SBE 16plusV2 SEACAT, RS-232

Conductivity and Temperature Recorder (Pressure Optional)
with RS-232 Interface

Serial Number: 16P57353-6479

User Manual, Version 002

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SBE 16plus CTD OPERATING AND REPAIR MANUAL

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Manual Generation Date: 08 January 2010

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Addendum

Revised 06 Nov 2008

Custom SBE 16*plus* V2 (RS-232) SEACAT with Interface for MBARI PUCK Specification Version 1.3

This Addendum describes a Custom SBE 16*plus* V2 (RS-232) SEACAT that is compatible with MBARI PUCK Specification Version 1.3. See the PUCK Version 1.3 documentation for details. All features not described in this addendum are as described in the 16*plus* V2 manual. Use this addendum in conjunction with 16*plus* V2 (RS-232) manual **version 002**.

Enable PUCK Command

PuckMode=x **x=Y**: Enable PUCK interface. **x=N**: Disable PUCK interface.
Note: Entries made with commands are permanently stored in the 16*plus* V2 and remain in effect until you change them.

Status Command Response

The SEACAT's status command (**DS**) displays the instrument's operating status and setup parameters. PUCK status (in bold italics in the example below) is listed after echo character status. See the SBE 16*plus* V2 manual for details on all the information in the status command response.

Example:
S>DS

```
SBE 16plus-PUCK V Puck V 2.0 SERIAL NO. 6001 24 Oct 2008 07:11:48
vbatt = 10.3, vlith = 8.5, ioper = 62.5 ma, ipump = 21.6 ma,
iext01 = 76.2 ma
status = not logging
samples = 0, free = 3463060
sample interval = 15 seconds, number of measurements per sample = 1
pump = run pump during sample, delay before sampling = 2.0 seconds
transmit real-time = yes
battery cutoff = 7.5 volts
pressure sensor = strain gauge, range = 1000.0
SBE 38 = no, SBE 50 = no, Gas Tension Device = no
Ext Volt 0 = yes, Ext Volt 1 = yes
Ext Volt 2 = no, Ext Volt 3 = no
Ext Volt 4 = no, Ext Volt 5 = no
echo characters = yes
Puck mode enabled
Puck UUID is set
output format = converted decimal
output salinity = no, output sound velocity = no
serial sync mode disabled
```

Note: The Sea-Bird version for this custom firmware is **Puck V 2.0**.

Note
The UUID (**U**niversal **U**nique **ID**entifier) is set at Sea-Bird. If the SEACAT is in PUCK mode and the UUID has not been set, the **DS** response displays *PUCK UUID not set* below the *PUCK mode enabled* line. If you see this, contact Sea-Bird for details on setting the UUID.

Memory Limitation

A standard SEACAT has 64 Mbytes of non-volatile FLASH memory for recording data. This custom SEACAT uses 304 Kbytes of FLASH for PUCK information, leaving 63,696 Kbytes for recording data. This results in a small reduction in the number of samples that can be recorded, as shown for two instrument configurations below (see *Specifications* and *Data Storage* in *Section 2: Description of SBE 16plus V2* in the manual for examples of how to do this calculation):

Recorded Parameters	Standard SEACAT Memory Space (number of samples)	Custom SEACAT with PUCK Interface Memory Space (number of samples)
C, T, Strain Gauge P, date and time	4,266,000	4,246,000
C, T, Quartz P, 6 external voltages, SBE 38 sensor, and date and time	2,133,000	2,123,000

WARNING !!

Do not submerge this instrument (S/N 16P57353-6479)
beyond the depth rating of the lowest rated component listed below!

Main Housing (Plastic)	600 meters
Pressure Sensor (110 dBar) Druck	**100 meters**
Pump (SBE 5M)	600 meters

SYSTEM CONFIGURATION 12 January 2010

Model SBE 16plusV2	**S/N 16P57353-6479**
Instrument Type	**SBE 16plusV2 SeaCaT**
Firmware Version	**V2.0 - PUCK Interface Protocol**
Communications	**9600 baud, 8 data bits, no parity, one stop bit**
Memory	**64MB**
Housing	**600 meter (Acetron plastic)**
0 Conductivity Raw Frequency	**2681.452 Hz**
Operating Mode	**Moored**
Pressure Sensor	**Strain Gauge: 110db, S/N 2926641**
Computer communications (Data I/O) connector	**located on the P/N 17797 Y-Cable**
Number of Voltages Sampled:	**0**
Serial RS-232C Sensor	**None**

Data Format:

Count	**Temperature**
Frequency	**Conductivity**
Count	**Pressure, Strain Gauge**

Pump (SBE 5M)	**051257**

IMPORTANT SOFTWARE & HARDWARE CONFIGURATION INFORMATION

Sea-Bird supplies two versions of our software package for communication, real-time data acquisition, and data analysis and display:

- SEASOFT-Win32 - Windows software for PC running Win 95/98/NT/2000/XP
- SEASOFT-DOS - DOS software for IBM-PC/AT/386/486 or compatible computer with a hard drive

Detailed information on the use of the **Windows** software follows:

SEASOFT-Win32

SEASOFT-Win32 software was supplied on a CD-ROM with your CTD. This software package is designed to run on a PC running Win 95/98/NT/2000/XP. The CD-ROM also contains software manuals that describe the appropriate applications for the various programs, the procedure for installing the software, and instructions on using the programs. There are three primary programs used with the CTD for setup, data collection and retrieval, data display, and data processing:

- SEATERM - terminal program for setup of the CTD and uploading of data from the CTD memory (**Note**: If using the CTD with the 90208 Auto Fire Module or SBE 17*plus* V2 SEARAM, use SeatermAF instead of SEATERM)
- SEASAVE - real-time data acquisition program
- SBE Data Processing - data processing program

Instructions for using the software are found in their Help files.

To communicate with the CTD to set it up or to upload data from the CTD memory to the computer hard drive, **SEATERM** must have information about the CTD hardware configuration (communication parameters, internal firmware, etc.) and about the computer. To communicate with the CTD, double click on Seaterm.exe:

1. In the Configure menu, select the CTD. The Configuration Options dialog box appears.
   A. On the COM Settings tab, select the firmware version (if applicable), baud rate, data bits, and parity to match the CTD's configuration sheet. If necessary, change the com port to match the computer you are using.
   B. On the Upload Settings tab, enter upload type (all as a single file, etc.) as desired.
   For the SBE 17 and 25 only: enter the serial number for the SBE 3 (temperature) and SBE 4 (conductivity) modular sensors, exactly as they appear in the configuration (.con) file.
   C. On the Header Information tab, change the settings as desired.

   Click OK when done. SEATERM saves the settings in a SEATERM.ini file.
2. On the Toolbar, click Connect to communicate with the CTD.
3. To set up the CTD prior to deployment:
   On the Toolbar, click Status. SEATERM sends the Status command and displays the response. Verify that the CTD setup matches your desired deployment. If not, send commands to modify the setup.
4. To upload data from the CTD:
   On the Toolbar, click Upload to upload data from the CTD memory to the computer.

Sea-Bird CTDs store and/or transmit data from their primary and auxiliary sensors in the form of binary or hexadecimal number equivalents of the sensors' frequency or voltage outputs. This is referred to as the *raw* data. The calculations required to convert from *raw* data to *engineering* units of the measured parameters (temperature, conductivity, pressure, dissolved oxygen, pH, etc.) are performed using the software, either in real time, or after the data has been stored in a file. SEASAVE creates the file in real time. As noted above, SEATERM uploads the recorded data and creates the file on the computer hard drive.

To successfully store data to a file on the computer and subsequently convert it to engineering units, the software must know the CTD type, CTD configuration, and calibration coefficients for the sensors installed on the CTD. This information is unique to each CTD, and is contained in a *configuration* file. The configuration file, which has a .con extension, was written onto a floppy disk and the CD-ROM shipped with the CTD. The .con file for a given CTD is named with the last four digits of the serial number for that CTD (e.g., 1234.con). The configuration file is created or modified (e.g., changing coefficients after recalibration, or adding another sensor) by using the Configure menu in **SEASAVE** or
SBE Data Processing. The configuration file is used by SEASAVE to convert raw data to engineering units when it acquires, stores, and displays real-time data. The configuration file is also used by some modules in SBE Data Processing (Data Conversion and Derive) that convert raw data to engineering units during data processing.

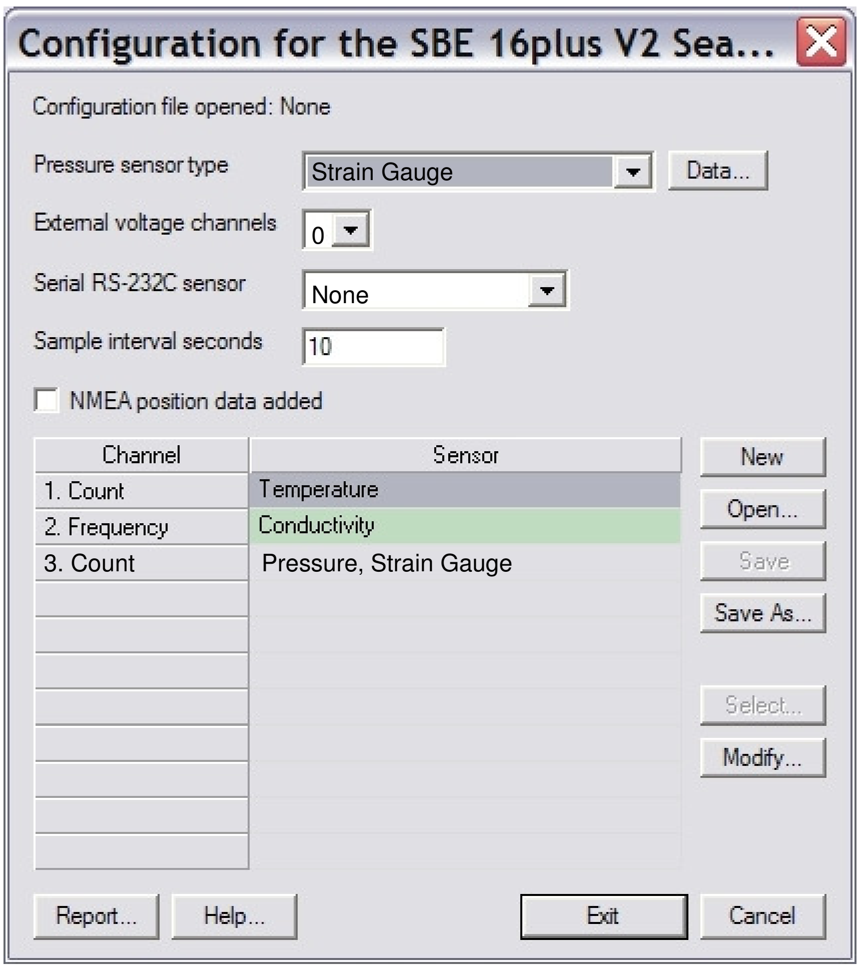
The instrument type and instrument configuration settings of the .con file and the required setup for the SEATERM.ini file for the CTD *as delivered* are documented below. The calibration coefficients for the CTD's sensors are contained in the calibration coefficient section of the CTD manual.

NOTE:

SEATERM will not upload data correctly without a properly configured SEATERM.ini file. SEASAVE and SBE Data Processing will not interpret the data correctly without the correct .con file.

SEASOFT CONFIGURATION:

The correct instrument type for your instrument is SBE 16plus V2 SEACAT Profiler. The correct settings for the configuration of your instrument as delivered are documented below:



SBE 16*plus* V2 SEACAT

Conductivity and Temperature Recorder (pressure optional)
with RS-232 Interface

User's Manual

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Manual Version #002, 02/25/08
Firmware Version 2.0b and later
SEASAVE V7 Version 7.16 and later
SBE Data Processing Version 7.16 and later

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Table of Contents

Section 1: Introduction

This section includes contact information, Quick Start procedure, and photos of a standard SBE 16*plus* V2 shipment.

About this Manual

This manual is to be used with the SBE 16*plus* V2 SEACAT Conductivity and Temperature (pressure optional) Recorder.

It is organized to guide the user from installation through operation and data collection. We have included detailed specifications, command descriptions, maintenance and calibration information, and helpful notes throughout the manual.

Sea-Bird welcomes suggestions for new features and enhancements of our products and/or documentation. Please e-mail any comments or suggestions to seabird@seabird.com.

How to Contact Sea-Bird

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Business hours:
Monday-Friday, 0800 to 1700 Pacific Standard Time
(1600 to 0100 Universal Time)
Except from April to October, when we are on *summer time*
(1500 to 0000 Universal Time)

Quick Start

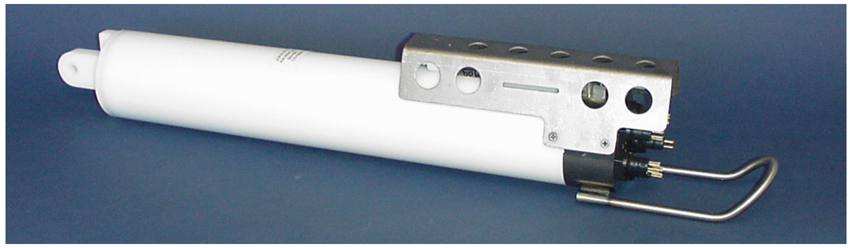
Follow these steps to get a Quick Start using the SBE 16*plus* V2. The manual provides step-by-step details for performing each task:

1. Install batteries and test power and communications (see *Section 3: Power and Communications Test*).

2. Deploy the 16*plus* V2 (see *Section 4: Deploying and Operating SBE 16plus V2*):
   A. Install new batteries if necessary.
   B. Ensure all data has been uploaded, and then send **InitLogging** to make entire memory available for recording if desired.
   C. Set date and time and establish setup and logging parameters.
   D. Set 16*plus* V2 to start logging now or in the future.
   E. Install dummy plugs and/or cable connectors, and locking sleeves.
   F. Remove protective plugs from anti-foulant device cups, and verify AF24173 Anti-Foulant Devices are installed. Leave protective plugs off for deployment.
   G. Deploy 16*plus* V2, using customer-supplied hardware.

Unpacking SBE 16*plus* V2

Shown below is a typical SBE 16*plus* V2 shipment.



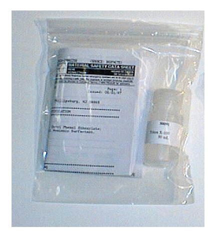
SBE 16*plus* V2 SEACAT
(shown in plastic housing)

I/O Cable

25-pin to 9-pin adapter
(for use with computer
with DB-25 connector)

Spare o-ring and
hardware kit

Conductivity cell filling
and storage kit



Conductivity cell cleaning
solution (Triton-X)

SBE 16*plus* V2
manual

Software, and Electronic Copies of
Software Manuals and User Manual

Section 2: Description of SBE 16*plus* V2

This section describes the functions and features of the SBE 16*plus* V2 SEACAT, including:

- system description
- specifications
- dimensions and end cap connectors
- communication settings
- data storage
- batteries and battery endurance
- external power and cable length limitations
- configuration options and plumbing

System Description

The SBE 16*plus* V2 SEACAT is designed to measure conductivity, temperature, and (optional) pressure in marine or fresh-water environments in moored applications at depths up to 10,500 meters (34,400 feet). The 16*plus* V2 operates as follows:

- **Autonomous sampling** - The 16*plus* V2 can acquire and record in memory time series measurements at sample rates of once every 10 seconds to once every 4 hours, adjustable in one-second increments. Between samples, the 16*plus* V2 powers down, drawing only 20 microamps of current. Simultaneous, real-time data transmission is possible using the 16*plus* V2 three-wire RS-232C interface.
- **Polled sampling** – A surface controller can request the last sample that was taken or ask the 16*plus* V2 to take a new sample. Data is transmitted over the RS-232 interface.
- **Serial line sync** – The 16*plus* V2 wakes up, samples, stores data in memory, transmits real-time data (if enabled), and powers off in response to a pulse on the serial line. This provides an easy method for synchronizing 16*plus* V2 sampling with other instruments such as Acoustic Doppler Current Profilers (ADCPs) or current meters, without drawing on their battery or memory resources.

Self-powered and self-contained, the SBE 16*plus* V2 features the proven Sea-Bird conductivity and temperature sensors. Nine D-size alkaline batteries provide power for approximately 355,000 samples (with no internally mounted pressure sensor, pump, or auxiliary sensors). The 64 Mbyte FLASH RAM memory records 2 years of conductivity, temperature, and date/time data while sampling every 10 seconds (other configurations/setups vary). User-selectable output format is raw data or engineering units, in hexadecimal or decimal form; XML output is also available. Setup, diagnostics, and data extraction are performed without opening the housing. The 16*plus* V2 can power external sensors and acquire their outputs.

A standard SBE 16*plus* V2 is supplied with:

- Plastic housing for depths to 600 meters (1950 feet)
- Bulkhead connectors (Impulse glass-reinforced epoxy):
  - one 6-pin connector for data I/O, external power, and pump power;
  - three 6-pin connectors, for two differential auxiliary A/D inputs each;
  - one 4-pin connector, for RS-232 auxiliary sensor (SBE 38 secondary temperature sensor, SBE 50 pressure sensor, or up to two Pro-Oceanus Gas Tension Devices)
- 64 Mbyte FLASH RAM memory
- 9 D-size alkaline batteries (Duracell MN1300, LR20)
- Anti-foulant device attachments and expendable AF24173 Anti-Foulant Devices. These are attached to each end of the conductivity cell, so that any water that enters the cell is treated.

SBE 16*plus* V2 options include:

- Titanium housing for use to 7000 or 10500 meters (22,900 or 34,440 feet)
- Internally mounted pressure sensor -
  - Strain gauge pressure sensor, or
  - Quartz pressure sensor
- Pump -
  - SBE 5M (available in plastic or titanium housing) for pumped conductivity, or
  - SBE 5P (plastic housing) or 5T (titanium housing) for pumped conductivity **and** pumped auxiliary sensors
- Sensors for dissolved oxygen, fluorescence, light (PAR), light transmission, turbidity, and gas tension
- Wet-pluggable (MCBH) connectors in place of standard connectors
- RS-485 interface in place of RS-232. See the *SBE 16plus V2 SEACAT (RS-485) Manual*.
- **I**nductive **M**odem (IM) interface in place of RS-232 - The inductive modem uses a mooring cable as the communication link, permitting the SBE 16*plus*-IM V2 to be easily positioned at any depth without the use of cable connectors. Each inductive modem instrument has a programmable address, allowing up to 100 SBE 16*plus*-IM V2 SEACATs (or other sensors compatible with the Sea-Bird inductive modem) to be attached to a single mooring cable. See the *SBE 16plus-IM V2 SEACAT Manual*.
- Battery pack kit for lithium batteries for longer deployments (lithium batteries **not** supplied by Sea-Bird).

Future upgrades and enhancements to the SBE 16*plus* V2 firmware can be easily installed in the field through a computer serial port and the *Data I/O, Pump, and External Power* bulkhead connector on the 16*plus* V2, without the need to return the 16*plus* V2 to Sea-Bird.

Notes:

- Help files and separate software manuals provide detailed information on the use of SEASAVE V7 and SBE Data Processing.
- Sea-Bird also supplies an older version of SEASAVE, SEASAVE-Win32. However, all SEASAVE instructions in this manual are written for SEASAVE V7. See SEASAVE-Win32's manual and/or Help files if you prefer to use the older software.

The SBE 16*plus* V2 is supplied with a powerful Win 2000/XP software package, SEASOFT-Win32, which includes:

- **SEASAVE V7** – program for acquiring, converting, and displaying real-time or archived raw data.
- **SBE Data Processing** – program for calculation and plotting of conductivity, temperature, pressure, auxiliary sensor data, and derived variables such as salinity and sound velocity.

The SBE 16*plus* V2 is also supplied with a **terminal program**, **SCPlusV2_RS232.exe**, for easy communication and data retrieval. The use of the terminal program is described in this manual, and in the software Help files.

Specifications

	Temperature (°C)	Conductivity (S/m)	Internally Mounted Pressure (optional)
Measurement Range	-5 to +35	0 to 9	0 to full scale range: • *Strain gauge sensor:* 20 / 100 / 350 / 600 / 1000 / 2000 / 3500 / 7000 meters • *Quartz sensor:* 20 / 60 / 130 / 200 / 270 / 680 / 1400 / 2000 / 4200 / 7000 / 10500 meters
Initial Accuracy	0.005	0.0005	• *Strain gauge sensor:* 0.1% of full scale range • *Quartz sensor:* 0.02% of full scale range
Typical Stability	0.0002/month	0.0003/month	• *Strain gauge sensor:* 0.1% of full scale range/year • *Quartz sensor:* 0.025% of full scale range/year
Resolution	0.0001	• 0.00005 (most oceanic water; resolves 0.4 ppm in salinity). • 0.00007 (high salinity water; resolves 0.4 ppm in salinity). • 0.00001 (fresh water; resolves 0.1 ppm in salinity).	• *Strain gauge sensor:* 0.002% of full scale range • *Quartz sensor:* 0.0006% of full scale range for 1-second integration; depends on sample integration time (see notes below)
Sensor Calibration (measurement outside these ranges may be at slightly reduced accuracy due to extrapolation errors)	+1 to +32	0 to 9; physical calibration over range 2.6 to 6 S/m, plus zero conductivity (air)	Ambient pressure to full scale range in 5 steps

***Notes on Internally Mounted Quartz Pressure Sensor Resolution:**
Pressure Sensor Resolution = Sensitivity * Counter Resolution

- Sensitivity = Δ pressure / Δ frequency
  where Δ pressure is change in pressure in desired units (psia, db, meters, etc.) = pressure sensor full scale range
  Δ frequency is change in frequency in Hz ≈ 3000 Hz over sensor's full scale range
- Counter Resolution = pressure sensor output frequency / (**ParosIntegration** * 1,843,200)
  where pressure sensor output frequency ≈ 35,000 Hz
  ParosIntegration = user-input integration time (seconds)
- To convert pressure units: db = psia / 1.45

Example:
What resolution can be obtained for a 7000 meter (10,000 psia) Quartz pressure sensor?

Sensitivity = Δ pressure / Δ frequency = 7000 m / 3000 Hz = 2.333 m / Hz

Counter Resolution = pressure sensor output frequency / (**ParosIntegration** * 1,843,200)
= 35,000 Hz / (**ParosIntegration** * 1,843,200)

Resolution = Sensitivity * Counter Resolution = 2.333 db/Hz * 35,000 Hz / (**ParosIntegration** * 1,843,200)
Looking at the resolution that can be obtained with a range of values for the integration time:

Integration time (ParosIntegration=)	Resolution
1 second	0.044 m (44 mm)
2.2 seconds	0.02 m (20 mm)
4.4 seconds	0.01 m (10 mm)
44 seconds	0.001 m (1 mm)

Continued on next page

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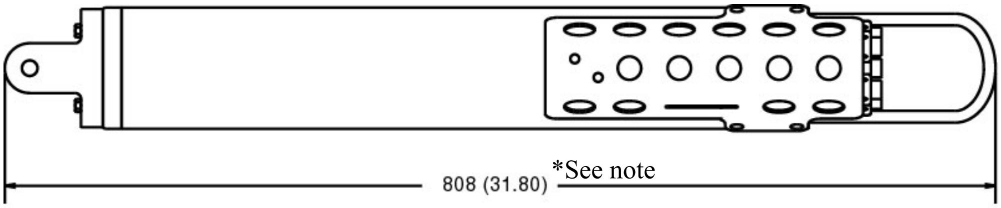
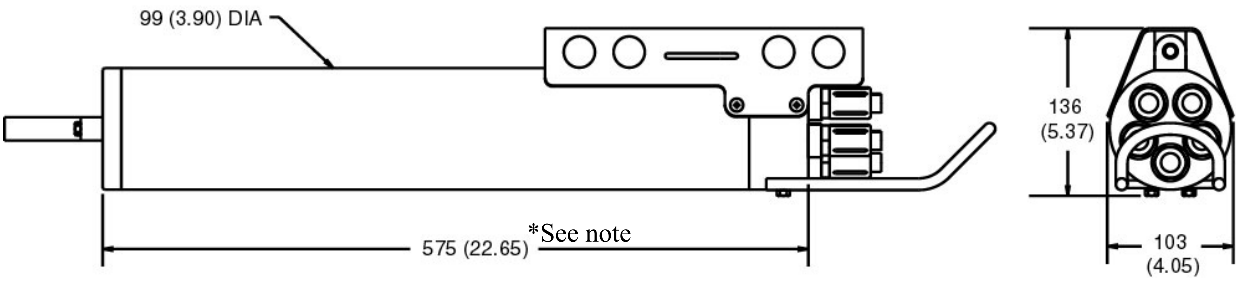
Memory	64 Mbyte non-volatile FLASH memory
Data Storage	**Recorded Parameter** — **Bytes/sample** temperature + conductivity — 6 (3 each) internally mounted strain gauge or Quartz pressure — 5 each external voltage — 2 SBE 38 secondary temperature — 3 SBE 50 pressure — 3 each Pro-Oceanus GTD — 4 (pressure) + 3 (temperature) date and time — 4
Real-Time Clock	32,768 Hz TCXO accurate to ±1 minute/year.
Internal Batteries	Nine alkaline D-cells (Duracell MN 1300, LR20; nominal capacity 14 amp-hours).
External Power Supply	9 - 28 VDC; current requirement varies, depending on voltage and pump: • 3 Amps at 9V input - no pump or SBE 5M pump (cannot use SBE 5P or 5T with 9V input) • 0.5 Amps at 12V input – no pump or SBE 5M pump • 3 Amps at 12V input – SBE 5P or 5T pump • 0.25 Amps at 19V input – no pump • 0.5 Amps at 19V input – SBE 5M pump • 1.5 Amps at 19V input – SBE 5P or 5T pump
Power Requirements	*Sampling*: no pressure sensor 55 mA with internally mounted pressure sensor 70 mA *Optional Pump:* SBE 5M 100 mA SBE 5P or 5T 150 mA *Communications:* 65 mA *Quiescent:* 20 μA Sampling time: • Minimum 2.2 seconds/sample (no pump, no internally mounted pressure sensor, 1 measurement/sample, and no delays). • Add 0.3 seconds with internally mounted strain gauge pressure sensor. • Add integration time with internally mounted Quartz pressure sensor (**ParosIntegration=**; minimum 1 second). • Add 0.25 seconds for each additional measurement/sample (**NCycles ≥ 2**). • Add pump on-time (0.5 second) if pump running before taking sample (**PumpMode=1**). • Add time for user-programmed delay before sampling (**DelayBeforeSampling=**). Approximate Battery Endurance [1]: CT: 355,000 samples CTD: 240,000 samples CTD & 5M pump: 140,000 samples [1] With Duracell MN 1300 (LR20) cells. Dependent on sampling scheme; see *Battery Endurance* for example calculations.
Auxiliary Voltage and RS-232 Sensors	*Auxiliary power out*: up to 500 mA at 10.5 - 11 VDC *Voltage sensor A/D resolution*: 14 bits *Voltage sensor input range*: 0 - 5 VDC
Housing Depth Range and Materials	600 meter (1950 ft): acetal copolymer (plastic) 7000 meter (22,900 ft): 3AL-2.5V titanium 10,500 meter (34,400 ft): 6AL-4V titanium
Weight (without pump)	With plastic housing: *in air* 7.3 kg (16 lbs) *in water* 2.3 kg (5 lbs) With 3AL-2.5V titanium housing: *in air* 13.7 kg (30 lbs) *in water* 8.6 kg (19 lbs)

Dimensions and End Cap Connectors

Dimensions in millimeters (inches)

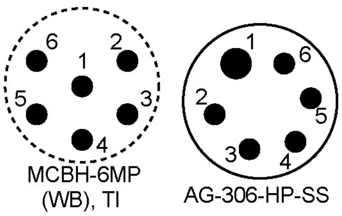


Note:
16*plus* V2 with optional *Quartz* pressure sensor is 190 mm (7.5 inches) longer than shown in drawing.



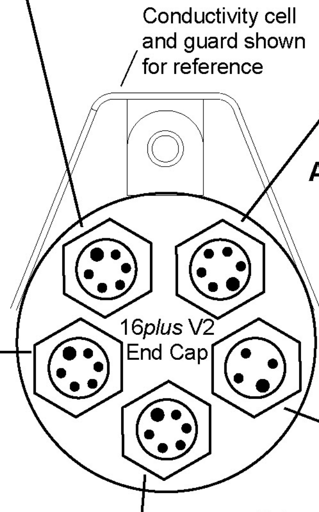
= standard connector

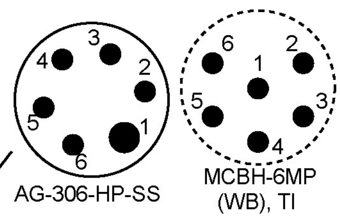
= optional MCBH connector (all with 3/8" length base, 1/2-20 thread)



Auxiliary Differential Input 2,3

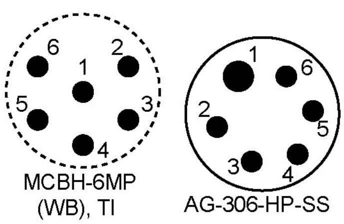
Pin	Signal
1	Common
2	Voltage 2 Signal
3	Voltage 2 Common
4	Voltage 3 Signal
5	Voltage 3 Common
6	Auxiliary Power Out





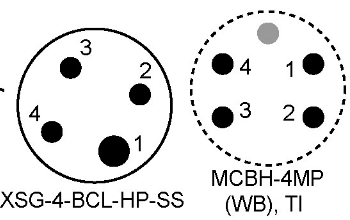
Auxiliary Differential Input 4,5

Pin	Signal
1	Common
2	Voltage 4Signal
3	Voltage 4 Common
4	Voltage 5 Signal
5	Voltage 5 Common
6	Auxiliary Power Out



Auxiliary Differential Input 0,1

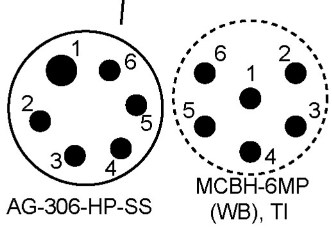
Pin	Signal
1	Common
2	Voltage 0 Signal
3	Voltage 0 Common
4	Voltage 1 Signal
5	Voltage 1 Common
6	Auxiliary Power Out



Auxiliary RS-232 Input

Pin	Signal
1	Common
2	RS-232 Data transmit to RS-232 sensor
3	RS-232 Data receive from RS-232 sensor
4	Power to RS-232 sensor

Note: RS-232 sensor must be set to same baud rate as 16*plus*.



Data I/O, Pump, and External Power

Pin	Signal
1	Common
2	RS-232 data receive
3	RS-232 data transmit
4	Pump power common
5	Pump power
6	Auxiliary power in (9-28 VDC)

Note:
A Y-cable from this connector connects to the pump and to a data I/O - power cable.

Data I/O

The SBE 16*plus* V2 receives setup instructions and outputs diagnostic information or previously recorded data via a three-wire RS-232C link, and is factory-configured for 9600 baud, 8 data bits, 1 stop bit, and no parity. SBE 16*plus* V2 RS-232 levels are directly compatible with standard serial interface cards (IBM Asynchronous Communications Adapter or equal). The communications baud rate can be changed using **BaudRate=** (see *Command Descriptions* in *Section 4: Deploying and Operating SBE 16plus V2*).

Data Storage

Note:
See *Battery Endurance* for power limitations.

The SBE 16*plus* V2 has a 64 Mbyte FLASH memory. If the memory is filled to capacity, data sampling and transmission of real-time data (if programmed) continue, but excess data is not saved in memory.

Shown below are examples of available data storage for several configurations. See *Specifications* for storage space required for each parameter.

Example 1: internally mounted strain gauge pressure and no auxiliary sensors
T & C = 6 bytes/sample
Internally mounted strain gauge P = 5 bytes/sample
Date/Time = 4 bytes/sample
Storage space ≈ 64,000,000 / (6 + 5 + 4) ≈ 4,266,000 samples

Example 2: internally mounted Quartz pressure, 6 external voltages, and SBE 38 secondary temperature sensor
T & C = 6 bytes/sample
Internally mounted Quartz P = 5 bytes/sample
External voltages = 2 bytes/sample * 6 voltages = 12 bytes/sample
SBE 38 = 3 bytes/sample
Date/Time = 4 bytes/sample
Storage space ≈ 64,000,000 / (6 + 5 + 12 + 3 + 4) ≈ 2,133,000 samples

Batteries

For the main battery, the SBE 16*plus* V2 uses nine D-cell alkaline batteries (Duracell MN 1300, LR20). If necessary, lithium, carbon-zinc, or mercury cells can also be used.

On-board lithium batteries (non-hazardous units which are unrestricted for shipping purposes) are provided to back-up the buffer and the real-time clock in the event of main battery failure or exhaustion. The main batteries may be replaced without affecting either the real-time clock or memory.

Battery Endurance

Notes:
- If the 16*plus* V2 is logging data and the battery voltage is less than 7.5 volts, the 16*plus* V2 halts logging and displays a low battery indication in the data.
- See *Data Storage* and *Specifications* for data storage limitations.

The standard alkaline battery pack has a nominal capacity of 14 amp-hours. For planning purposes, Sea-Bird recommends using a conservative value of:
- 12.2 amp-hours for a 16*plus* V2 with no pump or auxiliary sensors
- 10.5 amp-hours for a 16*plus* V2 drawing more current because of optional pump and/or auxiliary sensors

Current consumption and sampling times vary greatly, depending on the instrument configuration (inclusion of pressure sensor, pump, and/or auxiliary sensors) as well as user-programmed sampling parameters (pump operating mode, number of measurements per sample, delay before sampling, quartz pressure sensor integration time). Examples are shown below for several sampling schemes.

A 16*plus* V2 with standard alkaline batteries is set up to sample autonomously every 10 minutes (6 samples/hour). How long can it be deployed?

Example 1 – no pump, internally mounted pressure sensor, or auxiliary sensors; 1 measurement/sample (**NCycles=1**):

Sampling current = 55 mA * 2.2 sec = 0.12 amp-sec/sample
In 1 hour, sampling current = 6 * 0.12 amp-sec/sample = 0.72 amp-sec/hour

Quiescent current = 20 microamps = 0.02 mA
In 1 hour, quiescent current ≈ 0.02 mA * 3600 sec/hour = 0.072 amp-sec/hour

Current consumption / hour = 0.72 + 0.072 = 0.792 amp-sec/hour
Capacity = (12.2 amp-hours * 3600 sec/hr) / (0.792 amp-sec/hour) = 55454 hours = 2310 days = 6.3 years
However, Sea-Bird recommends that batteries should not be expected to last longer than 2 years in the field.

Example 2 - with 5M pump on for 0.5 sec/sample (**PumpMode=1**), no internally mounted pressure sensor or auxiliary sensors, 1 measurement/sample (**NCycles=1**):

Sampling current = 55 mA * (2.2 sec + 0.5 sec) = 0.148 amp-sec/sample
In 1 hour, sampling current = 6 * 0.148 amp-sec/sample = 0.89 amp-sec/hour

Pump current = 100 mA * 0.5 sec = 0.05 amp-sec/sample
In 1 hour, pump current = 6 * 0.05 amp-seconds/sample = 0.30 amp-sec/hour

Quiescent current = 20 microamps = 0.02 mA
In 1 hour, quiescent current ≈ 0.02 mA * 3600 sec/hour = 0.072 amp-sec/hour

Current consumption / hour = 0.89 + 0.30 + 0.072 = 1.26 amp-sec/hour
Capacity = (10.5 amp-hours * 3600 sec/hr) / (1.26 amp-sec/hour) = 30000 hours = 1250 days = 3.4 years
However, Sea-Bird recommends that batteries should not be expected to last longer than 2 years in the field.

Example 3 - with 5T pump on during sample (**PumpMode=2**), 15 sec delay before sampling (**DelayBeforeSampling=15**), internally mounted Quartz pressure sensor integrating for 3 sec/sample (**ParosIntegration=3**), auxiliary sensors drawing 100 mA, 4 measurements/sample (**NCycles=4**):

On-time = 2.2 + 3 (Quartz integration) + 15 (delay before sampling) + (4 – 1) * 0.25 (additional measurements/sample)
= 20.95 sec
Sampling current = 70 mA * 20.95 sec = 1.47 amp-sec/sample
In 1 hour, sampling current = 6 * 1.47 amp-sec/sample = 8.8 amp-sec/hour

5T Pump current = 150 mA * 20.95 sec = 3.14 amp-sec/sample
In 1 hour, pump current = 6 * 3.14 amp-sec/sample = 18.9 amp-sec/hour

Auxiliary sensor current = 100 mA * 20.95 sec = 2.10 amp-sec/sample
In 1 hour, auxiliary sensor current = 6 * 2.10 amp-sec/sample = 12.6 amp-sec/hour

Quiescent current = 20 microamps = 0.02 mA
In 1 hour, quiescent current ≈ 0.02 mA * 3600 sec/hour = 0.072 amp-sec/hour

Current consumption / hour = 8.8 + 18.9 + 12.6 + 0.072 = 40.4 amp-sec/hour
Capacity = (10.5 amp-hours * 3600 sec/hr) / (40.4 amp-sec/hour) = 935 hours = 38 days = 0.1 years

External Power

The SBE 16*plus* V2 can be powered from an external source (9 - 28 volts DC) through the Y-cable connected to the Data I/O, Pump, and External Power bulkhead connector on the sensor end cap. The internal battery pack is diode-OR'd with the external source, so power will be drawn from whichever voltage source is higher. The 16*plus* V2 can also be operated from the external supply without having the internal battery pack installed. Electrical isolation of conductivity is retained in units powered externally, preventing ground loop noise contamination in the conductivity measurement.

Cable Length and External Power

Note:
See *Real-Time Setup* in *Section 4: Deploying and Operating SBE 16plus V2* for baud rate limitations on cable length if transmitting real-time data.

There are two issues to consider if powering the SBE 16*plus* V2 externally:

- Limiting the communication IR loss to 1 volt **if transmitting real-time data**; higher IR loss will prevent the instrument from transmitting real-time data because of the difference in ground potential.
- Supplying enough power at the power source so that sufficient power is available at the instrument after considering IR loss.

Each issue is discussed below.

Note:
Common wire resistances:

Gauge	Resistance (ohms/foot)
12	0.0016
14	0.0025
16	0.0040
18	0.0064
19	0.0081
20	0.0107
22	0.0162
24	0.0257
26	0.0410
28	0.0653

Limiting Communication IR Loss to 1 Volt if Transmitting Real-Time Data

The limit to cable length is typically reached when the maximum ***communication*** current times the power common wire resistance is more than 1 volt, because the difference in ground potential of the SBE 16*plus* V2 and ground controller prevents the 16*plus* V2 from transmitting real-time data.

V_{limit} = 1 volt = IR_{limit}

Maximum cable length = R_{limit} / wire resistance per foot

where I = communication current required by SBE 16*plus* V2 (60 milliamps; see *Specifications*).

Example 1 – For 20 gauge wire, what is maximum distance to transmit power to 16*plus* V2 if transmitting real-time data?
For 60 milliamp communications current, $R_{limit} = V_{limit}$ / I = 1 volt / 0.060 Amps = 16.7 ohms
For 20 gauge wire, resistance is 0.0107 ohms/foot.
Maximum cable length = 16.7 ohms / 0.0107 ohms/foot = 1557 feet = 474 meters

Example 2 – Same as above, but there are 4 instruments powered from the same power supply.
For 60 milliamp communications current, $R_{limit} = V_{limit}$ / I = 1 volt / (0.060 Amps * 4 instruments) = 4.1 ohms
Maximum cable length = 4.1 ohms / 0.0107 ohms/foot = 389 feet = 118 meters (to 16*plus* V2 *furthest* from power source).

Supplying Enough Power to SBE 16plus V2

Another consideration in determining maximum cable length is supplying enough power at the power source so that sufficient voltage is available, after IR loss in the cable (***from the turn-on transient, two-way resistance***), to power the SBE 16*plus* V2. The table summarizes the maximum 2-way resistance for various input supplies and pump configurations:

Power Supply Input and Pump Configuration	**R_{limit} = Maximum 2-way Resistance (ohms)**
3 Amps at 9V input, no pump or SBE 5M pump (cannot use SBE 5P or 5T with 9V input)	1
0.5 Amps at 12V input, no pump	50
0.5 Amps at 12V input, SBE 5M pump	10
3.0 Amps at 12V input, SBE 5P or 5T pump	2
0.25 Amps at 19V input, no pump	150
0.5 Amps at 19V input, SBE 5M pump	30
1.5 Amps at 19V input, SBE 5P or 5T pump	7

Calculate maximum cable length as:

Maximum cable length = R_{limit} / 2 * wire resistance per foot

Example 1 – For 20 gauge wire, what is maximum distance to transmit power to 16*plus* V2 if using 12 volt power source with SBE 5T pump?
Maximum cable length = R_{limit} / 2 * wire resistance per foot = 2 ohms / 2 * 0.0107 ohms/foot = 93 ft = 28 meters
Note that 28 meters < 474 meters (maximum distance if 16*plus* V2 is transmitting real-time data), so IR drop in power is controlling factor for this example. Using a higher voltage power supply or a different wire gauge would increase allowable cable length.

Example 2 – Same as above, but there are 4 instruments powered from same power supply.
Maximum cable length = R_{limit} / 2 * wire resistance per foot * 4 instruments
= 2 ohms / 2 * 0.0107 ohms/foot * 4 = 23 ft = 7 meters (to 16*plus* V2 *furthest* from power source)

Configuration Options and Plumbing

The SBE 16*plus* V2 is available with an optional, externally mounted, submersible pump. The pump is required for a 16*plus* V2 configured with an optional dissolved oxygen sensor or pumped fluorometer, but also provides the following benefits for conductivity data:

- Improved conductivity response - The pump flushes the previously sampled water from the conductivity cell and brings a new water sample quickly into the cell.

- Improved anti-foulant protection - Water does not freely flow through the conductivity cell between samples, allowing the anti-foulant concentration inside the cell to build up.

Several pump models are available:

- SBE 5M miniature pump (available in plastic or titanium) - for pumped conductivity.

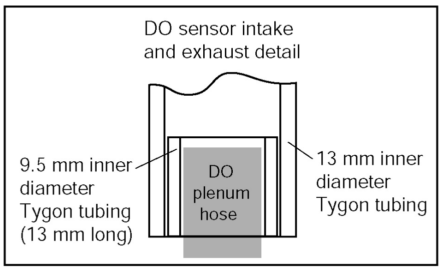
- SBE 5P (plastic) or 5T (titanium) pump - a more powerful pump for use if the SBE 16*plus* V2 is configured with a dissolved oxygen sensor and/or pumped fluorometer.

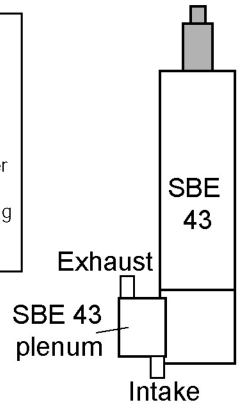
In all cases, the pump is powered via a cable connected to the 2-pin leg of the Y-cable (which is connected to the Data I/O, Pump, and External Power bulkhead connector on the sensor end cap).

The SBE 16*plus* V2 can be configured with a wide range of auxiliary sensors. Three standard 6-pin bulkhead connectors on the sensor end cap serve as the input ports for the auxiliary sensor signal voltages and provide power to the sensors. Additionally, a standard 4-pin bulkhead connector on the sensor end cap is provided for an RS-232 sensor, such as an SBE 38 secondary temperature sensor, an SBE 50 secondary strain-gauge pressure sensor, or Pro-Oceanus Gas Tension Devices (up to two GTDs can be integrated with the 16*plus* V2).

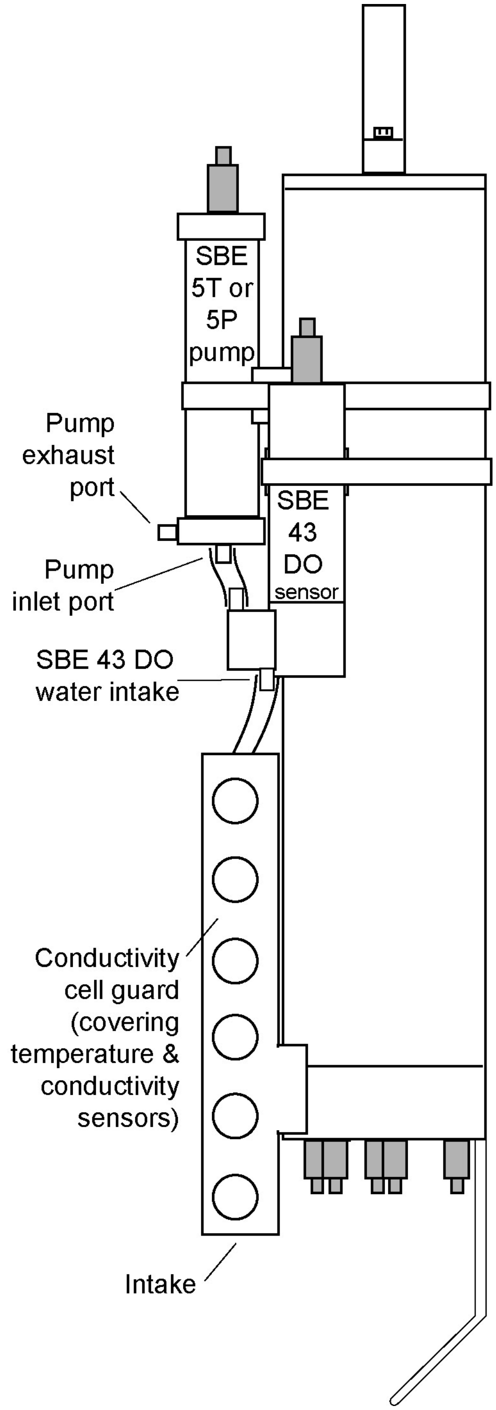
Shown below is the plumbing arrangement of an SBE 16*plus* V2 equipped with a pump and the optional SBE 43 Dissolved Oxygen sensor. See *Section 4: Deploying and Operating SBE 16plus V2* for pump setup and operation details.

- Main plumbing is 13 mm ID x 19 mm OD (1/2 inch x 3/4 inch) Tygon tubing.
- A 13 mm (0.5 inch) long piece of 9.5 mm ID x 13 mm OD (3/8 inch x 1/2 inch) Tygon tubing to fit to the main plumbing is installed:
  - on the conductivity cell exhaust, and
  - on the SBE 43 intake and exhaust





Place DO sensor with plenum intake closer than exhaust to SBE 43 housing, as shown.
Note: SBE 43 housing orientation (connector end up or down) does not affect operation. Plenum can be reversed on housing by removing and replacing 2 screws.



Section 3: Power and Communications Test

This section describes installing software and the pre-check procedure for preparing the SBE 16*plus* V2 for deployment. The power and communications test will verify that the system works, prior to deployment.

Software Installation

Sea-Bird recommends the following minimum system requirements for installing the software: Windows 2000 or later, 500 MHz processor, 256 MB RAM, and 90 MB free disk space for installation.

Note:
It is possible to use the 16*plus* V2 without the included terminal program (SCPlusV2_RS232.exe) by sending direct commands from a dumb terminal or terminal emulator, such as Windows HyperTerminal.

If not already installed, install Sea-Bird software programs on your computer using the supplied software CD:

1. Insert the CD in your CD drive.

2. Install terminal program software: Double click on **SCPlusV2_RS232_V*x_xx*.exe** (*x_xx* is the software version number). Follow the dialog box directions to install the software.

3. Install remaining software: Double click on **Seasoft-Win32_*date*.exe** (*date* is the date that version of the software was created). Follow the dialog box directions to install the software. The installation program allows you to install the desired components. Install all the components, or just install SEASAVE V7 (real-time data acquisition), SBE Data Processing (data processing), and SEATERM (terminal program for setting up SBE 38 or SBE 50 auxiliary sensors).

The default location for the software is c:/Program Files/Sea-Bird. Within that folder is a sub-directory for each program.

Test Setup

1. Remove the dummy plug and install the I/O cable:

   A. Pulling the plug firmly away from the connector, remove the dummy plug from the 4-pin connector on the Y-cable strapped to the 16*plus* V2 housing. Note that the Y-cable is connected to the Data I/O, Pump, and External Power connector on the 16*plus* V2 end cap, and provides power to the optional pump via the 2-pin connector as well as communications with the computer via the 4-pin connector.

   B. **Standard Connector** - Install the I/O cable connector, aligning the raised bump on the side of the connector with the large pin (pin 1 - ground) on the Y-cable. **OR**
   MCBH Connector - Install the I/O cable connector, aligning the pins.

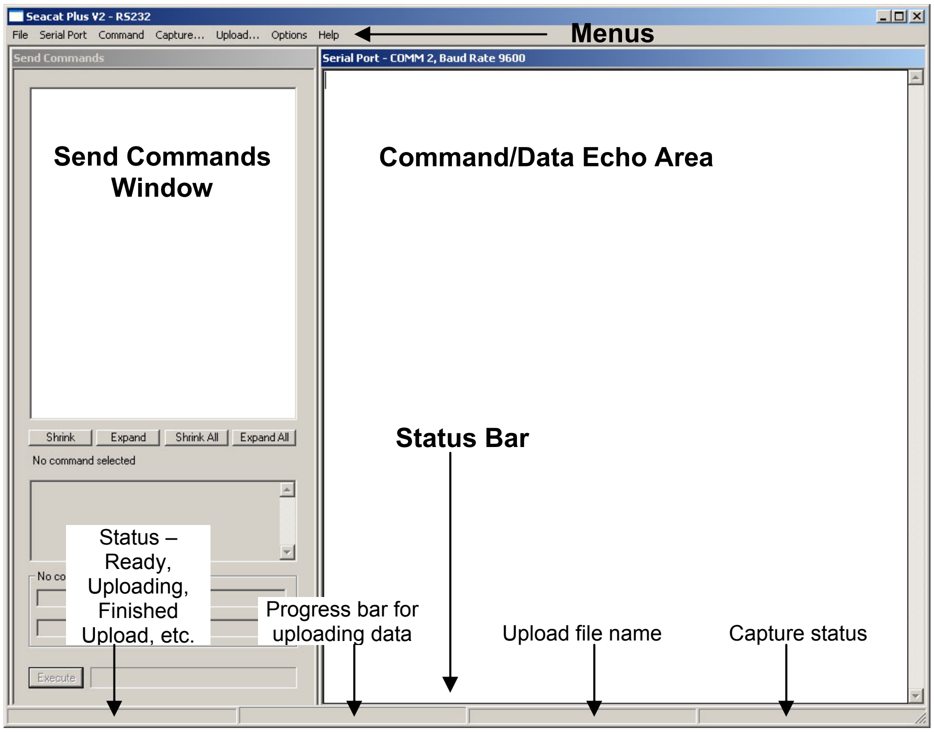
2. Connect the I/O cable connector to your computer's serial port.

Test

Note:
See the terminal program's Help files.

Proceed as follows:

1. Double click on SCPlusV2_RS232.exe. The main screen looks like this:



- Menus – Contains tasks and frequently executed instrument commands.
- Send Commands window – Contains a list of commands applicable to your 16*plus* V2. This list automatically appears after you connect to the 16*plus* V2.
- Command/Data Echo Area – Title bar of this window shows the terminal program's current configuration of comm port and baud rate. Commands are echoed in this area, as well as the instrument's response to the commands. Additionally, a command can be manually typed or pasted (ctrl + V) in this area, from the list of available commands for the 16*plus* V2. Note that the 16*plus* V2 must be *connected* and *awake* for it to respond to a command.
- Status bar – Located at the bottom of the main screen, and provides upload status and capturing status information.

Following is a description of the menus:

Menu	Description	Equivalent Command*
File	Exit program.	-
Serial Port	• Connect – connect to comm port • Disconnect – disconnect from comm port • Configure – Establish communication parameters (comm port and baud rate).	-
Command	• Abort – interrupt and stop 16*plus* V2's response • Send 5 second break (for use with Serial Line Sync mode) • Set date and time to Local time or UTC Time (Greenwich Mean Time) – Set date and time to time sent by timekeeping software on your computer; accuracy ± 25 msec of time provided by computer.	• (press Esc key several times for Abort) • **DateTime=**
Capture	Capture instrument responses on screen to file, to save real-time data or may be useful for diagnostics. File has .cap extension. Press Capture again to turn off capture. Capture status displays in Status bar.	—
Upload	Upload data stored in memory, in format Sea-Bird's data processing software can use (raw hex). Uploaded data has .xml extension, and is then automatically converted to a file with .hex extension. Before using Upload: **stop logging** by sending **Stop**.	**GetSD**, **DH**, **GetHD**, **GetSD**, **GetCD**, **GetCC**, **GetEC**, and appropriate data upload command as applicable to user selection of range of data to upload (use Upload menu if you will be processing data with SBE Data Processing or viewing archived data with SEASAVE)
Options	• Diagnostics - Keep a diagnostics log. • Convert .XML file to .HEX file – Using Upload menu automatically does this conversion; option is available in case there was a problem with the automatic conversion.	**-**

*See *Command Descriptions* in *Section 4: Deploying and Operating SBE 16plus V2*.

Note:
The terminal program's baud rate must be the same as the 16*plus* V2 baud rate (set with **BaudRate=**). Baud is factory-set to 9600, but can be changed by the user (see *Command Descriptions* in *Section 4: Deploying and Operating SBE 16plus V2*). Other communication parameters – 8 data bits, 1 stop bit, and no parity – cannot be changed.

2. In the Serial Port menu, select Configure. The Serial Port Configuration dialog box appears. Select the Comm port and baud rate for communication, and click OK.

3. The terminal program should automatically connect to the 16*plus* V2. As it connects, it sends **GetHD** and displays the response, which provides factory-set data such as instrument type, serial number, and firmware version. The terminal program also fills the Send Commands window with the correct list of commands for your 16*plus* V2. If there is no communication:
   A. In the Serial Port menu, select Connect (if Connect is grayed out, first select Disconnect and then select Connect).
   B. Check cabling between the computer and 16*plus* V2.
   C. If there is still no communication, repeat Step 2 with a different baud rate and/or comm port, and try to connect again. Note that the factory-set baud rate is documented on the Configuration Sheet.

After the terminal program displays the **GetHD** response, it provides an S> prompt to indicate it is ready for the next command.

> **Note:**
> If **OutputExecutedTag=Y**, the 16*plus* V2 does **not** provide an `S>` prompt after the `<Executed/>` tag at the end of a command response.

4. Display 16*plus* V2 status information by typing **DS** and pressing the Enter key. The display looks like this:

```
SBE 16plus V 2.0b SERIAL NO. 6001 24 Feb 2008 14:11:48
vbatt = 10.3, vlith = 8.5, ioper = 62.5 ma, ipump = 21.6 ma,
iext01 = 76.2 ma
status = not logging
samples = 0, free = 3463060
sample interval = 15 seconds, number of measurements per sample = 1
pump = run pump during sample, delay before sampling = 2.0 seconds
transmit real-time = yes
battery cutoff = 7.5 volts
pressure sensor = strain gauge, range = 1000.0
SBE 38 = no, SBE 50 = no, Gas Tension Device = no
Ext Volt 0 = yes, Ext Volt 1 = yes
Ext Volt 2 = no, Ext Volt 3 = no
Ext Volt 4 = no, Ext Volt 5 = no
echo characters = yes
output format = converted decimal
output salinity = no, output sound velocity = no
serial sync mode disabled
```

> **Notes:**
> - The 16*plus* V2 automatically enters quiescent (sleep) state after 2 minutes without receiving a command. This timeout algorithm is designed to conserve battery energy if the user does not send **QS** to put the 16*plus* V2 to sleep. If the system does not appear to respond, click Connect in the Serial Port menu to reestablish communications.
> - Sending the status command causes the optional pump to turn on for a moment, so that the 16*plus* V2 can measure and output the pump current. Because the pump is designed to be water lubricated, you may hear a noise when the impeller spins in air. Running the pump *dry* for **short** periods (for example, when sending the status command) will not harm the pump.

5. Command the 16*plus* V2 to take a sample by typing **TS** and pressing the Enter key. The display looks like this (if 16*plus* V2 includes optional internally mounted pressure sensor, and is set up for converted decimal output format, no output salinity or sound velocity, and auxiliary voltage sensors on channels 0 and 1):

```
23.7658, 0.00019, 0.062, 0.5632, 2.3748, 24 Feb 2008, 14:11:60
```

where 23.7658 = temperature in degrees Celsius
0.00019 = conductivity in S/m
0.062 = pressure in db
0.5632 = voltage for auxiliary sensor channel 0
2.3748 = voltage for auxiliary sensor channel 1
24 Feb 2008 = date
14:11:60 = time

These numbers should be reasonable; i.e., room temperature, zero conductivity, barometric pressure (gauge pressure), current date and time (set at factory to Pacific Daylight or Standard Time).

6. Command the 16*plus* V2 to go to sleep (quiescent state) by typing **QS** and pressing the Enter key.

The SBE 16*plus* V2 is ready for programming and deployment.

Section 4: Deploying and Operating SBE 16*plus* V2

This section includes discussions of:

- Sampling modes, including example sets of commands
- Pump operation
- Real-time setup
- Timeout description
- Command descriptions
- Data output formats
- Deployment
- Acquiring real-time data with SEASAVE
- Recovery - physical handling and uploading data
- Processing data

Note:
Separate software manuals and Help files contain detailed information on installation, setup, and use of Sea-Bird's software.

Sampling Modes

The SBE 16*plus* V2 has three basic sampling modes for obtaining data:
- Polled Sampling
- Autonomous Sampling
- Serial Line Synchronization

Commands can be used in various combinations to provide a high degree of operating flexibility.

Descriptions and examples of the sampling modes follow. Note that the SBE 16*plus* V2 response to each command is not shown in the examples. Review the operation of the basic sampling modes and the commands described in *Command Descriptions* before setting up your system.

Note:
The 16*plus* V2 automatically enters quiescent state after 2 minutes without receiving a command.

Polled Sampling

On command, the SBE 16*plus* V2 takes one sample of data and sends the data to the computer. Storing of data in the 16*plus* V2 FLASH memory is dependent on the particular command used.

