Data Report NBP0703

Punta Arenas, Chile to Punta Arenas, Chile * 31 March to 5 May 2007

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. It is readable by virtually every computing platform.

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

MultiBeam and BathyW 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

The NBP0703 data distribution consists of 5 disks. There is one master disk that contains all the DAS data, seismic data, bathy 2000W data and the final draft of the cruise data report. There are 4 supplemental disks that contain the Knudsen sub bottom and seg-y data.

Volume 1 of 5: NBP0703

root
- INSTCOEF.TXT
- 0703Data.doc
- 0703_be.gmt
- NBP0703.gmt
- NBP0703.mgd
- NBP0703.trk
- 0703_map.jpg
- 0703_map.ps
- 703Prsnl.xls

bathyw/
- Bathy data

Imagery/
- 0703Imag.zip

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seismic/
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- 0703gyr1.tar
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- 0703seap.tar
- 0703sp1b.tar
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rvdas/uw/
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- 0703bwnc.tar
- 0703lwnc.tar
- 0703eng1.tar
- 0703flr1.tar
- 0703grv1.tar
- 0703knud.tar
- 0703mbdp.tar
- 0703met1.tar
- 0703pco2.tar
- 0703pguv.tar
- 0703svp1.tar
- 0703tsg1.tar

science/
- Logs.tar
- Maps.tar
- Scirep.tar

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

Chief Scientists: Dr. John Anderson and Dr Bernard Hallet.

Cruise NBP0703 was a marine geophysical and glaciology cruise that started in Punta Arenas, Chile on March 31, 2007 and returned to Punta Arenas on May 5, 2007. Dr Anderson had permission to collect data in Argentine waters, resulting in 2 data distributions.

The only major error in the data systems during the cruise was the time clock. The NBP runs on a rubidium time standard while at sea. In order to propagate the time throughout the computer network, the main server 'Triton' has to be able to talk to the rubidium clock via a serial port. On March 28th before the start of the cruise there was an emergency generator check that necessitated the shutdown of all the NBPs computer systems and network. When Triton was brought back on line its device tables were rebuilt. As a result of this, the serial port that talks to the clock did not have the correct permissions on it for Triton to initiate the clock. Over the course of the cruise the clock slewed to the advance by 18 seconds. All events in the data are correctly synchronized, but the actual time stamp on the data is fast by about 18 seconds. Dr Anderson was informed of the problem on the 26th of April and chose not to change anything until after the cruise. The GPS data does include time from the GPS system if someone feels the need to reprocess the data.

Cruise Track

The distribution DVD includes a GMT cruise track file (`NBP0703.trk`). It contains the longitude and latitude at one-minute intervals extracted from the NBP0703.gmt file.

Jpeg and postscript files of the cruise track have also been placed in the DAS directory.

Satellite Images

Satellite Images processed for this cruise can be found in the directory `/Imagery` in two subdirectories, Ice and WX (weather). Files are named using the convention `IdDDDYYA.jpg` where:

Id = image type (ice = ice, wx = weather)
DDD = year-day
YY = year
A = allows for multiple images of one type for one day

Science Reports

Cruise science reports will be found in the directory `/science`.

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 `0703proc.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/NBP0703JGOF.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	volts (0-5 FSO)
20	Not used	-
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 `NBP0703.mgd`. The file `NBP0703.gmt` is created from the MGD77 dataset using the "mgd77togmt" utility. `NBP0703.gmt` can be used with the GMT plotting package.

The data used to produce the `NBP0703.mgd` file can be found on the distribution media in the file `/process/NBP0703proc.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

Col	Len	Type	Contents	Description, Possible Values, Notes
				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 `NBP0703adcp.tar` in the directory `/rvdas/nav`.

pCO_2

The NBP carries a pCO_2 measurement system from Lamont-Doherty Earth Observatory (LDEO). pCO_2 data is recorded by RVDAS and transmitted to LDEO at the end of each cruise. You will find pCO_2 data in a file named `NBP0703pco2.tar` in the `/process` directory, which contains the pCO_2 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/NBP0703ctd.tar`. The archive contains tar files `NBP0703proc.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 `NBP0703xbt.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: `NBP0703.met1.d065`

- The CruiseID is the numeric name of the cruise, in this case, NBP0703.
- The ChannelID is a 4-character code representing the system being logged. An example is “met1,” 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	met1	continuous	1 sec	R. M. Young 41372LC
Relative Humidity	met1	continuous	1 sec	
Wind Speed/Direction	met1	continuous	1 sec	R.M. Young 05106
Barometer	met1	continuous	1 sec	R.M. Young 61201
PIR (LW radiation)	met1	continuous	1 sec	Eppley PIR
PSP (SW radiation)	met1	continuous	1 sec	Eppley PSP
PAR	met1	continuous	1 sec	BSI QSR-240
GUV	guv	continuous	2 sec	BSI PUV-2511
PUV	puv	continuous		BSI PUG-2500

Geophysics

Measurement	Channel ID	Collect. Status	Rate	Instrument
Gravimeter	grv1	continuous	10 sec*	LaCoste & Romberg
Bathymetry	bat1	Only collected for a few days of 0703	Varies	ODEC Bathy 2000
Bathymetry	knu1	Primary source of bathy data for 0703	Varies	Knudsen 320B/R
Bathymetry	sim1	depth < 2500 m	Varies	Simrad EK500 Sonar

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

Oceanography

Measurement	Channel ID	Collect. Status	Rate	Instrument
Conductivity	tsg1	Continuous	6 sec	SeaBird SBE-21
Salinity	tsgfl	Continuous	6 sec	Calc. from pri. temp
Sea Surface Temp	tsg1	Continuous	6 sec	SeaBird 3-01/S
Fluorometry	flr1	Continuous	1 sec	Turner 10-AU-005
Transmissometry	tsg1	Continuous	6 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

Sound Velocity Probe (svp1)

```
00+348:01:59:52.128  1539.40
```

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

Meteorology (met1)

```
01+322:00:03:27.306 04.5 292 010 05.7 294 010 0959.6 000.2 093.1

-000.1537 0001.0886 0012.8248
```

Field	Data	Units
1	RVDAS time tag	
2	Port anemometer speed (relative)	m/s
3	Port anemometer direction (relative)	deg
4	Port anemometer standard deviation	deg
5	Starboard anemometer speed (relative)	m/s
6	Starboard anemometer direction (relative)	deg
7	Starboard anemometer standard deviation	deg
8	Barometer	mBar
9	Air temperature	°C
10	Relative humidity	%
11	PSP (short wave radiation)*	mV
12	PIR (long wave radiation)*	mV
13	PAR (photosynthetically available radiation)*	mV

*See page 21 for calculations.

