Data Report NBP1501

Transit to McMurdo, 04 Jan 2015 – 20 Jan 2015

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Pathways of Circumpolar Deep Water to West Antarctica from profiling float and satellite measurements.

United States Antarctic Program

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Antarctic Support Contract

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Introduction

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

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

The data is distributed on a DVD-R written in written in UDF format. It is readable by most modern computer platforms.

All the data has been compressed using Unix “gzip,” identified by the “.tz” 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, one can use Stuffit Expander with DropStuff. On Windows operating systems, one can use WinZip or 7zip.

MultiBeam and raw ADCP data are distributed separately.

IMPORTANT: Read the last section, “Acquisition Problems and Events,” for important information that may affect the processing of this data.

Distribution Contents at a Glance

Volume 1 of 1: NBP1501

File	Description
/	Root level directory
NBP1501.trk	Text file of cruise track (
NBP1501.mgd	Full Cruise MGD77 data file
NBP1501.gmt	GMT binary file of MGD77 data
INSTCOEF.TXT	Instrument Coefficient File
1501DATA.docx	Data Report NBP1501 (MS Word)
1501DATA.pdf	Data Report NBP1501 (PDF format)
/process	Processed data
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NBP1501_mocness.tgz	Mocness Data
/Imagery	Satellite Imagery
1501Imagery.tz	Collection of Imagery Files
/ocean	Ocean data
1501ctd.tz	CTD Data

Extracting Data

The UNIX tar command has many options. It is often useful to know exactly how an archive was produced when expanding its contents. All archives are gzipped tar files and were created using the command,

```
tar -czvf 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 ".tz" extension on the filename. ".tz" stands for tared and gziped. These files can be decompressed after de-archiving, using the UNIX command,

```
gunzip filename.tz
```

Distribution Contents

Cruise Track

The distribution DVD includes a GMT cruise track file (NBP1501.trk). It contains the longitude and latitude at one-minute intervals extracted from the NBP1501.gmt file.

Satellite Images

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

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

NBP Data Products

Two datasets are created on each cruise: JGOFS and MGD77.

The data processing scripts used to produce JGOFS and MGD77 data sets create a lot of intermediate files. These files are included on the data distribution media in a file called 1501proc.TAR. They are included to make re-processing easier in the event of an error, but no extensive detail of the formats is included in this document. If you have any questions, please contact itvessel@usap.gov.

JGOFS

The JGOFS data set can be found on the distribution media in the file /process/NBP1501JGOF.tar. The archive contains one file produced for each day named jgDDD.dat.gz, where DDD is the year-day the data was acquired. The ".gz" extension indicates that the individual files are compressed before archiving. Each daily file consists of 22 columnar fields in text format as described in the table below. The JGOFS data set is created from calibrated data decimated at one-minute intervals. Several fields are derived measurements from more than a single raw input. For example, Course Made Good (CMG) and Speed Over Ground (SOG) are calculated from gyro and GPS inputs. Daily plots during the cruise are produced from the JGOFS data set. Note: Null, unused, or unknown fields are indicated as "NAN" as 9999 in the JGOFS data.

Field	Data	Units
01	UTC date	dd/mm/yy
02	UTC time	hh:mm:ss
03	SEAPATH latitude (negative is South)	tt.tttt
04	SEAPATH longitude (negative is West)	ggg.gggg
05	Speed over ground	Knots
06	GPS HDOP	-
07	Gyro Heading	Degrees (azimuth)
08	Course made good	Degrees (azimuth)
09	Mast PAR	μEinsteins/meter^2 sec
10	Sea surface temperature (remote)	°C
11	Sea surface conductivity (TSG1)	siemens/meter
12	Sea surface salinity (TSG1)	PSU
13	Sea depth (uncorrected, calc. sw sound vel. 1500 m/s)	meters
14	True wind speed (max speed windbird)	meters/sec
15	True wind direction (max speed windbird)	degrees (azimuth)
16	Ambient air temperature	°C
17	Relative humidity	%
18	Barometric pressure	mBars
19	Sea surface fluorometry	μg/l (mg/m^3)
20	Transmissometer	%
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 NBP1501.mgd. The file NBP1501.gmt is created from the MGD77 dataset using the "mgd77togmt" utility. NBP1501.gmt can be used with the GMT plotting package.

The data used to produce the NBP1501.mgd file can be found on the distribution media in the file /process/1501proc.tar. The data files in the archive contain a day's data and follow the naming convention Dddd.fnl.tz, where ddd is the year-day. These files follow a space-delimited columnar format that may be more accessible for some purposes. They contain data at one-second intervals rather than one minute and are individually "gzipped" to save space. Below is a detailed description of the MGD77 data set format. The other files in the archive contain interim processing files and are included to simplify possible reprocessing of the data using the RVDAS NBP processing scripts.

All decimal points are implied. Leading zeros and blanks are equivalent. Unknown or unused fields are filled with 9's. All "corrections", such as time zone, diurnal magnetics, and EOTVOS, are understood to be added.

Col	Len	Type	Contents	Description, Possible Values, Notes
1	1	Int	Data record type	Set to "5" for data record
2-9	8	Char	Survey identifier	
10-12	3	int	Time zone correction	Corrects time (in characters 13-27) to UTC when added; 0 = UTC
13-16	4	int	Year	4 digit year
17-18	2	int	Month	2 digit month
19-20	2	int	Day	2 digit day
21-22	2	int	Hour	2 digit hour
23-27	5	real	Minutes x 1000	
28-35	8	real	Latitude x 100000	+ = North - = South. (–9000000 to 9000000)
36-44	9	real	Longitude x 100000	+ = East - = West. (–18000000 to 18000000)
45	1	int	Position type code	1=Observed fix 3=Interpolated 9=Unspecified
46-51	6	real	Bathymetry, 2- way travel time	In 10,000th of seconds. Corrected for transducer depth and other such corrections
52-57	6	real	Bathymetry, corrected depth	In tenths of meters.
58-59	2	int	Bathymetric correction code	This code details the procedure used for determining the sound velocity correction to depth
60	1	int	Bathymetric type code	1 = Observed 3 = Interpolated (Header Seq. 12) 9 = Unspecified
61-66	6	real	Magnetics total field, 1^{ST} sensor	In tenths of nanoteslas (gammas)
67-72	6	real	Magnetics total field, 2^{ND} sensor	In tenths of nanoteslas (gammas), for trailing sensor
73-78	6	real	Magnetics residual field	In tenths of nanoteslas (gammas). The reference field used is in Header Seq. 13
79	1	int	Sensor for residual field	1 = 1^{st} or leading sensor 2 = 2^{nd} or trailing sensor 9 = Unspecified

Col	Len	Type	Contents	Description, Possible Values, Notes
80-84	5	real	Magnetics diurnal correction	In tenths of nanoteslas (gammas). (In nanoteslas) if 9-filled (i.e., set to “+9999”), total and residual fields are assumed to be uncorrected; if used, total and residuals are assumed to have been already corrected.
85-90	6	F6.0	Depth or altitude of magnetics sensor	(In meters) + = Below sea level 3 = Above sea level
91-97	7	real	Observed gravity	In 10^{th} of mgals. Corrected for Eotvos, drift, tares
98-103	6	real	EOTVOS correction	In 10^{th} of mgals. E = 7.5 V cos phi sin alpha + 0.0042 V*V
104-108	5	real	Free-air anomaly	In 10^{th} of mgals G = observed G = theoretical
109-113	5	char	Seismic line number	Cross-reference for seismic data
114-119	6	char	Seismic shot-point number	
120	1	int	Quality code for navigation	5=Suspected, by the originating institution 6=Suspected, by the data center 9=No identifiable problem found

Science of Opportunity

ADCP

The shipboard ADCP system measures currents in a depth range from about 30 to 300 m -- in good weather. In bad weather or in ice, the range is reduced, and sometimes no valid measurements are made. ADCP data collection is the OPP-funded project of Eric Firing (University of Hawaii) and Teri Chereskin (Scripps Institution of Oceanography). Data is collected on both the LMG and the NBP for the benefit of scientists on individual cruises, and for the long-term goal of building a profile of current structure in the Southern Ocean.

A data feed is sent from the ADCP system to RVDAS whenever a reference layer is acquired. This feed contains east and north vectors for ship's speed, relative to the reference layer, and ship's heading. Collected files (one per day) are archived in 1501adcp.tar in the directory /rvdas/nav.

pCO_2

The NBP carries a pCO2 measurement system from Lamont-Doherty Earth Observatory (LDEO). pCO2 data is recorded by RVDAS and transmitted to LDEO at the end of each cruise. You will find pCO2 data in a file named 1501pco2.tar in the /process directory, which contains the pCO2 instrument's data merged with GPS, meteorological and other oceanographic measurements. For more information contact Colm Sweeney (csweeney@ldeo.columbia.edu).

Cruise Science

CTD

The ctd data has been placed in the tar file /`ocean/NBP1501ctd.tar`. The archive contains tar files `NBP1501proc.tar`.

XBT

During the cruise, eXpendable BathyThermographs were used to obtain water column temperature profiles, providing corrections to the sound velocity profile for the multibeam system. The data files from these launches are included as 1501xbt.tar in the /ocean directory. No XBTs were collected on this cruise.

RVDAS

The Research Vessel Data Acquisition System (RVDAS) was developed at Lamont-Doherty Earth Observatory of Columbia University and has been in use on its research ship for many years. It has been extensively adapted for use on the USAP research vessels.

Daily data processing of the RVDAS data is performed to calibrate and convert values into useable units and as a quality-control on operation of the DAS. Raw and processed data sets from RVDAS are included in the data distribution. The tables below provide detailed information on the sensors and data. Be sure to read the “Significant Acquisition Events” section for important information about data acquisition during this cruise.

Sensors and Instruments

RVDAS data is divided into two general categories, *underway and navigation*. They can be found on the distribution media as subdirectories under the top level rvdas directory: /rvdas/uw, and /rvdas/nav. Processed oceanographic data is in the top level directory, /process. Each instrument or sensor produces a data file named with its channel ID. Each data file is g-zipped to save space on the distribution media. Not all data types are collected every day or on every cruise.

The naming convention for data files produced by the sensors and instruments is

NBP[CruiseID][ChannelID].dDDD

Example: `NBP1501mwx1.d025`

- The CruiseID is the numeric name of the cruise, in this case, NBP1501.
- The ChannelID is a 4-character code representing the system being logged. An example is “mwx1,” the designation for meteorology.
- DDD is the day of year the data was collected

Underway Sensors

Meteorology and Radiometry

Measurement	Channel ID	Collect. Status	Rate	Instrument
Air Temperature	met1	continuous	1 sec	R. M. Young 41372LC
Relative Humidity	met1	continuous	1 sec	
Wind Speed/Direction	met1	continuous	1 sec	R.M. Young 05106
Barometer	met1	continuous	1 sec	R.M. Young 61201
PIR (LW radiation)	met1	continuous	1 sec	Eppley PIR
PSP (SW radiation)	met1	continuous	1 sec	Eppley PSP
PAR	met1	continuous	1 sec	BSI QSR-240
GUV	guv	continuous	2 sec	BSI PUV-2511
PUV	puv	continuous		BSI PUG-2500

Geophysics

Measurement	Channel ID	Collect. Status	Rate	Instrument
Gravimeter	grv1	continuous	1 sec	BGM3/210
Magnetometer	mag1	not collected	1 sec	Marine Magnetics SeaSPY Overhauser
Bathymetry	knu1	continuous	Varies	Knudsen Chirp
Bathymetry	sim1	depth < 2500 m	Varies	Simrad EK60 Sonar

Oceanography

Measurement	Channel ID	Collect. Status	Rate	Instrument
Conductivity	mtsg	Continuous	6 sec	SeaBird SBE-45
Salinity	mtsg	Continuous	6 sec	Calc. from pri. temp
Sea Surface Temp	mtsg	Continuous	6 sec	SeaBird SBE 38
Fluorometry	flr1	Continuous	1 sec	WetLabs AFLT
Transmissometry	tsg1	Continuous	6 sec	WET Lab C-Star
pCO_2	pco2	Continuous	70 sec	(LDEO)
ADCP	adcp	Continuous	varies	RD Instruments

Navigational Instruments

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

Data

Data is received from the RVDAS system via RS-232 serial connections. A time tag is added at the beginning of each line of data in the form,

