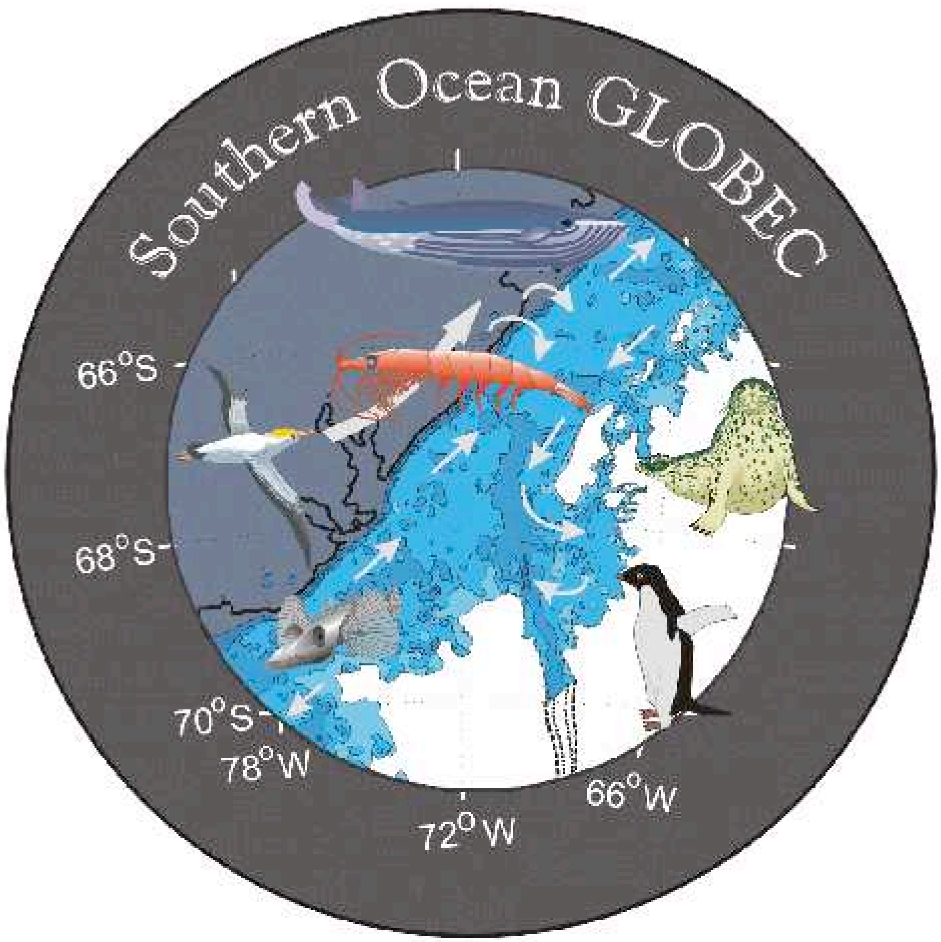
Data Report

GLOBEC III

April 9 – May 21, 2002



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Introduction

The NBP data acquisition systems continuously logs 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 CD-ROM written in ISO9660 level-1 format. It is readable by virtually every computing platform.

Much of the data has been compressed using Unix "gzip," identifiable 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.

SeaBeam and bathyw data, if collected, is 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

geopdata/ 0202jgof.tar
0202mgd.tar
0202proc.tar
0202qcps.tar
NBP0202.trk
NBP0202.mgd
NBP0202.gmt

plots/ *Cruise Plots*

report/ *Data Report*
rvdascal.txt

rvdas/uw/ 0202knud.tar
0202flr.tar
0202grv.tar
0202met.tar
0202pco2.tar
0202sim.tar
0202svp.tar
0202tsg.tar

scirep/*Daily Cruise Reports*

utility/ WinZip

Volume 2

adcp/ pingdata files
config files

imagery/ *TeraScan satellite images*

isobars/ *Isobar Charts*

aws/ 0202aws.tar

ocean/ 0202ctd.tar
ctd.doc
nutrients.txt
0202puv.tar
0202pco2.tar
0202tsgf.tar
0202xbt.tar
0202moc.tar

rvdas/nav/02023df.tar
0202adcp.tar
0202gyr.tar
0202ngl1.tar
0202PCOD.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

Cruise Track

The distribution CD includes a cruise track file (NBP0202.trk). It contains the longitude and latitude at one-minute intervals extracted from the NBP0202.gmt file.

Two PostScript cruise track files have been produced and placed in the /plots directory. Trk.large.ps is poster-sized (~36" x 40") and trk_small.ps is standard US Letter sized (8.5" x 11").

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 (is = ice ssmi, iv = ice visible, cw = seawifs, wx = weather)
DDD = year-day
YY = year
A = allows for multiple images of one type for one day

Isobars

Isobar charts were received daily with an isobaric analysis of the Antarctic continent from the University of Wisconsin – Madison. These JPEG images can be found in the `/Isobars` directory.

AWS

Weather data from the AMRC Automatic Weather Station (AWS) observations

from Kirkwood Island (ARGOS ID 8930) and Dismal Island (ARGOS ID 8932) at

Marguarite Bay have been included and may be found in `/aws/0202aws.tar.`

Daily Science Report

The daily science reports are stored in the directory /scirep.

NBP Data Products

Two data sets are created on each cruise: JGOFS and MGD77.

JGOFS

The JGOFS data set consists of a single file produced 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. The daily file consists of 22 columnar fields in text format described in the table below. The JGOFS data set is obtained primarily by applying calibrations to raw data and decimating to whole 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 by the NGL software package. During the cruise, the JGOFS data set produces the daily data plots. Note: Null, unused, or unknown fields are indicated as "NAN" 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	□Einsteins/meters^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 (port windbird)	meters/sec
15	True wind direction (port 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 NBP0202.mgd. Also at the root level, NBP0202.gmt is the output of the mgd77togmt utility using NBP0202.mgd as input. The NBP0202.gmt file can be used by GMT plotting software.

The data used to produce the NBP0202.mgd file can be found on the distribution media in the file /geopdata/NBP0202proc.tar. The data files in the PROC directory of 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 directories in the archive contina interim processing files and are included to simplify possible reprocssing 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 "3" for data record
2-9	8	Char	Survey identifier	
10-14	5	int	Time zone correction	In hundredths of hours. Corrects time (in characters 13-27) to GMT when added; 0 = GMT
15-16	2	int	Year	2 digit year

Col	Len	Type	Contents	Description, Possible Values, Notes
17-18	2	int	Month	2 digit month
19-20	2	int	Day	
21-22	2	int	Hour	
23-27	5	real	Minutes x 1000	
28-35	8	real	Latitude x 100000	+ = North - = South. (–9000000 to 9000000)
36-44	9	real	Longitude x 100000	+ = East - = West. (–18000000 to 18000000)
45	1	int	Position type code	1=Observed fix 3=Interpolated 9=Unspecified
46-51	6	real	Bathymetry, 2- way travel time	In 10,000th of seconds. Corrected for transducer depth and other such corrections
52-57	6	real	Bathymetry, corrected depth	In tenths of meters.
58-59	2	int	Bathymetric correction code	This code details the procedure used for determining the sound velocity correction to depth
60	1	int	Bathymetric type code	1 = Observed 3 = Interpolated (Header Seq. 12) 9 = Unspecified
61-66	6	real	Magnetics total field, 1ST sensor	In tenths of nanoteslas (gammas)
67-72	6	real	Magnetics total field, 2ND sensor	In tenths of nanoteslas (gammas), for trailing sensor
73-78	6	real	Magnetics residual field	In tenths of nanoteslas (gammas). The reference field used is in Header Seq. 13
79	1	int	Sensor for residual field	1 = 1st or leading sensor 2 = 2nd or trailing sensor 9 = Unspecified
80-84	5	real	Magnetics diurnal correction	In tenths of nanoteslas (gammas). (In nanoteslas) if 9-filled (i.e., set to “+9999”), total and residual fields are assumed to be uncorrected; if used, total and residuals are assumed to have been already corrected.
85-90	6	F6.0	Depth or altitude of magnetics sensor	(In meters) + = Below sea level 3 = Above sea level
91-97	7	real	Observed gravity	In 10th of mgals. Corrected for Eotvos, drift, tares
98-103	6	real	EOTVOS correction	In tenths of mgals. E = 7.5 V cos phi sin alpha + 0.0042 V*V
104-108	5	real	Free-air anomaly	In tenths of milligals 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 the depth range from about 30 to 300 m -- in good weather. In bad weather or in ice, the range is less, and sometimes no valid measurements are made. It is the USAP-funded project of Eric Firing (University of Hawaii) and Teri Chereskin (Scripps Institution of Oceanography). ADCP data collection occurs on the both LMG and the NBP for the benefit of the scientists on individual cruises, and for the long-term goal of building a climatology of current structure in the Southern Ocean.

The ADCP data set collected during this cruise has been placed in the directory /adcp. Each file represents 24 hours of data collection. The files are named `pingdata.xxx` where `xxx` is a day number that is NOT a year-day. For the date, use the file's creation date.

Some ADCP data is also transmitted to RVDAS. East and north vectors for ship's speed relative to the reference layer and ship's heading are archived as `0202adcp.tar` in the directory, `/rvdas/nav`.

PCO_2

The NBP carries Lamont-Doherty Earth Observatory's (LDEO) pCO_2 system and RPSC staff maintains it. Data is sent to LDEO at the end of each cruise. The pCO_2 data is transmitted and archived on RVDAS. You will find it in a file named `0202pco2.tar` in the `ocean/` 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) for additional information.

Cruise Science

CTD

The ctd data have been placed in the tar file `ocean/0202ctd.tar`. The archive contains tar files `0202proc.tar` (processed data) and `0202raw.tar` (raw data). Additionally, the file ocean/nutrients.txt contains results of nutrient analysis from water samples taken on CTD casts.

A detailed report from the Marine ET has been included and can be found in ocean/ctd.doc. This report is in MS Word format and details acquisition problems, events, and describes CTD configuration and sensor placement.

MOCNESS

Mocness data has been placed in the tar file `ocean/0202moc.tar.`

PUV / GUV

All files are placed in zip-archives the /ocean directory. GUV data was acquired continuously from the instrument mounted on top of the science mast. PUV data comes from a single cast on most days.

PUV files were converted to CSV (Comma Separated Value) format using the Biospherical Instruments' PUVLOG program. GUV files were converted to CSV format using the Biospherical Instruments' PUVPROF program.

The contents of the CSV files are shown below:

Field	PUV Data
1	Depth
2	308 U
3	320 U
4	Temp U
5	MATFL
6	340 U
7	380 U
8	PAR U
9	Temp U
10	308 S
11	Batt S
12	320
13	340
14	380
15	Gnd
16	PAR
17	K308
18	K320
19	K340
20	K380
21	Kpar
22	Chl
23	Prod

Field	GUV Data
1	Depth
2	306 U
3	320 U
4	Temp U
5	MATFL
6	340 U
7	380 U
8	PAR U
9	Temp S
10	300 S
11	Batt S
12	320 S
13	340 S
14	380 S
15	Gnd S
16	PAR S

xbt

During the cruise Expendable Bathythermographs were used to obtain water column temperature profiles. These were used to adjust the sound velocity profile for the SeaBeam system. The data files from these launches are included as 0202`xbt.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 several years. It has been adapted for use on the USAP research vessels.

Daily data processing of the RVDAS (Research Vessel Data Acquisition System) data is performed to convert values into useable units and as a check of the proper operation of the DAS. Both raw and processed data sets from RVDAS are included in the data distribution. The tables below provide detailed information on the 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, /ocean. 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: `NBP0107.met1.d317`

- The CruiseID is the numeric name of the cruise, in this case, NBP0202.
- The Channel ID 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		BSI PUV-511
PUV	puv	not collected		BSI PUG-500

Geophysics

Measurement	Channel ID	Collect. Status	Rate	Instrument
Gravimeter	grv1	continuous	10 sec*	LaCoste & Romberg
Magnetometer	mag1	not collected	15 sec	EG&G G-866
Bathymetry	bat1	continuous	Varies	ODEC Bathy 2000
Bathymetry	knu1	not collected	Varies	Knudsen 320B/R
Bathymetry	sim1	continuous	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 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
Fluorometry	flr1 & tsg1	continuous	6 sec	
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
Attitude GPS	3df1	continuous	1 sec	Ashtech ADU2
P-Code GPS	PCOD	continuous	1 sec	Trimble 20636-00SM
Gyro	gyr1	continuous	0.2 sec	Yokogawa Gyro
NGL	ngl1	Continuous	1 sec	NGL Processed Data

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

Meteorology (met1)

```
01+322:00:03:27.306 04.5 292 010 05.7 294 010 0959.6 000.2 093 -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 19 for calculations.

Gravimeter (grv1)

```
99+099:00:18:19.775 your_line#1999 99 01818 9735.4
```

Field	Data	Conversion	Units
1	RVDAS time tag		
2	Text string		
3	Gravity device date	yyyydddhhmmss	
4	Gravity count	mgal = count x 1.0047 + offset	count

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	kHz

Field	Data	Format / Possible Values	Units
		SB3=5 kHz	
15	Power level	PO1 = 0dB PO2 = -6dB PO3 = -12dB PO4 = -18dB PO5 = -24dB PO6 = -30dB PO6 = -30 dB PO7 = -36dB PO8 = -42dB	
16	Transmit mode	TX1=single ping active TX2=pinger listen TX3=multipinging TR TX4=multipinging TR TX5=multipinging TTRR TX6=multipinging TTTTRRRR TX7=multipinging TTTTTRRRRR	
17	Transmit Rate	TR3 = 4Hz TR4 = 2Hz TR5 = 1Hz TR6 = .5Hz TR7 = .33Hz TR8 = .25Hz TR9 = .20Hz TR: = .10Hz TR; = .05Hz	Hz
18	System gain mode	GM0=hydrographic AGC GM1 to GM9=hydrographic +3db to + 27db manual. GMA to GMD=hydrographic + 30db through + 60db manual GME to GMK=sub-bottom 1 through sub-bottom 7	
19	Speed of sound		m/sec
20	Depth of sonar window below sea-level		meters
21	Background noise level in fixed point reference		dB/V

Simrad (sim1) – Special String for GLOBEC