Example: ***Polled Sampling*** (user input in bold)
Wake up 16*plus* V2. Set date and time to November 1, 2008 at 9:05 am. Set up with internally mounted strain gauge pressure sensor and 1 voltage sensor, no pump, take and average 4 measurements for each sample, and output data in converted decimal format. After all parameters are entered, verify setup. Command 16*plus* V2 to take a sample, and send data to computer (do not store data in memory). Send power-off command.

(Click Connect in terminal program's Serial Port menu to connect and wake up.)

```
DATETIME=11012008090500
PTYPE=1
VOLT0=Y
PUMPMODE=0
NCYCLES=4
OUTPUTFORMAT=3
GETCD        (to verify setup)
TS
QS
```

Autonomous Sampling (logging)

Note:
Set **OutputFormat=0** if you will be using Sea-Bird's real-time data acquisition software (SEASAVE).

At pre-programmed intervals, the SBE 16*plus* V2 wakes up, samples data, stores the data in its FLASH memory, and enters quiescent (sleep) state. The 16*plus* V2 goes to sleep for a minimum of 3 seconds between each sample. Logging is started with **StartNow** or **StartLater**, and is stopped with **Stop**. If real-time data is to be transmitted (**TxRealTime=Y**), data is transmitted after measurements are complete for that sample and before sampling begins for the next sample.

Example: ***Autonomous Sampling*** (user input in bold)

Wake up 16*plus* V2. Set date and time to September 1, 2008 at 9:05 am. Initialize logging to overwrite previous data in memory. Set up with internally mounted strain gauge pressure sensor and 1 voltage sensor, take a sample every 120 seconds, take and average 4 measurements for each sample, do not transmit real-time data, and output data in raw hex format. Set up pump to run for 0.5 seconds before each sample. Set up to start logging on September 15, 2008 at 11 am. Send command to start logging at designated date and time. After all parameters are entered, verify setup. Send power-off command.

(Click Connect in terminal program's Serial Port menu to connect and wake up.)

DATETIME=09012008090500
INITLOGGING
PTYPE=1
VOLT0=Y
SAMPLEINTERVAL=120
NCYCLES=4
TXREALTIME=N
OUTPUTFORMAT=0
PUMPMODE=1
STARTDATETIME=09152008110000
STARTLATER
GETCD (to verify setup)
QS

Deploy 16*plus* V2. Logging starts automatically at designated date and time.

Upon recovering 16*plus* V2, stop logging. Upload data in memory, in format SBE Data Processing can use.
Send power-off command.

(Click Connect in terminal program's Serial Port menu to connect and wake up.)
STOP
(Click Upload– program leads you through screens to define data to be uploaded and where to store it.)
QS

Serial Line Synchronization (Serial Line Sync)

Serial Line Sync allows a simple pulse on the RS-232 line to initiate a sample. This mode provides easy integration with ADCPs or current meters, which can synchronize SBE 16*plus* V2 sampling with their own without drawing on their battery or memory resources.

If this mode is enabled (**SyncMode=Y**) and the SBE 16*plus* V2 is powered down, setting the RS-232 RX line high (3 –10 VDC) for 1 to 1000 milliseconds wakes up the 16*plus* V2 and executes a Take Sample command:

- Take sample
- Store sample in FLASH memory
- Output real-time data (if **TxRealTime=Y**)

After executing the Take Sample command, the SBE 16*plus* V2 checks the RS-232 line and **SyncWait**. These determine whether to power down immediately or accept commands from the computer, and whether to leave the serial line sync mode enabled or disable it:

- **SyncWait=0** and **Mark State** (RS-232 RX line less than 0.5 volts)
  16*plus* V2 immediately powers down. Serial line sync mode remains enabled (**SyncMode=Y**).
- **SyncWait=0** and **Space State** (RS-232 RX line greater than 3 volts)
  16*plus* V2 monitors the RS-232 line for a time equivalent to 25 characters (actual length of time is dependent on the baud rate):
  - ➢ Line remains in space state - 16*plus* V2 disables serial line sync mode (sets **SyncMode=N**) at end of time. Once serial line sync mode is disabled, you can communicate with the 16*plus* V2 using the full range of commands (operating commands, logging commands, uploading command, etc.).
  - ➢ Line returns to mark state - 16*plus* V2 immediately powers down. Serial line sync mode remains enabled (**SyncMode=Y**).
- **SyncWait>0**
  16*plus* V2 monitors the RS-232 line for **SyncWait** seconds. Each time a carriage return (Enter key) is detected, the time-out clock is reset to 2 minutes. Within that time period, you can communicate with the 16*plus* V2 using the full range of commands (operating commands, logging commands, uploading command, etc.). While the 16*plus* V2 is monitoring:
  - ➢ More than 25 break characters are received - 16*plus* V2 disables serial line sync mode (sets **SyncMode=N**). Once serial line sync mode is disabled, you can communicate with the 16*plus* V2 using the full range of commands (operating commands, logging commands, uploading command, etc.).
  - ➢ Less than 25 break characters are received - 16*plus* V2 powers down when the time-out clock runs down. Serial line sync mode remains enabled (**SyncMode=Y**).

In summary, to disable serial line sync mode after executing the take sample command:

- **SyncWait** = 0
  Put RS-232 line in space state (greater then 3 volts) for time equivalent to 25 characters.
- **SyncWait** > 0
  - ➢ Send 25 break characters, or
  - ➢ If **SyncWait** is greater than 5 seconds, send **SyncMode=N** after waiting at least 3 seconds after executing the take sample command.

Note:
If running the terminal program, select *Send 5 second break* in the Command menu to hold the RS-232 RX line in space state for 5 seconds. This will always be more than 25 break characters, and will cause the 16*plus* V2 to exit Serial Line Sync mode.

Example: ***Serial Line Sync*** (user input in bold)
Wake up 16*plus* V2. Set current date and time to November 1, 2008 at 9:05 am. Initialize logging to overwrite previous data in memory. Set up with internally mounted strain gauge pressure sensor and 1 voltage sensor, take and average 4 measurements for each sample, output data in converted decimal format. Set **SyncWait** to 25 seconds and enable serial line sync mode. After all parameters are entered, verify setup. Send power off command.

(Click Connect in terminal program's Serial Port menu to connect and wake up.)
DATETIME=11012008090500
INITLOGGING
PTYPE=1
VOLT0=Y
NCYCLES=4
TXREALTIME=Y
OUTPUTFORMAT=3
SYNCWAIT=25
SYNCMODE=Y
GETCD (to verify setup)
QS

Take samples using serial line sync mode:

(Set RS-232 RX line high [3-10 VDC] for 1-1000 milliseconds. 16*plus* V2 takes sample, stores data in memory, and outputs data. Do not send any characters – 16*plus* V2 powers down after 25 seconds.)
(Repeat this process at periodic intervals as desired.)

When ready to upload all data to computer, disable serial line sync mode, and then upload data and power down:

(Set RS-232 RX line high [3-10 VDC] for 1-1000 milliseconds. 16*plus* V2 takes sample, stores data in memory, and outputs data.)
(Within 25 seconds [**SyncWait** timeout], select *Send 5 second break* in Command menu to disable serial line sync mode.)
(Press Enter key)
GETSD (to verify 16*plus* V2 is communicating)
(Click Upload – program leads you through screens to define data to be uploaded and where to store it.)
QS

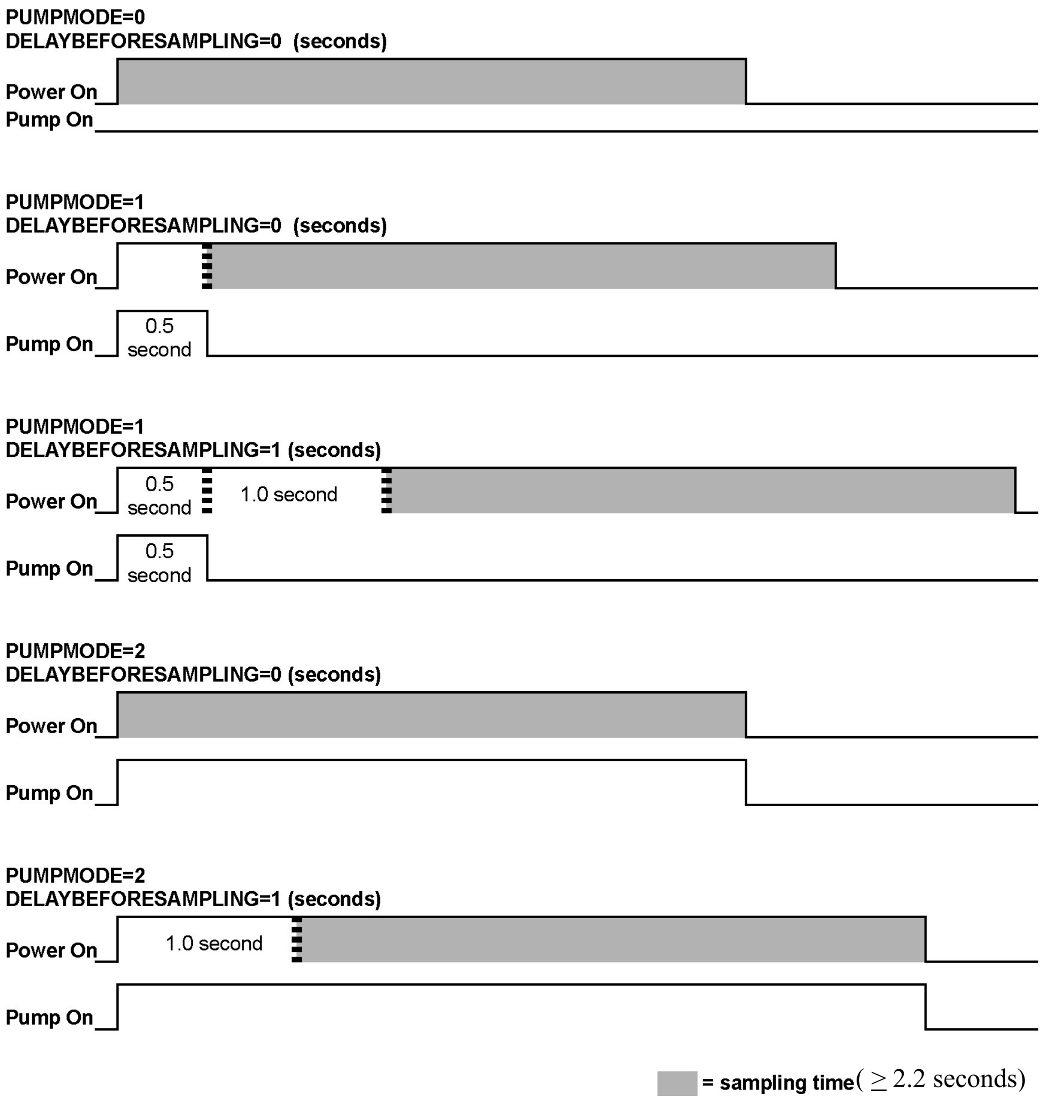
Pump Operation

Do not run the pump dry. The pump is water lubricated; running it without water will damage it. If briefly testing your system in dry conditions, fill the inside of the pump head with water via the pump exhaust port. This will provide enough lubrication to prevent pump damage during brief testing.

Pump operation is governed by two user-programmable parameters:

- **PumpMode=0**, **1**, or **2**
  The 16*plus* V2 can be set up to operate with no pump (0), with the pump running for 0.5 seconds before each sample (1), or with the pump running during each sample (2).
- **DelayBeforeSampling=**
  The 16*plus* V2 can be set up to delay sampling after turning on external voltage sensors. Some instruments require time to equilibrate or stabilize after power is applied, to provide good quality data.

PumpMode= and **DelayBeforeSampling=** interact in the operation of the pump, as shown below. Recommendations for settings are provided on the next page.



Note:
Sampling time includes time for instrument to warm up as well as time to actually measure parameters. The 2.2 second sampling time is for 16*plus* V2 with no internally mounted pressure sensor, and 1 measurement / sample (**NCycles=1**). See *Specifications* in *Section 2: Description of SBE 16plus V2* for sampling times for other setups.

Pump Setting Recommendations

Sea-Bird provides the following recommendations for pump settings. Note that longer pump times increase power usage, reducing battery endurance. See *Battery Endurance* in *Section 2: Description of SBE 16plus V2* for sample battery endurance calculations.

Pump through Conductivity Cell Only (SBE 5M, 5P, or 5T pump)

For most deployments, set **PumpMode=1** and **DelayBeforeSampling=0**. The pump operates for 0.5 seconds before the conductivity measurement is made, providing enough time to ventilate the cell and bring in a new sample of water.

If the 16*plus* V2 is moored in an area with large thermal gradients, it may be necessary to pump for a longer period of time, to eliminate any cell thermal mass effects on the measurement. In this case, set **PumpMode=2** and set **DelayBeforeSampling=** to a non-zero value, providing additional ventilation time (allowing the conductivity cell temperature to equilibrate to the water temperature) before taking the measurement.

Pump through Conductivity Cell and SBE 43 Dissolved Oxygen Sensor (requires SBE 5P or 5T pump)

Set **PumpMode=2**.

As the pump brings new water into the SBE 43 plenum, some time is required for the sensor to equilibrate to the new oxygen level. The time required is dependent on the sensor's membrane thickness, and on the water temperature. Prior to 2007, all SBE 43s were sold with a 0.5 mil thick membrane. Beginning in 2007, Sea-Bird began offering two membrane thicknesses – 0.5 mil (faster response, typically for profiling applications) and 1.0 mil (slower response but more durable, typically for moored applications).

- For a **0.5 mil thick** membrane – Recommended **DelayBeforeSampling=** varies in a non-linear fashion, from 15 seconds at 15 °C to 30 seconds at 0 °C.
- For a **1.0 mil thick** membrane – Recommended **DelayBeforeSampling=** varies in a non-linear fashion, from 25 seconds at 15 °C to 40 seconds at 0 °C.

Note:
See *Application Note 64: SBE 43 Dissolved Oxygen Sensor – Background Information, Deployment Recommendations, and Cleaning and Storage* for the response time curves.

Pump through Conductivity Cell and Beckman- or YSI-type Dissolved Oxygen Sensor (requires SBE 5P or 5T pump)

Set **PumpMode=2**. Set **DelayBeforeSampling=** to 120 to 180 seconds, allowing time for the oxygen sensor to polarize before taking the measurement.

Real-Time Setup

Notes:
- Set baud rate with **BaudRate=**.
- Set data storage rate and real-time output rate with **SampleInterval=**.
- Include auxiliary A/D sensors in the data stream with **VoltN=** commands. Include auxiliary RS-232 sensors in the data stream with **SBE38=**, **SBE50=**, **GTD=**, or **DualGTD=** commands.
- Set output format with **OutputFormat=**.
- Set **TxRealTime=Y** to output real-time data.
- If using external power, see *External Power* in *Section 2: Description of SBE 16plus V2* for power limitations on cable length.

Baud Rate and Cable Length

The rate that real-time data can be transmitted from the SBE 16*plus* V2 is dependent on the amount of data to be transmitted per scan and the serial data baud rate:

Time required to transmit data =
(number of characters * 10 bits/character) / baud rate

where

Number of characters is dependent on the included data and output format (see *Data Output Formats*).
Add 2 to the number of characters shown in the output format, to account for the carriage return and line feed at the end of each scan.
For decimal output (**OutputFormat=2**, **3**, or **5**), include decimal points, commas, and spaces when counting the number of characters.

Time required to transmit data plus the time required to make the measurements must be less than the (interval between samples – 3 seconds) for Autonomous Sampling, because the 16*plus* V2 goes to sleep for a minimum of 3 seconds between each sample.

The length of cable that the SBE 16*plus* V2 can drive is also dependent on the baud rate. The allowable combinations are:

Maximum Cable Length (meters)	Maximum Baud Rate
1600	600
800	1200
400	2400
200	4800
100	9600
50	19200
25	38400

Example 1 - 16*plus* V2 with optional internally mounted strain gauge pressure sensor, configured with 4 external voltages and 10 measurements/sample (**NCycles=10**). What is the smallest sample interval you can use if you want to transmit real-time data over 800 m with **OutputFormat=0** (raw hexadecimal data)?

With 800 meters of cable, the 16*plus* V2 requires a baud rate of 1200 or less.
Number of characters for **OutputFormat=0** (from *Data Output Formats*) =
6 (T) + 6 (C) + 6 (P) + 4 (P temperature compensation) + 4*4 (external voltages) + 8 (time) + 2 (carriage return & line feed) = 48
Time required to transmit data = (48 characters * 10 bits/character) / 1200 = 0.4 seconds

Minimum time required for each sample =
(2.2 + 0.3) second sampling time + [(10-1) * 0.25 seconds] + 0.4 seconds to transmit real-time
+ 3 seconds to go to sleep between samples = 8.15 seconds < minimum allowable sample interval of 10 seconds
Therefore, set **SampleInterval=10**, storing and transmitting one sample every 10 seconds for this configuration.

Example 2 – Same as above, but you have set **DelayBeforeSampling=15**.
Minimum time required for each sample = 8.15 seconds + 15 seconds (delay after turning on power) =
23.15 seconds, round up to 24 seconds
Therefore, set **SampleInterval=24**, storing and transmitting one sample every 24 seconds.

Real-Time Data Acquisition

Note:
If the FLASH memory is filled to capacity, data sampling and transmission of real-time data (if programmed) continue, but excess data is not saved in memory.

Real-time data can be acquired in either of the following ways:

- With SEASAVE (**typical method**) – When the 16*plus* V2 is set up for autonomous sampling, data can be viewed in SEASAVE in tabular form or as plots, as raw data or as converted (engineering units) data. Data acquired with SEASAVE can be processed with SBE Data Processing. See SEASAVE's Help files for details on setting up the program displays, baud rates, etc., and beginning data acquisition.

- With terminal program – Click the Capture menu; enter the desired file name in the dialog box, and click Save. Begin sampling. The data displayed in the terminal program will be saved to the designated file. Process the data as desired. Note that this file **cannot be processed by SEASAVE or SBE Data Processing, as it does not have the required headers and format for Sea-Bird's processing software**.

Timeout Description

The SBE 16*plus* V2 has a timeout algorithm. If the 16*plus* V2 does not receive a command or sample data for 2 minutes, it powers down its main digital circuits. This places the 16*plus* V2 in quiescent state, drawing minimal current. **To re-establish control (wake up), click Connect in the Serial Port menu or press the Enter key.**

Command Descriptions

This section describes commands and provides sample outputs.
See *Appendix III: Command Summary* for a summarized command list.

When entering commands:

- Input commands to the 16*plus* V2 in upper or lower case letters and register commands by pressing the Enter key.
- The 16*plus* V2 sends an error message if an invalid command is entered.
- (if **OutputExecutedTag=N**) If the 16*plus* V2 does not return an `S>` prompt after executing a command, press the Enter key to get the `S>` prompt.
- If a new command is not received within 2 minutes after the completion of a command, the 16*plus* V2 returns to the quiescent (sleep) state.
- If in quiescent state, re-establish communications by clicking Connect in the Serial Port menu or pressing the Enter key.
- If the 16*plus* V2 is transmitting data and you want to stop it, press the Esc key or type ^C. Then press the Enter key.
- Commands to enable a parameter or output (such as enabling a voltage channel) can be entered with the *argument* as Y or 1 for yes, and N or 0 for no (for example, **Volt0=y** and **Volt0=1** are equivalent; both enable voltage channel 0).
- The 16*plus* V2 cannot have samples with different scan lengths (more or fewer data fields per sample) in memory. If the scan length is changed by commanding it to add or subtract a data field (such as an external voltage), the 16*plus* V2 must initialize logging. Initializing logging sets the sample number and header number to 0, so the entire memory is available for recording data with the new scan length. **Initializing logging should only be performed after all previous data has been uploaded**. Therefore, commands that change the scan length (**PType=**, **Volt0=**, **Volt1=**, **Volt2=**, **Volt3=**, **Volt4=**, **Volt5=**, **SBE38=**, **SBE50=**, **GTD=**, and **DualGTD=**) prompt the user for verification before executing, to prevent accidental overwriting of existing data.
- The 16*plus* V2 responds only to **GetCD**, **GetSD**, **GetCC**, **GetEC**, **ResetEC**, **GetHD**, **DS**, **DCal**, **TS**, **SL**, **SLT**, **GetLastSamples:x**, **QS**, and **Stop** while sampling autonomously. If you wake the 16*plus* V2 while it is sampling autonomously (for example, to send **DS** to check on progress), it temporarily stops sampling. Autonomous sampling resumes when it goes back to sleep (either by sending **QS** or after the 2-minute timeout).
- The 16*plus* V2 responds only to **GetCD**, **GetSD**, **GetCC**, **GetEC**, **ResetEC**, **GetHD**, **DS**, **DCal**, **TS**, **SL**, **SLT**, **GetLastSamples:x**, **QS**, and **Stop** while *waiting to start autonomous sampling* (if you sent **StartLater** but sampling has not started yet). To send any other commands, send **Stop**, send the desired commands to modify the setup, and then send **StartLater** again.

Entries made with the commands are permanently stored in the SBE 16*plus* V2 and remain in effect until you change them.

- The only exception occurs if the electronics are removed from the housing and disconnected from the battery Molex connector (see *Appendix II: Electronics Disassembly/Reassembly*). Upon reassembly, reset the date and time (**DateTime=**) and initialize logging (**InitLogging**).

Status Command

> **Notes:**
> - **GetCD** output does not include calibration coefficients. To display calibration coefficients, use the **GetCC** command.
> - The **DS** response contains similar information as the combined responses from **GetSD** and **GetCD**, but in a different format.

GetCD

Get and display configuration data, which includes all parameters related to setup of 16*plus* V2, including communication settings and sampling settings. Most of these parameters can be user-input/modified. List below includes, where applicable, command used to modify parameter:

- Device type, Serial number
- Sample interval [**SampleInterval=**]
- Number of measurements to take and average per sample [**NCycles=**]
- Integration time for Quartz pressure sensor [**ParosIntegration=**] (only appears if **PType=3**)
- Reference pressure to use if no internally mounted pressure sensor [**RefPress=**] (only appears if **PType=0**)
- Pump turn-on parameter [**PumpMode=**]
- Pump turn-on delay [**DelayBeforeSampling=**]
- Transmit data real-time? [**TxRealTime=**]
- Sample external voltages 0, 1, 2, 3, 4, and 5? [**Volt0=** through **Volt5=**]
- Sample SBE 38 secondary temperature sensor [**SBE38=**]
- Sample SBE 50 secondary pressure sensor [**SBE50=**]
- Sample Gas Tension Device [**GTD=**], or dual Gas Tension Devices [**DualGTD=**]?
- Enable echoing? [**Echo=**]
- Output Executing and Executed tags? [**OutputExecutedTag=**]
- Output format [**OutputFormat=**]
- Output salinity? [**OutputSal=**] (only appears if output format = converted decimal or converted XML UVIC)
- Output sound velocity? [**OutputSV=**] (only appears if output format = converted decimal or converted XML UVIC)
- Output sigma-t, voltage, and current with each sample? [**OutputUCSD=**] (only appears if output format = converted decimal or converted XML UVIC)
- Serial line sync mode? [**SyncMode=**]

Status Commands (*continued*)

Example: Send **GetCD** to 16*plus* V2 with strain gauge pressure sensor
(user input in bold, command used to modify parameter in parentheses)

```
getcd
<ConfigurationData DeviceType='SBE16plus' SerialNumber='01606001'>
   <SamplingParameters>
      <SampleInterval>15</SampleInterval>                          [SampleInterval=]
      <MeasurementsPerSample>1</MeasurementsPerSample>             [NCycles=]
      <Pump>run pump during sample</Pump>                          [PumpMode=]
      <DelayBeforeSampling>0.0</DelayBeforeSampling>               [DelayBeforeSampling=]
      <TransmitRealTime>no</TransmitRealTime>                      [TxRealTime=]
   </SamplingParameters>
   <DataChannels>
      <ExtVolt0>yes</ExtVolt0>                                     [Volt0=]
      <ExtVolt1>no</ExtVolt1>                                      [Volt1=]
      <ExtVolt2>no</ExtVolt2>                                      [Volt2=]
      <ExtVolt3>yes</ExtVolt3>                                     [Volt3=]
      <ExtVolt4>no</ExtVolt4>                                      [Volt4=]
      <ExtVolt5>no</ExtVolt5>                                      [Volt5=]
      <SBE38>no</SBE38>                                            [SBE38=]
      <SBE50>no</SBE50>                                            [SBE50=]
      <GTD>no</GTD>                                                [GTD= or DualGTD=]
   </DataChannels>
   <EchoCharacters>yes</EchoCharacters>                            [Echo=]
   <OutputExecutedTag>no</OutputExecutedTag>                       [OutputExecutedTag=]
   <OutputFormat>converted decimal</OutputFormat>                  [OutputFormat=]
   <OutputSalinity>no</OutputSalinity>                             [OutputSal=]
   <OutputSoundVelocity>no</OutputSoundVelocity>                   [OutputSV=]
   <OutputSigmaT-V>no</OutputSigmaT-V>                             [OutputUCSD=]
   <SerialLineSync>no</SerialLineSync>                             [SyncMode=]
</ConfigurationData>
```

Status Commands (*continued*)

Notes:
- The **DS** response contains similar information as the combined responses from **GetSD** and **GetCD**, but in a different format.
- If configured with a pump, sending **GetSD** causes the pump to turn on for a moment, so that the 16*plus* V2 can measure and output the pump current. Because the pump is designed to be water lubricated, you will hear a noise when the impeller spins in air. Running the pump *dry* for such a **short** time will not harm the pump.
- In the example below, only voltage channel 0 is enabled, so external voltage current iext2345= (for channels 2, 3, 4, and 5) is not shown.
- In the example below, no RS-232 sensor is enabled, so RS-232 sensor current iserial= is not shown.
- If the 16*plus* V2 is set up with a WET Labs ECO-FL fluorometer with Bio-Wiper (**Biowiper=Y**) and if **OutputExecutedTag=Y**, the **GetSD** response shows: `<Executing/>` to allow time for the Bio-Wiper to close before it measures the enabled external voltage currents.

GetSD

Get and display status data, which contains data that changes while deployed.
List below includes, where applicable, command used to modify parameter:

- Device type, Serial number
- Date and time [**DateTime=**] in ISO8601-2000 extended format (yyyy – mm-ddThh:mm:ss)
- Logging status (not logging, logging, waiting to start at . . ., or unknown status)
- Number of recorded events in event counter [reset with **ResetEC**]
- Voltages and currents -
  - Main battery voltage
  - Back-up lithium battery voltage
  - Operating current
  - Pump current
  - External voltage sensor current (channels 0 and 1) – displays only if 1 or more channels enabled
  - External voltage sensor current (channels 2, 3, 4, and 5) – displays only if 1 or more channels enabled
  - RS-232 sensor current – displays only if channel enabled
- Memory - [reset with **InitLogging**]
  - Number of bytes in memory
  - Number of samples in memory
  - Number of additional samples that can be placed in memory
  - Length (number of bytes) of each sample

Example: (user input in bold, command used to modify parameter in parentheses)

```
getsd
<StatusData DeviceType = 'SBE16plus' SerialNumber = '01606001'>
   <DateTime>2008-02-24T10:53:03</DateTime>                    [DateTime=]
   <LoggingState>not logging</LoggingState>
   <EventSummary numEvents = '0'/>                             [can clear with ResetEC]
   <Power>
      <vMain>10.1</vMain>
      <vLith>8.9</vLith>
      <iMain>61.9</iMain>
      <iPump>20.6</iPump>
      <iExt01>67.2</iExt01>
   </Power>
   <MemorySummary>
      <Bytes>0</Bytes>                                         [can clear with InitLogging]
      <Samples>0</Samples>                                     [can clear with InitLogging]
      <SamplesFree>3463060</SamplesFree>                       [can clear with InitLogging]
      <SampleLength>19</SampleLength>
   </MemorySummary>
</StatusData>
```

Notes:

- **DCal** and **GetCC** responses contain similar information, but in different formats.
- Dates shown are when calibrations were performed.

Status Commands (*continued*)

GetCC Get and display calibration coefficients, which are initially factor-set and should agree with Calibration Certificates shipped with 16*plus* V2.

Example: 16*plus* V2 with internally mounted strain gauge pressure sensor (user input in bold, command used to modify coefficient in parentheses)

```
getcc
<CalibrationCoefficients DeviceType = 'SBE16plus' SerialNumber = '01606001'>
   <Calibration format = 'TEMP1' id = 'Main Temperature'>
      <SerialNum>01606001</SerialNum>
      <CalDate>19-Oct-07</CalDate>                      [TCalDate=]
      <TA0>1.155787e-03</TA0>                           [TA0=]
      <TA1>2.725208e-04</TA1>                           [TA1=]
      <TA2>-7.526811e-07</TA2>                          [TA2=]
      <TA3>1.716270e-07</TA3>                           [TA3=]
      <TOFFSET>0.000000e+00</TOFFSET>                   [TOffset=]
   </Calibration>
   <Calibration format = 'WBCOND0' id = 'Main Conductivity'>
      <SerialNum>01606001</SerialNum>
      <CalDate>19-Oct-07</CalDate>                      [CCalDate=]
      <G>-1.006192e+00</G>                              [CG=]
      <H>1.310565e-01</H>                               [CH=]
      <I>-2.437852e-04</I>                              [CI=]
      <J>3.490353e-05</J>                               [CJ=]
      <CPCOR>-9.570000e-08</CPCOR>                      [CPCor=]
      <CTCOR>3.250000e-06</CTCOR>                       [CTCor=]
      <CSLOPE>1.000000e+00</CSLOPE>                     [CSlope=]
   </Calibration>
   <Calibration format = 'STRAIN0' id = 'Main Pressure'>
      <SerialNum>01600003</SerialNum>
      <CalDate>27-oct-07</CalDate>                      [PCalDate=]
      <PA0>-5.137085e-02</PA0>                          [PA0=]
      <PA1>1.550601e-03</PA1>                           [PA1=]
      <PA2>7.210415e-12</PA2>                           [PA2=]
      <PTCA0>5.154159e+05</PTCA0>                       [PTCA0=]
      <PTCA1>2.560262e-01</PTCA1>                       [PTCA1=]
      <PTCA2>-8.533080e-02</PTCA2>                      [PTCA2=]
      <PTCB0>2.426612e+01</PTCB0>                       [PTCB0=]
      <PTCB1>-7.750000e-04</PTCB1>                      [PTCB1=]
      <PTCB2>0.000000e+00</PTCB2>                       [PTCB2=]
      <PTEMPA0>-7.667877e+01</PTEMPA0>                  [PTempA0=]
      <PTEMPA1>4.880376e+01</PTEMPA1>                   [PTempA1=]
      <PTEMPA2>-4.555938e-01</PTEMPA2>                  [PTempA2=]
      <POFFSET>0.000000e+00</POFFSET>                   [POffset= (decibars)]
      <PRANGE>1.000000e+03</PRANGE>                     [PRange= (psia)]
   </Calibration>
   <Calibration format = 'VOLT0' id = 'Volt 0'>
      <OFFSET>0.000000e+00</OFFSET>                     [VOffset0=]
      <SLOPE>1.260977e+00</SLOPE>                       [VSlope0=]
   </Calibration>
   <Calibration format = 'VOLT0' id = 'Volt 1'>
      <OFFSET>-4.728750e-02</OFFSET>                    [Voffset1=]
      <SLOPE>1.259474e+00</SLOPE>                       [VSlope1=]
   </Calibration>
   <Calibration format = 'VOLT0' id = 'Volt 2'>
      <OFFSET>-4.715313e-02</OFFSET>                    [Voffset2=]
      <SLOPE>1.259946e+00</SLOPE>                       [VSlope2=]
   </Calibration>
   <Calibration format = 'VOLT0' id = 'Volt 3'>
      <OFFSET>-4.772396e-02</OFFSET>                    [Voffset3=]
      <SLOPE>1.260486e+00</SLOPE>                       [VSlope3=]
   </Calibration>
   <Calibration format = 'VOLT0' id = 'Volt 4'>
      <OFFSET>-4.765417e-02</OFFSET>                    [Voffset4=]
      <SLOPE>1.260014e+00</SLOPE>                       [VSlope4=]
   </Calibration>
   <Calibration format = 'VOLT0' id = 'Volt 5'>
      <OFFSET>-4.744167e-02</OFFSET>                    [Voffset5=]
      <SLOPE>1.260255e+00</SLOPE>                       [VSlope5=]
   </Calibration>
   <Calibration format = 'FREQ0' id = 'external frequency channel'>
      <EXTFREQSF>1.000000e+00</EXTFREQSF>               [ExtFreqSF=]
   </Calibration>
</CalibrationCoefficients>
```

Status Commands (*continued*)

GetEC

Get and display event counter data, which can help to identify root cause of a malfunction. Event counter records number of occurrences of common timeouts, power-on resets, etc. Can be cleared with **ResetEC**. Possible events that may be logged include:

- Power fail – main batteries and/or external voltage below voltage cutoff
- EEPROM read or EEPROM write – all power removed (main batteries removed, and back-up lithium batteries are dead)
- Alarm short – woke up 16*plus* V2 to send a command while logging
- Alarm long –sent **StartLater**, but **StartDateTime=** is more than 1 month in future
- AD7730 timeout – response from temperature and pressure A/D converter delayed; typically if woke up to send a command while logging
- AD7714 timeout – response from voltage channel A/D converter delayed; typically if woke up to send a command while logging
- FLASH out of memory – all available memory space is used; autonomous sampling continues, but no additional data written to FLASH (does not overwrite)
- FLASH correctable error – single bit error in a page, corrects itself, does not affect data
- FLASH ECC error – does not affect data
- FLASH timeout – problem with FLASH
- FLASH ready – problem with FLASH; timeout error
- FLASH erase failed – problem with FLASH
- FLASH write failed – problem with FLASH
- FLASH uncorrectable – problem with FLASH; 2 or more bits of errors in a page
- FLASH block overrun – problem with FLASH
- New bad block – problem with FLASH; FLASH write or erase failed, or a FLASH uncorrectable error

Example (user input in bold, command used to modify parameter in parentheses)

getec

```
<EventCounters DeviceType = 'SBE16plus' SerialNumber = '01606001'>
   <EventSummary numEvents = '1'/>                    [can clear with ResetEC]
   <Event type='alarm short' count='1'/>
</EventCounters>
```

ResetEC

Delete all events in event counter (number of events displays in **GetSD** response, and event details display in **GetEC** response).

Status Commands (*continued*)

Note:
External sensor types and serial numbers can be changed in the field, to accommodate changes in auxiliary sensors cabled to the 16*plus* V2. Other hardware data is typically not changed by the user.

GetHD

Get and display hardware data, which is fixed data describing 16*plus* V2:

- Device type, Serial number
- Manufacturer
- Firmware version
- Firmware date
- PCB serial number and assembly number
- Manufacture date
- Internal sensor types and serial numbers
- External sensor types (for example, dissolved oxygen, fluorometer, etc.) and serial numbers

Example: (user input in bold, command used to modify parameter in parentheses)

```
gethd
<HardwareData DeviceType = 'SBE16plus' SerialNumber = '01606001'>
   <Manufacturer>Sea-Bird Electronics, Inc.</Manufacturer>
   <FirmwareVersion>2.0b</FirmwareVersion>
   <FirmwareDate>24 February 2008 13:00</FirmwareDate>
   <PCBAssembly PCBSerialNum = 'not assigned' AssemblyNum = '41054F'/>     [SetPcbSerialNum1=, SetPCBAssembly1=]
   <PCBAssembly PCBSerialNum = 'not assigned' AssemblyNum = '41580'/>      [SetPcbSerialNum2=, SetPCBAssembly2=]
   <PCBAssembly PCBSerialNum = 'not assigned' AssemblyNum = '41056E'/>     [SetPcbSerialNum3=, SetPCBAssembly3=]
   <PCBAssembly PCBSerialNum = 'not assigned' AssemblyNum = '41059D'/>     [SetPcbSerialNum4=, SetPCBAssembly4=]
   <MfgDate>03 february 2008</MfgDate>                                                         [SetMfgDate=]
   <InternalSensors>
      <Sensor id = 'Main Temperature'>
         <type>temperature0</type>
         <SerialNumber>01606001</SerialNumber>
      </Sensor>
      <Sensor id = 'Main Conductivity'>
         <type>conductivity-0</type>
         <SerialNumber>01606001</SerialNumber>
      </Sensor>
      <Sensor id = 'Main Pressure'>
         <type>strain-0</type>                                                                    [PType=]
         <SerialNumber>2580011</SerialNumber>
      </Sensor>
   </InternalSensors>
   <ExternalSensors>
      <Sensor id = 'volt 0'>
         <type>not assigned</type>                                                          [SetVoltType0=]
         <SerialNumber>not assigned</SerialNumber>                                            [SetVoltSN0=]
      </Sensor>
      <Sensor id = 'volt 1'>
         <type>not assigned</type>                                                          [SetVoltType1=]
         <SerialNumber>not assigned</SerialNumber>                                            [SetVoltSN1=]
      </Sensor>
      <Sensor id = 'volt 2'>
         <type>not assigned</type>                                                          [SetVoltType2=]
         <SerialNumber>not assigned</SerialNumber>                                            [SetVoltSN2=]
      </Sensor>
      <Sensor id = 'volt 3'>
         <type>not assigned</type>                                                          [SetVoltType3=]
         <SerialNumber>not assigned</SerialNumber>                                            [SetVoltSN3=]
      </Sensor>
      <Sensor id = 'volt 4'>
         <type>not assigned</type>                                                          [SetVoltType4=]
         <SerialNumber>not assigned</SerialNumber>                                            [SetVoltSN4=]
      </Sensor>
      <Sensor id = 'volt 5'>
         <type>not assigned</type>                                                          [SetVoltType5=]
         <SerialNumber>not assigned</SerialNumber>                                            [SetVoltSN5=]
      </Sensor>
   </ExternalSensors>
</HardwareData>
```

Status Commands (*continued*)

Notes:
- The **DS** response contains similar information as the combined responses from **GetSD** and **GetCD**, but in a different format.
- If configured with a pump, sending **DS** causes the pump to turn on for a moment, so that the 16*plus* V2 can measure and output the pump current. Because the pump is designed to be water lubricated, you will hear a noise when the impeller spins in air. Running the pump *dry* for such a **short** time will not harm the pump.
- In the example below, only voltage channel 0 is enabled, so external voltage current iext2345= (for channels 2, 3, 4, and 5) is not shown.
- In the example below, no RS-232 sensor is enabled, so RS-232 sensor current iserial= is not shown.
- If the 16*plus* V2 is set up for dual GTDs, the **DS** response shows: `Dual Gas Tension Device = Yes`
- If the 16*plus* V2 is set up with a WET Labs ECO-FL fluorometer with Bio-Wiper (**Biowiper=Y**), the **DS** response shows: `wait 4 seconds for biowiper to close` before it measures the enabled external voltage currents.

DS

Get and display operating status and setup. List below includes, where applicable, command used to modify parameter.
- Firmware version, serial number, date and time [**DateTime=**]
- Voltages and currents (main and back-up lithium battery voltages; currents – operating, pump, external voltage sensors, RS-232 sensor)
- Logging status (not logging, logging, waiting to start at . . ., or unknown status)
- Number of samples and available sample space in memory
- Sample interval [**SampleInterval=**] and number of measurements to take and average per sample [**NCycles=**]
- Integration time [**ParosIntegration=**] (only appears if pressure sensor = quartz with temp comp)
- Pump turn-on parameter [**PumpMode=**] and turn-on delay [**DelayBeforeSampling=**]
- Transmit data real-time [**TxRealTime=**]?
- Battery cut-off voltage
- Internally mounted pressure sensor type [**PType=**] and range [**PRange=**]
- Sample SBE 38 secondary temperature sensor [**SBE38=**]? Sample SBE 50 pressure sensor [**SBE50=**]? Sample Gas Tension Device or Dual Gas Tension Devices [**GTD=** or **DualGTD=**]?
- Sample external voltages 0, 1, 2, 3, 4, and 5? [**Volt0=** through **Volt5=**]
- Show entered commands on screen as you type [**Echo=**]?
- Output format [**OutputFormat=**]
- Output salinity [**OutputSal=**] and sound velocity [**OutputSV=**]? (only if output format = converted decimal or converted XML UVIC)
- Serial sync mode state [**SyncMode=**] and wait time [**SyncWait=**] (only if enabled)
- Output sigma-t, voltage, and current with each sample [**OutputUCSD=**]? (only if output format = converted decimal or converted XML UVIC; and if set to Y)

Example: (user input in bold, command used to modify parameter in parentheses)

```
DS
SBE 16plus V 2.0b SERIAL NO. 6001 24 Feb 2008 14:11:48                      [DateTime=]
vbatt = 10.3, vlith = 8.5, ioper = 62.5 ma, ipump = 21.6 ma,
iext01 = 76.2 ma,
status = not logging
samples = 0, free = 3463060
sample interval = 15 seconds, number of measurements per sample = 1        [SampleInterval=, NCycles=]
pump = run pump during sample, delay before sampling = 2.0 seconds        [PumpMode=, DelayBeforeSampling=]
transmit real-time = yes                                                  [TxRealTime=]
battery cutoff = 7.5 volts
pressure sensor = strain gauge, range = 1000.0                            [PType=,PRange=]
SBE 38 = no, SBE 50 = yes, Gas Tension Device = no                        [SBE38=, SBE50=, GTD=, DualGTD=]
Ext Volt 0 = no, Ext Volt 1 = no                                          [Volt0= and Volt1=]
Ext Volt 2 = no, Ext Volt 3 = no                                          [Volt2= and Volt3=]
Ext Volt 4 = no, Ext Volt 5 = no                                          [Volt4= and Volt5=]
echo characters = yes                                                     [Echo=]
output format = raw HEX                                                   [OutputFormat=]
serial sync mode disabled                                                 [SyncMode=]
```

Status Commands (*continued*)

Notes:
- The **DCal** and **GetCC** responses contain the same information, but in different formats.
- Dates shown are when calibrations were performed.

DCal — Get and display calibration coefficients, which are initially factory-set and should agree with Calibration Certificates shipped with 16*plus* V2.

Example: 16*plus* V2 with internally mounted strain gauge pressure sensor (user input in bold, command used to modify coefficient in parentheses).

```
dcal
SeacatPlus V 2.0b  SERIAL NO. 6001  24 Feb 2008  14:46:05        [DateTime=]
temperature:  20-oct-07                                           [TCalDate=]
    TA0 = -3.178124e-06                                           [TA0=]
    TA1 = 2.751603e-04                                            [TA1=]
    TA2 = -2.215606e-06                                           [TA2=]
    TA3 = 1.549719e-07                                            [TA3=]
    TOFFSET = 0.000000e+00                                        [TOffset=]
conductivity:  20-oct-07                                          [CCalDate=]
    G = -9.855242e-01                                             [CG=]
    H = 1.458421e-01                                              [CH=]
    I = -3.290801e-04                                             [CI=]
    J = 4.784952e-05                                              [CJ=]
    CF0 = 2.584100e+03                (not used in calculations; ignore)
    CPCOR = -9.570000e-08                                         [CPCor=]
    CTCOR = 3.250000e-06                                          [CTCor=]
    CSLOPE = 1.000000e+00                                         [CSlope=]
pressure S/N 2580011, range = 1000 psia:  24-oct-07   [PRange= (psia), PCalDate=]
    PA0 = 0.000000e+00                                            [PA0=]
    PA1 = 0.000000e+00                                            [PA1=]
    PA2 = 0.000000e+00                                            [PA2=]
    PTEMPA0 = 0.000000e+00                                        [PTempA0=]
    PTEMPA1 = 0.000000e+00                                        [PTempA1=]
    PTEMPA2 = 0.000000e+00                                        [PTempA2=]
    PTCA0 = 0.000000e+00                                          [PTCA0=]
    PTCA1 = 0.000000e+00                                          [PTCA1=]
    PTCA2 = 0.000000e+00                                          [PTCA2=]
    PTCB0 = 0.000000e+00                                          [PTCB0=]
    PTCB1 = 0.000000e+00                                          [PTCB1=]
    PTCB2 = 0.000000e+00                                          [PTCB2=]
POFFSET = 0.000000e+00                                  [POffset= (decibars)]
volt 0: offset = 0.000000e+00, slope = 1.000000e+00   [VOffset0=, VSlope0=]
volt 1: offset = 0.000000e+00, slope = 1.000000e+00   [Voffset1=, VSlope1=]
volt 2: offset = 0.000000e+00, slope = 1.000000e+00   [Voffset2=, VSlope2=]
volt 3: offset = 0.000000e+00, slope = 1.000000e+00   [Voffset3=, VSlope3=]
volt 4: offset = 0.000000e+00, slope = 1.000000e+00   [Voffset4=, VSlope4=]
volt 5: offset = 0.000000e+00, slope = 1.000000e+00   [Voffset5=, VSlope5=]
    EXTFREQSF = 1.000000e+00                                      [ExtFreqSF=]
```

General Setup Commands

DateTime=mmddyyyyhhmmss Set real-time clock month, day, year, hour, minute, and second.

Example: Set current date and time to 05 February 2008 12:05:00 (user input in bold).
datetime=02052008120500

Notes:
- The 16*plus* V2 baud rate (set with **BaudRate=**) must be the same as the terminal program's baud rate (set in the Serial Port menu).
- An RS-232 sensor (SBE 38, SBE 50, or GTD) integrated with the 16*plus* V2 must use the same baud rate as the 16*plus* V2. See the RS-232 sensor's manual to set its baud.
- **BaudRate=** must be sent twice. After the first entry, the 16*plus* V2 changes to the new baud, and then waits for the command to be sent again at the new baud. This prevents you from accidentally changing to a baud that is not supported by your computer. If it does not receive the command again at the new baud, it reverts to the previous baud rate.

BaudRate=x **x=** baud rate (600, 1200, 2400, 4800, 9600, 19200, 33600, 38400, 57600, or 115200). ***Default 9600.*** Check capability of your computer and terminal program before increasing baud rate. **Command must be sent twice to change rate.**

Echo=x **x=Y**: Echo characters received from computer (***default***) - computer monitor will show entered commands as you type.

x=N: Do not echo characters.

OutputExecutedTag=x **x=Y**: Display XML Executing and Executed tags (***default***). Executed tag displays at end of each command response; Executing tag displays one or more times if 16*plus* V2 response to command requires additional time.

x=N: Do not.

Example: Set 16*plus* V2 to output Executed and Executing tags (user input in bold).
outputexecutedtag=y
<Executed/>**getcd**
. . . (**GetCD** response)
<Executed/>
(Note: <Executed/> tag at end of command response takes place of S> prompt.)

TxRealTime=x Applies to both autonomous (logging) and serial line sync modes.
x=Y: Output real-time data.

x=N: Do not output real-time data.

Note:
Pump operation is affected by both **PumpMode=** and **DelayBeforeSampling=**. See *Pump Operation*.

PumpMode=x **x=0**: No pump.

x=1: Run pump for 0.5 seconds before each sample (typical for pumping through conductivity cell only, with no auxiliary sensors connected to plumbing).

x=2: Run pump during each sample (typical for pumping through conductivity cell and in-line auxiliary sensor).

Note:
NCycles=, **ParosIntegration=** and **DelayBeforeSampling=** affect the time required to sample. If these are too high, the 16*plus* V2 is unable to take the required number of measurements and do the calculations within **SampleInterval=**. When it is beginning to log, the 16*plus* V2 checks all parameters, and if necessary it internally increases **SampleInterval=**.

Notes:
- The 16*plus* V2 requires verification when **InitLogging**, **SampleNumber=**, or **HeaderNumber=** are sent. The 16*plus* V2 responds: `this command will change the scan length and/or initialize logging. Repeat the command to verify.`
  Type the command again and press the Enter key to proceed. The 16*plus* V2 responds: `Scan length has changed, initializing logging`
- **InitLogging** and **SampleNumber=0** have identical effects. Use either command to initialize logging.
- **Do not initialize logging until all data has been uploaded.** These commands do not delete data; they reset the data pointer. **If you accidentally initialize logging before uploading**, recover data as follows:
  1. Set **SampleNumber=a** and **HeaderNumber=b**, where **a** and **b** are your estimate of number of samples and headers in memory.
  2. Upload data. If **a** is more than actual number of samples or **b** is more than actual number of headers in memory, data for non-existent samples/headers will be bad, random data. Review uploaded data file carefully and delete any bad data.
  3. If desired, increase **a** and/or **b** and upload data again, to see if there is additional valid data in memory.

Note:
The 16*plus* V2 automatically enters quiescent (sleep) state after 2 minutes without receiving a command. This timeout algorithm is designed to conserve battery energy if the user does not send **QS** to put the 16*plus* V2 to sleep.

General Setup Commands (*continued*)

NCycles=x

x= number of measurements to take and average for each sample. Range 1 – 100; ***default 1***. 16*plus* V2 takes and averages **NCycles=** measurements (each 0.25 seconds apart). For autonomous sampling and serial line sync mode, averaged data is stored in FLASH memory and (if **TxRealTime=Y**) transmitted real-time. Maximum **NCycles=** is *smaller* of 100 *or* [4 * (**SampleInterval** - 3)].

InitLogging

Initialize logging - after all previous data has been uploaded, initialize logging before starting to sample again to make entire memory available for recording. **InitLogging** sets sample number (**SampleNumber=**) and header number (**HeaderNumber=**) to 0 (sampling will start with sample 1 and header 1). If not set to 0, data will be stored after last recorded sample. **Do not send InitLogging until all existing data has been uploaded.**

SampleNumber=x

x= sample number for last sample in memory. After all previous data has been uploaded, send **SampleNumber=0** (sets sample and header number to 0) before starting to sample to make entire memory available for recording (sampling will start with sample 1 and header 1). If not set to 0, data will be stored after last recorded sample. **Do not send SampleNumber=0 until all existing data has been uploaded.**

HeaderNumber=x

x= header number for last header in memory. Typically only used to recover data if you accidentally initialize logging (using **InitLogging** or **SampleNumber=0**) before uploading all existing data. 16*plus* V2 can have a maximum of 1000 stored headers. Note that 16*plus* V2 writes a new header each time autonomous sampling is started and after every 2000 samples are stored in memory.

QS

Quit session and place 16*plus* V2 in quiescent (sleep) state. Main power turned off. Data logging and memory retention are not affected.

Pressure Sensor Setup Commands

Notes:
- The 16*plus* V2 requires verification when **PType=** is sent. The 16*plus* V2 responds: `this command will change the scan length and/or initialize logging. Repeat the command to verify.` Type the command again and press the Enter key to proceed. The 16*plus* V2 responds: `Scan length has changed, initializing logging`
- The 16*plus* V2 configuration (.con) file must match the **PType=** selection of internally mounted pressure sensor when viewing real-time data or processing uploaded data. View and edit the .con file in SEASAVE or SBE Data Processing. **PType=** is factory-set to match the ordered configuration.

PType=x

Internally mounted pressure sensor type.

x=0: No internally mounted pressure sensor.

x=1: Strain gauge.

x=3: Quartz with temperature compensation.

RefPress=x

x= reference pressure (gauge) in decibars to use if 16*plus* V2 does not include an internally mounted pressure sensor. 16*plus* V2 uses reference pressure in conductivity, salinity, and sound velocity calculation. Value entered for **RefPress=** is displayed in **GetCD** and **DS** responses if 16*plus* V2 does not include internally mounted pressure sensor.
Entry ignored if 16*plus* V2 includes internally mounted pressure sensor.
If 16*plus* V2 interfaces with an SBE 50 pressure sensor, it does **not** use SBE 50 data in conductivity, salinity, and sound velocity calculation.

Notes:
- The 16*plus* V2 does the integration for the Quartz pressure sensor *after* **NCycles=** measurements have been taken.
- **NCycles=**, **ParosIntegration=**, **DelayBeforeSampling=**, and **PumpMode=** affect the time required to sample. The 16*plus* V2 checks these parameters when beginning to log, and if necessary it internally increases **SampleInterval=** to provide enough time to take the required number of measurements and do the calculations within **SampleInterval=**.

ParosIntegration=x

x= integration time for optional internally mounted Quartz pressure sensor (not applicable for strain gauge pressure sensor). Range 1 – 600 seconds; default 1 second. Increasing integration time increases resolution.
See *Specifications* in *Section 2: Description of SBE 16plus V2* to determine resolution for Quartz pressure sensor.

Notes:

- The 16*plus* V2 requires verification when **Volt0 =** through **Volt5=** are sent. The 16*plus* V2 responds: `this command will change the scan length and/or initialize logging. Repeat the command to verify.` Type the command again and press the Enter key to proceed. The 16*plus* V2 responds: `Scan length has changed, initializing logging`
- The 16*plus* V2 configuration (.con) file must match this selection of number of external voltages when viewing real-time data or processing uploaded data. View and edit the .con file in SEASAVE or SBE Data Processing. These parameters are factory-set to match the ordered instrument configuration.
- External voltage numbers 0, 1, 2, 3, 4, and 5 correspond to wiring of sensors to a voltage channel on the 16*plus* V2 end cap (see *Dimensions and End Cap Connectors* in *Section 2: Description of SBE 16plus V2*). However, in the .con file, voltage 0 is the first external voltage in the data stream, voltage 1 is the second, etc.

Voltage Sensor Setup Commands

Volt0=x

x=Y: Enable external voltage 0.

x=N: Do not enable external voltage 0.

Volt1=x

x=Y: Enable external voltage 1.

x=N: Do not enable external voltage 1.

Volt2=x

x=Y: Enable external voltage 2.

x=N: Do not enable external voltage 2.

Volt3=x

x=Y: Enable external voltage 3.

x=N: Do not enable external voltage 3.

Volt4=x

x=Y: Enable external voltage 4.

x=N: Do not enable external voltage 4.

Volt5=x

x=Y: Enable external voltage 5.

x=N: Do not enable external voltage 5.

Example: Enable voltage sensors wired to channels 0 and 3 on end cap (user input in bold).

```
VOLT0=Y
VOLT1=N
VOLT2=N
VOLT3=Y
VOLT4=N
VOLT5=N
```

There will be 2 external sensor voltages in data stream. In .con file (in SBE Data Processing or SEASAVE), indicate *2* external voltage channels. Voltage 0 corresponds to sensor wired to external voltage channel 0; voltage 1 corresponds to sensor wired to external voltage channel 3.

Notes:

- If **DelayBeforeSampling** is too high, the 16*plus* V2 will not be able to take **NCycles** samples within **SampleInterval** seconds; the 16*plus* V2 internally increases **SampleInterval** to the smallest feasible number.
- Pump operation is affected by both **PumpMode=** and **DelayBeforeSampling=**. See *Pump Operation*.

DelayBeforeSampling=x

x= time (seconds) to wait after switching on external voltage sensors before sampling (0-600 seconds). ***Default 0 seconds***. Typical values if using:

- SBE 43 oxygen sensor – time is dependent on membrane thickness and water temperature (see *Pump Operation*). Use with **PumpMode=2**.

- Beckman- or YSI-type oxygen sensor – 120 to 180 seconds required to provide time for sensor to polarize. Use with **PumpMode=2**.

- Sea Tech fluorometer - 15 seconds required to provide time for sensor to stabilize.

Note:
If an ECO-FL with Bio-Wiper is installed and **Biowiper=N**, sending **GetSD** or **DS** will open the Bio-Wiper, but not provide enough powered time to close it again. If you then deploy the instrument with the Bio-Wiper open and with a delayed start time, the ECO-FL may become fouled because the Bio-Wiper will remain open until the first sample is completed.

Biowiper=x

x=Y: Configuration includes WET Labs ECO-FL fluorometer with Bio-Wiper. With this setup, 16*plus*V2 is powered longer for **GetSD** and **DS**, providing sufficient time for Bio-Wiper to open and then shut again if Bio-Wiper is set up to take 1 measurement for each sample (see *Application Note 72*).

x=N (***default***): No ECO-FL with Bio-Wiper.

RS-232 Sensor Setup Commands

Notes:

- The 16*plus* V2 requires verification when **SBE38=**, **SBE50=**, **GTD=**, or **DualGTD=** is sent. The 16*plus* V2 responds:
  `this command will change the scan length and/or initialize logging. Repeat the command to verify.`
  Type the command again and press the Enter key to proceed. The 16*plus* V2 responds:
  `Scan length has changed, initializing logging`
- The 16*plus* V2 configuration (.con) file must match this selection of RS-232 sensor when viewing real-time data or processing uploaded data. View and edit the .con file in SEASAVE or SBE Data Processing. These parameters are factory-set to match the ordered instrument configuration.
- See the SBE 38, SBE 50, or Pro-Oceanus GTD manual for command details for these instruments.

The 16*plus* V2 can interface with an SBE 38 secondary temperature sensor, an SBE 50 pressure sensor, or up to 2 Pro-Oceanus Gas Tension Devices (GTDs).

Setup for SBE 38:

Set up SBE 38 to interface with SBE 16*plus* V2, **before** you connect it to 16*plus* V2. Connect SBE 38 directly to computer, power with an external power supply, and (using SEATERM) set:

- **Baud rate** to same baud rate as 16*plus* V2 (**Baud=**)
- **Interface** to RS-232 (**Interface=232**)
- **Sampling** to begin when power applied (**AutoRun=Y**)
- **Output** to converted data (**Format=C**)

Connect SBE 38 to SBE 16*plus* V2 RS-232 bulkhead connector, using provided cable. In the 16*plus* V2, set **SBE38=Y** to enable interface.

SBE38=x

x=Y: Enable RS-232 SBE 38 secondary temperature sensor.

x=N: Do not enable SBE 38.

Setup for SBE 50:

Set up SBE 50 to interface with SBE 16*plus* V2, **before** you connect it to 16*plus* V2. Connect SBE 50 directly to computer, power with an external power supply, and (using SEATERM) set:

- **Baud rate** to same baud rate as 16*plus* V2 (**Baud=**).
- **Output** to converted data in psia, decibars, meters, or feet (**OutputFormat= 1**, **2**, **3**, **4**, **5**, or **6**).
  Note: **If you will be using SEASAVE or SBE Data Processing**, you **must** set the SBE 50 format to psia (**OutputFormat=1**).

Connect SBE 50 to SBE 16*plus* V2 RS-232 bulkhead connector, using provided cable. In the 16*plus* V2, set **SBE50=Y** to enable interface.

SBE50=x

x=Y: Enable RS-232 SBE 50 pressure sensor.

x=N: Do not enable SBE 50.