```
yy+dd:hh:mm:ss.sss [data stream from instrument]
```

where

yy	= two-digit year
ddd	= day of year
hh	= 2 digit hour of the day
mm	= 2 digit minute
ss.sss	= seconds

All times are reported in UTC.

The delimiters that separate fields in the raw data files are often spaces and commas but can be other characters such as : = @. Occasionally no delimiter is present. Care should be taken when reprocessing the data that the field's separations are clearly understood.

In the sections below a sample data string is shown, followed by a table that lists the data contained in the string.

Underway Data /rvdas/uw

Each section below describes a type of data file (file name extension in parentheses) followed by a typical line of data in the file. In the table(s) for each section is a description of the fields within each line of data. Note: most data files listed below will be included with each cruise's data distribution; however some types of files may be omitted if the instrument was not operating during the cruise. The available data files can be found in the /rvdas/uw directory on the distribution disc.

Sound Velocity Probe (svp1)

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

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

Meteorology (mwx1)

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

MET

08+330:23:59:57.725 MET,12.1,-54,6.64,88.7,111.3374,0.02414567,-
0.4827508,282.9581,281.8823,1005.119

PUS

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

SUS

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

MET string

Field	Data	Units
1	RVDAS time tag	
2	MET (string flag)	
3	Power Supply Voltage	V
4	Enclosure Relative Humidity (not currently implemented)	%
5	Air temperature	°C
6	Air Relative Humidity	%
7	PAR (photosynthetically available radiation)*	mV
8	PSP (short wave radiation)*	mV
9	PIR Thermopile (long wave radiation)*	mV
10	PIR Case Temperature	°Kelvin
11	PIR Dome Temperature	°Kelvin
12	Barometer	mBar

*See page 21 for calculations.

PUS string

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

SUS string

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

Knudsen (knud)

```
14+197:00:01:11.853 3.5kHz,3844.41,0,,,,1500,-21.036569,-14.608191
```

Field	Data	Units
1	RVDAS time tag	
2	3.5kHz	
3	Low frequency depth	meters
4	Valid flag	
5	12.0kHz	
6	High frequency depth	meters
7	Valid flag	
8	Sound Speed Velocity	meters/sec
9	Latitude	
10	Longitude	

Gravimeter (grv1)

14+050:00:01:32.363 01:025415 00

Field	Data	Conversion	Units
1	RVDAS time tag		
2	01:		
3	Gravity count	mgal = count x 4.99407552 + bias	count
4	Error Flag		

Fluorometer (flr1)

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

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

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

pCO_2 (pco2)

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

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

Micro-TSG (tsg1)

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

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

Micro-TSG #2 (tsg2)

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

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

Engineering (eng1)

```
13+079:10:22:16.035 12.26 19.68 507.4  0.3 173.3 -751.9 0 0 NAN
NAN 43.2 85.7
```

Field	Data	Units
1	RVDAS time tag	
2	Power Supply Voltage	V
3	Internal Case Temperature	°C
4	Pump #1 flow rate (aquarium room)	L/min
5	Pump #2 flow rate (helo deck)	L/min
6	Pump #3 flow rate (hydro-lab)	L/min
7	Seismic air pressure	Lbs/sq-in
8	PIR case resistance (not currently hooked up, data is irrelevant)	Kohm
9	PIR case ratiometric output (not currently hooked up, data is irrelevant)	mV
10	Freezer #1 temperature	°C
11	Freezer #2 temperature	°C
12	Altimeter, OIS benthic (yoyo) camera; distance from the seafloor	m
13	Transmissometer, OIS benthic (yoyo) camera	%

*See page 24 for PIR calculations.

Hydro-DAS (hdas)

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

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

GUV Data (pguv)

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

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

Remote Temperature (rtmp)

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

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

Winch Data (bwnc, twnc, cwnc)

```
13+157:04:20:20.976 ^^^A03RD,2013-06-
06T04:20:29.352,BALTIC,00000236,-00000.0,-00009.3,3306
```

Field	Data	Units
1	RVDAS time tag	alphanumeric
2	LAN ID	alphanumeric
3	LCI-90i Date and Time	alphanumeric
4	Winch Name	alphanumeric
5	Tension	lbs
6	Speed	m/min
7	Pay-out	m
8	Checksum	numeric

Navigational Data /rvdas/nav

Seapath GPS (s330, seap)

The s330 and seap have the same format. The Seapath GPS outputs the following data strings, four in NMEA format and two in proprietary PSXN format:

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

GPZDA

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

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

GPGGA

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

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

GPVTG

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

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

GPHDT

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

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

PSXN,20

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

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

PSXN,22

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

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

PSXN,23

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

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

Trimble (P-Code) GPS (PCOD)

The Trimble GPS, which formerly output Precise Position (*P-Code*) strings, but now only outputs Standard Position (*Civilian*) strings, outputs three NMEA standard data strings:

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

GGA: GPS Position Fix – Geoid/Ellipsoid

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

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

GLL: GPS Latitude/Longitude

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

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

VTG: GPS Track and Ground Speed

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

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

Gyro Compass (gyr1)

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

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

ADCP Course (adcp)

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

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

Processed Data /process/

pCO2-merged

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

Field	Data	Units
1	RVDAS time tag	
2	pCO_2 time tag (decimal is fractional time of day)	yyyyddd.ttt
3	Raw voltage (IR)	mV
4	Cell temperature	°C
5	Barometer	MBar
6	Flow rate	ml / min
7	Concentration	ppm
8	pCO_2 pressure	microAtm
9	Equilibrated temperature	°C
10	Sea Water Temp	1 or 2 digits
11	Valve position	°C
12	Flow source (Equil = pCO_2 measurement)	text
13	RVDAS latitude	degrees
14	RVDAS longitude	degrees
15	TSG external temperature	°C
16	TSG 1 salinity	PSU
17	Fluorometer	V
18	RVDAS true wind speed	m/s
19	RVDAS true wind direction	degrees
20	Barometric Pressure	mBars
21	Uncontaminated seawater pump flow rate	l/min
22	Speed over ground	knots
23	Course made good	degrees
24	Oxygen	µM
25	TSG 2 internal temperature	°C
26	TSG 2 salinity	PSU
27	TSG 1 internal temperature	°C
28	H2O Input Source	-1 stern thrustor 0 moonpool

Calculations

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

PAR

Coefficients parc1 and parcv for this cruise can be found in the `instrument.coeff` file as the variable labeled PAR, respectively. Variable par is the raw data in mV, as described in the "mwx1" file description. The calibration scale and probe offset dark are values taken from the PAR Cal Sheet.