```
02+119:00:00:00.974 Q2,23584296,0,    0.00,    0.0,  100.0,250,   10.0,
-5.0, 75,

  -235.2,-235.2,-235.2,-235.2,-235.2,-235.2,-235.2,-235.2,-235.2,-235.2,

  -235.2,-235.2,-235.2,-235.2,-235.2,-235.2,  -4.7,  -3.9,  -8.0, -42.3,

   -49.1, -57.9, -55.8, -54.1, -61.6, -67.1, -67.3, -66.2, -68.7, -59.3,

   -59.0, -63.7, -71.1, -73.7, -70.8, -68.4, -73.2, -83.1, -81.5, -86.9,

   -98.8, -97.9, -98.4, -97.6, -92.4, -93.3,-104.2,-105.6, -97.8, -98.3,

  -105.6,-105.1,-109.9,-106.2,-103.9,-112.2,-109.7,-111.1,-108.1,-112.0,
```

```
-115.5,-107.8,-103.1,-106.3,-101.1,-102.0,-114.4,-112.0,-107.1,-108.5,
-111.0,-111.9,-121.6,-235.2,-117.3,-123.3,-235.2,-235.2,-112.9,-106.2,
-107.6,-108.9,-122.7,-108.5,-107.3,-110.8,-111.2,-116.1,-121.8,-117.7,
-112.2,-108.3,-102.3,-100.0,-103.7,-106.9,-105.8,-115.2,-120.5,-120.3,
-112.5,-107.5,-107.6,-108.5,-115.0,-114.1,-112.8,-235.2,-235.2,-235.2,
-235.2,-235.2,-235.2,-235.2,-235.2,-235.2,-110.7,-235.2,-110.7,-235.2,
-235.2,-114.1,-110.1,-114.4,-235.2,-235.2,-235.2,-235.2,-235.2,-106.3,
-105.1,-113.5,-108.0,-108.6,-116.2,-235.2,-235.2,-235.2,-115.8,-235.2,
-110.5,-115.4,-110.3,-235.2,-235.2,-235.2,-107.1,-107.7,-108.1,-235.2,
-235.2,-107.0,-105.2,-235.2,-235.2,-106.2,-100.3,-109.6,-235.2,-235.2,
-235.2,-101.8, -98.3,-103.4,-103.1,-235.2,-104.2,-109.5,-235.2,-108.5,
 -99.3,-104.3,-109.1,-102.7,-235.2,-103.1,-100.8,-235.2,-235.2,-235.2,
-235.2,-235.2,-235.2,-102.8, -99.2,-111.5,-235.2,-235.2,-235.2,-235.2,
-235.2,-235.2,-235.2,-235.2,-235.2,-235.2,-110.6,-235.2,-235.2,-235.2,
-235.2,-105.1,-235.2,-235.2,-235.2,-101.8,-100.7,-235.2,-235.2,-235.2,
-235.2,-235.2,-235.2,-235.2,-100.4, -96.5,-235.2,-106.0,-100.2, -99.9,
-235.2,-235.2,-108.7,-235.2,-235.2, -82.2, -59.7, -60.7, -62.6, -62.3,
 -62.1, -62.6, -62.9, -62.7, -62.7, -62.7, -62.8, -62.7, -62.7, -62.5,
 -62.5, -62.4, -62.3, -62.3, -62.2, -62.2, -62.2, -62.1, -58.7,-235.2,
-235.2,-235.2,-235.2,-235.2,-235.2,-235.2,-235.2,-235.2,-235.2,-235.2,
-235.2,-235.2,-235.2,-235.2,-235.2,-235.2,-235.2,-235.2,-235.2,-235.2,
-235.2,-235.2,-235.2,-235.2,-235.2,-235.2,-235.2,-235.2,-235.2,-235.2,
-235.2,-235.2,-235.2,-235.2,-235.2,-235.2,-235.2,-235.2,-235.2,-235.2,
-235.2,-235.2,-235.2,-235.2,-235.2,-235.2,-235.2,-235.2,-235.2,-235.2,
-235.2,-235.2,-235.2,-235.2,-235.2,-235.2,-235.2,-235.2,-235.2,-235.2,
-235.2,-235.2,-235.2,-235.2,-235.2,-235.2,-235.2,-235.2,-235.2,-235.2,
-235.2,-235.2,-235.2,-235.2,-235.2,
```

Thermosalinograph (tsg1)

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

Field	Data	Units
1	RVDAS time tag	
2	Seabird hex string (see page 19 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	
9	Temperature units	

pCO_2

```
00+021:23:59:43.190 2000021.9992 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)	yyyddd.ttt
3	Raw voltage	mV
4	Barometer	mBar
5	Cell temperature	°C
6	Flow rate	cm^3/min
7	Concentration	ppm
8	pCO_2 pressure	microAtm
9	Equilibrated temperature	°C
10	Latitude (not collected)	
11	Longitude (not collected)	
10	Flow source (Equil = pCO_2 measurement)	

Navigational Data

Ashtech GPS (3df1)

The Ashtech GPS outputs three NMEA standard data strings:

- Measurement data (PBN)
- Attitude data (ATT)
- GPS position fix (GGA)

Measurement data (PBN)

```
01+324:00:00:00.064 $PASHR,PBN,172812.00,2129908.6,-1869076.7,-5694992.4,
-063:41.9477,-041:16.0918,00066.2,000.16,002.85,-000.90,08,????,02,01,01,
01*3A
```

Field	Data	Units

Field	Data	Units
1	RVDAS time tag	
2	$PASHR	
3	PBN	
4	GPS Time sec. of the week	seconds
5	Station Position: ECEF X	meters
6	Station Position: ECEF Y	meters
7	Station Position: ECEF Z	meters
8	Latitude (- = South)	deg:min
9	Longitude (- = West)	deg:min
10	Altitude	meters
11	Velocity in ECEF X	m/sec
12	Velocity in ECEF Y	m/sec
13	Velocity in ECEF Z	m/sec
14	Number of satellites used	
15	Site name	
16	PDOP	
17	HDOP	
18	VDOP	
19	TDOP	

GPS Position Fix – Geoid/Ellipsoid (GGA)

```
01+324:00:00:00.323 $GPGGA,235959.00,6341.9477,S,04116.0918,W,1,08,00.9,
+00066,M,,M,,*77
```

Field	Data	Units
1	RVDAS time tag	
2	$GPGGA	
3	UTC time at position	hhmmss.ss
4	Latitude	ddmm.mmm
5	North (N) or South (S)	
6	Longitude	ddmm.mmm
7	East (E) or West (W)	
8	GPS quality: (1 = GPS, 2 = DGPS)	
9	Number of GPS satellites used	
10	HDOP	
11	Antenna height	meters
12	M for Meters	
13	Geoidal height (no data in the sample string)	meters
14	M for meters	
15	Age of diff. 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)	

Attitude Data (ATT)

```
01+324:00:00:00.845 $PASHR,ATT,172813.0,137.88,+000.52,-001.41,0.0029,
0.0254,0*2F
```

Field	Data	Units
1	RVDAS Time tag	
2	$PASHR	
3	ATT	
4	GPS Time sec. Of the week	seconds

Field	Data	Units
5	Heading (rel. to true North)	degrees
6	Pitch	degrees
7	Roll	degrees
8	Measurement RMS error	meters
9	Baseline RMS error	meters
10	Attitude reset flag	

Trimble P-Code GPS (PCOD)

The PCode GPS 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	

Field	Data	Units
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 $HEHRC 25034,-020*73
```

Field	Data	Units
1	RVDAS time tag	
2	$HEHRC	
3	Heading XXXXX = ddd.dd	degrees
4	Rate of change SYYY S = +/-, YYY = r.rr	
5	Checksum	

NGL System (ngl1)