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

Field	Data	Conversion	Units
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

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 frequency	SF1=3.5 kHz SF2=12.0 kHz	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	

Field	Data	Format / Possible Values	Units
		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

Simrad EM120 (mbdp)

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

Simrad EK500 (sim1)

```
00+005:00:00:52.388 D1,23583509,1479.6, 17,  1,  0
```

Field	Data	Units
1	RVDAS time tag	
2	Header	
3	Time tag	hhmmss.sss
4	Depth	m
5	Bottom surface backscattering strength	dBar
6	Transducer number (1 = 38 kHz)	
7		

Thermosalinograph (tsg1)

```
00+019:23:59:46.976 15A16CFC163F8C2C100
```

Field	Data	Units
1	RVDAS time tag	
2	Seabird hex string (see page 22 for conversion to real units)	

Fluorometer (flr1)

```
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

```
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

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
4	Rate of change SYYY S = +/-, YYY = r.rr	
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

Sound Velocity Probe (svp1)

```
00+348:01:59:52.128  1539.40
```

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

Processed Data

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
```

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

tsgfl

```
00+075:00:00:04.467 -01.488 -01.720 02.6783 33.63748 1.002442 0.002442
```

Field	Data	Units
1	RVDAS time tag	
2	Internal water temperature	°C
3	Sea Surface Temperature	°C
4	Conductivity	μSiemens
5	Salinity	PSU
6	Fluorometry	V
7	Transmissivity	V

Calculations

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

TSG

Raw TSG data is stored as a 20 byte (character) long hex string

Bytes	Data
1-4	Sensor Temperature
5-8	Conductivity
9-14	Remote Temperature
15-18	Transmissometer voltage

The coefficients for temperature and conductivity sensors can be found the `rvdascal.txt` file and on the calibrations sheets in the appendix.

Calculating Temperature – ITS-90

T = decimal equivalent of bytes 1-4
Temperature Frequency: f = T/19 +2100
Temperature = $1/\{g + h[ln(f_0/f)] + i[ln^2(f_0/f)] + j[ln^3(f_0/f)]\} - 273.15$ (°C)

Calculating Conductivity – ITS-90

C = decimal equivalent of bytes 5-8
Conductivity Frequency f = sqrt(C*2100+6250000)
Conductivity = $(g + hf^2 + if^3 + jf^4)/[10(1 + \delta t + \varepsilon p)]$ (siemens/meter)
t = temperature (°C); p = pressure (decibars); δ = Ctcor; ε = CPcor

Calculating Transmittance

V_{dark} = 0.058 V
V_{ref} = 4.765 V
t = decimal equivalent of bytes 18 – 20
Transmissometer Voltage (V_{signal}) = t/819
% Transmittance = $(V_{signal} - V_{dark}) / (V_{ref} - V_{dark})$

PAR

raw data = mV

calibration scale = 6.27 V/(μEinstiens/cm 2sec)

offset (Vdark) = 0.1 mV

(raw mV - Vdark)/scale x 104 cm2/m2 x 10-3 V/mV= μEinstiens/m2sec

or

(data mV – 0.1 mV) x 1.65 (μEinstiens/m2sec)/mV = μEinstiens/m2sec

PSP

raw data = mV

calibration scale = 7.94 x 10-6 V/(W/m2)

data mV / (scale x 103 mV/V) = W/m2

or

data mV x 120.7 (W/m2)/V = W/m2

Acquisition Problems and Events

This section lists acquisition problem and events 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
091:10:39		Left Chilean EEZ, entered Argentine EEZ. Started Data collection
093:00:30		(approx) Leave Argentine EEZ
093:14:18		Replaced SCSI drive on eltanin (logging computer)
104:13:08		Changed from Knudsen to Bathy
107:18:13		Changed back to Knudsen
122:13:16		Enter Argentine EEZ
		Stopped Loggers at Chilean EEZ limit

Appendix: Sensors and Calibrations

NBP0703 Sensors:

Shipboard Sensors

Sensor	Description	Serial #	Last Calibration
Port Anemometer	RM Young 5106	WM 46263	05/20/06
Stbd Anemometer	RM Young 5106	WM 73682	07/10/06
Barometer	RM Young 61201	0872	06/24/05
Humidity/Wet Temp	RM Young 41372LC	06733	06/24/05
PIR (Pyrgeometer)	Eppley PIR	32845F3	08/17/06
PSP (Pyranometer)	Eppley PSP	32850F3	08/16/06
PAR (Mast)	BSI-QSR-240	6356	05/16/05
GUV (Mast)	BSI GUV-2511	25110805126	10/17/06