```
par = raw data mV
calibration scale = 5.8644 V/(µEinstiens/cm2sec)
parc1 = 1 / scale = .17
probe offset dark = -.1 mV
parcv = dark x 1000 mV/V = -0.0001 V
((par / 1000 mV/V) – parcv) x parc1 x 10000 cm2/m2 =
µEinstiens/m2sec

Calculations (extracted from the C code):
/* Convert from mV to V */
par /= 1000;
/* (par V - vdark V) / Calibration Scale Factor V/uE/cm2sec */
parCalc = (par - parcv) * parc1 * 10000;
```

PSP

Coefficient pspCoeff for this cruise can be found in the `instrument.coeff` file as the variable labeled PSP1. Variable psp is the raw data in mV, as described in the "mwx1" file description.

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

Calculations (extracted from the C code):
     /* Convert from mV to W/m^2  */
     pspCalc = (psp * 1000 / pspCoeff);
```

PIR

Coefficient pirCoeff for this cruise can be found in the `instrument.coeff` file as the variable labeled PIR1. Variable pir_thermo is the raw data in mV, pir_case is the PIR case temperature in Kelvins and pir_dome is the PIR dome temperature in Kelvins, as described in the "mwx1" file description. Hard-coded "C" coefficients are shown below:

```
Dome constant = 3.5
Sigma = 5.6704e-8

pir_thermo = raw data mV
calibration scale = pirCoeff x 10^-6  V/(W/m2)
pir_thermo / (scale x 1000 mV/V) = W/m2

Calculations (extracted from the C code):
      /* convert mV to W/m^2 */
     pirCalc = (pir_thermo * 1000 / pirCoeff)
     /* correct for case temperature */
     pirCalc += sigma * pow(pir_case,4)
     /* correct for dome temperature */
     pirCalc -= 3.5 * sigma * (pow(pir_dome, 4) - pow(pir_case,
4))
```

Acquisition Problems and Events

This section lists problems with acquisition noted during this cruise including instrument failures, data acquisition system failures and any other factor affecting this data set. The format is ddd:hh:mm (ddd is year-day, hh is hour, and mm is minute). Times are reported in GMT.

Start	End	Description
005:18:22		Data collection begins. -52.7647, -67.9905
006:11:40		SVP restarted
006:13:43		ADCP bottom track off
007:11:00		GUV restarted with updated calibration file
018:19:23		ADCP bottom track on
	018:23:57	Data Collection ends. -77.0002, 174.1364

Appendix: Sensors and Calibrations

NBP1501 Sensors:

Sensor	Description	Serial #	Last Calibration Date	Comments
Meteorology & Radiometers				
Port Anemometer	Gill Instruments 1390-PK-062	924057	11/18/09	Port side installed 03/05/10
Stbd Anemometer	Gill Instruments 1390-PK-062	847014	09/29/10	Stbd side installed 11/17/10
Barometer	RM Young 61201	01706	04/10/14	Installed 12/01/14
Humidity/Wet Temp	RM Young 41372LC	06135	06/03/14	Installed 10/13/14
PIR (Pyrgeometer)	Eppley PIR	32845F3	07/18/13	Installed n/a
PSP (Pyranometer)	Eppley PSP	32850F3	08/07/13	Installed n/a
PAR (Mast)	BSI-QSR-240	6356	02/03/14	Installed 12/17/14
GUV (Mast)	BSI GUV-2511	25110203113	02/05/14	Installed 08/14/14
Underway				
Micro-TSG (Primary)	SeaBird SBE 45	4546167-0199	11/02/13	Installed 08/11/14
Micro-TSG (Secondary)	SeaBird SBE 45	4549120-0226	06/13/13	Installed 03/15/14
Digital Remote Temp	SeaBird SBE 38	3850449-0389	02/01/13	Installed 06/25/14
Fluorometer	WetLabs FLRTD	FLRTD-855	03/26/14	Installed 10/21/14
Transmissometer	WET Labs C-Star	CST-557DR	08/28/13	Installed 01/25/14
Gravimeter	BGM3/210	B-210	11/29/14	Installed on 01/25/14
Bathymetry	Simrad EK60	3001	n/a	
Bathymetry	Knudsen Chirp	n/a	n/a	

NBP1501 CTD Sensors:

Sensor	Description	Serial #	Last Calibration Date	Comments
CTD Fish	SeaBird model SBE 9+	09P78915-1190	06/09/14	Installed on 10/19/14
CTD Pressure	SeaBird model SBE 9+	130016	06/09/14	Installed on 10/19/14
CTD Deck Unit	SeaBird model SBE 11+	11P19858-0490	n/a	Installed on 11/08/07
Primary Temperature Sensor	SeaBird model 3-02/F	03P2438	01/07/14	Installed on 12/27/14
Secondary Temperature Sensor	SeaBird model 3-02/F	03P2308	8/8/14	Installed on 12/27/14
Primary Conductivity Sensor	SeaBird model 4-02/0	044151	3/7/14	Installed on 12/27/14
Secondary Conductivity Sensor	SeaBird model 4-02/0	042513	7/16/14	Installed on 12/27/14
Primary Dissolved Oxygen Sensor	SeaBird model SBE43	2267	10/15/14	Installed on 12/27/14
Secondary Dissolved Oxygen Sensor	SeaBird model SBE43	0080	7/11/14	Installed on 12/27/14
SPAR Sensor	Biospherical Instruments QSP-200L4S	6356	02/03/14	Installed on 8/14/2014
Transmissometer	WET Labs C-Star	CST-889DR	09/05/13	Installed on 11/30/14
Fluorometer	WET Labs AFLT	AFLD-011	06/11/14	Installed on 11/30/14
Altimeter	Teledyne Benthos PSA-916	49432	n/a	Installed on 10/19/14
CTD Pump (Primary)	SeaBird 5T, PN 90543	055641 3.0K	03/31/14	Installed on 12/27/14
CTD Pump (Secondary)	SeaBird 5T, PN 90741	051646 3.0K	8/10/14	Installed on 12/27/14
Bottom Contact Switch	SeaBird	#3	n/a	Installed on 10/20/14
Slip Ring Assembly		1.406	n/a	Installed on
Carousel Water Sampler	SeaBird SBE-32	3270675-0925	n/a	Installed on 12/11/14

Calibrations

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

Gravity Tie

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

Date: 11/29/2014
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 (Filt Counts)	25199.84	11:46
Ship's meter after gravity tie (Filt Counts)	25199.89	12:44
Average	25199.87	
Ship Gravimeter's Calibration Constant	4.99407055	
Corrected ship's meter (QC Grav (mgal))	125849.90	

	Value	Time (GMT)
Ship's meter before gravity tie (serial, RVDAS)		
Ship's meter after gravity tie (serial, RVDAS)		
Average (for comparison check only)	#DIV/0!	

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

Station	Value	Time (GMT)	Temp	Date	OBS mgal, averaged
Pier measurement 1	4919.22	11:58	53.6	November 29, 2014	
Pier measurement 2	4919.03	12:00	53.6	November 29, 2014	4968.63
Pier measurement 3	4919.04	12:02	53.6	November 29, 2014	
Average	4919.10				
Station measurement 1	4919.81	12:19	53.5	November 29, 2014	
Station measurement 2	4919.85	12:21	53.5	November 29, 2014	4969.38
Station measurement 3	4919.84	12:24	53.5	November 29, 2014	
Average	4919.83				
Pier measurement 4	4919.60	12:33	53	November 29, 2014	
Pier measurement 5	4919.60	12:35	53.4	November 29, 2014	4969.19
Pier measurement 6	4919.74	12:37	53.4	November 29, 2014	
Average	4919.65				

Gravity Bias from last tie 855468.60
Drift since last tie 1.91

OBS Differences	
Station to Pier (1, 2, & 3 averaged)	-0.74
Station to Pier (4, 5, & 6 averaged)	-0.19
Averaged Differences	-0.47
Gravity at pier	981320.35
Elevation of pier above gravimeter, meters	0.2
Earth differential gravity, mgal/meter	0.3
Gravity at ship's gravimeter	981320.41
Gravity Bias (Offset for RVDAS)	855470.51

Comments

Tie done by Gabby Ingles and Adina Scott under stable conditions. RVDAS value was not available at time of tie.

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

Meteorology System

Barometer

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

YOUNG

CALIBRATION REPORT
Barometric Pressure

Customer: *Lockheed Martin Corp*

Test Number: 4410-02B
Test Date: 10 April 2014
Customer PO: 4900045904
Sales Order: 4006

Test Sensor:
Model: 61201
Description: Barometric Pressure Sensor
Serial Number: *BP01706*

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

Reference Pressure (hPa)	Voltage Output (millivolts)	Indicated (1) Pressure (hPa)
800.0	-1	800.0
875.0	1251	875.0
950.0	2501	950.0
1025.0	3750	1025.0
1100.0	4999	1099.9

(1) Calculated from voltage output

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

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

Tested By: R Thrulling

METEOROLOGICAL INSTRUMENTS
Tel: 231-946-3980 Fax: 231-946-4772 Email: met.sales@youngusa.com Website: youngusa.com
ISO 9001:2008 CERTIFIED

Temperature/Relative Humidity

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

COPY

CALIBRATION REPORT
Temperature

Customer: *Lockheed Martin Corp*

Test Number: 4603-01T
Test Date: 3 June 2014
Customer PO: 4900048811
Sales Order: 4077

Test Sensor:
Model: 41372LC
Serial Number: *TS06135*
Description: Temperature/Relative Humidity Sensor

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

Bath Temperature (degrees C)	Current Output (milliamps)	Indicated (1) Temperature (degrees C)
-49.85	4.032	-49.80
-0.01	12.002	0.01
49.89	19.982	49.89

(1) Calculated from current output

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

Reference Instrument	Serial #	NIST Test Reference
Brooklyn Thermometer Model 43-FC	3006-118	W204690
Brooklyn Thermometer Model 22332-D5-FC	25071	W204691
Brooklyn Thermometer Model 2X400-D7-FC	77532	W204692
Keithley Multimeter Model 191	15232	4200646497

Tested By: _____

METEOROLOGICAL INSTRUMENTS
Tel: 231-946-3980 Fax: 231-946-4772 Email: met.sales@youngusa.com Website: youngusa.com
ISO 9001:2008 CERTIFIED

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

COPY

CALIBRATION REPORT
Relative Humidity

Customer: *Lockheed Martin Corp*

Test Number: 4603-01R
Test Date: 3 June 2014
Customer PO: 4900048811
Sales Order: 4077

Test Sensor:
Model: 41372LC
Serial Number: *TS06135*
Description: Temperature/Relative Humidity Sensor

Report of calibration comparison of test relative humidity sensor with National Institute of Standards and Technology traceable standard relative humidity sensor at five humidity levels in the R.M. Young Company controlled humidity chamber facility. Calibration accuracy ± 2.0 %.