RS-232 Sensor Setup Commands (*continued*)

> **Note:**
> The 16*plus* V2 sample interval (**SampleInterval=**) must be greater than or equal to the sum of the times required to sample. Total time is affected by the following:
> - **Programmable pressure integration time for GTD**.
> - **Programmable temperature integration time for GTD**.
> - Minimum time required for 16*plus* V2 to take a sample (≈ 2.5 sec).
> - Time required for integration of optional Quartz pressure sensor (**ParosIntegration=**).
> - Time required for 16*plus* V2 to take and average **NCycles=** samples; samples are taken 0.25 sec apart.
> - Delay after providing power to external voltage sensors before sampling (**DelayBeforeSampling=**).
> - Time required to run pump before sampling (0.5 sec if **PumpMode=1**).

Setup for GTD:

Set up GTD to interface with SBE 16*plus* V2, **before** you connect it to 16*plus* V2. Connect GTD directly to computer, power with an external power supply, and (using software provided by Pro-Oceanus) set:

- **Baud rate** to same baud rate as 16*plus* V2.
- **Output** to millibars.
- Sum of **pressure integration time** and **temperature integration time** so that the GTD responds to a *take pressure reading* command in 40 seconds or less (required so that 16*plus* V2 does not *time out* while waiting for reply).

Connect GTD to SBE 16*plus* V2 RS-232 bulkhead connector, using provided cable (end labeled *Pro-Oceanus* to GTD and end labeled *Sea-Bird* to 16*plus* V2). In the 16*plus*V2, set:

- **GTD=Y** or **DualGTD=Y** to enable interface.
- **SendGTD=** to change IDs if necessary.

Each time a sample is to be taken, SBE 16*plus* V2 sends following commands to GTD (ID= 01, 02, etc.):

- ***ID00VR** <CR><LF> - get GTD firmware version; wait up to 3 seconds for reply.
- ***ID00SN** <CR><LF> - get GTD serial number; wait up to 5 seconds for reply.
- ***9900P5** <CR><LF> - command all GTDs to sample pressure; hold data in GTD.
- ***ID00DB** <CR.<LF> - get held pressure; wait up to 90 seconds for reply.
- ***9900Q5 <**CR><LF> - command all GTDs to sample temperature; hold data in GTD.
- ***ID00DB** <CR.<LF> - get held temperature; wait up to 90 seconds for reply.

> **Notes:**
> - A 16*plus* V2 with dual GTDs is shipped with a Y-cable installed for the GTDs. The GTD ends are labeled GTD #1 and #2, and Sea-Bird set the GTD IDs to match.
> - If **DualGTD=Y**, setting for **GTD=** has no effect.

GTD=x — **x=Y**: Enable RS-232 GTD.
x=N: Do not enable GTD.

DualGTD=x — **x=Y**: Enable dual (2) GTDs.
x=N: Do not enable dual GTDs.

TGTD — Measure GTD(s), output 1 sample of data from each GTD (firmware version, serial number, pressure, and temperature).

Example: Output GTD data for system with dual GTDs (user input in bold):

```
TGTD
GTD#1 VR reply = *0001VR=s2.03    (GTD firmware version)
GTD#2 VR reply = *0002VR=s2.03    (GTD firmware version)
GTD#1 SN reply = *0001SN = 75524    (GTD serial number)
GTD#2 SN reply = *0002SN = 81440    (GTD serial number)
GTD#1 pressure reply = *00011010.04661, p = 101004661   (millibars x 10^5)
GTD#2 pressure reply = *00021010.01580, p = 101001580   (millibars x 10^5)
GTD#1 temperature reply = *000123.49548, t = 23.4955    (°C)
GTD#2 temperature reply = *000223.0357038, t = 23.0357   (°C)
```

SendGTD=command — Command 16*plus* V2 to send **command** to GTD and receive response; **command** can be any command recognized by GTD (see GTD manual).

Examples: (user input in bold)

Send firmware version command to GTD #1:

```
SENDGTD=*0100vr
Sending GTD: **0100vr
GTD RX = *0001VR=s2.03
```

Send serial number command to GTD #2:

```
SENDGTD=*0200sn
Sending GTD: **0200sn
GTD RX = *0002SN=81440
```

Output Format Setup Commands

See *Data Output Formats* after the command descriptions for complete details on all the formats.

Note:
Output format does not affect how data is stored in FLASH memory. Sea-Bird's real-time data acquisition (SEASAVE) and data processing (SBE Data Processing) software require data in raw hexadecimal.

Typical use of the output format command is:
- Before beginning logging:
  - **If you will use SEASAVE to view real-time data** - Set output format to raw hex.
  - **If you will use the terminal program to view real-time data** - Set output format to converted decimal for ease in viewing real-time data.
- After stopping sampling, use the terminal program's Upload menu to upload data from memory. This automatically uploads the data in raw hex (regardless of the **OutputFormat=** setting), so the uploaded data is compatible with SBE Data Processing for processing and with SEASAVE for viewing archived data.

OutputFormat=x

x=0: Output raw frequencies and voltages in hexadecimal. **Must use this format for acquiring and viewing real-time data in SEASAVE**. When using terminal program's Upload menu, terminal program always upload data from memory in raw hex (compatible with SBE Data Processing), regardless of user-programmed **OutputFormat=**.

x=1: Output converted (engineering units) data in hexadecimal.

x=2: Output raw frequencies and voltages in decimal.

x=3: Output converted (engineering units) data in decimal; required to output salinity or sound velocity.

x=4: Not a valid output format.

x=5: Output converted (engineering units) data in decimal, in XML.

OutputSal=x

x=Y: Calculate and output salinity (psu). Only applies if **OutputFormat=3** or **5**.

x=N: Do not.

OutputSV=x

x=Y: Calculate and output sound velocity (m/sec), using Chen and Millero formula (UNESCO Technical Papers in Marine Science #44). Only applies if **OutputFormat=3** or **5**.

x=N: Do not.

OutputUCSD=x

x=Y: Calculate and output density sigma-t (kg/m^3), battery voltage, and operating current (mA) with data polled while logging. Voltage and current measured after delay before sampling,
but before sampling. Only applies if **OutputFormat=3** or **5**.

x=N: Do not.

Autonomous Sampling (logging) Commands

Notes:
- In the terminal program, to save real-time data to a file, click the Capture menu before beginning logging.
- If the FLASH memory is filled to capacity, data sampling and transmission of real-time data (if enabled) continue, but excess data is not saved in memory.
- If the maximum number of headers is reached but there is still room for samples in FLASH memory, data sampling and transmission of real-time data (if enabled) continue without writing additional headers.
- If the 16*plus* V2 is sampling and the voltage is less than the cut-off voltage (7.5 volts) for five consecutive scans, the 16*plus* V2 halts logging and displays `WARNING: LOW BATTERY VOLTAGE`.

Autonomous sampling commands direct the SBE 16*plus* V2 to sample at a pre-programmed interval. When commanded to start sampling with **StartNow** or **StartLater**, the 16*plus* V2 takes samples, stores the data in its FLASH memory, transmits real-time data (if **TxRealTime=Y**), and enters quiescent (sleep) state between samples.

To start sampling, use **StartNow**; sampling starts **SampleInterval=** seconds after receipt of **StartNow**. Alternatively, use **StartDateTime=** and **StartLater** to start sampling at a designated date and time. The first time sampling starts after receipt of the initialize logging command (**InitLogging**), data recording starts at the beginning of memory and any previously recorded data is written over. When **Stop** is sent, recording stops. Each time **StartNow** or **StartLater** is sent again, recording continues, with new data stored after the previously recorded data. A new header is written each time sampling starts and every 2000 samples thereafter. A maximum of 1000 headers can be written.

The SBE 16*plus* V2 responds only to **GetCD**, **GetSD**, **GetCC**, **GetEC**, **ResetEC**, **GetHD**, **DS**, **DCal**, **TS**, **SL**, **SLT**, **GetLastSamples:x**, **QS**, and **Stop** while sampling. If you wake the 16*plus* V2 (for example, to send **DS** to check progress), it temporarily stops sampling. Sampling resumes when it goes back to sleep again (either by sending **QS** or after 2-minute timeout).

Note:
NCycles=, **ParosIntegration=**, and **DelayBeforeSampling=** affect the time required to sample. If these are too high, the 16*plus* V2 is unable to take the required number of measurements and do the calculations within **SampleInterval=**. When it is beginning to log, the 16*plus* V2 checks all parameters, and if necessary it internally increases **SampleInterval=**.

SampleInterval=x — **x**= interval (seconds) between samples (10 - 14,400 seconds).

> *Example:* If **SampleInterval=10** and **NCycles=4**, every 10 seconds 16*plus* V2 takes 4 measurements (each 0.25 seconds apart), averages data from 4 measurements, and stores averaged data in FLASH memory.

Notes:
- After receiving **StartLater**, the 16*plus* V2 displays `waiting to start at...` in reply to **GetSD** or **DS**. Once sampling starts, the reply displays `logging`.
- If the delayed start time has already passed when **StartLater** is received, the 16*plus* V2 executes **StartNow**.
- If the delayed start date and time is more then 1 month in the future when **StartLater** is received, the 16*plus* V2 assumes that the user made an error in setting the delayed start date and time, and it executes **StartNow**.

StartNow — Start autonomous sampling now.

StartDateTime=mmddyyyyhhmmss — Set delayed start month, day, year, hour, minute, and second.

StartLater — Start autonomous sampling at time set with **StartDateTime=**.

> *Example:* Program 16*plus* V2 to start logging on 20 March 2008 12:05:00 (user input in bold).
>
> **`STARTDATETIME=02202008120500`**
> **`STARTLATER`**

Notes:
- You may need to send **Stop** several times to get the 16*plus* V2 to respond.
- You must stop sampling before uploading data.

Stop — Stop autonomous sampling or stop waiting to start autonomous sampling (if **StartLater** was sent but sampling has not begun yet). Press Enter key before sending **Stop**.

Polled Sampling Commands

Notes:
- The 16*plus* V2 has a buffer that stores the most recent data samples. Unlike data in the FLASH memory, data in the buffer is erased upon removal or failure of power.
- *Leave power on* in **SL**, **SLT**, **TS**, and **TSSOn** descriptions refers to power for the 16*plus* V2 as well as for a pump and any auxiliary sensors. Power remains on until **QS** is sent or the instrument times out (after 2 minutes).

These commands request a single sample. The 16*plus* V2 always stores data for the most recent sample in its buffer. Some polled sampling commands also store data in FLASH memory - the 16*plus* V2 will not execute the *store data in FLASH memory* portion of those commands while sampling autonomously.

SL — Output last sample from buffer (obtained with polled sampling command, or latest sample from autonomous sampling), and leave power on.

SLT — Output last sample from buffer, then take new sample and store data in buffer. Leave power on. **Data is not stored in FLASH memory**.

TS — Take new sample, store data in buffer, output data, and leave power on. **Data is not stored in FLASH memory**.

TSS — Take new sample, **store data in buffer and FLASH memory**, output data, and turn power off.

TSSOn — Take new sample, **store data in buffer and FLASH memory**, output data, and leave power on.

GetLastSamples:x — Output last **x** samples from FLASH memory. If **x** is greater than the number of samples in memory, 16*plus* V2 outputs all samples in memory. If **x** is omitted, 16*plus* V2 outputs just the last sample.

Serial Line Sync Commands

Note:
See *Sampling Modes*.

SyncMode=x — **x=Y**: Enable serial line synchronization. When RS-232 RX line is high (3-10 VDC) for 1 to 1000 milliseconds, 16*plus* V2 takes a sample, stores data in FLASH memory, transmits real-time data (if **TxRealTime=Y**), and powers down.

x=N: Disable serial line synchronization.

SyncWait=x — **x**= time (in seconds) 16*plus* V2 monitors RS-232 line for commands after taking a sample in serial line sync mode. Range 0 to 120 seconds; default 0 seconds.

Data Upload Commands

Notes:

- **Use the Upload menu to upload data that will be processed by SBE Data Processing or viewed in SEASAVE**. Manually entering a data upload command does not produce data with the required header information for processing by our software. These commands are included here for reference for users who are writing their own software.
- **If not using the Upload menu** - To save data to a file, click the Capture menu before entering a data upload command.
- See *Data Output Formats*.

Stop sampling autonomously before uploading data.
If manually sending a data upload command, data is uploaded in the format defined by **OutputFormat=**.

GetSamples:b,e or **DDb,e** — Upload data from sample **b** to sample **e**. If **b** and **e** are omitted, all data is uploaded. First sample number is 1.

Examples: Upload samples 1 to 1000 to a file (user input in bold):
(Click Capture menu and enter desired filename in dialog box.)
GETSAMPLES:1,1000
or
DD1,1000

GetHeaders:b,e or **DHb,e** — Upload header **b** to header **e**. If **b** and **e** are omitted, all headers are uploaded. First header number is 1. Header includes:

- header number
- month, day, hour, minute, and second when header was written
- first and last sample for header
- interval between samples (**SampleInterval=**)
- reason logging was halted (batfail = battery voltage too low; stop cmd = received **Stop** command or Home or Ctrl Z character; timeout = error condition; unknown = error condition; ?????? = error condition)

Example: Upload second header to a file (user input in bold):
(Click Capture menu and enter desired filename in dialog box.)
GETHEADERS:2,2
or
DH2,2
16*plus* V2 responds:

```
hdr 2 30 Nov 2007 12:30:33 samples 35 to 87, int=60, stop=stop cmd
```

Testing Commands

> **Note:**
> ***If your 16plus V2 includes an optional pump:***
> Testing commands do not automatically turn the pump on. Thus, for sensors plumbed with the pump, they report data from essentially the same sample of water for all 100 measurements, because the pump does not run but the pump and associated plumbing prevent water from freely flowing through the conductivity cell and other plumbed sensors (for example, dissolved oxygen sensor). To get data from fresh samples, send **PumpOn** before sending a testing command, and then send **PumpOff** when the test is complete.

The 16*plus* V2 takes and outputs **100 samples** for each test (except as noted); data is **not** stored in FLASH memory. Press the Esc key (or send a break character) to stop a test.

TC Measure conductivity, output converted data.

TCR Measure conductivity, output raw data.

TT Measure temperature, output converted data.

TTR Measure temperature, output raw data.

TP Measure internally mounted pressure (strain gauge or Quartz), output converted data.

TPR Measure internally mounted pressure (strain gauge or Quartz), output raw data.

TV Measure 6 external voltage channels, output converted data.

TVR Measure voltages read by A/D converter, output raw data:

Column	Output
1-6	External voltages
7	Main battery voltage / 11
8	Back-up lithium battery voltage / 3.741
9	External current / 333.33
10	Pressure temperature voltage

TF Measure frequency (internally mounted Quartz pressure sensor), output converted pressure data.

TFR Measure frequency (internally mounted Quartz pressure sensor), output raw data.

T38 Measure SBE 38 (secondary temperature), output converted data.

T50 Measure SBE 50 pressure, output converted data.

PumpOn Turn pump on for testing purposes. Use this command:
- Before sending testing command to obtain pumped data from sensors plumbed with the pump, or
- To test pump.

PumpOff Turn pump off for testing purposes.

Calibration Coefficients Commands

Notes:
- F = floating point number
  S = string with no spaces
- If using an SBE 38 secondary temperature sensor or SBE 50 pressure sensor, its calibration coefficients are not stored in the 16*plus* V2 EEPROM. View and/or modify the instrument's calibration coefficients by connecting the instrument to the computer directly and using SEATERM.

Calibration coefficients are initially factory-set and should agree with Calibration Certificates shipped with the 16*plus* V2.

Temperature

TCalDate=S	**S**=calibration date
TA0=F	**F**=A0
TA1=F	**F**=A1
TA2=F	**F**=A2
TA3=F	**F**=A3
TOffset=F	**F**=offset correction

Conductivity

CCalDate=S	**S**=calibration date
CG=F	**F**=G
CH=F	**F**=H
CI=F	**F**=I
CJ=F	**F**=J
CPCor=F	**F**=pcor
CTCor=F	**F**=tcor
CSlope=F	**F**=slope correction

Internally Mounted Pressure - General

PCalDate=S	**S**=calibration date
PRange=F	**F**=sensor full scale range (**psia**)
POffset=F	**F**=offset correction (**decibars**)

Internally Mounted Strain Gauge Pressure

PA0=F	**F**=A0
PA1=F	**F**=A1
PA2=F	**F**=A2
PTempA0=F	**F**=pressure temperature A0
PTempA1=F	**F**=pressure temperature A1
PTempA2=F	**F**=pressure temperature A2
PTCA0=F	**F**=pressure temperature compensation ptca0
PTCA1=F	**F**=pressure temperature compensation ptca1
PTCA2=F	**F**=pressure temperature compensation ptca2
PTCB0=F	**F**=pressure temperature compensation ptcb0
PTCB1=F	**F**=pressure temperature compensation ptcb1
PTCB2=F	**F**=pressure temperature compensation ptcb2

Internally Mounted Quartz Pressure

PC1=F	**F**=C1
PC2=F	**F**=C2
PC3=F	**F**=C3
PD1=F	**F**=D1
PD2=F	**F**=D2
PT1=F	**F**=T1
PT2=F	**F**=T2
PT3=F	**F**=T3
PT4=F	**F**=T4
PSlope=F	**F**=slope correction

External Frequency

ExtFreqSF=F	**F**=external frequency scale factor (applies to internally mounted Quartz pressure sensor)

Note:
If using auxiliary A/D sensors (**Volt0=** through **Volt5=**), their calibration coefficients are not stored in the 16*plus* V2 EEPROM, but are stored in the 16*plus* V2 configuration (.con) file. View and/or modify the calibration coefficients using the Configure menu in SBE Data Processing or the Configure Inputs menu in SEASAVE.

Voltage Channels

The following commands set voltage channel offsets and slopes **at the factory**. These are properties of the 16*plus* V2's electronics, and are not calibration coefficients for the auxiliary sensors. These commands are included here for completeness, **but should never be used by the customer**.

VOffset0=	**VSlope0=**
VOffset1=	**VSlope1=**
VOffset2=	**VSlope2=**
VOffset3=	**VSlope3=**
VOffset4=	**VSlope4=**
VOffset5=	**VSlope5=**

Hardware Configuration Commands

The following commands are used to set manufacturing date, PCB serial numbers, PCB assembly numbers, and auxiliary channel sensor types and serial number, **at the factory**.

Factory Settings – do not modify in the field
SetMfgDate=
SetPcbSerialNum1=
SetPcbSerialNum2=
SetPcbSerialNum3=
SetPcbSerialNum4=
SetPcbAssembly1=
SetPcbAssembly2=
SetPcbAssembly3=
SetPcbAssembly4=

Auxiliary Sensor Settings – can be modified in the field to accommodate changes in auxiliary sensors cabled to the 16plus V2
SetVoltType0=
SetVoltSN0=
SetVoltType1=
SetVoltSN1=
SetVoltType2=
SetVoltSN2=
SetVoltType3=
SetVoltSN3=
SetVoltType4=
SetVoltSN4=
SetVoltType5=
SetVoltSN5=

Data Output Formats

Note:
For the date and time output, time is the time at the **start** of the sample, after:
- a small amount of time (1 to 2 seconds) for the 16*plus* V2 to wake up and prepare to sample, and
- any programmed **DelayBeforeSampling=**.

For example, if the 16*plus* V2 is programmed to wake up and sample at 12:00:00, and **DelayBeforeSampling=20**, the output time for the first sample will be 12:00:21 or 12:00:22.

The SBE 16*plus* V2 stores data in a compact machine code. Data is converted and output in the user-selected format without affecting data in memory. Because memory data remains intact until deliberately overwritten, you can upload in one format, then choose another format and upload again.

Output format is dependent on **OutputFormat= (0, 1, 2, 3, or 5)** and on the command used to retrieve the data, as detailed below. The inclusion of some data is dependent on the system configuration - if the system does not include the specified sensor, the corresponding data is not included in the output data stream, shortening the data string.

If outputting real-time data (**TxRealTime=Y**) for autonomous (logging) sampling or for serial line sync mode, a # sign precedes the real-time output for each sample.

Notes:

- If you will be using SEASAVE to acquire real-time data, you must set **OutputFormat=0**.
- When using the terminal program's Upload menu, the terminal program always upload data from memory in raw hex, regardless of the user-programmed format, providing the data in a format that SBE Data Processing can use.
- Our software uses the equations shown to perform these calculations; alternatively, you can use the equations to develop your own processing software.
- The internally mounted pressure sensor is an absolute sensor, so its **raw** output includes the effect of atmospheric pressure (14.7 psi). As shown on the Calibration Sheet, Sea-Bird's calibration (and resulting calibration coefficients) is in terms of psia. However, when outputting pressure in **engineering units**, the 16*plus* V2 outputs pressure relative to the ocean surface (i.e., at the surface the output pressure is 0 decibars). The 16*plus* V2 uses the following equation to convert psia to decibars:
  pressure (db) =
  [pressure (psia) - 14.7] * 0.689476
- Although **OutputFormat=0** outputs *raw* data for temperature, conductivity, etc., it outputs engineering units for SBE 38, SBE 50, and GTD data.
  SBE 50 units are dependent on **OutputFormat=** programmed into the SBE 50; if you will be using SEASAVE or SBE Data Processing, you must set the SBE 50 format to psia (**OutputFormat=1**).

OutputFormat=0 (raw frequencies and voltages in Hex)

Data is output in the order listed, with no spaces or commas between parameters. Shown with each parameter is the number of digits, and how to calculate the parameter from the data (use the decimal equivalent of the hex data in the equations).

1. Temperature
   A/D counts = tttttt
2. Conductivity
   conductivity frequency (Hz) = cccccc / 256
3. Internally mounted strain gauge pressure sensor pressure (if **PType=1**)
   A/D counts = pppppp
4. Internally mounted strain gauge pressure sensor pressure temperature compensation (if **PType=1**)
   pressure temperature compensation voltage = vvvv / 13,107
5. Internally mounted Quartz pressure sensor pressure (if **PType=3**)
   pressure frequency (Hz) = pppppp / 256
6. Internally mounted Quartz pressure sensor temperature compensation (if **PType=3**)
   temperature compensation voltage = vvvv / 13,107
7. External voltage 0 (if **Volt0=Y**)
   external voltage 0= vvvv / 13,107
8. External voltage 1 (if **Volt1=Y**)
   external voltage 1 = vvvv / 13,107
9. External voltage 2 (if **Volt2=Y**)
   external voltage 2 = vvvv / 13,107
10. External voltage 3 (if **Volt3=Y**)
    external voltage 3 = vvvv / 13,107
11. External voltage 4 (if **Volt4=Y**)
    external voltage 4 = vvvv / 13,107
12. External voltage 5 (if **Volt5=Y**)
    external voltage 5 = vvvv / 13,107
13. SBE 38 secondary temperature (if **SBE38=Y**)
    SBE 38 temperature (°C, ITS-90) = (tttttt / 100,000) – 10
14. SBE 50 strain gauge pressure (if **SBE50=Y**)
    SBE 50 pressure (decibars, psia, meters, or feet) = (pppppp / 10,000) - 100
15. GTD #1 pressure (if **GTD=Y** or **DualGTD=Y**)
    GTD #1 pressure (millibars) = pppppppp / 100,000
16. GTD #1 temperature (if **GTD=Y** or **DualGTD=Y**)
    GTD #1 temperature (°C, ITS-90) = (tttttt / 100,000) - 10
17. GTD #2 pressure (if **DualGTD=Y**)
    GTD #2 pressure (millibars) = pppppppp / 100,000
18. GTD #2 temperature (if **DualGTD=Y**)
    GTD #2 temperature (°C, ITS-90) = (tttttt / 100,000) - 10
19. Time
    seconds since January 1, 2000 = ssssssss

Example: 16*plus* V2 with internally mounted strain gauge pressure sensor and 2 external voltages sampled,
example scan = ttttttccccccppppppvvvvvvvvvvvvssssssss = 0A53711BC7220C14C17D82030505940EC4270B

- Temperature = tttttt = 0A5371 (676721 decimal);
  temperature A/D counts = 676721
- Conductivity = 1BC722 (1820450 decimal);
  conductivity frequency = 1820450 / 256 = 7111.133 Hz
- Internally mounted strain gauge pressure = pppppp = 0C14C1 (791745 decimal);
  Strain gauge pressure A/D counts = 791745
- Internally mounted strain gauge temperature compensation = vvvv = 7D82 (32,130 decimal);
  Strain gauge temperature = 32,130 / 13,107 = 2.4514 volts
- First external voltage = vvvv = 0305 (773 decimal); voltage = 773 / 13,107 = 0.0590 volts
- Second external voltage = vvvv = 0594 (1428 decimal); voltage = 1428 / 13,107 = 0.1089 volts
- Time = ssssssss = 0EC4270B (247,736,075 decimal)
  seconds since January 1, 2000 = 247,736,075

OutputFormat=1 (engineering units in Hex)

Data is output in the order listed, with no spaces or commas between the parameters. Shown with each parameter is the number of digits, and how to calculate the parameter from the data (use the decimal equivalent of the hex data in the equations).

1. Temperature
   temperature (°C, ITS-90) = (tttttt / 100,000) - 10
2. Conductivity
   Conductivity (S/m) = (cccccc / 1,000,000) - 1
3. Internally mounted pressure (strain gauge or Quartz - **PType=1** or **3**)
   pressure (decibars) = (pppppp / 1,000) - 100
4. External voltage 0 (if **Volt0=Y**)
   external voltage 0= vvvv / 13,107
5. External voltage 1 (if **Volt1=Y**)
   external voltage 1 = vvvv / 13,107
6. External voltage 2 (if **Volt2=Y**)
   external voltage 2 = vvvv / 13,107
7. External voltage 3 (if **Volt3=Y**)
   external voltage 3 = vvvv / 13,107
8. External voltage 4 (if **Volt4=Y**)
   external voltage 4 = vvvv / 13,107
9. External voltage 5 (if **Volt5=Y**)
   external voltage 5 = vvvv / 13,107
10. SBE 38 secondary temperature (if **SBE38=Y**)
    SBE 38 temperature (°C, ITS-90) = (tttttt / 100,000) – 10
11. SBE 50 strain gauge pressure (if **SBE50=Y**)
    SBE 50 pressure (decibars, psia, meters, or feet) = (pppppp / 10,000) - 100
12. GTD #1 pressure (if **GTD=Y** or **DualGTD=Y**)
    GTD #1 pressure (millibars) = pppppppp / 100,000
13. GTD #1 temperature (if **GTD=Y** or **DualGTD=Y**)
    GTD #1 temperature (°C, ITS-90) = (tttttt / 100,000) - 10
14. GTD #2 pressure (if **DualGTD=Y**)
    GTD #2 pressure (millibars) = pppppppp / 100,000
15. GTD #2 temperature (if **DualGTD=Y**)
    GTD #2 temperature (°C, ITS-90) = (tttttt / 100,000) - 10
16. Time
    seconds since January 1, 2000 = ssssssss

Note:
SBE 50 units are dependent on **OutputFormat=** programmed into the SBE 50.

Example: 16*plus* V2 with internally mounted strain gauge pressure sensor and 2 external voltages sampled,
example scan = ttttttccccccppppppvvvvvvvvssssssss
= 3385C40F42FE0186DE030505940EC4270B

- Temperature = tttttt = 3385C4 (3376580 decimal);
  temperature (°C, ITS-90) = (3376580 / 100,000) - 10 = 23.7658
- Conductivity = cccccc = 0F42FE (1000190 decimal);
  conductivity (S/m) = (1000190 / 1,000,000) - 1 = 0.00019
- Internally mounted pressure = pppppp = 0186DE (100062 decimal);
  pressure (decibars) = (100062 / 1,000) - 100 = 0.062
- First external voltage = vvvv = 0305 (773 decimal); voltage = 773 / 13,107 = 0.0590 volts
- Second external voltage = vvvv = 0594 (1428 decimal); voltage = 1428 / 13,107 = 0.1089 volts
- Time = ssssssss = 0EC4270B (247,736,075 decimal)
  seconds since January 1, 2000 = 247,736,075

OutputFormat=2 (raw frequencies and voltages in decimal)

Data is output in the order listed, with a comma followed by a space between each parameter. Shown with each parameter are the number of digits and the placement of the decimal point. Leading zeros are suppressed, except for one zero to the left of the decimal point.

1. Temperature
   A/D counts = tttttt
2. Conductivity
   conductivity frequency (Hz) = cccc.ccc
3. Internally mounted strain gauge pressure sensor pressure (if **PType=1**)
   A/D counts = pppppp
4. Internally mounted strain gauge pressure sensor pressure temperature compensation (if **PType=1**)
   pressure temperature compensation voltage = v.vvvv
5. Internally mounted Quartz pressure sensor pressure (if **PType=3**)
   Quartz pressure frequency (Hz) = ppppp.ppp
6. Internally mounted Quartz pressure sensor temperature compensation (if **PType=3**)
   Quartz temperature compensation voltage = v.vvvv
7. External voltage 0 (if **Volt0=Y**)
   external voltage 0= v.vvvv
8. External voltage 1 (if **Volt1=Y**)
   external voltage 1 = v.vvvv
9. External voltage 2 (if **Volt2=Y**)
   external voltage 2 = v.vvvv
10. External voltage 3 (if **Volt3=Y**)
    external voltage 3 = v.vvvv
11. External voltage 4 (if **Volt4=Y**)
    external voltage 4 = v.vvvv
12. External voltage 5 (if **Volt5=Y**)
    external voltage 5 = v.vvvv
13. SBE 38 secondary temperature (if **SBE38=Y**)
    SBE 38 temperature (°C, ITS-90) = ttt.tttt
14. SBE 50 strain gauge pressure (if **SBE50=Y**)
    SBE 50 pressure (decibars, psia, meters, or feet) = pppp.ppp
15. GTD #1 pressure (if **GTD=Y** or **DualGTD=Y**)
    GTD #1 pressure (millibars) = ppppppppp / 100,000
16. GTD #1 temperature (if **GTD=Y** or **DualGTD=Y**)
    GTD #1 temperature (°C, ITS-90) = tt.ttt
17. GTD #2 pressure (if **DualGTD=Y**)
    GTD #2 pressure (millibars) = ppppppppp / 100,000
18. GTD #2 temperature (if **DualGTD=Y**)
    GTD #2 temperature (°C, ITS-90) = tt.ttt
19. Time
    date, time = dd Mmm yyyy, hh:mm:ss (day month year hour:minute:second)

Notes:
- Although **OutputFormat=2** outputs *raw* data for temperature, conductivity, etc., it outputs engineering units for SBE 38, SBE 50, and GTD data.
- SBE 50 units are dependent on **OutputFormat=** programmed into the SBE 50.

Example: 16*plus* V2 with internally mounted strain gauge pressure sensor and 2 external voltages sampled,
example scan = tttttt, cccc.ccc, pppppp, v.vvvv, v.vvvv, v.vvvv, dd mmm yyyy, hh:mm:ss
= 676721, 7111.133, 791745, 2.4514, 0.0590, 0.1089, 7 Nov 2007, 07:34:35

- Temperature = tttttt = 676721; temperature A/D counts = 676721
- Conductivity = cccc.ccc = 7111.133; conductivity frequency = 7111.133 Hz
- Internally mounted strain gauge pressure = pppppp = 791745; Strain gauge pressure A/D counts = 791745
- Internally mounted strain gauge temperature compensation = v.vvvv = 2.4514; Strain gauge temperature = 2.4514 volts
- First external voltage = v.vvvv = 0.0590; voltage = 0.0590 volts
- Second external voltage = v.vvvv = 0.1089; voltage = 0.1089 volts
- Date, time = dd Mmm yyyy, hh:mm:ss = 7 Nov 2007, 07:34:35 Date, time = 7 November 2007, 07:34:35

OutputFormat=3 (engineering units in decimal)

Data is output in the order listed, with a comma followed by a space between each parameter. Shown with each parameter are the number of digits and the placement of the decimal point. Leading zeros are suppressed, except for one zero to the left of the decimal point.

Uploaded Data (from **GetSamples:b,e**, or **DDb,e**):

1. Temperature
   temperature (°C, ITS-90) = ttt.tttt
2. Conductivity
   Conductivity (S/m) = cc.ccccc
3. Internally mounted pressure (strain gauge or Quartz - **PType=1** or **3**)
   pressure (decibars) = pppp.ppp
4. External voltage 0 (if **Volt0=Y**)
   external voltage 0= v.vvvv
5. External voltage 1 (if **Volt1=Y**)
   external voltage 1 = v.vvvv
6. External voltage 2 (if **Volt2=Y**)
   external voltage 2 = v.vvvv
7. External voltage 3 (if **Volt3=Y**)
   external voltage 3 = v.vvvv
8. External voltage 4 (if **Volt4=Y**)
   external voltage 4 = v.vvvv
9. External voltage 5 (if **Volt5=Y**)
   external voltage 5 = v.vvvv
10. SBE 38 secondary temperature (if **SBE38=Y**)
    SBE 38 temperature (°C, ITS-90) = ttt.tttt
11. SBE 50 strain gauge pressure (if **SBE50=Y**)
    SBE 50 pressure (decibars, psia, meters, or feet) = pppp.ppp
12. GTD #1 pressure (if **GTD=Y** or **DualGTD=Y**)
    GTD #1 pressure (millibars) = pppppppp / 100,000
13. GTD #1 temperature (if **GTD=Y** or **DualGTD=Y**)
    GTD #1 temperature (°C, ITS-90) = tt.ttt
14. GTD #2 pressure (if **DualGTD=Y**)
    GTD #2 pressure (millibars) = pppppppp / 100,000
15. GTD #2 temperature (if **DualGTD=Y**)
    GTD #2 temperature (°C, ITS-90) = tt.ttt
16. Salinity (if **OutputSal=Y**)
    salinity (psu) = sss.ssss
17. Sound velocity (if **OutputSV=Y**)
    sound velocity (meters/second) = vvvv.vvv
18. Time
    date, time = dd Mmm yyyy, hh:mm:ss (day month year hour:minute:second)

Note:
SBE 50 units are dependent on **OutputFormat=** programmed into the SBE 50.

Example: 16*plus* V2 with internally mounted strain gauge pressure sensor and 2 external voltages sampled,
example scan = ttt.tttt, cc.ccccc, pppp.ppp, v.vvvv, v.vvvv, dd mmm yyyy, hh:mm:ss
= 23.7658, 0.00019, 0.062, 0.0590, 0.1089, 7 Nov 2007, 07:34:35

- Temperature = ttt.tttt = 23.7658; temperature (°C, ITS-90) = 23.7658
- Conductivity = cc.ccccc = 0.00019; conductivity (S/m) = 0.00019
- Internally mounted pressure = pppp.ppp = 0.062; pressure (decibars) = 0.062
- First external voltage = v.vvvv = 0.0590; voltage = 0.0590 volts
- Second external voltage = v.vvvv = 0.1089; voltage = 0.1089 volts
- Date, time = dd Mmm yyyy, hh:mm:ss = 7 Nov 2007, 07:34:35 Date, time = 7 November 2007, 07:34:35

Polled Data from SL, SLT, TS, TSS, or TSSOn:
If **OutputUCSD=Y** and the 16*plus* V2 is logging (autonomous sampling is in progress), data is followed by density sigma-t in kg/m^3 (ddd.dddd), battery voltage (vv.v), and operating current in mA (ccc.c), each separated by a comma and a space. The rest of the data stream is as described above for uploaded data.

OutputFormat=5 (engineering units in decimal, in XML)

> **Note:**
> **OutputFormat=5** is listed in the **GetCD** and **DS** response as `converted XML UVIC`.

Data is output in the order listed, with **no** carriage return or line feed between each parameter (however, there is a carriage return and line feed at the end of the data stream, after the </datapacket> closing tag). Shown with each parameter are the number of digits and the placement of the decimal point. Leading zeroes are suppressed, except for one zero to the left of the decimal point.

> **Note:**
> For ease in reading, the data structure is shown with each XML tag on a separate line. However, there are no carriage returns or line feeds between tags (see example below).

Uploaded Data (from GetSamples:b,e or DDb,e):

<?xml?>	
<datapacket>	
<hdr>	
<mfg>Sea-Bird</mfg>	
<model>16plus</model>	
<sn>nnnnnnn</sn>	
</hdr>	
<data>	
<t1>ttt.tttt</t1>	
<c1>cc.ccccc</c1>	
<p1>pppp.ppp </p1>	(if **PType=1** or **3**)
<v0>v.vvvv</v0>	(if **Volt0=Y**)
<v1>v.vvvv</v1>	(if **Volt1=Y**)
<v2>v.vvvv</v2>	(if **Volt2=Y**)
<v3>v.vvvv</v3>	(if **Volt3=Y**)
<v4>v.vvvv</v4>	(if **Volt4=Y**)
<v5>v.vvvv</v5>	(if **Volt5=Y**)
<ser1>	
<type>*sbe38, sbe50, or gtd*</type>	(indicates type of RS-232 sensor)
<t38>ttt.tttt</t38>	(if **SBE38=Y**)
<p2>pppp.ppp</p2>	(if **SBE50=Y**)
<p1>ppppppppp</p1>	(if **GTD=Y** or **DualGTD=Y**)
<t1>tt.ttt</t1>	(if **GTD=Y** or **DualGTD=Y**)
<p2>ppppppppp</p2>	(if **DualGTD=Y**)
<t2>tt.ttt</t2>	(if **DualGTD=Y**)
<ser1>	
<sal>sss.ssss</sal>	(if **OutputSal=Y**)
<sv>vvvv.vvv</sv>	(if **OutputSV=Y**)
<dt>yyyy-mm-ddThh:mm:ss</dt>	
</data>	
</datapacket>	

where

- Serial number = nnnnnnn
- Temperature (°C, ITS-90) = ttt.tttt
- Conductivity (S/m) = cc.ccccc
- Internally mounted pressure (decibars) = pppp.ppp
- External voltage = v.vvvv (for voltage 0, 1, 2, 3, 4, and 5)
- SBE 38 temperature (°C, ITS-90) = ttt.tttt
- SBE 50 pressure (decibars, psia, meters, or feet) = pppp.ppp
- GTD pressure (millibars) = ppppppppp / 100,000 (for GTD #1 and #2)
- GTD temperature (°C, ITS-90) = tt.ttt (for GTD #1 and #2)
- Salinity (psu) = sss.ssss
- Sound velocity (meters/second) = vvvv.vvv
- Date, time = year month day T hour:minute:second (yyyy-mm-ddThh:mm:ss)

> **Note:**
> SBE 50 units are dependent on **OutputFormat=** programmed into the SBE 50.

Example: 16*plus* V2 with internally mounted strain gauge pressure sensor and 2 external voltages sampled, example scan =

<?xml?><datapacket><hdr><mfg>Sea-Bird</mfg><model>16plus</model><sn>1606001</sn></hdr>
<data><t1>23.7658</t1><c1>0.00019</c1><p1>0.062</p1><v0>0.0590</v0><v1>0.1089</v1>
<dt>2007-11-07T07:34:35</dt></data></datapacket>CRLF

This data indicates Serial number = 1606001, Temperature (°C, ITS-90) = 23.7658, Conductivity (S/m) = 0.00019, Internally mounted pressure (decibars) = 0.062, First external voltage = 0.0590 volts, Second external voltage = 0.1089 volts, and Date, time = November 7, 2007, 07:34:35

Polled Data from SL, SLT, TS, TSS, or TSSOn:
If **OutputUCSD=Y** and the 16*plus* V2 is logging (autonomous sampling is in progress), data is followed by:
<dens>ddd.dddd</dens><vb>vv.v</vb><i>ccc.c</i>

where
density sigma-t (kg/m^3) = ddd.dddd
battery voltage = vv.v
operating current (mA) = ccc.c

The rest of the data stream is as described above for uploaded data.

Setup for Deployment

1. Install new batteries or ensure the existing batteries have enough capacity to cover the intended deployment (see *Replacing Alkaline Batteries* in *Section 5: Routine Maintenance and Calibration*).

2. Program the 16*plus* V2 for the intended deployment using the terminal program (see *Section 3: Power and Communications Test* for connection information; see this section for commands):

   A. Set the date and time (**DateTime=**).

   B. Ensure all data has been uploaded, and then send **InitLogging** to make the entire memory available for recording. If **InitLogging** is not sent, data will be stored after the last recorded sample.

   C. Establish the setup and (if applicable) autonomous sampling parameters.
   If you will be using SEASAVE to acquire and view real-time data, you must set OutputFormat=0 (raw hexadecimal).

   D. Send **GetCD** or **DS** to verify the setup.

   E. If desired, use **StartDateTime=** and **StartLater** to establish delayed start date and time.

3. If you will be using the terminal program to view real-time data, click the Capture menu to save the data to a file. Enter the desired capture file name in the dialog box, and click Save.

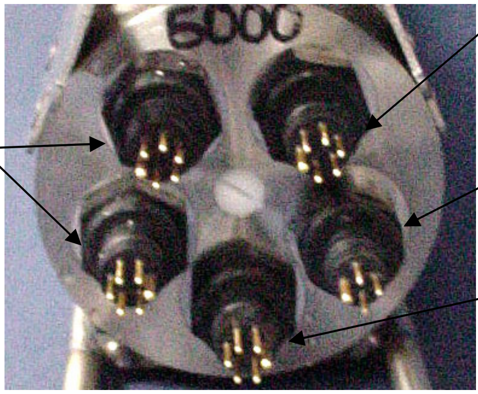
4. If you will be using SEASAVE to acquire and view real-time data, verify that the configuration (.con) file matches the instrument configuration. Sea-Bird supplies a .con file to match the factory configuration and calibrations. If the instrument is recalibrated or the configuration is changed (such as by adding external sensors), the .con file must be updated to reflect the current condition. See *Verifying Contents of .con File*.

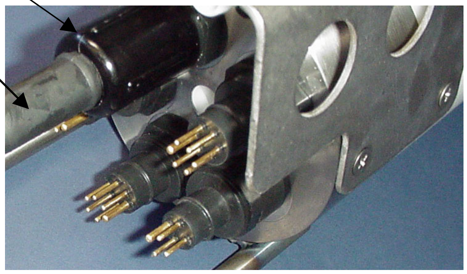
Note:
When we ship a new instrument, we include a .con file that reflects the current instrument configuration *as we know it*. The .con file is named with the instrument serial number, followed with the .con extension. For example, for an instrument with serial number 2375, Sea-Bird names the .con file *2375.con*. You may rename the .con file if desired; this will not affect the results.

Deployment

CAUTION:
Do not use WD-40 or other petroleum-based lubricants, as they will damage the connectors.

1. Install a cable or dummy plug for each connector on the 16*plus* V2 sensor end cap:
   A. Lightly lubricate the inside of the dummy plug/cable connector with silicone grease (DC-4 or equivalent).
   B. **Standard Connector** - Install the plug/cable connector, aligning the raised bump on the side of the plug/cable connector with the large pin (pin 1 - ground) on the 16*plus* V2. Remove any trapped air by *burping* or gently squeezing the plug/connector near the top and moving your fingers toward the end cap. **OR**
   MCBH Connector – Install the plug/cable connector, aligning the pins.
   C. Place the locking sleeve over the plug/cable connector. Tighten the locking sleeve finger tight only. **Do not overtighten the locking sleeve and do not use a wrench or pliers.**





2. Connect the other end of the cables installed in Step 1 to the appropriate sensors.

3. Verify that the hardware and external fittings are secure.

4. As applicable, remove the plug(s) from the anti-foulant device cap(s), or remove the Tygon tubing (and associated barbed anti-foulant device caps) that was looped end-to-end around the conductivity cell for storage (see *Conductivity Cell Maintenance* in *Section 5: Routine Maintenance and Calibration*). Verify that the two plastic cups contain AF24173 Anti-Foulant Devices (see *Section 5: Routine Maintenance and Calibration* for Anti-Foulant Device replacement). If using the 16*plus* V2 with a pump, verify that the system plumbing is correctly installed (see *Configuration Options and Plumbing* in *Section 2: Description of SBE 16plus V2*).

5. For autonomous sampling: If not already done, send **StartNow** or send **StartDateTime=** and **StartLater**.

The SBE 16*plus* V2 is ready to go into the water.

Acquiring Real-Time Data with SEASAVE

Notes:

- When we ship a new instrument, we include a .con file that reflects the current instrument configuration *as we know it*. The .con file is named with the instrument serial number, followed with the .con extension. For example, for an instrument with serial number 2375, we name the .con file *2375.con*. You may rename the .con file if desired; this will not affect the results.
- In the 16*plus* V2 setup commands, external voltage numbers 0, 1, 2, 3, 4, and 5 correspond to wiring of sensors to a voltage channel on the end cap (see *Dimensions and End Cap Connectors* in *Section 2: Description of SBE 16plus V2*). However, in the .con file, voltage 0 is the first external voltage in the data stream, voltage 1 is the second, etc.
- SEASAVE and SBE Data Processing use the same .con file.

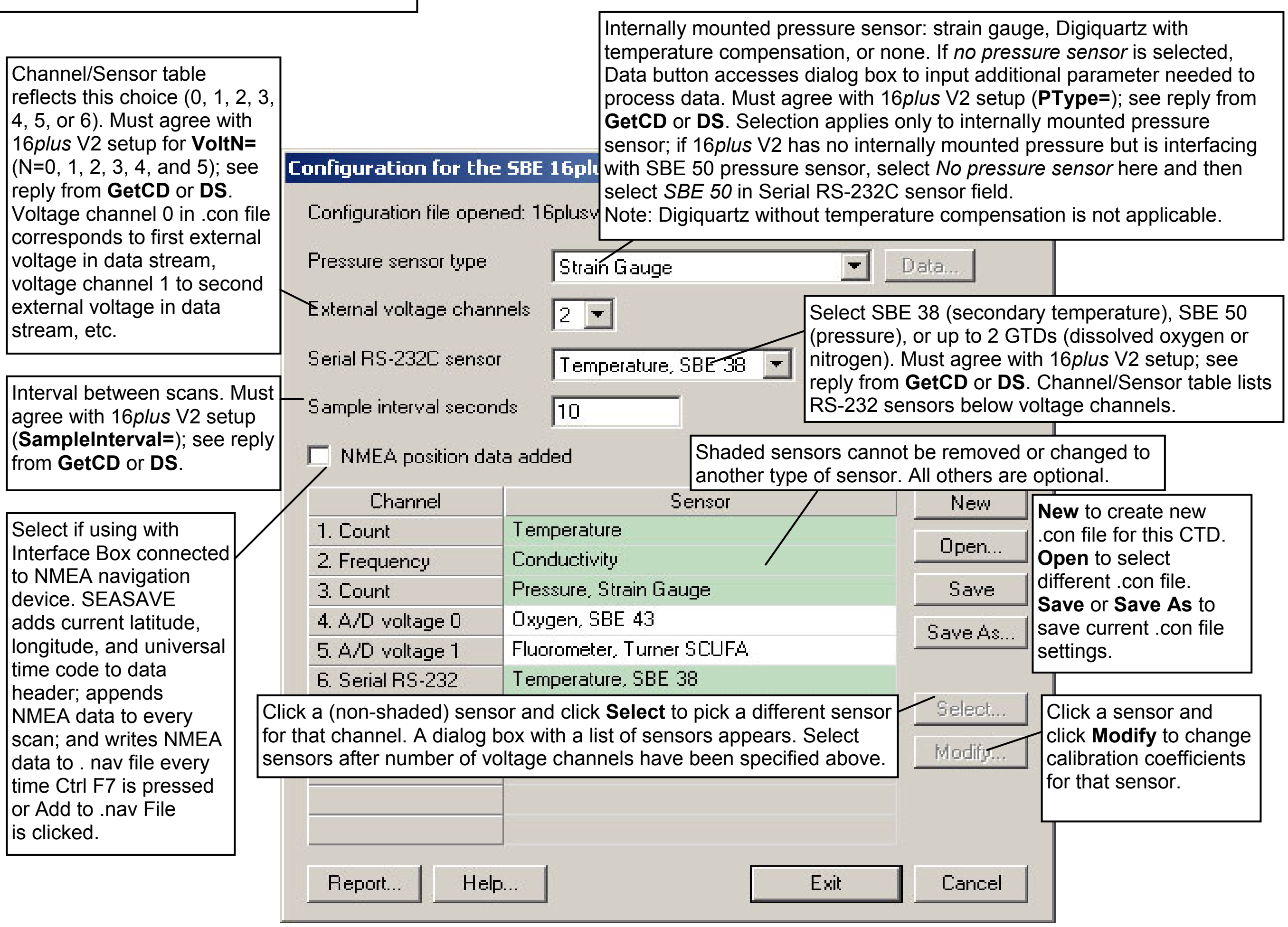
Verifying Contents of .con File

SEASAVE, our real-time data acquisition and display program, requires a .con file, which defines the instrument – integrated auxiliary sensors, and channels, serial numbers, and calibration dates and coefficients for all the sensors (conductivity, temperature, and internally mounted pressure as well as auxiliary sensors). SEASAVE (as well as our data processing software) uses the information in the .con file to interpret and process the raw data. **If the .con file does not match the actual instrument configuration, the software will be unable to interpret and process data correctly.**

1. Double click on Seasave.exe.

2. Click Configure Inputs. On the Instrument Configuration tab, click *Open*. In the dialog box, select the .con file and click Open.

3. The configuration information appears on the Instrument Configuration tab. Verify that the sensors match those on your 16*plus* V2, and that auxiliary sensors are assigned to the correct voltage channels. Click Modify to bring up a dialog box (shown below) to change the configuration and/or to view / modify calibration coefficients.



4. Click *Save* or *Save As* to save any changes to the .con file. Click Exit when done reviewing / modifying the .con file

Acquiring Real-Time Data

Instructions below are for an SBE 16*plus* V2 with a conventional single-core armored cable, used without a Sea-Bird Deck Unit. **If using the 16*plus* V2 with the SEACAT/SEALOGGER RS-232 and Navigation Interface Box, see the Interface Box manual**.

1. Wiring - Terminate the single-core armored cable with an RMG-4FS connector (16*plus* V2 with standard connectors) or MCIL-4FS (16*plus* V2 with optional wet-pluggable connectors). Wire the cable armor to pin 1 (large pin for 16*plus* V2 with standard connectors) and the inner conductor to pin 3 (opposite large pin) on the 16*plus* V2 data I/O - power connector (4-pin leg on Y-cable connected to Data I/O, Pump, and External Power bulkhead connector). On deck, wire:

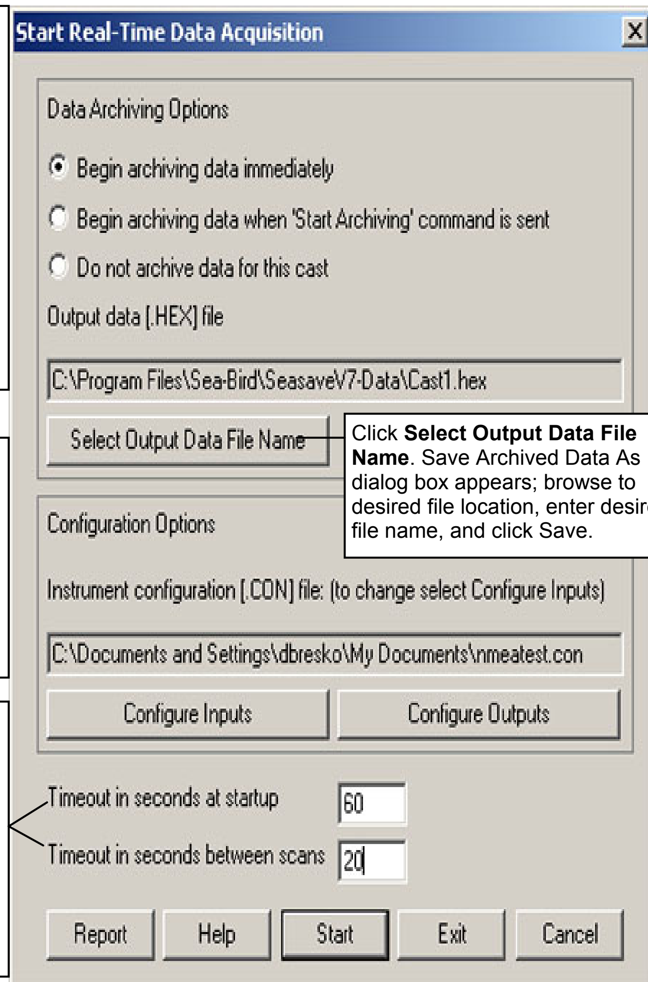
Slip-ring lead	25-pin serial port	9-pin serial port
from armor	Pin 7	Pin 5
from inner conductor	Pin 3	Pin 2

Note:
The baud rate between the 16*plus* V2 and computer (defined in Configure Inputs, on the Serial Ports tab) must match the baud rate set in the 16*plus* V2 with **BaudRate=**.

2. Double click on **Seasave.exe**.

3. Perform any desired setup in the Configure Inputs, Configure Outputs, and Display menus. .

4. In the Real-Time Data menu, select *Start*. The dialog box looks like this:



Data Archiving Options:
- **Begin archiving data immediately** to store raw (frequencies, A/D counts, and/or voltages) real-time data as soon as Start button is clicked and communication is established.
- **Begin archiving data when 'Start Archiving' command is sent** to control when data begins to be written to file. This allows you to eliminate scans associated with deploying CTD from ship deck and soaking instrument near surface (alternatively, remove these scans later in SBE Data Processing). If you make this selection, when you click Start button and communication is established, a dialog box with Start Archiving button appears. Click this button when ready to begin saving scans to file, or select Start Archiving in Real-Time Data menu.
- **Do not archive data for this cast** to not save data to a file. Real-time data will still appear in displays.

Click **Select Output Data File Name**. Save Archived Data As dialog box appears; browse to desired file location, enter desired file name, and click Save.

Configuration Options: Currently selected instrument configuration (.con) file is shown, containing information on number and type of sensors interfacing with 16*plus* V2, calibration coefficients, and inclusion of NMEA data with output from CTD. To select different .con file or modify input configuration (.con file, serial ports, TCP/IP ports, and/or miscellaneous), click Configure Inputs. To modify outputs (serial data output, serial ports, shared file output, mark variables, TCP/IP output, TCP/IP ports, SBE 14 remote display, header form, and/or diagnostics), click Configure Outputs.

- **Timeout in seconds at startup**: Time allowed before first data scan is received from 16*plus* V2. SEASAVE will *time out* and stop attempting to acquire data if data is not received from 16*plus* V2 within this time period.
- **Timeout in seconds between scans**: Maximum **gap** allowed between scans after first data scan is received from 16*plus* V2. SEASAVE will *time out* and stop attempting to acquire data if data is not received from 16*plus* V2 within this time period (for example, if a shark bites cable and interrupts data acquisition, SEASAVE stops attempting to acquire data after this gap).

Notes:
- The 16*plus* V2 must be sampling autonomously to use SEASAVE for real-time data acquisition. Start sampling by sending **StartNow** or **StartLater** in the terminal program before starting acquisition in SEASAVE.
- To prevent problems in the use of the COM port, click Disconnect in the Serial Port menu in the terminal program and close the terminal program before starting real-time acquisition in SEASAVE.

5. In the Start Real-Time Data Acquisition dialog box, click *Start*.
   A. If you selected *Begin archiving data immediately* or *Begin archiving data when 'Start Archiving' command is sent* above, and selected *Prompt for Header Information* in the Header Form setup (Configure Outputs), the Header Information dialog box appears. Fill in the desired header and click OK.
   B. If you selected *NMEA position data added* in the .con file, SEASAVE initializes NMEA communications.
   C. If you selected *Check Scan Length* in the Options menu, SEASAVE checks the .con file to verify that the scan length defined by the .con file matches the 16*plus* V2 (i.e., number of sensors and inclusion of NMEA is as defined in the .con file). If a *Scan length error* appears, verify that:
      - You are using the correct .con file.
      - The .con file has been updated as necessary if you added or deleted sensors, added or deleted NMEA, etc.
   D. SEASAVE sends a message: *Waiting for data* . . . SEASAVE will *time out* if data is not received within *Timeout in seconds at startup*.
   E. The data then starts appearing in the screen displays.

6. To stop real-time data acquisition: In the Real-Time Data menu, select *Stop*. Close SEASAVE.

7. In the **terminal program**, stop logging by sending **Stop**.

Recovery

WARNING!
If the 16*plus* V2 stops working while underwater, is unresponsive to commands, or shows other signs of flooding or damage, carefully secure it away from people until you have determined that abnormal internal pressure does not exist or has been relieved. Pressure housings may flood under pressure due to dirty or damaged o-rings, or other failed seals. When a sealed pressure housing floods at great depths and is subsequently raised to the surface, water may be trapped at the pressure at which it entered the housing, presenting a danger if the housing is opened before relieving the internal pressure. Instances of such flooding are rare. However, a housing that floods at 5000 meters depth holds an internal pressure of more than 7000 psia, and has the potential to eject the end cap with lethal force. A housing that floods at 50 meters holds an internal pressure of more then 85 psia; this force could still cause injury. If you suspect the 16*plus* V2 is flooded, point the 16*plus* V2 in a safe direction away from people, and loosen 1 end cap bulkhead connector very slowly, at least 1 turn. This opens an o-ring seal under the connector. Look for signs of internal pressure (hissing or water leak). If internal pressure is detected, let it bleed off slowly past the connector o-ring. Then, you can safely remove the end cap.

Physical Handling

1. Rinse the instrument and conductivity cell with fresh water. (See *Section 5: Routine Maintenance and Calibration* for cell cleaning and storage.)

2. Reinsert the protective plugs in the anti-foulant device cups.

3. If the batteries are exhausted, new batteries must be installed before the data can be extracted. Stored data will not be lost as a result of exhaustion or removal of batteries. (See *Section 5: Routine Maintenance and Calibration* for replacement of batteries.)

4. If immediate redeployment is not required, it is best to leave the 16*plus* V2 with batteries in place and in a quiescent state (**QS**). Because the quiescent current required is only 20 microamps, the batteries can be left in place without significant loss of capacity. If the 16*plus* V2 is to be stored for a long time, **replace the batteries yearly to prevent battery leakage** (which could damage the 16*plus* V2).

Uploading Data

Note:
Data may be uploaded during deployment or after recovery. If uploading after recovery, connect the I/O cable as described in *Section 3: Power and Communications Test*.

1. Double click on SCPlusV2_RS232.exe. The main screen appears.

2. In the Serial Port menu, select Configure. The Serial Port Configuration dialog box appears. Verify/modify the Comm port and baud, and click OK.