TSG (pre-Feb 7)	SeaBird SBE21	214857-0857	03/15/06
TSG (Feb 7 and later)	SeaBird SBE21	2131020-3198	05/20/2006
TSG Remote Temp	SeaBird 3-01/S	031267	04/12/06
Fluorometer	Turner 10-AU-005	5333-FRXX	N/A
Transmissometer	WET Labs C-Star	CST-439DR	12/09/05
Gravimeter	LaCoste & Romberg		n/a
Bathymetry	Knudsen 320B/R		n/a
Bathymetry	Bathy 2000		n/a
P-Code GPS	Trimble 20636-00 (SM)	0220035116	

CTD Sensors:

Sensor	Description	Serial #	Last Calibration
CTD Fish	SeaBird model SBE 9+	09P10716-0377	07/05/05
CTD Fish Pressure	Paroscientific model 410K-105	58949	07/05/05
CTD Deck Unit	SeaBird model SBE 11+	11P19858-0490	n/a
Primary Temperature	SeaBird model 3+	03P2367	04/12/06
Secondary Temperature	SeaBird model 3+	03P2168	05/17/06
Primary Conductivity	SeaBird model 4C	041799	05/17/06
Secondary Conductivity	SeaBird model 4C	041850	04/11/06
Transmissometer	WET Labs C-Star	CST-892DR	10/12/05
CTD Pump (Primary)	SeaBird 5T, PN 90160	051645 3.0K	04/10/06
CTD Pump (Secondary)	SeaBird 5T, PN 90160	051646 3.0K	04/10/06
Bottom Contact Switch	SeaBird	#1	n/a
Pinger	OIS 6000 (6000m)	5118	n/a
Slip Ring Assembly		1.406	n/a
Carousel Water Sampler	SeaBird SBE-32	3211265-0066	n/a

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: 3/26/2007
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))	8960.4	20:25
Ship's meter after gravity tie (Gravity (cu))	8960.4	21:27
Average	8960.4	
Ship Gravimeter's Calibration Constant	1.0046	
Corrected ship's meter (QC Grav (mgal))	9001.6	

	Value	Time (GMT)
Ship's meter before gravity tie (serial, RVDAS)	8960.5	20:28
Ship's meter after gravity tie (serial, RVDAS)	8960.4	21:26
Average (for comparison check only)	8960.5	

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	4910.99	20:53	54	April 1, 2007	
Pier measurement 2	4910.95	20:58	54	April 1, 2007	4960.39
Pier measurement 3	4910.87	21:00	54	April 1, 2007	
Average	4910.94				
Station measurement 1	4911.67	21:09	54	April 1, 2007	
Station measurement 2	4911.58	21:10	54	April 1, 2007	4961.10
Station measurement 3	4911.66	21:11	54	April 1, 2007	
Average	4911.64				
Pier measurement 4	4910.89	21:19	54	April 1, 2007	
Pier measurement 5	4910.88	21:20	54	April 1, 2007	4960.38
Pier measurement 6	4911.00	21:21	54	April 1, 2007	
Average	4910.92				

Gravity offset from last tie 972316.86
Drift since last tie 1.79

OBS Differences

Station to Pier (1, 2, & 3 averaged)	-0.71
Station to Pier (4, 5, & 6 averaged)	-0.72
Averaged Differences	-0.71
Gravity at pier	981320.11
Elevation of pier above gravimeter, meters	0.5
Earth differential gravity, mgal/meter	0.3
Gravity at ship's gravimeter	981320.27
Gravity Offset (for RVDAS)	972318.65

Comments

Gravity Tie taken by Greg Watson and Jennifer Ayers at Pier in Punta Arenas and at Gravity Station by Guard shack. All reading went smoothly without any complications.

Meteorology System

Anemometer (Port)

RM Young Anemometer Calibration, Model 05106

S/N: 46263 **Date:** 20-May-06 **Cal'd By:** S. Blackman

Clockwise Cal Motor RPM	Calculated Windspeed m/s	Measured Windspeed m/s	Delta m/s	Knots
0	0.00	0.0	0.00	0.0
200	0.98	0.9	0.08	1.9
500	2.45	2.3	0.15	4.8
1000	4.90	4.8	0.10	9.5
1500	7.35	7.2	0.15	14.3
2000	9.80	9.8	0.00	19.0
3000	14.70	14.7	0.00	28.6
4000	19.60	19.7	-0.10	38.1
5000	24.50	24.7	-0.20	47.6
6000	29.40	29.6	-0.20	57.1
7000	34.30	34.6	-0.30	66.6
8000	39.20	39.6	-0.40	76.2
9000	44.10	44.6	-0.50	85.7
10000	49.00	49.5	-0.50	95.2
12000	58.80	59.4	-0.60	114.2

Direction	Measured Direction	Delta Direction
0	0	0
30	30	0
60	60	0
90	90	0
120	120	0
150	150	0
180	180	0
210	210	0
240	240	0
270	270	0
300	300	0
330	330	0
0	0	0

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	0.0	0.00
200	0.98	0.8	0.18
500	2.45	2.3	0.15
1000	4.90	4.8	0.10
1500	7.35	7.3	0.05
2000	9.80	9.8	0.00
3000	14.70	14.8	-0.10
4000	19.60	19.7	-0.10
5000	24.50	24.7	-0.20
6000	29.40	29.6	-0.20
7000	34.30	34.6	-0.30
8000	39.20	39.6	-0.40
9000	44.10	44.6	-0.50
10000	49.00	49.5	-0.50
12000	58.80	59.4	-0.60

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

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