```
00+019:23:59:59.857 -68.82822,-137.21416,1.10,279.27,251.10,0.00,0.00,0,
18.2587,1,1146973
```

Field	Data	Units
1	RVDAS time tag	
2	Latitude (south is negative)	degrees
3	Longitude (west is negative)	degrees
4	Ship speed	knots
5	Course made good	degrees
6	Gyro heading	degrees
7	PDOP	
8	HDOP	
9	Quality	
10	GPS up	
11	Fix Number	

Field	Data	Units
12		

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	kn
5	Ship Speed relative to reference layer, north vector	kn
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

Ocean

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 time of day)	yyyddd.ttt
3	Raw voltage	mV
4	Barometer	mB
5	Cell temperature	°C
6	Flow rate	cm^3/min
7	Concentration	ppm
8	PCO_2 pressure	microAtm
9	Equilibrated temperature	°C
10	Flow Source (Equil = pCO_2 measurement)	
11	RVDAS latitude	degrees
12	RVDAS longitude	degrees
13	TSG external temperature	°C
14	TSG salinity	PSU
15	TSG fluorometry	V
16	RVDAS true wind speed	m/s
17	RVDAS true wind direction	degrees
18	Barometric Pressure	mBars
19	Uncontaminated seawater pump flow rate	l/min
20	Speed over ground	knots
21	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	□Siemens
5	Salinity	PSU
6	Fluorometry	V
7	Unused	

Calculations

The file *rvdascal.txt* located in the `/reports` 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
15-17	Fluorometer voltage
18-20	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
$\text{Temperature} = 1/\{g + h[\ln(f_0/f)] + i[\ln^2(f_0/f)] + j[\ln^3(f_0/f)]\} - 273.15$ (°C)

Calculating Conductivity – ITS-90

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

Calculating Fluorometry Voltage

f = decimal equivalent of bytes 15-17
Fluorometry Voltage = f/819

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 = 6.08 V/(□Einstiens/cm ^{2}sec)
offset (V_{dark}) = 0.3 mV
(*raw* mV - V_{dark})/scale x 10^4 cm^2/m^2 x 10^{-3} V/mV= □Einstiens/m^2sec
or
(*data* mV – 0.3 mV) x 1.65 (□Einstiens/m^2sec)/mV = □Einstiens/m^2sec

PIR

raw data = mV

calibration scale = 3.88×10^{-6} V/(W/m^2)
data mV / (scale x 10^3 mV/V) = W/m^2
or
data mV x 257.7(W/m^2)/mV = W/m^2

PSP

raw data = mV
calibration scale = 8.19×10^{-6} V/(W/m^2)
data mV / (scale x 10^3 mV/V) = W/m^2
or
data mV x 122.1 (W/m^2)/V = W/m^2

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
100:0328		Reached 68° W. Start of ADCP, TSG, and PCO_2 data collection.
102:0536		Start of Data Collection at 200 mile limit.
103:1220	103:1240	Seawater pump turned off and back on.
103:1750	103:1809	Concern that transducer interfering with other equipment. Turned Simrad off, and back on.
103:1800	103:1809	Concern that transducer interfering with other equipment. Turned Bathy off, and back on.
103:1806	103:1809	Concern that transducer interfering with other equipment. Turned ADCP off, and back on.
103:1220	103:1240	Seawater pump turned off and back on.
104:0915	104:1040	Seawater pump turned off and back on.
104:1625	104:1706	PCO_2, TSG and FL pump was reversed and then forwarded. After this all pumps were running.
108:1826	108:1845	Bathy crashed and it was restarted.
110:0445	110:0530	Underway fluorometer and transmissometer were cleaned.
110:644	Not logged	Transmissometer still having a poor signal.
110:0810	Not logged	Stopped Fluorometer and transmissometer to run tests. Tests were found to be good.
110:2141		Killed all loggers on RVDAS and restarted system. RVDAS was giving a “too many files open error”.
110:0513	110:1130	Turned off flow in underway sampling system to fluorometer and transmissometer to clean both. Then restarted both.
113:0014		Had to restart the rv_nav program when display was lost.
112:0450	112:0455	Shutdown RVDAS (all loggers) and restarted due to winch logging problem.
114:0722	114:0725	Stopped and restarted the PCO_2 computer program.
114:0050	Not logged	Turned off transmissometer to clean flow tube and swap out fluorometers. The new transmissometer is S/N 423PR.
115:0450	115:0605	Stopped TSG and reinstalled original transmissometer. Back to original transmissometer is S/N 422PR.
118:2140		Stopped PCO_2 logging and adjusted gas flows then restarted logging.
119:1300		Adjusted equilibrator gas Flow on PCO_2.

119:1611	119:1640	Stopped PCO_2 logging and adjusted gas flows then restarted PCO_2 logging.
120:0655		Adjusted PCO_2 equilibrator and atmos. flow rates.
120:1448		Adjusted PCO_2 equilibrator and atmos. flow rates.
120:1635	120:1651	Cleaning PCO_2 needle “opening and closing valve” to flush.
120:1843		Cleaned equilibrator needle valve on PCO_2.
121:0224		Adjusted PCO_2 equilibrator and atmos. flow rates.
121:1549		Adjusted PCO_2 equilibrator.
122:0543	122:0650	Underway Fluorometer And transmissometer shutdown for cleanning. Stopped TSG computer – display only (logging continued). Then restarted transmissometer and fluorometer.
123:1013		Adjusted PCO_2 equilibrator flow rate.
124:1342		Adjusted PCO_2 equilibrator and atmos. flow rates.
125:1950		Adjusted PCO_2 equilibrator flow rate.
126:2237	126:2240	PCO_2 logging turned off on the PCO_2 computer and then restarted.
127:1700		Adjusted PCO_2 equilibrator flow rate.
129:1258	129:1326	Turned off transmissometer and fluorometer for cleaning and then resarted.
130:		Bathy data was very poor for this day due to the ice. Used SeaBeam data for daily processing.
131:		Bathy data was very poor for this day due to the ice. Used SeaBeam data for daily processing.
133:1918	133:2030	Took transmissometer out to clean flow tube and dry out the internal moisture. Put the transmissometer back in and restarted system at normal level.
134:0926		Adjusted PCO_2 equilibrator and atmos. flow rates.
134:2318		Stopped and restarted the RVDAS (all loggers) due to a problem with discovery computer.
134:2330		Adjusted PCO_2 equilibrator flow rate.
136:0802		Adjusted PCO_2 equilibrator and atmos. flow rates.
137:1205		Adjusted PCO_2 equilibrator and atmos. flow rates.
137:2052		Adjusted PCO_2 equilibrator flow rate.
138:0831		Adjusted PCO_2 equilibrator flow rate.
139:0248		Reached 200 mile limit.
		Reached 68° W.

Appendix: Sensors and Calibrations

NBP0202 Sensors:

Shipboard Sensors

Sensor	Description	Serial #	Last Calibration Date	Status
Meteorology & Radiometers				
Port Anemometer	RM Young 5106	WM45834	03/15/02	Collect
Stbd Anemometer	RM Young 5106	WM46263	03/15/02	Collect
Barometer	RM Young 61201	01705	06/01/01	Collect
Air Temp/Rel. Hum.	RM Young 41372LC	06134	06/01/01	Collect
Mast PRR	BSI PRR-610			Not used
UW PRR	BSI PRR-600			Not used
PIR (Pyrgeometer)	Eppley PIR	33023F3	12/07/01	Collect
PSP (Pyranometer)	Eppley PSP	33090F3	12/06/01	Collect
Mast PAR	BSI QSR-240	6356	2/15/01	Collect
GUV	BSI PUV-511	9228	06/26/01	Collect
PUV				Not used
Underway				
TSG	SeaBird SBE21	1390	02/26/02	Collect
TSG Remote Temp	SeaBird 3-01/S	1267	06/12/01	Collect
Fluorometer	Turner 10-AU-005 Lamp: daylight 10-045; ref. filter: 10-052, em. filter: 10-051, ex. filter: 10-050	5651 FRTD	N/A	Collect
Transmissometer	WET Labs C-Star	CST-422PR	12/20/01	Collect
Magnetometer	EG&G G-866			Not used
Gravimeter	LaCoste & Romberg Gravity Meter			Collect
Bathymetry	Simrad EK500	3001	11/1/95	Collect
Bathymetry	Knudsen 320B/R			Collect
Bathymetry	Bathy 2000			Collect
Other				
P-Code GPS	Trimble 20636-00 (SM)	0220035119	Key expires 10/31/02	Collect
Attitude GPS	Ashtech 12	700273F2114 FW 7B13-D1-C21	N/A	Collect

NBP0202 CTD Sensors:

Sensor	Description	Serial #	Last Calibration Date	Status
CTD Fish	SeaBird model SBE 9+	09P10716-0377	07/13/01	Collect

Sensor	Description	Serial #	Last Calibration Date	Status
CTD Fish Pressure	Paroscientific model 410K-105 pressure sensor	58949	07/13/01	Collect
CTD Deck Unit	SeaBird model SBE 11+	11P19858-0490		Collect
Primary Temperature Sensor	SeaBird 3plus 6800m	2367	06/12/01	Collect
Secondary Temperature Sensor	SeaBird 3plus 6800m	2186	12/15/01	Collect
Primary Conductivity Sensor	SeaBird model 4C	2067	12/13/01	Collect
Secondary Conductivity Sensor	SeaBird model 4C	2513	12/13/01	Collect
Dissolved Oxygen Sensor	SeaBird model SBE 43	0080	01/02/02	Collect
Second Dissolved Oxygen Sensor	SeaBird model SBE 43	0082	01/12/02	Used on casts 070-073
PAR Sensor	Biospherical Instruments QSR-240	4361	12/12/01	Collect
Fluorometer	Chelsea MKIII	088080	02/01/02	Collect
Transmissometer	Sea-Tech 25cm	207D	06/21/01	Collect

NBP0202 MOCNESS (1m) Sensors:

Sensor	Description	Serial #	Last Calibration Date	Collect
Underway Electronics		146	09/30/00	Collect
Pressure (in U/W Electronics)		146	09/30/00	Collect
Conductivity	SeaBird 4C 6800m	041798	07/13/01	Collect
Dissolved Oxygen				Not used
Fluorometer	WetLabs AFLT	AFL-016D	12/21/01	Collect
Transmissometer	WetLAbs C-Star	CST-533DR	11/30/01	Collect
Temperature	SeaBird 3plus 6800m	03P2299	06/12/01	Collect

NBP0202 APOP Sensors:

Sensor	Description	Serial #	Last Calibration Date	Collect
Conductivity Temperature and Pressure	Microcat 37SM	1264	01/04/02	Collect

NBP0202 Sea-Rover ROV Sensors:

Sensor	Description	Serial #	Last Calibration Date	Collect
Conductivity Temperature and	Microcat 37SM	1262	12/11/01	Collect

Pressure				

Calibrations

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

Gravity Tie

Gravity Tie Spreadsheet

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

Date: 3/8/02
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 (Digital Gravity)	8945.1	16:53
Ship's meter after gravity tie (Digital Gravity)	8945.1	17:45
Average	8945.1	
Ship Gravimeter's Calibration Constant	1.0046	
Corrected ship's meter (Digital Gravity)	8986.2	

	Value	Time (GMT)
Ship's meter before gravity tie (serial, RVDAS)	8986.2	16:53
Ship's meter after gravity tie (serial, RVDAS)	8986.3	17:45
Average (for comparison check only)	8986.3	

Portable Gravimeter Correction Divisor 1.007937

Station	Value	Time (GMT)	Temp	Date	OBS mgal, averaged
Pier measurement 1	4903.36	17:00	53.5	March 8, 2002	
Pier measurement 2	4903.43	17:05	53.5	March 8, 2002	4864.80
Pier measurement 3	4903.44	17:08	53.5	March 8, 2002	