3. The terminal program should automatically connect to the 16*plus* V2. As it connects, it sends **GetHD** and displays the response. The terminal program also fills the Send Commands window with the correct list of commands for your 16*plus* V2. If there is no communication:
   A. In the Serial Port menu, select Connect (if Connect is grayed out, first select Disconnect and then select Connect).
   B. Check cabling between the computer and 16*plus* V2.
   C. If there is still no communication, repeat Step 2 with a different baud rate and/or comm port, and try to connect again. Note that the factory-set baud rate is documented on the Configuration Sheet.

Note:
You may need to send **Stop** several times to get the 16*plus* V2 to respond.

4. Command the 16*plus* V2 to stop logging by pressing the Enter key, typing **Stop**, and pressing the Enter key again.

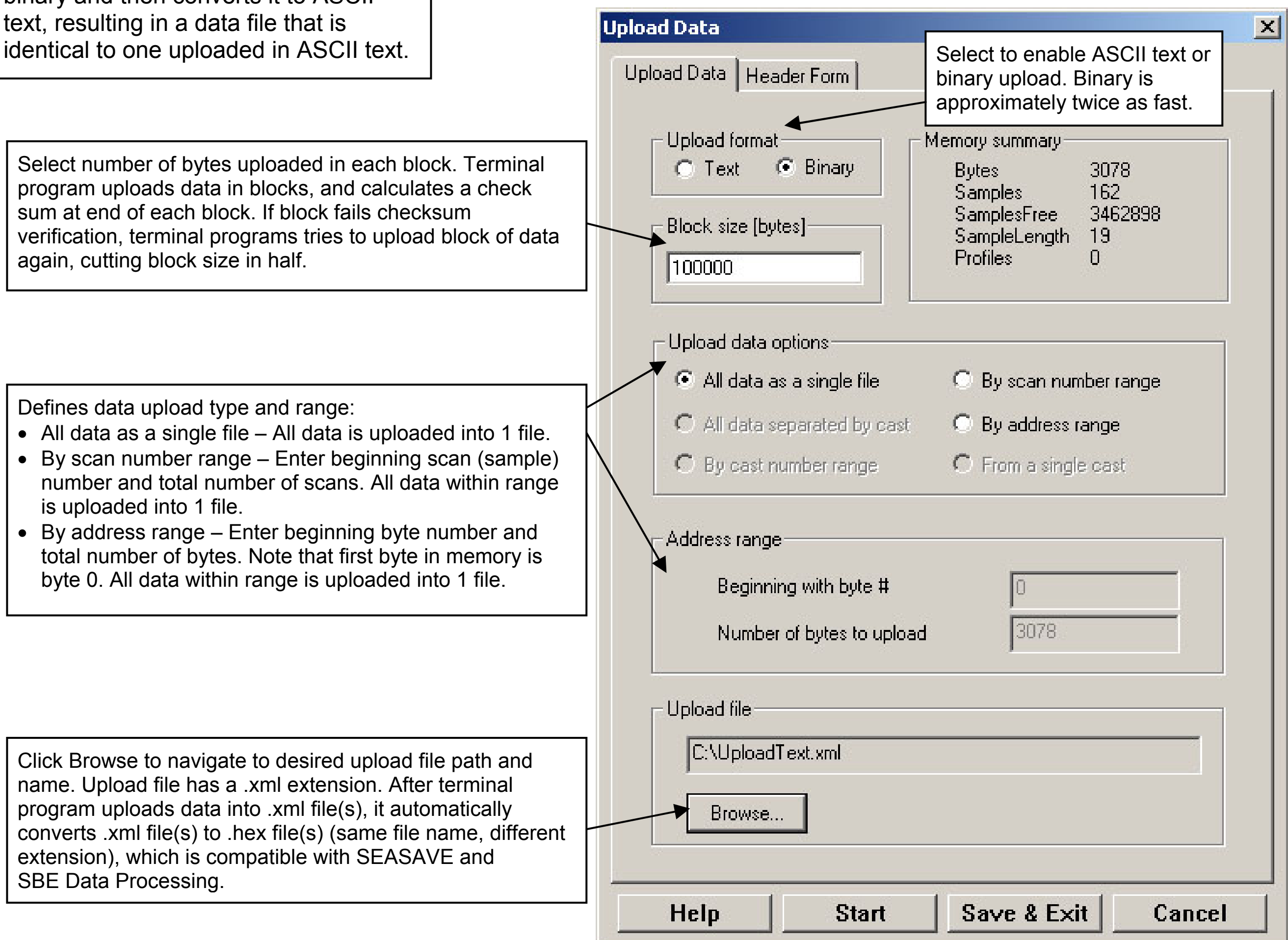
5. Display 16*plus* V2 status information by typing **DS** and pressing the Enter key. The display looks like this:

```
SBE 16plus V 2.0b SERIAL NO. 6001 24 Feb 2008 14:11:48
vbatt = 10.3, vlith = 8.5, ioper = 62.5 ma, ipump = 21.6 ma,
iext01 = 76.2 ma
status = not logging
samples = 162, free = 3462898
sample interval = 15 seconds, number of measurements per sample = 1
pump = run pump during sample, delay before sampling = 2.0 seconds
transmit real-time = yes
battery cutoff = 7.5 volts
pressure sensor = strain gauge, range = 1000.0
SBE 38 = no, SBE 50 = no, Gas Tension Device = no
Ext Volt 0 = yes, Ext Volt 1 = yes
Ext Volt 2 = no, Ext Volt 3 = no
Ext Volt 4 = no, Ext Volt 5 = no
echo characters = yes
output format = converted decimal
output salinity = no, output sound velocity = no
serial sync mode disabled
```

Verify that the status shows `status = not logging`.

Note:
If binary upload is selected, the terminal program uploads the data in binary and then converts it to ASCII text, resulting in a data file that is identical to one uploaded in ASCII text.

6. Click Upload to upload stored data. The terminal program responds as follows:
   A. The terminal program sends **GetSD** and displays the response. **GetSD** provides information on the instrument status, and number of samples in memory.
   B. The terminal program sends **DH** and displays the response. **DH** provides information on the headers in memory.
   C. An Upload Data dialog box appears:

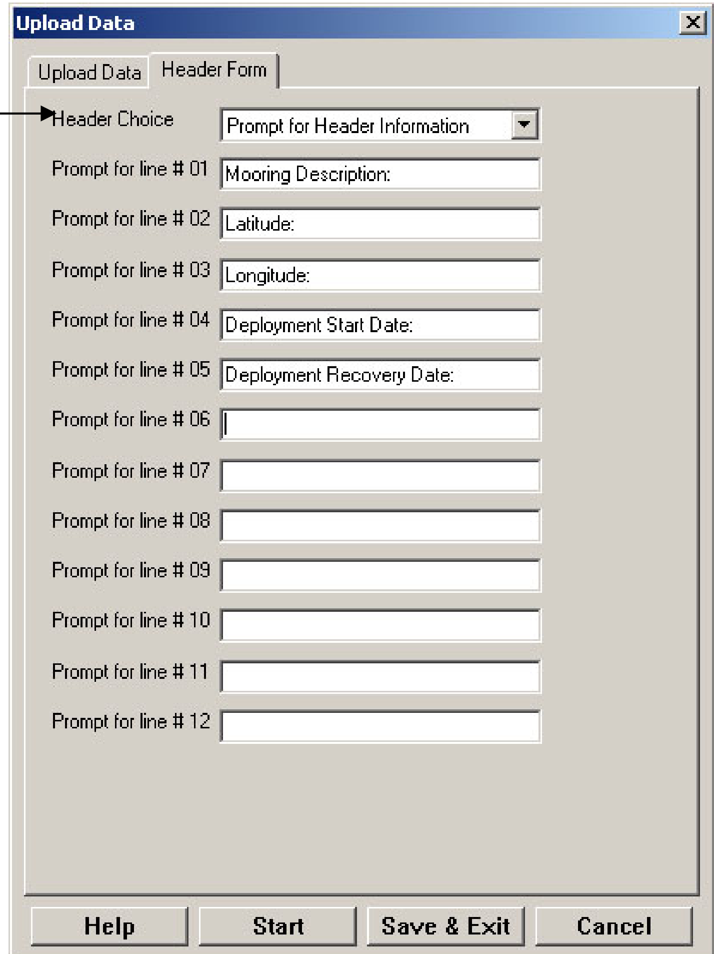


Make the desired selections.

7. Click the Header Form tab to customize the header:

Defines header information included with uploaded data:

- Prompt for header information – As data is uploaded, user is prompted to fill out user-defined header form.
- Include default header form in upload file – User-defined default header form included in upload file. User is not prompted to add any information when data is uploaded.
- Don't include default header form in upload file – Header information not included in upload file.



The entries are free form, 0 to 12 lines long. This dialog box establishes:

- the header prompts that appear for the user to fill in when uploading data, if *Prompt for header information* was selected
- the header included with the uploaded data, if *Include default header form in upload file* was selected

Enter the desired header/header prompts.

Note:
The commands and responses automatically sent by the terminal program during the upload do not appear in the Command/Data Echo Area.

8. Click Start; the Status bar at the bottom of the window displays the upload progress:
   A. The terminal program sends **GetHD** (get hardware data), **GetSD** (get status data), **GetCD** (get configuration data), **GetCC** (get calibration coefficients), and **GetEC** (get event counter), and writes the responses to the upload file. These commands provide information regarding the number of samples in memory, mode, header/cast numbers, calibration coefficients, etc.
   B. The terminal program sends **GetHD** (get hardware data), **GetSD** (get status data), **GetCD** (get configuration data), **GetCC** (get calibration coefficients), and **GetEC** (get event counter), and writes the responses to the upload file. These commands provide information regarding the number of samples in memory, mode, header/cast numbers, calibration coefficients, etc.
   C. The terminal program sends the data upload command, based on your selection of upload range in the Upload Data dialog box, writes the data to the upload .xml file, and then creates the .hex file from the .xml file. The .hex file contains the data in raw hexadecimal, for compatibility with SEASAVE and SBE Data Processing.
   D. When the data has been uploaded, the terminal program shows the `S>` prompt (if **OutputExecutedTag=N**).

Note:
To prepare for re-deployment:
1. After all data has been uploaded, send **InitLogging**. If this command is not sent and sampling is started, new data will be stored after the last recorded sample, preventing use of the entire memory capacity.
2. Send **QS** to put the 16*plus* V2 in quiescent (sleep) state until ready to redeploy. The quiescent current is only 20 microamps, so the batteries can be left in place without significant loss of capacity.

9. Ensure all data has been uploaded by reviewing and processing the data:
   A. Use **SEASAVE** to display and plot the *raw* hexadecimal data in engineering units (see *Verifying Contents of .con File* and SEASAVE manual / Help files).
   B. Use **SBE Data Processing** to process and plot the data (see *Processing Data Using SBE Data Processing* and SBE Data Processing manual / Help files).

Processing Data Using SBE Data Processing

Notes:

- See the SBE Data Processing manual and/or Help files.
- When we ship a new instrument, we include a .con file that reflects the current instrument configuration *as we know it*. The .con file is named with the instrument serial number, followed with the .con extension. For example, for an instrument with serial number 2375, Sea-Bird names the .con file *2375.con*. You may rename the .con file if desired; this will not affect the results.
- In the 16*plus* V2 setup commands, external voltage numbers 0, 1, 2, 3, 4, and 5 correspond to wiring of sensors to a voltage channel on the end cap (see *Dimensions and End Cap Connectors* in *Section 2: Description of SBE 16plus V2*). However, in the .con file, voltage 0 is the first external voltage in the data stream, voltage 1 is the second, etc.
- SEASAVE and SBE Data Processing use the same .con file.

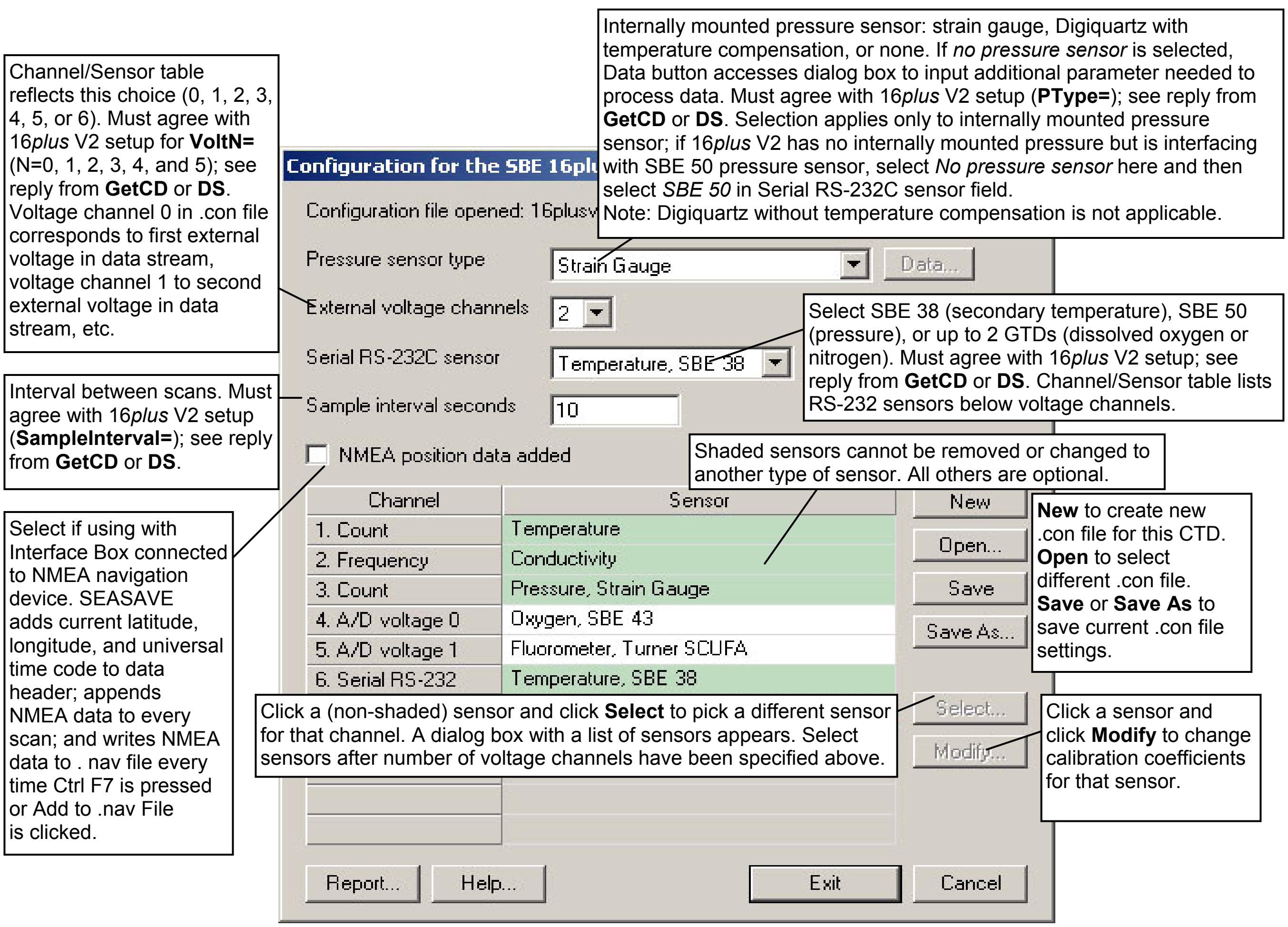
1. Convert the .hex (raw data) file (uploaded from 16*plus* V2 memory or real-time file from SEASAVE) to a .cnv (engineering units) file in SBE Data Processing's Data Conversion module.
2. Once the data is converted: perform further processing (filter, remove bad data, etc.), calculate derived variables, and plot data using SBE Data Processing's other modules.

Verifying Contents of Configuration (.con) File

To convert the .hex (raw data) file, you need a .con file, which defines the instrument – integrated sensors, and channels, serial numbers, and calibration dates and coefficients for all sensors (conductivity, temperature, and pressure as well as auxiliary sensors). SBE Data Processing uses the .con file information to interpret and process the raw data. **If the .con file does not match the actual instrument configuration, the software will be unable to interpret and process the data correctly.**

To view or modify the .con file:

1. Double click on SBEDataProc.exe.
2. In the Configure menu, select *SBE 16plus **V2** Seacat CTD*. The configuration dialog box appears; click Open.
3. In the Open dialog box, select the appropriate .con file and click Open. Verify that the sensors match those on your 16*plus* V2, and that auxiliary sensors are assigned to the correct voltage channels. Verify that calibration coefficients for all sensors are up-to-date.



4. Click *Save* or *Save As* to save any changes to the .con file. Click Exit when done reviewing / modifying the .con file.

Editing Raw Data File

Sometimes users want to edit the raw .hex data file before beginning processing, to remove data at the beginning of the file corresponding to instrument *soak* time, to remove blocks of bad data, to edit the header, or to add explanatory notes about the cast. **Editing the raw .hex file can corrupt the data, making it impossible to perform further processing using Sea-Bird software.** Sea-Bird strongly recommends that you first convert the data to a .cnv file (using the Data Conversion module in SBE Data Processing), and then use other SBE Data Processing modules to edit the .cnv file as desired.

Note:
Although we provide this technique for editing a raw .hex file, **Sea-Bird's strong recommendation, as described above, is to always convert the raw data file and then edit the converted file.**

The procedure for editing a .hex data file described below has been found to work correctly on computers running Windows 98, 2000, and NT. **If the editing is not performed using this technique, SBE Data Processing may reject the edited data file and give you an error message.**

1. **Make a back-up copy of your .hex data file before you begin.**
2. Run **WordPad**.
3. In the File menu, select Open. The Open dialog box appears. For *Files of type*, select *All Documents (*.*)*. Browse to the desired .hex data file and click Open.
4. Edit the file as desired, **inserting any new header lines after the System Upload Time line**. Note that all header lines must begin with an asterisk (*), and *END* indicates the end of the header. An example is shown below (for an SBE 21), with the added lines in bold:

```
* Sea-Bird SBE 21 Data File:
* FileName = C:\Odis\SAT2-ODIS\oct14-19\oc15_99.hex
* Software Version Seasave Win32 v1.10
* Temperature SN = 2366
* Conductivity SN = 2366
* System UpLoad Time = Oct 15 1999  10:57:19
* Testing adding header lines
* Must start with an asterisk
* Place anywhere between System Upload Time & END of header
* NMEA Latitude = 30 59.70 N
* NMEA Longitude = 081 37.93 W
* NMEA UTC (Time) = Oct 15 1999  10:57:19
* Store Lat/Lon Data = Append to Every Scan and Append to .NAV
File When <Ctrl F7> is Pressed
** Ship:       Sea-Bird
** Cruise:     Sea-Bird Header Test
** Station:
** Latitude:
** Longitude:
*END*
```

5. In the File menu, select Save (**not** Save As). If you are running Windows 2000, the following message displays:
```
You are about to save the document in a Text-Only format,
which will remove all formatting. Are you sure you want to do
this?
```
Ignore the message and click *Yes*.
6. In the File menu, select Exit.

Section 5: Routine Maintenance and Calibration

This section reviews:

- corrosion precautions
- connector mating and maintenance
- battery replacement
- conductivity cell storage and cleaning
- pressure sensor maintenance
- pump maintenance
- AF24173 Anti-Foulant Device replacement
- sensor calibration

The accuracy of the SBE 16*plus* V2 is sustained by the care and calibration of the sensors and by establishing proper handling practices.

Corrosion Precautions

Rinse the SBE 16*plus* V2 with fresh water after use and prior to storage.

For both the plastic and titanium housing, all exposed metal is titanium (the plastic housing has a titanium end cap). No corrosion precautions are required, but direct electrical connection of the titanium to dissimilar metal hardware should be avoided.

Connector Mating and Maintenance

Note:
See *Application Note 57: Connector Care and Cable Installation*.

CAUTION:
Do not use WD-40 or other petroleum-based lubricants, as they will damage the connectors.

Clean and inspect connectors, cables, and dummy plugs before every deployment and as part of your yearly equipment maintenance. Inspect connectors that are unmated for signs of corrosion product around the pins, and for cuts, nicks or other flaws that may compromise the seal.

When remating:

1. Lightly lubricate the inside of the dummy plug/cable connector with silicone grease (DC-4 or equivalent).
2. **Standard Connector** - Install the plug/cable connector, aligning the raised bump on the side of the plug/cable connector with the large pin (pin 1 - ground) on the 16*plus*V2. Remove any trapped air by *burping* or gently squeezing the plug/connector near the top and moving your fingers toward the end cap. **OR**
   MCBH Connector – Install the plug/cable connector, aligning the pins.
3. Place the locking sleeve over the plug/cable connector. Tighten the locking sleeve finger tight only. **Do not overtighten the locking sleeve and do not use a wrench or pliers.**

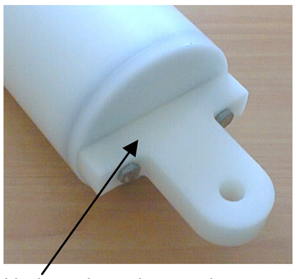
Verify that a cable or dummy plug is installed for each connector on the system before deployment.

Replacing Alkaline Batteries

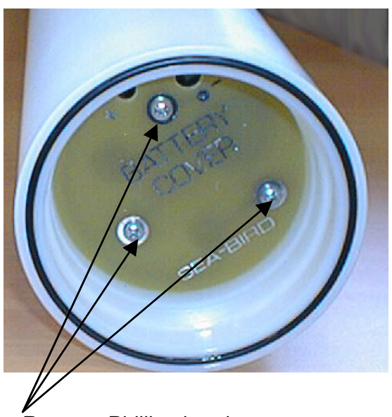
Alkaline D-cell (MN1300, LR20)

The SBE 16*plus* V2 uses alkaline D-cells (Duracell MN1300, LR20), dropped into the battery compartment.

Leave the batteries in place when storing the SBE 16*plus* V2 to prevent depletion of the back-up lithium batteries by the real-time clock. Even *exhausted* main batteries will power the clock (20 microamperes) almost indefinitely. If the 16*plus* V2 is to be stored for long periods, **replace the batteries yearly to prevent battery leakage** (which could damage the 16*plus* V2).



Unthread cap by rotating counter-clockwise



Remove Phillips-head screws and washers

1. Remove the battery end cap (end cap without connectors):
   A. Wipe the outside of the end cap and housing dry, being careful to remove any water at the seam between them.
   B. Unthread the end cap by rotating counter-clockwise (use a wrench on the white plastic bar if necessary).
   C. Remove any water from the O-ring mating surfaces inside the housing with a lint-free cloth or tissue.
   D. Put the end cap aside, being careful to protect the O-ring from damage or contamination.

2. Remove the battery cover plate from the housing:
   A. Remove the three Phillips-head screws and washers from the battery cover plate inside the housing.
   B. The battery cover plate will pop out. Put it aside.

3. Turn the 16*plus* V2 over and remove the batteries.

4. Install the new batteries, with the + terminals against the flat battery contacts and the - terminals against the spring contacts.

5. Reinstall the battery cover plate in the housing:
   A. Align the battery cover plate with the housing. The posts inside the housing are not placed symmetrically, so the cover plate fits into the housing only one way. Looking at the cover plate, note that one screw hole is closer to the edge than the others, corresponding to the post that is closest to the housing.
   B. Reinstall the three Phillips-head screws and washers, while pushing hard on the battery cover plate to depress the spring contacts at the bottom of the battery compartment. **The screws must be fully tightened, or battery power to the circuitry will be intermittent**.

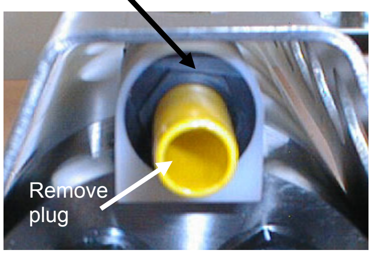
6. Check the battery voltage at BAT + and BAT - on the battery cover plate. It should be approximately 13.5 volts.

7. Reinstall the battery end cap:
   A. Remove any water from the O-rings and mating surfaces with a lint-free cloth or tissue. Inspect the O-rings and mating surfaces for dirt, nicks, and cuts. Clean or replace as necessary. Apply a light coat of o-ring lubricant (Parker Super O Lube) to O-rings and mating surfaces.
   B. Carefully fit the end cap into the housing and rethread the end cap into place. Use a wrench on the white plastic bar to ensure the end cap is tightly secured.

Conductivity Cell Maintenance

CAUTIONS:

- **Do not put a brush or any object inside the conductivity cell to dry it or clean it.** Touching and bending the electrodes can change the calibration. Large bends and movement of the electrodes can damage the cell.
- **Do not store the 16*plus* V2 with water in the conductivity cell.** Freezing temperatures (for example, in Arctic environments or during air shipment) can break the cell if it is full of water.



The SBE 16*plus* V2's conductivity cell is shipped dry to prevent freezing in shipping. **Refer to *Application Note 2D: Instructions for Care and Cleaning of Conductivity Cells* for conductivity cell cleaning procedures and cleaning materials.**

- The Active Use (after each cast) section of the application note is not applicable to the 16*plus* V2, which is intended for use as a moored instrument.

The 16*plus* V2 is shipped with a kit for cell filling and storage. The kit includes a syringe and tubing assembly, and two anti-foulant device caps with hose barbs. The tubing cannot attach to an anti-foulant device cap that is not barbed.

- If your 16*plus* V2 does not include a pump - the installed anti-foulant device caps at both ends of the conductivity cell are not barbed.
- If your 16*plus* V2 includes a pump - the installed anti-foulant device cap at the pump end of the cell is barbed; the installed anti-foulant device cap at the intake end of the cell is not barbed.

Cleaning and storage instructions require use of the syringe and tubing assembly at the intake end of the cell (requiring one barbed cap), and looping Tygon tubing from end to end of the cell (requiring two barbed caps). Remove the installed anti-foulant device cap(s) and replace them with the anti-foulant device cap(s) with hose barbs **for cleaning and storage only**. Remember to reinstall the original anti-foulant device cap(s) before deployment. **Deploying an SBE 16*plus* V2 with barbed anti-foulant device cap(s) in place of the installed caps is likely to produce undesirable results in your data.** See *Replacing Anti-Foulant Devices* for safety precautions when handling the AF24173 Anti-Foulant Devices.

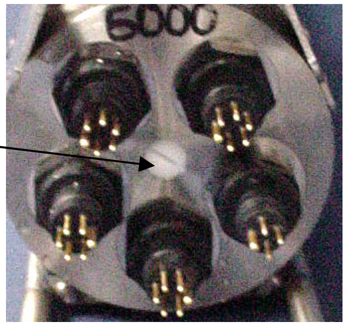
Internally Mounted Pressure Sensor (optional) Maintenance

CAUTION:
Do not put a brush or any object in the pressure port. Doing so may damage or break the pressure sensor.

Pressure sensor maintenance varies, depending on the type of pressure sensor in your SBE 16*plus* V2.

Strain Gauge Pressure Sensor

Pressure sensor port

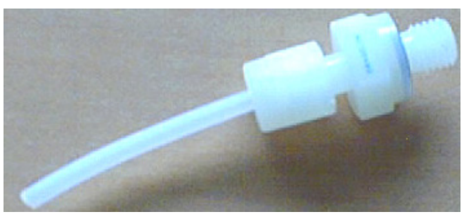


The pressure port plug has a small vent hole to allow hydrostatic pressure to be transmitted to the pressure sensor inside the instrument, while providing protection for the pressure sensor, keeping most particles and debris out of the pressure port.

Periodically (approximately once a year) inspect the pressure port to remove any particles, debris, etc:

1. Unscrew the pressure port plug from the pressure port.
2. Rinse the pressure port with warm, de-ionized water to remove any particles, debris, etc.
3. Replace the pressure port plug.

Quartz Pressure Sensor



Nylon pressure capillary fitting for 16*plus* V2 with Quartz pressure sensor

At the factory, the pressure sensor and pressure port were filled with a silicon oil, and a nylon pressure capillary fitting – which includes a pressure port fitting and an external capillary tube – were used to retain the oil. The oil transmits hydrostatic pressure via internal, stainless steel, capillary tubing to the pressure sensor inside the instrument, and prevents corrosion that might occur if the sensor diaphragm was exposed to water. The internal tubing and nylon capillary fitting are vacuum back-filled at the factory.

Because of the viscosity of the silicone oil and capillary action, the silicone oil does not run out of the external capillary tube. However, due to temperature and pressure cycling over long periods, it is normal for some oil to slowly leak out of the external capillary tube. **When the oil is not visible or is receding inside the translucent tube, or if the fitting has been damaged, refill the oil** using the supplied pressure sensor oil refill kit. See *Application Note 12-1: Pressure Port Oil Refill Procedure & Nylon Capillary Fitting Replacement*.

Pump (optional) Maintenance

See *Application Note 75: Maintenance of SBE 5T, 5P, and 5M Pumps*.

Replacing Anti-Foulant Devices (SBE 16*plus*, SBE 19*plus*)

AF24173 Anti-Foulant Device

The SBE 16*plus* and 19*plus* (moored option) have an anti-foulant device cup and cap on each end of the conductivity cell. A new SBE 16*plus* (or moored option 19*plus*) is shipped with an Anti-Foulant Device and a protective plug pre-installed in each cup.

Wearing rubber or latex gloves, follow this procedure to replace each Anti-Foulant Device (two):

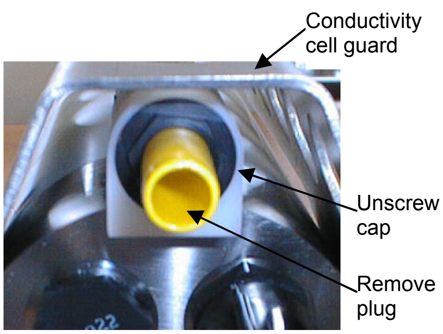
1. Remove the protective plug;
2. Unscrew the cap with a 5/8-inch socket wrench;
3. Remove the old Anti-Foulant Device. If the old Anti-Foulant Device is difficult to remove:
   - Use needle-nose pliers and carefully break up material;
   - If necessary, remove the conductivity cell guard to provide easier access;
4. Place the new Anti-Foulant Device in the cup;
5. Rethread the cap onto the cup. Do not over tighten;
6. Replace the protective plug if not ready to redeploy.

WARNING!

AF24173 Anti-Foulant Devices contain bis(tributyltin) oxide. Handle the devices only with rubber or latex gloves. Wear eye protection. Wash with soap and water after handling.

Read precautionary information on product label (see Appendix V) before proceeding.

It is a violation of US Federal Law to use this product in a manner inconsistent with its labeling.



CAUTION:

One of the anti-foulant device cups is attached to the guard and connected to the conductivity cell. **Removing the guard without disconnecting the cup from the guard will break the cell.** If the guard must be removed:

1. Remove the two screws connecting the anti-foulant device cup to the guard;
2. Remove the four Phillips-head screws connecting the guard to the housing and sensor end cap;
3. Gently lift the guard away.

Sensor Calibration

> **Note**
> After recalibration, Sea-Bird enters the new calibration coefficients in the 16*plus* V2 EEPROM, and ships the instrument back to the user with Calibration Certificates showing the new coefficients. The user must enter the coefficients in the instrument configuration (.con) file in the Configure menu in SEASAVE or SBE Data Processing.

Sea-Bird sensors are calibrated by subjecting them to known physical conditions and measuring the sensor responses. Coefficients are then computed, which may be used with appropriate algorithms to obtain engineering units. The conductivity, temperature, and (optional) internally mounted pressure sensor on the SBE 16*plus* V2 are supplied fully calibrated, with coefficients stored in EEPROM in the 16*plus* V2 and printed on their respective Calibration Certificates.

We recommend that the SBE 16*plus* V2 be returned to Sea-Bird for calibration.

Conductivity Sensor

The conductivity sensor incorporates a fixed precision resistor in parallel with the cell. When the cell is dry and in air, the sensor's electrical circuitry outputs a frequency representative of the fixed resistor. This frequency is recorded on the Calibration Certificate and should remain stable (within 1 Hz) over time.

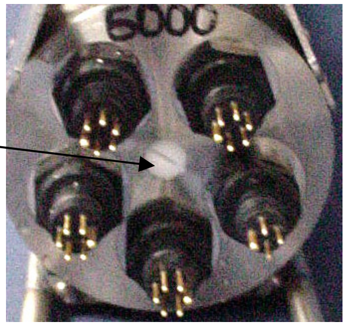
The primary mechanism for calibration drift in conductivity sensors is the fouling of the cell by chemical or biological deposits. Fouling changes the cell geometry, resulting in a shift in cell constant.

Accordingly, the most important determinant of long-term sensor accuracy is the cleanliness of the cell. We recommend that the conductivity sensors be calibrated before and after deployment, but particularly when the cell has been exposed to contamination by oil slicks or biological material.

Temperature Sensor

The primary source of temperature sensor calibration drift is the aging of the thermistor element. Sensor drift will usually be a few thousandths of a degree during the first year, and less in subsequent intervals. Sensor drift is not substantially dependent upon the environmental conditions of use, and — unlike platinum or copper elements — the thermistor is insensitive to shock.

Internally Mounted Pressure Sensor



Note:
The internally mounted pressure sensor is an absolute sensor, so its **raw** output includes the effect of atmospheric pressure (14.7 psi). As shown on the Calibration Sheet, Sea-Bird's calibration (and resulting calibration coefficients) is in terms of psia. However, when outputting pressure in **engineering units**, the 16*plus* V2 outputs pressure relative to the ocean surface (i.e., at the surface the output pressure is 0 decibars). The 16*plus* V2 uses the following equation to convert psia to decibars:
pressure (db) =
[pressure (psia) - 14.7] * 0.689476

The SBE 16*plus* V2 is available with an internally mounted strain-gauge or Quartz pressure sensor. These sensors are capable of meeting the 16*plus* V2 error specification with some allowance for aging and ambient-temperature induced drift.

Pressure sensors show most of their error as a linear offset from zero. A technique is provided below for making small corrections to the pressure sensor calibration using the *offset* (**POffset=**) calibration coefficient term by comparing SBE 16*plus* V2 pressure output to readings from a barometer.

Allow the SBE 16*plus* V2 to equilibrate in a reasonably constant temperature environment for at least 5 hours before starting. Pressure sensors exhibit a transient change in their output in response to changes in their environmental temperature. Sea-Bird instruments are constructed to minimize this by thermally decoupling the sensor from the body of the instrument. However, there is still some residual effect; allowing the 16*plus* V2 to equilibrate before starting will provide the most accurate calibration correction.

1. Place the 16*plus* V2 in the orientation it will have when deployed.

2. In the terminal program:
   A. Set the pressure offset to 0.0 (**POffset=0**).
   B. Send **TP** to measure the 16*plus* V2 pressure 100 times and transmit converted data in engineering units (decibars).

3. Compare the 16*plus* V2 output to the reading from a good barometer at the same elevation as the 16*plus* V2 pressure sensor.
   Calculate *offset* = barometer reading – 16*plus* V2 reading

4. Enter the calculated offset (positive or negative) in two places:
   - In the 16*plus* V2 EEPROM, using **POffset=** in the terminal program, **and**
   - In the configuration (.con) file, using SEASAVE or SBE Data Processing.

Offset Correction Example
Absolute pressure measured by a barometer is 1010.50 mbar. Pressure displayed from 16*plus* V2 is -2.5 dbars.
Convert barometer reading to dbars using the relationship: mbar * 0.01 = dbar
Barometer reading = 1010.50 mbar * 0.01 = 10.1050 dbar
The 16*plus* V2's internal calculations and our processing software output gage pressure, using an assumed value of 14.7 psi for atmospheric pressure. Convert 16*plus* V2 reading from gage to absolute by adding 14.7 psia to the 16*plus* V2 output:
-2.5 dbars + (14.7 psi * 0.689476 dbar/psia) = -2.5 + 10.13 = 7.635 dbars
Offset = 10.1050 – 7.635 = + 2.47 dbars
Enter offset in 16*plus* V2 and in .con file.

For demanding applications, or where the sensor's air ambient pressure response has changed significantly, calibration using a dead-weight generator is recommended. The end cap's 7/16-20 straight thread permits mechanical connection to the pressure source. Use a fitting that has an O-ring tapered seal, such as Swagelok-200-1-4ST, which conforms to MS16142 boss.

Section 6: Troubleshooting

This section reviews common problems in operating the SBE 16*plus* V2, and provides the most common causes and solutions.

Problem 1: Unable to Communicate with SBE 16*plus* V2

If **OutputExecutedTag=N**, the `S>` prompt indicates that communications between the SBE 16*plus* V2 and computer have been established. Before proceeding with troubleshooting, attempt to establish communications again by clicking Connect in the Serial Port menu in the terminal program or pressing the Enter key several times.

Cause/Solution 1: The I/O cable connection may be loose. Check the cabling between the 16*plus* V2 and computer for a loose connection.

Cause/Solution 2: The instrument communication settings may not have been entered correctly in the terminal program. Verify the settings in the Serial Port Configuration dialog box (Serial Port menu -> Configure). The settings should match those on the instrument Configuration Sheet.

Cause/Solution 3: The I/O cable may not be the correct one. The I/O cable supplied with the 16*plus* V2 permits connection to standard 9-pin RS-232 interfaces. See *Dimensions and End Cap Connectors* in *Section 2: Description of SBE 16plus V2* for cable pinouts.

Problem 2: No Data Recorded

Cause/Solution 1: The memory may be full; once the memory is full, no further data is recorded. Verify that the memory is not full using **GetSD** or **DS** (*free = 0* or *1* if memory is full). Sea-Bird recommends that you upload all previous data before beginning another deployment. Once the data is uploaded, send **InitLogging** to reset the memory. After the memory is reset, **GetSD** or **DS** will show *samples = 0*.

Problem 3: Nonsense or Unreasonable Data

> **Note:**
> Each 16*plus* V2 is shipped with a configuration (.con) file that matches the configuration of the instrument (number and type of auxiliary sensors, etc.) and includes the instrument calibration coefficients.

The symptom of this problem is a data file that contains nonsense values (for example, 9999.999) or unreasonable values (for example, values that are outside the expected range of the data).

Cause/Solution 1: A data file with nonsense values may be caused by incorrect instrument configuration:

- Bad data may be caused by incorrect configuration in the 16*plus* V2. Send **GetCD** or **DS** to verify the 16*plus* V2 setup matches the instrument Configuration Sheet (correct internally mounted pressure sensor, voltage sensors assigned to correct channels, etc).
- Bad data may be caused by incorrect configuration in the instrument .con file. Verify the settings in the instrument .con file match the instrument Configuration Sheet.

Cause/Solution 2: A data file with unreasonable (i.e., out of the expected range) values for temperature, conductivity, etc. may be caused by incorrect calibration coefficients:

- If you manually uploaded data in engineering units (**OutputFormat=1**, **3,** or **5**) – Bad data may be caused by incorrect calibration coefficients in the 16*plus* V2. Send **GetCC** or **DCal** to verify the calibration coefficients in the 16*plus* V2 match the instrument Calibration Certificates. Note that calibration coefficients do not affect the raw data stored in 16*plus* V2 memory. If you have not yet overwritten the memory with new data, you can correct the coefficients and then upload the data again.
- If you are viewing real-time data in SEASAVE, manually uploaded data in raw hexadecimal (**OutputFormat=0**), or used the terminal program's Upload menu to upload data and are processing the data in SEASAVE or SBE Data Processing - Bad data may be caused by incorrect calibration coefficients in the instrument .con file. Verify the calibration coefficients in the .con file match the instrument Calibration Certificates.
- For RS-232 sensors interfacing to the 16*plus* V2: Bad data may be caused by incorrect calibration coefficients programmed into the RS-232 sensor. Connect the sensor directly to the computer and use SEATERM to verify the calibration coefficients match the instrument Calibration Certificate.

Problem 4: Program Corrupted

> **Note:**
> Using the reset switch does not affect the 16*plus* V2 memory - data in memory and user-programmable parameter values are unaffected.

Cause/Solution 1: In rare cases, the program that controls the 16*plus* V2 microprocessor can be corrupted by a severe static shock or other problem. This program can be initialized by using the reset switch. Proceed as follows to initialize:

1. Open the battery end cap and remove the batteries (see *Replacing Alkaline Batteries* in *Section 5: Routine Maintenance and Calibration*).
2. There is a small, pushbutton switch on the battery compartment bulkhead, which is visible after the batteries are removed. The switch is used to disconnect the internal back-up lithium batteries from the electronics. Push the switch in for 1 second.
3. Reinstall or replace the batteries, and close the battery end cap.
4. Establish communications with the 16*plus* V2 (see *Section 3: Power and Communications Test*). Send **GetSD** or **DS** to verify that the date and time and sample number are correct.

Glossary

Battery pack – Nine alkaline D-cells (Duracell MN1300, LR20) standard.

Fouling – Biological growth in the conductivity cell during deployment.

PCB – Printed Circuit Board.

SBE Data Processing – Sea-Bird's Win 2000/XP data processing software, which calculates and plots temperature, conductivity, and optional internally mounted pressure, data from auxiliary sensors, and derived variables such as salinity and sound velocity.

Scan – One data sample containing temperature, conductivity, optional internally mounted pressure, date and time, and optional auxiliary inputs.

SCPlusV2_RS232.exe – Win 2000/XP terminal program used to communicate with the SBE 16*plus* V2 and SBE 19*plus* V2. This terminal program is not yet incorporated in the SEASOFT-Win32 package.

SEACAT – High-accuracy conductivity, temperature, and pressure recorder. The SEACAT is available as the SBE 16*plus* (moored applications) and SBE 19*plus* (moored or profiling applications).
The 16*plus* is available in three versions:

- 16*plus* with **RS-232** interface (this manual)
- 16*plus* with **RS-485** interface
- 16*plus*-IM with **inductive modem** interface

Version 2 (V2) models of each of these instruments became available in late 2007 /early 2008, and have 2 additional A/D channels (for a total of 6), a standard channel for an RS-232 sensor, and larger memory (64 MB).
A *plus* version of the SBE 21 SEACAT (thermosalinograph) is under development.

SEASAVE V7 – Sea-Bird's Win 2000/XP software used to acquire, convert, and display real-time or archived raw data.

SEASOFT-Win32– Sea-Bird's complete Win 2000/XP software package, which includes software for communication, real-time data acquisition, and data analysis and display. SEASOFT-Win32 includes ***SEASAVE* V7**, ***SBE Data Processing***, and ***SEATERM***.

SEATERM – Sea-Bird's Win 95/98/NT/2000/XP terminal program used to communicate with the SBE 38 or SBE 50.

TCXO – Temperature Compensated Crystal Oscillator.

Triton X-100 – Reagent grade non-ionic surfactant (detergent), used for cleaning the conductivity cell. Triton can be ordered from Sea-Bird, but should also be available locally from chemical supply or laboratory products companies. Triton is manufactured by Mallinkrodt Baker; see http://www.mallbaker.com/changecountry.asp?back=/Default.asp for local distributors.

Appendix I: Functional Description and Circuitry

Sensors

The SBE16*plus* V2 embodies the same sensor elements (3-electrode, 2-terminal, borosilicate glass cell, and pressure-protected thermistor) previously employed in Sea-Bird's modular SBE 3 and SBE 4 sensors and in the original SEACAT design. The SBE 16*plus* V2 differs from the SBE 16 in that it uses three independent channels to digitize temperature, conductivity, and internally mounted pressure concurrently. Multiplexing is not used for these channels.

The optional internally mounted pressure sensor is a Druck strain-gauge sensor or a Quartz pressure sensor.

Sensor Interface

Temperature is acquired by applying an AC excitation to a bridge circuit containing an ultra-stable aged thermistor with a drift rate of less than 0.002 ºC per year. The other elements in the bridge are VISHAY precision resistors. A 24-bit A/D converter digitizes the output of the bridge. AC excitation and ratiometric comparison avoids errors caused by parasitic thermocouples, offset voltages, leakage currents, and reference errors.

Conductivity is acquired using an ultra-precision Wein-Bridge oscillator to generate a frequency output in response to changes in conductivity.

Internally mounted strain-gauge pressure is acquired by applying an AC excitation to the pressure bridge. A 24-bit A/D converter digitizes the output of the bridge. AC excitation and ratiometric comparison avoids errors caused by parasitic thermocouples, offset voltages, leakage currents, and reference errors. A silicon diode embedded in the pressure bridge is used to measure the temperature of the pressure bridge. This temperature is used to perform offset and span corrections on the measured pressure signal.

The six external 0 to 5 volt DC voltage channels are processed by differential amplifiers with an input resistance of 50K ohms and are digitized with a 14-bit A/D converter.

Real-Time Clock

To minimize power and improve clock accuracy, a temperature-compensated crystal oscillator (TCXO) is used as the real-time-clock frequency source. The TCXO is accurate to ± 1 minute per year (0 ºC to 40 ºC).

Battery Wiring

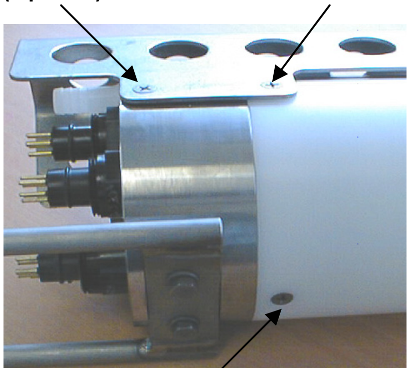
SBE 16*plus* V2 main battery is a series connection of D-cells that drop into the battery compartment as a cluster of end-to-end stacks, three batteries each (standard 9-cell battery pack has three stacks). The positive battery connections are contact areas on double-thick printed circuit disks that form the internal bulkhead and battery retainer plates. Battery negative contacts are heavy beryllium-copper springs. The three cell stacks are aligned by plastic insulated aluminum spacers which also serve as electrical interconnects. The battery-to-circuit card connection is made by means of a Molex-type 3-pin pc board connector (JP3 on the power PCB).

The Power PCB contains three series-connected Panasonic BR-2/3A lithium cells (non-hazardous) which are diode OR'd with the main battery (and external power source, if used). The back-up lithium supply is capable of maintaining the buffer and the real-time clock if the main batteries and/or external power are removed. If the back-up lithium battery voltage (*Vlith* in the **GetSD** or **DS** response) falls below 7 volts, replace the back-up batteries.

Appendix II: Electronics Disassembly/Reassembly

CAUTION:
Use caution during disassembly and reassembly to avoid breaking the conductivity cell.

Disassembly



1. **As a precaution, upload any data in memory before beginning.**
2. Remove the two Phillips-head screws holding the conductivity cell guard to the housing. **Do not remove the two screws holding the conductivity cell guard to the sensor end cap.**
3. Remove the Phillips-head screw holding the sensor end cap to the housing on the side opposite the conductivity cell guard.
4. Remove the sensor end cap (with attached conductivity cell and cell guard) and electronics:
   A. Wipe the outside of the sensor end cap and housing dry, being careful to remove any water at the seam between them.
   B. Slide the end cap and attached electronics out of the housing.
   C. The electronics are electrically connected to the battery compartment bulkhead with a Molex connector. Disconnect the Molex connector.
   D. Remove any water from the O-rings and mating surfaces inside the housing with a lint-free cloth or tissue.
   E. Be careful to protect the O-rings from damage or contamination.

Reassembly

Note:
Before delivery, a desiccant package is placed in the electronics chamber, and the electronics chamber is filled with dry Argon gas. These measures help prevent condensation.
If the electronics are exposed to the atmosphere, dry gas backfill with Argon and replace the desiccant package.
See *Application Note 71: Desiccant Use and Regeneration (drying)* for desiccant information.
Battery replacement does not affect desiccation of the electronics, as no significant gas exchange is possible unless the electronics PCBs are actually removed from the housing.

1. Reinstall the sensor end cap, conductivity cell and guard, and electronics:
   A. Remove any water from the O-rings and mating surfaces in the housing with a lint-free cloth or tissue. Inspect the O-rings and mating surfaces for dirt, nicks, and cuts. Clean or replace as necessary. Apply a light coat of O-ring lubricant (Parker Super O Lube) to the O-rings and mating surfaces.
   B. Plug the Molex connector onto the pins on the battery compartment bulkhead. Verify the connector holes and pins are properly aligned.
   C. Carefully fit the end cap and electronics into the housing until the O-rings are fully seated.
2. Reinstall the three screws to secure the end cap.
3. Reset the date and time (**DateTime=**) and initialize logging (**InitLogging**) before redeploying. No other parameters should have been affected by electronics disassembly (send **GetCD** or **DS** to verify).

Appendix III: Command Summary

CATEGORY	COMMAND	DESCRIPTION
Status	**GetCD**	Get and display configuration data (setup parameters).
	GetSD	Get and display status data.
	GetCC	Get and display calibration coefficients.
	GetEC	Get and display event counter data.
	ResetEC	Delete all events in event counter
	GetHD	Get and display hardware data.
	DS	Get and display configuration data (setup parameters) and status data.
	DCal	Get and display calibration coefficients.
General Setup	**DateTime= mmddyyyyhhmmss**	Set real-time clock month, day, year, hour, minute, second.
	BaudRate=x	**x=** baud rate (600, 1200, 2400, 4800, 9600, 19200, 33600, 38400, 57600, or 115200). Default 9600.
	Echo=x	**x=Y**: Echo characters as you type. **x=N**: Do not.
	OutputExecutedTag=x	**x=Y**: Display XML Executing and Executed tags. **x=N**: Do not.
	TxRealTime=x	**x=Y**: Output real-time data. **x=N**: Do not.
	PumpMode=x	**x=0**: No pump. **x=1**: Run pump for 0.5 seconds before each sample. **x=2**: Run pump during each sample.
	NCycles=x	**x=** number of measurements to take and average for each sample. Default 1.
	InitLogging	After all previous data uploaded, send this before starting to sample to make entire memory available for recording. If not sent, data stored after last sample. Equivalent to **SampleNumber=0**.
	SampleNumber=x	**x=** sample number for last sample in memory. After all previous data uploaded, set to 0 before starting to sample to make entire memory available for recording. If not reset to 0, data stored after last sample. **SampleNumber=0** is equivalent to **InitLogging**.
	HeaderNumber=x	**x=** header number for last header in memory.
	QS	Enter quiescent (sleep) state. Main power turned off, but data logging and memory retention unaffected.
Pressure Sensor Setup	**PType=x**	**Internally mounted pressure sensor type -** **x=0**: No internally mounted pressure sensor. **x=1**: Strain gauge. **x=3**: Quartz with temperature compensation.
	RefPress=x	**x=** reference pressure (gauge) in db to use if 16*plus* V2 does not include internally mounted pressure sensor.
	ParosIntegration=x	**x=** integration time (seconds) for optional internally mounted Quartz pressure sensor (1 - 600 seconds; default 1 second).
Voltage Sensor Setup	**Volt0=x**	**x=Y**: Enable external voltage 0. **x=N**: Do not.
	Volt1=x	**x=Y**: Enable external voltage 1. **x=N**: Do not.
	Volt2=x	**x=Y**: Enable external voltage 2. **x=N**: Do not.
	Volt3=x	**x=Y**: Enable external voltage 3. **x=N**: Do not.
	Volt4=x	**x=Y**: Enable external voltage 4. **x=N**: Do not.
	Volt5=x	**x=Y**: Enable external voltage 5. **x=N**: Do not.
	DelayBeforeSampling =x	**x=** time (seconds) to wait after switching on external voltage before sampling (0-600 seconds). Default 0.
	Biowiper=x	**x=Y**: Configuration includes ECO-FL fluorometer with Bio-Wiper. **x=N** (default): Does not.

CATEGORY	COMMAND	DESCRIPTION
RS-232 Sensor Setup	**SBE38=x**	**x=Y**: Enable SBE 38. **x=N**: Do not.
	SBE50=x	**x=Y**: Enable SBE 50. **x=N**: Do not.
	GTD=x	**x=Y**: Enable GTD. **x=N**: Do not.
	DualGTD=x	**x=Y**: Enable dual (2) GTDs. **x=N**: Do not.
	TGTD	Measure GTD(s), output 1 converted data sample for each GTD.
	SendGTD=command	Command 16*plus* V2 to send **command** to GTD and receive response (**command** can be any command recognized by GTD).
Output Format Setup	**OutputFormat=x**	**x=0**: output raw frequencies and voltages in Hex (required if using SEASAVE or SBE Data Processing). **x=1**: output converted data in Hex. **x=2**: output raw frequencies and voltages in decimal. **x=3**: output converted data in decimal. **x=5**: output converted data in decimal, in XML.
	OutputSal=x	**x=Y**: Calculate and output salinity (psu). Only applies if **OutputFormat=3** or **5**. **x=N**: Do not.
	OutputSV=x	**x=Y**: Calculate and output sound velocity (m/sec). Only applies if **OutputFormat=3** or **5**. **x=N**: Do not.
	OutputUCSD=x	**x=Y**: Calculate and output density sigma-t (kg/m^3), battery voltage, and operating current (mA) with data polled while logging. Only applies if **OutputFormat=3** or **5**. **x=N**: Do not.
Autonomous Sampling (logging)	**SampleInterval=x**	**x**= interval (seconds) between samples (10 - 14,400).
	StartNow	Start autonomous sampling now.
	StartDateTime= mmddyyyyhhmmss	Delayed start: month, day, year, hour, minute, second.
	StartLater	Start autonomous sampling at **StartDateTime=**.
	Stop	Stop autonomous sampling or stop waiting to start autonomous sampling. Press Enter key before sending **Stop**. Must stop sampling before uploading data.
Polled Sampling	**SL**	Output last sample from buffer and leave power on.
	SLT	Output last sample from buffer, then take new sample and store data in buffer. Leave power on.
	TS	Take sample, store data in buffer, output data, and leave power on.
	TSS	Take sample, **store in buffer and FLASH memory**, output data, and turn power off.
	TSSOn	Take sample, **store in buffer and FLASH memory**, output data, and leave power on.
	GetLastSamples:x	Output last **x** samples from FLASH memory.
Serial Line Sync	**SyncMode=x**	**x=Y**: enable serial line sync mode. When RS-232 RX line is high (3-10 VDC) for 1-1000 milliseconds, 16*plus* V2 takes a sample, stores data in FLASH memory, and (if **TxRealTime=Y**) transmits real-time data. **x=N**: disable serial line sync mode.
	SyncWait=x	**x**= time (seconds) 16*plus* V2 monitors RS-232 line for commands after executing take sample command. Range 0 - 120 seconds; default 0 seconds.
Data Upload Stop autonomous sampling before upload.	**GetSamples:b,e** or **DDb,e**	Upload data from scan **b** to scan **e**.
	GetHeaders:b,e or **DHb,e**	Upload header **b** to header **e**.

Note:
Use the Upload menu to upload data that will be processed by SBE Data Processing. Manually entering the data upload command does not produce data with the required header information for processing by SBE Data Processing.

CATEGORY	COMMAND	DESCRIPTION
Testing Takes and outputs 100 samples for each test (except as noted). Press Esc key or send a break character to stop test.	**TC**	Measure conductivity, output converted data.
	TCR	Measure conductivity, output raw data.
	TT	Measure temperature, output converted data.
	TTR	Measure temperature, output raw data
	TP	Measure internally mounted pressure, output converted data.
	TPR	Measure internally mounted pressure, output raw data.
	TV	Measure 6 external voltage channels, output converted data.
	TVR	Measure 6 external voltage channels, main battery voltage, lithium battery voltage, external current, pressure temperature; output raw data.
	TF	Measure frequency (internally mounted Quartz pressure sensor), output converted data.
	TFR	Measure frequency (internally mounted Quartz pressure sensor), output raw data.
	T38	Measure SBE 38, output converted data.
	T50	Measure SBE 50 pressure, output converted data.
	PumpOn	Turn pump on for testing purposes.
	PumpOff	Turn pump off for testing purposes.
Calibration Coefficients (F=floating point number; S=string with no spaces) Dates shown are when calibrations were performed. Calibration coefficients are initially factory-set and should agree with Calibration Certificates shipped with 16*plus* V2. Pressure sensor coefficients are for internally mounted pressure sensor. View all coefficients with **GetCC** or **DCal**.	**TCalDate=S**	**S**=Temperature calibration date.
	TAO=F	**F**=Temperature A0.
	TA1=F	**F**=Temperature A1.
	TA2=F	**F**=Temperature A2.
	TA3=F	**F**=Temperature A3.
	TOffset=F	**F**=Temperature offset correction.
	CCalDate=S	**S**=Conductivity calibration date.
	CG=F	**F**=Conductivity G.
	CH=F	**F**=Conductivity H.
	CI=F	**F**=Conductivity I.
	CJ=F	**F**=Conductivity J.
	CPCor=F	**F**=Conductivity pcor.
	CTCor=F	**F**=Conductivity tcor.
	CSlope=F	**F**=Conductivity slope correction.
	PCalDate=S	**S**=Pressure calibration date.
	PRange=F	**F**=Pressure sensor full scale range (psia).
	POffset=F	**F**=Pressure offset correction.
	PA0=F	**F**=Strain gauge pressure A0.
	PA1=F	**F**=Strain gauge pressure A1.
	PA2=F	**F**=Strain gauge pressure A2.
	PTempA0=F	**F**=Strain gauge pressure temperature A0.
	PTempA1=F	**F**=Strain gauge pressure temperature A1.
	PTempA2=F	**F**=Strain gauge pressure temperature A2.
	PTCA0=F	**F**=Strain gauge pressure temperature compensation ptca0.
	PTCA1=F	**F**=Strain gauge pressure temperature compensation ptca1.
	PTCA2=F	**F**=Strain gauge pressure temperature compensation ptca2.
	PTCB0=F	**F**=Strain gauge pressure temperature compensation ptcb0.
	PTCB1=F	**F**=Strain gauge pressure temperature compensation ptcb1.
	PTCB2=F	**F**=Strain gauge pressure temperature compensation ptcb2.
	PC1=F	**F**=Quartz pressure C1.
	PC2=F	**F**=Quartz pressure C2.
	PC3=F	**F**=Quartz pressure C3.
	PD1=F	**F**=Quartz pressure D1.
	PD2=F	**F**=Quartz pressure D2.
	PT1=F	**F**=Quartz pressure T1.
	PT2=F	**F**=Quartz pressure T2.
	PT3=F	**F**=Quartz pressure T3.
	PT4=F	**F**=Quartz pressure T4.
	PSlope=F	**F**=Quartz pressure slope correction.
	ExtFreqSF=F	**F**=External frequency (internally mounted Quartz pressure sensor) scale factor.
	VOffset0=, **VSlope0=**, . . . **VSlope5=**, **VOffset5=**	Voltage channel offsets and slopes are all factory set, and should never be modified by customer. These are properties of 16*plus* V2 electronics, and are not calibration coefficients for auxiliary sensors. Enter calibration coefficients for auxiliary sensors in .con file in SEASAVE and/or SBE Data Processing.