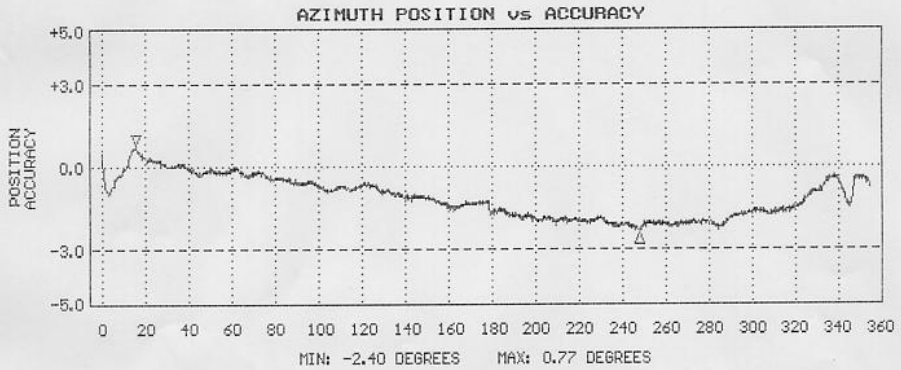
Additional Comments
Removed from drawer for installation. Calibration checked.

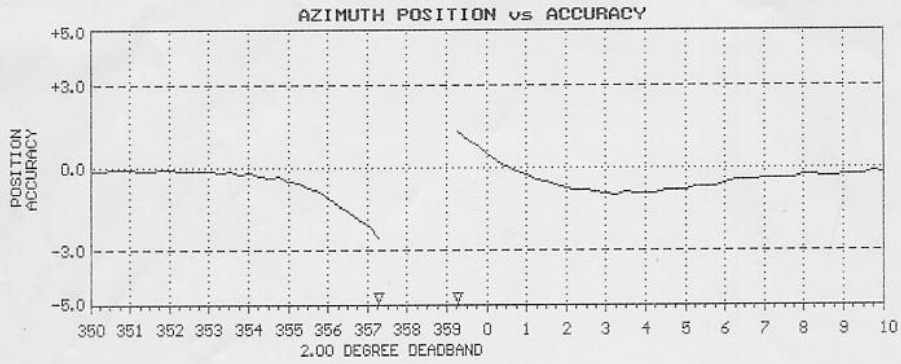
Note: Delta Windspeed should not exceed + or - 0.3 m/s for 0 - 5000 rpm

Anemometer (Starboard)

R. M. YOUNG COMPANY WIND SENSOR CALIBRATION CERTIFICATE

SENSOR: 05106 WIND MONITOR-MA
SENSOR SERIAL NUMBER: WM73682
BEARINGS: SEALED/WATERPROOF GREASE
DATE: JUL 10 2006
WIND SPEED THRESHOLD TEST: PASS
LOW WIND SPEED AMPLITUDE/FREQUENCY TEST: PASS
HIGH WIND SPEED AMPLITUDE/FREQUENCY TEST: PASS
VANE TORQUE TEST: PASS
SPECIAL NOTES:
SPECIAL NOTES:





NOTE: Azimuth Position vs Accuracy graphs are accurate to within 0.5 degrees. The accuracy shown in the potentiometer deadband region between 355 and 0 degrees is the result of no resistance change while position changes. The gap represents the actual deadband (open circuit).

Barometer

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

Barometric Pressure Sensor Calibration Report

Customer: *Raytheon Polar Services*

Test Number: 56165
Test Date: 24 June 2005

Customer PO: RM19274-50
Sales Order: 7837

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

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	1252	875.1
950.0	2503	950.2
1025.0	3753	1025.2
1100.0	5001	1100.1

(1) Calculated from voltage output

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

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

Tested By: E. Chemosky

tel: 231-946-3980 fax: 231-946-4772 email: met.sales@youngusa.com Website: www.youngusa.com

Humidity/Wet Temp

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

Temperature Sensor Calibration Report

Customer: *Raytheon Polar Services*

Test Number: 56163
Test Date: 24 June 2005
Customer PO: RM19274-50
Sales Order: 7837

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)
-49.98	4.005	-49.97
0.03	12.004	0.02
50.04	20.006	50.04

(1) Calculated from current output

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

Reference Instrument	Serial #	NIST Test Reference
Brooklyn Thermometer Model 43-FC	8006-118	204365
Brooklyn Thermometer Model 22332-D5-FC	25071	249763
Brooklyn Thermometer Model 2X400-D7-FC	77532	228060
Keithley Multimeter Model 191	15232	234027

Tested By: E. Chemosky

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
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for Precision Measurements
Since 1917

STANDARDIZATION OF EPPLEY PRECISION INFRARED RADIOMETER Model PIR

Serial Number: 32845F3

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:

4.13 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.

Shipped to:
National Science Foundation
c/o RPSC
Port Hueneme, CA
S.O. Number: 60834
Date: August 23, 2006

Date of Test: August 17, 2006

In Charge of Test: R.EGGEMAN

Reviewed by: Thomas J. Kirk

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: 32850F3

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

This radiometer has been compared with Standard Precision Spectral Pyranometer, Serial Number 21231F3 in Eppley's Integrating Hemisphere under radiation intensities of approximately 700 watts meter^{-2} (roughly one-half a solar constant). The adopted calibration temperature is 25 °C.

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

7.87 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 Ninth International Pyrheliometric Comparisons (IPC IX) at Davos, Switzerland in September-October 2000.

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

Shipped to:
National Science Foundation
c/o RPSC
Port Hueneme, CA
S.O. Number: 60835
Date: August 23, 2006

Date of Test: August 16, 2006

In Charge of Test: R. EGGEMAN

Reviewed by: Thomas J Kuhl

Remarks:

PAR

Biospherical Instruments Inc.

CALIBRATION CERTIFICATE

Calibration Date	5/16/2005
Model Number	QSR-240
Serial Number	6356
Operator	TPC
Standard Lamp	99189(4/12/05)
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	86.9	mV
Probe Dark	0.1	mV
Probe Net Response	86.8	mV

Corrected Lamp Output:

Output In Air (same condition as calibration):

8.34E+15	quanta/cm²sec
0.01384	uE/cm²sec

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

Dry:	1.04E-17	V/(quanta/cm²sec)
	6.27E+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

Biospherical Instruments Inc.

GUV-2511 Calibration Certificate

System Serial Number	25110805126	Date of Calibration	10/17/2006
Calibration database	25110805126v2.mdb	Date of Certificate	10/17/2006
DASSN	0109	Standard of Spectral Irradiance	F-863(9/30/06)
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
Ed0305	2	305	4.4600E-11	4.5841E-06	1.3396E-03	4.0786E-01	-9.6000E-05	-9.6000E-05	6.7900E-04	µW/(cm²nm)
Ed0313	6	313	2.4900E-10	2.5389E-05	7.4223E-03	2.6122E+00	-1.2000E-05	-1.4000E-05	9.2900E-04	µW/(cm²nm)
Ed0320	8	320	2.6970E-10	2.7447E-05	8.0670E-03	2.7924E+00	-2.7000E-04	-2.7400E-04	1.7900E-04	µW/(cm²nm)
Ed0340	10	340	1.9272E-10	1.9624E-05	5.7526E-03	2.0331E+00	-1.9000E-05	-2.1000E-05	8.8200E-04	µW/(cm²nm)
Ed0380	12	380	7.7831E-11	7.9310E-06	2.3143E-03	8.1242E-01	-2.9800E-04	-3.0000E-04	2.1100E-04	µW/(cm²nm)
Ed0395	13	395	3.6442E-10	3.7265E-05	1.0943E-02	3.8064E+00	8.3000E-05	8.4000E-05	1.1160E-03	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	18	400-700	1.7213E-05	1.7534E+00	5.1378E+02	1.7984E+05	-7.7000E-05	-7.6000E-05	1.0270E-03	µE/(cm²sec)

Auxilliary Channels	Address	Wavelength	Responsivity	ScaleS	ScaleM	ScaleL	OffsetS	OffsetM	OffsetL	Measurement Units
Ed0Temp	22	0	1	0.01	0.01	0.01	0	0	0	°C
Ed0Vln	27	0	1	-0.25	-0.25	-0.25	0	0	0	V

TSG Calibration Files

Underway 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: 3198
CALIBRATION DATE: 20-May-06

SBE21 CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Seimens/meter

GHIJ COEFFICIENTS
g = -4.27061383e+000
h = 5.04384737e-001
i = -4.53257393e-004
j = 4.72934991e-005
CPcor = -9.5700e-008 (nominal)
CTcor = 3.2500e-006 (nominal)

ABCDM COEFFICIENTS
a = 2.81077465e-006
b = 5.02715558e-001
c = -4.26259709e+000
d = -8.83813520e-005
m = 4.8
CPcor = -9.5700e-008 (nominal)

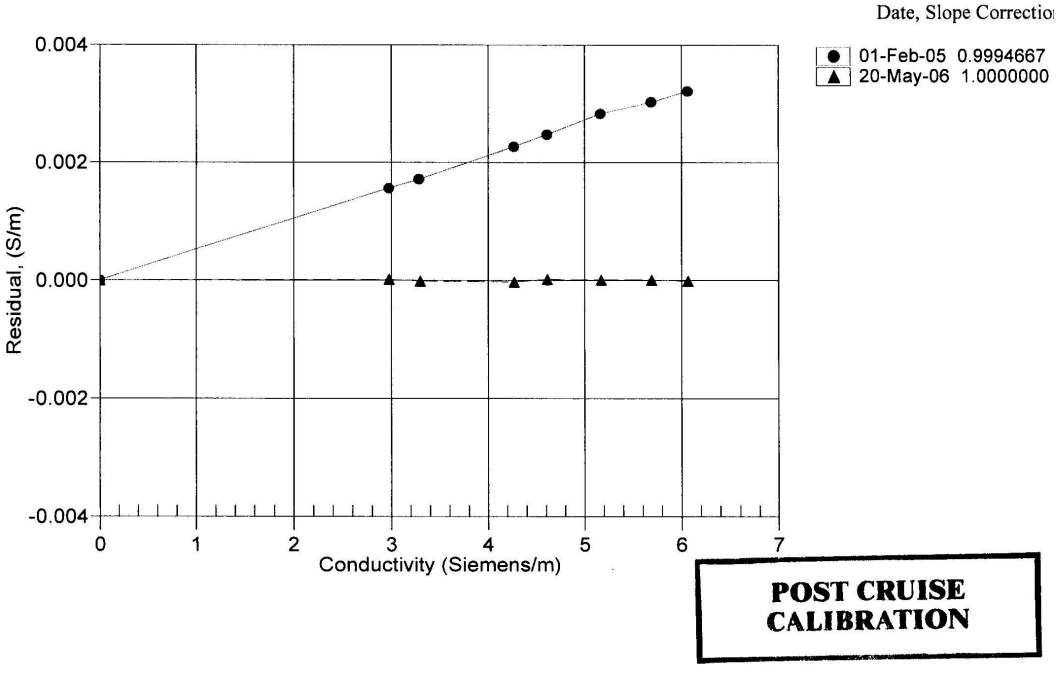
BATH TEMP (ITS-90)	BATH SAL (PSU)	BATH COND (Siemens/m)	INST FREQ (kHz)	INST COND (Siemens/m)	RESIDUAL (Siemens/m)
22.0000	0.0000	0.00000	2.91246	0.00000	0.00000
1.0000	34.8123	2.97566	8.21793	2.97567	0.00002
4.6261	34.7919	3.29397	8.59263	3.29396	-0.00001
15.0000	34.7503	4.26437	9.64425	4.26434	-0.00003
18.4999	34.7417	4.60953	9.99119	4.60955	0.00002
24.0000	34.7323	5.16751	10.52728	5.16752	0.00001
29.0000	34.7279	5.68947	11.00456	5.68948	0.00001
32.4999	34.7263	6.06206	11.33261	6.06205	-0.00001

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



Underway 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: 3198
CALIBRATION DATE: 20-May-06

SBE21 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPRATURE SCALE

ITS-90 COEFFICIENTS

g = 4.22473160e-003
h = 6.29770835e-004
i = 2.05272425e-005
j = 1.54706370e-006
f0 = 1000.0

ITS-68 COEFFICIENTS

a = 3.64763347e-003
b = 5.95315785e-004
c = 1.61762223e-005
d = 1.54852177e-006
f0 = 2568.439

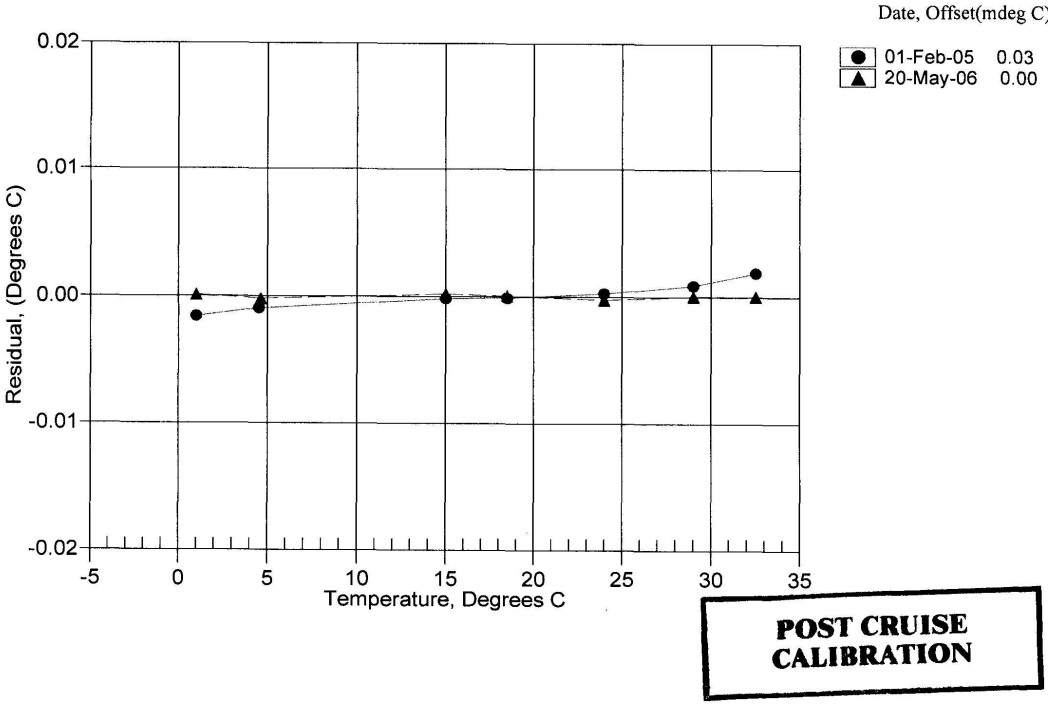
BATH TEMP (ITS-90)	INSTRUMENT FREQ (Hz)	INST TEMP (ITS-90)	RESIDUAL (ITS-90)
1.0000	2568.439	1.0001	0.00011
4.6261	2782.830	4.6259	-0.00021
15.0000	3467.526	15.0002	0.00020
18.4999	3723.433	18.5000	0.00006
24.0000	4152.193	23.9998	-0.00023
29.0000	4571.111	29.0000	0.00004
32.4999	4881.298	32.4999	0.00004

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

Temperature 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



Underway 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: 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

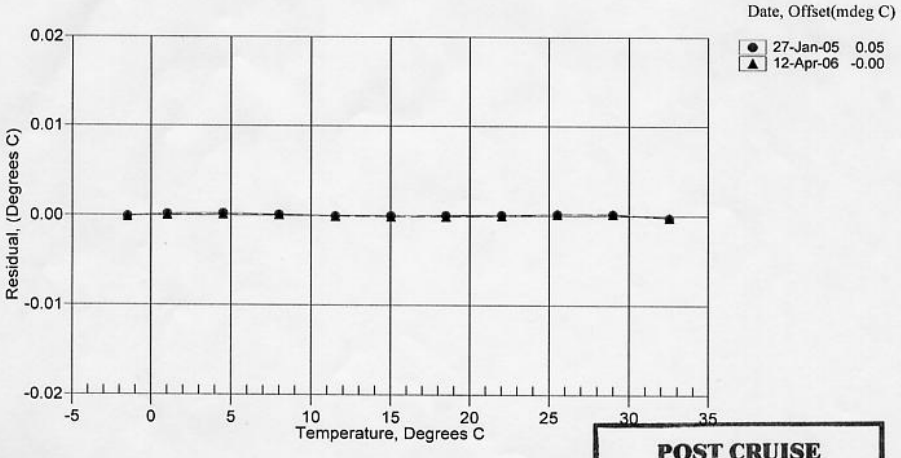
BATH TEMP (ITS-90)	INSTRUMENT FREQ (Hz)	INST TEMP (ITS-90)	RESIDUAL (ITS-90)
-1.5001	5707.029	-1.5002	-0.00010
1.0000	6042.027	1.0001	0.00005
4.4999	6534.652	4.5000	0.00014
7.9999	7055.608	8.0000	0.00007
11.4999	7605.659	11.4998	-0.00008
14.9999	8185.578	14.9998	-0.00014
18.4999	8796.088	18.4998	-0.00011
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 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 December 9, 2005 Customer National Science Foundation Work order 007