Reference Humidity (%)	Current Output (milliamps)	Indicated (1) Humidity (%)
10.0	5.9	12.1
30.0	9.0	31.2
50.0	12.3	52.1
70.0	15.3	70.8
90.0	18.1	87.9

(1) Calculated from voltage output

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

Reference Instrument	Serial #	NIST Test Reference
Vaisala Humidity Sensor Model 35AC	N475040	TN 266152
Agilent Multimeter Model 34405A	MY53020093	4200646497

Tested By: R Rutling

METEOROLOGICAL INSTRUMENTS
Tel: 231-946-3980 Fax: 231-946-4772 Email: met.sales@youngusa.com Website: youngusa.com
ISO 9001:2008 CERTIFIED

PIR

EPLAB

THE EPPLEY LABORATORY, INC.

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

STANDARDIZATION OF EPPLEY PRECISION INFRARED RADIOMETER Model PIR

Serial Number: 32845F3

Resistance: 712 Ω at 23°C
Temperature Compensation Range: -20° to +40°C

This pyrgeometer has been compared against Eppley's Blackbody Calibration System under radiation intensities of approximately 200 watts meter^{-2} and an average ambient temperature of 30°C as measured by Standard Omega Temperature Probe, RTD#1.

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

4.08×10^{-6} volts/watts meter^{-2}

The calculation of this constant is based on the fact that the relationship between radiation intensity and emf is rectilinear to intensities of 700 watts meter^{-2}. This radiometer is linear to within ±1.0% up to this intensity.

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

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

Shipped to: LMP4 ISGS N.S.F.
Port Hueneme, CA

S.O. Number: 63850
Date: July 18, 2013

Remarks:

Date of Test: July 17, 2013

In Charge of Test: Debra L. Gluntz

Reviewed by: Thomas J. Kucke

PSP

EPLAB

THE EPPLEY LABORATORY, INC.

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

Calibration Certificate

Instrument:	Precision Spectral Pyranometer, Model PSP, Serial Number 32850F3
Procedure:	This pyranometer was compared in Eppley's Integrating Hemisphere according to procedures described in ***ISO 9847 Section 5.3.1*** and Technical Procedure, TP01 of The Eppley Laboratory, Inc.'s Quality Assurance Manual on Calibrations.
Transfer Standard:	Eppley Precision Spectral Pyranometer, Model PSP, Serial Number 21231F3
Results:	**Sensitivity:** **S = 7.68 µV / Wm^{-2}**
	Uncertainty: U_{95} = ±0.91% (95% confidence level, k=2)
	Resistance: 706 Ω at 23°C
	Date of Test: August 7, 2013
Traceability:	This calibration is traceable to the World Radiation Reference (WRR) through comparisons with Eppley's AHF standard self-calibrating cavity pyrheliometers which participated in the Eleventh International Pyrheliometric Comparisons (IPC XI) at Davos, Switzerland in September-October 2010. Unless otherwise stated in the remarks section below or on the Sales Order, the results of this calibration are "AS FOUND / AS LEFT".
Due Date:	Eppley recommends a minimum calibration cycle of five (5) years but encourages annual calibrations for highest measurement accuracy.
Customer:	LMP4 ISGS Port Hueneme, CA
Signatures:	D. GIENTY — In Charge of Test:
	Reviewed by:
Eppley SO	63884
Date of Certificate	August 15, 2013
Remarks:	

GUV

Biospherical Instruments Inc.

System Calibration Certificate

THE INSTRUMENTS REFERENCED BELOW WERE FACTORY TESTED AND CALIBRATED BY

BIOSPHERICAL INSTRUMENTS INC.
5340 Riley Street
San Diego, California 92110 USA

Instruments: GUV-2511 No 25110203113

Optical Calibrations:

NIST Traceability. For wavelengths longer than 313 nm, the specific instruments cited here were calibrated using a 1000W FEL #V-034 (3/7/12) following procedures and standards traceable to NIST Standard of Spectral Irradiance F-616. Traceability paths and all procedures for all calibrated lamps and associated apparatus (shunts, power supplies, DMMs, etc) are maintained following calibration methodologies per National Bureau of Standards (US) (NBS) Special Publication 250-20 Spectral Irradiance Calibrations (1987) and NBS Publication 594–13 Optical Radiation Measurements: The 1973 Scale of Spectral Irradiance (1977).

Solar Calibrations. Lamp calibrations are problematic for solar UV measurements (wavelengths below 320 nm) 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 measurements of a high resolution scanning spectroradiometer in San Diego (SUV-100), which is part of the National Science Foundation's UV Monitoring Network. The SUV-100 instrument has a bandwidth of 1 nm. Calibrated filter radiometer data therefore report spectral irradiance at the channel's nominal wavelengths with a bandwidth of 1 nm. Solar calibrations are typically accurate to within ±10% for solar zenith angles smaller than 75°. At larger solar zenith angles, UV channels have a greater uncertainty due to the rapid change of the solar UV spectrum.

Note that this certificate contains a subset of the information delivered in the calibration database **25110203113v7.mdb**. This database is required for operation of this system using Biospherical Instruments Inc.'s Logger® software.

Biospherical Instruments Inc.

GUV-2511 Calibration Certificate

System Serial Number	25110203113	Date of Calibration	2/5/2014
Calibration database	25110203113v7.mdb	Date of Certificate	2/5/2014
DASSN	0068	Standard of Spectral Irradiance	V-034(3/7/12)
Microprocessor Tag Number	2	Operator	TC

Monochromatic Channels	Address	Wavelength [nm]	Responsivity [Amps per µW/(cm²-nm)]	ScaleSmall [Volts per µW/(cm²-nm)]	ScaleMedium [Volts per µW/(cm²-nm)]	ScaleLarge [Volts per µW/(cm²-nm)]	OffsetSmall [volts]	OffsetMedium [volts]	OffsetLarge [volts]	Measurement Units
Ed0320	2	320	2.6356E-10	2.6883E-05	7.8542E-03	2.7807E+00	-6.0000E-06	-9.0000E-06	1.7200E-04	µW/(cm²nm)
Ed0340	6	340	2.1334E-10	2.1761E-05	6.3577E-03	2.2417E+00	3.0500E-04	3.0500E-04	1.1770E-03	µW/(cm²nm)
Ed0313	8	313	2.5014E-10	2.5515E-05	7.4543E-03	2.6611E+00	6.3000E-05	6.5000E-05	7.6700E-04	µW/(cm²nm)
Ed0305	10	305	1.6730E-11	1.7064E-06	4.9855E-04	1.5423E-01	3.5000E-04	3.3900E-04	-2.2550E-03	µW/(cm²nm)
Ed0380	12	380	6.5920E-11	6.7239E-06	1.9644E-03	6.5511E-01	1.0890E-03	1.0750E-03	-1.4790E-03	µW/(cm²nm)
Ed0395	18	395	3.4630E-10	3.5323E-05	1.0320E-02	3.3709E+00	6.8000E-05	6.3000E-05	2.1600E-04	µW/(cm²nm)

Broadband Channels	Address	Wavelength [nm]	Responsivity [Amps per µE/(cm²-s)]	ScaleSmall [Volts per µE/(cm²-s)]	ScaleMedium [Volts per µE/(cm²-s)]	ScaleLarge [Volts per µE/(cm²-s)]	OffsetSmall [volts]	OffsetMedium [volts]	OffsetLarge [volts]	Measurement Units
Ed0PAR	13	400-700	1.8985E-05	1.9365E+00	5.6576E+02	2.0143E+05	8.5300E-04	8.4400E-04	-1.3230E-03	µE/(cm²sec)

Auxiliary Channels	Address	Wavelength	Responsivity	ScaleS	ScaleM	ScaleL	OffsetS	OffsetM	OffsetL	Measurement Units
Ed0Gnd	0	0	1	1.00	1.00	1.00	0	0	0	V
Ed0Temp	22	0	1	0.01	0.01	0.01	0	0	0	C
Ed0Vin	27	0	1	-0.25	-0.25	-0.25	0	0	0	V

PAR

Biospherical Instruments Inc.

CALIBRATION CERTIFICATE

Calibration Date	2/3/2014			
Model Number	QSR-240			
Serial Number	6356			
Operator	TPC			
Standard Lamp	V-032(3/7/12)			
Probe Excitation Voltage Range:	6	to	18	VDC(+)
Output Polarity:	Positive			

Probe Conditions at Calibration(in air):

Calibration Voltage:	6	VDC(+)
Probe Current:	1.2	mA

Probe Output Voltage:

Probe Illuminated	99.5	mV
Probe Dark	0.2	mV
Probe Net Response	99.3	mV
RG780	0.3	mV

Corrected Lamp Output:

Output In Air (same condition as calibration):

9.264E+15	quanta/cm²sec
0.01538	uE/cm^{2}sec

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

Dry:	1.0720E-17	V/(quanta/cm²sec)
	6.4555E+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

Micro-TSG (Primary)

Sea-Bird Electronics, Inc.
13431 NE 20th Street, Bellevue, WA 98005-2010 USA
Phone: (+1) 425-643-9866 Fax (+1) 425-643-9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 0199
CALIBRATION DATE: 02-Nov-13

