SBE 26plus SEAGAUGE

Wave and Tide Recorder

Serial Number: 26P46716-1134

User Manual, Version 009

Sea-Bird Electronics, Inc.
1808 136th Place NE
Bellevue, Washington 98005 USA
Tel: 425/643-9866
Fax:425/643-9954

This page Intentionally Left Blank.

SBE 26plus SEAGAUGE WAVE AND TIDE RECORDER OPERATING MANUAL

TABLE OF CONTENTS

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

Manual Generation Date: 15 June 2007

LIMITED LIABILITY STATEMENT

Extreme care should be exercised when using or servicing this equipment. It should be used or serviced only by personnel with knowledge of and training in the use and maintenance of oceanographic electronic equipment.

SEA-BIRD ELECTRONICS, INC. disclaims all product liability risks arising from the use or servicing of this system. SEA-BIRD ELECTRONICS, INC. has no way of controlling the use of this equipment or of choosing the personnel to operate it, and therefore cannot take steps to comply with laws pertaining to product liability, including laws which impose a duty to warn the user of any dangers involved in operating this equipment. Therefore, acceptance of this system by the customer shall be conclusively deemed to include a covenant by the customer to defend, indemnify, and hold SEA-BIRD ELECTRONICS, INC. harmless from all product liability claims arising from the use of servicing of this system.

This page intentionally left blank.

WARNING !!

Do not submerge this instrument (S/N 26P46716-1134)
beyond the depth rating of the lowest rated component listed below!

Main Housing (Plastic)	600 meters
Digiquartz (100 psia)	**58 meters**

SYSTEM CONFIGURATION 15 June 2007

Model 26plus	**S/N 26P46716-1134**
Firmware Version	**6.1C**
Baud Rate	**9600**
Pressure Sensor	**Digiquartz w/ Temp-Comp: 100 psia, S/N 104279**
Memory	**32 Mbyte**
Housing	**600 meter (Celcon)**
Conductivity Interface Installed	**Yes**
Conductivity Sensor	**None**

SBE 26*plus* SEAGAUGE

Wave and Tide Recorder

Shown in optional mounting fixture

User's Manual

Sea-Bird Electronics, Inc.
1808 136th Place NE
Bellevue, Washington 98005 USA
Telephone: 425-643-9866
Fax: 425-643-9954
E-mail: seabird@seabird.com
Website: www.seabird.com

Manual Version #009, 12/07/06
Quartz Firmware Version 6.1c and later
Strain Gauge Firmware Version 6.1c and later
SEASOFT for Waves Version 1.13 and later

Limited Liability Statement

Extreme care should be exercised when using or servicing this equipment. It should be used or serviced only by personnel with knowledge of and training in the use and maintenance of oceanographic electronic equipment.

SEA-BIRD ELECTRONICS, INC. disclaims all product liability risks arising from the use or servicing of this system. SEA-BIRD ELECTRONICS, INC. has no way of controlling the use of this equipment or of choosing the personnel to operate it, and therefore cannot take steps to comply with laws pertaining to product liability, including laws which impose a duty to warn the user of any dangers involved in operating this equipment. Therefore, acceptance of this system by the customer shall be conclusively deemed to include a covenant by the customer to defend, indemnify, and hold SEA-BIRD ELECTRONICS, INC. harmless from all product liability claims arising from the use or servicing of this system.

Table of Contents

Section 1: Introduction

This section includes contact information, Quick Start procedure, and photos of a standard SBE 26*plus*.

About this Manual

This manual is for use with the SBE 26*plus* SEAGAUGE Wave and Tide Recorder. It is organized to guide the user from installation through operation, data collection, and processing. 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

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

Telephone:	425-643-9866	Fax:	425-643-9954
E-mail:	seabird@seabird.com	Website:	http://www.seabird.com

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 26*plus*. The manual provides step-by-step details for performing each task.