Job # 0102007 S/N# CST-439DR Pathlength 25 cm

	Analog meter
V_d	0.060 V
V_{air}	4.804 V
V_{ref}	4.707 V

Temperature of calibration water	16.9 °C
Ambient temperature during calibration	22.6 °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.

cstarwkbkf1.xls Revision F 1/17/05

CTD SENSORS

CTD Fish & Pressure 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: 0377
CALIBRATION DATE: 05-Jul-05

SBE9plus PRESSURE CALIBRATION DATA
10000 psia S/N 58949

DIGIQUARTZ COEFFICIENTS:

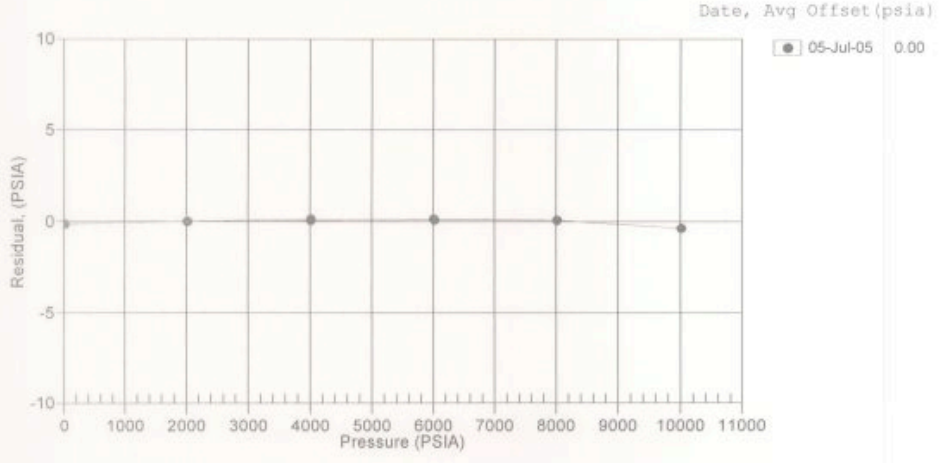
C1 =	-4.840395e+004
C2 =	-2.017057e-003
C3 =	1.464810e-002
D1 =	3.990600e-002
D2 =	0.000000e+000
T1 =	2.998386e+001
T2 =	-2.560542e-004
T3 =	3.869120e-006
T4 =	2.452640e-009
T5 =	0.000000e+000

AD590M, AD590B, SLOPE AND OFFSET:

AD590M =	1.14600e-002
AD590B =	-8.45734e+000
Slope =	0.99999
Offset =	0.4330 (dbars)

PRESSURE (PSIA)	INST OUTPUT(Hz)	INST TEMP(C)	INST OUTPUT (PSIA)	CORRECTED INST OUTPUT (PSIA)	RESIDUAL (PSIA)
14.628	33360.29	22.9	13.878	14.506	-0.122
2014.722	34041.39	22.9	2014.110	2014.720	-0.002
4014.470	34706.83	23.0	4013.938	4014.530	0.060
6014.358	35357.68	23.0	6013.863	6014.437	0.079
8014.299	35994.73	23.0	8013.818	8014.374	0.075
10014.546	36618.67	23.1	10013.656	10014.194	-0.352
8014.164	35994.70	23.1	8013.697	8014.253	0.089
6014.172	35357.65	23.1	6013.744	6014.318	0.146
4014.313	34706.82	23.1	4013.864	4014.456	0.143
2014.485	34041.34	23.1	2013.900	2014.510	0.025
14.626	33360.31	23.1	13.858	14.485	-0.141

Residual = corrected instrument pressure - reference pressure



CTD Temperature (Primary)

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

SENSOR SERIAL NUMBER: 2367
CALIBRATION DATE: 12-Apr-06

SBE3 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPRATURE SCALE

ITS-90 COEFFICIENTS

g = 4.33451959e-003
h = 6.42747643e-004
i = 2.34868835e-005
j = 2.24043744e-006
f0 = 1000.0

ITS-68 COEFFICIENTS

a = 3.68121324e-003
b = 6.00886794e-004
c = 1.64377178e-005
d = 2.24201073e-006
f0 = 2865.877

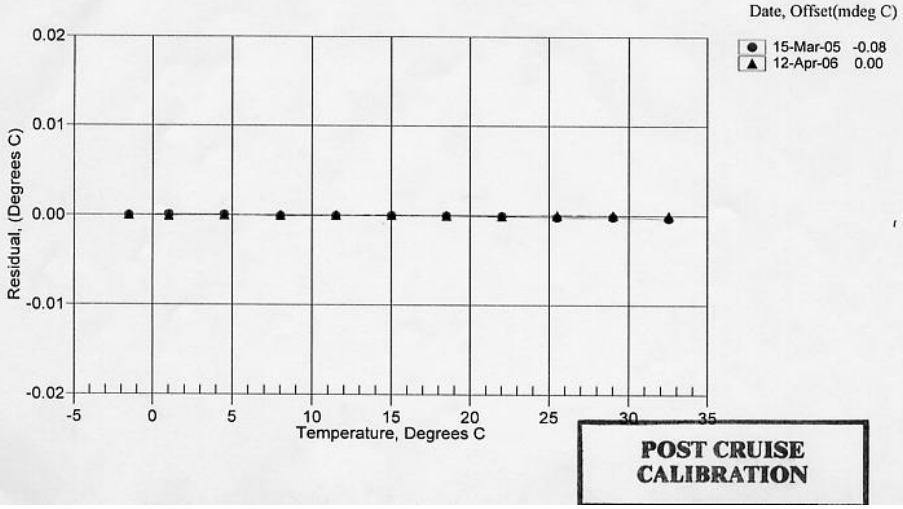
BATH TEMP (ITS-90)	INSTRUMENT FREQ (Hz)	INST TEMP (ITS-90)	RESIDUAL (ITS-90)
-1.5001	2865.877	-1.5001	0.00003
1.0000	3030.839	0.9999	-0.00005
4.4999	3273.201	4.4999	0.00000
7.9999	3529.234	7.9999	0.00001
11.4999	3799.306	11.4999	0.00002
14.9999	4083.780	14.9999	0.00004
18.4999	4382.997	18.4999	-0.00002
22.0000	4697.315	21.9999	-0.00006
25.4999	5027.045	25.4999	0.00004
28.9999	5372.505	28.9999	0.00002
32.4999	5733.997	32.4999	-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 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

CTD Temperature (Secondary)

SEA-BIRD ELECTRONICS, INC.

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

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

SENSOR SERIAL NUMBER: 2168
CALIBRATION DATE: 17-May-06

SBE3 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPRATURE SCALE

ITS-90 COEFFICIENTS

g = 4.35087157e-003
h = 6.43883971e-004
i = 2.34087172e-005
j = 2.20948684e-006
f0 = 1000.0

ITS-68 COEFFICIENTS

a = 3.68121356e-003
b = 6.01263938e-004
c = 1.62908639e-005
d = 2.21104550e-006
f0 = 2938.752

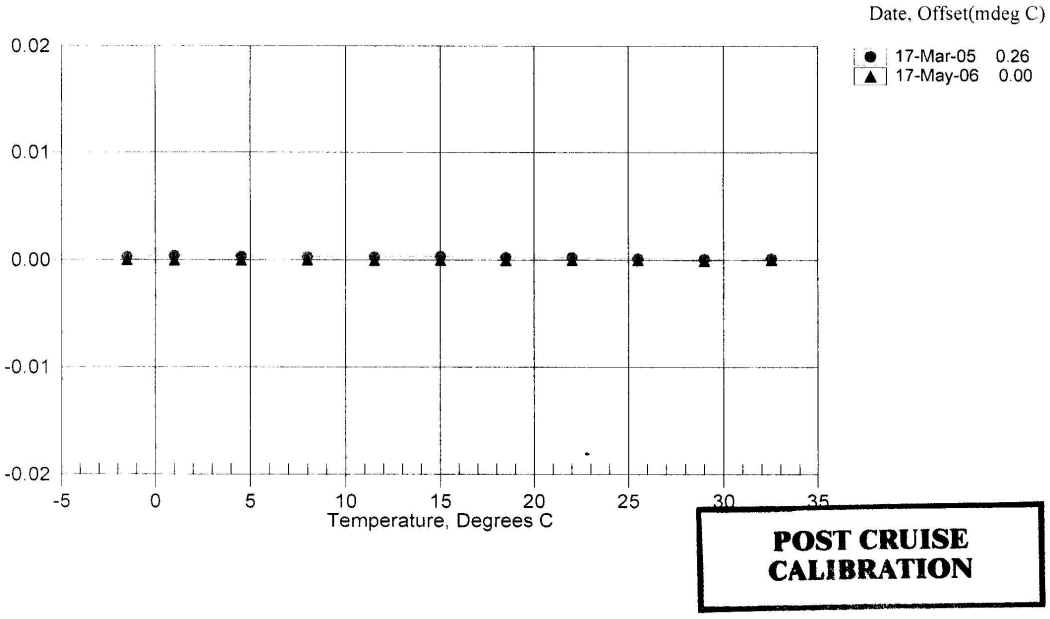
BATH TEMP (ITS-90)	INSTRUMENT FREQ (Hz)	INST TEMP (ITS-90)	RESIDUAL (ITS-90)
-1.5001	2938.752	-1.5001	0.00001
0.9999	3107.795	0.9999	-0.00000
4.4999	3356.138	4.4999	-0.00002
7.9999	3618.465	7.9999	0.00002
11.4999	3895.146	11.4999	-0.00001
14.9999	4186.556	14.9999	0.00001
18.4999	4493.046	18.4999	-0.00001
21.9999	4814.970	21.9999	0.00003
25.4999	5152.648	25.4999	0.00001
29.0000	5506.413	28.9999	-0.00006
32.4999	5876.560	32.4999	0.00003

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

Temperature 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



CTD Conductivity (Primary)

SEA-BIRD ELECTRONICS, INC.

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

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

SENSOR SERIAL NUMBER: 1799
CALIBRATION DATE: 17-May-06

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

GHIJ COEFFICIENTS