Average	4903.41				
Station measurement 1	4904.12	17:20	53.5	March 8, 2002	
Station measurement 2	4904.09	17:24	53.5	March 8, 2002	4865.49
Station measurement 3	4904.10	17:27	53.5	March 8, 2002	
Average	4904.10				
Pier measurement 4	4903.42	17:35	53.5	March 8, 2002	
Pier measurement 5	4903.42	17:39	53.5	March 8, 2002	4864.81
Pier measurement 6	4903.43	17:42	53.5	March 8, 2002	
Average	4903.42				

Gravity offset from last tie 972334.66
Drift since last tie -0.62

OBS Differences

Station to Pier (1, 2, & 3 averaged)	-0.69
Station to Pier (4, 5, & 6 averaged)	-0.67
Averaged Differences	-0.68
Gravity at pier	981320.14
Elevation of pier above gravimeter, meters	0.5
Earth differential gravity, mgal/meter	0.3
Gravity at ship's gravimeter	981320.29
Gravity Offset	972334.04

Comments

Gravity tie done by Romeo LaRiviere installed new shock cords for Gravimeter, and performed Gravity tie before and after installing new shock cords.

CTD

Pressure Sensor

Pressure Calibration Check 13 July 2001

pressure sensor model: Digiquartz 410K-105
sensor serial number: 58949
installed in: CTD 09P10716-0377

This pressure calibration is a check of the 'test' sensor against a stable reference pressure sensor. The reference pressure sensor is itself checked several times per year against a NIST-traceable pressure standard maintained at Paroscientific, Inc.. The circumstances of this pressure check introduce no more than 1.5 psia total error in 10,000 psi (0.015 %) in addition to the error resident in the Paroscientific site standard. The check offers a very high level certification of the health and proper operation of the 'test' sensor.

Input Pressure* [psia]	Sensor Output [hz]	Sensor Temperature [deg C]	Pressure Factory Coef [psia]	Pressure Corrected [psia]	Error [psia]
14.700	33360.59	23.2	14.668	14.986	0.286
2014.689	34041.54	23.2	2014.473	2014.776	0.087
4014.348	34706.93	23.3	4014.163	4014.452	0.104
6013.814	35357.64	23.3	6013.643	6013.918	0.104
8013.175	35994.51	23.3	8013.027	8013.288	0.113
10012.889	36618.31	23.3	10012.365	10012.612	-0.277
8013.257	35994.54	23.3	8013.101	8013.362	0.105
6013.753	35357.61	23.3	6013.535	6013.811	0.058
4014.262	34706.87	23.4	4013.938	4014.227	-0.035
2014.600	34041.43	23.4	2014.097	2014.400	-0.200
14.670	33360.38	23.4	14.007	14.325	-0.345

Input pressure is generated with a Ruska model 5201 dead-weight tester, serial number 23330/380, and is determined by measurement with reference pressure sensor model Digiquartz 410K-000, serial number 73292.

Sensor Temperature: pressure sensor internal temperature.

Pressure Corrected: pressure computed with original factory coefficients and then corrected with a slope and offset to give the best linear agreement with the 'reference' Input pressure.

Error: Corrected pressure - Input pressure

A linear fit of this calibration data, between sensor pressure computed with factory coefficients and the Input pressure, yields correction coefficients:
Corrected pressure = psi_slope * Factory pressure + psi_offset [psia]
psi_slope = 0.99999 and psi_offset = +0.32 [psia]

These are converted to Slope and Offset in decibars for use in the SEASOFT programs by: Slope = psi_slope = 0.99999
Offset = C * (psi_offset - 14.7 * (1 - psi_slope)) = +0.2188 [dbars]
C = 0.689476 [dbar/psi]

Slope and Offset coefficients are entered into the pressure sensor calibration coefficient section of the <>.CON file using the program SEACON.

Digiquartz Coefficients:

C1 = -4.840395e+04
C2 = -2.017057e-03
C3 = 1.464810e-02
D1 = 3.990600e-02
D2 = 0.000000e+00
T1 = 2.998386e+01
T2 = -2.560542e-04
T3 = 3.869120e-06
T4 = 2.452640e-09

AD590 Pressure Temperature Coefficients:

AD590M = 0.01146
AD590B = -8.45734

Calibration Correction:

Slope = 0.99999
Offset = +0.2188

Primary Temperature Sensor

SEA-BIRD ELECTRONICS, INC.

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

SENSOR SERIAL NUMBER = 2367
CALIBRATION DATE: 12-Jun-01s

TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

ITS-90 COEFFICIENTS

g = 4.33466091e-03
h = 6.43057120e-04
i = 2.37105286e-05
j = 2.29326732e-06
f_0 = 1000.000

IPTS-68 COEFFICIENTS

a = 3.67984263e-03
b = 6.00825717e-04
c = 1.64787789e-05
d = 2.29484943e-06
f_0 = 2872.430

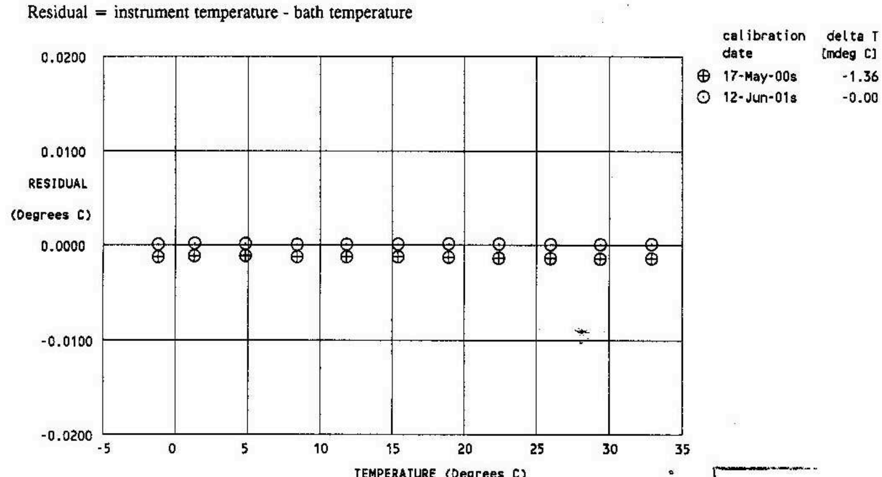
BATH TEMP (ITS-90 °C)	INSTRUMENT FREQ (Hz)	INST TEMP (ITS-90 °C)	RESIDUAL (ITS-90 °C)
-1.3989	2872.430	-1.3989	-0.00004
1.1096	3038.239	1.1097	0.00006
4.6023	3280.499	4.6023	0.00003
8.2003	3544.317	8.2003	-0.00006
11.6341	3809.950	11.6341	-0.00003
15.1913	4099.764	15.1913	-0.00000
18.6957	4400.200	18.6958	0.00004
22.1954	4715.340	22.1954	0.00001
25.7553	5051.734	25.7553	-0.00001
29.1723	5389.951	29.1723	-0.00002
32.7057	5755.773	32.7057	0.00001

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

Temperature IPTS-68 $= 1/\{a + b[\ln(f_0/f)] + c[\ln^2(f_0/f)] + d[\ln^3(f_0/f)]\} - 273.15$ (°C)

Following the recommendation of JPOTS: T_{68} is assumed to be 1.00024 * T_{90} (-2 to 35 °C).

Residual = instrument temperature - bath temperature



Secondary Temperature Sensor

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

SENSOR SERIAL NUMBER = 2186
CALIBRATION DATE: 15-Dec-01s

TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

ITS-90 COEFFICIENTS

g = 4.34039773e-03
h = 6.45080125e-04
i = 2.35267825e-05
j = 2.25318679e-06
f_0 = 1000.000

IPTS-68 COEFFICIENTS

a = 3.67967235e-03
b = 6.02906732e-04
c = 1.63815162e-05
d = 2.25476053e-06
f_0 = 2889.706

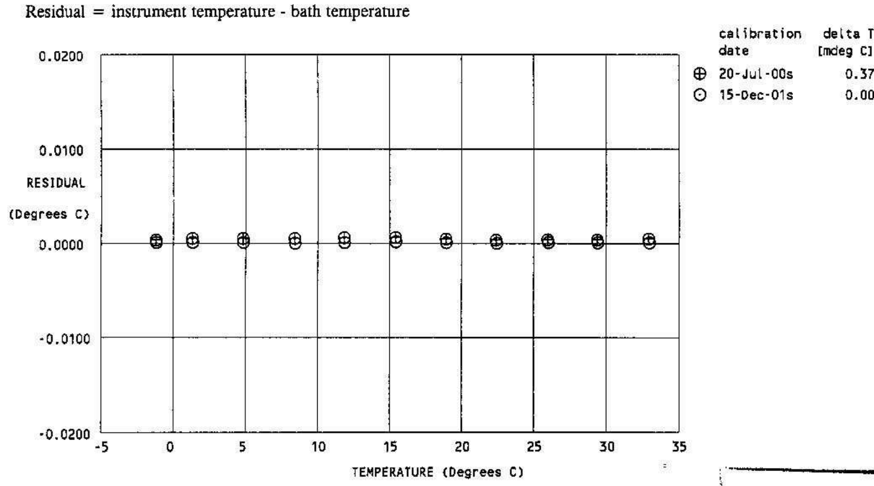
BATH TEMP (ITS-90 °C)	INSTRUMENT FREQ (Hz)	INST TEMP (ITS-90 °C)	RESIDUAL (ITS-90 °C)
-1.3863	2889.706	-1.3863	-0.00001
1.1236	3055.997	1.1237	0.00002
4.6196	3298.995	4.6196	0.00002
8.2205	3563.501	8.2204	-0.00008
11.6580	3829.836	11.6580	0.00000
15.2179	4120.249	15.2180	0.00009
18.7262	4421.303	18.7262	0.00001
22.2302	4737.073	22.2302	-0.00007
25.7946	5074.073	25.7946	0.00001
29.2157	5412.798	29.2157	-0.00000
32.7540	5779.149	32.7540	0.00001

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

Temperature IPTS-68 $= 1/\{a + b[\ln(f_0/f)] + c[\ln^2(f_0/f)] + d[\ln^3(f_0/f)]\} - 273.15$ (°C)

Following the recommendation of JPOTS: T_{68} is assumed to be 1.00024 * T_{90} (-2 to 35 °C).

Residual = instrument temperature - bath temperature



POST CRUISE CALIBRATION

Dissolved Oxygen Sensor (1)

SEA-BIRD ELECTRONICS, INC.

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

SENSOR SERIAL NUMBER = 0080
CALIBRATION DATE: 02-Jan-02w

SBE 43
OXYGEN CALIBRATION DATA

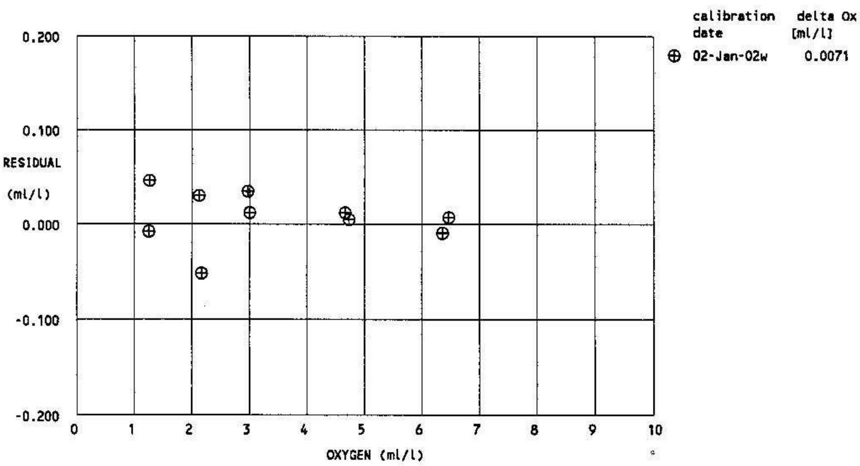
COEFFICIENTS:

Soc = 0.3810
Boc = 0.0153
Voffset = -0.6242

TCor = 0.0005
PCor = 1.350e-04

BATH OX ml/l	BATH TEMP (ITS-90 °C)	BATH SAL PSU	INSTRUMENT VOLTS	INST OX ml/l	RESIDUAL ml/l
1.20	25.00	0.03	1.141	1.19	-0.01
1.21	5.00	0.04	0.958	1.26	0.05
2.07	5.00	0.04	1.206	2.10	0.03
2.12	25.00	0.03	1.535	2.07	-0.05
2.92	5.00	0.04	1.456	2.95	0.03
2.95	25.00	0.03	1.936	2.96	0.01
4.61	5.00	0.04	1.945	4.62	0.01
4.68	25.00	0.03	2.710	4.68	0.00
6.31	5.00	0.04	2.438	6.30	-0.01
6.42	25.00	0.03	3.493	6.43	0.01

V = voltage output from SBE-43
T = ocean temperature [°C] from CTD
S = ocean salinity [PSU] from CTD
P = ocean pressure [dbar] from CTD
Oxsat(T, S) = oxygen saturation [ml/l]
oxygen (ml/l) = (Soc * (V + Voffset) + Boc * exp(-0.03 * T)) * exp(Tcor * T) * Oxsat(T, S) * exp(Pcor * P)
Residual = instrument oxygen - bath oxygen



Dissolved Oxygen Sensor (2)

SEA-BIRD ELECTRONICS, INC.

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

SENSOR SERIAL NUMBER = 0082
CALIBRATION DATE: 04-Jan-02w

SBE 43
OXYGEN CALIBRATION DATA

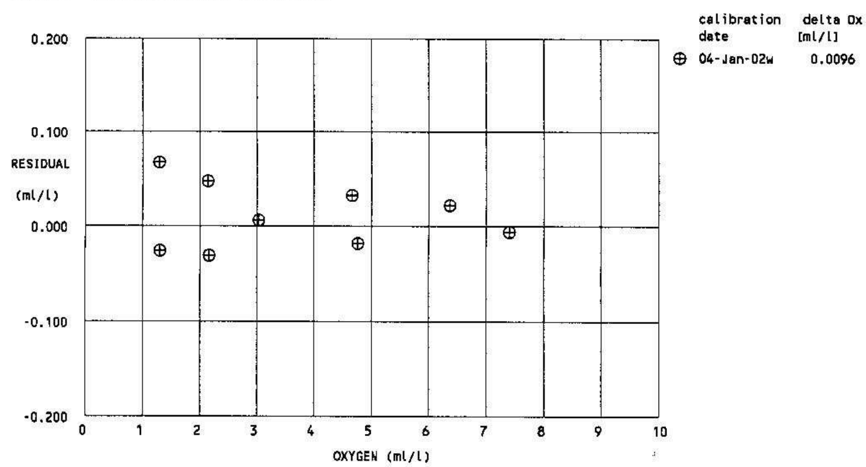
COEFFICIENTS:

Soc = 0.3710
Boc = 0.0214
Voffset = -0.6270

TCor = 0.0023
PCor = 1.350e-04

BATH OX ml/l	BATH TEMP (ITS-90 °C)	BATH SAL PSU	INSTRUMENT VOLTS	INST OX ml/l	RESIDUAL ml/l
1.24	5.00	0.04	0.967	1.31	0.07
1.25	25.00	0.03	1.140	1.22	-0.03
2.09	5.00	0.04	1.215	2.14	0.05
2.11	25.00	0.03	1.517	2.08	-0.03
2.98	25.00	0.03	1.917	2.99	0.01
4.61	5.00	0.04	1.963	4.64	0.03
4.71	25.00	0.03	2.670	4.69	-0.02
6.32	25.00	0.03	3.397	6.34	0.02
7.35	5.00	0.04	2.770	7.34	-0.01

V = voltage output from SBE-43
T = ocean temperature [°C] from CTD
S = ocean salinity [PSU] from CTD
P = ocean pressure [dbar] from CTD
Oxsat(T, S) = oxygen saturation [ml/l]
oxygen (ml/l) = (Soc * (V + Voffset) + Boc * exp(-0.03 * T)) * exp(Tcor * T) * Oxsat(T, S) * exp(Pcor * P)
Residual = instrument oxygen - bath oxygen



Fluorometer

CERTIFICATE OF CALIBRATION

Date of issue 1st February 2002

Description Mk III Aquatracka (Chlorophyll-a)

Serial Number 088080

REPORT

The fluorimeter was exposed to various concentrations of Chlorophyll-a dissolved in acetone in addition to pure water and pure acetone. The following formula was derived from the readings to relate instrument output to chlorophyll-a concentration.

$$\text{Conc.} = (0.0140 \times 10^{\text{Output}}) - 0.0182$$

Where:-

conc. = fluorophor concentration in µg/l
Output = Aquatracka output in volts

The above formula can be used in the range 0 - 100 microgrammes per litre to an uncertainty of 0.02 microgrammes per litre plus 6% of value.

Notes

The above formula has been derived using Chlorophyll-a dissolved in acetone. No guarantee is given as to the performance of the instrument to biologically active chlorophyll in sea-water.

The zero offset has been determined in the laboratory using purified water from a reverse osmosis/ion exchange column. It is possible that purer water may be found in clean deep ocean conditions. Under these conditions, the offset shown in the above formula should be replaced by the antilogarithm of the Aquatracka output in the purest water found, multiplied by the scale factor.

Serial number 088080 Page 1 of 2

Fluorimeter calibration readings

Ambient temperature 20°C

Output for detector mechanically blanked 0.0273 Volts

Output for pure water 0.1136 Volts

chlorophyll concentration in acetone (μg/l)	Output (volts)