CATEGORY	COMMAND
Hardware Configuration	*Factory Settings – do not modify in the field* **SetMfgDate=** **SetPcbSerialNum1=, SetPcbSerialNum2=,** **SetPcbSerialNum3=, SetPcbSerialNum4=** **SetPcbAssembly1=, SetPcbAssembly2=,** **SetPcbAssembly3=, SetPcbAssembly4=** *Auxiliary Sensor Settings – can be modified in the field to accommodate changes in auxiliary sensors cabled to 16plus V2* **SetVoltType0=, SetVoltSN0=** **SetVoltType1=, SetVoltSN1=** **SetVoltType2=, SetVoltSN2=** **SetVoltType3=, SetVoltSN3=** **SetVoltType4=, SetVoltSN4=** **SetVoltType5=, SetVoltSN5=**

Appendix IV: AF24173 Anti-Foulant Device

AF24173 Anti-Foulant Devices supplied for user replacement are supplied in polyethylene bags displaying the following label:

AF24173 ANTI-FOULANT DEVICE

FOR USE ONLY IN SEA-BIRD ELECTRONICS' CONDUCTIVITY SENSORS TO CONTROL THE GROWTH OF AQUATIC ORGANISMS WITHIN ELECTRONIC CONDUCTIVITY SENSORS.

ACTIVE INGREDIENT:

Bis(tributyltin) oxide…………..………………………….....	53.0%
OTHER INGREDIENTS: ………………………………....	47.0%
Total………………………………………………………....	100.0%

DANGER

See the complete label within the Conductivity Instrument Manual for Additional Precautionary Statements and Information on the Handling, Storage, and Disposal of this Product.

Net Contents: Two anti-foulant devices

Sea-Bird Electronics, Inc.
1808 - 136th Place Northeast
Bellevue, WA 98005

EPA Registration No. 74489-1
EPA Establishment No. 74489-WA-1

AF24173 Anti-Foulant Device

FOR USE ONLY IN SEA-BIRD ELECTRONICS' CONDUCTIVITY SENSORS TO CONTROL THE GROWTH OF AQUATIC ORGANISMS WITHIN ELECTRONIC CONDUCTIVITY SENSORS.

ACTIVE INGREDIENT:
Bis(tributyltin) oxide…………..…………………………..... 53.0%
OTHER INGREDIENTS: ……………………………….... 47.0%
Total……………………………………………………..... 100.0%

DANGER
See Precautionary Statements for additional information.

FIRST AID	
If on skin or clothing	• Take off contaminated clothing. • Rinse skin immediately with plenty of water for15-20 minutes. • Call a poison control center or doctor for treatment advice.
If swallowed	• Call poison control center or doctor immediately for treatment advice. • Have person drink several glasses of water. • Do not induce vomiting. • Do not give anything by mouth to an unconscious person.
If in eyes	• Hold eye open and rinse slowly and gently with water for 15-20 minutes. • Remove contact lenses, if present, after the first 5 minutes, then continue rinsing eye. • Call a poison control center or doctor for treatment advice.
HOT LINE NUMBER	
Note to Physician	Probable mucosal damage may contraindicate the use of gastric lavage.
Have the product container or label with you when calling a poison control center or doctor, or going for treatment. For further information call National Pesticide Telecommunications Network (NPTN) at 1-800-858-7378.	

Net Contents: Two anti-foulant devices

Sea-Bird Electronics, Inc.
1808 - 136th Place Northeast
Bellevue, WA 98005

EPA Registration No. 74489-1
EPA Establishment No. 74489-WA-1

PRECAUTIONARY STATEMENTS

HAZARD TO HUMANS AND DOMESTIC ANIMALS

DANGER

Corrosive - Causes irreversible eye damage and skin burns. Harmful if swallowed. Harmful if absorbed through the skin or inhaled. Prolonged or frequently repeated contact may cause allergic reactions in some individuals. Wash thoroughly with soap and water after handling.

PERSONAL PROTECTIVE EQUIPMENT

USER SAFETY RECOMMENDATIONS

Users should:

- Remove clothing immediately if pesticide gets inside. Then wash thoroughly and put on clean clothing.
- Wear protective gloves (rubber or latex), goggles or other eye protection, and clothing to minimize contact.
- Follow manufacturer's instructions for cleaning and maintaining PPE. If no such instructions for washables, use detergent and hot water. Keep and wash PPE separately from other laundry.
  - Wash hands with soap and water before eating, drinking, chewing gum, using tobacco or using the toilet.

ENVIRONMENTAL HAZARDS

Do not discharge effluent containing this product into lakes, streams, ponds, estuaries, oceans, or other waters unless in accordance with the requirements of a National Pollutant Discharge Elimination System (NPDES) permit and the permitting authority has been notified in writing prior to discharge. Do not discharge effluent containing this product to sewer systems without previously notifying the local sewage treatment plant authority. For guidance contact your State Water Board or Regional Office of EPA. This material is toxic to fish. Do not contaminate water when cleaning equipment or disposing of equipment washwaters.

PHYSICAL OR CHEMICAL HAZARDS

Do not use or store near heat or open flame. Avoid contact with acids and oxidizers.

DIRECTIONS FOR USE

It is a violation of Federal Law to use this product in a manner inconsistent with its labeling. For use only in Sea-Bird Electronics' conductivity sensors. Read installation instructions in the applicable Conductivity Instrument Manual.

STORAGE AND DISPOSAL

PESTICIDE STORAGE: Store in original container in a cool, dry place. Prevent exposure to heat or flame. Do not store near acids or oxidizers. Keep container tightly closed.

PESTICIDE SPILL PROCEDURE: In case of a spill, absorb spills with absorbent material. Put saturated absorbent material to a labeled container for treatment or disposal.

PESTICIDE DISPOSAL: Pesticide that cannot be used according to label instructions must be disposed of according to Federal or approved State procedures under Subtitle C of the Resource Conservation and Recovery Act.

CONTAINER DISPOSAL: Dispose of in a sanitary landfill or by other approved State and Local procedures.

Sea-Bird Electronics/label revised 01-31-05

Appendix V: Replacement Parts

Part Number	Part	Application Description	Quantity in 16*plus* V2
22018	Batteries, alkaline D-cell, Duracell MN 1300 (LR20)	Power 16*plus* V2	9
41124B	Battery cover plate	Retains batteries	1
801483	9D (10.8V / 42 amp-hour) lithium battery pack kit	For longer deployments; **batteries not included in kit, and not available from Sea-Bird**	-
801479	3DD (10.8V / 30 amp-hour) lithium battery pack kit	For longer deployments; **batteries not included in kit, and not available from Sea-Bird**	-
30411	Triton X-100	Octyl Phenol Ethoxylate – Reagent grade non-ionic cleaning solution for conductivity cell (supplied in 100% strength; dilute as directed)	1
801542	AF24173 Anti-Foulant Device	bis(tributyltin) oxide device inserted into anti-foulant device cup	1 (set of 2)
231505	Anti-foulant device cap	Secures AF24173 Anti-Foulant Device in cup	2
30984	Anti-foulant device plug	Seals end of anti-foulant assembly when not deployed	2
17709*	6-pin AG-206 to 2-pin RMG-2FS and 4-pin RMG-4MP Pump / Data I/O-Power Y-cable	From SBE 16*plus* V2 bulkhead connector to pump (2-pin) and data I/O - power (4-pin)	1
801225*	4-pin RMG-4FS to 9-pin DB -9S I/O cable, 2.4 m (8 ft) long	From 4-pin connector on Y-cable 17709 to computer	1
171888	25-pin DB-25S to 9-pin DB-9P cable adapter	For use with computer with DB-25 connector	-
17133*	2-pin RMG-2FS to 2-pin RMG-2FS cable, 1.1 m (3.7 ft.) long	From 2-pin connector on Y-cable 17709 to optional pump	1
17044.1*	2-pin RMG-2FS dummy plug and locking sleeve	For 2-pin connector on Y-cable 17709, when pump not used	1
17046.1*	4-pin RMG-4FS dummy plug and locking sleeve	For 4-pin connector on Y-cable 17709, when I/O cable not used. Also, for 4-pin RS-232 auxiliary sensor connector when not used.	2
17047.1*	6-pin AG-206 dummy plug and locking sleeve	For when auxiliary differential input sensors not used	3
171883	6-pin MCIL-6FS to 2-pin MCIL-2FS and 4-pin MCIL-4MP Pump / Data I/O Y-cable	From SBE 16*plus* V2 bulkhead connector to pump (2-pin) and data I/O - power (4-pin)	1
801374	4-pin MCIL-4FS (wet-pluggable connector) to 9-pin DB-9S I/O cable, 2.4 m (8 ft) long	From 4-pin connector on Y-cable 171883 to computer	1
171503	2-pin MCIL-2FS to 2-pin MCIL-2FS (wet-pluggable connector) cable, 1.1 m (3.7 ft) long	From 2-pin connector on Y-cable 171883 to pump	1
171497.1	2-pin MCDC-2-F wet-pluggable dummy plug and locking sleeve	For 2-pin connector on Y-cable 171883 when pump not used	1
171398.1	4-pin MCDC-4-F wet-pluggable dummy plug and locking sleeve	For 4-pin connector on Y-cable 171883 when I/O cable not used. Also, for 4-pin RS-232 auxiliary sensor connector when not used.	2
171498.1	6-pin MCDC-6-F wet-pluggable dummy plug and locking sleeve	For when auxiliary differential input sensors not used	3
30388	Tygon tube, ½ inch ID x ¾ inch OD	Main plumbing tubing for pumped configuration	-
30579	Tygon tube, 3/8 inch ID x ½ inch OD	13 mm (0.5 inch) long pieces used for pumped configurations on conductivity cell exhaust cap and for SBE 43 intake and exhaust to fit to main plumbing	-
22009	Panasonic BR-2/3A lithium batteries	Back-up lithium cells on Power PCB	3

* For standard bulkhead connectors

continued on next page

continued from previous page

Part Number	Part	Application Description	Quantity in 16*plus* V2
60021	Spare battery end cap hardware and o-rings	O-rings and hardware, including: • 30145 Screw, 6-32 x 1/2 Phillips-head, stainless steel (secures battery cover plate to battery posts) • 30242 Washer, #6 flat, stainless steel (for 30145) • 30816 Parker 2-234E603-70 (battery end cap to housing piston seal, sensor end cap to housing seals) • 30090 Parker 2-153N674-70 (battery end cap to housing face seal)	-
50274	Spare o-ring kit	Assorted o-rings, including: • 30816 Parker 2-234E603-70 (battery end cap to housing piston seal, sensor end cap to housing seals) • 30090 Parker 2-153N674-70 (battery end cap to housing face seal) • 30507 Parker 2-206N674-70 (each end of conductivity cell) • 30802 Parker 2-110DUR070, ethylene (titanium conductivity cell tray face seal, groove surface) • 30809 Morrison seal, .047" hole, NIT (temperature probe Morrison seal) • 30072 Parker 2-017N674-70 (bulkhead connector seal) • 30070 Parker 3-904N674-70 (pressure sensor mounting seal) • 30087 Parker 2-232N674-70 (buffer for top retainer of PCB sandwich assembly) • 30801 Parker 5-374E603-70 (base of battery bulkhead seal)	-
50273	Spare hardware kit	Assorted hardware, including: • 30145 Screw, 6-32 x 1/2 Phillips-head, stainless steel (secures battery cover plate to battery posts) • 30242 Washer, #6 flat, stainless steel (for 30145) • 30414 Washer, #12, internal tooth (secures battery bulkhead retainer) • 30954 Screw 4-40 x 3/16 Phillips-head, stainless steel (securing screw for PCB retainer rod) • 31119 Screw 6-32 x 5/8 Truss Head (secures battery bulkhead retainer to bulkhead bottom plate) • 30176 Screw, 10-24 x 3/4, Phillips-head, stainless steel (secures Celcon threaded ring inside titanium battery end cap) • 30249 Washer #10, Flat, stainless steel (for 30176) • 30447 Bolt, ¼-20 x 1 ¼ Hex, titanium (secures lift eye to battery end cap) • 31089 Screw, 10-32 x 1/2 flat Phillips-head, titanium (secures sensor end cap to housing - side opposite conductivity cell guard) • 31090 Screw, 10-32 x 5/8 flat Phillips-head, titanium (secures conductivity cell guard to housing) • 31118 Screw, 10-32 x 3/8 Phillips-head, titanium (secures conductivity cell guard to sensor end cap) • 30875 Bolt ¼-20 x 5/8 Hex, titanium (secures connector guard to sensor end cap) • 30633 Washer, ¼" split ring lock, titanium (for 30875) • 30919 Screw, 6-32 x 3/8 flat slotted, titanium (secures anti-foulant device cup to conductivity cell guard) • 31066 Screw, 8-32 x ¾ socket, titanium (secures conductivity cell and TC duct to sensor end cap)	-
50434	Seaspares kit, standard connectors	Includes o-rings, hardware, bulkhead connectors, dummy plugs, etc.: • 50087 Conductivity cell filling and storage kit • 50273 Spare hardware kit (see above) • 50274 Spare o-ring kit (see above) • 41124 Battery cover plate • 801225 Data I/O cable, 4-pin RMG-4FS to 9-pin DB -9S I/O cable, 2.4 m (8 ft) long • 171888 Cable adapter, DB-25 to DB-9 • 17046.1 4-pin RMG-4FS dummy plug with locking sleeve • 17047.1 6-pin AG-206 dummy plug with locking sleeve • 17654 4-pin XSG-4-BCL-HP-SS bulkhead connector • 17628 6-pin AG-306-HP-SS bulkhead connector • 30388 Vinyl tube, ¾" x ½" (main sensor plumbing tubing) • 30409 Teflon tape (for insides of hose clamps) • 30411 Triton X100 (for cell cleaning) • 30457 Parker O-Lube (o-ring lubricant)	-

continued on next page

continued from previous page

Part Number	Part	Application Description	Quantity in 16*plus* V2
50435	Seaspares kit, wet-pluggable connectors	Includes o-rings, hardware, bulkhead connectors, dummy plugs, etc.: • 50087 Conductivity cell filling and storage kit • 50273 Spare hardware kit (see above) • 50274 Spare o-ring kit (see above) • 41124 Battery cover plate • 801374 Data I/O cable, 4-pin MCIL-4FS (wet-pluggable connector) to 9-pin DB-9S I/O cable, 2.4 m (8 ft) long • 171888 Cable adapter, DB-25 to DB-9 • 171192 Locking sleeve • 171398 4-pin MCDC-4-F wet-pluggable dummy plug • 171498 6-pin MCDC-6-F wet-pluggable dummy plug • 172021 4-pin MCBH-4MP(WB), TI ½-20 bulkhead connector • 172022 6-pin MCBH-6MP(WB), TI ½-20 bulkhead connector • 30388 Vinyl tube, ¾” x ½” (main sensor plumbing tubing) • 30409 Teflon tape (for insides of hose clamps) • 30411 Triton X100 (for cell cleaning) • 30457 Parker O-Lube (o-ring lubricant)	-

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SBE 16*plus* V2 (RS-232) SEACAT Reference Sheet
(see SBE 16*plus* V2 [RS-232] User's Manual for complete details)

Sampling Modes

- **Autonomous sampling** - The 16*plus* V2 takes time series measurements once every 10 seconds to once every 4 hours, stores data in FLASH memory, and powers down between samples. Data can also be simultaneously transmitted real-time.
- **Polled sampling** – The 16*plus* V2 takes one sample. Depending on command used, the 16*plus* V2 can store data in FLASH memory and / or transmit data to computer.
- **Serial line sync** – The 16*plus* V2 wakes up, samples, stores data in FLASH memory, and powers off in response to a pulse on serial line. Depending on setup, the 16*plus* V2 can transmit data to computer. This provides an easy method for synchronizing 16*plus* V2 sampling with other instruments such as Acoustic Doppler Current Profilers (ADCPs) or current meters, without drawing on their battery or memory resources.

Communication Setup Parameters

1. Double click on SCPlusV2_RS232.exe.

2. Once main screen appears, in the Serial Port menu, select Configure. Select the Comm port and baud rate (factory set to 9600), and click OK.

3. The terminal program should automatically connect to the 16*plus* V2. As it connects, it sends **GetHD** and displays the response, and then fills the Send Commands window with the list of commands for your 16*plus* V2.

Deployment

1. Batteries:
   A. *Remove battery end cap*: Wipe dry housing/end cap seam. Unthread end cap by rotating counter-clockwise. Wipe dry O-ring mating surfaces in housing with lint-free cloth.
   B. *Remove and replace battery cover plate and batteries*: Remove three Phillips-head screws and washers from battery cover plate, and remove cover plate. Turn 16*plus* V2 over and remove batteries. Install new batteries, + terminals against flat contacts and - terminals against spring contacts. Align battery cover plate with housing. Reinstall three Phillips-head screws and washers, while pushing hard on battery cover plate to depress spring contacts at bottom of battery compartment.
   C. *Reinstall battery end cap*: Remove water from O-rings and mating surfaces with lint-free cloth. Inspect O-rings and mating surfaces for dirt, nicks, and cuts. Clean/replace as necessary. Apply light coat of O-ring lubricant to O-ring and mating surfaces. Fit end cap into housing and rethread into place, using a wrench to ensure end cap is tightly secured.

2. Program 16*plus* V2 for intended deployment (see other side of this sheet for *Command Instructions and List*):
   A. Send **DateTime=mmddyyyyhhmmss** (month, day, year, hour, minute, second) to set date and time.
   B. Ensure all data has been uploaded, and then send **InitLogging** to make entire memory available for recording. If **InitLogging** is not sent, data will be stored after last recorded sample.
   C. Establish setup and sampling parameters. If desired, use **StartDateTime=** and **StartLater** to establish delayed start date and time.

3. Install a cable or dummy plug for each connector on 16*plus* V2 sensor end cap. Install a locking sleeve over each plug/cable connector. Connect other end of cables to appropriate sensors.

4. Verify hardware and external fittings are secure.

5. Remove Tygon tubing that is looped end-to-end around conductivity cell.

6. For Autonomous sampling: If not already done, send **StartNow** or send **StartDateTime=** and **StartLater**.

Command Instructions and List

- Input commands in upper or lower case letters and register commands by pressing Enter key.
- 16*plus* V2 sends an error message if an invalid command is entered.
- (if **OutputExecutedTag=N**) If 16*plus* V2 does not return `S>` prompt after executing a command, press Enter key to get `S>`.
- If new command is not received within 2 minutes after completion of a command, 16*plus* V2 returns to quiescent (sleep) state.
- If in quiescent (sleep) state, re-establish communications by clicking Connect in Serial Port menu or pressing Enter key.

Shown below are the commands used most commonly in the field. See the Manual for complete listing and detailed descriptions.

CATEGORY	COMMAND	DESCRIPTION
Status	**GetCD**	Get and display Configuration Data.
	GetSD	Get and display Status Data.
	GetCC	Get and display Calibration Coefficients.
	GetEC	Get and display Event Counters.
	ResetEC	Reset Event Counters.
	GetHD	Get and display Hardware Data.
	DS	Display status and setup parameters.
	DCal	Display calibration coefficients.
General Setup	**DateTime=mmddyyyyhhmmss**	Set real-time clock month, day, year, hour, minute, second.
	BaudRate=x	**x=** baud (600, 1200, 2400, 4800, 9600, 19200, 33600, 38400, 57600, 115200). Default 9600.
	Echo=x	**x=Y**: Echo characters as you type. **x=N**: Do not.
	OutputExecutedTag=x	**x=Y**: Display XML Executing and Executed tags. **x=N**: Do not.
	TxRealTime=x	**x=Y**: Output real-time data for autonomous sampling and serial line sync. **x=N**: Do not.
	PumpMode=x	**x=0**: No pump. **x=1**: Run pump for 0.5 seconds before each sample. **x=2**: Run pump during each sample.
	NCycles=x	**x=** number of measurements to take and average for every sample.
	InitLogging	After uploading data, initialize logging to make entire memory available for recording.
	SampleNumber=x	After uploading data, set **SampleNumber=0** to make entire memory available for recording.
	HeaderNumber=x	**x=** header number for first header when sampling begins.
	QS	Place 16*plus* V2 in quiescent (sleep) state. Logging and memory retention not affected.
Pressure Sensor Setup (*internally mounted*)	**PType=x**	**x=0**: No pressure. **x=1**: Strain gauge pressure sensor. **x=3**: Quartz pressure sensor with temperature compensation.
	RefPress=x	**x=** reference pressure (gauge) in db to use if 16*plus* V2 does not include pressure sensor.
	ParosIntegration=x	**x=** integration time (seconds) for Quartz pressure sensor.
Voltage Sensor Setup	**Volt0=x Volt1=x Volt2=x** **Volt3=x Volt4=x Volt5=x**	**x=Y**: Enable external voltage (voltage 0, 1, 2, 3, 4, and 5). **x=N**: Do not.
	DelayBeforeSampling=x	**x=** time (seconds) to wait after switching on external voltage before sampling.
	BioWiper=x	**x=Y**: Configuration includes ECO-FL fluorometer with Bio-Wiper. **x=N**: Does not.
RS-232 Sensor Setup	**SBE38=x**	**x=Y**: Enable SBE 38 secondary temperature sensor. **x=N**: Do not.
	SBE50=x	**x=Y**: Enable SBE 50 pressure sensor. **x=N**: Do not.
	GTD=x	**x=Y**: Enable GTD (Pro-Oceanus Gas Tension Device). **x=N**: Do not.
	DualGTD=x	**x=Y**: Enable dual (2) GTDs (Pro-Oceanus Gas Tension Devices). **x=N**: Do not.
	TGTD	Measure Gas Tension Device(s), output 1 converted data sample for each GTD.
	SendGTD=command	Send **command** to GTD (any command recognized by GTD) and receive response.
Output Format	**OutputFormat=x**	**x=0**: Raw frequencies/voltages, Hex. **x=1**: Converted data, Hex. **x=2**: Raw frequencies/voltages, decimal. **x=3**: Converted data, decimal. **x=4**: Not valid format; do not use. **x=5**: Converted data, decimal, XML.
	OutputSal=x	x=Y: Output salinity (psu). **x=N**: Do not.
	OutputSV=x	x=Y: Output sound velocity (m/sec). **x=N**: Do not.
	OutputUCSD=x	x=Y: Output sigma-t (kg/m^3), battery voltage, operating current (mA). **x=N**: Do not.
Autonomous Sampling (logging)	**SampleInterval=x**	**x** = interval between samples (10 - 14,400 seconds).
	StartNow	Start autonomous sampling now.
	StartDateTime=mmddyyyyhhmmss	Delayed start: month, day, year, hour, minute, second.
	StartLater	Start autonomous sampling at delayed start time.
	Stop	Stop autonomous sampling or waiting to start autonomous sampling. Press Enter key before entering command. Must stop sampling before uploading data.
Polled Sampling	**SL**	Output last sample from buffer and leave power on.
	SLT	Output last sample from buffer, take new sample and store data in buffer. Leave power on.
	TS	Take sample, store in buffer, output data. Leave power on.
	TSS	Take sample, **store in buffer and FLASH memory**, output data, turn power off.
	TSSOn	Take sample, **store in buffer and FLASH memory**, output data, leave power on.
	GetLastSamples:x	Output last **x** samples from FLASH memory.
Serial Line Sync	**SyncMode=x**	**x=Y**: Enable serial line sync mode. **x=N**: Do not.
	SyncWait=x	**x=** time (seconds) 16*plus* V2 monitors line for commands after taking sample in sync mode.
Data Upload	**GetSamples:b,e** or **DDb,e**	Upload data from scan **b** to **e**.
	GetHeaders:b,e or **DHb,e**	Upload headers from header **b** to **e**.

SPECIFICATIONS

SEACAT C-T Recorder

SBE 16*plus* V2

The SBE 16*plus* **V2** (Version 2) SEACAT Recorder measures temperature and conductivity (pressure optional) and provides high acccuracy and resolution, reliability, and ease-of-use on moorings and other long-duration, fixed-site deployments. The V2 is the most versatile successor in the line of SEACAT Recorders begun with the original SBE 16 SEACAT in 1987.

Standard plastic and optional titanium housing shown

Compared to the previous 16*plus*, the 16*plus* V2 incorporates an electronics upgrade and additional features. The V2 has two additional (six total) differentially-amplified A/D input channels, FLASH memory is increased from 8 to 64 MB, and one RS-232 data input channel is added. Data can be output in XML as well as ASCII and HEX formats. Firmware upgrades can be downloaded through the communications port by the user, without opening the instrument.

The SBE 16*plus* V2 uses the same temperature and conductivity sensors proven in 10,000 SEACATs and MicroCATs, and (optionally) a silicon strain gauge or Digiquartz® pressure sensor. Improvements in design, materials, and signal acquisition techniques yield a low-cost instrument with superior performance that is also easy to use. Calibration coefficients, obtained in our computer-controlled high accuracy calibration baths, are stored in EEPROM memory. They permit data output in ASCII engineering units (degrees C, Siemens/m, decibars, salinity [PSU], sound velocity [m/sec.], etc.).

The SBE 16*plus* V2 sample interval is soft-programmable in 1-second increments ranging from 10 to 14,400 seconds. Between samples, the 16*plus* V2 powers down, drawing only 20 microamps of current. Nine alkaline D-cells provide power for 355,000 samples of C and T (operation time is shorter if powering auxiliary sensors). Conditioned power (500 ma) is available for auxiliary sensors (dissolved oxygen, turbidity, fluorescence, PAR, etc.). Data is recorded in non-volatile FLASH memory for 38.4K baud upload after recovery.

Real-time monitoring is practical using the SBE 16*plus* V2 3-wire RS-232C data output. The 16*plus* V2 is well suited to networked sensor arrays where its operation can be triggered by satellite, radio, or hardwire telemetry equipment. Optional RS-485 (2-wire) and inductive modem (1-wire loop) interfaces allow multiple SEACATs to share a simple and robust telemetry cable.

CONFIGURATION, OPTIONS, AND ACCESSORIES

A standard SBE 16*plus* V2 is supplied with:
- Plastic housing for depths to 600 meters
- 64 Mbyte FLASH RAM memory
- 9 D-size alkaline batteries
- Glass-reinforced epoxy bulkhead connectors
- Anti-foul attachments and expendable anti-foulant devices

Options and accessories include:
- Titanium housing for depths to 7000 or 10,500 meters
- Semi-conductor strain gauge pressure sensor or Digiquartz® pressure sensor
- RS-485 half-duplex interface in place of RS-232
- Inductive modem interface in place of RS-232 / RS-485 (see SBE 16*plus*-IM V2 datasheet for details)
- Auxiliary sensors for dissolved oxygen, fluorescence, radiance (PAR), light transmission, and optical backscatter (turbidity)
- SBE 5M miniature pump for pumped conductivity; SBE 5P or 5T pump for pumped conductivity and pumped auxiliary sensor(s)
- Wet-pluggable MCBH series connectors
- Battery pack kit for lithium batteries (lithium batteries **not** supplied by Sea-Bird)

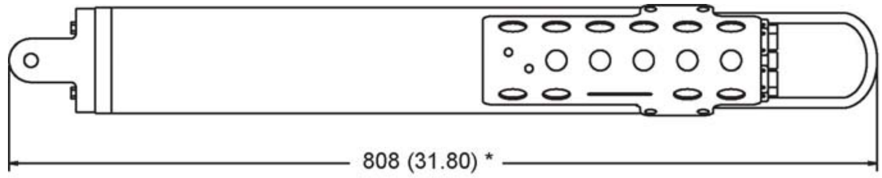
SOFTWARE

The SBE 16*plus* V2 is supplied with a powerful Windows 2000/XP software package, SEASOFT©-Win32, which includes programs for communication and data retrieval, real-time data acquisition and display, and data processing (filtering, aligning, averaging) and plotting of CTD and auxiliary sensor data and derived variables.

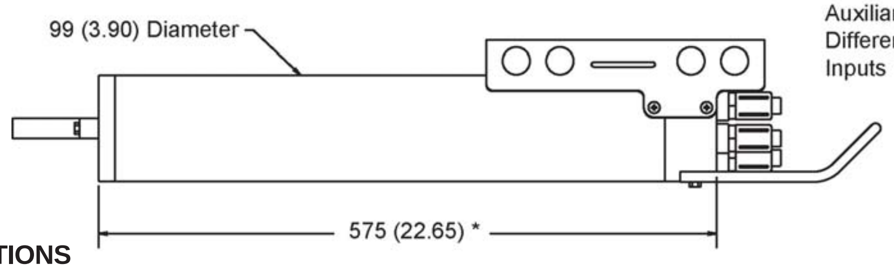
SEACAT C-T Recorder

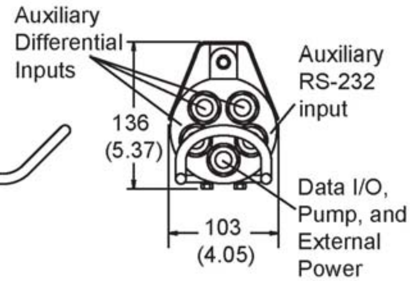
SBE 16*plus* V2

Dimensions in millimeters (inches)



* Note: 16*plus* V2 with optional Quartz pressure sensor is 190 mm (7.5 inches) longer than shown in drawing.





SPECIFICATIONS

Measurement Range
Temperature -5 to +35 °C
Conductivity 0 to 9 S/m
Pressure (optional) Strain-gauge 0 to 20/100/350/600/1000/2000/3500/7000 meters
Quartz 0 to 20/60/130/200/270/680/1400/2000/4200/7000/10,500 meters

Initial Accuracy
Temperature 0.005 °C
Conductivity 0.0005 S/m
Pressure (optional) Strain-gauge 0.1% of full scale range
Quartz 0.02% of full scale range

Typical Stability
Temperature 0.0002 °C/month
Conductivity 0.0003 S/m/month
Pressure (optional) Strain-gauge 0.1% of full scale range/year
Quartz 0.025% of full scale range/year

Resolution
Temperature 0.0001 °C
Conductivity 0.00005 S/m typical
Pressure (optional) Strain-gauge 0.002% of full scale range
Quartz — depends on sample integration time;
0.0006% of full scale range for 1-second integration

Memory 64 Mbyte non-volatile FLASH memory

Data Storage

Recorded Parameter	Bytes/Sample
T + C	6
pressure - *strain gauge* or *Quartz*	5
each external voltage	2
auxiliary RS-232 sensor	sensor dependent
date and time	4

Real-Time Clock 32,768 Hz TCXO accurate to ±1 minute/year

Internal Batteries 9 alkaline D-cells

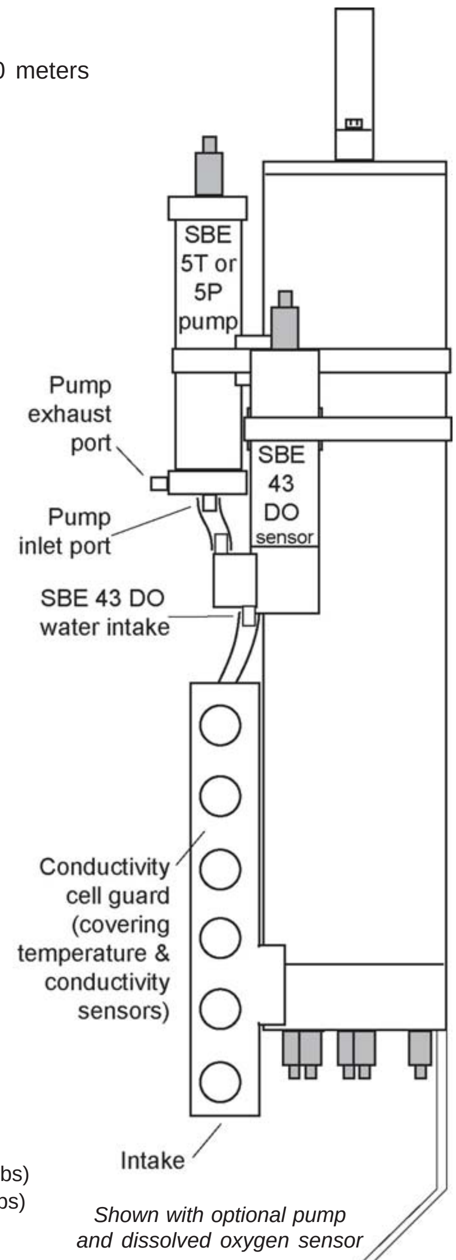
External Power Supply 9 - 28 VDC; consult factory for required current

Battery Endurance [1]
CT only 355,000 samples
CTD only 240,000 samples
CTD & 5M pump 140,000 samples

[1] With Duracell MN1300 cells. Dependent on sampling scheme.

Auxiliary Sensors
Auxiliary power out up to 500 mA at 10.5 - 11 VDC
Voltage Sensor A/D resolution 14 bits
Voltage sensor input range 0 - 5 VDC

Housing Materials — Depth Rating — Weight
Acetal Copolymer *Plastic* housing — 600 meter (1950 feet) — *in air* 7.3 kg (16 lbs); *in water* 2.3 kg (5 lbs)
3AL-2.5V *Titanium* housing — 7000 meter (22,900 feet) — *in air* 13.7 kg (30 lbs); *in water* 8.6 kg (19 lbs)
6AL-4V *Titanium* housing — 10500 meter (34,400 feet)



Shown with optional pump and dissolved oxygen sensor

02/08

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Telephone: (425) 643-9866
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Mini Submersible Pump SBE 5M

The SBE 5M pump module consists of a centrifugal pump head and a long-life, DC, ball-bearing motor contained in a compact, titanium pressure housing usable to 10,500 meters (34,400 ft) deep. A plastic housing for depths to 600 meters (1960 ft) is available as an option. The pump impeller and electric drive motor are coupled magnetically through the housing, providing high reliability by eliminating moving seals. Motor speed and pumping rate remain constant over the entire input voltage range. The motor drive electronics is intrinsically protected against accidental reversed polarity.

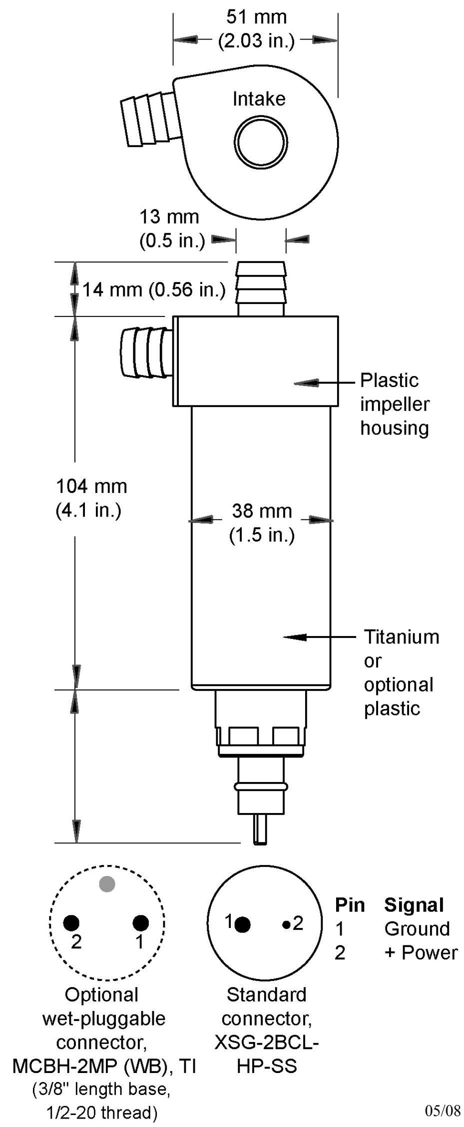
APPLICATIONS

The SBE 5M is standard on the SBE 19*plus* V2 SEACAT Profiler CTD, and is optional on the SBE 16*plus* V2 and 16*plus*-IM V2 SEACAT C-T Recorders. The pump flushes water through the conductivity cell at a constant rate, independent of the CTD's motion, improving dynamic performance. For applications requiring pumping through additional sensors (for example, a dissolved oxygen sensor), use the SBE 5T or 5P pump instead.

Specify:

- Option **5M-1** for profiling (continuous duty) applications such as the SBE 19*plus* V2.
- Option **5M-2** for moored (pulsed duty) applications such as the SBE 16*plus* V2 or 16*plus*-IM V2.

Contact Sea-Bird for use in other applications.



SPECIFICATIONS

Option 5M-1 (continuous duty):
Input voltage range 9 - 18 VDC

Flow Rate 25 ml/s   Supply current 95 mA
Note: Supply current is independent of operating voltage.

Option 5M-2 (pulsed duty):
Input voltage range 6 - 18 VDC

Pulse Duration	*Flow Volume*	*Electrical Charge*
0.5 seconds	15 ml	0.148 Amp-seconds
1.0 seconds	21 ml	0.283 Amp-seconds
1.5 seconds	31 ml	0.418 Amp-seconds
2.0 seconds	40 ml	0.553 Amp-seconds

Weight
With standard ***titanium*** housing:
In Air - 0.42 kg (0.91 lbs); In Water - 0.28 kg (0.60 lbs)
With optional ***plastic*** housing:
In Air - 0.28 kg (0.60 lbs); In Water - 0.13 kg (0.29 lbs)

05/08

CALIBRATION SHEETS

SEA-BIRD ELECTRONICS, INC.

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

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

SENSOR SERIAL NUMBER: 6479
CALIBRATION DATE: 30-Dec-09

SBE19plus TEMPERATURE CALIBRATION DATA
ITS-90 TEMPERATURE SCALE

ITS-90 COEFFICIENTS

a0 = 1.296268e-003
a1 = 2.570590e-004
a2 = 8.561273e-008
a3 = 1.338387e-007

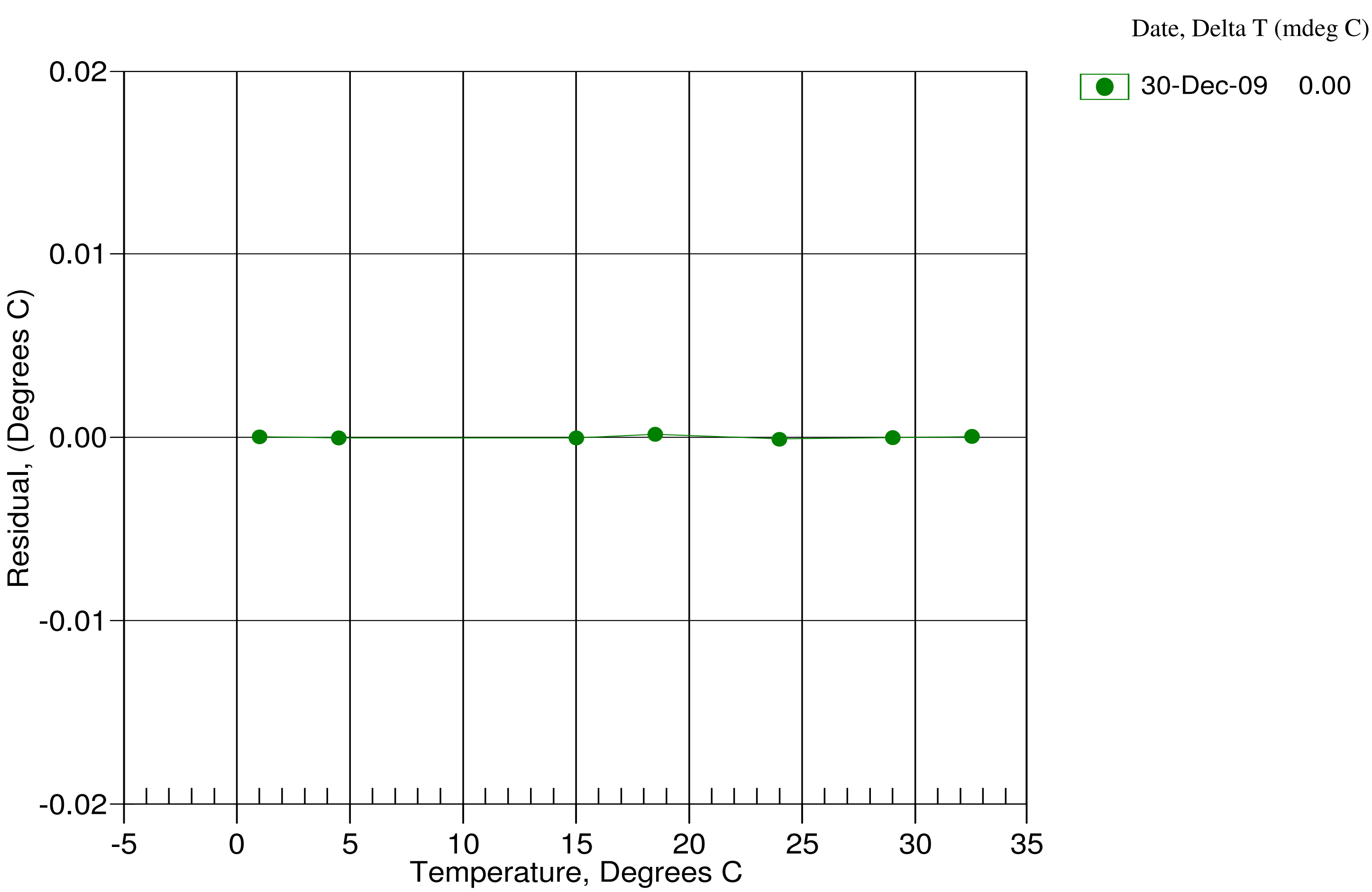
BATH TEMP (ITS-90)	INSTRUMENT OUTPUT(n)	INST TEMP (ITS-90)	RESIDUAL (ITS-90)
1.0000	636986.475	1.0000	0.0000
4.5000	564664.288	4.5000	-0.0000
15.0001	385311.322	15.0001	-0.0000
18.5000	337275.644	18.5001	0.0001
24.0000	272224.881	23.9999	-0.0001
29.0001	222870.915	29.0001	-0.0000
32.5001	193151.576	32.5001	0.0000

MV = (n - 524288) / 1.6e+007

R = (MV * 2.900e+009 + 1.024e+008) / (2.048e+004 - MV * 2.0e+005)

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

Residual = instrument temperature - bath temperature



SEA-BIRD ELECTRONICS, INC.

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

SENSOR SERIAL NUMBER: 6479
CALIBRATION DATE: 30-Dec-09

SBE19plus CONDUCTIVITY CALIBRATION DATA
PSS 1978: C(35,15,0) = 4.2914 Siemens/meter

COEFFICIENTS:

g = -1.067472e+000
h = 1.488908e-001
i = -2.544682e-004
j = 3.924910e-005

CPcor = -9.5700e-008
CTcor = 3.2500e-006

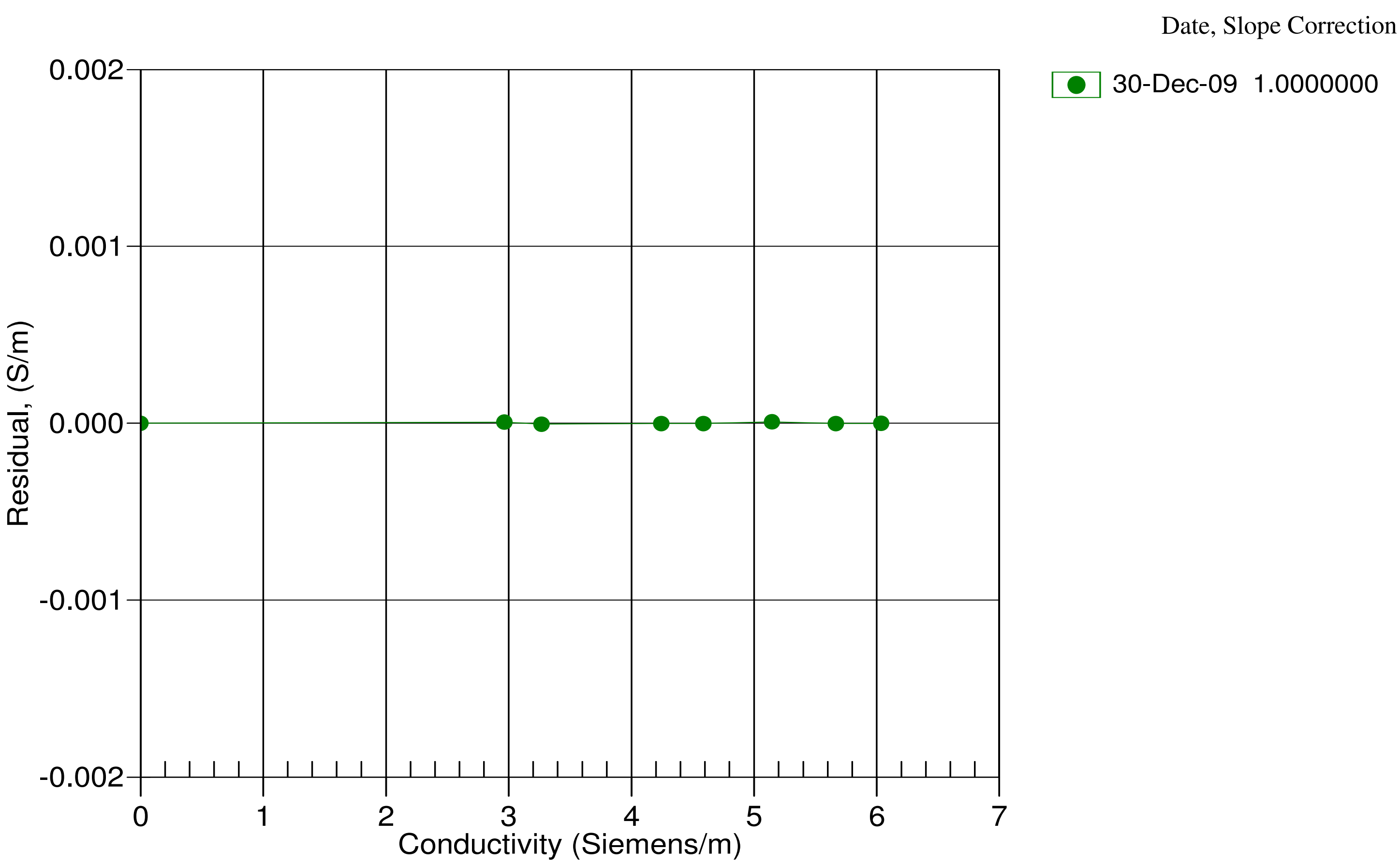
BATH TEMP (ITS-90)	BATH SAL (PSU)	BATH COND (Siemens/m)	INST FREQ (Hz)	INST COND (Siemens/m)	RESIDUAL (Siemens/m)
22.0000	0.0000	0.00000	2681.20	0.0000	0.00000
1.0000	34.6428	2.96254	5207.16	2.9625	0.00001
4.5000	34.6227	3.26825	5400.50	3.2682	-0.00001
15.0001	34.5788	4.24556	5976.12	4.2456	-0.00000
18.5000	34.5692	4.58911	6165.47	4.5891	-0.00000
24.0000	34.5582	5.14446	6459.55	5.1445	0.00001
29.0001	34.5516	5.66383	6722.66	5.6638	-0.00000
32.5001	34.5473	6.03437	6904.07	6.0344	-0.00000

f = INST FREQ / 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.

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

SENSOR SERIAL NUMBER: 6479
CALIBRATION DATE: 10-Dec-09

SBE19plus PRESSURE CALIBRATION DATA
160 psia S/N 2926641

COEFFICIENTS:

PA0 =	4.049016e-002	PTCA0 =	5.242168e+005
PA1 =	4.872830e-004	PTCA1 =	1.276062e+001
PA2 =	-5.509904e-012	PTCA2 =	-5.608900e-001
PTEMPA0 =	-6.508839e+001	PTCB0 =	2.499250e+001
PTEMPA1 =	5.263066e+001	PTCB1 =	-9.000000e-004
PTEMPA2 =	-5.566800e-001	PTCB2 =	0.000000e+000

PRESSURE SPAN CALIBRATION

PRESSURE PSIA	INST OUTPUT	THERMISTOR OUTPUT	COMPUTED PRESSURE	ERROR %FSR
14.70	554357.0	1.5	14.70	-0.00
29.94	585619.0	1.5	29.92	-0.01
59.93	647290.0	1.5	59.93	0.00
94.96	719365.0	1.5	94.94	-0.01
124.94	781203.0	1.5	124.94	-0.00
159.96	853509.0	1.5	159.95	-0.00
124.95	781265.0	1.5	124.97	0.01
94.97	719438.0	1.5	94.98	0.00
59.98	647429.0	1.5	60.00	0.01
14.69	554359.0	1.6	14.70	0.01

THERMAL CORRECTION

TEMP ITS90	THERMISTOR OUTPUT	INST OUTPUT
32.50	1.89	554547.32
29.00	1.82	554606.65
24.00	1.72	554686.42
18.50	1.62	554758.03
15.00	1.55	554789.81
4.50	1.34	554770.42
1.00	1.27	554718.13

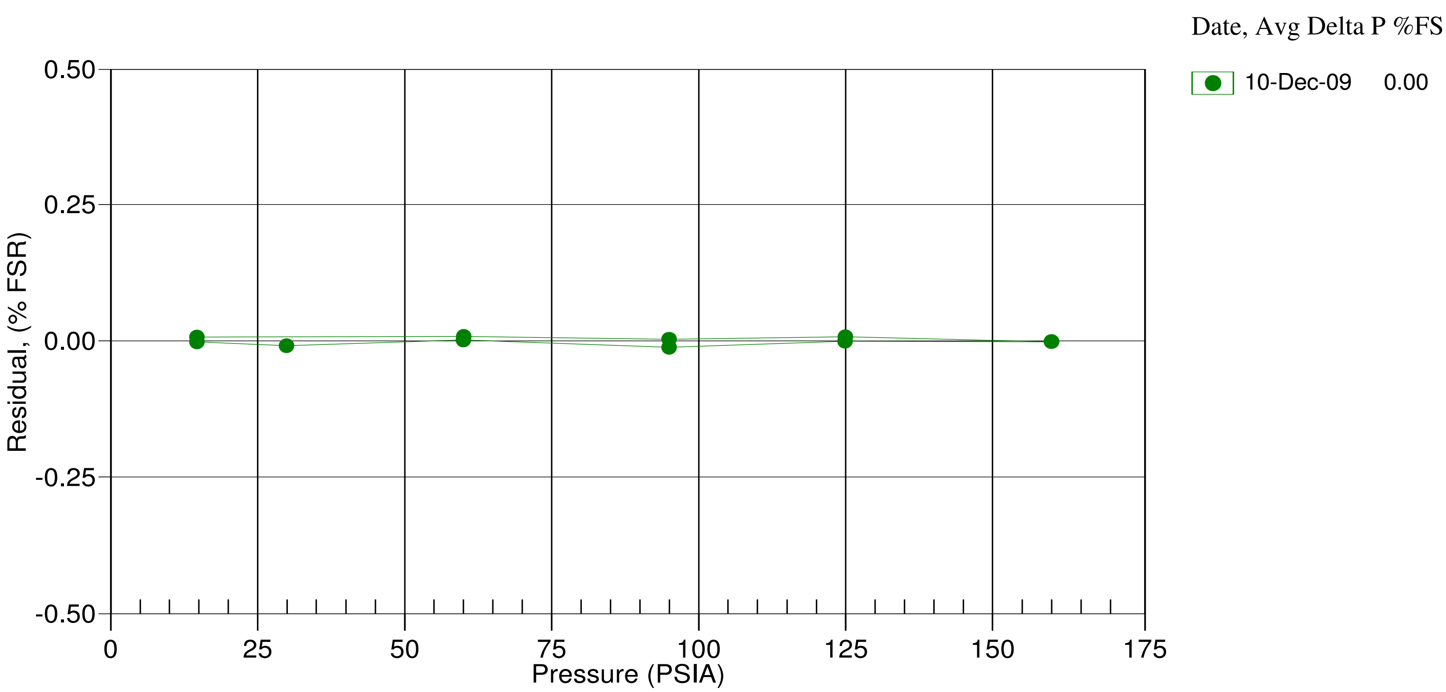
TEMP(ITS90)	SPAN(mV)
-5.00	25.00
35.00	24.96

y = thermistor output; $t = PTEMPA0 + PTEMPA1 * y + PTEMPA2 * y^2$

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

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

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



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SBE 5M MINI SUBMERSIBLE PUMP CONFIGURATION SHEET

Serial Number: 1257

Job Number: 57353

Customer: EMS/SPAIN

Delivery Date: 1/12/2010

Single Bulkhead Connector.

Pressure Case: 600 meters (Plastic)

Maxon Motor Type:

P/N 801605, Motor PN 20130 (Pulsed Duty 6 VDC, 2000 RPM MAX) ☑

P/N 801606, Motor PN 20127 (Continuous Duty 9 VDC, 2000 RPM MAX) ☐

Vin 15V voltage across C2:	***5.055***	VDC	Current	***15.7***	mA
Vin 9V voltage across C2:	***5.056***	VDC	Current	***15.4***	mA
Vin 6V voltage across C2:	***5.057***	VDC	Current	***15.1***	mA

Pump submerged test, no load, Vin 12VDC Average current draw in water: ***271.6*** mA

PRESSURE TEST CERTIFICATES

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SBE Pressure Test Certificate

Test Date: **1/5/2010** Description **SBE-16Plus SeaCat**

Job Number: **57353** Customer Name **EMS/SPAIN**

SBE Sensor Information:

Model Number: **16P**

Serial Number: **6479**

Pressure Sensor Information:

Sensor Type: **Druck**

Sensor Serial Number: **2926641**

Sensor Rating: **160**

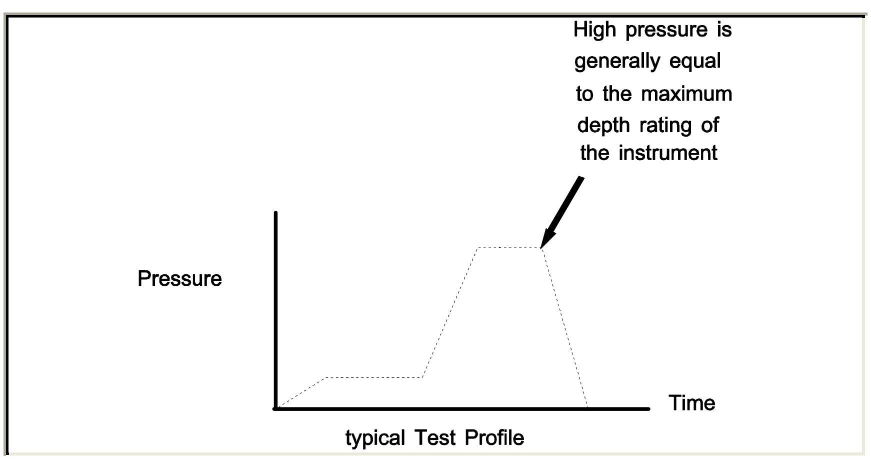
Pressure Test Protocol:

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

High Pressure Test: **100** PSI Held For **15** Minutes

Passed Test: ☑

Tested By: ND



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SBE Pressure Test Certificate

Test Date: **1/4/2010** Description **SBE-5M Mini-Submersible Pump**

Job Number: **57353** Customer Name **EMS/SPAIN**

SBE Sensor Information:

Model Number: **5M**
Serial Number: **1257**

Pressure Sensor Information:

Sensor Type: **None**
Sensor Serial Number: **None**
Sensor Rating: **0**

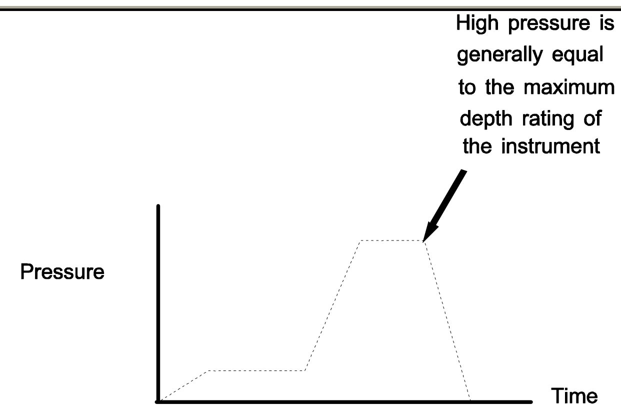
Pressure Test Protocol:

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

High Pressure Test: **800** PSI Held For **15** Minutes

Passed Test: ☑

Tested By: VG



typical Test Profile

APPLICATION NOTES

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APPLICATION NOTE NO. 2D **Revised September 2008**

Instructions for Care and Cleaning of Conductivity Cells

This application note presents new recommendations (as of October 2006), based on our recent research, for cleaning and storing conductivity sensors. In the past, Sea-Bird had recommended cleaning and storing conductivity sensors with a Triton X-100 solution, and cleaning conductivity sensors with an acid solution. **Our latest research leads us to recommend adding the use of a dilute bleach solution to eliminate growth of bio-organisms, and eliminating the use of acid in most cases**.

The application note is divided into three sections:
- General discussion
- Rinsing, cleaning, and storage procedures
- Cleaning materials

General Discussion

Since any conductivity sensor's output reading is proportional to its cell dimensions, it is important to keep the cell clean of internal coatings. Also, cell electrodes contaminated with oil, biological growths, or other foreign material will cause low conductivity readings. A desire to provide better control of growth of bio-organisms in the conductivity cell led us to develop revised rinsing and cleaning recommendations.
- A dilute bleach solution is extremely effective in controlling the growth of bio-organisms in the conductivity cell. Lab testing at Sea-Bird indicates no damaging effect from use of a dilute bleach solution in cleaning the conductivity cell. Sea-Bird now recommends cleaning the conductivity sensor in a bleach solution.
- Triton X-100 is a mild, non-ionic surfactant (detergent), valuable for removal of surface and airborne oil ingested into the CTD plumbing as the CTD is removed from the water and brought on deck. Sea-Bird had previously recommended, and continues to recommend, rinsing and cleaning the conductivity sensor in a Triton solution.
- Sea-Bird had previously recommended acid cleaning for eliminating bio-organisms or mineral deposits on the inside of the cell. However, bleach cleaning has proven to be effective in eliminating growth of bio-organisms; bleach is much easier to use and to dispose of than acid. Furthermore, data from many years of use shows that mineral deposits are an unusual occurrence. Therefore, Sea-Bird now recommends that, in most cases, acid should not be used to clean the conductivity sensor. ***In rare instances***, acid cleaning may still be required for mineral contamination of the conductivity cell. ***Sea-Bird recommends that you return the equipment to the factory for this cleaning if it is necessary***.

