATE: 19-Aug-10p

SBE 43 OXYGEN CALIBRATION DATA

COEFFICIENTS

Soc = 0.3910

Voffset = -0.6971

Tau20 = 1.44

A = -3.1323e-003

B = 1.2979e-004

C = -2.7232e-006

E nominal = 0.036

NOMINAL DYNAMIC COEFFICIENTS

D1 = 1.92634e-4 H1 = -3.30000e-2

D2 = -4.64803e-2 H2 = 5.00000e+3

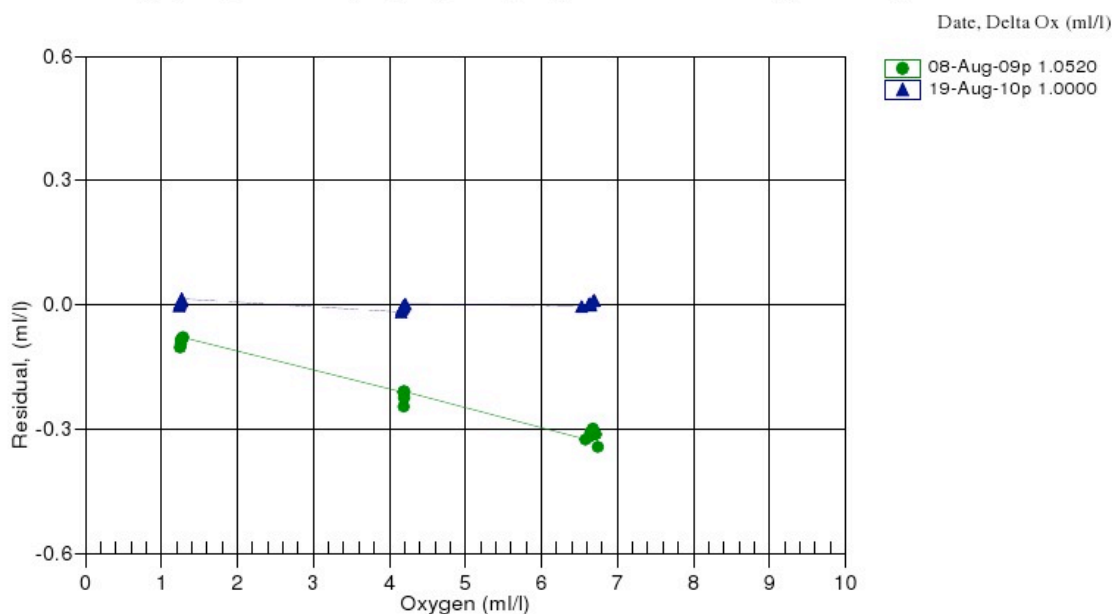
H3 = 1.45000e+3

BATH OX (ml/l)	BATH TEMP ITS-90	BATH SAL PSU	INSTRUMENT OUTPUT(VOLTS)	INSTRUMENT OXYGEN(ml/l)	RESIDUAL (ml/l)
1.23	2.00	0.01	1.024	1.23	-0.00
1.24	6.00	0.02	1.067	1.24	-0.00
1.25	12.00	0.02	1.132	1.25	0.00
1.26	20.00	0.02	1.223	1.27	0.01
1.27	26.00	0.02	1.298	1.28	0.01
1.27	30.00	0.02	1.352	1.29	0.01
4.16	2.00	0.01	1.797	4.14	-0.02
4.16	6.00	0.02	1.933	4.15	-0.01
4.17	12.00	0.02	2.143	4.16	-0.01
4.18	20.00	0.02	2.431	4.17	-0.01
4.19	26.00	0.02	2.665	4.19	-0.00
4.21	30.00	0.02	2.842	4.21	0.00
6.53	30.00	0.02	4.020	6.52	-0.00
6.63	20.00	0.02	3.453	6.63	0.00
6.64	12.00	0.02	3.006	6.65	0.00
6.65	26.00	0.02	3.822	6.65	-0.00
6.68	6.00	0.02	2.691	6.69	0.01
6.70	2.00	0.01	2.480	6.71	0.01

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

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 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 $V = \log I \text{ (Amps)} / I_{\text{Ref}}$
 To calculate irradiance, use this formula:

$$\text{Irradiance} = \text{Calibration factor} * (10^{\text{Light Signal Voltage}} - 10^{\text{Dark Voltage}})$$

With the appropriate (solar corrected) Irradiance Calibration Factor:

Dry Calibration Factor:	6.59E+12	quanta/cm ² ·sec/"amps"	1.09E-05	μEinsteins/cm ² ·sec/"amps"
Wet Calibration Factor:	1.11E+13	quanta/cm ² ·sec/"amps"	1.84E-05	μEinsteins/cm ² ·sec/"amps"

Sensor Test Data and Results⁴⁾

Sensor Supply Current (Dark):		63.3	mA							
Supply Voltage:		6	Volts							
Lamp Integrated PAR Irradiance:		9.09E+15	quanta/cm ² ·sec	0.01509		μEinsteins/cm ² ·sec				
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/cm ² ·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							
Dark After - NFH:	0.141	Volts							
Average Dark	0.141	Volts							
				$I_{\text{Ref}} = 1.00\text{E-}10$	Amps				
				$I_{\text{Dark}} = 1.38\text{E-}10$	Amps				
				$10^{V_{\text{Dark}}} = 1.381974$	Amps				
						RG780		0.607	

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 Fluorometer

PO Box 518
620 Applegate St.
Philomath, OR 97370



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

ECO Chlorophyll Fluorometer Characterization Sheet

Date: 9/22/2010

S/N: FLRTD-855

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

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

	Analog Range 1	Analog Range 2	Analog Range 4 (default)	Digital
Dark Counts	0.106	0.067	0.048 V	65 counts
Scale Factor (SF)	6	12	25 $\mu\text{g/l/V}$	0.0076 $\mu\text{g/l/count}$
Maximum Output	4.97	4.97	4.97 V	16326 counts
Resolution	0.9	0.9	0.9 mV	1.0 counts

Ambient temperature during characterization

22.3 °C

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

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

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

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

Resolution: Standard deviation of 1 minute of collected data.

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

FLRTD-855.xls

Revision J

3/17/08

CTD Transmissimeter

PO Box 518
620 Applegate St.
Philomath, OR 97370



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

C-Star Calibration

Date **June 28, 2010** S/N# **CST-831DR** Pathlength **25 cm**

	Analog meter
V_d	0.059 V
V_{air}	4.804 V
V_{ref}	4.728 V

Temperature of calibration water	24.2 °C
Ambient temperature during calibration	22.1 °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

Trace Metal CTD

The trace metal CTD on this cruise was provided by Dr. Chris Measures. He has a record of all calibration data.