Acetone (pure)	0.1179
0.1	0.9900
0.3	1.3403
1.0	1.8602
2.99	2.3500
9.9	2.8689
29.1	3.3242
90.9	3.7978

The uncertainty of the chlorophyll concentration is estimated not to exceed 3%. The uncertainty of output voltage measurement is estimated not to exceed 2mV.

Signed

Date 1st Feb 2002

Serial number 088080 Page 2 of 2

PAR

Biospherical Instruments Inc

CALIBRATION CERTIFICATE

UNDERWATER PAR SENSOR WITH LOG AMPLIFIER

Calibration Date: 12/12/01 **Job No.:** R7902
Model Number: QSP200L
Serial Number: 4361
Operator: TPC
Standard Lamp: 94532 (05/19/01)
Operating Voltage Range: 6 to 15 VDC (+)

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

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

With the appropriate (solar corrected) Irradiance Calibration Factor:

Dry Calibration Factor:	**1.80E+12**	**quanta/cm² sec/"amps"**	**3.00E-06**	**μEinsteins/cm² sec/"amps"**
Wet Calibration Factor:	**3.04E+12**	**quanta/cm² sec/"amps"**	**5.05E-06**	**μEinsteins/cm² sec/"amps"**

Sensor Test Data and Results[4)]

Sensor Supply Current (Dark):	76.5	mA			
Supply Voltage:	6	Volts			
'mp Integrated PAR Irradiance:	8.58E+15	quanta/cm² sec	0.01424	μEinsteins/cm²sec	
SC3 Immersion Coefficient:	0.594	Scalar Correction:	1	PAR Solar Correction:	1.0000

Nominal Filter OD	Calibrated Trans.	Sensor Voltage	Measured Trans.		Measured Signal (Amps)	Estimated Signal (Amps)	Calc. Output (Volts)	Error (Volts)	Error (%)	Test Irrad. (quanta/ cm² sec)
No Filter	100.00%	3.677	100.00%		4.75E-07	4.75E-07	3.677	0.000	0.0	8.58E+15
0.3	36.10%	3.231	35.79%		1.70E-07	1.72E-07	3.235	0.004	0.9	3.07E+15
0.5	27.60%	3.120	27.71%		1.32E-07	1.31E-07	3.118	-0.002	-0.4	2.38E+15
1	9.27%	2.660	9.59%		4.56E-08	4.41E-08	2.646	-0.014	-3.3	8.22E+14
2	1.11%	1.759	1.18%		5.59E-09	5.28E-09	1.735	-0.024	-5.7	1.01E+14
3	0.05%	0.730	0.08%		3.86E-10	2.54E-10	0.607	-0.123	-34.3	6.97E+12

Dark Before:	0.178	Volts			
Light - No Filter Hldr.:	3.678	Volts	I_{Ref} =	1.00E-10	Amps
Dark After - NFH:	0.178	Volts	I_{Dark} =	1.51E-10	Amps
Average Dark	0.1781	Volts	10^{VDark} =	1.506954	Amps

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

QSP-200L .xls

Transmissometer

SBE SEA-BIRD ELECTRONICS, INC.
1808 - 136th Place Northeast, Bellevue, Washington, 98005 USA
Phone: (206) 643-9866 Fax: (206) 643-9954 e-mail: seabird@seabird.com

APPLICATION NOTE NO. 7 Revised November 1996

CALCULATION OF M AND B COEFFICIENTS FOR TRANSMISSOMETERS

The data sheet supplied from the factory indicates the air calibration voltage and the blocked path voltage. These values along with the current air voltage and blocked path voltage are used derive the M and B coefficients used in SEACON.

To calibrate the transmissometer with the Sea-Bird instrument to which it is interfaced, you must obtain readings with the light path in air and then with the light path blocked. To obtain the in air reading, the lenses of the transmissometer need to be clean and dry. Consult the users manual for recommendations on cleaning the lenses. An opaque material should be used for the blocked voltage reading. Run SEASAVE in 'Real Time Data Acquisition' and view the transmissometer voltage. Refer to the configuration page of your manual to determine what channel the transmissometer voltage is located.

A0 is the AIR CALIBRATION voltage from the calibration sheet
Y0 is the blocked path voltage from the calibration sheet

A1 is the current air voltage
Y1 is the current blocked path voltage

then $M = 20(A0 - Y0)/(A1 - Y1)$

and $B = -M\ Y1$

For example:

If the calibration gave the following values:

A0 = 4.743 volts
Y0 = 0.002 volts

and the current calibration gave:

A1 = 4.719 volts
Y1 = 0.006 volts

then

$M = 20(4.743 - 0.002)/(4.719 - 0.006) = 20.119$
$B = -0.006 * 20.119 = -0.1207$

These are the M and B values that are to be entered into SEACON. If your instrument has AV = 2 inputs (used on some SBE 9 configurations) follow the same procedure. You will obtain A1 and Y1 values approximately twice as large as those in the example (9.438 volts and 0.012 volts respectively) leading to M = 10.0594 and B = -0.1207.

25 cm TRANSMISSOMETER OPERATING INSTRUCTIONS

OPERATION & CALIBRATION:

First, connect a power source (9 to 30 VDC) to the instrument as shown on the connector wiring diagram, see figure 1. Observe polarity when connecting the power supply to the transmissometer, connect positive to pin 4 and negative to pin 1.

Use a voltmeter to measure the output voltage, pin 2 is the output and pin 3 is ground.

Block the light path to measure the zero output, it should be 0.00, +/- .01 VDC.

Clean the windows using kimwipes (or other non abrasive material), with a solution of dish washing liquid and water. When the windows are clean, the output voltage in air should be within +/- .02 VDC of the AIR CALIBRATION value listed below.

Perform the above procedure before each calibration and use of the instrument to measure transmission of water. The wavelength of the source is 660 nm, and at this wavelength the maximum value for light transmission in clean water with a 25 cm path length is 91.3% (4.565 VDC). Pure water absorption is 8.7% for a 25 cm path length at 660 nm.

MOUNTING INSTRUCTIONS:

A mounting bracket is provided with the transmissometer to simplify mounting the instrument on your system, see figure 2.

PRECAUTIONS:

DO NOT OPEN THE INSTRUMENT--this voids the warranty. If the instrument does not function properly, please consult the factory.

DO NOT LEAVE THE INSTRUMENT ON WHEN NOT IN USE. The LED is quite stable, but it will decrease in intensity, like most light sources, if left on for a long period of time.

DATA REDUCTION:

Air calibration may change with time. The LED light output can decrease approximately 1% in 1000 hours of operation. If the air calibration is measured frequently and the following correction is applied, then this change can be compensated for and will not affect the accuracy of the data.

$$V=(A/B) \cdot (X-Z) \quad \text{and} \quad \%\ \text{Transmission} = 20 \cdot V$$

V=Corrected output voltage, (≤ 4.565 VDC since 91.3% is pure water).
A=Air calibration value listed below.
B=Air calibration (present value).
X=Data value (output voltage measured in water).
Z=Zero offset with light path blocked.

The AIR CALIBRATION for SN-207D was 4.650 VDC on 6/21/2001. / 4.64 on 7/24/01

The ZERO OFFSET with the light path blocked is -0.001 VDC / 0.000 on 7/24/01

NBP01 - 04

11/12/01 Air Calibration 4.528 VDC
11/12/01 Zero Offset 0.020 VDC

Primary Conductivity Sensor

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

SENSOR SERIAL NUMBER = 2067
CALIBRATION DATE: 13-Dec-01s

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

GHIJ COEFFICIENTS

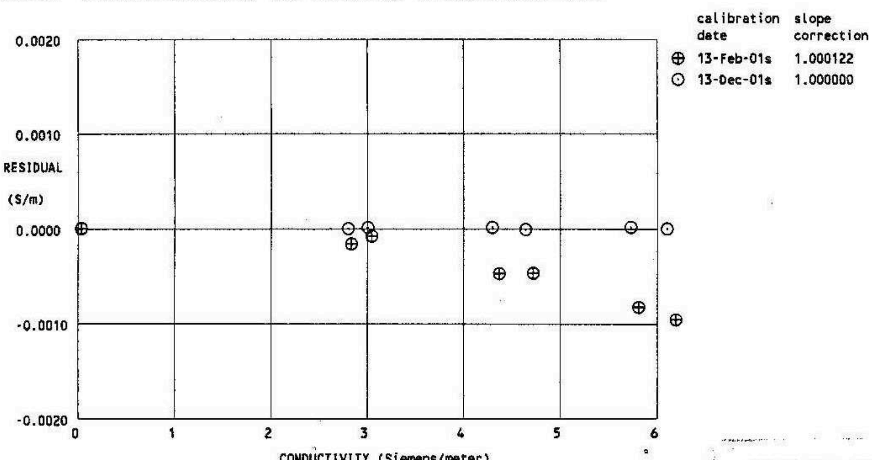
g = -1.03980803e+01
h = 1.46700966e+00
i = -5.12766449e-03
j = 4.41800486e-04
CPcor = -9.57e-08 (nominal)
CTcor = 3.25e-06 (nominal)

ABCDM COEFFICIENTS

a = 7.69702145e-11
b = 1.45059594e+00
c = -1.03540520e+01
d = -4.31904514e-05
m = 10.5
CPcor = -9.57e-08 (nominal)

BATH TEMP (IPTS-68 °C)	BATH SAL (PSU)	BATH COND (Siemens/m)	INST FREQ (kHz)	INST COND (Siemens/m)	RESIDUAL (Siemens/m)
0.0000	0.0000	0.00000	2.67194	0.00000	0.00000
-1.4001	34.7896	2.76885	5.12096	2.76885	-0.00000
0.9999	34.7904	2.97393	5.25718	2.97394	0.00001
14.9999	34.7909	4.26847	6.04615	4.26848	0.00001
18.4999	34.7903	4.61484	6.24018	4.61483	-0.00001
29.0000	34.7871	5.69734	6.81061	5.69735	0.00001
32.4999	34.7815	6.06976	6.99591	6.06975	-0.00001

Conductivity = $(g + hf^2 + if^3 + jf^4) / [10(1 + \delta t + \epsilon p)]$ Siemens/meter
Conductivity = $(af^m + bf^2 + c + dt) / [10(1 + \epsilon p)]$ Siemens/meter
t = temperaure [deg C]; p = pressure [decibars]; δ = CTcor; ϵ = CPcor;
Residual = (instrument conductivity - bath conductivity) using g, h, i, j coefficients



POST CRUISE

Secondary Conductivity Sensor

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

SENSOR SERIAL NUMBER = 2513
CALIBRATION DATE: 13-Dec-01s

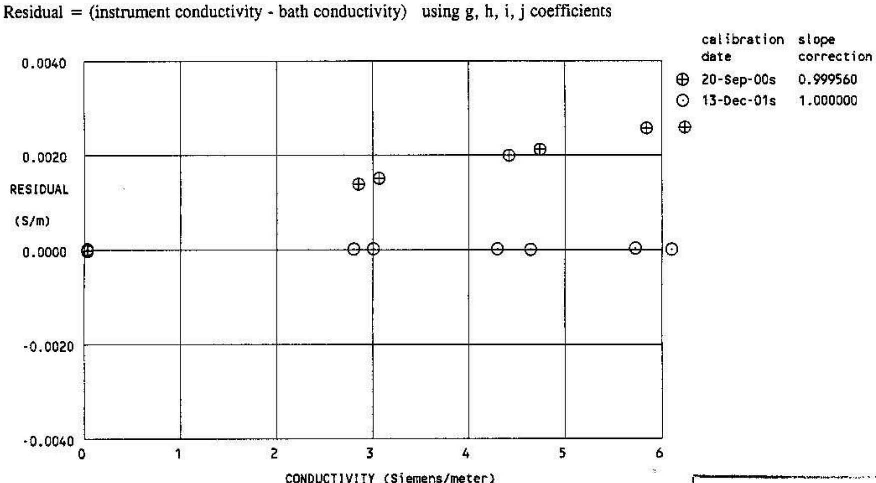
CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Siemens/meter

GHIJ COEFFICIENTS
g = -1.05905818e+01
h = 1.63509839e+00
i = -2.18814632e-03
j = 2.63682166e-04
CPcor = -9.57e-08 (nominal)
CTcor = 3.25e-06 (nominal)

ABCDM COEFFICIENTS
a = 1.42778378e-06
b = 1.62957303e+00
c = -1.05799895e+01
d = -8.12365681e-05
m = 5.9
CPcor = -9.57e-08 (nominal)

BATH TEMP (IPTS-68 °C)	BATH SAL (PSU)	BATH COND (Siemens/m)	INST FREQ (kHz)	INST COND (Siemens/m)	RESIDUAL (Siemens/m)
0.0000	0.0000	0.00000	2.54801	-0.00000	-0.00000
-1.4001	34.7896	2.76885	4.84501	2.76885	-0.00000
0.9999	34.7904	2.97393	4.97304	2.97393	0.00000
14.9999	34.7909	4.26847	5.71501	4.26847	0.00000
18.4999	34.7903	4.61484	5.89760	4.61483	-0.00001
29.0000	34.7871	5.69734	6.43463	5.69735	0.00001
32.4999	34.7815	6.06976	6.60918	6.06975	-0.00001

Conductivity = $(g + hf^2 + if^3 + jf^4) / [10(1 + \delta t + \epsilon p)]$ Siemens/meter
Conductivity = $(af^m + bf^2 + c + dt) / [10(1 + \epsilon p)]$ Siemens/meter
t = temperaure [deg C]; p = pressure [decibars]; δ = CTcor; ϵ = CPcor;
Residual = (instrument conductivity - bath conductivity) using g, h, i, j coefficients



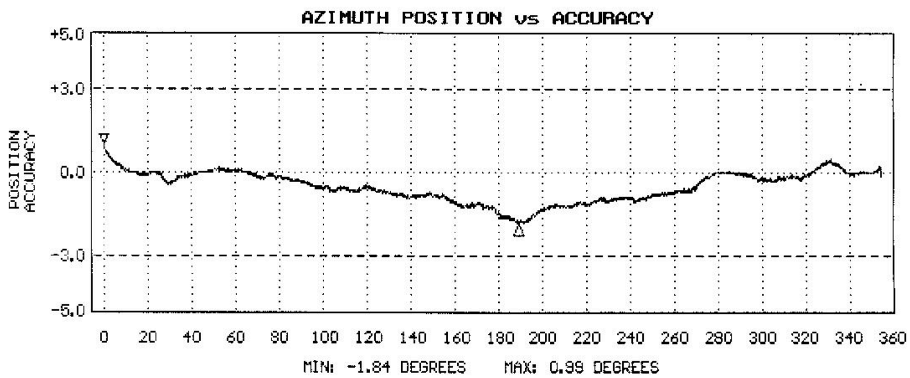
POST CRUISE CALIBRATION

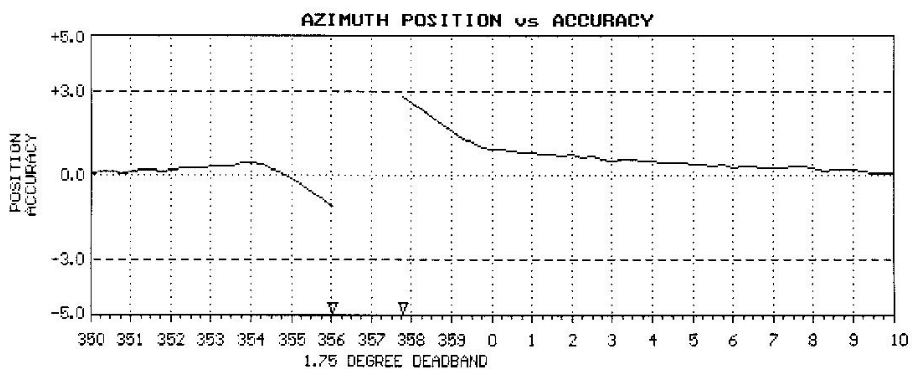
Meteorology System

Anemometer (Port)

R. M. YOUNG COMPANY WIND SENSOR CALIBRATION CERTIFICATE

SENSOR: 05106 WIND MONITOR-MA
SENSOR SERIAL NUMBER: WM45834
BEARINGS: SEALED/WATERPROOF GREASE
DATE: APR 6 2001
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:



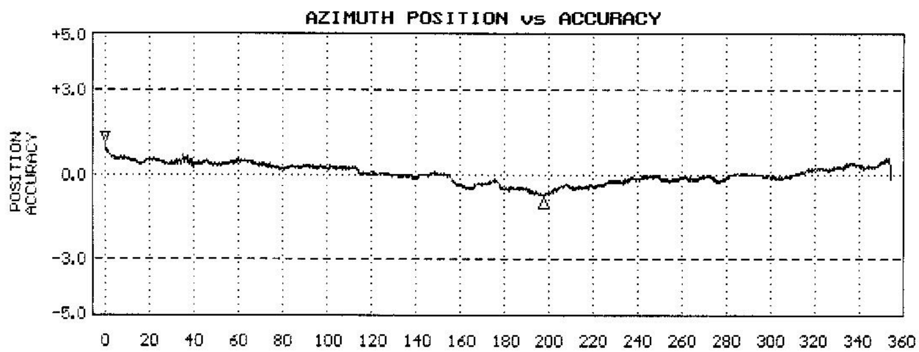


NOTE: Azimuth Position vs Accuracy graphs are accurate to within 0.5 degrees. The accuracy shown in the potentiometer deadband region between 355 and 0 degrees is the result of no resistance change while position changes. The gap represents the actual deadband (open circuit).

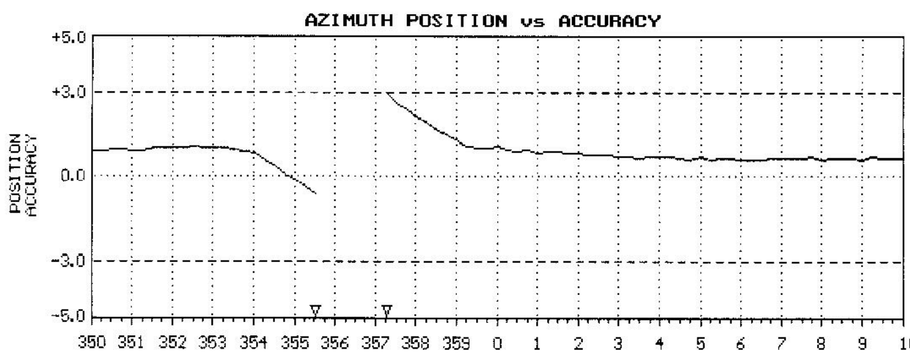