Sea-Bird had previously recommended storing the conductivity cell filled with water to keep the cell wetted, unless the cell was in an environment where freezing is a possibility (the cell could break if the water freezes). However, no adverse affects have been observed as a result of dry storage, if the cell is rinsed with fresh, clean water before storage to remove any salt crystals. This leads to the following revised conductivity cell storage recommendations:
- Short term storage (less than 1 day, typically between casts): If there is no danger of freezing, store the conductivity cell with a dilute bleach solution in Tygon tubing looped around the cell. If there is danger of freezing, store the conductivity cell dry, with Tygon tubing looped around the cell.
- Long term storage (longer than 1 day): Since conditions of transport and long term storage are not always under the control of the user, we now recommend storing the conductivity cell dry, with Tygon tubing looped around the cell ends. Dry storage eliminates the possibility of damage due to unforeseen freezing, as well as the possibility of bio-organism growth inside the cell. Filling the cell with a Triton X-100 solution for 1 hour before deployment will *rewet* the cell adequately.

Note that the Tygon tubing looped around the ends of the conductivity cell, whether dry or filled with a bleach or Triton solution, has the added benefit of keeping air-borne contaminants (abundant on most ships) from entering the cell.

Rinsing, Cleaning, and Storage Procedures

Note: See *Cleaning Materials* below for discussion of appropriate sources / concentrations of water, Triton X-100, bleach, and tubing.

CAUTIONS:

- The conductivity cell is primarily glass, and can break if mishandled. Use the correct size Tygon tubing; using tubing with a smaller ID will make it difficult to remove the tubing, and the cell end may break if excessive force is used. **The correct size tubing for use in cleaning / storing all conductivity cells produced since 1980 is 7/16" ID, 9/16" OD**. Instruments shipped prior to 1980 had smaller retaining ridges at the ends of the cell, and 3/8" ID tubing is required for these older instruments.
- **Do not put a brush or object (e.g., Q-Tip) inside the conductivity cell to clean it or dry it.** Touching and bending the electrodes can change the calibration; large bends and movement of the electrodes can damage the cell.
- **If an SBE 43 dissolved oxygen (DO) sensor is plumbed to the CTD** - Before soaking the conductivity cell for more than 1 minute in Triton X-100 solution, **disconnect the tubing between the conductivity cell and DO sensor** to prevent extended Triton contact with the DO sensor membrane (extended Triton contact can damage the membrane). See *Application Note 64* for rinsing, cleaning, and storage recommendations for the SBE 43.

Active Use (after each cast)

1. Rinse: Remove the plumbing (Tygon tubing) from the exhaust end of the conductivity cell. **Flush** the cell with a **0.1% Triton X-100** solution. **Rinse** thoroughly with **fresh, clean water** and drain.
   - If not rinsed between uses, salt crystals may form on the conductivity cell platinized electrode surfaces. When the instrument is used next, sensor accuracy may be temporarily affected until these crystals dissolve.
2. Store: The intent of these storage recommendations is to keep contamination from aerosols and spray/wash on the ship deck from harming the sensor's calibration.
   - ***No danger of freezing***: **Fill** the cell with a **500 – 1000 ppm bleach** solution, using a length of Tygon tubing attached to each end of the conductivity sensor to close the cell ends.
   - ***Danger of freezing***: Remove larger droplets of water by blowing through the cell. **Do not use compressed air**, which typically contains oil vapor. Attach a length of Tygon tubing to each end of the conductivity cell to close the cell ends.

Routine Cleaning (no visible deposits or marine growths on sensor)

1. **Agitate** a **500 – 1000 ppm Bleach** solution warmed to 40 °C through the cell in a washing action (this can be accomplished with Tygon tubing and a syringe kit – see *Application Note 34*) for **2 minutes**. **Drain and flush** with warm (not hot) fresh, clean water for **5 minutes**.
2. **Agitate** a **1%-2% Triton X-100** solution warmed to 40 °C through the cell many times in a washing action (this can be accomplished with Tygon tubing and a syringe kit). Fill the cell with the solution and let it **soak** for **1 hour**. **Drain and flush** with warm (not hot) fresh, clean water for **5 minutes**.

Cleaning Severely Fouled Sensors (visible deposits or marine growths on sensor)

Repeat the *Routine Cleaning* procedure up to 5 times.

Long-Term Storage (after field use)

1. Rinse: Remove the plumbing (Tygon tubing) from the exhaust end of the conductivity cell. **Flush** the cell with a **0.1% Triton X-100** solution. **Rinse** thoroughly with **fresh, clean water** and drain. Remove larger droplets of water by blowing through the cell. **Do not use compressed air**, which typically contains oil vapor.
2. Store: Attach a length of Tygon tubing to each end of the conductivity cell to close the cell ends. The loop prevents any contaminants from entering the cell.
   - Storing the cell dry prevents the growth of any bio-organisms, thus preserving the calibration.
3. When ready to deploy again: **Fill** the cell with a **0.1% Triton X-100** solution for **1 hour** before deployment. Drain the Triton X-100 solution; there is no need to rinse the cell.

Cleaning Materials

Water

De-ionized (DI) water, commercially distilled water, or fresh, clean, tap water is recommended for rinsing, cleaning, and storing sensors.

- On ships, **fresh water is typically made in large quantities by a distillation process, and stored in large tanks. This water may be contaminated with small amounts of oil, and should not be used for rinsing, cleaning, or storing sensors**.

Where fresh water is in extremely limited supply (for example, a remote location in the Arctic), you can substitute **clean seawater** for rinsing and cleaning sensors. If not immediately redeploying the instrument, follow up with a **brief fresh water rinse** to eliminate the possibility of salt crystal formation (salt crystal formation could cause small shifts in calibration).

- **The seawater must be extremely clean, free of oils that can coat the conductivity cell. To eliminate any bio-organisms in the water, Sea-Bird recommends boiling the water or filtering it with a 0.5 micron filter.**

Triton X-100

Triton X-100 is Octyl Phenol Ethoxylate, a mild, non-ionic surfactant (detergent). Triton X-100 is included with every CTD shipment and can be ordered from Sea-Bird, but may be available locally from a chemical supply or lab products company. It is manufactured by Mallinckrodt Baker (see http://www.mallbaker.com/changecountry.asp?back=/Default.asp for local distributors). Other liquid detergents can probably be used, but scientific grades (with no colors, perfumes, glycerins, lotions, etc.) are required because of their known composition. It is better to use a non-ionic detergent, since conductivity readings taken immediately after use are less likely to be affected by any residual detergent left in the cell.

100% Triton X-100 is supplied by Sea-Bird; dilute the Triton as directed in *Rinsing, Cleaning, and Storage Procedures*.

Bleach

Bleach is a common household product used to whiten and disinfect laundry. Commercially available bleach is typically 4 % - 7% (40,000 – 70,000 ppm) sodium hypochlorite (Na-O-Cl) solution that includes stabilizers. Some common commercial product names are Clorox (U.S.) and eau de Javel (French).

Dilute to 500 – 1000 ppm. For example, if starting with 5% (50,000 ppm) sodium hypochlorite, diluting 50 to 1 (50 parts water to 1 part bleach) yields a 1000 ppm (50,000 pm / 50 = 1000 ppm) solution.

Tygon Tubing

Sea-Bird recommends use of Tygon tubing, because it remains flexible over a wide temperature range and with age. Tygon is manufactured by Saint-Gobain (see *www.tygon.com*). It is supplied by Sea-Bird, but may be available locally from a chemical supply or lab products company.

Keep the Tygon in a clean place (so that it does not pick up contaminants) while the instrument is in use.

Acid

In rare instances, acid cleaning is required for mineral contamination of the conductivity cell. ***Sea-Bird recommends that you return the equipment to the factory for this cleaning***. Information below is provided if you cannot return the equipment to Sea-Bird.

CAUTIONS:

- **SBE 37-IMP, 37-SMP, or 37-SIP MicroCAT; SBE 49 FastCAT; SBE 52-MP Moored Profiler CTD; or other instruments with an integral, internal pump - Do not perform acid cleaning.** Acid cleaning may damage the internal, integral pump. Return these instruments to Sea-Bird for servicing if acid cleaning is required.
- **SBE 9*plus* or SBE 25 CTD** – Remove the SBE 4 conductivity cell from the CTD and remove the TC Duct before performing the acid cleaning procedure.
- **All instruments which include AF24173 Anti-Foulant Devices** – Remove the AF24173 Anti-Foulant Devices before performing the acid cleaning procedure. See the instrument manual for details and handling precautions when removing AF24173 Anti-Foulant Devices.

WARNING! Observe all precautions for working with strong acid. Avoid breathing acid fumes. Work in a well-ventilated area.

The acid cleaning procedure for the conductivity cell uses approximately 50 - 100 cc of acid. Sea-Bird recommends using a 20% concentration of HCl. However, acid in the range of 10% to full strength (38%) is acceptable.

If starting with a strong concentration of HCl that you want to dilute:
For each 100 cc of concentrated acid, to get a 20% solution, mix with this amount of water -
Water = [(conc% / 20%) – 1] * [100 + 10 (conc% / 20%)] cc
Always add acid to water; never add water to acid.

Example -- concentrated solution 31.5% that you want to dilute to 20%:
[(31.5% / 20%) – 1] * [100 + 10 (31.5% / 20%)] = 66.6 cc of water.
So, adding 100 cc of 31.5% HCl to 66.6 cc of water provides 166.6 cc of the desired concentration.
For 100 cc of solution:
100 cc * (100 / 166.6) = 60 cc of 31.5% HCl   66.6 cc * (100 / 166.6) = 40 cc of water

For acid disposal, dilute the acid heavily or neutralize with bicarbonate of soda (baking soda).

1. Prepare for cleaning:
   A. Place a 0.6 m (2 ft) length of Tygon tubing over the end of the cell.
   B. Clamp the instrument so that the cell is vertical, with the Tygon tubing at the bottom end.
   C. Loop the Tygon tubing into a U shape, and tape the open end of the tubing in place at the same height as the top of the glass cell.
2. Clean the cell:
   A. Pour **10% to 38% HCl** solution into the open end of the tubing until the cell is nearly filled. **Let it soak for 1 minute only.**
   B. Drain the acid from the cell and flush for 5 minutes with warm (not hot), clean, de-ionized water.
   C. Rinse the exterior of the instrument to remove any spilled acid from the surface.
   D. Fill the cell with a **1% Triton X-100** solution and let it stand for 5 minutes.
   E. Drain and flush with warm, clean, de-ionized water for 1 minute.
   F. Carefully remove the 0.6 m (2 ft) length of Tygon tubing.
3. Prepare for deployment, **or** follow recommendations above for storage.

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APPLICATION NOTE NO. 6 **Revised August 2004**

DETERMINATION OF SOUND VELOCITY FROM CTD DATA

Use of CTD measurement for determination of sound velocity is appealing because these instruments are simpler and more rugged, and because their resolution, accuracy, and stability lead to far better **precision** than can be obtained with direct SV measuring devices. For example, specifications of 0.01 mS/cm conductivity, 0.01 degrees C temperature, and 1 meter in depth are readily achieved with good quality CTD equipment. Assuming that the relationship between C, T, and D *and* SV is exactly known (see below), the resulting uncertainty in SV would be as follows:

Error Type	Sound Velocity Error
temperature error of 0.01 deg C	0.021 meters/second
conductivity error of 0.01 mS/cm	0.011 meters/second
salinity error of 0.01 psu	0.012 meters/second
depth error of 1 meter	0.017 meters/second

The equivalent SV errors (considered at 15 degrees C, 42.9 mS/cm, 35 psu, and 0 pressure, i.e., typical open-ocean surface conditions) are much smaller than those usually claimed for direct-measurement instruments.

The question about the **absolute** accuracy of the inference of SV from CTD data is more difficult to answer. The main reason for this is apparently the result of differences in the instrumentation used by various researchers and is compounded by the difficulty of performing direct measurements of sound velocity under controlled conditions of temperature, salinity, and (especially) pressure. For example, three widely used equations (Wilson, 1959; Del Grosso, 1972; Millero and Chen, 1977) show differences in absolute sound speed on the order of 0.5 meters/second for various combinations of water temperature, salinity, and pressure, despite being based on careful measurements made under laboratory conditions.

The work of Millero and Chen is, however, the most modern, and it builds upon and attempts to incorporate the work of earlier investigators. Accordingly, the SV/CTD relationship described by these researchers in their paper of 1977 was used as a major component in the derivation of the Equation of State (Unesco technical papers in marine science no. 44). Millero and Chen's 1977 equation is also the one endorsed by the Unesco/SCOR/ICES/IASPO Joint Panel on Oceanographic Tables and Standards, which comprises the internationally recognized authority for measurements of ocean parameters (in Sea-Bird's SEASOFT software, users may select any of the 3 equations mentioned above).

Pike and Beiboer, 1993, made a careful comparison of algorithms used to calculate sound velocity. They concluded that use of the Wilson equation should be discontinued, and that the Chen and Millero algorithm should be used on the continental shelf while the Del Grosso formula is more appropriate for deep ocean waters and long path lengths. Their paper includes tables showing valid temperature and salinity ranges for each of the algorithms.

We draw the following conclusions from the research papers listed above:

1) Investigators using specialized equipment under scrupulously controlled laboratory conditions report measurements of SV vs. changes in temperature, salinity, and pressure which differ by 0.5 meters/second and more. *It is unrealistic to expect that commercial direct-measurement instruments will be more accurate under field conditions than the laboratory equipment used by successions of careful researchers.*

2) The claimed *accuracy* of commercial direct-measurement SV probes probably more legitimately represents their *precision* (compare with CTD/SV uncertainties tabulated above) rather than their absolute accuracy. The relationship between what these instruments read and true sound velocity is probably just as dependent on the same vagaries that are also the only significant sources of error when employing the CTD approach.

3) Because of the uncertainties in the time-delays associated with the acoustic transducers and electronics (and because of the difficulty of measuring with sufficient accuracy the length of the acoustic path), direct-measurement probes must be calibrated in water. As suggested by the research under controlled laboratory conditions, this is not an easy task, especially over a range of temperature, pressure, and salinity. On the other hand, a CTD probe can easily be calibrated using accepted methods.

4) A CTD can predict **absolute** SV to something better than 0.5 meters/second (a judgment seconded by Professor Millero in a private conversation), while its **relative accuracy** (precision) is probably better than 0.05 meters/second under the most demanding conditions of field use.

5) The very high precision associated with CTD measurements and the existence of an internationally accepted relationship (even if imperfect) between CTD and SV permits very consistent intercomparison and a high degree of uniformity among CTD-derived SV data sets, no matter when and where taken.

Bibliography

C-T. Chen and F. J. Millero, 1977, Speed of Sound in Seawater at High Pressures. J Acoust Soc Am, 32(10), p 1357.

V. A. Del Grosso, 1974, New Equation for the Speed of Sound In Natural Waters (with Comparisons to Other Equations). J Acoust Soc Am, 56(4), pp 1084-1091.

J. M. Pike and F. L. Beiboer, 1993, A Comparison Between Algorithms for the Speed of Sound in Seawater. The Hydrographic Society, Special Publication No. 34.

Wilson W D, 1960, Equation for the Speed of Sound in Seawater. J Acoust Soc Am, 32(10), p 1357.

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APPLICATION NOTE NO. 10 **Revised March 2008**

COMPRESSIBILITY COMPENSATION OF SEA-BIRD CONDUCTIVITY SENSORS

Sea-Bird conductivity sensors provide precise characterization of deep ocean water masses. To achieve the accuracy of which the sensors are capable, an accounting for the effect of hydrostatic loading (pressure) on the conductivity cell is necessary. Conductivity calibration certificates show an equation containing the appropriate pressure-dependent correction term, which has been derived from mechanical principles and confirmed by field observations. The form of the equation varies somewhat, as shown below:

SBE 4, 9, 9*plus*, 16, 19, 21, 25, 26, 26*plus*, and 53 BPR

$$\text{Conductivity (Siemens/meter)} = \text{slope}\ \frac{(g + h f^2 + i f^3 + j f^4) / 10}{1 + [CTcor]\, t + [CPcor]\, p} + \text{offset} \qquad (\textbf{recommended})$$

or

$$\text{Conductivity (Siemens/meter)} = \text{slope}\ \frac{(a f^m + b f^2 + c + dt) / 10}{1 + [CPcor]\, p} + \text{offset}$$

SBE 16*plus*, 16*plus*-IM, 16*plus* V2, 16*plus*-IM V2, 19*plus*, 19*plus* V2, 37, 45, 49, and 52-MP

$$\text{Conductivity (Siemens/meter)} = \text{slope}\ \frac{g + h f^2 + i f^3 + j f^4}{1 + [CTcor]\, t + [CPcor]\, p} + \text{offset}$$

where

- a, b, c, d, m, and CPcor are the calibration coefficients used for older sensors (prior to January 1995). Sea-Bird continues to calculate and print these coefficients on the calibration sheets for use with old software, but recommends use of the g, h, i, j, CTcor, CPcor form of the equation for most accurate results.
- g, h, i, j, CTcor, and CPcor are the calibration coefficients used for newer sensors.
  Note: The SBE 26, 26*plus*, and 53 BPR use the SBE 4 conductivity sensor, so both sets of calibration coefficients are reported on the calibration sheet. *SEASOFT for Waves* **for DOS**, which can be used with the SBE 26 only, only supports use of the a, b, c, d, CTcor, and CPcor coefficients. The current processing software for these instruments, *SEASOFT for Waves* **for Windows**, only supports use of the g, h, i, j, CTcor, CPcor coefficients.
- **CPcor is the correction term for pressure effects on conductivity (see below for discussion)**
- slope and offset are correction coefficients used to make corrections for sensor drift between calibrations; set to 1.0 and 0 respectively on initial calibration by Sea-Bird (see Application Note 31 for details on calculating slope and offset)
- f is the instrument frequency (kHz) for all instruments except the SBE 52-MP.
  For the SBE 52-MP, $f = \text{instrument frequency (kHz)} * (1.0 + WBOTC * t)^{0.5} / 1000.00$
- t is the water temperature (°C).
- p is the water pressure (decibars).

Sea-Bird CTD data acquisition, display, and post-processing software *SEASOFT for Waves* (for SBE 26, 26*plus*, and 53 only) and *SEASOFT* (for all other instruments) automatically implement these equations.

DISCUSSION OF PRESSURE CORRECTION

Conductivity cells do not measure the specific conductance (the desired property), but rather the conductance of a *specific geometry* of water. The ratio of the cell's length to its cross-sectional area (*cell constant*) is used to relate the measured conductance to specific conductance. Under pressure, the conductivity cell's length and diameter are reduced, leading to a lower indicated conductivity. The magnitude of the effect is not insignificant, reaching 0.0028 S/m at 6800 dbars.

The compressibility of the borosilicate glass used in the conductivity cell (and all other homogeneous, noncrystalline materials) can be characterized by E (Young's modulus) and ν (Poisson's ratio). For the Sea-Bird conductivity cell, $E = 9.1 \times 10^6$ psi, $\nu = 0.2$, and the ratio of indicated conductivity divided by true conductivity is:

$1 + s$
where $s = (CPcor)(p)$
Typical value for CPcor is -9.57×10^{-8} for pressure in decibars **or** -6.60×10^{-8} for pressure in psi

Note: This equation and the mathematical derivations below deal only with the pressure correction term, and do not address the temperature correction term.

MATHEMATICAL DERIVATION OF PRESSURE CORRECTION

For a cube under hydrostatic load:

$\Delta L / L = s = -p (1 - 2\nu) / E$
where
- p is the hydrostatic pressure
- E is Young's modulus
- ν is Poisson's ratio
- $\Delta L / L$ and s are strain (change in length per unit length)

Since this relationship is linear in the forces and displacements, the relationship for strain also applies for the length, radius, and wall thickness of a cylinder.

To compute the effect on conductivity, note that $R_0 = \rho L / A$, where R_0 is resistance of the material at 0 pressure, ρ is volume resistivity, L is length, and A is cross-sectional area. For the conductivity cell $A = \pi r^2$, where r is the cell radius. Under pressure, the new length is $L(1 + s)$ and the new radius is $r(1 + s)$. If R_p is the cell resistance under pressure:

$$R_p = \rho L (1 + s) / (\pi r^2 [1 + s]^2) = \rho L / \pi r^2 (1 + s) = R_0 / (1 + s)$$

Since conductivity is 1/R:

$C_p = C_0 (1 + s)$ and $C_0 = C_p / (1 + s) = C_p / (1 + [Cpcor][p])$
where
- C_0 is conductivity at 0 pressure
- C_p is conductivity measured at pressure

A less rigorous determination may be made using the material's bulk modulus. For small displacements in a cube:

$\Delta V / V = 3\Delta L / L = -3p (1 - 2\nu) / E$ or $\Delta V/V = -p / K$
where
- $\Delta V / V$ is the change in volume per volume or volume strain
- K is the bulk modulus. K is related to E and ν by $K = E / 3 (1 - 2\nu)$.

In this case, $\Delta L / L = -p / 3K$.

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APPLICATION NOTE NO. 14 **January 1989**

1978 PRACTICAL SALINITY SCALE

Should you not be already familiar with it, we would like to call your attention to the January 1980 issue of the IEEE Journal of Oceanic Engineering, which is dedicated to presenting the results of a multi-national effort to obtain a uniform repeatable Practical Salinity Scale, based upon electrical conductivity measurements. This work has been almost universally accepted by researchers, and all instruments delivered by Sea-Bird since February 1982 have been supplied with calibration data based upon the new standard.

The value for conductivity at 35 ppt, 15 degrees C, and 0 pressure [C(35,15,0)] was not agreed upon in the IEEE reports -- Culkin & Smith used 42.914 mmho/cm (p 23), while Poisson used 42.933 mmho/cm (p 47). It really does not matter which value is used, provided that the same value is used during data reduction that was used to compute instrument calibration coefficients. Our instrument coefficients are computed using C(35,15,0) = 42.914 mmho/cm.

The PSS 1978 equations and constants for computing salinity from *in-situ* measurements of conductivity, temperature, and pressure are given in the 'Conclusions' section of the IEEE journal (p 14) and are reproduced back of this note. In the first equation, 'R' is obtained by dividing the conductivity value measured by your instrument by C(35,15,0), or 42.914 mmho/cm. Note that the PSS equations are based upon conductivity in units of mmho/cm, which are equal in magnitude to units of mS/cm. **If you are working in conductivity units of Siemens/meter (S/m), multiply your conductivity values by 10 before using the PSS 1978 equations**.

Also note that the equations assume pressure relative to the sea-surface. Absolute pressure gauges (as used in all Sea-Bird CTD instruments) have a vacuum on the reference side of their sensing diaphragms and indicate atmospheric pressure (nominally 10.1325 dBar) at the sea-surface. This reading must be subtracted to obtain pressure as required by the PSS equations. The pressure reading displayed when using Sea-Bird's SEASOFT CTD acquisition, display, and post-processing software is the corrected sea-surface pressure and is used by SEASOFT to compute salinity, density, etc in accordance with the PSS equations.

1978 PRACTICAL SALINITY SCALE EQUATIONS, from IEEE Journal of Oceanic Engineering, Vol. OE-5, No. 1, January 1980, page 14.

CONCLUSIONS

Using Newly generated data, a fit has been made giving the following algorithm for the calculation of salinity from data of the form:

$$R = \frac{C(S, T, P)}{C(35, 15, 0)}$$

T in °C (IPTS '68), P in decibars.

$$R_T = \frac{R}{R_P r_T}; R_P = 1 + \frac{P \times (A_1 + A_2 P + A_3 P^2)}{1 + B_1 T + B_2 T^2 + B_3 R + B_4 RT}$$

$$r_T = c_0 + c_1 T + c_2 T^2 + c_3 T^3 + c_4 T^4$$

$A_1 = 2.070 \times 10^{-5}$ $\quad B_1 = 3.426 \times 10^{-2}$

$A_2 = -6.370 \times 10^{-10}$ $\quad B_2 = 4.464 \times 10^{-4}$

$A_3 = 3.989 \times 10^{-15}$ $\quad B_3 = 4.215 \times 10^{-1}$

$B_4 = -3.107 \times 10^{-3}$

$c_0 = 6.766097 \times 10^{-1}$

$c_1 = 2.00564 \times 10^{-2}$

$c_2 = 1.104259 \times 10^{-4}$

$c_3 = -6.9698 \times 10^{-7}$

$c_4 = 1.0031 \times 10^{-9}$

$$S = \sum_{j=0}^{5} a_j R_T^{\,j/2} + \frac{(T-15)}{1 + k(T-15)} \sum_{j=0}^{5} b_j R_T^{\,j/2}$$

$a_0 = 0.0080$ $\quad b_0 = 0.0005$ $\quad k = 0.0162.$

$a_1 = -0.1692$ $\quad b_1 = -0.0056$

$a_2 = 25.3851$ $\quad b_2 = -0.0066$

$a_3 = 14.0941$ $\quad b_3 = -0.0375$

$a_4 = -7.0261$ $\quad b_4 = 0.0636$

$a_5 = 2.7081$ $\quad b_5 = -0.0144$

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APPLICATION NOTE NO. 31 **Revised July 2007**

Computing Temperature and Conductivity *Slope* and *Offset* Correction Coefficients from Laboratory Calibrations and Salinity Bottle Samples

Conductivity Sensors

The conductivity sensor *slope* and *offset* entries in the configuration (.con) file in SEASOFT permit the user to make corrections for sensor drift between calibrations. The correction formula is:

(corrected conductivity) = slope * (computed conductivity) + offset

where :
slope = (true conductivity span) / (instrument reading conductivity span)
offset = (true conductivity - instrument reading conductivity) * slope *measured at 0 S/m*

For newly calibrated sensors, use slope = 1.0, offset = 0.0.

Sea-Bird conductivity sensors usually drift by changing span (the slope of the calibration curve), and changes are typically toward lower conductivity readings with time. Any offset error in conductivity (error at 0 S/m) is usually due to electronics drift, typically less than ±0.0001 S/m per year. Offsets greater than ±0.0002 S/m per year are symptomatic of sensor malfunction. **Therefore, Sea-Bird recommends that conductivity drift corrections be made by assuming no offset error, unless there is strong evidence to the contrary or a special need.**

Example
true conductivity =3.5 S/m
instrument reading conductivity = 3.49965 S/m
slope = 3.5 / 3.49965 = 1.000100

Correcting for Conductivity Drift Based on Pre- and Post-Cruise Laboratory Calibrations

Suppose a conductivity sensor is calibrated (pre-cruise), then immediately used at sea, and then returned for post-cruise calibration. The pre- and post-cruise calibration data can be used to generate a slope correction for data obtained between the pre- and post-cruise calibrations.

If **α** is the conductivity computed from the **pre-cruise bath data** (temperature and frequency) using **post-cruise calibration coefficients** and **β** is the true conductivity in the **pre-cruise bath**, then:

$$\textbf{postslope} = \frac{\sum_{i=1}^{n} (\alpha_i)(\beta_i)}{\sum_{i=1}^{n} (\alpha_i)(\alpha_i)} \qquad \text{(postslope is typically < 1.0)}$$

Sea-Bird calculates and prints the value for postslope on the conductivity calibration sheet for all calibrations since February 1995 (see *Appendix I: Example Conductivity Calibration Sheet*)
.

To correct conductivity data taken between pre- and post-cruise calibrations:

islope = 1.0 + (b / n) [(1 / postslope) - 1.0]

where

islope = interpolated slope; this is the value to enter in the .con file
b = number of days between pre-cruise calibration and the cast to be corrected
n = number of days between pre- and post-cruise calibrations
postslope = slope from calibration sheet as calculated above (see *Appendix I: Example Conductivity Calibration Sheet*)

In the .con file, use the **pre-cruise calibration coefficients** and use **islope** for the value of slope.*

Note: In our SEASOFT-Win32 suite of programs, edit the CTD configuration (.con) file using the Configure Inputs menu in SEASAVE V7 (real-time data acquisition software) or the Configure menu in SBE Data Processing (data processing software).

For typical conductivity drift rates (equivalent to -0.003 PSU/month), islope does not need to be recalculated more frequently than at weekly intervals.

* You can also calculate preslope. If **α** is the conductivity computed from **post-cruise bath data** (temperature and frequency) using **pre-cruise calibration coefficients** and **β** is the true conductivity in the **post-cruise bath**, then:

$$\textbf{preslope} = \frac{\sum_{i=1}^{n} (\alpha_i)(\beta_i)}{\sum_{i=1}^{n} (\alpha_i)(\alpha_i)}$$

(preslope is typically > 1.0)

In this case, pre-cruise calibration coefficients would be used and:
islope = 1.0 + (b / n) (preslope - 1.0)

Correcting for Conductivity Drift Based on Salinity Bottles Taken At Sea

For this situation, the **pre-cruise** calibration coefficients are used to compute conductivity and CTD salinity. Salinity samples are obtained using water sampler bottles during CTD profiles, and the difference between CTD salinity and bottle salinity is used to determine the drift in conductivity.

In using this method to correct conductivity, it is important to realize that differences between CTD salinity and hydrographic bottle salinity are due to errors in conductivity, temperature, and pressure measurements, as well as errors in obtaining and analyzing bottle salinity values. For typical Sea-Bird sensors that are calibrated regularly, 70 - 90% of the CTD salinity error is due to conductivity calibration drift, 10 - 30% is due to temperature calibration drift, and 0 - 10% is due to pressure calibration drift. All CTD temperature and pressure errors and bottle errors must first be corrected before attributing the remaining salinity difference as due to CTD conductivity error and proceeding with conductivity corrections.

Example
Three salinity bottles are taken during a CTD profile; assume for this discussion that shipboard analysis of the bottle salinities is perfect. The **uncorrected** CTD data (from SEASAVE V7) and bottle salinities are:

Approximate Depth (m)	CTD Raw Pressure (dbar)	CTD Raw Temperature (°C) *	CTD Raw Conductivity (S/m)	CTD Raw Salinity	Bottle Salinity
200	202.7	18.3880	4.63421	34.9705	34.9770
1000	1008.8	3.9831	3.25349	34.4634	34.4710
4000	4064.1	1.4524	3.16777	34.6778	34.6850

** Temperatures shown are **ITS-90**. However, the salinity equation is in terms of IPTS-68; you must convert ITS-90 to IPTS-68 (IPTS-68 = 1.00024 * ITS-90) before calculating salinity. SEASOFT does this automatically.*

The uncorrected salinity differences (CTD raw salinity - bottle salinity) are approximately -0.007 psu. To determine conductivity drift, first correct the CTD temperature and pressure data. Suppose that the error in temperature is +0.0015 °C uniformly at all temperatures, and the error in pressure is +0.5 dbar uniformly at all pressures (drift offsets are obtained by projecting the drift history of both sensors from pre-cruise calibrations). Enter these offsets in the .con file to calculate the corrected CTD temperature and pressure, and calculate the CTD salinity using the corrected CTD temperature and pressure. This correction method assumes that the pressure coefficient for the conductivity cell is correct. The CTD data with **corrected** temperature (ITS-90) and pressure are:

Corrected CTD Pressure (dbar)	Corrected CTD Temperature (°C)	CTD Raw Conductivity (S/m)	CTD Salinity [T,P Corrected]	Bottle Salinity
202.2	18.3865	4.63421	34.9719	34.9770
1008.3	3.9816	3.25349	34.4653	34.4710
4063.6	1.4509	3.16777	34.6795	34.6850

The salinity difference (CTD salinity – bottle salinity) of approximately -0.005 psu is now properly categorized as conductivity error, equivalent to about -0.0005 S/m at 4.0 S/m.

Compute bottle conductivity (conductivity calculated from bottle salinity and CTD temperature and pressure) using SeacalcW (in SBE Data Processing); enter bottle salinity for *salinity*, corrected CTD temperature for *ITS-90 temperature*, and corrected CTD pressure for *pressure*:

CTD Raw Conductivity (S/m)	Bottle Conductivity (S/m)	[CTD - Bottle] Conductivity (S/m)
4.63421	4.63481	-0.00060
3.25349	3.25398	-0.00049
3.16777	3.16822	-0.00045

By plotting conductivity error versus conductivity, it is evident that the drift is primarily a slope change. If **α** is the CTD conductivity computed with **pre-cruise** coefficients and **β** is the true bottle conductivity, then:

$$\textbf{slope} = \frac{\sum_{i=1}^{n} (\alpha_i)(\beta_i)}{\sum_{i=1}^{n} (\alpha_i)(\alpha_i)} \qquad \text{(slope is typically > 1.0)}$$

Using the above data, the slope correction coefficient for conductivity at this station is:
Slope = [(4.63421 * 4.63481) + (3.25349 * 3.25398) + (3.16777 * 3.16822)] /
[(4.63421 * 4.63421) + (3.25349 * 3.25349) + (3.16777 * 3.16777)] = **+1.000138**

Following Sea-Bird's recommendation of assuming no offset error in conductivity, **set offset to 0.0**.

Temperature Sensors

The temperature sensor *slope* and *offset* entries in the configuration (.con) file in SEASOFT permit the user to make corrections for sensor drift between calibrations. The correction formula is:

corrected temperature = slope * (computed temperature) + offset

where :

slope = (true temperature span) / (instrument reading temperature span)

offset = (true temperature - instrument reading temperature) * slope *measured at 0.0 °C*

For newly calibrated sensors, use slope = 1.0, offset = 0.0.

Sea-Bird temperature sensors usually drift by changing offset (an error of equal magnitude at all temperatures). In general, the drift can be toward higher or lower temperature with time; however, for a specific sensor the drift remains the same sign (direction) for many consecutive years. Many years of experience with thousands of sensors indicates that the drift is smooth and uniform with time, allowing users to make very accurate drift corrections to field data based only on pre- and post-cruise laboratory calibrations.

Span errors cause slope errors, as described in the equation for slope above. Sea-Bird temperature sensors rarely exhibit span errors larger than 0.005 °C over the range -5 to 35 °C, even after years of drift. Temperature calibrations performed at Sea-Bird since January 1995 have slope errors less than 0.0002 °C in 30 °C. Prior to January 1995, some calibrations were delivered that include slope errors up to 0.004 °C in 30 °C because of undetected systematic errors in calibration. A slope error that increases by more than ±0.0002 [°C per °C per year] indicates an unusual aging of electronic components and is symptomatic of sensor malfunction. **Therefore, Sea-Bird recommends that drift corrections to temperature sensors be made assuming no slope error, unless there is strong evidence to the contrary or a special need.**

Calibration checks at-sea are advisable for consistency checks of the sensor drift rate and for early detection of sensor malfunction. However, data from reversing thermometers is rarely accurate enough to make calibration corrections that are better than those possible by shore-based laboratory calibrations. **For the SBE 9*plus***, a proven alternate consistency check is to use dual SBE 3 temperature sensors on the CTD and to track the difference in drift rates between the two sensors. In the deep ocean, where temperatures are uniform, the difference in temperature measured by two sensors can be resolved to better than 0.0002 °C and will change smoothly with time as predicted by the difference in drift rates of the two sensors.

Correcting for Temperature Drift Based on Pre- and Post-Cruise Laboratory Calibrations

Suppose a temperature sensor is calibrated (pre-cruise), then immediately used at-sea, and then returned for post-cruise calibration. The pre-and post-cruise calibration data can be used to generate an offset correction for data obtained between the pre- and post-cruise calibrations.

Calibration coefficients are calculated with the post-cruise calibration. Using the pre-cruise bath data and the post-cruise calibration coefficients, a mean residual over the calibration temperature range is calculated.

residual = instrument temperature – bath temperature

Sea-Bird calculates and prints the value for the residual on the temperature calibration sheet (see *Appendix II: Example Temperature Calibration Sheet*).

To correct temperature data taken between pre- and post-cruise calibrations:

Offset = b * (residual / n)

where

b = number of days between pre-cruise calibration and the cast to be corrected
n = number of days between pre- and post-cruise calibrations
residual = residual from calibration sheet as described above (see *Appendix II: Example Temperature Calibration Sheet*)

In the .con file, use the **pre-cruise calibration coefficients** and use the calculated **offset** for the value of offset.

Note: In our SEASOFT-Win32 suite of programs, edit the CTD configuration (.con) file using the Configure Inputs menu in SEASAVE V7 (real-time data acquisition software) or the Configure menu in SBE Data Processing (data processing software).

Example

Instrument was calibrated (pre-cruise), used at sea for 4 months, and returned for post-cruise calibration. Using **pre-cruise bath data** and **post-cruise coefficients**, the calibration sheet shows a mean residual of -0.2 millidegrees C (-0.0002 °C).

For preliminary work at sea, use the **pre-cruise calibration coefficients** and **slope = 1.0, offset = 0.0**. After the cruise, correct temperature data obtained during the cruise for drift using properly scaled values of correction coefficients:

For data from the end of the first month (30 days) at sea:
Offset = b * (residual / n) = 30 * (0.0002 / 120) = - 0.00005;
Convert data using **pre-cruise coefficients** and **-0.00005** as the offset in the .con file.

For data from the end of the second month (60 days) at sea:
Offset = b * (residual / n) = 60 * (0.0002 / 120) = - 0.0001;
Convert data using **pre-cruise coefficients** and **-0.0001** as the offset in the .con file.

For data from the end of the third month (90 days) at sea:
Offset = b * (residual / n) = 90 * (0.0002 / 120) = - 0.00015;
Convert data using **pre-cruise coefficients** and **-0.00015** as the offset in the .con file.

For data from the end of the 4-month cruise:
Offset = - 0.0002;
Convert data using **pre-cruise coefficients** and **-0.0002** as the offset in the .con file, or using **post-cruise** coefficients and **0** as the offset in the .con file.

Appendix I: Example Conductivity Calibration Sheet

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SENSOR SERIAL NUMBER: 2218
CALIBRATION DATE: 30-Dec-99

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

GHIJ COEFFICIENTS

```
g =  -1.02414422e+001
h =   1.49331006e+000
i =  -1.50844862e-003
j =   1.99364517e-004
CPcor = -9.5700e-008 (nominal)
CTcor =  3.2500e-006 (nominal)
```

Coefficients from *30-Dec-99* calibration.

ABCDM COEFFICIENTS

```
a =   3.56563909e-006
b =   1.48964234e+000
c =  -1.02346588e+001
d =  -8.62052534e-005
m =   5.4
CPcor = -9.5700e-008 (nominal)
```

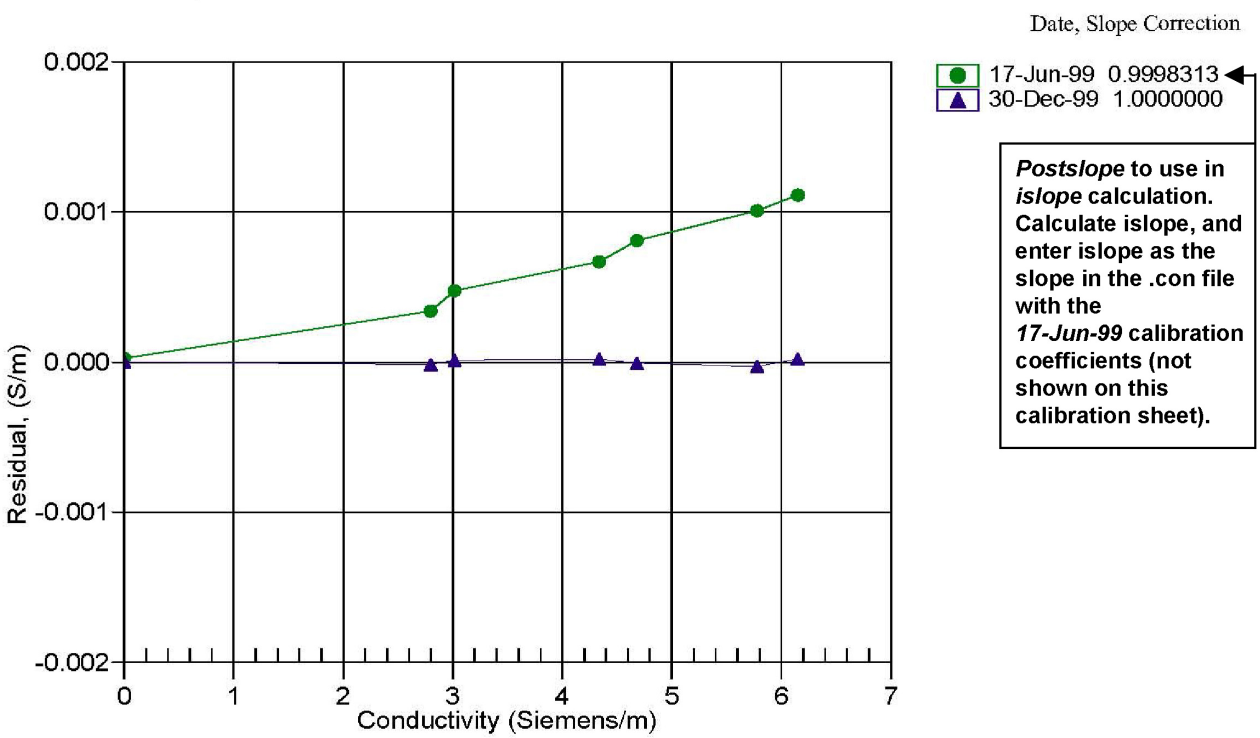
BATH TEMP (ITS-90)	BATH SAL (PSU)	BATH COND (Siemens/m)	INST FREQ (kHz)	INST COND (Siemens/m)	RESIDUAL (Siemens/m)
0.0000	0.0000	0.00000	2.62109	0.00000	0.00000
-1.3895	35.1839	2.79817	5.06354	2.79815	-0.00002
1.1492	35.1843	3.01746	5.20666	3.01747	0.00001
15.2688	35.1829	4.33837	5.99642	4.33839	0.00002
18.7065	35.1798	4.68224	6.18534	4.68224	-0.00001
29.2500	35.1699	5.78041	6.75306	5.78038	-0.00003
32.6897	35.1622	6.15002	6.93359	6.15004	0.00002

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



Appendix II: Example Temperature Calibration Sheet

SEA-BIRD ELECTRONICS, INC.

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

SENSOR SERIAL NUMBER: 2700
CALIBRATION DATE: 28-Dec-99

SBE3 TEMPERATURE CALIBRATION DATA
IPTS-90 TEMPERATURE SCALE

ITS-90 COEFFICIENTS

```
g =  4.36260004e-003
h =  6.49083037e-004
i =  2.42497805e-005
j =  2.36365545e-006
f0 = 1000.0
```

Coefficients from *28-Dec-99* calibration.

ITS-68 COEFFICIENTS

```
a =  3.67991178e-003
b =  6.04738390e-004
c =  1.65374250e-005
d =  2.36525963e-006
f0 = 2978.914
```

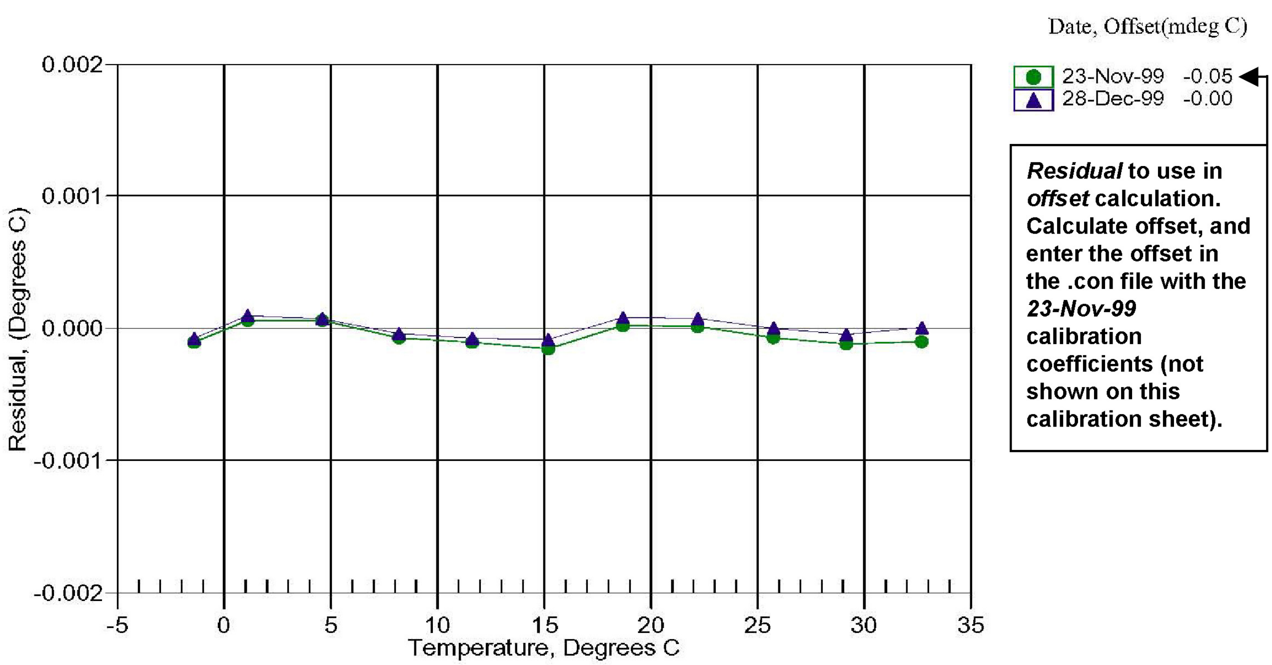
BATH TEMP (ITS-90)	INSTRUMENT FREQ (Hz)	INST TEMP (ITS-90)	RESIDUAL (ITS-90)
-1.4039	2978.914	-1.4040	-0.00008
1.1062	3149.847	1.1063	0.00009
4.5979	3399.248	4.5980	0.00007
8.1955	3670.718	8.1954	-0.00004
11.6295	3943.970	11.6295	-0.00007
15.1862	4241.874	15.1861	-0.00009
18.6903	4550.560	18.6904	0.00008
22.1892	4874.139	22.1893	0.00007
25.7491	5219.423	25.7491	-0.00000
29.1638	5566.173	29.1637	-0.00005
32.6970	5941.274	32.6970	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



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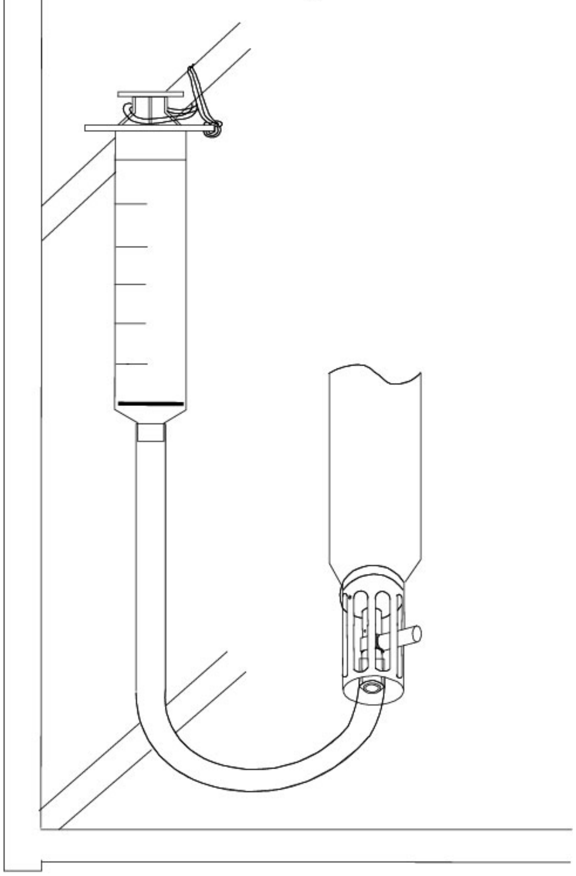
APPLICATION NOTE NO. 34 **Revised March 2008**

Instructions for Use of Conductivity Cell Filling and Storage Device PN 50087 and 50087.1

Figure 1



This application note provides instructions for use of PN 50087 / 50087.1 syringe and tubing assembly in rinsing, cleaning, and storing conductivity sensors. The tubing assembly consists of a length of 6.35 mm (1/4 inch) I.D. tube connected by a plastic reducing union to a short piece of 11.1 mm (7/16 inch) I.D. tube. Refer to *Application Note 2D: Instructions for Care and Cleaning of Conductivity Cells* for information on water and solutions recommended for use.

- SBE 9*plus*, 19*plus* V2, 25, and 49 are shipped with PN 50087.
- SBE 16*plus* V2 and 16*plus*-IM V2 are shipped with PN 50087.1, which includes the parts in 50087, plus hose barbs to replace the anti-foulant cap on the instrument. The hose barbs allow for connection of the tubing for cleaning and storing, as described below.

Note: This procedure can also be used with the SBE 16, 16*plus*, 16*plus*-IM, 19, and 19*plus*, which are no longer in production.

Procedure for Use

1. To fill the conductivity cell, draw about 40-60 cc of solution into the syringe.
2. Connect the plastic tubing to the TC duct intake on the temperature sensor [Figure 1] (or to the open end of the conductivity cell on systems without the TC duct [Figure 2]), and inject solution into the cell and pump plumbing.
   - CTDs with a TC duct or hose barb fitting - remove the plastic reducing union and connect the smaller diameter tubing directly to the TC duct / fitting.
   - CTDs without a TC duct or hose barb fitting (older instruments) - leave the reducing union and large diameter tubing attached and carefully connect the tubing directly to the end of the glass conductivity cell [Figure 2].
3. (If applicable) Loop the rubber band around a bar on the CTD cage and back over the top of the syringe to secure the apparatus for storage.

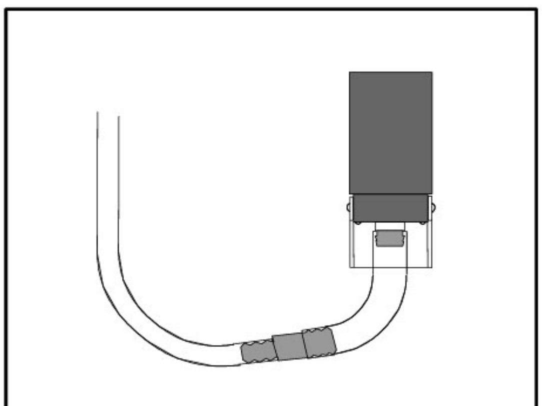


Figure 2

REMOVE THE SYRINGE AND TUBING ASSEMBLY BEFORE DEPLOYMENT!

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APPLICATION NOTE NO. 42 **Revised March 2008**

ITS-90 TEMPERATURE SCALE

Beginning in January 1995, Sea-Bird's temperature metrology laboratory (based upon water triple-point and gallium melt cell, SPRT, and ASL F18 Temperature Bridge) converted to ITS-90 (T90). These T90 standards are employed in calibrating *all* Sea-Bird temperature sensors, and as the reference temperature used in conductivity calibrations.

The international oceanographic research community continues to use IPTS-68 (T68) for computation of salinity and other seawater properties. Therefore, following the recommendations of Saunders (1990) and as supported by the Joint Panel on Oceanographic Tables and Standards (1991), our software and our instrument firmware (for instruments that can calculate and output salinity and other seawater properties directly) converts between T68 and T90 according to the linear relationship:

$$T_{68} = 1.00024 * T_{90}$$

The use of T68 for salinity and other seawater calculations is automatic in our software and in those instruments that directly output salinity and other seawater parameters.

Note: In our SEASOFT-Win32 suite of software programs, edit the CTD configuration (.con) file to enter calibration coefficients using the Configure Inputs menu in SEASAVE V7 (real-time data acquisition software) or the Configure menu in SBE Data Processing (data processing software).

SBE 9*plus* (using SBE 3*plus* temperature sensor), 16, 19, 21, and 25 (using SBE 3F temperature sensor)

Beginning in January 1995, Sea-Bird temperature calibration certificates began listing a set of coefficients labeled *g*, *h*, *i*, *j*, and *F0*, corresponding to ITS-90 (T90) temperatures. For user convenience and for historical comparison with older calibrations, the certificates also continue to list *a*, *b*, *c*, *d*, and *F0* coefficients corresponding to IPTS-68 (T68) temperatures. The T90 coefficients result directly from T90 standards; the T68 coefficients are computed using the Saunders linear approximation.

SEASOFT supports entry of either the T90 or the T68 coefficients for these instruments. When selecting temperature as a display/output variable, you must select which standard (T90 or T68) is to be used to compute temperature. SEASOFT recognizes whether you have entered T90 or T68 coefficients in the configuration (.con) file, and performs the calculations accordingly, depending on which coefficients were used and which display variable type is selected.

- If *g, h, i, j, F0* coefficients (T90) are entered in the .con file and you select temperature display/output variable type as T68, SEASOFT computes T90 temperature directly and multiplies it by 1.00024 to display or output T68.
- If *a, b, c, d,* and *F0* coefficients (T68) are entered in the .con file and you select temperature display/output variable type as T90, SEASOFT computes T68 directly and divides by 1.00024 to display or output T90.

SBE 16*plus*, 16*plus*-IM, 16*plus* V2, 16*plus*-IM V2, 19*plus*, 19*plus* V2, 26*plus*, 35, 35RT, 37 (all), 38, 39 and 39-IM, 45, 49, 51, 52-MP, 53, *and all higher numbered instruments*

For these instruments, all first manufactured after the switch of our metrology lab to ITS-90, Sea-Bird provides only one set of temperature calibration coefficients, based on the T90 standards. These instruments all have user-programmable internal calibration coefficients, and can output data in engineering units (°C, S/m, dbar, etc. as applicable to the instrument). When outputting temperature in engineering units, these instruments always output T90 temperatures.

- Instruments that can internally compute and then output salinity and other seawater parameters (for example, SBE 37-SI) - Use of T68 for salinity and other seawater calculations is automatic; the instrument internally performs the conversion between T90 and T68 according to the Saunders equation.
- Instruments supported in SEASOFT (for example, SBE 19*plus* V2) - Use of T68 for salinity and other seawater calculations is automatic; the software performs the conversion between T90 and T68 according to the Saunders equation. When selecting temperature as a display/output variable, you must select which standard (T90 or T68) is to be used to compute temperature.

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APPLICATION NOTE NO. 57 **Revised May 2003**

I/O Connector Care and Installation

This Application Note describes the proper care and installation of standard I/O connectors for Sea-Bird CTD instruments. Once properly installed, the connections require minimal care. Unless access to the bulkhead is required, the connections can be left in place indefinitely.

The Application Note is divided into three sections:

- Connector Cleaning and Installation
- Locking Sleeve Installation
- Cold Weather Tips

Connector Cleaning and Installation

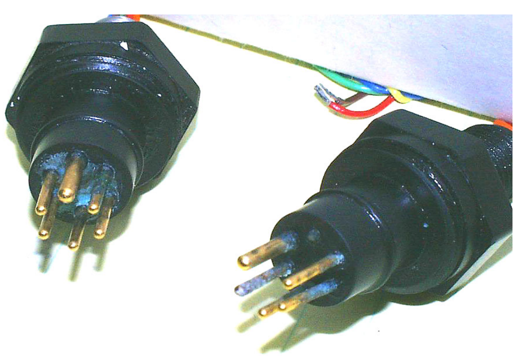
1. Carefully clean the bulkhead connector and the inside of the mating inline (cable end) connector with a Kimwipe. Remove all grease, hair, dirt, and other contamination.

Clean bulkhead connector

Clean inside of connector

2. Inspect the connectors:
   A. Inspect the pins on the bulkhead connector for signs of corrosion. The pins should be bright and shiny, with no discoloration. If the pins are discolored or corroded, clean with alcohol and a Q-tip.
   B. Inspect the bulkhead connector for chips, cracks, or other flaws that may compromise the seal.
   C. Inspect the inline connector for cuts, nicks, breaks, or other problems that may compromise the seal.

   Replace severely corroded or otherwise damaged connectors - contact SBE for instructions or a Return Authorization Number (RMA number).

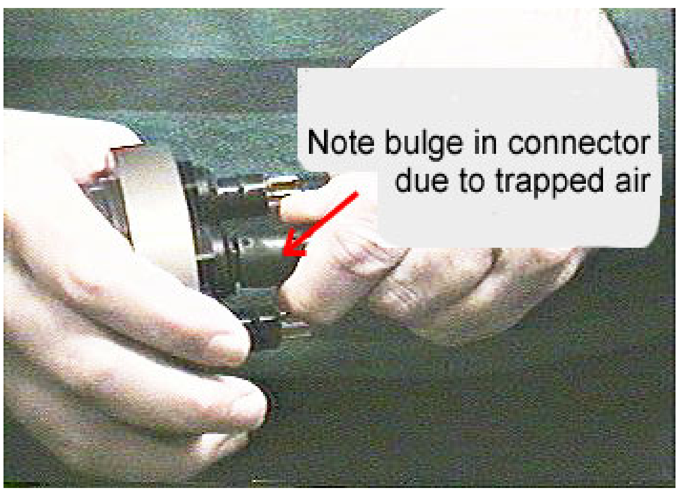


Corroded pins on bulkhead connectors -
Connector on right has a missing pin

3. Using a tube of 100% silicone grease (Dow DC-4 or equivalent), squeeze approximately half the size of a pea onto the end of your finger.

CAUTION:
Do not use WD-40 or other petroleum-based lubricants, as they will damage the connectors.

4. Apply a light, even coating of grease to the molded ridge around the base of the bulkhead connector. The ridge looks like an o-ring molded into the bulkhead connector base and fits into the groove of the mating inline connector.

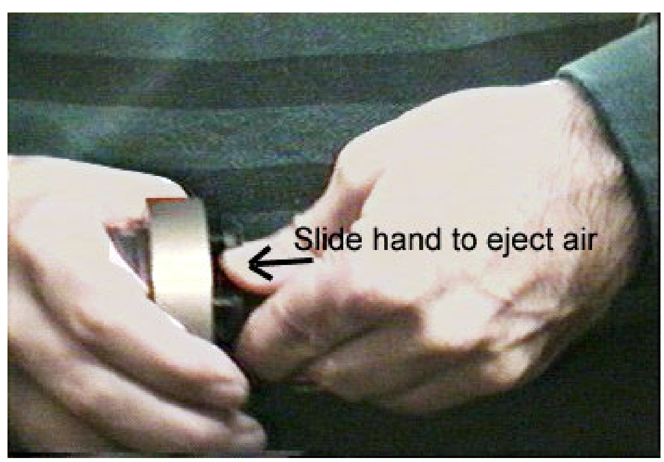


5. Mate the inline connector to the bulkhead, being careful to align the pins with the sockets. Do not twist the inline connector on the bulkhead connector. Twisting can lead to bent pins, which will soon break.