SBE 45 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

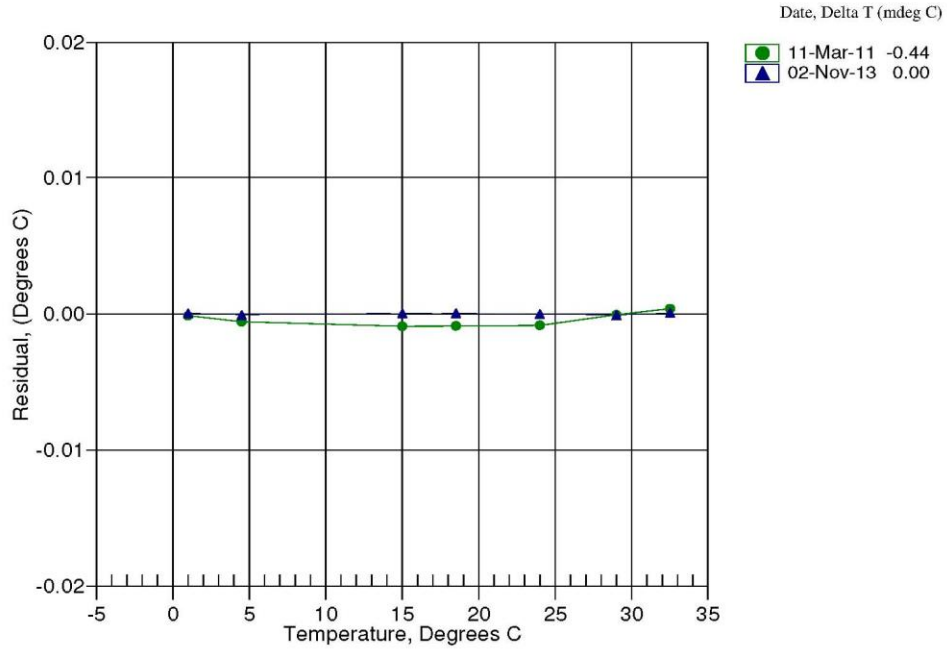
ITS-90 COEFFICIENTS

a0 = 1.853068e-005
a1 = 2.716266e-004
a2 = -2.093146e-006
a3 = 1.483856e-007

BATH TEMP (ITS-90)	INSTRUMENT OUTPUT	INST TEMP (ITS-90)	RESIDUAL (ITS-90)
1.0000	678395.6	1.0000	0.0000
4.5000	580509.7	4.4999	-0.0001
15.0000	370800.2	15.0001	0.0001
18.5000	321296.5	18.5000	0.0000
24.0000	258018.8	24.0000	-0.0000
29.0000	212643.2	28.9999	-0.0001
32.5000	186322.1	32.5001	0.0001

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

Residual = instrument temperature - bath temperature



Sea-Bird Electronics, Inc.
13431 NE 20th Street, Bellevue, WA 98005-2010 USA
Phone: (+1) 425-643-9866 Fax (+1) 425-643-9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 0199
CALIBRATION DATE: 02-Nov-13

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

COEFFICIENTS:

g = -1.002257e+000	CPcor = -9.5700e-008
h = 1.426088e-001	CTcor = 3.2500e-006
i = -1.618469e-004	WBOTC = -1.0552e-005
j = 3.383846e-005	

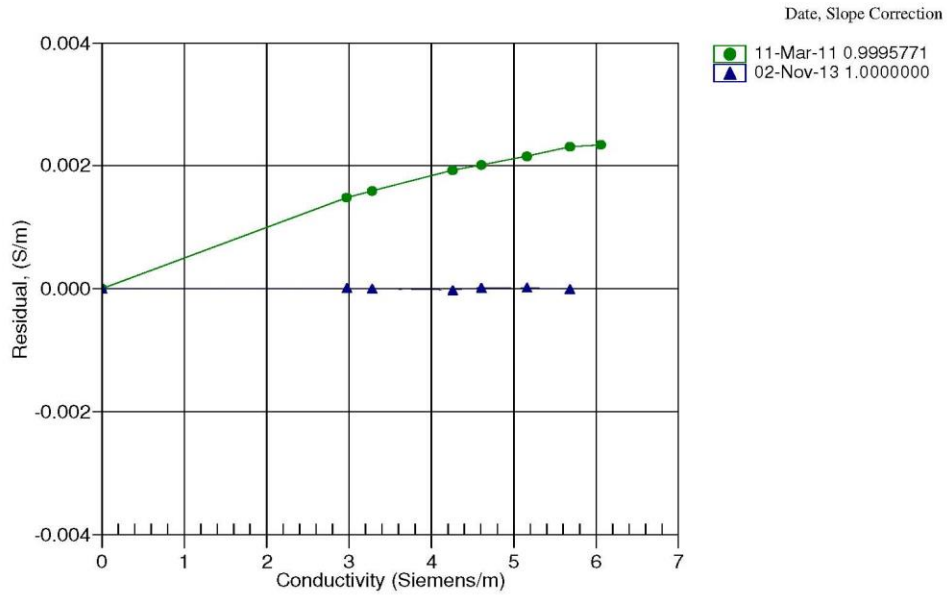
BATH TEMP (ITS-90)	BATH SAL (PSU)	BATH COND (Siemens/m)	INST FREO (Hz)	INST COND (Siemens/m)	RESIDUAL (Siemens/m)
22.0000	0.0000	0.00000	2653.13	0.00000	0.00000
1.0000	34.7663	2.97210	5277.51	2.97211	0.00001
4.5000	34.7462	3.27876	5476.68	3.27876	-0.00000
15.0000	34.7026	4.25914	6069.01	4.25911	-0.00003
18.5000	34.6921	4.60367	6263.64	4.60368	0.00001
24.0000	34.6804	5.16064	6565.79	5.16066	0.00002
29.0000	34.6720	5.68134	6835.87	5.68133	-0.00001

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

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

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

Residual = instrument conductivity - bath conductivity



Micro-TSG (Secondary)

Sea-Bird Electronics, Inc.
13431 NE 20th Street, Bellevue, WA 98005-2010 USA
Phone: (+1) 425-643-9866 Fax (+1) 425-643-9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 0226
CALIBRATION DATE: 13-Jun-13

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

COEFFICIENTS:

```
g = -1.020162e+000
h =  1.581071e-001
i = -6.516728e-004
j =  7.473666e-005

CPcor = -9.5700e-008
CTcor =  3.2500e-006
WBOTC =  9.8072e-007
```

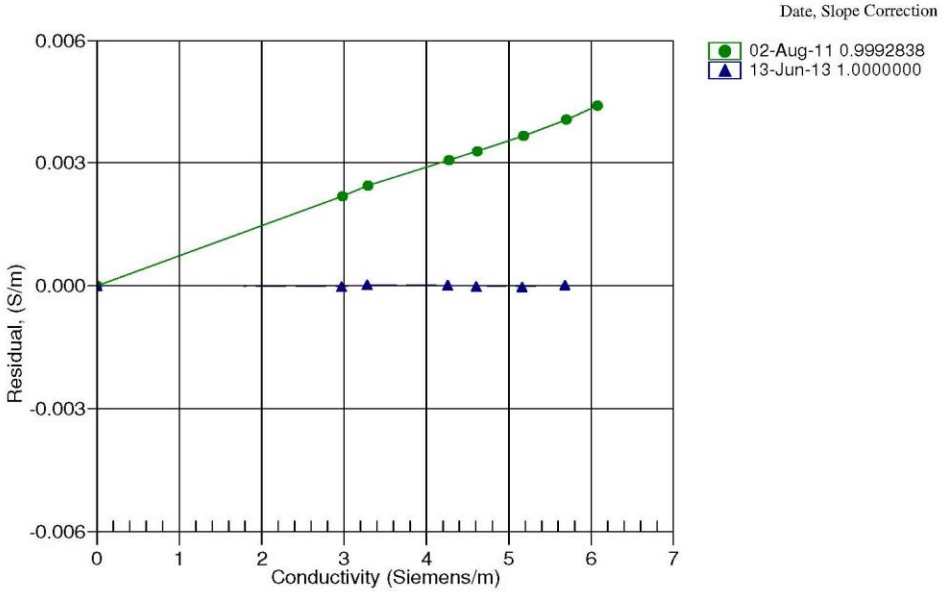
BATH TEMP (ITS-90)	BATH SAL (PSU)	BATH COND (Siemens/m)	INST FREQ (Hz)	INST COND (Siemens/m)	RESIDUAL (Siemens/m)
22.0000	0.0000	0.00000	2549.62	0.00000	0.00000
0.9999	34.7532	2.97108	5046.48	2.97105	-0.00002
4.5000	34.7326	3.27760	5236.35	3.27763	0.00002
15.0000	34.6894	4.25769	5801.01	4.25771	0.00002
18.5000	34.6799	4.60222	5986.56	4.60222	-0.00001
24.0000	34.6695	5.15920	6274.58	5.15917	-0.00003
29.0000	34.6640	5.68017	6532.15	5.68019	0.00002

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

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

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

Residual = instrument conductivity - bath conductivity



Sea-Bird Electronics, Inc.
13431 NE 20th Street, Bellevue, WA 98005-2010 USA
Phone: (+1) 425-643-9866 Fax (+1) 425-643-9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 0226
CALIBRATION DATE: 13-Jun-13

SBE 45 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

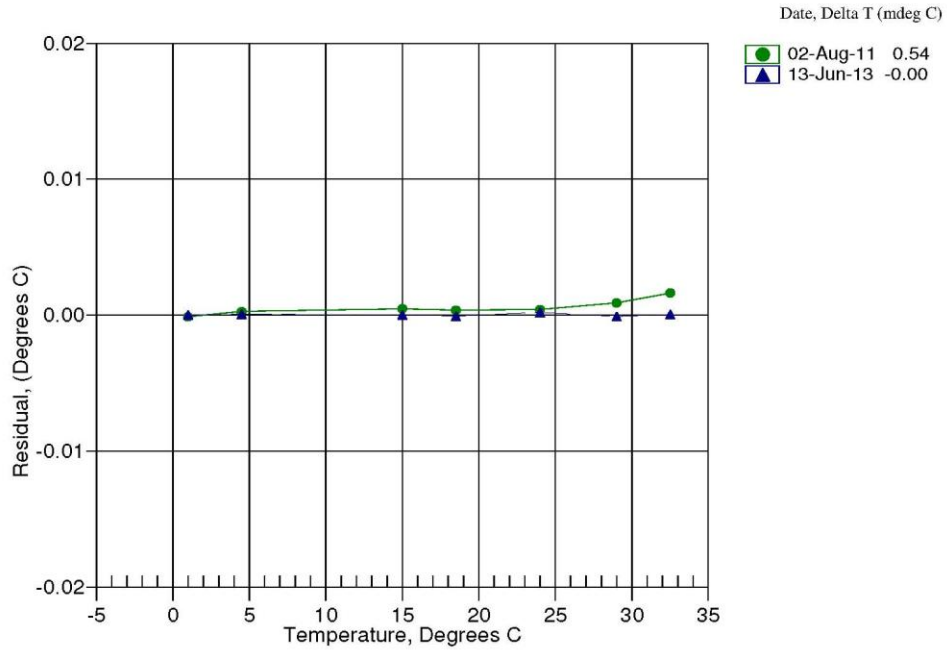
ITS-90 COEFFICIENTS

a0 = -1.290681e-004
a1 = 3.016680e-004
a2 = -4.417110e-006
a3 = 2.045426e-007

BATH TEMP (ITS-90)	INSTRUMENT OUTPUT	INST TEMP (ITS-90)	RESIDUAL (ITS-90)
0.9999	744329.7	0.9999	-0.0000
4.5000	636489.5	4.5000	0.0000
15.0000	405773.4	15.0000	-0.0000
18.5000	351390.0	18.4999	-0.0001
24.0000	281930.4	24.0002	0.0002
29.0000	232178.4	28.9999	-0.0001
32.5000	203340.8	32.5000	0.0000