```
g = -4.14638291e+000
h =  5.02896275e-001
i = -7.32204277e-004
j =  6.04528865e-005
CPcor = -9.5700e-008 (nominal)
CTcor =  3.2500e-006 (nominal)
```

ABCDM COEFFICIENTS

```
a =  3.34199625e-007
b =  5.00176930e-001
c = -4.13701233e+000
d = -8.46848293e-005
m =  5.6
CPcor = -9.5700e-008 (nominal)
```

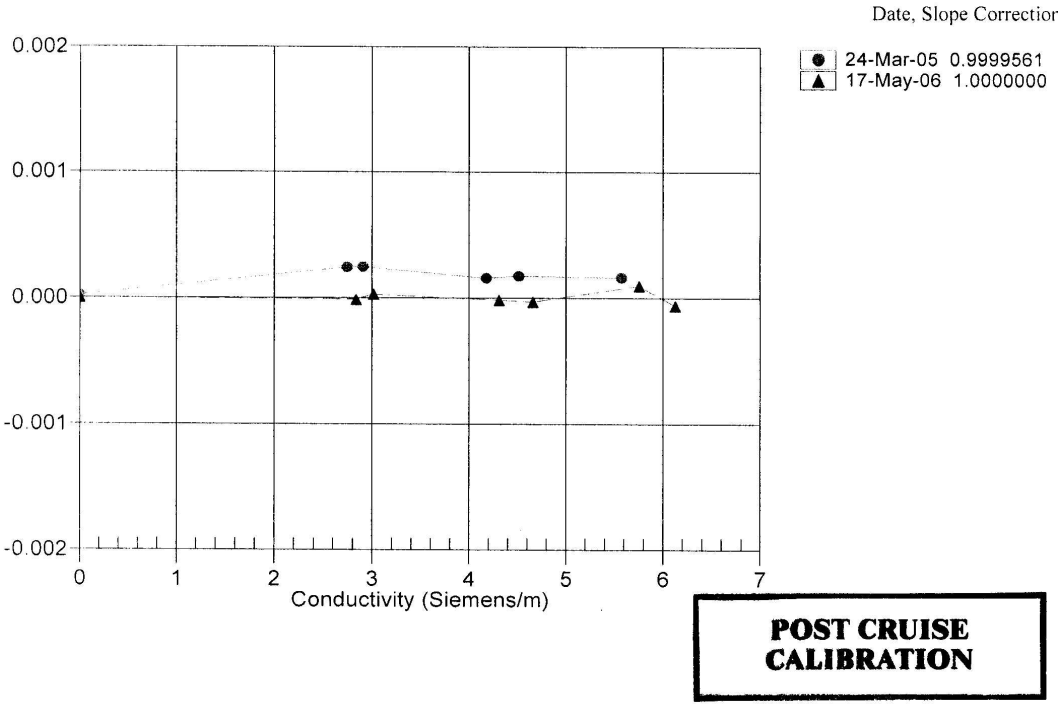
BATH TEMP (ITS-90)	BATH SAL (PSU)	BATH COND (Siemens/m)	INST FREQ (kHz)	INST COND (Siemens/m)	RESIDUAL (Siemens/m)
0.0000	0.0000	0.00000	2.87601	0.00000	0.00000
-0.9686	35.1595	2.83231	8.05105	2.83230	-0.00001
1.0947	35.1591	3.01073	8.26891	3.01076	0.00003
14.9999	35.1613	4.30942	9.70594	4.30940	-0.00002
18.4999	35.1622	4.65926	10.05732	4.65923	-0.00003
29.0000	35.1606	5.75232	11.08197	5.75242	0.00010
32.4999	35.1543	6.12821	11.41227	6.12814	-0.00006

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



POST CRUISE CALIBRATION

CTD Conductivity (Secondary)

SEA-BIRD ELECTRONICS, INC.

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

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

SENSOR SERIAL NUMBER: 1850
CALIBRATION DATE: 11-Apr-06

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

GHIJ COEFFICIENTS