6. Push the connector all the way onto the bulkhead. There may be an audible pop, which is good. With some newer cables, or in cold weather, there may not be an initial audible pop.

7. After the cable is mated, run your fingers along the inline connector toward the bulkhead, *milking* any trapped air out of the connector. You should hear the air being ejected.

   CAUTION:
   Failure to eject the trapped air will result in the connector leaking.



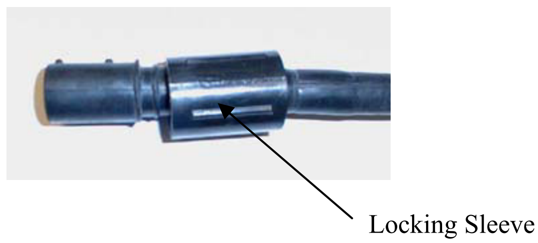
Locking Sleeve Installation

After the connectors are mated, install the locking sleeve. The locking sleeve secures the inline connector to the bulkhead connector and prevents the cable from being inadvertently removed.
Important points regarding locking sleeves:

- Tighten the locking sleeve by hand. **Do not** use a wrench or pliers to tighten the locking sleeve. Overtightening will gall the threads, which can bind the locking sleeve to the bulkhead connector. Attempting to remove a tightly bound locking sleeve may instead result in the bulkhead connector actually unthreading from the end cap. A loose bulkhead connector will lead to a flooded instrument. **Pay particular attention when removing a locking sleeve to ensure the bulkhead connector is not loosened**.

- It is a common misconception that the locking sleeve provides watertight integrity. **It does not, and continued re-tightening of the locking sleeve will not *fix* a leaking connector**.

- As part of routine maintenance at the end of every cruise, remove the locking sleeve, slide it up the cable, and rinse the connection (still mated) with fresh water. This will prevent premature cable failure.



Cold Weather Tips

In cold weather, the connector may be hard to install and remove.

Removing a *frozen* inline connector:

1. Wrap the connector with a washrag or other cloth.

2. Pour hot water on the cloth and let the connector sit for a minute or two. The connector should thaw and become flexible enough to be removed.

Installing an inline connector:
When possible, mate connectors in warm environments before the cruise and leave them connected.
If not, warm the connector sufficiently so it is flexible. A flexible connector will install properly.

By following these procedures, you will have many years of reliable service from your cables!

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APPLICATION NOTE NO. 67 — October 2001

Editing Sea-Bird .hex Data Files

After acquiring real-time .hex data or uploading .hex data from CTD memory, users sometimes want to edit the header to add or change explanatory notes about the cast. Some text editing programs modify the file in ways that are not visible to the user (such as adding or removing carriage returns and line feeds), but that corrupt the format and prevent further processing by SEASOFT (both DOS and Windows versions). **This Application Note provides details on one way to edit a .hex data file with a text editor while retaining the required format.** The procedure described below has been found to work correctly on computers running Win 98, Win 2000, and Win NT. If the editing is not performed using this technique, SEASOFT may reject the data file and give you an error message.

1. Make a back-up copy of your .hex data file before you begin.

2. Run **WordPad**.

3. In the File menu, select Open. The Open dialog box appears. For *Files of type*, select *All Documents (*.*)*. Browse to the desired .hex data file and click Open.

4. Edit the file as desired, **inserting any new header lines after the System Upload Time line**. Note that all header lines must begin with an asterisk (*), and *END* indicates the end of the header. An example is shown below, with the added lines in bold:

```
* Sea-Bird SBE 21 Data File:
* FileName = C:\Odis\SAT2-ODIS\oct14-19\oc15_99.hex
* Software Version Seasave Win32 v1.10
* Temperature SN = 2366
* Conductivity SN = 2366
* System UpLoad Time = Oct 15 1999  10:57:19
* Testing adding header lines
* Must start with an asterisk
* Can be placed anywhere between System Upload Time and END of header
* NMEA Latitude = 30 59.70 N
* NMEA Longitude = 081 37.93 W
* NMEA UTC (Time) = Oct 15 1999  10:57:19
* Store Lat/Lon Data = Append to Every Scan and Append to .NAV File When <Ctrl F7> is Pressed
** Ship:      Sea-Bird
** Cruise:    Sea-Bird Header Test
** Station:
** Latitude:
** Longitude:
*END*
```

5. In the File menu, select Save (**not** Save As). If you are running Windows 2000, the following message displays:
   You are about to save the document in a Text-Only format, which will remove all formatting. Are you sure you want to do this?
   Ignore the message and click *Yes*.

6. In the File menu, select Exit.

NOTE: This Application Note **does not apply to .dat data files**. Sea-Bird is not aware of a technique for editing a .dat file that will not corrupt the file.

SBE

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APPLICATION NOTE NO. 68

Revised **June 2009**

Using USB Ports to Communicate with Sea-Bird Instruments

Most Sea-Bird instruments use the RS-232 protocol for transmitting setup commands to the instrument and receiving data from the instrument. However, most newer PCs and laptop computers have USB port(s) instead of RS-232 serial port(s).

USB serial adapters are available commercially. These adapters plug into the USB port, and allow one or more serial devices to be connected through the adapter. Sea-Bird tested USB serial adapters from several manufacturers on computers at Sea-Bird, and verified compatibility with our instruments. These manufacturers and the tested adapters are:

- **FTDI** (www.ftdichip.com) -
  "ChiPi" USB-RS232 Converter (model # FTDI UC232R-10).
  Note: This adapter can also be purchased from Sea-Bird, as Sea-Bird part # 20200.
  Drivers for this adapter can be found at http://www.ftdichip.com/Drivers/VCP.htm.

- **IOGEAR** (www.iogear.com) –
  USB 1.1 to Serial Converter Cable (model # GUC232A).
  Note: We have had several reports from customers that they could not communicate with their instrument using a laptop computer and this adapter.

- **Keyspan** (www.keyspan.com) -
  USB 4-Port Serial Adapter (part # USA-49WLC, replacing part # USA-49W)
  Note: We have one report from a customer that he could not communicate with his instrument using a notebook computer and this adapter. He was able to successfully communicate with the instrument using an XH8290 DSE Serial USB Adapter (www.dse.co.nz).

- **Edgeport** (www.ionetworks.com) -
  Standard Serial Converter Edgeport/2 (part # 301-1000-02)

Other USB adapters from these manufacturers, and adapters from other manufacturers, **may** also be compatible with Sea-Bird instruments.

We recommend testing any adapters, *including those listed above*, with the instrument and the computer you will use it with before deployment, to verify that there is no problem.

See Application Note 56: Interfacing to RS-485 Sensors for information on using a USB port to communicate with a Sea-Bird instrument that communicates via RS-485 telemetry.

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APPLICATION NOTE NO. 71 — Revised March 2008

Desiccant Use and Regeneration (drying)

This application note applies to all Sea-Bird instruments intended for underwater use. The application note covers:

- When to replace desiccant
- Storage and handling of desiccant
- Regeneration (drying) of desiccant
- Material Safety Data Sheet (MSDS) for desiccant

When to Replace Desiccant Bags

Before delivery of the instrument, a desiccant package is placed in the housing, and the electronics chamber is filled with dry Argon. These measures help prevent condensation. To ensure proper functioning:

1. Install a new desiccant bag each time you open the housing and expose the electronics.
2. If possible, dry gas backfill each time you open the housing and expose the electronics. If you cannot, wait at least 24 hours before redeploying, to allow the desiccant to remove any moisture from the chamber.

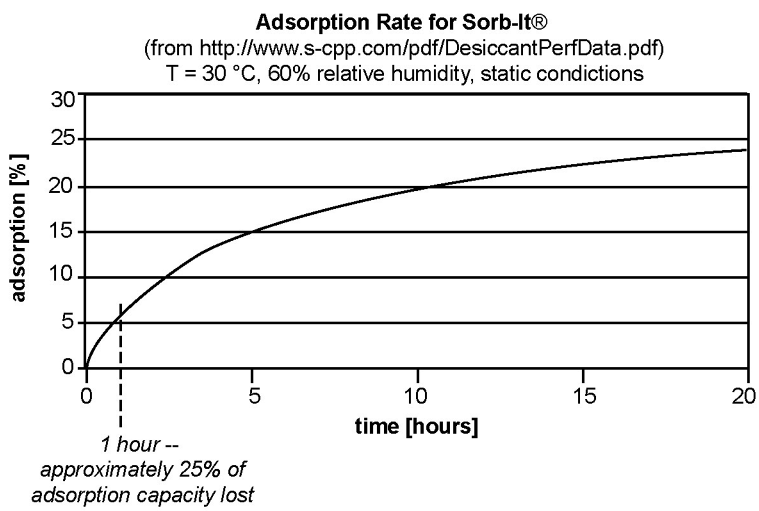
What do we mean by *expose the electronics*?

- For most battery-powered Sea-Bird instruments (such as SBE 16, 16*plus*, 16*plus* V2, 16*plus*-IM, 16*plus*-IM V2, 17*plus*, 19, 19*plus*, 19*plus* V2, 25, 26, 26*plus*, 37-SM, 37-SMP, 37-IM, 37-IMP, 44, 53, 54, 55, Auto Fire Module [AFM]), there is a bulkhead between the battery and electronics compartments. Battery replacement does not affect desiccation of the electronics, as the batteries are removed without removing the electronics and no significant gas exchange is possible through the bulkhead. Therefore, opening the battery compartment to replace the batteries does not expose the electronics; you do not need to install a new desiccant bag in the electronics compartment each time you open the battery compartment. For these instruments, install a new desiccant bag if you open the electronics compartment to access the printed circuit boards.
- For the SBE 39, 39-IM, and 48, the electronics must be removed or exposed to access the battery. Therefore, install a new desiccant bag each time you open the housing to replace a battery.

Storage and Handling

Testing by Süd-Chemie (desiccant's manufacturer) at 60% relative humidity and 30 °C shows that approximately 25% of the desiccant's adsorbing capacity is used up after only 1 hour of exposure to a constantly replenished supply of moisture in the air. In other words, if you take a bag out of a container and leave it out on a workbench for 1 hour, one-fourth of its capacity is gone before you ever install it in the instrument. Therefore:

- Keep desiccant bags in a tightly sealed, impermeable container until you are ready to use them. Open the container, remove a bag, and quickly close the container again.
- Once you remove the bag(s) from the sealed container, rapidly install the bag(s) in the instrument housing and close the housing. **Do not use the desiccant bag(s) if exposed to air for more than a total of 30 minutes.**



Regeneration (drying) of Desiccant

Replacement desiccant bags are available from Sea-Bird:

- PN 60039 is a metal can containing 25 1-gram desiccant bags and 1 humidity indicator card. The 1-gram bags are used in our smaller diameter housings, such as the SBE 3 (*plus*, F, and S), 4 (M and C), 5T and 5P, 37 (-SI, -SIP, -SM, -SMP, -IM, and –IMP), 38, 39, 39-IM, 43, 44, 45, 48, 49, and 50.
- PN 31180 is a 1/3-ounce desiccant bag, used in our SBE 16*plus*, 16*plus* V2, 16*plus*-IM, 16*plus*-IM V2, 19*plus*, 19*plus* V2, 21, and 52-MP.
- PN 30051 is a 1-ounce desiccant bag. The 1-ounce bags are used in our larger diameter housings, such as the SBE 9*plus*, 16, 17*plus*, 19, 25, 26, 26*plus*, 32, 53 BPR, 54, 55, AFM, and PDIM.

However, if you run out of bags, you can regenerate your existing bags using the following procedure provided by the manufacturer (Süd-Chemie Performance Packaging, a Division of United Catalysts, Inc.):

MIL-D-3464 Desiccant Regeneration Procedure

Regeneration of the United Desiccants' Tyvek Desi Pak® or Sorb-It® bags or United Desiccants' X-Crepe Desi Pak® or Sorb-It® bags can be accomplished by the following method:

1. Arrange the bags on a wire tray in a single layer to allow for adequate air flow around the bags during the drying process. The oven's inside temperature should be room or ambient temperature (25 – 29.4 °C [77 – 85 °F]). **A convection, circulating, forced-air type oven is recommended for this regeneration process. Seal failures may occur if any other type of heating unit or appliance is used.**

2. When placed in forced air, circulating air, or convection oven, allow a minimum of 3.8 to 5.1 cm (1.5 to 2.0 inches) of air space between the top of the bags and the next metal tray above the bags. If placed in a radiating exposed infrared-element type oven, shield the bags from direct exposure to the heating element, giving the closest bags a minimum of 40.6 cm (16 inches) clearance from the heat shield. Excessive surface film temperature due to infrared radiation will cause the Tyvek material to melt and/or the seals to fail. Seal failure may also occur if the temperature is allowed to increase rapidly. This is due to the fact that the water vapor is not given sufficient time to diffuse through the Tyvek material, thus creating internal pressure within the bag, resulting in a seal rupture. Temperature should not increase faster than 0.14 to 0.28 °C (0.25 to 0.50 °F) per minute.

3. Set the temperature of the oven to 118.3 °C (245 °F), and allow the bags of desiccant to reach equilibrium temperature. **WARNING**: Tyvek has a melt temperature of 121.1 – 126.7 °C (250 – 260 °F) (Non MIL-D-3464E activation or reactivation of both silica gel and Bentonite clay can be achieved at temperatures of 104.4 °C [220 °F]).

4. Desiccant bags should be allowed to remain in the oven at the assigned temperature for 24 hours. At the end of the time period, the bags should be immediately removed and placed in a desiccator jar or dry (0% relative humidity) airtight container for cooling. If this procedure is not followed precisely, any water vapor driven off during reactivation may be re-adsorbed during cooling and/or handling.

5. After the bags of desiccant have been allowed to cool in an airtight desiccator, they may be removed and placed in either an appropriate type polyliner tightly sealed to prevent moisture adsorption, or a container that prevents moisture from coming into contact with the regenerated desiccant.

NOTE: Use only a metal or glass container with a tight fitting metal or glass lid to store the regenerated desiccant. Keep the container lid **closed tightly** to preserve adsorption properties of the desiccant.

SÜD-CHEMIE
Creating Performance Technology

ISO 9002 CERTIFIED

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Phone: (505) 864-6691
Fax: (505) 864-9296

MATERIAL SAFETY DATA SHEET – August 13, 2002
SORB-IT®
Packaged Desiccant

SECTION I -- PRODUCT IDENTIFICATION

Trade Name and Synonyms:	Silica Gel, Synthetic Amorphous Silica, Silicon, Dioxide
Chemical Family:	Synthetic Amorphous Silica
Formula:	SiO_2.x H_2O

SECTION II -- HAZARDOUS INGREDIENTS

Components in the Solid Mixture

COMPONENT	CAS No	%	ACGIH/TLV (PPM)	OSHA-(PEL)
Amorphous Silica	63231-67-4	>99	PEL - 20 (RESPIRABLE), TLV – 5	LIMIT – NONE, HAZARD - IRRITANT

Synthetic amorphous silica is not to be confused with crystalline silica such as quartz, cristobalite or tridymite or with diatomaceous earth or other naturally occurring forms of amorphous silica that frequently contain crystalline forms.

This product is in granular form and packed in bags for use as a desiccant. Therefore, no exposure to the product is anticipated under normal use of this product. Avoid inhaling desiccant dust.

SECTION III -- PHYSICAL DATA

Appearance and Odor:	White granules; odorless.
Melting Point:	>1600 Deg C; >2900 Deg F
Solubility in Water:	Insoluble.
Bulk Density:	>40 lbs./cu. ft.
Percent Volatile by Weight @ 1750 Deg F:	<10%.

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Packaged Desiccant

SECTION IV -- FIRE EXPLOSION DATA

Fire and Explosion Hazard - Negligible fire and explosion hazard when exposed to heat or flame by reaction with incompatible substances.

Flash Point - Nonflammable.

Firefighting Media - Dry chemical, water spray, or foam. For larger fires, use water spray fog or foam.

Firefighting - Nonflammable solids, liquids, or gases: Cool containers that are exposed to flames with water from the side until well after fire is out. For massive fire in enclosed area, use unmanned hose holder or monitor nozzles; if this is impossible, withdraw from area and let fire burn. Withdraw immediately in case of rising sound from venting safety device or any discoloration of the tank due to fire.

SECTION V -- HEALTH HAZARD DATA

Health hazards may arise from inhalation, ingestion, and/or contact with the skin and/or eyes. Ingestion may result in damage to throat and esophagus and/or gastrointestinal disorders. Inhalation may cause burning to the upper respiratory tract and/or temporary or permanent lung damage. Prolonged or repeated contact with the skin, in absence of proper hygiene, may cause dryness, irritation, and/or dermatitis. Contact with eye tissue may result in irritation, burns, or conjunctivitis.

First Aid (Inhalation) - Remove to fresh air immediately. If breathing has stopped, give artificial respiration. Keep affected person warm and at rest. Get medical attention immediately.

First Aid (Ingestion) - If large amounts have been ingested, give emetics to cause vomiting. Stomach siphon may be applied as well. Milk and fatty acids should be avoided. Get medical attention immediately.

First Aid (Eyes) - Wash eyes immediately and carefully for 30 minutes with running water, lifting upper and lower eyelids occasionally. Get prompt medical attention.

First Aid (Skin) - Wash with soap and water.

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NOTE TO PHYSICIAN: This product is a desiccant and generates heat as it adsorbs water. The used product can contain material of hazardous nature. Identify that material and treat accordingly.

SECTION VI -- REACTIVITY DATA

Reactivity - Silica gel is stable under normal temperatures and pressures in sealed containers. Moisture can cause a rise in temperature which may result in a burn.

SECTION VII --SPILL OR LEAK PROCEDURES

Notify safety personnel of spills or leaks. Clean-up personnel need protection against inhalation of dusts or fumes. Eye protection is required. Vacuuming and/or wet methods of cleanup are preferred. Place in appropriate containers for disposal, keeping airborne particulates at a minimum.

SECTION VIII -- SPECIAL PROTECTION INFORMATION

Respiratory Protection - Provide a NIOSH/MSHA jointly approved respirator in the absence of proper environmental control. Contact your safety equipment supplier for proper mask type.

Ventilation - Provide general and/or local exhaust ventilation to keep exposures below the TLV. Ventilation used must be designed to prevent spots of dust accumulation or recycling of dusts.

Protective Clothing - Wear protective clothing, including long sleeves and gloves, to prevent repeated or prolonged skin contact.

Eye Protection - Chemical splash goggles designed in compliance with OSHA regulations are recommended. Consult your safety equipment supplier.

SECTION IX -- SPECIAL PRECAUTIONS

Avoid breathing dust and prolonged contact with skin. Silica gel dust causes eye irritation and breathing dust may be harmful.

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MATERIAL SAFETY DATA SHEET – August 13, 2002
SORB-IT®
Packaged Desiccant

* No Information Available

HMIS (Hazardous Materials Identification System) for this product is as follows:

Health Hazard	0
Flammability	0
Reactivity	0
Personal Protection	HMIS assigns choice of personal protective equipment to the customer, as the raw material supplier is unfamiliar with the condition of use.

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APPLICATION NOTE NO. 83 **revised March 2008**

Deployment of Moored Instruments

This Application Note applies to Sea-Bird instruments intended to provide time series data on a mooring or fixed site:

- SBE 16*plus*, 16*plus*-IM, 16*plus* V2, and 16*plus*-IM V2 SEACAT Conductivity and Temperature Recorder
- SBE 19*plus* and 19*plus* V2 SEACAT Profiler CTD (in moored mode)
- SBE 26*plus* SEAGAUGE Wave and Tide Recorder
- SBE 37 (-IM, -IMP, -SM, -SMP, -SI, -SIP) MicroCAT Conductivity and Temperature Recorder
- SBE 39 and 39-IM Temperature Recorder
- SBE 53 BPR Bottom Pressure Recorder

We have developed a check list to assist users in deploying moored instruments. **This checklist is intended as a guideline to assist you in developing a checklist specific to your operation and instrument setup.** The actual procedures and procedure order may vary, depending on such factors as:

- Instrument communication interface - RS-232, RS-485, or inductive modem
- Deployment interface for RS-232 or RS-485 - with I/O cable for real-time data or dummy plug for self-contained operation
- Sampling initiation - using delayed start commands to set a date and time for sampling to automatically begin or starting sampling just before deploying the instrument
- Sensors included in your instrument –
  - Pressure is optional in the SBE 16*plus*, 16*plus*-IM, 16*plus* V2, 16*plus*-IM V2, 37 (all), 39, and 39-IM.
  - Conductivity is optional in the SBE 26*plus* and 53, and is not provided in the SBE 39 and 39-IM.
  - Optional auxiliary sensors can be integrated with the SBE 16*plus*, 16*plus*-IM, 16*plus* V2, 16*plus*-IM V2, 19*plus*, and 19*plus* V2.

Deployment Summary

Instrument serial number	
Mooring number	
Date of deployment	
Depth of instrument	
Intended date of recovery	
Capture file printout(s) attached, or file name and location (showing status command, calibration coefficients command if applicable, any other applicable commands)	
Actual date of recovery	
Condition of instrument at recovery	
Notes	

Preparation for Deployment

Task	Completed ?
If applicable, upload existing data in memory. Perform preliminary processing / analysis of data to ensure you have uploaded all data, that data was not corrupted in upload process, and that (if uploading converted data) instrument EEPROM was programmed with correct calibration coefficients. If there is a problem with data, you can try to upload again now. Once you record over data in next deployment, opportunity to correct any upload problem is gone.	
Initialize memory to make entire memory available for recording. If memory is not initialized, data will be stored after last recorded sample.	
Calculate battery endurance to ensure sufficient power for intended sampling scheme. See instrument manual for example calculations.	
Calculate memory endurance to ensure sufficient memory for intended sampling scheme. See instrument manual for example calculations.	
Install fresh batteries. Even if you think there is adequate battery capacity left for another deployment, cost of fresh batteries is small price to pay to ensure successful deployment.	
Establish setup / operating parameters. 1. Click Capture in terminal program and enter file name to record instrument setup, so you have complete record of communication with instrument. 2. Set current date and time. 3. Establish setup / operating parameters. 4. If desired, set date and time for sampling to automatically begin. 5. Send *Status* command (**DS** or **#iiDS**) to verify and provide record of setup. ** 6. Send *Calibration Coefficients* command (**DC**, **#iiDC**, **DCal**, or **#iiDCal**) to verify and provide record of calibration coefficients. **	
Get conductivity sensor ready for deployment: Remove protective plugs that were placed in Anti-Foulant Device caps **or** remove Tygon tubing that was looped end-to-end around conductivity cell to prevent dust / dirt from entering cell. *Note*: Deploying instrument with protective plugs or looped Tygon tubing in place will prevent instrument from measuring conductivity during deployment, and may destroy cell.	
Install fresh AF24173 Anti-Foulant Devices for conductivity sensor. Rate of anti-foul use varies greatly, depending on location and time of year. If you think there is adequate capability remaining, and previous deployment(s) in this location and at this time of year back up that assumption, you may not choose to replace Anti-Foulant Devices for every deployment. However, as for batteries, cost of fresh Anti-Foulant Devices is small price to pay to ensure successful deployment.	
For instrument with external pump (16*plus*, 16*plus*-IM, 16*plus* V2, 16*plus*-IM V2, 19*plus*, 19*plus* V2), verify that system plumbing is correctly installed. See instrument manual for configuration.	
Start sampling (if you did not set up instrument with a delayed start command), or verify that sampling has begun (if you set up instrument with a delayed start command). 1. Click Capture in terminal program and enter file name to record instrument setup, so you have a complete record of communication with instrument. 2. If you did not set up instrument with a delayed start command, send command to start sampling. 3. Send *Status* command (**DS** or **#iiDS**) to verify and provide record that instrument is sampling. ** 4. Send *Send Last* command (**SL** or **#iiSL**) to look at most recent sample and verify that output looks reasonable (i.e., ambient temperature, zero conductivity, atmospheric pressure). ** 5. If instrument has pressure sensor, record atmospheric pressure with barometer. You can use this information during data processing to check and correct for pressure sensor drift, by comparing to instrument's pressure reading in air (from Step 4). Note: For instrument with pump (external **or** integral), avoid running pump *dry* for extended period of time.	
If cable connectors or dummy plugs were unmated, reinstall cables or dummy plugs as described in *Application Note 57: Connector Care and Cable Installation*. Failure to correctly install cables may result in connector leaking, causing data errors as well as damage to bulkhead connector.	
Install mounting hardware on instrument. Verify that hardware is secure.	

** **Note:** Actual instrument command is dependent on communication interface and instrument.

Recovery

Immediately upon recovery

Task	Completed?
Rinse instrument with fresh water.	
Remove locking sleeve on dummy plug or cable, slide it up cable (if applicable), and rinse connection (still mated) with fresh water.	
For instrument with pump (external or integral), stop sampling. Connect to instrument in terminal program and send command to stop sampling (**Stop** or **#iiStop**). Stop sampling as soon as possible upon recovery to avoid running pump *dry* for an extended period of time. **	
If instrument has pressure sensor, record atmospheric pressure with barometer. You can use this information during data processing to check and correct for pressure sensor drift, by comparing to instrument's pressure reading in air.	
Gently rinse conductivity cell with clean de-ionized water, drain, and gently blow through cell to remove larger water droplets. • If cell is not rinsed between uses, salt crystals may form on platinized electrode surfaces. When instrument is used next, sensor accuracy may be temporarily affected until these crystals dissolve. • Note that **vigorous flushing is not recommended** if you will be sending instrument to Sea-Bird for post-deployment calibration to establish drift during deployment.	
For instrument with external pump (16*plus*, 16*plus*-IM, 16*plus* V2, 16*plus*-IM V2, 19*plus*, 19*plus* V2): Remove Tygon tubing from pump head's hose barbs, and rinse inside of pump head, pouring fresh water through a hose barb. If pump head is not rinsed between uses, salt crystals may form on impeller. Over time, this may *freeze* impeller in place, preventing pump from working.	
Install protective plugs in Anti-Foulant Device caps or loop Tygon tubing end-to-end around conductivity cell for *long term* storage. This will prevent dust / dirt from entering conductivity cell. *Note*: For short term (< 1 day) storage, see *Application Note 2D: Instructions for Care and Cleaning of Conductivity Cells*.	
Upload data in memory. 1. Connect to instrument in terminal program. 2. If you have not already done so, send command to stop sampling (**Stop** or **#iiStop**). ** 3. Click Upload in terminal program to upload data in memory. 4. Perform preliminary processing / data analysis to ensure you have uploaded all data, data was not corrupted in upload process, and (if uploading converted data) instrument EEPROM was programmed with correct calibration coefficients. If there is a problem with data, you can try to upload again now. Once you record over data in next deployment, opportunity to correct any upload problem is gone.	

** **Note:** Actual instrument command is dependent on communication interface and instrument.

Later

Task	Completed?
Clean conductivity cell, as needed: • Do not clean cell if you will be sending instrument to Sea-Bird for post-deployment calibration to establish drift during deployment. • Clean cell if you will not be performing a post-deployment calibration to establish drift. See cleaning instructions in instrument manual and *Application Note 2D: Instructions for Care and Cleaning of Conductivity Cells*.	
For instrument with external pump (16*plus*, 16*plus*-IM, 16*plus* V2, 16*plus*-IM V2, 19*plus*, 19*plus* V2): Clean pump as described in *Application Note 75: Maintenance of SBE 5T and 5M Pumps*.	
(Annually) Inspect and (if applicable) rinse pressure port. See instructions in instrument manual.	
Send instrument to Sea-Bird for calibrations / regular inspection and maintenance. We typically recommend that instrument be recalibrated once a year, but possibly less often if used only occasionally. Return instrument to Sea-Bird for recalibration. Between lab calibrations, take field salinity samples to document conductivity cell drift. ***Notes:*** 1. We cannot place instrument in our calibration bath if heavily covered with biological material or painted with anti-foul paint. Remove as much material as possible before shipping to Sea-Bird; if we need to clean instrument before calibrating it, we will charge you for cleaning. To remove barnacles, plug ends of conductivity cell to prevent cleaning solution from getting into cell, then soak instrument in white vinegar *for a few minutes*. To remove anti-foul paint, use Heavy Duty Scotch-Brite pad or similar material. 2. If using lithium batteries, do not ship batteries installed in instrument. See http://www.seabird.com/customer_support/LithiumBatteriesRev2005.htm for shipping details.	

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APPLICATION NOTE 27Druck **Revised April 2008**

Minimizing Strain Gauge Pressure Sensor Errors

The following Sea-Bird instruments use strain gauge pressure sensors manufactured by GE Druck:

- SBE 16*plus*, 16*plus*-IM, 16*plus* V2, and 16*plus*-IM V2 SEACAT (not 16*) with optional strain gauge pressure sensor
- SBE 19*plus* and 19*plus* V2 SEACAT Profiler (not 19*)
- SBE 25 SEALOGGER CTD, which uses SBE 29 Strain-Gauge Pressure Sensor (built after March 2001)
- SBE 26*plus* SEAGAUGE Wave and Tide Recorder with optional strain gauge pressure sensor in place of Quartz pressure sensor
- SBE 37 MicroCAT (-IM, -IMP, -SM, -SMP, -SI, and -SIP) with optional pressure sensor (built after September 2000)
- SBE 39 Temperature Recorder with optional pressure sensor (built after September 2000) and 39-IM Temperature Recorder with optional pressure sensor
- SBE 49 FastCAT CTD Sensor
- SBE 50 Digital Oceanographic Pressure Sensor
- SBE 52-MP Moored Profiler CTD and DO Sensor

*** Note:** SBE 16 and SBE 19 SEACATs were originally supplied with other types of pressure sensors. However, a few of these instruments have been retrofitted with Druck sensors.

The Druck sensors are designed to respond to pressure in nominal ranges 0 - 20 meters, 0 - 100 meters, 0 - 350 meters, 0 – 600 meters, 0 – 1000 meters, 0 – 2000 meters, 0 – 3500 meters, and 0 – 7000 meters (with pressures expressed in meters of deployment depth capability). The sensors offer an initial accuracy of 0.1% of full scale range.

DEFINITION OF PRESSURE TERMS

The term *psia* means *pounds per square inch, absolute* (*absolute* means that the indicated pressure is referenced to a vacuum).

For oceanographic purposes, pressure is most often expressed in *decibars* (1 dbar = 1.4503774 psi). A dbar is 0.1 bar; a bar is approximately equal to a standard atmosphere (1 atmosphere = 1.01325 bar). For historical reasons, pressure at the water surface (rather than absolute or total pressure) is treated as the reference pressure (0 dbar); this is the value required by the UNESCO formulas for computation of salinity, density, and other derived variables.

Some oceanographers express pressure in Newtons/meter^2 or *Pascals* (the accepted SI unit). A Pascal is a very small unit (1 psi = 6894.757 Pascals), so the mega-Pascal (MPa = 10^6 Pascals) is frequently substituted (1 MPa = 100 dbar).

Since the pressure sensors used in Sea-Bird instruments are *absolute* types, their raw data inherently indicate atmospheric pressure (about 14.7 psi) when in air at sea level. Sea-Bird outputs pressure in one of the following ways:

- CTDs that output **raw data** (**SBE 16*plus*, 16*plus*-IM, 16*plus* V2, 16*plus*-IM V2, 19*plus*, 19*plus* V2, 25, and 49**) and are supported by SEASOFT's Seasave V7 (real-time data acquisition) and SBE Data Processing (data processing) software – In SEASOFT, user selects pressure output in psi (*not* psia) or dbar. SEASOFT subtracts 14.7 psi from the raw absolute reading and outputs the remainder as psi or converts the remainder to dbar.
- **SBE 26*plus*** – Real-time wave and tide data is output in psia. Wave and tide data stored in memory is processed using SEASOFT for Waves' Convert Hex module, and output in psia. Tide data can be converted to psi by subtracting a barometric pressure file using SEASOFT for Waves' Merge Barometric Pressure module.
- **SBE 50** – User selects pressure output in psia (including atmospheric pressure) or dbar. Calculation of dbar is as described above.
- All other instruments that can output **converted data in engineering units** (**SBE 16*plus*, 16*plus*-IM, 16*plus* V2, 16*plus*-IM V2, 19*plus*, 19*plus* V2, 37, 39, 39-IM, 49, and 52-MP**) – Instrument subtracts 14.7 psi from the raw absolute reading and converts the remainder to dbar.

Note: SBE 16*plus*, 16*plus*-IM, 16*plus* V2, 16*plus*-IM V2, 19*plus*, 19*plus* V2, 49, and 52-MP can output raw **or** converted data.

RELATIONSHIP BETWEEN PRESSURE AND DEPTH

Despite the common nomenclature (CTD = **C**onductivity - **T**emperature - **D**epth), all CTDs measure *pressure*, which is not quite the same thing as depth. The relationship between pressure and depth is a complex one involving water density and compressibility as well as the strength of the local gravity field, but it is convenient to think of a decibar as essentially equivalent to a meter, an approximation which is correct within 3% for almost all combinations of salinity, temperature, depth, and gravitational constant.

SEASOFT (most instruments)

SEASOFT offers two methods for estimating depth from pressure.

- For **oceanic applications**, salinity is presumed to be 35 PSU, temperature to be 0^o C, and the compressibility of the water (with its accompanying density variation) is taken into account. This is the method recommended in UNESCO Technical Paper No. 44 and is a logical approach in that by far the greatest part of the deep-ocean water column approximates these values of salinity and temperature. Since pressure is also proportional to gravity and the major variability in gravity depends on latitude, the latitude is used to estimate the magnitude of the local gravity field.
  - SBE 16*plus*, 16*plus*-IM, 16*plus* V2, 16*plus*-IM V2, 19*plus*, 19*plus* V2, 25, and 49 -
    Seasave V7 - User enters latitude on the Miscellaneous tab in the Configure Inputs dialog box; the entry is used if Depth [salt water] is selected as a display or output variable.
    SBE Data Processing - User is prompted to enter latitude if Depth [salt water] is selected as an output variable in the Data Conversion or Derive module. Latitude can also be changed on the Miscellaneous tab in those modules.
    Note: For both Seasave V7 and SBE Data Processing, if the data includes NMEA data, the software uses the latitude from the NMEA data instead of the user entry for latitude when calculating depth.
  - SBE 37-SM, 37-SMP, 37-IM, and 37-IMP - User is prompted to enter latitude if Depth [salt water] is selected as an output variable in SBE Data Processing's Derive module. Latitude can also be changed on the Miscellaneous tab in that module.
  - SBE 37-SI, 37-SIP, and 50 - Latitude is entered in the instrument's EEPROM using the **Latitude=** command in SEASOFT's SEATERM (terminal program) software.
  - SBE 39 and 39-IM – User is prompted to enter latitude if conversion of pressure to depth is requested when converting an uploaded .asc file to a .cnv file in SEATERM.
- For **fresh water applications**, compressibility is not significant in the shallow depths encountered and is ignored, as is the latitude-dependent gravity variation. Fresh water density is presumed to be 1 gm/cm, and depth (in meters) is calculated as 1.019716 * pressure (in dbars). No latitude entry is required for freshwater applications for the following:
  - SBE 16*plus*, 16*plus*-IM, 16*plus* V2, 16*plus*-IM V2, 19*plus*, 19*plus* V2, 25, and 49
  - SBE 37-SM, 37-SMP, 37-IM, and 37-IMP
  - SBE 50

  Notes:
  - The SBE 37-SI and 37-SIP firmware does not differentiate between freshwater and saltwater applications when calculating depth; the **Latitude=** entry is always used for the depth calculation.
  - The Convert utility in SEATERM for the SBE 39 and 39-IM does not differentiate between freshwater and saltwater applications when calculating depth; the user is always prompted to enter latitude if conversion of pressure to depth is requested.

SEASOFT for Waves (SBE 26plus SEAGAUGE Wave and Tide Recorder)

SEASOFT for Waves' Merge Barometric Pressure module subtracts a user-input barometric pressure file from the tide data file, and outputs the remainder as pressure in psi or as depth in meters. When converting to depth, the compressibility of the water is taken into account by prompting for user-input values for average density and gravity. See the SBE 26*plus* manual's appendix for the formulas for conversion of pressure to depth.

CHOOSING THE RIGHT SENSOR

Initial accuracy and resolution are expressed as a percentage of the full scale range for the pressure sensor. The initial accuracy is 0.1% of the full scale range. Resolution is 0.002% of full scale range, except for the SBE 25 (0.015% resolution). For best accuracy and resolution, select a pressure sensor full scale range to correspond to no more than the greatest depths to be encountered. The effect of this choice on CTD accuracy and resolution is shown below:

Range (meters)	**Maximum Initial Error (meters)**	**SBE 16*plus*, 16*plus*-IM, 16*plus* V2, 16*plus*-IM V2, 19*plus*, 19*plus* V2, 37, 39, 39-IM, 49, 50, and 52-MP - Resolution (meters)**	**SBE 25 - Resolution (meters)**
0 – 20	0.02	0.0004	0.003
0 – 100	0.10	0.002	0.015
0 – 350	0.35	0.007	0.052
0 – 600	0.60	0.012	0.090
0 – 1000	1.0	0.02	0.15
0 - 2000	2.0	0.04	0.30
0 - 3500	3.5	0.07	0.52
0 - 7000	7.0	0.14	1.05

Note: See the SBE 26*plus* manual or brochure for its resolution specification; 26*plus* resolution is a function of integration time as well as pressure sensor range.

The meaning of *accuracy*, as it applies to these sensors, is that the indicated pressure will conform to true pressure to within ± *maximum error* (expressed as equivalent depth) throughout the sensor's operating range. Note that a 7000-meter sensor reading + 7 meters at the water surface is operating within its specifications; the same sensor would be expected to indicate 7000 meters ± 7 meters when at full depth.

Resolution is the magnitude of indicated increments of depth. For example, a 7000-meter sensor on an SBE 25 (resolution 1.05 meters) subjected to slowly increasing pressure will produce readings approximately following the sequence *0, 1.00, 2.00, 3.00* (meters). Resolution is limited by the design configuration of the CTD's A/D converter. For the SBE 25, this restricts the possible number of discrete pressure values for a given sample to somewhat less than 8192 (13 bits); an approximation of the ratio 1 : 7000 is the source of the SBE 25's 0.015% resolution specification.

Note: SEASOFT (and other CTD software) presents temperature, salinity, and other variables as a function of depth or pressure, so the CTD's pressure resolution limits the number of plotted data points in the profile. For example, an SBE 25 with a 7000-meter sensor might acquire several values of temperature and salinity during the time required to descend from 1- to 2-meters depth. However, all the temperature and salinity values will be graphed in clusters appearing at either 1 or 2 meters on the depth axis.

High-range sensors used in shallow water generally provide better accuracy than their *absolute* specifications indicate. With careful use, they may exhibit *accuracy* approaching their *resolution* limits. For example, a 3500-meter sensor has a nominal accuracy (irrespective of actual operating depth) of ± 3.5 meters. Most of the error, however, derives from variation over time and temperature of the sensor's *offset*, while little error occurs as a result of changing *sensitivity*.

MINIMIZING ERRORS

Offset Errors

Note: Follow the procedures below for all instruments except the SBE 26*plus* (see the 26*plus* manual for details).

The primary *offset* error due to drift over time can be eliminated by comparing CTD readings in air before beginning the profile to readings from a barometer. Follow this procedure:

1. Allow the instrument to equilibrate in a reasonably constant temperature environment for at least 5 hours. Pressure sensors exhibit a transient change in their output in response to changes in their environmental temperature; allowing the instrument to equilibrate before starting will provide the most accurate calibration correction.

2. Place the instrument in the orientation it will have when deployed.

3. Set the pressure offset to 0.0:
   - In the .con file, using Seasave V7 or SBE Data Processing (for SBE 16*plus*, 16*plus*-IM, 16*plus* V2, 16*plus*-IM V2, 19*plus*, 19*plus* V2, 25, or 49).
   - In the CTD's EEPROM, using the appropriate command in the terminal program (for SBE 16*plus*, 16*plus*-IM, 16*plus* V2, 16*plus*-IM V2, 19*plus*, 19*plus* V2, 37, 39, 39-IM, 49, 50, or 52-MP).

4. Collect pressure data from the instrument using Seasave V7 or the terminal program, as appropriate (see instrument manual for details). If the instrument is not outputting data in decibars, convert the output to decibars.

5. Compare the instrument output to the reading from a good barometer placed at the same elevation as the pressure sensor. Calculate *offset* (decibars) = barometer reading (converted to decibars) – instrument reading (decibars).

6. Enter calculated offset (positive or negative) in decibars:
   - In the .con file, using Seasave V7 or SBE Data Processing (for SBE 16*plus*, 16*plus*-IM, 16*plus* V2, 16*plus*-IM V2, 19*plus*, 19*plus* V2, 25, or 49). **AND**
   - In the CTD's EEPROM, using the appropriate command in the terminal program (for SBE 16*plus*, 16*plus*-IM, 16*plus* V2, 16*plus*-IM V2, 19*plus*, 19*plus* V2, 37, 39, 39-IM, 49, 50, or 52-MP).

Note: For instruments that store calibration coefficients in EEPROM and **also** use a .con file (SBE 16*plus*, 16*plus*-IM, 16*plus* V2, 16*plus*-IM V2, 19*plus*, 19*plus* V2, and 49), set the pressure offset (Steps 3 and 6 above) in both the EEPROM and in the .con file.

Offset Correction Example
Absolute pressure measured by a barometer is 1010.50 mbar. Pressure displayed from instrument is -2.5 dbars.
Convert barometer reading to dbars using the relationship: mbar * 0.01 = dbars
Barometer reading = 1010.50 mbar *0.01 = 10.1050 dbars
Instrument's internal calculations and/or our processing software output gage pressure, using an assumed value of 14.7 psi for atmospheric pressure. Convert instrument reading from gage to absolute by adding 14.7 psia to instrument output:
- 2.5 dbars + (14.7 psi * 0.689476 dbar/psia) = - 2.5 + 10.13 = 7.635 dbars
Offset = 10.1050 – 7.635 = + 2.47 dbar Enter offset in .con file (if applicable) and in instrument EEPROM (if applicable).

Another source of *offset* error results from temperature-induced drifts. Because Druck sensors are carefully temperature compensated, errors from this source are small. Offset errors can be estimated for the conditions of your profile, and eliminated when post-processing the data in SBE Data Processing by the following procedure:

1. **Immediately** before beginning the profile, take a pre-cast *in air* pressure reading.

2. **Immediately** after ending the profile, take a post-cast *in air* pressure reading with the instrument at the same elevation and orientation. This reading reflects the change in the instrument temperature as a result of being submerged in the water during the profile.

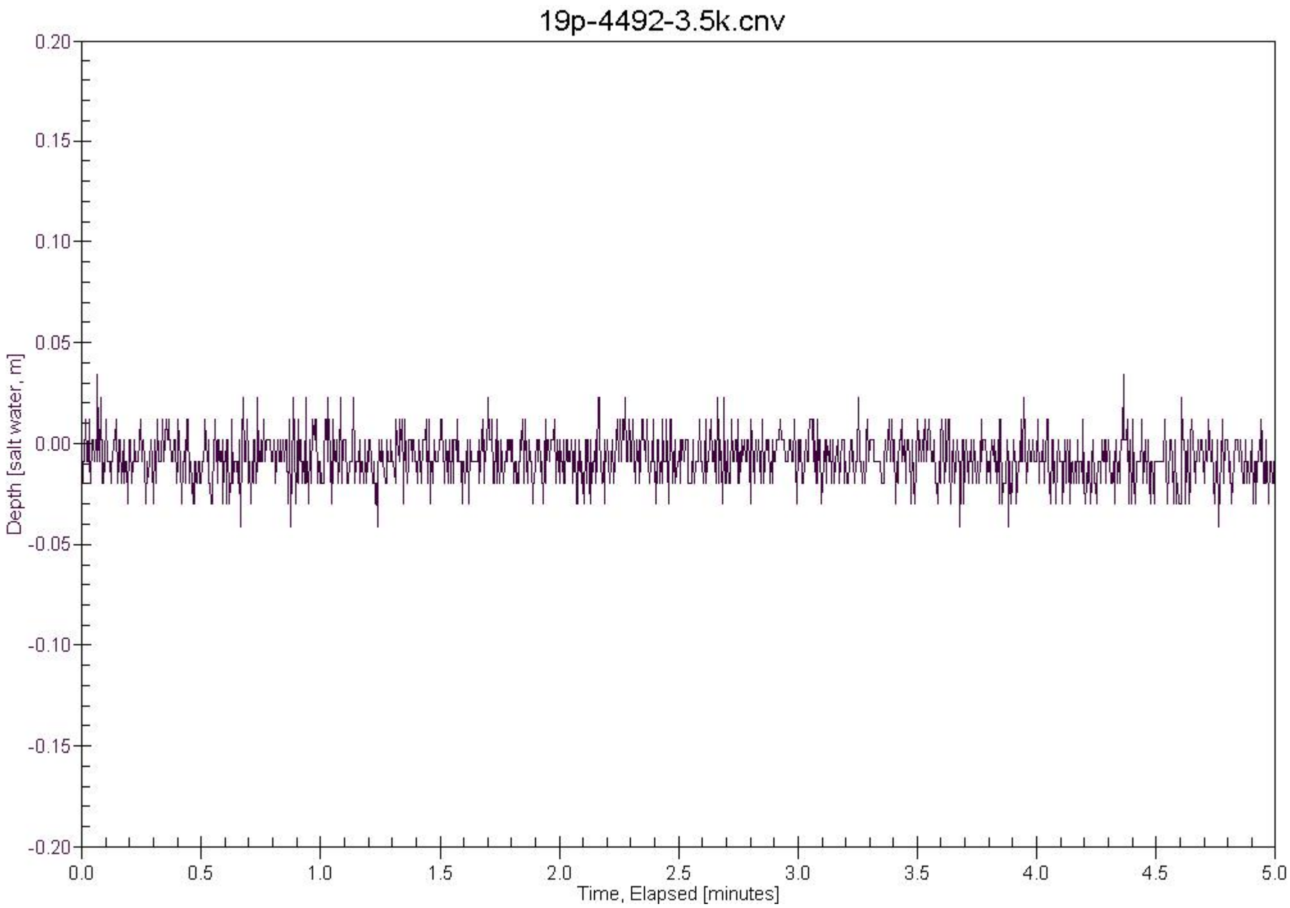
3. Calculate the average of the pre- and post-cast readings. Enter the negative of the average value (in decibars) as the *offset* in the .con file.

Hysteresis Errors

Hysteresis is the term used to describe the failure of pressure sensors to repeat previous readings after exposure to other (typically higher) pressures. The Druck sensor employs a micro-machined silicon diaphragm into which the strain elements are implanted using semiconductor fabrication techniques. Unlike metal diaphragms, silicon's crystal structure is perfectly elastic, so the sensor is essentially free of pressure hysteresis.

Power Turn-On Transient

Druck pressure sensors exhibit virtually no power turn-on transient. The plot below, for a 3500-meter pressure sensor in an SBE 19*plus* SEACAT Profiler, is representative of the power turn-on transient for all pressure sensor ranges.



Thermal Transient

Pressure sensors exhibit a transient change in their output in response to changes in their environmental temperature, so the thermal transient resulting from submersion in water must be considered when deploying the instrument.

During calibration, the sensors are allowed to *warm-up* before calibration points are recorded. Similarly, for best depth accuracy the user should allow the CTD to *warm-up* for several minutes before beginning a profile; this can be part of the *soak* time in the surface water. *Soaking* also allows the CTD housing to approach thermal equilibrium (minimizing the housing's effect on measured temperature and conductivity) and permits a Beckman- or YSI-type dissolved oxygen sensor (if present) to polarize.

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APPLICATION NOTE NO. 69 **July 2002**

Conversion of Pressure to Depth

Sea-Bird's SEASOFT software can calculate and output depth, if the instrument data includes pressure. Additionally, some Sea-Bird instruments (such as the SBE 37-SI or SBE 50) can be set up by the user to internally calculate depth, and to output depth along with the measured parameters.

Sea-Bird uses the following algorithms for calculating depth:

Fresh Water Applications

Because most fresh water applications are shallow, and high precision in depth not too critical, Sea-Bird software uses a very simple approximation to calculate depth:

depth (meters) = pressure (decibars) * 1.019716

Seawater Applications

Sea-Bird uses the formula in UNESCO Technical Papers in Marine Science No. 44. This is an empirical formula that takes compressibility (that is, density) into account. An ocean water column at 0 °C (t = 0) and 35 PSU (s = 35) is assumed.

The gravity variation with latitude and pressure is computed as:

$$g\ (m/sec^2) = 9.780318 * [\ 1.0 + (\ 5.2788x10^{-3} + 2.36x10^{-5} * x) * x\ ] + 1.092x10^{-6} * p$$

where
$x = [\sin (latitude / 57.29578)\ ]^2$
p = pressure (decibars)

Then, depth is calculated from pressure:

$$depth\ (meters) = [(((-1.82x10^{-15} * p + 2.279x10^{-10}) * p - 2.2512x10^{-5}) * p + 9.72659) * p] / g$$

where
p = pressure (decibars)
g = gravity (m/sec^2)

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APPLICATION NOTE NO. 73 **Revised February 2009**

Using Instruments with Pressure Sensors at Elevations Above Sea Level

This application note covers use of a Sea-Bird instrument that includes a pressure sensor at elevations above sea level, such as in a mountain lake or stream.

Background

Sea-Bird pressure sensors are absolute sensors, so their raw output includes the effect of atmospheric pressure. As shown on the Calibration Sheet that accompanies the instrument, our calibration (and resulting calibration coefficients) is in terms of psia. However, when outputting pressure in engineering units, most of our instruments output pressure relative to the ocean surface (i.e., at the surface the output pressure is 0 decibars). Sea-Bird uses the following equation in our instruments and/or software to convert psia to decibars:

Pressure (db) = [pressure (psia) – 14.7] * 0.689476
where 14.7 psia is the assumed atmospheric pressure (based on atmospheric pressure at sea level).

This conversion is based on the assumption that the instrument is being used in the ocean; the surface of the ocean water is by definition at sea level. However, if the instrument is used in a mountain lake or stream, the assumption of sea level atmospheric pressure (14.7 psia) in the instrument and/or software can lead to incorrect results. Procedures are provided below for measuring the pressure *offset* from the assumed sea level atmospheric pressure, and entering the offset in the instrument and/or software to make the appropriate correction.

- **Perform the correction procedure at the elevation at which the instrument will be deployed.** Allow the instrument to equilibrate in a reasonably constant temperature environment for at least 5 hours before starting. Pressure sensors exhibit a transient change in their output in response to changes in their environmental temperature. Sea-Bird instruments are constructed to minimize this by thermally decoupling the sensor from the body of the instrument. However, there is still some residual effect; allowing the instrument to equilibrate before starting will provide the most accurate calibration correction.

Inclusion of calibration coefficients in the instrument itself or in a file used by our software to interpret raw data varies, depending on the instrument. Commands used to program the instrument vary as well. Therefore, there are variations in the correction procedure, depending on the instrument. These instruments are addressed below:

- SBE **9*plus*** CTD and SBE **25** SEALOGGER CTD
- SBE **16*plus*** and **16*plus* V2 (RS-232 versions)** SEACAT C-T (pressure optional) Recorder, SBE **19*plus*** and **19*plus* V2** SEACAT Profiler CTD, and SBE **49** FastCAT CTD Sensor
- SBE **16*plus*** and **16*plus* V2 (RS-485 versions)** SEACAT C-T (pressure optional) Recorder, and SBE **16*plus*-IM** and **16*plus*-IM V2** SEACAT C-T (pressure optional) Recorder
- SBE **37** MicroCAT (all models, firmware version ≥ 3.0)
- SBE **37** MicroCAT (all models, firmware version < 3.0)
- SBE **50** Digital Oceanographic Pressure Sensor
- SBE **52-MP** Moored Profiler CTD and DO Sensor
- SBE **39-IM** Temperature (pressure optional) Recorder
- SBE **39** Temperature (pressure optional) Recorder
- SBE **26*plus*** SEAGAUGE Wave and Tide Recorder and SBE **53** BPR Bottom Pressure Recorder

SBE 9*plus* and 25

Sea-Bird real-time data acquisition software (SEASAVE) and post-processing software (SBE Data Processing) use calibration coefficients programmed in a configuration (.con) file to convert raw data from these instruments to engineering units.

Follow this procedure to correct the pressure:
1. With the instrument in the air, place it in the orientation it will have when deployed.
2. In SEASAVE, in the .con file, set the pressure offset to 0.0.
3. Acquire data in SEASAVE, and display the pressure sensor output in decibars.
4. Calculate *offset* = (0 – instrument reading).
5. Enter the calculated offset in the .con file.

Offset Correction Example:
Pressure displayed at elevation is -1.655 db. *Offset* = 0 – (-1.655) = + 1.655 db
Enter offset in .con file.

SBE 16*plus* and 16*plus* V2 (RS-232 versions), 19*plus* and 19*plus* V2, and 49

Sea-Bird real-time data acquisition software (SEASAVE) and post-processing software (SBE Data Processing) use calibration coefficients programmed in a configuration (.con) file to convert raw data from these instruments to engineering units. These instruments are also able to directly output data that is already converted to engineering units (pressure in decibars), using calibration coefficients that are programmed into the instrument.

Follow this procedure to correct the pressure:
1. With the instrument in the air, place it in the orientation it will have when deployed.
2. In SEASAVE, in the .con file, set the pressure offset to 0.0.
3. Acquire data in SEASAVE, and display the pressure sensor output in decibars.
4. Calculate *offset* = (0 – instrument reading).
5. Enter the calculated offset in the .con file.
6. Also enter the calculated offset in the instrument (using the **POffset=** command in the terminal program*).
   *Note: SBE 16*plus* V2 and 19*plus* V2 use SeatermV2 terminal program; the other instruments use SEATERM.

Offset Correction Example:
Pressure displayed at elevation is -1.655 db. *Offset* = 0 – (-1.655) = + 1.655 db
Enter offset in .con file and in instrument.

SBE 16*plus* and 16*plus* V2 (RS-485 versions), and 16*plus*-IM and 16*plus*-IM V2

Sea-Bird real-time data acquisition software (SEASAVE) and post-processing software (SBE Data Processing) use calibration coefficients programmed in a configuration (.con) file to convert raw data from these instruments to engineering units. These instruments are also able to directly output data that is already converted to engineering units (pressure in decibars), using calibration coefficients that are programmed into the instrument.

Follow this procedure to correct the pressure:
1. With the instrument in the air, place it in the orientation it will have when deployed.
2. In the terminal program*, set the pressure offset to 0.0 (**#iiPOffset=0**) and set the output format to converted data in decimal form (**#iiOutputFormat=3**).
   *Note: 16*plus* V2 and 16*plus*-IM V2 use SeatermV2; the other instruments use SEATERM.
3. Acquire data using the **#iiTP** command.
4. Calculate *offset* = (0 – instrument reading).
5. Enter the calculated offset in the instrument (using the **#iiPOffset=** command).
6. Also enter the calculated offset in the .con file, using SBE Data Processing.

Offset Correction Example:
Pressure displayed at elevation is -1.655 db. *Offset* = 0 – (-1.655) = + 1.655 db
Enter offset in .con file and in instrument.

SBE 37 (all models, firmware version ≥ 3.0)

The SBE 37 is able to directly output data that is already converted to engineering units (pressure in decibars), using calibration coefficients that are programmed into the instrument. The SBE 37 does not use a .con file.

Follow this procedure to correct the pressure:
1. With the SBE 37 in the air, place it in the orientation it will have when deployed.
2. In the SeatermV2 terminal program, set the pressure offset to 0.0 and pressure sensor output to decibars. *
3. Acquire data. *
4. Calculate *offset* = (0 – instrument reading).
5. Enter the calculated offset in the SBE 37 in SeatermV2. *

Offset Correction Example:
Pressure displayed at elevation is -1.655 db. *Offset* = 0 – (-1.655) = + 1.655 db
Enter offset in the SBE 37.

* NOTE: Commands for setting pressure offset, setting output format, and acquiring data vary:

Instrument	Pressure Offset Command	Output Format Command	Command to Acquire Data **
MicroCATs with Inductive Modem (IM) or RS-485 telemetry	**#iiPOffset=**	**#iiOutputFormat=1**	**#iiTSn:100** (measures and outputs data 100 times)
MicroCATs with RS-232 telemetry	**POffset=**	**OutputFormat=1**	**TSn:100** (measures and outputs data 100 times)

** See MicroCAT manual for location of pressure data in output data string.

SBE 37 (all models, firmware version < 3.0)

The SBE 37 is able to directly output data that is already converted to engineering units (pressure in decibars), using calibration coefficients that are programmed into the instrument. The SBE 37 does not use a .con file.

Follow this procedure to correct the pressure:
1. With the SBE 37 in the air, place it in the orientation it will have when deployed.
2. In the SEATERM terminal program, set the pressure offset to 0.0 and pressure sensor output to decibars. *
3. Acquire data. *
4. Calculate *offset* = (0 – instrument reading).
5. Enter the calculated offset in the SBE 37 in SEATERM. *

Offset Correction Example:
Pressure displayed at elevation is -1.655 db. *Offset* = 0 – (-1.655) = + 1.655 db
Enter offset in the SBE 37.

* NOTE: Commands for setting pressure offset, setting output format, and acquiring data vary:

Instrument	Pressure Offset Command	Output Format Command	Command to Acquire Data
MicroCATs with Inductive Modem (IM) or RS-485 telemetry	**#iiPOffset=**	**#iiFormat=1**	**#iiTP** (measures and outputs pressure 30 times)
MicroCATs with RS-232 telemetry	**POffset=**	**Format=1**	**TP** (measures and outputs pressure 100 times)

SBE 50

The SBE 50 is able to directly output data that is already converted to engineering units (psia, decibars, or depth in feet or meters), using calibration coefficients that are programmed into the instrument. The SBE 50 does not use a .con file.