Anemometer (Starboard)

R. M. YOUNG COMPANY WIND SENSOR CALIBRATION CERTIFICATE

SENSOR:	**05106 WIND MONITOR-MA**
SENSOR SERIAL NUMBER:	**WM46263**
BEARINGS:	**SEALED/WATERPROOF GREASE**
DATE:	**APR 11 2001**
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:	



MIN: -0.77 DEGREES MAX: 1.07 DEGREES



1.75 DEGREE DEADBAND

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).

PIR

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12 Sheffield Ave., P.O. Box 419, Newport, RI 02840 USA
Telephone: 401-847-1020 Fax: 401-847-1031
Email: eplab@mail.bbsnet.com Internet: www.eppleylab.com

EPLAB
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STANDARDIZATION OF EPPLEY PRECISION INFRARED RADIOMETER Model PIR

Serial Number: 33023F3

Resistance: 769 Ω at 23 °C
Temperature Compensation Range: -20 to 40 °C

This pyrgeometer has been compared with Precision Infrared Radiometer, Serial Number 29326F3 in Eppley's Blackbody Calibration System under radiation intensities of approximately 200 watts meter^{-2} and an average ambient temperature of 24 °C.

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

3.88×10^{-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
Port Hueneme, CA

S.O. Number: 58775
Date: December 13, 2001

Date of Test: December 7, 2001

In Charge of Test: R. T. Egeman

Reviewed by: Thomas D 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: eplab@mail.bbsnet.com Internet: www.eppleylab.com

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STANDARDIZATION OF EPPLEY PRECISION SPECTRAL PYRANOMETER Model PSP

Serial Number: 33090F3

Resistance: 699 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:

8.19 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 Scientific Foundation
Port Hueneme, CA

Date of Test: December 6, 2001
In Charge of Test: R.T. Egman

S.O. Number: 58775
Date: December 13, 2001

Reviewed by: Thomas D Kirk

Remarks:

GUV

Calibration Certificate

Biospherical Instruments Inc.

Calibration Certificate for GUV & PUV Radiometers

Serial Number: 9228 **Instrument Model: PUV-511A** **Date Solar Data Processed: 06/26/01**
Solar Calibration Dates: 06/24/01 to 06/25/01 **Solar Reference GUV(s): 9250**
Lamp Calibration Date: 06/21/01 **Solar Ref Cal Factor Version: 1**
Owner of Instrument: Raytheon **Solar Calibration at: San Diego, CA (BSI)**
Data Analyst(s): JSR **General Comments: Standard Calibration**

A note to the end-user. Instrument calibration is easily as important as instrument deployment, but it is often overlooked. This document has been prepared to help explain the conditions under which the different sensors in your instrument have been calibrated. Please read this information carefully and completely. If you do not understand a calibration factor, please feel free to contact the factory for a more detailed explanation.

GUV radiometers are precision, temperature-controlled filter radiometers designed for long term monitoring. PUV-510 Reference Ultraviolet Radiometers are designed to provide the above-water counterpart to the PUV-500 providing fast and accurate measurements of solar UV in the water column. Both of these series of instruments are calibrated in two different ways: "lamp calibrations" and "solar calibrations." The more familiar lamp calibration is performed in our laboratory using a NIST-traceable 1000 Watt FEL-type Standard of Spectral Irradiance and the methods described in National Bureau of Standards (US) publications 594-13 and 250-20. This standardized procedure gives good accuracy when calibrating the PAR visible channel and is useful in indicating if channel sensitivities have changed over time. Lamp calibrations are problematic for solar UV measurements because the solar spectrum is radically different from the lamp spectrum and changes greatly as a function of wavelength. Solar calibrations are achieved through direct comparison with "reference" GUVs (RGUVs) using the sun as the source of irradiance. These RGUVs are, in turn, calibrated through continuous intercomparison with a high resolution scanning spectroradiometer in San Diego (SUV-100) that is part of a world-wide UV monitoring network.

As a result of our calibration research, we have now standardized on solar calibrations for the UV channels while retaining the traditional lamp-based calibration for PAR. It is important to note that the solar calibration procedure automatically takes into account the spectral bandwidth of the detectors and therefore report the irradiance as a 1nm wide triangular bandpass centered on the nominal wavelength.

Caveats. The reference instruments used at Biospherical are "GUV" model radiometers that are temperature controlled and equipped with cosine collectors optimized for use in air. Years of GUV solar calibration experience have shown the procedure to be robust, accurate and reproducible for generalized GUV calibrations. PUVs are not temperature stabilized, a factor adding uncertainty to GUV/PUV calibration transfers. We are recommending that researchers use the solar calibration constants. Generally, these effects are well below the 10% uncertainty level. For a more detailed discussion, see Booth et al. (1994) Errors in reporting of solar irradiance using moderate bandwidth radiometers: an experimental investigation. SPIE Vol. 2258 Ocean Optics XII: 654-663.

Note: These calibration documents also apply to the "GTR" variant of the GUV instruments.

UV Irradiance Channels Calibrated Using Solar Intercomparison

ROM Tag Number	Ch#	Nominal Wavelength (nm)	Initial Offset (Volts)	Scale Factor in Air	Resulting Units
N/A	2	305	0.01655	0.93106	μW/(cm²·nm)
N/A	4	320	-0.00951	-0.14029	μW/(cm²·nm)
N/A	5	340	-0.00506	-0.11170	μW/(cm²·nm)
N/A	6	380	-0.00229	-0.05093	μW/(cm²·nm)

Note: Units for the Scale Factors are Volts/(μW/(cm² ·nm)). The initial offsets shown above resulted from our rooftop intercomparisons and they should be redetermined after the instrument is in its final installation, since the offset at 305nm is known to shift somewhat during shipping.

1 6/27/2001 9228 PUV-511 Solar Calibration 6-01.xls

Calibration Certificate

Standard Lamp Calibrated Channels (PAR)

Serial Number: 9228

ROM Tag Number	Ch#	Nominal Wavelength (nm)	Initial Offset (Volts)	Scale Factor in Air	Resulting Units
N/A	8	PAR	0.00000	-10.8519	μE/(cm²·sec)

Lamp Reference 91773 (03/13/98)

Units for the Scale Factors are Volts/(μEinsteins/(cm²·sec))

Photosynthetically Active (or Available) Radiation (PAR). In our instruments, PAR is measured over the spectral region from 400 to 700 nm using sensors with a constant quantum response (responds equally to all wavelengths). Instruments are available from Biospherical with one of two different irradiance measurement geometries. The PAR channel in the PUV measures (plane) downwelling irradiance, "Ed (PAR)", which is the downward irradiance incident on a flat surface of unit area. The measurement in a PUV-500 is made with a "cosine" collector optimized for use underwater. The GUV and PUV-510 also uses cosine collectors, but optimized for use in air. For this reason, direct comparisons of PUV-500 with PUV-510 or GUV-511 instruments are difficult.

Ed(PAR) is often confused with scalar irradiance, Eo (PAR), which is a measure of the radiance flux integrated from all directions incident on a point in space, as used by the PNF-300 Natural Fluorometer. Downwelling PAR irradiance will always be less than the scalar PAR under natural aquatic conditions.

Please note that the PUV is calibrated in μE/(cm²·sec), difference in areal unit from the PNF (cm^{-2}, not m^{-2}).

This channel is calibrated by a standard lamp.

Instrument Diagnostic Channels

ROM Tag Number	Ch#	Variable	Offset	Scale Factor	Original Value	Resulting Units
N/A	7	Ground	0	1	0.000820	Volts

Note: These channels are not normally used in data analysis, but are available for monitoring instrument performance, and for monitoring long term changes in the electronics. The offsets in these channels are normally entered with Offset as 0 and Scale as 1. Ground channels track the potential at several locations in the instrument, and the reference voltage is used to monitor the performance of the analog to digital converter. The voltages shown are not calibration factors, but they are the values at the time of this calibration and are included for reference.

Temperature

ROM Tag Number	Ch#	Function	Offset	Scale Factor	Resulting Units
N/A	1	Detector Array Temperature	0	0.01	°C
N/A	3	Electronics Temperature	0	0.01	°C

Note: "Detector Array Temperature records the temperature of the detector/filter array. It is possible to use data from this to compensate for the residual temperature sensitivity in the PUV, but this compensation is not supported in our software.

2 6/27/2001 9228 PUV-511 Solar Calibration 6-01.xls

PAR

DO NOT [illegible]
Biospherical [illegible] Inc.
CALIBRATION [illegible]

Biospherical Instruments Inc.

CALIBRATION CERTIFICATE

Calibration Date 2/15/01
Model Number QSR-240
Serial Number 6356
Operator TPC
Standard Lamp 94532(03/13/98)
Probe Excitation Voltage Range: 5 to 18 VDC(+)
Output Polarity: POSITIVE

Probe Conditions at Calibration(in air):

Calibration Voltage: 6 VDC(+)
Probe Current: 1.1 mA

Probe Output Voltage:

Probe Illuminated 86.6 mV
Probe Dark 0.3 mV
Probe Net Response 86.3 mV

Corrected Lamp Output:

Output In Air (same condition as calibration):

8.55E+15 quanta/cm²sec
0.014 uE/cm^{2}sec

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

Dry: 1.01E-17 V/(quanta/cm²sec)
6.08E+00 V/(uE/cm^{2}sec)

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

QSR240R 05/24/95

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 Internet: seabird@seabird.com

SENSOR SERIAL NUMBER = 1390
CALIBRATION DATE: 26-Feb-02

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

GHIJ COEFFICIENTS

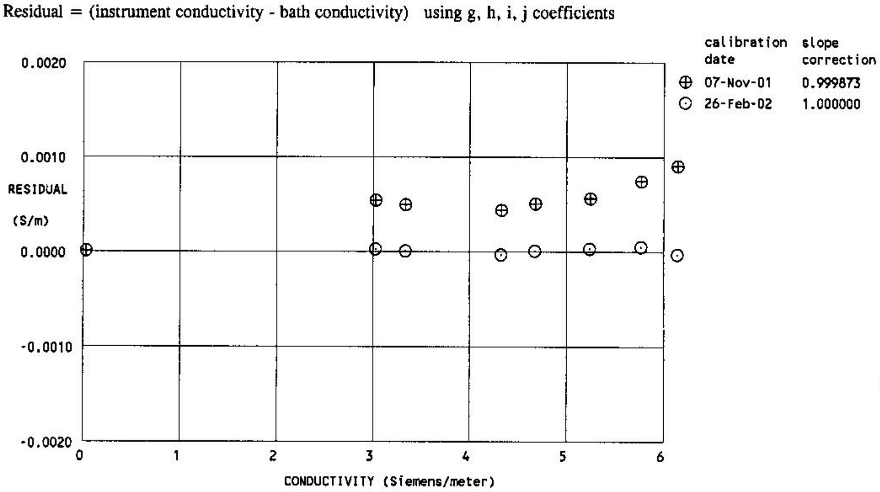
g = -3.93721982e+00