```
g = -4.34134564e+000
h =  5.21795743e-001
i =  1.82589216e-004
j =  1.71130573e-005
CPcor = -9.5700e-008 (nominal)
CTcor =  3.2500e-006 (nominal)
```

ABCDM COEFFICIENTS

```
a =  4.63929821e-005
b =  5.22418178e-001
c = -4.34355481e+000
d = -8.03864882e-005
m =  3.8
CPcor = -9.5700e-008 (nominal)
```

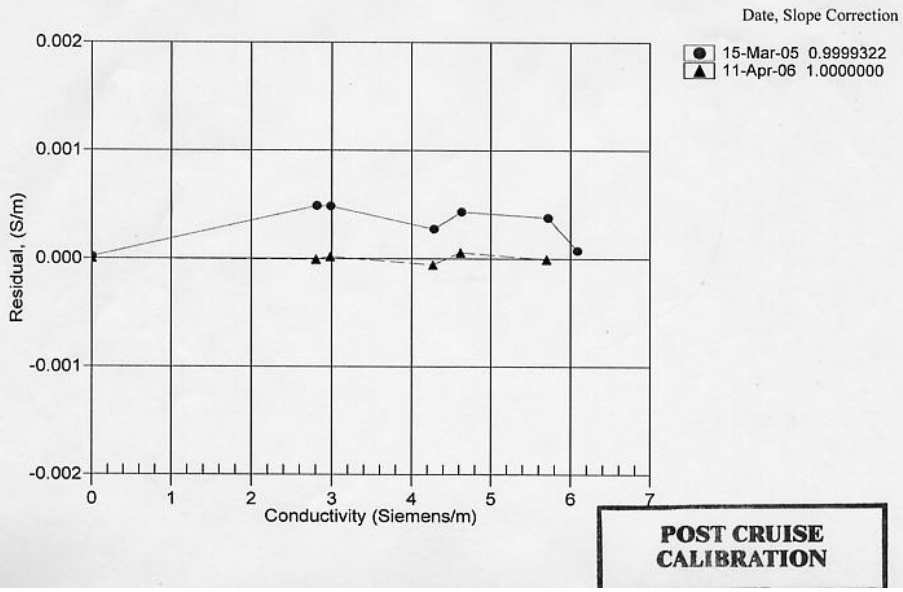
BATH TEMP (ITS-90)	BATH SAL (PSU)	BATH COND (Siemens/m)	INST FREQ (kHz)	INST COND (Siemens/m)	RESIDUAL (Siemens/m)
0.0000	0.0000	0.00000	2.88260	0.00000	0.00000
-1.0000	34.7768	2.80169	7.85610	2.80168	-0.00001
1.0655	34.7771	2.97860	8.06732	2.97862	0.00002
14.9999	34.7769	4.26728	9.46277	4.26722	-0.00006
18.4999	34.7762	4.61361	9.80366	4.61367	0.00006
29.0000	34.7720	5.69588	10.79828	5.69587	-0.00001

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



POST CRUISE CALIBRATION

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 October 12, 2005 Customer National Science Foundation Work order 001

Job # 0508008 S/N# CST-892DR Pathlength 25 cm

	Analog meter
V_d	0.061 V
V_{air}	4.789 V
V_{ref}	4.678 V

Temperature of calibration water	21.5 °C
Ambient temperature during calibration	23.1 °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

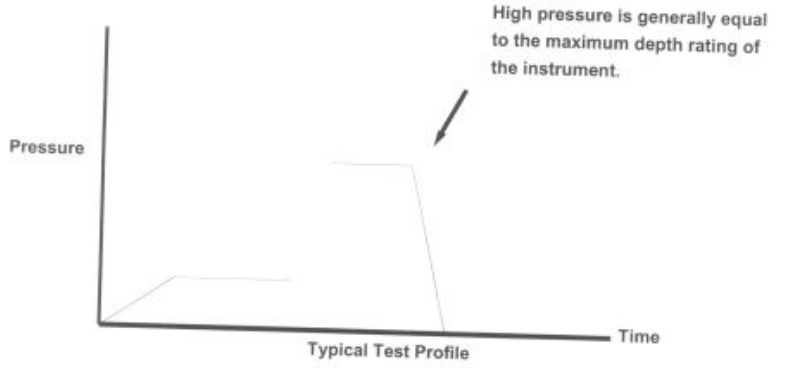
CTD Pump (Primary)

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

Pressure Test Certificate

Customer	Raytheon Polar Services Co.
Job Number	34445
Date	1/10/04
Technician	GM
Serial Number	051645
Low Pressure (PSI)	50 PSI
Time (Minutes)	15 Minutes
High Pressure (PSI)	10000 PSI
Time (Minutes)	30 Minutes
Pass	☑
Fail	☐

Comments
Replaced the main piston "O"-Rings



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CTD Pump (Secondary)

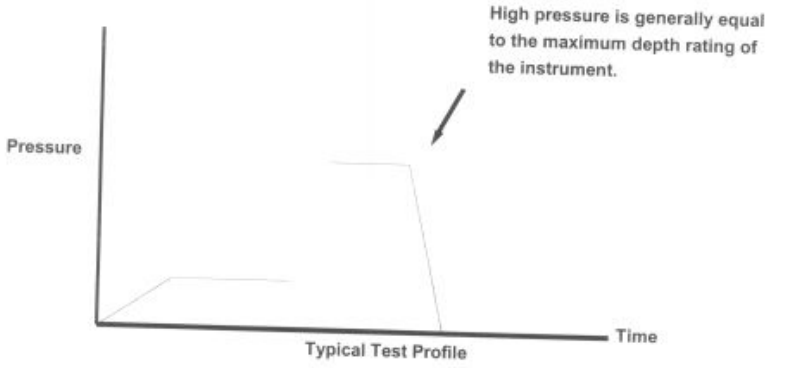
SEA-BIRD ELECTRONICS, INC.
1808 - 136th Place Northeast, Bellevue, Washington 98005 USA
Phone: (425) 643-9866 Fax: (425) 643-9954 www.seabird.com

Pressure Test Certificate

Customer	Raytheon Polar Services Co.
Job Number	34445
Date	1/10/04
Technician	GM
Serial Number	051646
Low Pressure (PSI)	50 PSI
Time (Minutes)	15 Minutes
High Pressure (PSI)	10000 PSI
Time (Minutes)	30 Minutes

Pass ☑
Fail ☐

Comments
Replaced the main piston "O"-Rings



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