Follow this procedure to correct the pressure:
1. With the SBE 50 in the air, place it in the orientation it will have when deployed.
2. In the SEATERM terminal program, set the pressure offset to 0.0 (**POffset=0**) and set the output format to the desired format (**OutputFormat=**).
3. Acquire data using the **TS** command a number of times.
4. Calculate *offset* = (0 – instrument reading).
5. Enter the calculated offset in the SBE 50 (use **POffset=** in SEATERM). The offset must be entered in units consistent with **OutputFormat=**. For example, if the output format is decibars (**OutputFormat=2**), enter the offset in decibars.

   Offset Correction Example:
   Pressure displayed at elevation with **OutputFormat=2** (db) is -1.655 db.   *Offset* = 0 – (-1.655) = + 1.655 db
   Enter offset in the SBE 50.

SBE 52-MP

The SBE 52-MP is able to directly output data that is already converted to engineering units (pressure in decibars), using calibration coefficients that are programmed into the instrument. The SBE 52-MP does not use a .con file.

Follow this procedure to correct the pressure:
1. With the SBE 52-MP in the air, place it in the orientation it will have when deployed.
2. In the SEATERM terminal program, set the pressure offset to 0.0 (**POffset=0**).
3. Acquire data using the **TP** command.
4. Calculate *offset* = (0 – instrument reading).
5. Enter the calculated offset in the SBE 52-MP (use **POffset=** in SEATERM).

   Offset Correction Example:
   Pressure displayed at elevation is -1.655 db.   *Offset* = 0 – (-1.655) = + 1.655 db
   Enter offset in the SBE 52-MP.

SBE 39-IM

The SBE 39-IM directly outputs data that is already converted to engineering units (pressure in decibars), using calibration coefficients that are programmed into the SBE 39-IM. The SBE 39-IM does not use a .con file.

Follow this procedure to correct the pressure:
1. With the SBE 39-IM in the air, place it in the orientation it will have when deployed.
2. In the SEATERM terminal program, set the pressure offset to 0.0 (**#iiPOffset=0**).
3. Acquire data using the **#iiTP** command.
4. Calculate *offset* = (0 – instrument reading).
5. Enter the calculated offset in the SBE 39-IM (use **#iiPOffset=** in SEATERM)

   Offset Correction Example:
   Pressure displayed at elevation is -1.655 db.   *Offset* = 0 – (-1.655) = + 1.655 db
   Enter offset in the SBE 39-IM.

SBE 39

The SBE 39 directly outputs data that is already converted to engineering units (pressure in decibars), using calibration coefficients that are programmed into the SBE 39. The SBE 39 does not use a .con file. The SBE 39 is a special case, because its programmed calibration coefficients do not currently include a pressure offset term. The lack of a pressure offset term creates two difficulties when deploying at elevations above sea level:

- After the data is recorded and uploaded, you must perform post-processing to adjust for the pressure offset. Sea-Bird software cannot currently perform this adjustment for the SBE 39.
- Without adjusting the instrument range, internal calculation limitations prevent the SBE 39 from providing accurate data at high elevations. Specifically, if (0.1 * sensor range) < (decrease in atmospheric pressure from sea level to elevation), an error condition in the SBE 39's internal calculations occurs. The table below tabulates the atmospheric pressure and approximate elevation at which this calculation limitation occurs for different pressure sensor ranges.

Range (m or db) *	Range (psi) = Range (db) / 0.689476	0.1 * Range (psi)	Atmospheric Pressure (psi) at elevation at which error occurs = [14.7 – 0.1 * Range (psi)]	Approximate Corresponding Elevation (m)
20	29	2.9	11.8	1800
100	145	14.5	0.2	No where on Earth!
350	507	50.7	-	-
1000	1450	145	-	-
2000	2900	290	-	-
3500	5076	507	-	-
7000	10152	1015	-	-

* Notes:

- Although decibars and meters are not strictly equal, this approximation is close enough for this Application Note. See Application Note 69 for conversion of pressure (db) to depth (m) for fresh or salt water applications.
- Equations used in conversions -
  As shown on page 1: pressure (db) = [pressure (psia) – 14.7] * 0.689476;
  Rearranging: pressure (psia) = [Pressure (db) / 0.689476] + 14.7
  Measuring relative to atmospheric: pressure (psi; relative to atmospheric pressure) = Pressure (db) / 0.689476

From the table, it is apparent that the only practical limitation occurs with a 20 meter pressure sensor. To use the SBE 39 in this situation, change the sensor range internally to 100 meters by entering **PRange=100** in the SBE 39 (using SEATERM). This changes the electronics' operating range, allowing you to record pressure data at high elevations, but slightly decreases resolution. After the data is recorded and uploaded, perform post-processing to adjust for the pressure offset. Note that Sea-Bird software cannot currently perform this adjustment for the SBE 39.

CAUTION: Changing **PRange** in the SBE 39 does not increase the actual maximum water depth at which the instrument can be used (20 meters) without damaging the sensor.

> *Example 1*: You want to deploy the SBE 39 with a 20 m pressure sensor in a mountain lake at 1400 meters (4590 feet). This is lower than 1800 meters shown in the table, so you do not need to adjust the sensor range. After the data is recorded and uploaded, perform post-processing to adjust for the pressure offset.
>
> *Example 2*: You want to deploy the SBE 39 with a 20 m pressure sensor in a mountain lake at 2000 meters (6560 feet). This is higher than 1800 meters shown in the table, so you need to adjust the sensor range. In SEATERM, set **PRange=100** to allow use of the SBE 39 at this elevation. After the data is recorded and uploaded, perform post-processing to adjust for the pressure offset.

SBE 26*plus* and 53

Unlike our other instruments that include a pressure sensor, the SBE 26*plus* and 53 output absolute pressure (i.e., at the surface the output pressure is atmospheric pressure at the deployment elevation). Therefore, no corrections are required when using these instruments above sea level. SBE 26*plus* / 53 software (SEASOFT for Waves) includes a module that can subtract measured barometric pressures from tide data, and convert the resulting pressures to water depths.

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APPLICATION NOTE NO. 84 July 2006

Using Instruments with Druck Pressure Sensors in Muddy or Biologically Productive Environments

This Application Note applies to Sea-Bird instruments with **Druck** pressure sensors, for moored applications or other long deployments that meet **either** of the following conditions:

- used in a **high-sediment (muddy)** environment, in a **pressure sensor end up** orientation
- used in a **biologically productive** environment, in **any** orientation

Standard pressure sensor port plug

At Sea-Bird, a pressure port plug with a small (0.042-inch diameter) vent hole in the center is inserted in the pressure sensor port. The vent hole allows hydrostatic pressure to be transmitted to the pressure sensor inside the instrument.

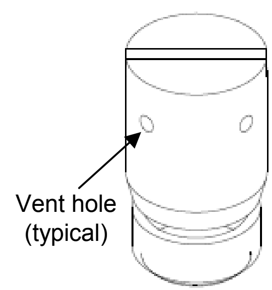
- If the instrument is deployed in a **high-sediment (muddy)** environment **with the pressure sensor end up**, the pressure port may partially fill with sediment (through the vent hole) over time, causing a delay in the pressure response.
- If the instrument is deployed in a **biologically productive** environment, the vent hole may be covered with biological growth over time, causing a delay in the pressure response, or in extreme cases completely blocking the pressure signal.

***Note**:* Photo is for an SBE 37-SM. Pressure port details are similar for all instruments included in this application note.

Sea-Bird has developed a high-head pressure port plug for deployment in muddy and/or biologically productive environments. The high-head plug extends beyond the surface of the instrument end cap, and has *four* horizontal vent holes connecting *internally* to a vertical vent hole.

- The horizontal orientation of the external holes prevents the deposit of sediment inside the pressure port.
- Each of the four vent holes is larger (0.062-inch vs. 0.042-inch diameter) than the single vent hole in the standard pressure port plug, significantly reducing the possibility that biological growth will cover all of the hole(s).

To purchase the high-head pressure port plug, Part Number 233186, contact Sea-Bird.



High-Head
Pressure Port Plug,
Part Number 233186

High-Head Pressure Port Plug Installation

1. Unscrew the standard pressure port plug from the pressure port.
2. Rinse the pressure port with warm, de-ionized water to remove any particles, debris, etc. **Do not put a brush or any object in the pressure port;** doing so may damage or break the pressure sensor.
3. Install the *high-head* pressure port plug in the pressure port.

Note: Until several years ago, Sea-Bird filled the pressure port with silicon oil at the factory. For **Druck** pressure sensors, we determined that this was unnecessary, and no longer do so. It is not necessary to refill the oil in the field. However, for **Paine** or **Paroscientific Digiquartz** pressure sensors, the pressure port **does** need to be refilled with silicon oil. Please contact Sea-Bird with the serial number of your instrument if you are unsure of the type of pressure sensor installed in your instrument.

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APPLICATION NOTE NO. 75 **Revised June 2007**

Maintenance of SBE 5T, 5P, and 5M Pumps

This application note is intended to assist you in maintaining your pump:

- SBE **5T** Titanium Submersible Pump – titanium housing (depth to 10,500 meters).
- SBE **5P** Plastic Submersible Pump – plastic housing (depth to 600 meters).
  Note: The SBE 5P's *operational* characteristics (power requirements, flow rate, etc.) are identical to the SBE 5T. However, the SBE 5P's construction is similar to the SBE 5M; therefore, the **maintenance procedures for the SBE 5P are grouped with the SBE 5M**.
- SBE **5M** Miniature Submersible Pump – available in titanium housing (depth to 10,500 meters) or plastic housing (depth to 600 meters).

A properly maintained pump will provide constant flow for your CTD and any pumped auxiliary sensors, resulting in high quality data. The main symptom of a non-functioning or poorly functioning pump is bad conductivity data, because the pump is not pulling water through the conductivity cell.

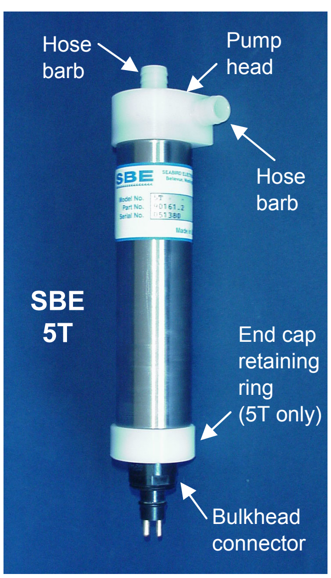
CAUTION: Do not run the pump *dry*. The pump is water lubricated; running it without water will damage it. If testing your system in dry conditions, remove the Tygon tubing from the hose barb at the top of the pump head, and fill the inside of the pump head with water. This will provide enough lubrication to prevent pump damage during testing.

The application note is organized as follows:

- Routine rinsing after recovery (applies to all pumps)

- SBE 5T -
  Periodic cleaning for SBE 5T
  Yearly maintenance for SBE 5T
  Non-functioning or poorly functioning SBE 5T

- SBE 5M or SBE 5P -
  Periodic cleaning for SBE 5M or SBE 5P
  Yearly maintenance for SBE 5M or SBE 5P
  Non-functioning or poorly functioning SBE 5M or SBE 5P



SBE 5M with ***titanium*** *housing*

SBE 5M with ***plastic*** *housing*

Routine Rinsing after Recovery (applies to all pumps)

At the end of a day of taking casts:

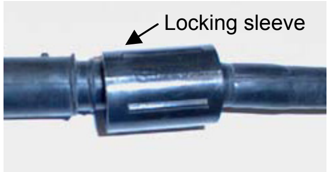
1. Remove the Tygon tubing from the pump head's hose barbs.

2. Leaving the pump head on the housing, thoroughly rinse the inside of the pump head, pouring clean, fresh water through a hose barb. If the pump head is not rinsed between uses, salt crystals may form on the impeller. Over time, this may *freeze* the impeller in place, preventing the pump from working.

3. Replace the Tygon tubing on the hose barbs.

4. Unscrew the cable locking sleeve from the bulkhead connector, and slide it up the cable. Thoroughly rinse the cable connection (still mated) with clean, fresh water. This will prevent premature cable failure.

5. Slide the locking sleeve back into place, and screw it back onto the bulkhead connector. Do not use a wrench or pliers to tighten the locking sleeve.



SBE 5T

Periodic Cleaning for SBE 5T

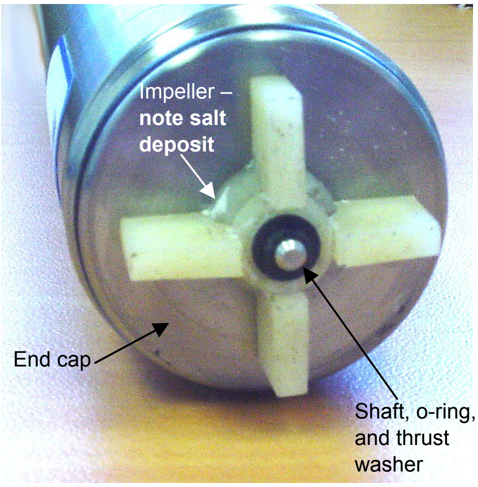
If you are going to store the pump for more than 1 week, or have removed the pump from a mooring, perform a more thorough cleaning:

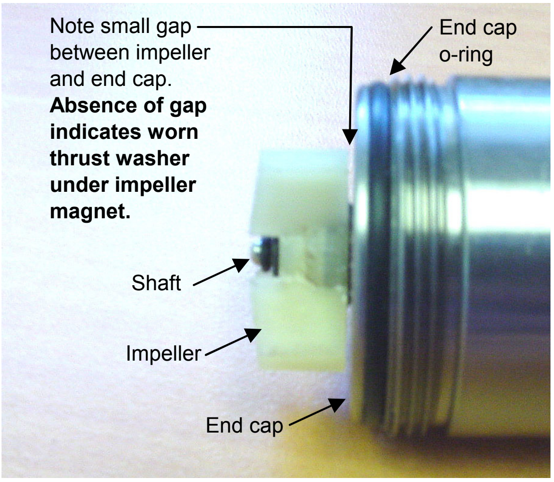
1. Unscrew the pump head from the housing.

2. Using clean, fresh water, thoroughly rinse the pump head and impeller.

3. Inspect the impeller for salt deposits. Clean any deposits with clean, fresh water and a toothbrush. Verify that the impeller can turn freely.

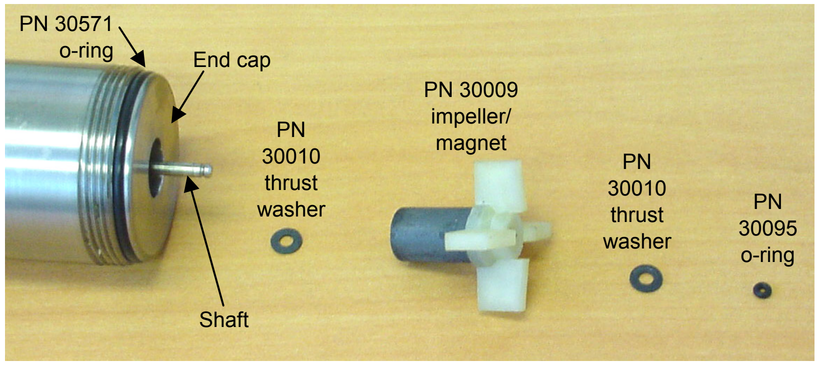
4. Inspect the shaft, and the o-ring and thrust washer holding the impeller on the shaft. There is another thrust washer underneath the impeller magnet, inside the housing. If this thrust washer is in good condition, you should observe a small gap between the bottom of the impeller and the end cap. If there is no gap, the thrust washer is worn and needs to be replaced (see *Yearly Maintenance for SBE 5T* for replacement procedure).





SBE 5T with Pump Head Removed

Yearly Maintenance for SBE 5T



SBE 5T with Pump Head and Impeller Removed

1. Unscrew the pump head from the housing.

2. Replace the o-ring and 2 thrust washers on the shaft:
   A. Remove the o-ring from the shaft. A pair of tweezers works well for this.
   B. Pull the impeller and attached magnet off the shaft. The thrust washer above the impeller will come off at the same time. Inspect the impeller for salt build-up, and clean if necessary. Inspect the magnet for wear. Particularly in sandy coastal environments, the magnet may be worn down from abrasion. If necessary, replace the impeller / magnet assembly (PN 30009).
   C. Remove the second thrust washer from the bottom of the shaft. A pair of tweezers works well for this.
   D. Inspect the shaft for wear.
   E. Rinse the shaft and depression in the housing with clean, fresh water. Allow to dry.
   F. Using new thrust washers (2 of PN 30010) and o-ring (PN 30095), replace the thrust washer and impeller / magnet on the shaft. Replace the other thrust washer and o-ring on the shaft, above the impeller, pushing hard with your fingertip to seat the thrust washer and o-ring in place.

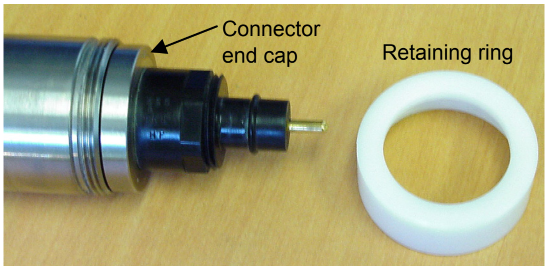
3. Inspect the end cap o-ring and the mating surface on the pump head for dirt, nicks, and cuts. Clean or replace as necessary. Apply a light coat of o-ring lubricant (Parker Super O Lube) to the o-ring and mating surfaces.

4. Reinstall the pump head on the pump housing.

5. Inspect the bulkhead connector for corrosion, which is a sign of seawater leakage between the bulkhead connector and cable. If there is corrosion, thoroughly clean the connector with water, followed by alcohol. Inspect the bulkhead connector for chips, cracks, or other flaws that may compromise the seal. Inspect the mating cable's connector for cuts, nicks, breaks, or other problems that may compromise the seal. Give the connector surfaces a light coating of **silicon** grease, and remate the connector properly; see *Application Note 57: I/O Connector Care and Installation*.
   - If the bulkhead connector is severely corroded or damaged, it must be replaced. Sea-Bird recommends that this work be performed at the factory, because the pump's physical configuration makes customer-replacement of the connector difficult.

Non-Functioning or Poorly Functioning SBE 5T

Perform the inspection procedures listed above in *Yearly Maintenance for SBE 5T*. If you do not discover the problem there, proceed as follows.



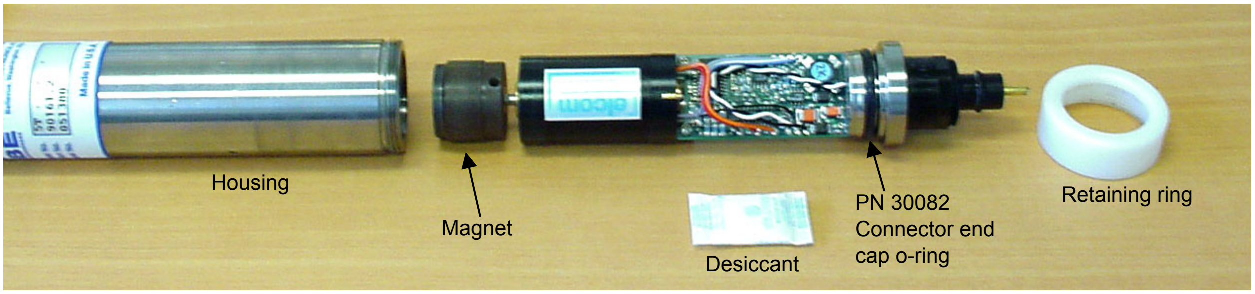
1. Unscrew the connector end cap retaining ring. Install a 2-pin dummy plug with locking sleeve over the bulkhead connector to provide a good grip and protect the connector pins. Rotate the end cap back and forth while carefully pulling the end cap away from the housing. Pull out the end cap and attached electronics from the housing.

2. Verify that the magnet can spin freely and is not broken or damaged.

3. Look for other signs of damage on the electronics.

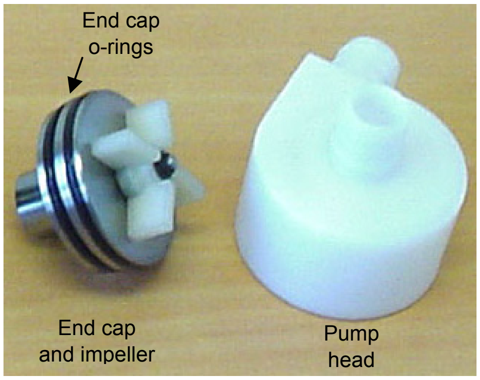
4. Inspect the connector end cap o-ring and the mating surface in the housing for dirt, nicks, and cuts. Clean as necessary. If the o-ring or mating surface is damaged, return the pump to Sea-Bird for repairs.
   - Sea-Bird recommends that connector end cap o-ring replacement be performed at the factory, because the pump's physical configuration makes customer-replacement of this o-ring difficult to perform without special tools.

5. Apply a light coat of o-ring lubricant (Parker Super O Lube) to the o-ring and mating surfaces. Gently place a **new desiccant bag** (PN 30558 – 1 gram) on the electronics (see *Application Note 71* for desiccant use and regeneration). Reinstall the electronics in the housing, until the o-ring has fully seated. Reinstall the retaining ring on the connector end cap.



SBE 5M or SBE 5P

Periodic Cleaning for SBE 5M or SBE 5P



If you are going to store the pump for more than 1 week, or have removed the pump from a mooring, perform a more thorough cleaning:

CAUTION: **Remove the end cap and impeller from the housing before cleaning the impeller.** The end cap o-rings seal the electronics chamber. The end cap may *walk* out of the housing after the pump head is removed, allowing water to enter the electronics chamber if you clean the impeller without first removing the end cap from the housing.

1. Unscrew the pump head from the housing.

2. Pull out the end cap from the housing.

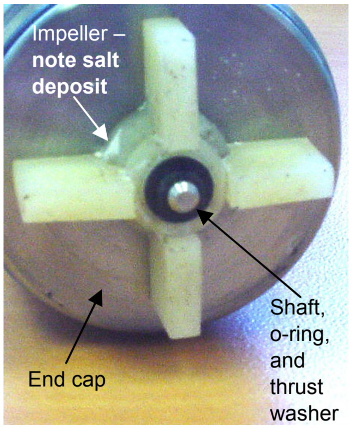
3. Using clean, fresh water, thoroughly rinse the pump head and impeller.

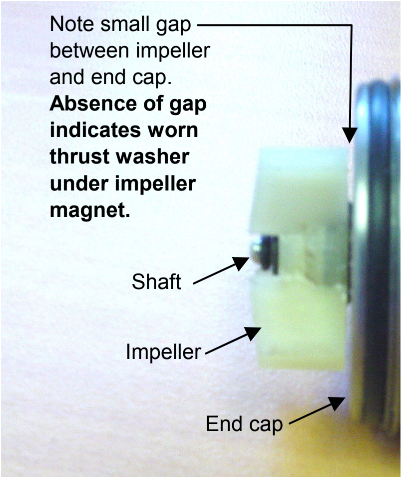
4. Inspect the impeller for salt deposits. Clean any deposits with clean, fresh water and a toothbrush. Verify that the impeller can turn freely.

5. Inspect the shaft, and the o-ring and thrust washer holding the impeller on the shaft. There is another thrust washer underneath the impeller magnet, inside the housing. If this thrust washer is in good condition, you should observe a small gap between the bottom of the impeller and the end cap. If there is no gap, the thrust washer is worn and needs to be replaced (see *Yearly Maintenance for SBE 5M or SBE 5P* for replacement procedure).

6. Apply a light coat of o-ring lubricant (Parker Super O Lube) to the o-ring and mating surfaces. Reinstall the end cap in the housing, carefully aligning the end cap with the housing and pushing hard on the end cap to seat the first o-ring in the housing (only 1 o-ring should now be visible).
CAUTION: If you are not careful, you may *pinch* the o-ring, which may allow water to enter the housing, damaging the electronics.

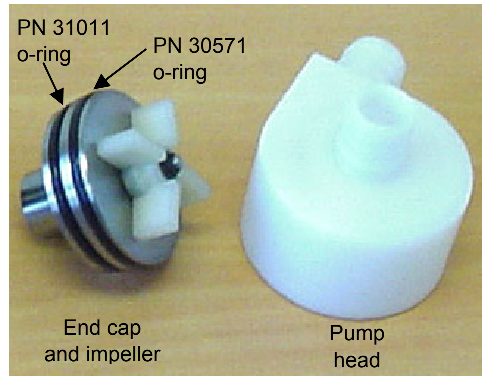
7. Reinstall the pump head on the end cap.





SBE 5M or 5P with Pump Head Removed

Yearly Maintenance for SBE 5M or SBE 5P

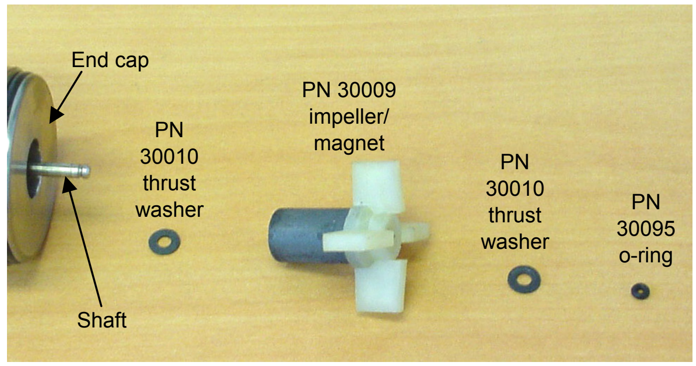


CAUTION: **Remove the end cap and impeller from the housing before cleaning the impeller.** The end cap o-rings seal the electronics chamber. The end cap may *walk* out of the housing after the pump head is removed, allowing water to enter the electronics chamber if you clean the impeller without first removing the end cap from the housing.

1. Unscrew the pump head from the housing.

2. Pull out the end cap from the housing.

3. Replace the o-ring and 2 thrust washers on the shaft:
   A. Remove the o-ring from the shaft. A pair of tweezers works well for this.
   B. Pull the impeller and attached magnet off the shaft. The thrust washer above the impeller will come off at the same time. Inspect the impeller for salt build-up, and clean if necessary. Inspect the magnet for wear. Particularly in sandy coastal environments, the magnet may be worn down from abrasion. If necessary, replace the impeller / magnet assembly (PN 30009).
   C. Remove the second thrust washer from the bottom of the shaft. A pair of tweezers works well for this.
   D. Inspect the shaft for wear.
   E. Rinse the shaft and depression in the housing with clean, fresh water. Allow to dry.
   F. Using new thrust washers (2 of PN 30010) and o-ring (PN 30095), replace the thrust washer and impeller / magnet on the shaft. Replace the other thrust washer and o-ring on the shaft, above the impeller, pushing hard with your fingertip to seat the thrust washer and o-ring in place.



SBE 5M or 5P with Pump Head and Impeller Removed

4. Inspect the end cap o-rings and the mating surface on the pump head for dirt, nicks, and cuts. Clean or replace as necessary. Apply a light coat of o-ring lubricant (Parker Super O Lube) to the o-rings and mating surfaces.

5. Reinstall the end cap in the housing, carefully aligning the end cap with the housing and pushing hard on the end cap to seat the first o-ring in the housing (only 1 o-ring should now be visible).
   CAUTION: If you are not careful, you may *pinch* the o-ring, which may allow water to enter the housing, damaging the electronics.

6. Reinstall the pump head on the end cap.

7. Inspect the bulkhead connector for corrosion, which is a sign of seawater leakage between the bulkhead connector and cable. If there is corrosion, thoroughly clean the connector with water, followed by alcohol. Inspect the bulkhead connector for chips, cracks, or other flaws that may compromise the seal. Inspect the mating cable's connector for cuts, nicks, breaks, or other problems that may compromise the seal. Give the connector surfaces a light coating of **silicon** grease, and remate the connector properly; see *Application Note 57: I/O Connector Care and Installatio*n.
   - If the bulkhead connector is severely corroded or damaged, it must be replaced. Sea-Bird recommends that this work be performed at the factory, because the pump's physical configuration makes customer-replacement of the connector difficult.

Non-Functioning or Poorly Functioning SBE 5M or SBE 5P

Perform the inspection procedures listed above in *Yearly Maintenance for SBE 5M or SBE 5P*. If you do not discover the problem there, proceed as follows.

1. Unscrew the pump head from the housing.

2. Pull out the end cap from the housing.

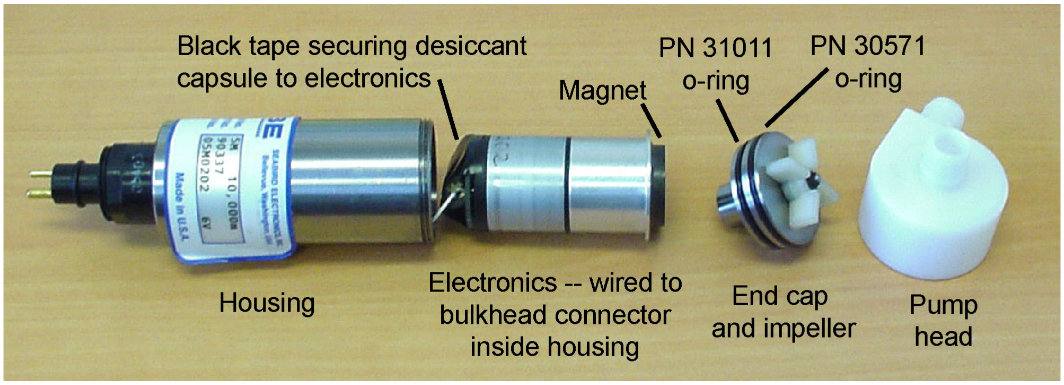
3. Pull out the electronics from the housing. Note that the electronics are wired to the bulkhead connector inside the housing.

4. Verify that the magnet can spin freely and is not broken or damaged.

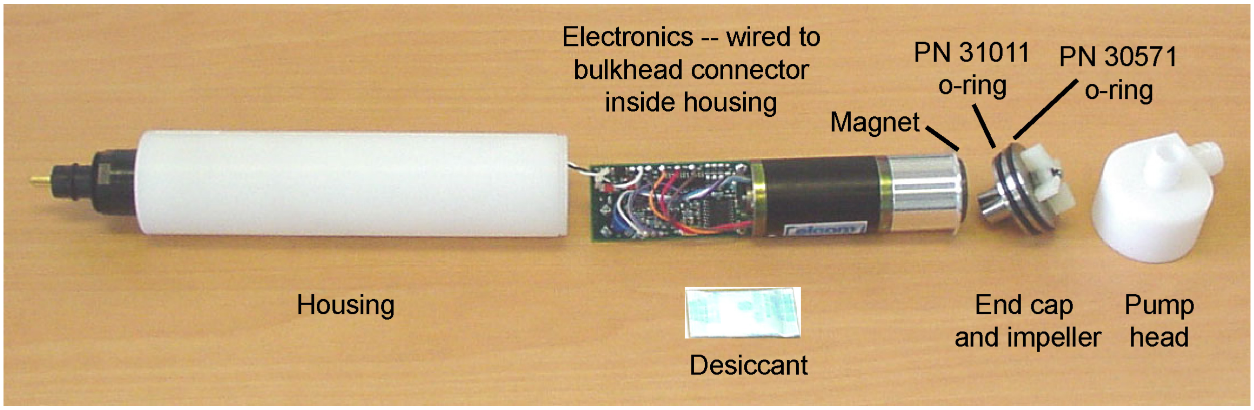
5. Look for other signs of damage on the electronics.

6. Reinstall the end cap in the housing:
   A. Apply a light coat of o-ring lubricant (Parker Super O Lube) to the o-ring and mating surfaces.
   B. **SBE 5M** – Gently place a **new desiccant capsule** (PN 31044 – 0.4 gram) on the electronics, and replace the black tape to secure it in place.
   SBE 5P - Gently place a **new desiccant bag** (PN 30558 – 1 gram) on the electronics.
   (see *Application Note 71* for desiccant use and regeneration).
   C. Reinstall the electronics in the housing.
   D. Reinstall the end cap in the housing, carefully aligning the end cap with the housing and pushing hard on the end cap to seat the first o-ring in the housing (only 1 o-ring should now be visible).
   CAUTION: If you are not careful, you may *pinch* the o-ring, which may allow water to enter the housing, damaging the electronics.

7. Reinstall the pump head on the end cap.

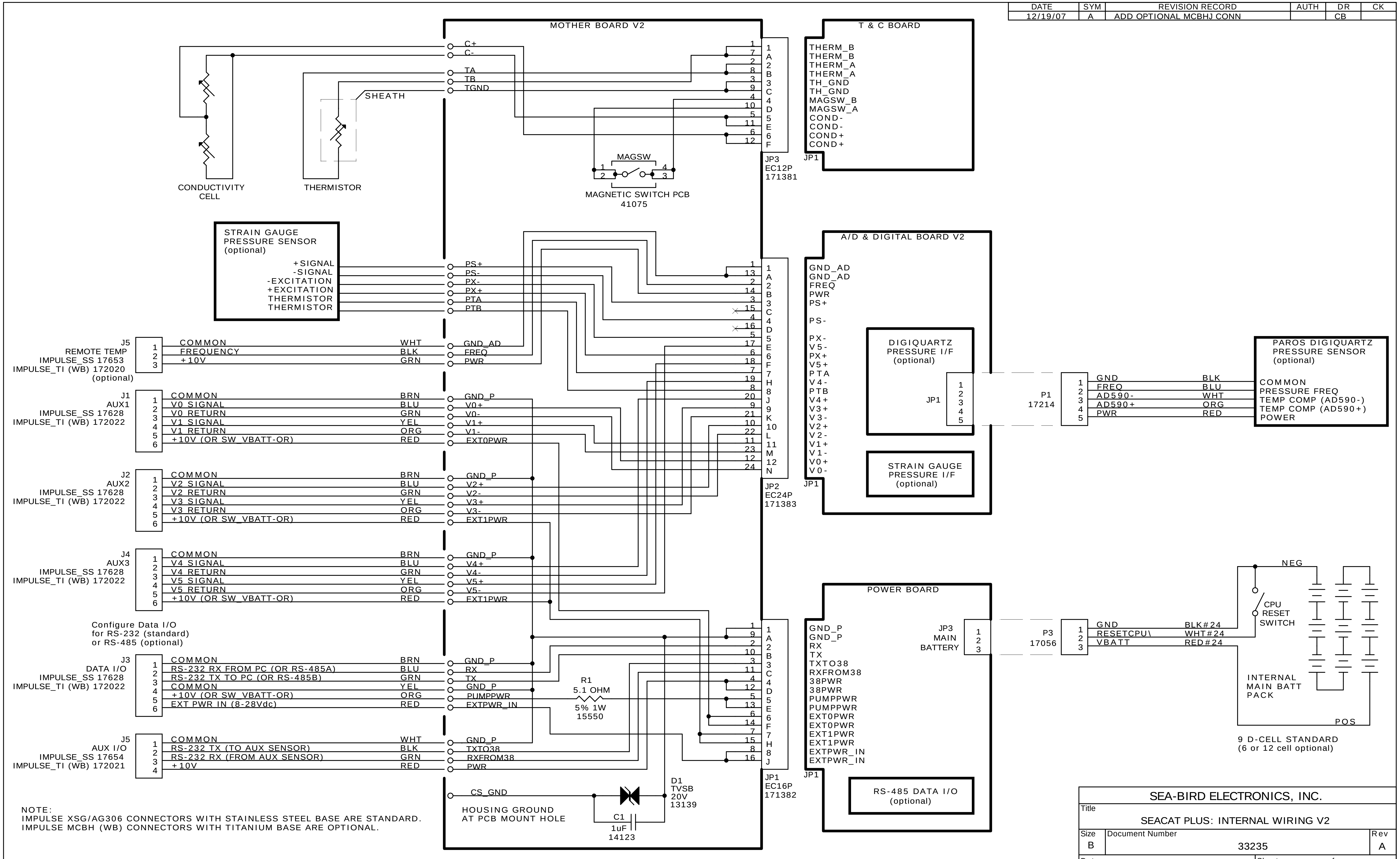


SBE 5M with Electronics Removed (titanium version shown; plastic version similar

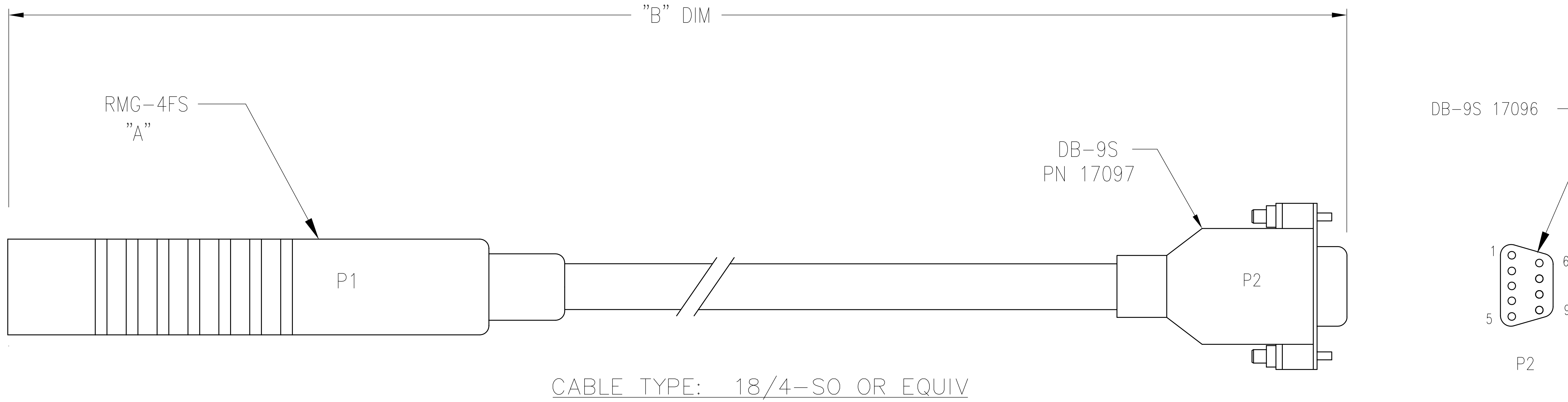


SBE 5P with Electronics Removed

DRAWINGS


DATE | SYM | REVISION RECORD | AUTH | DR | CK
12/19/07 | A | ADD OPTIONAL MCBHJ CONN | | CB |
MOTHER BOARD V2
C+
C-
TA
TB
TGND
SHEATH
CONDUCTIVITY CELL
THERMISTOR
MAGSW
MAGNETIC SWITCH PCB 41075
JP3 EC12P 171381
T & C BOARD
THERM_B
THERM_B
THERM_A
THERM_A
TH_GND
TH_GND
MAGSW_B
MAGSW_A
COND-
COND-
COND+
COND+
JP1
STRAIN GAUGE PRESSURE SENSOR (optional)
+SIGNAL
-SIGNAL
-EXCITATION
+EXCITATION
THERMISTOR
THERMISTOR
PS+
PS-
PX-
PX+
PTA
PTB
J5 REMOTE TEMP IMPULSE_SS 17653 IMPULSE_TI (WB) 172020 (optional)
COMMON WHT GND_AD
FREQUENCY BLK FREQ
+10V GRN PWR
J1 AUX1 IMPULSE_SS 17628 IMPULSE_TI (WB) 172022
COMMON BRN GND_P
V0 SIGNAL BLU V0+
V0 RETURN GRN V0-
V1 SIGNAL YEL V1+
V1 RETURN ORG V1-
+10V (OR SW_VBATT-OR) RED EXT0PWR
J2 AUX2 IMPULSE_SS 17628 IMPULSE_TI (WB) 172022
COMMON BRN GND_P
V2 SIGNAL BLU V2+
V2 RETURN GRN V2-
V3 SIGNAL YEL V3+
V3 RETURN ORG V3-
+10V (OR SW_VBATT-OR) RED EXT1PWR
J4 AUX3 IMPULSE_SS 17628 IMPULSE_TI (WB) 172022
COMMON BRN GND_P
V4 SIGNAL BLU V4+
V4 RETURN GRN V4-
V5 SIGNAL YEL V5+
V5 RETURN ORG V5-
+10V (OR SW_VBATT-OR) RED EXT1PWR
JP2 EC24P 171383
A/D & DIGITAL BOARD V2
GND_AD
GND_AD
FREQ
PWR
PS+
PS-
PX-
V5-
PX+
V5+
PTA
V4-
PTB
V4+
V3+
V3-
V2+
V2-
V1+
V1-
V0+
V0-
JP1
DIGIQUARTZ PRESSURE I/F (optional)
STRAIN GAUGE PRESSURE I/F (optional)
P1 17214
GND BLK
FREQ BLU
AD590- WHT
AD590+ ORG
PWR RED
PAROS DIGIQUARTZ PRESSURE SENSOR (optional)
COMMON
PRESSURE FREQ
TEMP COMP (AD590-)
TEMP COMP (AD590+)
POWER
Configure Data I/O for RS-232 (standard) or RS-485 (optional)
J3 DATA I/O IMPULSE_SS 17628 IMPULSE_TI (WB) 172022
COMMON BRN GND_P
RS-232 RX FROM PC (OR RS-485A) BLU RX
RS-232 TX TO PC (OR RS-485B) GRN TX
COMMON YEL GND_P
+10V (OR SW_VBATT-OR) ORG PUMPPWR
EXT PWR IN (8-28Vdc) RED EXTPWR_IN
R1 5.1 OHM 5% 1W 15550
J5 AUX I/O IMPULSE_SS 17654 IMPULSE_TI (WB) 172021
COMMON WHT GND_P
RS-232 TX (TO AUX SENSOR) BLK TXTO38
RS-232 RX (FROM AUX SENSOR) GRN RXFROM38
+10V RED PWR
CS_GND
HOUSING GROUND AT PCB MOUNT HOLE
D1 TVSB 20V 13139
C1 1uF 14123
JP1 EC16P 171382
POWER BOARD
GND_P
GND_P
RX
TX
TXTO38
RXFROM38
38PWR
38PWR
PUMPPWR
PUMPPWR
EXT0PWR
EXT0PWR
EXT1PWR
EXT1PWR
EXTPWR_IN
EXTPWR_IN
JP1
JP3 MAIN BATTERY
RS-485 DATA I/O (optional)
P3 17056
GND BLK#24
RESETCPU\ WHT#24
VBATT RED#24
NEG
CPU RESET SWITCH
INTERNAL MAIN BATT PACK
POS
9 D-CELL STANDARD (6 or 12 cell optional)
NOTE:
IMPULSE XSG/AG306 CONNECTORS WITH STAINLESS STEEL BASE ARE STANDARD.
IMPULSE MCBH (WB) CONNECTORS WITH TITANIUM BASE ARE OPTIONAL.
SEA-BIRD ELECTRONICS, INC.
Title
SEACAT PLUS: INTERNAL WIRING V2
Size B
Document Number 33235
Rev A
Date: Wednesday, December 19, 2007
Sheet 1 of 1

DATE	SYM	REVISION RECORD	AUTH.	DR.	CK.
1.4.07	A	ECN 1047: UPDATE SPEC TO 18/4 CABLE	RB	CB	



SBE PART NO	CABLE 'A' PN	DIM 'B'
801225	17741	8 FT

P1 RMG-4FS	COLOR	P2 DB-9S
PIN 1	WHITE	PIN 5
PIN 2	BLACK	PIN 3
PIN 3	GREEN	PIN 2
PIN 4	RED	

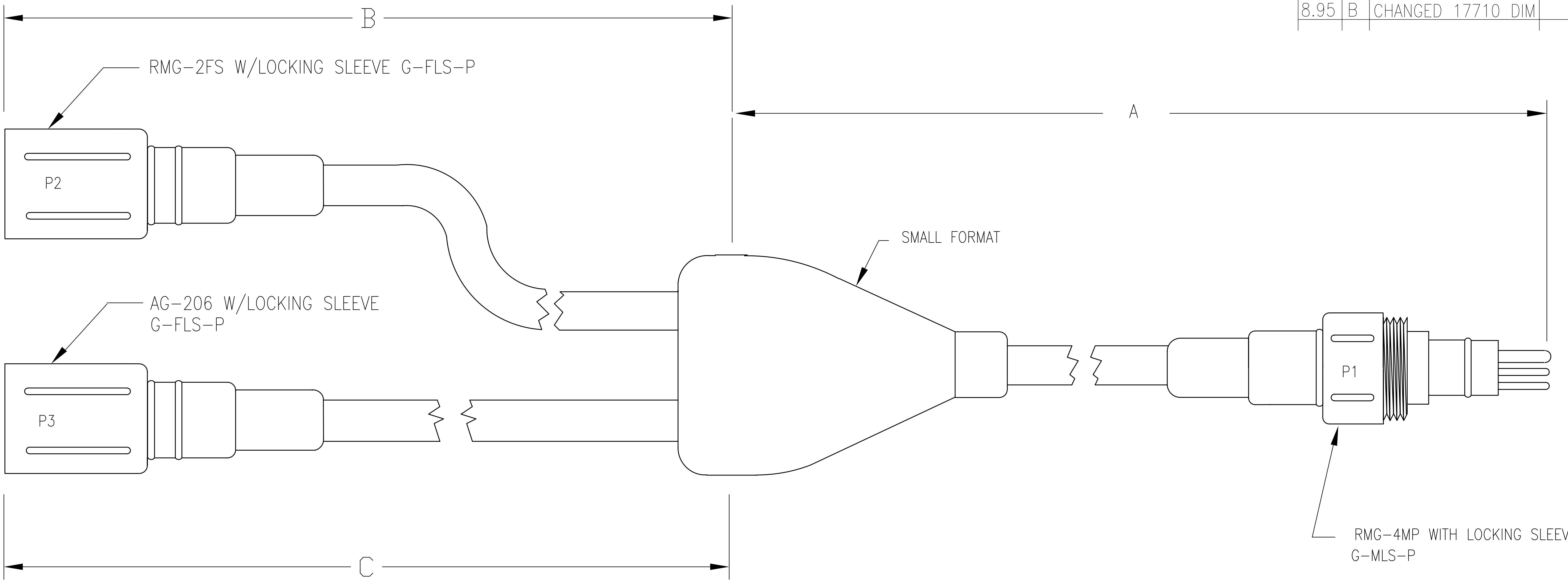
SEA-BIRD ELECTRONICS, INC

P/N	SCALE	DRAWN BY	APPROVED BY
SEE TABLE	NTS	PMc	

RMG-4FS TO DB-9S CABLE ASSEMBLY

DATE	DWG NO.	SHEET	REV
6/26/00	32421	1 of 1	A

DATE	REV	REVISION RECORD	AUTH.	DR.	CK.
4/94	A	ADDED PART NOS			
8.95	B	CHANGED 17710 DIM			



P3 AG-206	P2 RMG-2FS	P1 RMG-4MP
PIN 1		PIN 1
PIN 2		PIN 2
PIN 3		PIN 3
PIN 4	PIN 1	
PIN 5	PIN 2	
PIN 6		PIN 4

PART NUMBER	A	B	C
17709	18 IN	18 IN	18 IN
17710	13 IN	15 IN	17 IN
17755	12 IN	31 IN	21 IN
17797	18 IN	36 IN	18 IN
171352	18 IN	48 IN	18 IN
171360	28 IN	36 IN	18 IN
171980	197 IN	79 IN	79 IN
172239	18 IN	197 IN	18 IN
172549	36 IN	60 IN	60 IN

TOLERANCES	SEA-BIRD ELECTRONICS, INC		
FRACTIONAL	P/N SEE TABLE	SCALE NTS	DRAWN BY BMC / APPROVED BY
DECIMAL	TITLE Y-CABLE, SBE 19/25 PUMP I/O		
ANGULAR	DATE 8/1/93	DRAWING NUMBER 31551	REV B

WARRANTY POLICY 2006

5-YEAR LIMITED WARRANTY (NEW PRODUCTS)

For a period of five years after the date of original shipment from our factory, products manufactured by Sea-Bird are warranted to function properly and be free of defects in materials and workmanship. Should a Sea-Bird instrument fail during the warranty period, return it freight pre-paid to our factory. We will repair it (or at our option, replace it) at no charge, and pay the cost of shipping it back to you. Certain products and components have modified coverage under this warranty as described below.

LIMITED WARRANTY ON SERVICE & REPAIRS

Service work, repairs, replacement parts and modifications are warranted to be free of defects in materials or workmanship for the remainder of the original 5-year warranty or one year from the date of shipment from our factory after repair or service, which ever is longer. Certain products and components have modified coverage under this warranty as described below.

MODIFICATIONS / EXCEPTIONS / EXCLUSIONS

1. The SBE 43 DO sensor is warranted to function properly for 5 years. Under normal use however, the electrolyte in an SBE 43 DO sensor will require replenishment after about 3 years. Purchase of an SBE 43 includes one free electrolyte replenishment (as necessitated by chemical depletion of electrolyte) anytime during the warranty period. To obtain the replenishment, return the sensor freight pre-paid to our factory. We will refurbish it for free (electrolyte refill, membrane replacement, and recalibration) and pay the cost of shipping it back to you. Membrane damage or depletion of electrolyte caused by membrane damage is not covered by this warranty.

2. Because pH and other dissolved oxygen (DO) electrodes have a limited life caused by the depletion of their chemical constituents during normal storage and use, our warranty applies differently to such electrodes. Electrodes in SBE 13Y and 23Y DO sensors, SBE 18 pH sensors, and SBE 27 pH/ORP sensors are covered under warranty for the first 90 days only. Other components of the sensor are covered for 5 years.

3. Equipment manufactured by other companies (e.g., fluorometers, transmissometers, PAR, optical backscatter sensors, altimeters, etc.) are warranted only to the limit of the warranties provided by their original manufacturers (typically 1 year).

4. Batteries, zinc anodes or other consumable/expendable items are not covered under this warranty.

5. Electrical cables and dummy plugs are warranted to function properly and be free of defects in materials and workmanship for 1 year.

6. This warranty is void if in our opinion the instrument has been damaged by accident, mishandled, altered, improperly serviced, or repaired by the customer where such treatment has affected its performance or reliability. In the event of such misuse/abuse by the customer, costs for repairs plus two-way freight costs will be borne by the customer. Instruments found defective should be returned to the factory carefully packed, as the customer will be responsible for freight damage.

7. Incidental or consequential damages or costs incurred as a result of product malfunction are not the responsibility of SEA-BIRD ELECTRONICS, INC

Warranty Administration Policy

Sea-Bird Electronics, Inc. and its authorized representatives or resellers provide warranty support only to the original purchaser. Warranty claims, requests for information or other support, and orders for post-warranty repair and service, by end-users that did not purchase directly from Sea-Bird or an authorized representative or reseller, must be made through the original purchaser. The intent and explanation of our warranty policy follows:

1. Warranty repairs are only performed by Sea-Bird.

2. Repairs or attempts to repair Sea-Bird products performed by customers (owners) shall be called *owner repairs*.

3. Our products are designed to be maintained by competent owners. Owner repairs of Sea-Bird products will NOT void the warranty coverage (as stated above) simply as a consequence of their being performed.

4. Owners may make repairs of any part or assembly, or replace defective parts or assemblies with Sea-Bird manufactured spares or authorized substitutes without voiding warranty coverage of the entire product, or parts thereof. Defective parts or assemblies removed by the owner may be returned to Sea-Bird for repair or replacement within the terms of the warranty, without the necessity to return the entire instrument. If the owner makes a successful repair, the repaired part will continue to be covered under the original warranty, as if it had never failed. Sea-Bird is not responsible for any costs incurred as a result of owner repairs or equipment downtime.

5. We reserve the right to refuse warranty coverage *on a claim by claim basis* based on our judgment and discretion. We will not honor a warranty claim if in our opinion the instrument, assembly, or part has been damaged by accident, mishandled, altered, or repaired by the customer *where such treatment has affected its performance or reliability*.

6. For example, if the CTD pressure housing is opened, a PC board is replaced, the housing is resealed, and then it floods on deployment, we do not automatically assume that the owner is to blame. We will consider a claim for warranty repair of a flooded unit, subject to our inspection and analysis. If there is no evidence of a fault in materials (e.g., improper or damaged o-ring, or seal surfaces) or workmanship (e.g., pinched o-ring due to improper seating of end cap), we would cover the flood damage under warranty.

7. In a different example, a defective PC board is replaced with a spare and the defective PC board is sent to Sea-Bird. We will repair or replace the defective PC board under warranty. The repaired part as well as the instrument it came from will continue to be covered under the original warranty.

8. As another example, suppose an owner attempts a repair of a PC board, but solders a component in backwards, causing the board to fail and damage other PC boards in the system. In this case, the evidence of the backwards component will be cause for our refusal to repair the damage under warranty. However, this incident will NOT void future coverage under warranty.

9. If an owner's technician attempts a repair, we assume his/her qualifications have been deemed acceptable to the owner. The equipment owner is free to use his/her judgment about who is assigned to repair equipment, and is also responsible for the outcome. The decision about what repairs are attempted and by whom is entirely up to the owner.

Service Request Form

To return your instrument for calibration or other service, please take a few moments to provide us with the information we need, so we can serve you better.

PLEASE:

1. **Get a Returned Material Authorization (RMA) number from Sea-Bird (*phone 425-643-9866, fax 425-643-9954, or email seabird@seabird.com*). Reference the RMA number on this form, on the outside shipping label for the equipment, and in all correspondence related to this service request.**
2. **Fill out 1 form for each type (model) of instrument.**
3. **Include this form when shipping the instrument to Sea-Bird for servicing.**
4. **Fax us a copy of this form on the day you ship.** ***FAX: (425) 643-9954***

RETURNED MATERIAL AUTHORIZATION (RMA) NUMBER: ______________________________

DATE EQUIPMENT REQUIRED BY: ______________________________

DO YOU REQUIRE A WRITTEN QUOTE? ______________________________

CONTACT INFORMATION

Your name: ______________________________

Institution/Organization/Company: ______________________________

Shipping/Delivery address for packages: ______________________________

____

____

Telephone: ____________________ Fax: ____________________

e-mail: ______________________________

SERVICE INFORMATION

Date Shipped: ______________________________

Sea-Bird Model Number (for example, SBE 37-SM): ______________________________

Quantity: ______________________________

Serial Numbers: ______________________________

____

____

(**Note**: **Specify instrument serial numbers below** if specific services are required for some instruments. For example, if 10 instruments are being returned for calibration, and 1 of the 10 also requires repairs, specify the serial number for the instrument requiring repairs in the appropriate section of the form.)

SEASOFT Version you have been using with this instrument(s): ____________________

[ ] **Calibration Services:**

____Calibration (includes basic diagnostic):

___Temperature ___Conductivity ___Pressure ___DO ___pH

(Please allow a minimum of 3 weeks after we receive the instrument(s) to complete calibration.)

____Other (specify): ______________________________

____

[ ] **Internal Inspection and O-Ring Replacement (includes hydrostatic pressure test):**

Additional charges may apply.

____

____

[ ] **System Upgrade or Conversion:**

Specify (include instrument serial number if multiple instruments are part of shipment): __________

____

____

[ ] **Diagnose and Repair Operational Faults:**

Please send a disk containing the raw data (.hex or .dat files) that shows the problems you describe. Also send the .con files you used to acquire or display the data.

Problem Description (continue on additional pages if needed; include instrument serial number if multiple instruments are part of shipment): ______________________________

____

____

____

PAYMENT/BILLING INFORMATION

Credit Card: Sea-Bird accepts payment by VISA, MasterCard, or American Express.
[ ] MasterCard [ ] Visa [ ] American Express
Account Number: ______________________________ Expiration Date: __________
Credit Card Holder Name (printed or typed): ______________________________
Credit Card Holder Signature: ______________________________
Credit Card Billing Address (if different than shipping address):
____
____
____

Invoice/Purchase Order: If you prefer us to invoice you, please complete the following or enclose a copy of your Purchase Order:
Purchase Order Number: ______________________________
Billing Address (if different than shipping address):
____
____
____

Instructions for Returning Goods to Sea-Bird

1. **Domestic Shipments (USA) - Ship prepaid** (via UPS, FedEx, DHL, etc.) directly to:
   Sea-Bird Electronics, Inc.
   1808 136th Place NE
   Bellevue, WA 98005, USA
   Telephone: (425) 643-9866 Fax: (425) 643-9954
2. **International Shipments** –
   Option A. Ship via **PREPAID AIRFREIGHT to SEA-TAC International Airport (IATA Code "SEA")**:
   Sea-Bird Electronics, Inc.
   1808 136th Place NE
   Bellevue, WA 98005, USA
   Telephone: (425) 643-9866 Fax: (425) 643-9954 E-mail: seabird@seabird.com

   Notify: MTI Worldwide Logistics for Customs Clearance
   Seattle, WA, USA
   Telephone: (206) 431-4366 Fax: (206) 431-4374 E-mail: bill.keebler@mti-worldwide.com

   E-mail flight details and airway bill number to seabird@seabird.com and bill.keebler@mti-worldwide.com when your shipment is en-route. Include your RMA number in the e-mail.

   Option B. Ship via **EXPRESS COURIER directly to Sea-Bird Electronics**:
   If you choose this option, **we recommend shipping via UPS, FedEx, or DHL**. Their service is door-to-door, including customs clearance. It is not necessary to notify our customs agent, MTI Worldwide, if you ship using a courier service.

   E-mail the airway bill / tracking number to seabird@seabird.com when your shipment is en-route. Include your RMA number in the e-mail.

   For All International Shipments:
   Include a **commercial invoice** showing the description of the instruments, and **Value for Customs purposes only**. Include the following statement:
   "U.S. Goods Returned for Repair/Calibration. Country of Origin: USA. Customs Code: 9801001012."
   Failure to include this statement in your invoice will result in US Customs assessing duties on the shipment, which we will in turn pass on to the customer/shipper.

Note: Due to changes in regulations, if Sea-Bird receives an instrument from outside the U.S. in a crate containing non-approved (i.e., non-heat-treated) wood, we will return the instrument in a new crate that meets the requirements of ISPM 15 (see http://www.seabird.com/customer_support/retgoods.htm for details). We will charge for the replacement crate based on the dimensions of the crate we receive, determined as follows:
1. Multiply the crate length x width x height in centimeters (overall volume in cm^3, not internal volume).
2. Determine the price based on your calculated overall volume and the following chart:

Overall Volume (cm^3)	< 52,000	52,000 to < 65,000	65,000 to < 240,000	> 240,000
Example Instrument	37-SM MicroCAT	SEACAT, no cage	CTD in cage	--
Price (USD)	$45	$70	$125	consult factory

These prices are valid only for crate replacement required in conjunction with return of a customer's instrument after servicing, and only when the instrument was shipped in a crate originally supplied by Sea-Bird.