h = 4.71760725e-01
i = 3.91210505e-04
j = 2.24390213e-06
CPcor = -9.57e-08 (nominal)
CTcor = 3.25e-06 (nominal)

ABCDM COEFFICIENTS

a = 4.34273451e-04
b = 4.71515703e-01
c = -3.93435367e+00
d = -8.27365845e-05
m = 3.0
CPcor = -9.57e-08 (nominal)

BATH TEMP (ITS-90 °C)	BATH SAL (PSU)	BATH COND (Siemens/m)	INST FREQ (kHz)	INST COND (Siemens/m)	RESIDUAL (Siemens/m)
22.0000	0.0000	0.00000	2.88540	-0.00000	-0.00000
0.9999	35.0470	2.99379	8.44293	2.99381	0.00002
4.5000	35.0467	3.30431	8.81993	3.30431	-0.00000
15.0000	35.0464	4.29683	9.92836	4.29679	-0.00004
18.5000	35.0459	4.64552	10.28917	4.64552	-0.00000
23.9998	35.0448	5.20882	10.84635	5.20884	0.00002
28.9999	35.0411	5.73496	11.34172	5.73500	0.00004
32.5001	35.0337	6.10960	11.68138	6.10956	-0.00004

Conductivity = $(g + hf^2 + if^3 + jf^4) / [10(1 + \delta t + \epsilon p)]$ Siemens/meter
Conductivity = $(af^m + bf^2 + c + dt) / [10(1 + \epsilon p)]$ Siemens/meter
t = temperaure [deg 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 Internet: seabird@seabird.com

SENSOR SERIAL NUMBER = 1390
CALIBRATION DATE: 26-Feb-02

TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

ITS-90 COEFFICIENTS
g = 4.21133811e-03
h = 5.97506417e-04
i = 6.74711109e-06
j = -1.26911965e-06
f_0 = 1000.000

IPTS-68 COEFFICIENTS
a = 3.64763440e-03
b = 5.81273311e-04
c = 1.04100442e-05
d = -1.26850783e-06
f_0 = 2600.195

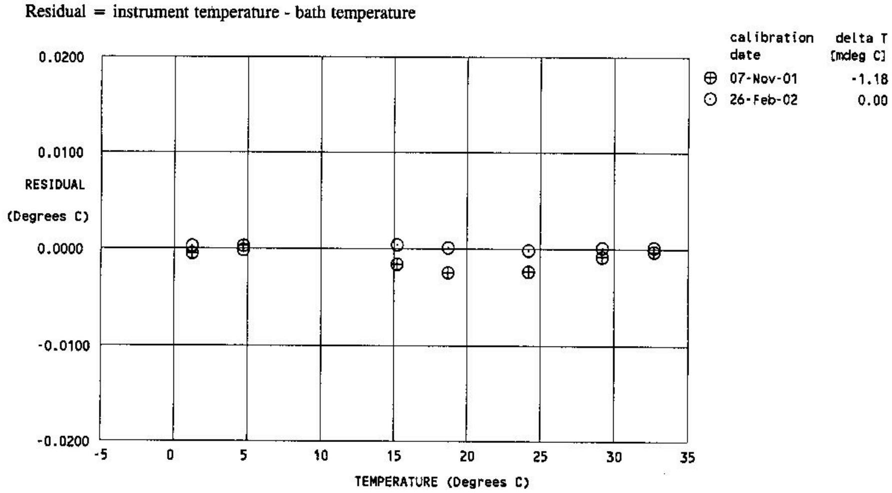
BATH TEMP (ITS-90 °C)	INSTRUMENT FREQ (Hz)	INST TEMP (ITS-90 °C)	RESIDUAL (ITS-90 °C)
0.9999	2600.195	1.0000	0.00014
4.5000	2814.589	4.4997	-0.00027
15.0000	3533.526	15.0003	0.00027
18.5000	3799.626	18.5000	0.00001
23.9998	4245.947	23.9996	-0.00023
28.9999	4682.700	28.9999	0.00002
32.5001	5006.561	32.5002	0.00005

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

Temperature IPTS-68 $= 1/\{a + b[\ln(f_0/f)] + c[\ln^2(f_0/f)] + d[\ln^3(f_0/f)]\} - 273.15$ (°C)

Following the recommendation of JPOTS: T_{68} is assumed to be 1.00024 * T_{90} (-2 to 35 °C).

Residual = instrument temperature - bath temperature



Underway Remote Temperature Sensor

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

SENSOR SERIAL NUMBER = 1267
CALIBRATION DATE: 12-Jun-01s

TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

ITS-90 COEFFICIENTS
g = 4.76637285e-03
h = 6.64703922e-04
i = 2.85244583e-05
j = 2.64328920e-06
f_0 = 1000.000

IPTS-68 COEFFICIENTS
a = 3.67984422e-03
b = 5.89471142e-04
c = 1.47206122e-05
d = 2.64476073e-06
f_0 = 5720.436

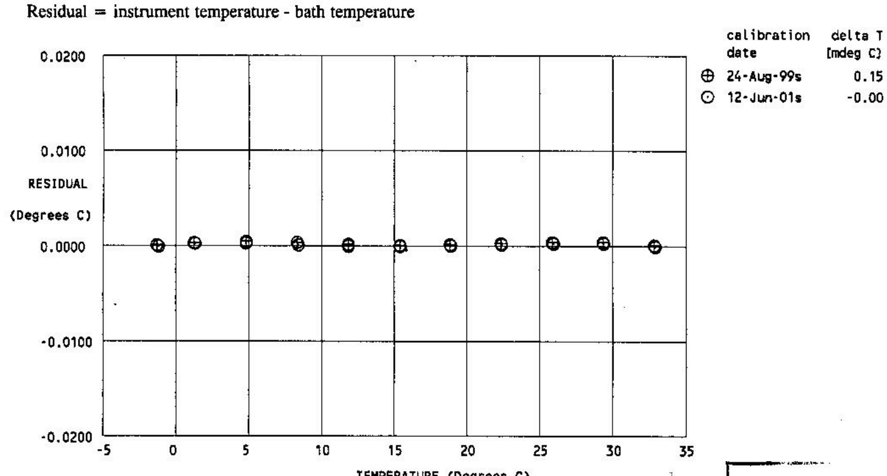
BATH TEMP (ITS-90 °C)	INSTRUMENT FREQ (Hz)	INST TEMP (ITS-90 °C)	RESIDUAL (ITS-90 °C)
-1.3989	5720.436	-1.3990	-0.00016
1.1096	6057.177	1.1098	0.00015
4.6023	6549.634	4.6024	0.00018
8.2003	7086.466	8.2003	-0.00001
11.6341	7627.516	11.6340	-0.00011
15.1913	8218.360	15.1911	-0.00015
18.6957	8831.382	18.6956	-0.00007
22.1954	9474.904	22.1954	0.00004
25.7553	10162.291	25.7555	0.00015
29.1723	10853.790	29.1725	0.00016
32.7057	11602.038	32.7055	-0.00018

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

Temperature IPTS-68 $= 1/\{a + b[\ln(f_0/f)] + c[\ln^2(f_0/f)] + d[\ln^3(f_0/f)]\} - 273.15$ (°C)

Following the recommendation of JPOTS: T_{68} is assumed to be 1.00024 * T_{90} (-2 to 35 °C).

Residual = instrument temperature - bath temperature



Underway Transmissometer

PO Box 518
620 Applegate St.
Philomath OR 97370

WET Labs

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

C-Star Calibration Sheet

Date:	**12/20/01**
Customer:	**National Science Foundation**
Serial Number:	**CST-422PR**
Job Number:	**0012016**
Work Order:	**003**

V_d = V dark	**0.058**
V_{air} = V out in air	**4.841**
V_{ref} = V out in water	**4.733**
Calibration Temperature of water	**23.0**
Ambient Temperature	**21.8**

% Transmission = $(V_{sig}-V_d)/(V_{ref}-V_d)$
$Tr = e^{-cx}$
To solve for the attenuation coefficient **c** in units of m^{-1} use the following equation.
$c = -1/x\ (\ln(V_{sig}-V_d)/(V_{ref}-V_d))$
For further information on these calculations please see C-Star User's Guide, Section 2.

Temperature Error: 0.02% F.S./°C

NOTES

- (V_d)—analog output of the instrument with the beam blocked. This is an instrumental offset.
- (V_{air})—analog output voltage of the instrument with a cleared beam path.
- (V_{ref})—analog output voltage of the instrument with clean H_2O in the path.
- **(Calibration Temperature of water)**—temperature of the clean water used to obtain V_{ref}.
- **(Ambient Temperature)**—temperature of the instrument during the calibration procedures.
- (V_{sig})—measured signal voltage of the C-Star.

MOCNESS

Temperature Sensor

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

SENSOR SERIAL NUMBER = 2299
CALIBRATION DATE: 12-Jun-01s

TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

ITS-90 COEFFICIENTS
g = 4.33179958e-03
h = 6.43561810e-04
i = 2.34768275e-05
j = 2.28344189e-06
f_0 = 1000.000

IPTS-68 COEFFICIENTS
a = 3.67984199e-03
b = 6.01987986e-04
c = 1.63176949e-05
d = 2.28501491e-06
f_0 = 2855.098

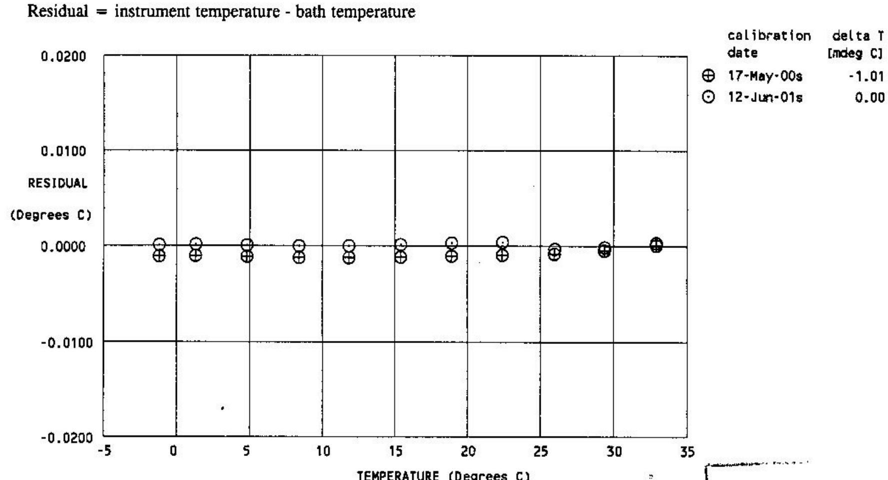
BATH TEMP (ITS-90 °C)	INSTRUMENT FREQ (Hz)	INST TEMP (ITS-90 °C)	RESIDUAL (ITS-90 °C)
-1.3989	2855.098	-1.3989	0.00000
1.1096	3019.572	1.1097	0.00006
4.6023	3259.840	4.6022	-0.00002
8.2003	3521.436	8.2002	-0.00012
11.6341	3784.777	11.6340	-0.00009
15.1913	4072.039	15.1913	0.00004
18.6957	4369.772	18.6959	0.00023
22.1954	4682.011	22.1957	0.00032
25.7553	5015.162	25.7549	-0.00042
29.1723	5350.135	29.1721	-0.00023
32.7057	5712.403	32.7059	0.00023

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

Temperature IPTS-68 $= 1/\{a + b[\ln(f_0/f)] + c[\ln^2(f_0/f)] + d[\ln^3(f_0/f)]\} - 273.15$ (°C)

Following the recommendation of JPOTS: T_{68} is assumed to be 1.00024 * T_{90} (-2 to 35 °C).

Residual = instrument temperature - bath temperature



Conductivity Sensor

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

SENSOR SERIAL NUMBER = 1798
CALIBRATION DATE: 13-Jul-01s

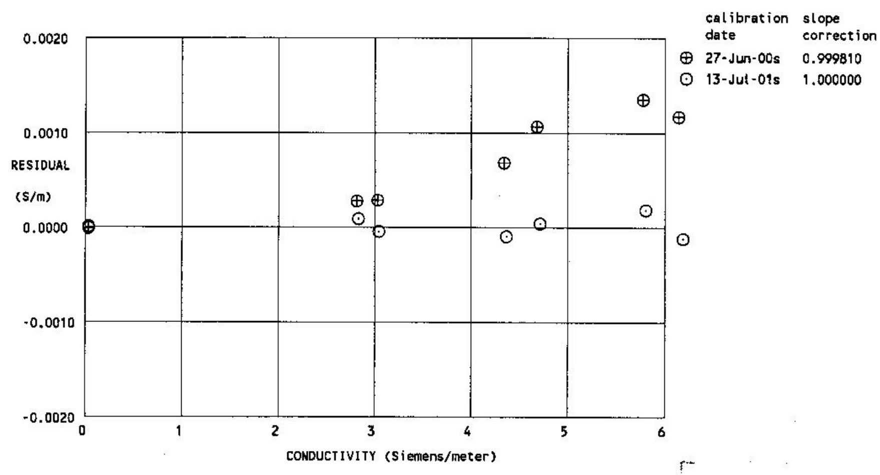
CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Siemens/meter

GHIJ COEFFICIENTS
g = -4.12496112e+00
h = 4.82403346e-01
i = -7.19158599e-04
j = 6.01313235e-05
CPcor = -9.57e-08 (nominal)
CTcor = 3.25e-06 (nominal)

ABCDM COEFFICIENTS
a = 4.38034898e-07
b = 4.79732020e-01
c = -4.11571113e+00
d = -8.70679690e-05
m = 5.5
CPcor = -9.57e-08 (nominal)

BATH TEMP (IPTS-68 °C)	BATH SAL (PSU)	BATH COND (Siemens/m)	INST FREQ (kHz)	INST COND (Siemens/m)	RESIDUAL (Siemens/m)
0.0000	0.0000	0.00000	2.92901	-0.00000	-0.00000
-1.4228	35.2266	2.79844	8.17437	2.79852	0.00008
1.0381	35.2274	3.01104	8.43986	3.01099	-0.00005
15.2043	35.2293	4.33673	9.93474	4.33662	-0.00011
18.6850	35.2304	4.68561	10.29148	4.68564	0.00003
29.1088	35.2305	5.77336	11.32957	5.77354	0.00018
32.6739	35.2273	6.15753	11.67311	6.15741	-0.00012

Conductivity = $(g + hf^2 + if^3 + jf^4) / [10(1 + \delta t + \epsilon p)]$ Siemens/meter
Conductivity = $(af^m + bf^2 + c + dt) / [10(1 + \epsilon p)]$ Siemens/meter
t = temperaure [deg C]; p = pressure [decibars]; δ = CTcor; ϵ = CPcor;
Residual = (instrument conductivity - bath conductivity) using g, h, i, j coefficients



Fluorometer

PO Box 518
620 Applegate St.
Philomath OR 97370

WET Labs

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

Chlorophyll Fluorometer Characterization

Date:	**12/21/01**
Serial #:	AFL-016
Job#:	0102007
Tech:	K.C

CWO (Vblank)	**0.83 volts**
CEV	**4.47 volts**
SF	**6.8681**
FSV	**5.45 volts**
Linearity:	**0.999 R^2 (0–1.5 volts)**
	0.995 R^2 (0– 5.45 volts)

Notes:

CWO (Vblank) is the clean water offset value and is obtain using pure filtered de-ionized water.

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

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

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

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

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

Chlorophyll Fluorometer Calibration

Date: 2/21/01
Serial # AFLD016
Tester Christian

Test Description

1. Dissolved chlorophyll fluorescence (fresh spinach tea) is measured against spectrophotometric readings for given concentrations
2. Chlorophyll concentration is determinied by CHL = achl/a*
   where CHL is concentration in ug/l
   achl is absorption due to chlorophyll a676 - (a650+a715)/2 as perscribed by Zaneveld
   a* is estimated chlorophyll absorption
3. Sensitivity T is calculated by T = CHL/Volts
   where T is sensitivity factor in ug/l Volts
   V is value in volts
4. Resolution is calculated by taking the noise in Volts /T
5. Range is calculated by Maximum No of Volts * T

NOTE: To Calculate ug/l chlorophhyl fluorescence from Voltage:

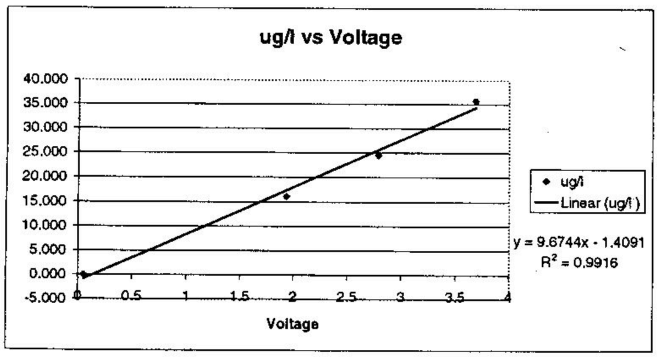
Fchl =	**SF**	***(Measured Voltage -**	**CWO**	**)**
Fchl =	**9.674**	***(Measured Voltage -**	**0.0520**	**)**

Stdev 0.000983192
a* 0.02
BG = Background Concentration
SF = Scale Factor
CWO = Clean Water Offset

Chlorophyll Absoprtion Calculations

Rel Conc	**a650**	**A676**	**A715**
0 (BG)	0.113	0.109	0.106
1	0.396	0.631	0.223
2	0.496	0.854	0.231
3	0.666	1.187	0.278

Rel Conc	**achl**	**Abs est Conc** µg/l	**Volts+BG** V+BG	**Voltage** Voltage	***Sensitivity*** (Scale Factor)	**Resolution**	**Range**
0 (BG)	-0.001	-0.025	0.052	0.000	µg/l/V	µg/l	µg/l
1.00	0.322	16.075	1.94	1.888	9.674	0.010	48.372
2.00	0.491	24.525	2.791	2.739			
3.00	0.715	35.750	3.689	3.637			



Pressure Sensor

DEPTH SENSOR CALIBRATION 146
September 30, 2000

The pressure sensor used in the MOCNESS is a titanium strain gauge with an internal temperature sensor. The temperature of the sensor is measured and used to correct for the thermal offsets in the measurement of pressure. The MOCNESS measures the voltage across the pressure and temperature bridges of the sensor and reports these values in its output data stream. The MOCNESS pressure sensor is calibrated at several pressure points and at two temperatures. There are no adjustments in the MOCNESS hardware and all calibration is done in software in the surface control computer. The values sent up the wire in the MOCNESS data stream (the bridge voltages) are scaled to be sent as integers in the range of 0-99999 for pressure and 0-9999 for temperature. The calibration data is fit by the following equation-