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

Residual = instrument temperature - bath temperature



Digital Remote Temperature Sensor

Sea-Bird Electronics, Inc.
13431 NE 20th Street, Bellevue, WA 98005-2010 USA
Phone: (+1) 425-643-9866 Fax (+1) 425-643-9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 0389
CALIBRATION DATE: 01-Feb-13

SBE 38 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

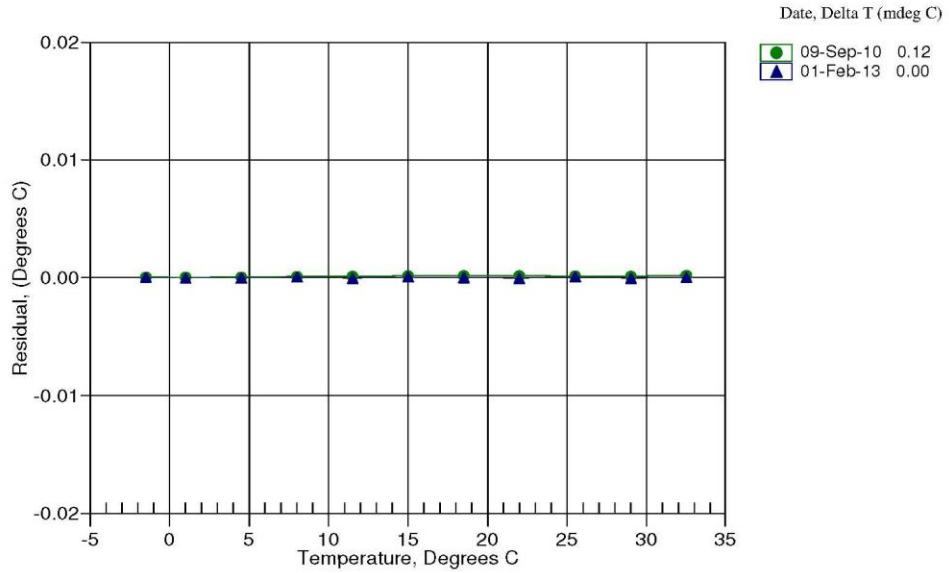
ITS-90 COEFFICIENTS

a0 = 5.817069e-005
a1 = 2.716655e-004
a2 = -2.274819e-006
a3 = 1.472026e-007

BATH TEMP (ITS-90)	INSTRUMENT OUTPUT	INST TEMP (ITS-90)	RESIDUAL (ITS-90)
-1.50000	749667.4	-1.49998	0.00002
1.00000	667858.7	0.99998	-0.00002
4.50000	569779.9	4.49997	-0.00003
7.99990	487736.0	7.99995	0.00005
11.50000	418865.9	11.49995	-0.00005
14.99990	360858.9	14.99996	0.00006
18.49970	311844.4	18.49969	-0.00001
22.00000	270286.5	21.99995	-0.00005
25.49990	234949.3	25.49996	0.00006
29.00000	204808.5	28.99995	-0.00005
32.49990	179024.2	32.49992	0.00002

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

Residual = instrument temperature - bath temperature



Fluorometer

PO Box 518
620 Applegate St.
Philomath, OR 97370

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

WET Labs

ECO Chlorophyll Fluorometer Characterization Sheet

Date: 3/26/2014 S/N: FLRTD-855

Chlorophyll concentration expressed in µg/l can be derived using the equation:

CHL (µg/l) = Scale Factor * (Output - Dark Counts)

	Analog Range 1	Analog Range 2	Analog Range 4 (default)		Digital	
Dark Counts	0.116	0.073	0.050	V	71	counts
Scale Factor (SF)	6	13	26	µg/l/V	0.0078	µg/l/count
Maximum Output	4.97	4.97	4.97	V	16326	counts
Resolution	0.8	0.8	0.8	mV	1.0	counts

Ambient temperature during characterization 22.3 °C

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

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

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

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

Resolution: Standard deviation of 1 minute of collected data.

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

FLRTD-855 Revision J 3/17/08

Transmissometer

PO Box 518
620 Applegate St.
Philomath, OR 97370

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

WET Labs

C-Star Calibration

Date August 28, 2013 S/N# CST-557DR Pathlength 25cm

	Analog output	Digital output
V_d	0.009 V	0 counts
V_{air}	4.760 V	15596 counts
V_{ref}	4.700 V	15399 counts

Temperature of calibration water	21.2 °C
Ambient temperature during calibration	21.8 °C

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

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

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

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

Revision L 6/9/09

CTD

Pressure Sensor

SEA-BIRD ELECTRONICS, INC.
13431 NE 20th St, Bellevue Washington 98005 USA
Phone: (425) 643-9866 Fax: (425) 643-9954 Email: seabird@seabird.com

Digiquartz Pressure Calibration dP/dT Corrected Coefficients
(Changed coefficients are posted in italics)

Pressure Transducer Serial Number: 130016
Original Calibration Date: 2013-12-23
Date of Correction: 2014-06-09
Installed in: SBE 9Plus S/N 1190

PRESSURE COEFFICIENTS

C1	***-40856.42***	***psia***
C2	***-6.8584644e-01***	***psia/deg C***
C3	1.2613e-02	psia/deg C^2
D1	0.035242	
D2	0.0	
T1	***30.1865***	***µsec***
T2	***-5.300152e-04***	***µsec/deg C***
T3	4.0491e-06	µsec/deg C^2
T4	3.10496e-09	µsec/deg C^3
T5	0e+00	

AD590M = 0.0128082
AD590B = -8.80033622
Slope = 1.0
Offset = 0.0

Corrected at Sea-Bird Electronics as per Paroscientific Calibration and Sea-Bird Electronics dP/dT tests. The original calibration from Paroscientific assumes an operating temperature range of 0 to 125 degrees C. dP/dT correction adjusts this operating range to a nominal range of 0 to 22 degrees C. This increases the accuracy of the transducer in this temperature range.

NOTE: Original coefficients from Paroscientific are attached to this form for informational purposes and should not be used.

CALIBRATION COEFFICIENTS SERIAL NO : **130016**

PRESSURE TRANSDUCER DATE : **12-20-2013**

MODEL :	PRESSURE RANGE :	TEMP. RANGE :	PORT :
410K-134	0 to 10000 psia	0 to 125 deg C	

TEMPERATURE COEFFICIENTS

X = temperature period (μsec)

$U = X - U_0$

Temperature : (deg C)

$Temp = Y_1U + Y_2U^2 + Y_3U^3$

U_0	5.826575	μsec
Y_1	-3904.181	deg C/μsec
Y_2	-9965.538	deg C/μsec^2
Y_3	0	

PRESSURE COEFFICIENTS

T = pressure period (μsec)

$C = C_1 + C_2U + C_3U^2$

$D = D_1 + D_2U$

$T_0 = T_1 + T_2U + T_3U^2 + T_4U^3 + T_5U^4$

Pressure : (psia)

$$P = C\left(1 - \frac{T_0^2}{T^2}\right)\left(1 - D\left(1 - \frac{T_0^2}{T^2}\right)\right)$$

C_1	-40855.91	psia
C_2	2012.569	psia/μsec
C_3	149152.2	psia/μsec^2

D_1	0.035227
D_2	0

T_1	30.18714	μsec
T_2	2.054575	μsec/μsec
T_3	66.67620	μsec/μsec^2
T_4	161.0770	μsec/μsec^3
T_5	0	

(12-20-2013)

PAROSCIENTIFIC, INC.
4500 148th AVENUE N.E.
REDMOND, WA. 98052

CUSTOMER : SEABIRD ELECTRONICS, INC.

PAROTEST 18

SALES ORDER : 31634 PREPARED BY : RM

CALIBRATION COEFFICIENTS SERIAL NO : **130016**

PRESSURE TRANSDUCER DATE : 12-20-2013

MODEL :	PRESSURE RANGE :	TEMP. RANGE :	PORT :
410K-134	0 to 10000 psia	0 to 125 deg C	

PRESSURE COEFFICIENTS AT FIXED TEMPERATURE

(only valid at specified temperature)

T = pressure period (μsec)

Pressure equation : (psia)

$$P = C\left(1 - \frac{T_0^2}{T^2}\right)\left(1 - D\left(1 - \frac{T_0^2}{T^2}\right)\right)$$

Temperature: 21.0 C

C (psia)	-40862.45				
D	0.035227				
T_0 (μsec)	30.17789				

(12-20-2013)

PAROSCIENTIFIC, INC.
4500 148th AVENUE N.E.
REDMOND, WA. 98052

CUSTOMER : SEABIRD ELECTRONICS, INC.