Z=(C1*Vt+C0)*Vp^2+(B1*Vt+B0)*Vp+(A1*Vt+A0)

where-
Z=pressure in decibars (1 decibar is approx 1m of water)
Vp=voltage reading in data stream from pressure sensor
Vt=voltage reading in data stream from temperature sensor

The following constants are for your MOCNESS underwater unit.

→ serial_number =
146 146
C1 =
-9.663075072905441e-13
C0 =
1.598781571931517e-09
B1 =
-2.101781306682122e-08
B0 =
0.10445782281928
A1 =
-0.00273391925043
A0 =
-2.425180326826662e+02

Transmissometer

PO Box 518
620 Applegate St.
Philomath OR 97370

WET Labs

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

C-Star Calibration Sheet

Date:	**11/30/01**
Customer:	**Raytheon Polar Service Company**
Serial Number:	**CST-533DR**
Job Number:	**0111019**
Work Order:	**001**

V_d = V dark	**0.057**
V_{air} = V out in air	**4.838**
V_{ref} = V out in water	**4.709**
Calibration Temperature of water	**22.8**
Ambient Temperature	**24.4**

% Transmission = $(V_{sig}-V_d)/(V_{ref}-V_d)$
$Tr = e^{-cx}$
To solve for the attenuation coefficient **c** in units of m^{-1} use the following equation.
$c = -1/x\ (\ln(V_{sig}-V_d)/(V_{ref}-V_d))$
For further information on these calculations please see C-Star User's Guide, Section 2.

Temperature Error: 0.02% F.S./°C

NOTES
- **(V_d)**—analog output of the instrument with the beam blocked. This is an instrumental offset.
- **(V_{air})**—analog output voltage of the instrument with a cleared beam path.
- **(V_{ref})**—analog output voltage of the instrument with clean H_2O in the path.
- **(Calibration Temperature of water)**—temperature of the clean water used to obtain V_{ref}.
- **(Ambient Temperature)**—temperature of the instrument during the calibration procedures.
- **(V_{sig})**—measured signal voltage of the C-Star.

MICROCAT (ROV)

RTC

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

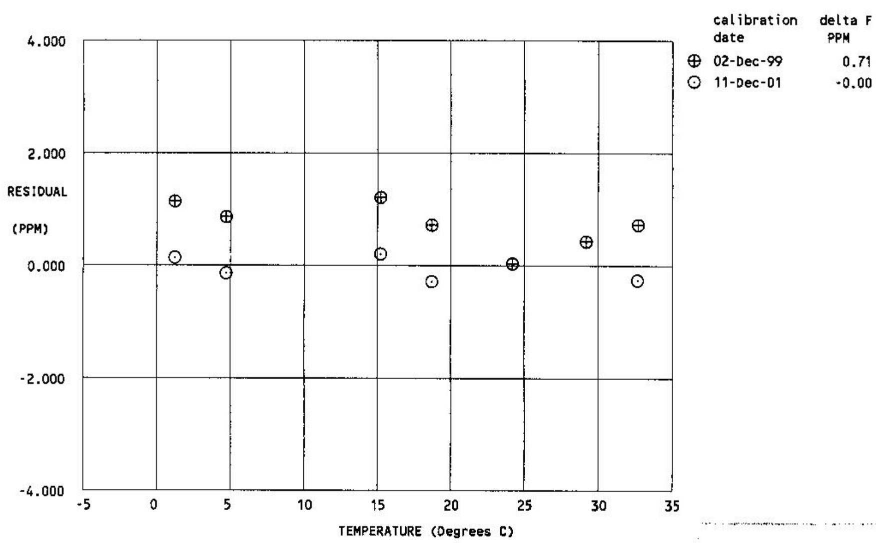
SENSOR SERIAL NUMBER = 1262
CALIBRATION DATE: 11-Dec-01

RTC CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

SBE 37 COEFFICIENTS
rtca0 = 9.999883e-01
rtca1 = 1.814977e-06
rtca2 = -3.277505e-08

BATH TEMP (ITS-90 °C)	RTC FREQ	COMPUTED FREQ	RESIDUAL PPM
0.9999	0.9999900	0.9999901	0.1
4.4999	0.9999960	0.9999958	-0.2
14.9999	1.0000080	1.0000082	0.2
18.5000	1.0000110	1.0000107	-0.3
23.9999	1.0000130	1.0000130	0.0
28.9960	1.0000130	1.0000134	0.4
32.4442	1.0000130	1.0000127	-0.3

RTC frequency = a0 + a1 * t + a2 * t^2
Residual = (Computed RTC frequency - Measured RTC frequency) * 1e6



POST CRUISE CALIBRATION

Temperature Sensor

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

SENSOR SERIAL NUMBER = 1262
CALIBRATION DATE: 11-Dec-01

SBE 37
TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

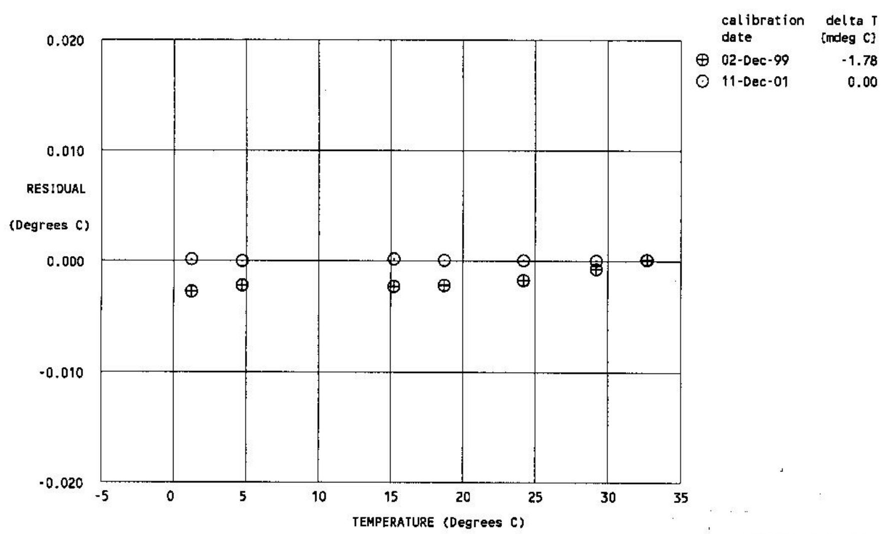
COEFFICIENTS:

a0 = -1.650011e-04
a1 = 3.216173e-04
a2 = -5.897442e-06
a3 = 2.512517e-07

BATH TEMP (ITS-90 °C)	INSTRUMENT OUTPUT: n	INST TEMP (ITS-90 °C)	RESIDUAL (ITS-90 °C)
0.9999	572125.3	1.0000	0.0001
4.4999	490093.0	4.4998	-0.0001
14.9999	313979.0	15.0000	0.0001
18.5000	272319.3	18.5000	-0.0000
23.9999	219010.0	23.9999	-0.0000
28.9960	180761.4	28.9960	-0.0000
32.4442	158840.1	32.4442	0.0000

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

Residual = instrument temperature - bath temperature



Conductivity Sensor

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

SENSOR SERIAL NUMBER = 1262
CALIBRATION DATE: 11-Dec-01

SBE 37
CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Siemens/meter

COEFFICIENTS:

g = -1.065872e+00
h = 1.587292e-01
i = -5.083360e-05
j = 3.091052e-05

CPcor = -9.5700e-08
CTcor = 3.2500e-06
WBOTC = -2.7708e-05

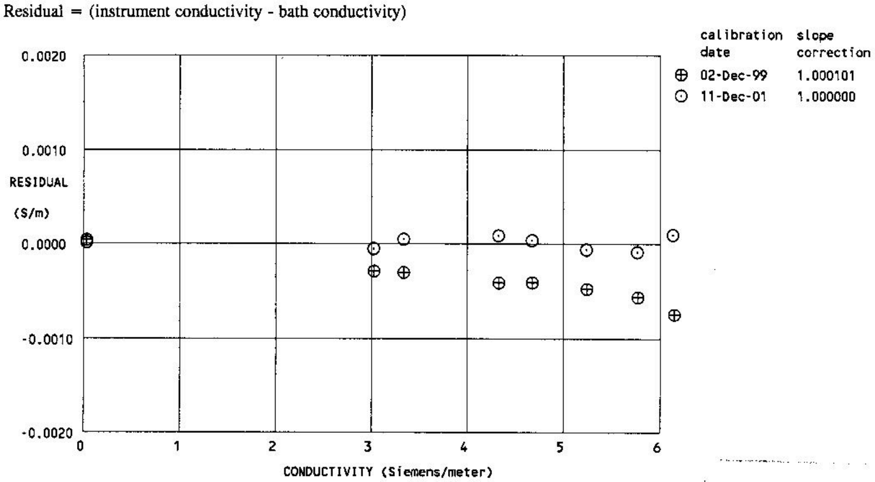
BATH TEMP (ITS-90 °C)	BATH SAL (PSU)	BATH COND (Siemens/m)	INST FREQ (Hz)	INST COND (Siemens/m)	RESIDUAL (Siemens/m)
22.0000	0.0000	0.00000	2591.51	0.00000	0.00000
0.9999	35.0405	2.99329	5048.56	2.99322	-0.00006
4.4999	35.0398	3.30371	5237.56	3.30375	0.00004
14.9999	35.0402	4.29615	5799.91	4.29623	0.00008
18.5000	35.0398	4.64480	5984.71	4.64483	0.00003
23.9999	35.0372	5.20782	6271.43	5.20776	-0.00007
28.9960	35.0294	5.73285	6527.27	5.73275	-0.00009
32.4442	35.0181	6.10115	6700.88	6.10124	0.00009

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

t = temperaure [deg C]; p = pressure [decibars]; δ = CTcor; ϵ = CPcor;

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

Residual = (instrument conductivity - bath conductivity)



POST CRUISE CALIBRATION

Pressure Sensor

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

SENSOR SERIAL NUMBER = 1262
CALIBRATION DATE: 14-Dec-01

PRESSURE CALIBRATION DATA
3000 psia S/N 189783

SBE 37 PRESSURE COEFFICIENTS

PA0 = 2.746007e+00
PA1 = 1.404863e-01
PA2 = -1.439020e-08

PTCA0 = 4.788939e+01
PTCA1 = 1.086817e+00
PTCA2 = -6.628779e-03
PTCB0 = 2.603700e+01
PTCB1 = 1.866667e-03
PTCB2 = 0.000000e+00

PRESSURE SPAN CALIBRATION:

PRESSURE PSIA	PRESSURE OUTPUT	TEMP (ITS-90 °C)	COMPUTED PRESSURE	ERROR % FSR
14.70	147.8	20.6	14.02	-0.02
614.87	4429.6	20.6	614.39	-0.02
1214.82	8709.9	20.6	1214.03	-0.03
1814.80	12995.4	20.6	1813.87	-0.03
2414.71	17288.3	20.6	2414.22	-0.02
3014.65	21585.8	20.6	3014.68	0.00
2414.69	17295.6	20.7	2415.21	0.02
1814.79	13006.8	20.6	1815.46	0.02
1214.77	8721.6	20.6	1215.67	0.03
614.80	4437.6	20.7	615.50	0.02
14.71	156.8	20.7	15.27	0.02

THERMAL OFFSET:

TEMPERATURE (ITS-90 °C)	PRESSURE OUTPUT
32.44	160.61
29.00	158.14
24.00	154.60
18.50	150.16
15.00	147.08
4.50	137.00
1.00	133.40

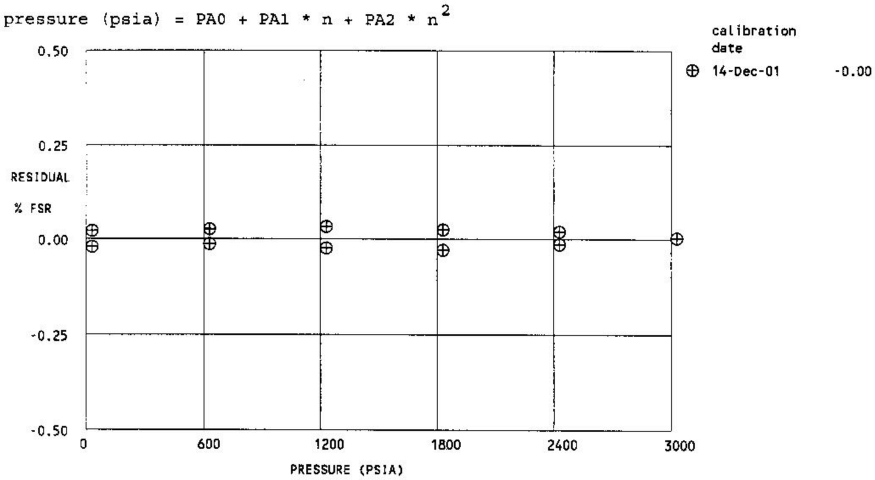
SPAN THERMAL SENSITIVITY:

TEMPERATURE (ITS-90 °C)	SPAN MV
0.00	26.04
30.00	26.09

$$x = \text{pressure output} - PTCA0 - PTCA1 * t - PTCA2 * t^2$$

$$n = x * PTCB0 / (PTCB0 + PTCB1 * t + PTCB2 * t^2)$$

$$\text{pressure (psia)} = PA0 + PA1 * n + PA2 * n^2$$



MICROCAT (APOP)

RTC

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

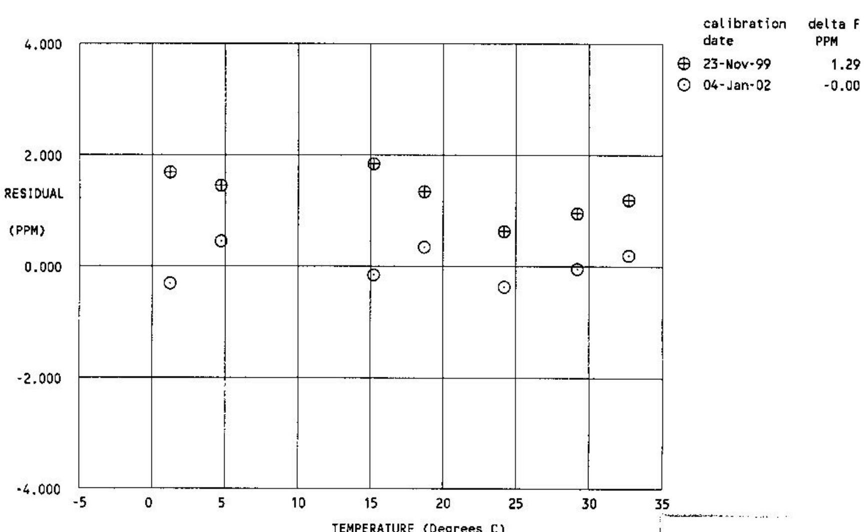
SENSOR SERIAL NUMBER = 1264
CALIBRATION DATE: 04-Jan-02

RTC CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

SBE 37 COEFFICIENTS
rtca0 = 9.999799e-01
rtca1 = 1.829314e-06
rtca2 = -3.327764e-08

BATH TEMP (ITS-90 °C)	RTC FREQ	COMPUTED FREQ	RESIDUAL PPM
1.0000	0.9999820	0.9999817	-0.3
4.4999	0.9999870	0.9999874	0.4
14.9999	1.0000000	0.9999998	-0.2
18.5000	1.0000020	1.0000023	0.3
23.9999	1.0000050	1.0000046	-0.4
29.0000	1.0000050	1.0000049	-0.1
32.5001	1.0000040	1.0000042	0.2

RTC frequency = a0 + a1 * t + a2 * t^2
Residual = (Computed RTC frequency - Measured RTC frequency) * 1e6



Temperature Sensor

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

SENSOR SERIAL NUMBER = 1264
CALIBRATION DATE: 04-Jan-02

SBE 37
TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

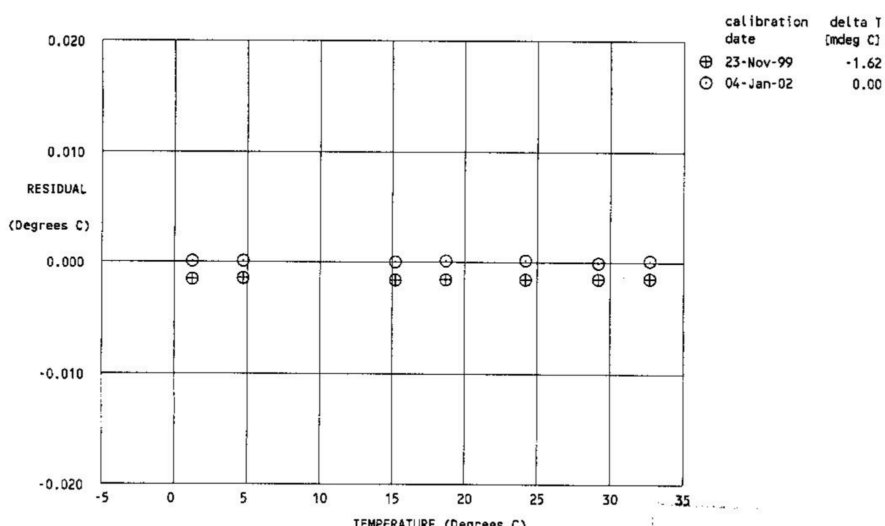
COEFFICIENTS:

a0 = -7.716983e-05
a1 = 2.926741e-04
a2 = -3.577425e-06
a3 = 1.906043e-07

BATH TEMP (ITS-90 °C)	INSTRUMENT OUTPUT: n	INST TEMP (ITS-90 °C)	RESIDUAL (ITS-90 °C)
1.0000	631365.6	1.0000	-0.0000
4.4999	541229.0	4.4999	0.0000
14.9999	347473.9	14.9998	-0.0001
18.5000	301568.4	18.5000	0.0000
23.9999	242775.4	24.0000	0.0001
29.0000	200518.9	28.9999	-0.0001
32.5001	175961.1	32.5002	0.0001

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

Residual = instrument temperature - bath temperature



Conductivity Sensor

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

SENSOR SERIAL NUMBER = 1264
CALIBRATION DATE: 04-Jan-02

SBE 37
CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Siemens/meter

COEFFICIENTS:

g = -1.033303e+00
h = 1.523429e-01
i = -1.663841e-04
j = 3.876200e-05

CPcor = -9.5700e-08
CTcor = 3.2500e-06
WBOTC = -2.8442e-05

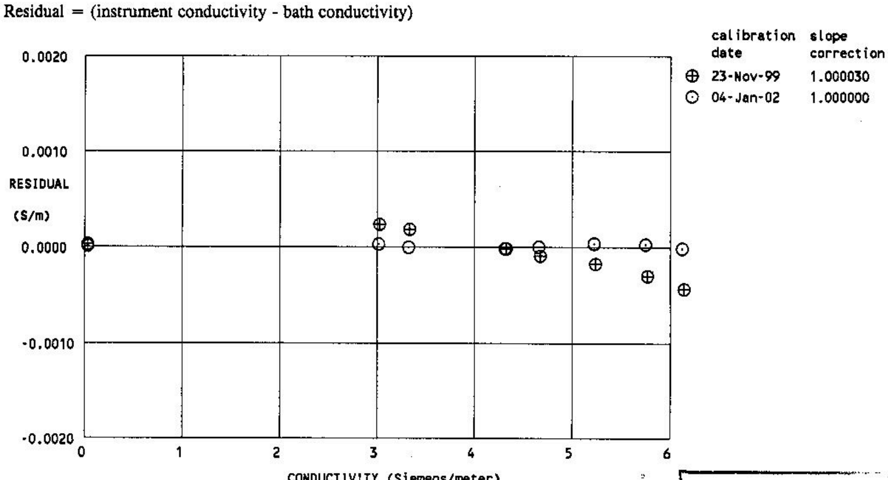
BATH TEMP (ITS-90 °C)	BATH SAL (PSU)	BATH COND (Siemens/m)	INST FREQ (Hz)	INST COND (Siemens/m)	RESIDUAL (Siemens/m)
22.0000	0.0000	0.00000	2606.64	-0.00000	-0.00000
1.0000	34.9392	2.98547	5133.40	2.98548	0.00002
4.4999	34.9392	3.29516	5326.99	3.29515	-0.00001
14.9999	34.9388	4.28504	5902.73	4.28501	-0.00002
18.5000	34.9381	4.63278	6091.87	4.63277	-0.00001
23.9999	34.9366	5.19453	6385.35	5.19455	0.00003
29.0000	34.9327	5.71923	6647.49	5.71925	0.00002
32.5001	34.9267	6.09307	6827.95	6.09305	-0.00002

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

t = temperaure [deg C]; p = pressure [decibars]; δ = CTcor; ϵ = CPcor;

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

Residual = (instrument conductivity - bath conductivity)



POST CRUISE CALIBRATION

Pressure Sensor

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

SENSOR SERIAL NUMBER = 1264
CALIBRATION DATE: 09-Jan-02

PRESSURE CALIBRATION DATA
1500 psia S/N 192801

SBE 37 PRESSURE COEFFICIENTS

PA0 = 2.074322e+00
PA1 = 6.009998e-02
PA2 = 2.406744e-08

PTCA0 = 1.186228e+02
PTCA1 = 1.092963e+00
PTCA2 = 2.165792e-02
PTCB0 = 3.009700e+01
PTCB1 = 5.000000e-04
PTCB2 = 0.000000e+00

PRESSURE SPAN CALIBRATION:

PRESSURE PSIA	PRESSURE OUTPUT	TEMP (ITS-90 °C)	COMPUTED PRESSURE	ERROR % FSR
14.70	354.5	22.0	14.17	-0.04
314.43	5329.1	22.0	313.68	-0.05
614.29	10287.4	22.0	613.39	-0.06
914.18	15235.8	22.0	913.68	-0.03
1214.27	20162.1	22.0	1213.80	-0.03
1514.24	25074.9	22.0	1514.26	0.00
1214.20	20174.7	22.0	1214.57	0.02
914.12	15251.7	22.0	914.65	0.04
614.17	10315.8	22.0	615.11	0.06
314.21	5350.1	22.0	314.95	0.05
14.15	362.8	22.0	14.67	0.03

THERMAL OFFSET:

TEMPERATURE (ITS-90 °C)	PRESSURE OUTPUT
32.50	393.73
29.00	384.91
24.00	373.51
18.50	363.01
15.00	355.87
4.50	341.69
1.00	335.36

SPAN THERMAL SENSITIVITY:

TEMPERATURE (ITS-90 °C)	SPAN MV
0.00	30.10
30.00	30.11

x = pressure output - PTCA0 - PTCA1 * t - PTCA2 * t^2

n = x * PTCB0 / (PTCB0 + PTCB1 * t + PTCB2 * t^2)

pressure (psia) = PA0 + PA1 * n + PA2 * n^2