PARO TEST 18

SALES ORDER : 31634 PREPARED BY : RM

Fish Sensor

Sea-Bird Electronics, Inc.
13431 NE 20th St. Bellevue, Washington 98005 USA
Website: http://www.seabird.com

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

SBE Pressure Test Certificate

Test Date: **6/2/2014** Description **SBE-9plus CTD**

SBE Sensor Information:

Model Number: **09**
Serial Number: **1190**

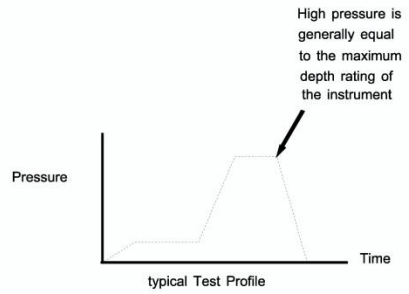
Pressure Test Protocol:

Low Pressure Test: **40** PSI Held For **15** Minutes

High Pressure Test: **10000** PSI Held For **15** Minutes

Passed Test: ☑

Tested By: nd



typical Test Profile

SYSTEM CONFIGURATION

SBE 9plus CTD Underwater Unit	**S/N 09P78915-1190**
Depth Capability	**6800 meters**
Pressure Sensor Range	**10,000 psia**
Digiquartz Pressure Sensor (w/ temp-comp)	**S/N 130016**
Modulo 12P	**S/N MOD12P-1187**
AD590M (Pressure Temperature Coefficient)	**0.012808**
AD590B (Pressure Temperature Coefficient)	**-8.800336**
A/D Input Voltage Range	**0 to 5 Volts DC**

Primary Temperature Sensor

Sea-Bird Electronics, Inc.
13431 NE 20th Street, Bellevue, WA 98005-2010 USA
Phone: (+1) 425-643-9866 Fax (+1) 425-643-9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 2438
CALIBRATION DATE: 07-Jan-14

SBE3 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

ITS-90 COEFFICIENTS

g = 4.31118159e-003
h = 6.41557351e-004
i = 2.27593316e-005
j = 2.12780590e-006
f0 = 1000.0

IPTS-68 COEFFICIENTS

a = 3.68121215e-003
b = 6.02077452e-004
c = 1.63075948e-005
d = 2.12935680e-006
f0 = 2759.436

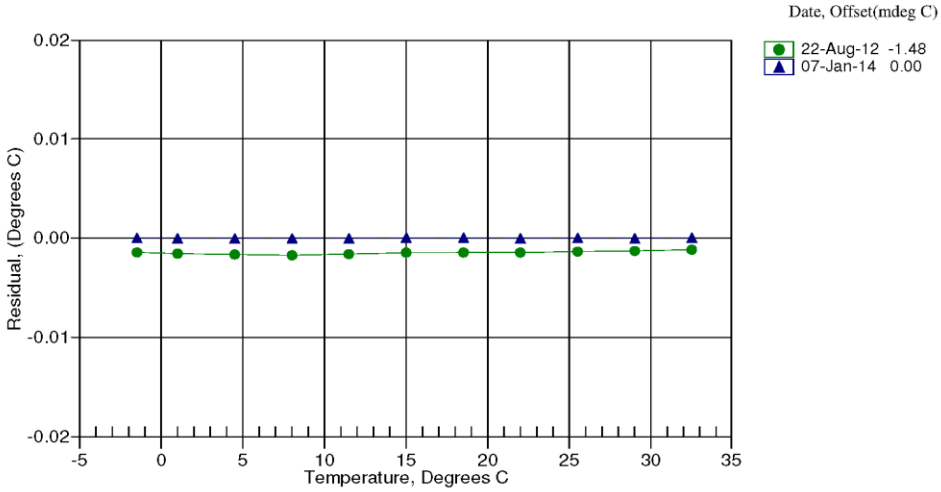
BATH TEMP (ITS-90)	INSTRUMENT FREQ (Hz)	INST TEMP (ITS-90)	RESIDUAL (ITS-90)
-1.5000	2759.436	-1.5000	0.00001
1.0000	2917.943	1.0000	-0.00001
4.5000	3150.787	4.5000	-0.00001
8.0000	3396.715	8.0000	-0.00000
11.5000	3656.079	11.5000	-0.00000
15.0000	3929.226	15.0000	0.00002
18.5000	4216.487	18.5000	0.00003
22.0000	4518.183	22.0000	-0.00001
25.5000	4834.634	25.5000	0.00000
29.0001	5166.139	29.0000	-0.00006
32.5000	5512.979	32.5000	0.00004

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

Temperature 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.
13431 NE 20th Street, Bellevue, WA 98005-2010 USA
Phone: (+1) 425-643-9866 Fax (+1) 425-643-9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 2308
CALIBRATION DATE: 09-Jul-14

SBE 3 TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

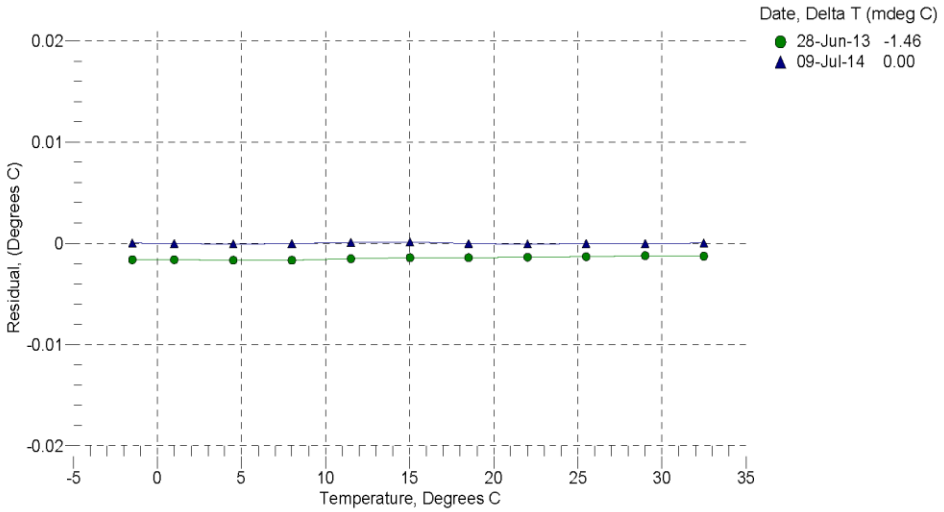
ITS-90 COEFFICIENTS:

```
g =  4.34520558e-003
h =  6.44678977e-004
i =  2.32841969e-005
j =  2.17957706e-006
f0 =  1000.0
```

BATH TEMP (ITS-90)	INSTRUMENT FREQ (Hz)	INST TEMP (ITS-90)	RESIDUAL (ITS-90)
-1.5000	2906.585	-1.5000	0.00003
1.0000	3073.399	1.0000	-0.00001
4.5000	3318.431	4.4999	-0.00006
8.0000	3577.218	8.0000	-0.00005
11.5000	3850.134	11.5001	0.00008
15.0000	4137.522	15.0001	0.00010
18.5000	4439.725	18.5000	-0.00004
22.0000	4757.103	21.9999	-0.00007
25.5000	5089.982	25.5000	-0.00000
29.0000	5438.660	29.0000	-0.00000
32.5000	5803.445	32.5000	0.00002

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

Residual = instrument temperature - bath temperature



Primary Dissolved Oxygen Sensor

Sea-Bird Electronics, Inc.
13431 NE 20th Street, Bellevue, WA 98005-2010 USA
Phone: (+1) 425-643-9866 Fax (+1) 425-643-9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 2267
CALIBRATION DATE: 15-Oct-14

SBE 43 OXYGEN CALIBRATION DATA

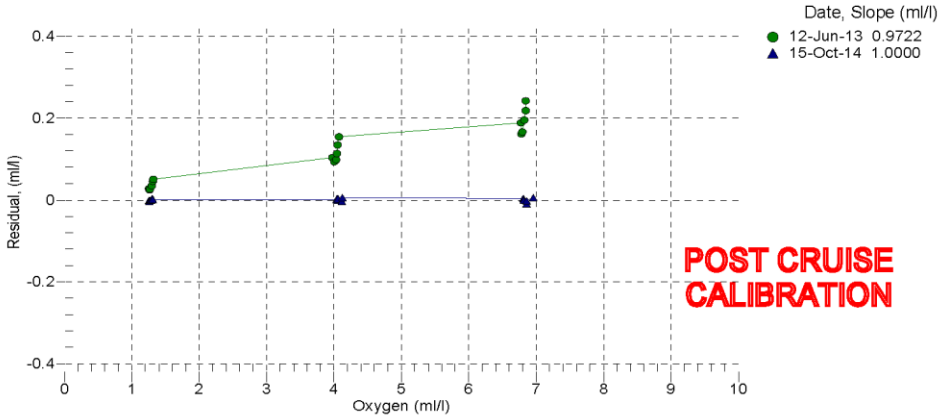
COEFFICIENTS:
Soc = 0.5022
Voffset = -0.5217
Tau20 = 1.33

A = -3.9990e-003
B = 2.2855e-004
C = -4.1463e-006
E nominal = 0.036

NOMINAL DYNAMIC COEFFICIENTS
D1 = 1.92634e-4
D2 = -4.64803e-2
H1 = -3.300000e-2
H2 = 5.00000e+3
H3 = 1.45000e+3

BATH OX (ml/l)	BATH TEMP (ITS-90)	BATH SAL (PSU)	INSTRUMENT OUTPUT (VOLTS)	INSTRUMENT OXYGEN (ml/l)	RESIDUAL (ml/l)
1.26	2.00	0.00	0.782	1.26	-0.00
1.26	6.00	0.00	0.815	1.26	-0.00
1.27	12.00	0.00	0.865	1.27	-0.00
1.29	20.00	0.00	0.934	1.29	-0.00
1.31	26.00	0.00	0.992	1.31	0.00
1.31	30.00	0.00	1.028	1.31	0.00
4.04	12.00	0.00	1.612	4.04	0.00
4.04	2.00	0.00	1.361	4.05	0.00
4.05	6.00	0.00	1.463	4.05	-0.00
4.06	20.00	0.00	1.823	4.07	0.00
4.11	30.00	0.00	2.111	4.11	-0.00
4.12	26.00	0.00	2.002	4.13	0.01
6.81	12.00	0.00	2.362	6.82	0.00
6.82	6.00	0.00	2.107	6.82	0.00
6.82	30.00	0.00	3.156	6.81	-0.00
6.86	20.00	0.00	2.712	6.85	-0.01
6.86	2.00	0.00	1.943	6.86	-0.00
6.96	26.00	0.00	3.019	6.96	0.01

Oxygen (ml/l) = Soc * (V + Voffset) * (1.0 + A * T + B * T^2 + C * T^3) * OxSol(T,S) * exp(E * P / K)
V = voltage output from SBE43, T = temperature [deg C], S = salinity [PSU], K = temperature [deg K]
OxSol(T,S) = oxygen saturation [ml/l], P = pressure [dbar]
Residual = instrument oxygen - bath oxygen



Secondary Dissolved Oxygen Sensor

Sea-Bird Electronics, Inc.
13431 NE 20th Street, Bellevue, WA 98005-2010 USA
Phone: (+1) 425-643-9866 Fax (+1) 425-643-9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 0080
CALIBRATION DATE: 08-Jul-14

SBE 43 OXYGEN CALIBRATION DATA

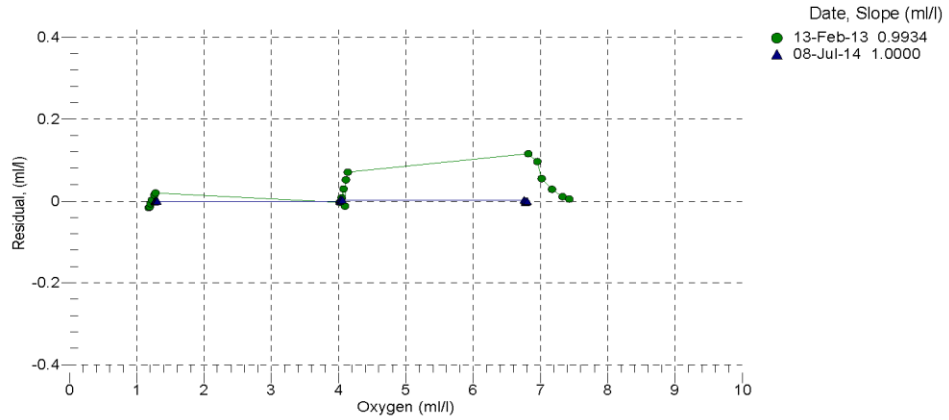
COEFFICIENTS:
Soc = 0.4896
Voffset = -0.5087
Tau20 = 1.28

A = -2.9415e-003
B = 1.6034e-004
C = -2.6804e-006
E nominal = 0.036

NOMINAL DYNAMIC COEFFICIENTS
D1 = 1.92634e-4
D2 = -4.64803e-2
H1 = -3.300000e-2
H2 = 5.00000e+3
H3 = 1.45000e+3

BATH OX (ml/l)	BATH TEMP (ITS-90)	BATH SAL (PSU)	INSTRUMENT OUTPUT (VOLTS)	INSTRUMENT OXYGEN (ml/l)	RESIDUAL (ml/l)
1.27	2.00	0.00	0.777	1.26	-0.00
1.27	6.00	0.00	0.810	1.27	-0.00
1.27	12.00	0.00	0.859	1.27	-0.00
1.29	20.00	0.00	0.929	1.29	0.00
1.30	26.00	0.00	0.983	1.30	0.00
1.31	30.00	0.00	1.021	1.30	-0.00
4.01	6.00	0.00	1.462	4.01	-0.00
4.02	12.00	0.00	1.615	4.02	0.00
4.02	2.00	0.00	1.361	4.02	0.00
4.03	20.00	0.00	1.825	4.03	0.00
4.04	26.00	0.00	1.987	4.05	0.00
4.06	30.00	0.00	2.102	4.06	0.00
6.75	12.00	0.00	2.370	6.76	0.00
6.77	20.00	0.00	2.716	6.77	-0.00
6.77	6.00	0.00	2.116	6.77	-0.00
6.78	2.00	0.00	1.947	6.78	0.00
6.79	26.00	0.00	2.990	6.79	-0.00
6.81	30.00	0.00	3.180	6.80	-0.00

Oxygen (ml/l) = Soc * (V + Voffset) * (1.0 + A * T + B * T^2 + C * T^3) * OxSol(T,S) * exp(E * P / K)
V = voltage output from SBE43, T = temperature [deg C], S = salinity [PSU], K = temperature [deg K]
OxSol(T,S) = oxygen saturation [ml/l], P = pressure [dbar]
Residual = instrument oxygen - bath oxygen



Transmissometer

PO Box 518
620 Applegate St.
Philomath, OR 97370

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

WET Labs

C-Star Calibration

Date September 5, 2013 S/N# CST-889DR Pathlength 25cm

	Analog output
V_d	0.060 V
V_{air}	4.726 V
V_{ref}	4.624 V

Temperature of calibration water	23.1 °C
Ambient temperature during calibration	21.2 °C

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

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

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

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

Revision M 7/26/11

Primary Conductivity Sensor

Sea-Bird Electronics, Inc.
13431 NE 20th Street, Bellevue, WA 98005-2010 USA
Phone: (+1) 425-643-9866 Fax (+1) 425-643-9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 4151
CALIBRATION DATE: 07-Mar-14

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

GHIJ COEFFICIENTS

```
g = -1.02595636e+001
h =  1.45511536e+000
i = -1.48161705e-003
j =  1.68953182e-004
CPcor = -9.5700e-008 (nominal)
CTcor =  3.2500e-006 (nominal)
```

ABCDM COEFFICIENTS

```
a =  5.32370698e-007
b =  1.45124183e+000
c = -1.02518029e+001
d = -8.59679024e-005
m =  6.1
CPcor = -9.5700e-008 (nominal)
```

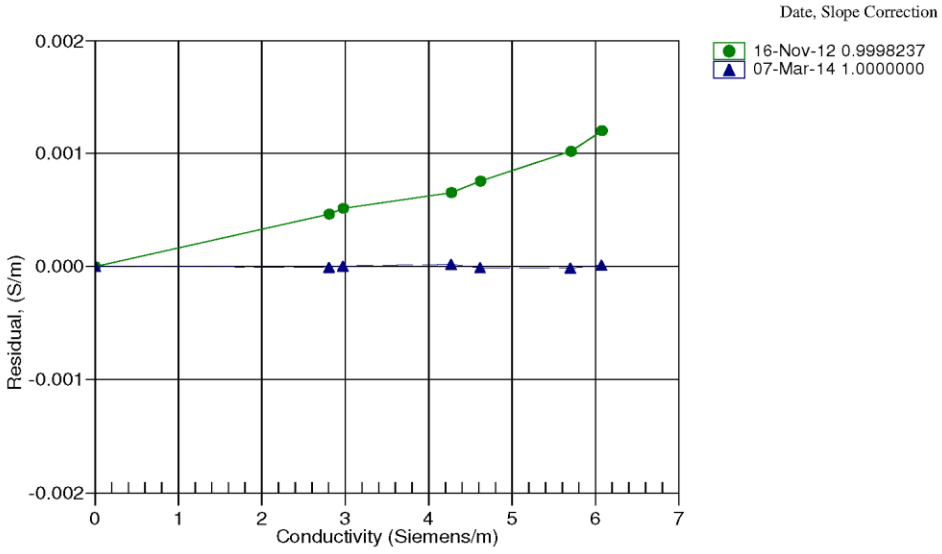
BATH TEMP (ITS-90)	BATH SAL (PSU)	BATH COND (Siemens/m)	INST FREO (kHz)	INST COND (Siemens/m)	RESIDUAL (Siemens/m)
0.0000	0.0000	0.00000	2.65782	0.00000	0.00000
-1.0000	34.7681	2.80106	5.13395	2.80105	-0.00001
1.0000	34.7687	2.97228	5.24751	2.97229	0.00000
15.0000	34.7687	4.26639	6.03672	4.26641	0.00002
18.5000	34.7685	4.61271	6.23087	4.61270	-0.00001
29.0000	34.7671	5.69517	6.80185	5.69515	-0.00002
32.5000	34.7598	6.06725	6.98726	6.06726	0.00001

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

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

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

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



Secondary Conductivity Sensor

Sea-Bird Electronics, Inc.
13431 NE 20th Street, Bellevue, WA 98005-2010 USA
Phone: (+1) 425-643-9866 Fax (+1) 425-643-9954 Email: seabird@seabird.com

SENSOR SERIAL NUMBER: 2513
CALIBRATION DATE: 09-Jul-14

SBE 4 CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Siemens/meter

COEFFICIENTS:

```
g =  -1.05879957e+001
h =   1.63361950e+000
i =  -1.77902981e-003
j =   2.47101458e-004

CPcor = -9.5700e-008 (nominal)
CTcor =  3.2500e-006 (nominal)
```

BATH TEMP (ITS-90)	BATH SAL (PSU)	BATH COND (Siemens/m)	INST FREQ (kHz)	INST COND (Siemens/m)	RESIDUAL (Siemens/m)
0.0000	0.0000	0.00000	2.54813	0.00000	0.00000
-1.0000	34.7531	2.79996	4.86430	2.79994	-0.00002
0.9999	34.7536	2.97111	4.97093	2.97113	0.00002
15.0000	34.7542	4.26480	5.71234	4.26477	-0.00003
18.5000	34.7537	4.61096	5.89483	4.61099	0.00003
29.0000	34.7541	5.69328	6.43165	5.69327	-0.00000
32.5000	34.7494	6.06564	6.60615	6.06564	-0.00000

f = INST FREQ / 1000.0

Conductivity = $(g + h * f^2 + i * f^3 + j * f^4) / (1 + \delta * t + \varepsilon * p)$ Siemens / meter

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

Residual = instrument conductivity - bath conductivity