Deployment:

1. Run Plan Deployment and Battery and Memory Endurance to determine sampling parameters (*Section 4*).
2. Install new batteries.
3. Connect 26*plus* to computer and run SeatermW (*Section 5*):
   A. Ensure all data has been uploaded, and then send **InitLogging** to make entire memory available for recording if desired.
   B. Set date and time (**SetTime**) and wave and tide sampling parameters (**SetSampling**); enable conductivity if SBE 4M conductivity sensor is installed (**Conductivity=Y**); enable external thermistor if optional external thermistor installed (**ExternalTemperature=Y**).
   C. Check status (**DS**) and calibration coefficients (**DC**).
   D. Start logging (**Start**).

Recovery and Data Processing:

1. Connect 26*plus* to computer and run SeatermW. Stop logging (**Stop**), and upload data from 26*plus* memory (*Section 5*).
2. If the uploaded data is from multiple logging sessions, run Extract Tide to create a separate file for each logging session (*Section 6*).
3. Run Convert Hex to convert uploaded data into separate wave and tide files (*Section 6*).
4. Run Merge Barometric Pressure to remove barometric pressure from tide file (*Section 7*).
5. Run Process Wave Burst Data and Create Reports to calculate and summarize wave statistics (*Section 8*).
6. Run Plot Data to display the data (*Section 9*).

Unpacking SBE 26*plus*

Shown below is a typical SBE 26*plus* shipment.

SBE 26*plus*

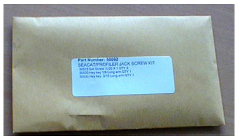
I/O Cable

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

Pressure sensor oil refill kit

Spare battery end cap hardware and o-ring kit

Spare hardware kit



Jackscrew kit

26*plus* manual

Software, and electronic copies of software manuals and user manual

Section 2: Description of SBE 26*plus*

This section describes the functions and features of the SBE 26*plus*, including specifications, dimensions, end cap connectors, power supply and cable length limitations, data I/O protocols, and real-time setup.

System Description

The SBE 26*plus* SEAGAUGE Wave and Tide Recorder combines Sea-Bird's non-volatile FLASH memory with a stable time base, quartz pressure sensor, precision thermometer, and an optional SBE 4M conductivity sensor to provide wave and tide recording and real-time data of unprecedented resolution and accuracy.

- For tide and water level monitoring, the pressure sensor output is integrated to average out wave action. The user-programmable tide interval can be set from 1 minute to 12 hours. The 26*plus* can continuously measure pressure (if equipped with Quartz pressure sensor), or can conserve battery power by measuring pressure for only a portion of the tide interval, with the pressure sensor not drawing power for the remainder of the interval. The tide integration duration is programmable from 10 seconds to the entire tide interval. High-accuracy temperature information is recorded with each tide measurement. As an option, an SBE 4M conductivity sensor can be integrated for recording conductivity data with each tide measurement. Tide data is always recorded in memory; in addition, real-time tide data can be output.
- Waves are characterized by burst sampling, with the number of samples per burst, burst interval, and burst integration time programmed by the user. Wave data is always recorded in memory; in addition, real-time wave data and/or real-time wave statistics can be output.

The 26*plus* is self-contained in a rugged, non-corroding, plastic housing (600-meter depth rating). After recovery (and without opening the housing), the recorded data is transferred to a computer via an RS-232C (or optional RS-422 / RS-485 full duplex) data link for analysis, plotting, and permanent archiving. The battery compartment contains twelve standard alkaline D-cells (Duracell MN1300, LR20) and is sealed separately to minimize risk to the electronics.

The standard pressure sensor is a 20 meter (45 psia) Paroscientific Digiquartz, with a temperature-compensated quartz element. As an option, the Digiquartz is available in other ranges, from 0.2 to 680 meters (15 to 1000 psia). Another option is substitution of a Druck strain gauge pressure sensor with a temperature-compensated strain gauge element, available in ranges from 20 to 600 meters (45 to 880 psia). The lower-priced Druck sensor is generally intended for wave sampling applications, and will not provide the highest quality tide data.

Temperature is measured with an aged, super-stable thermistor embedded in the 26*plus* end cap. An AC excitation is applied to a hermetically sealed VISHAY reference resistor and the thermistor. A 24-bit A/D converter digitizes the reference resistor and thermistor outputs.

For the 26*plus* with Quartz pressure sensor, tide measurements are obtained by counting the pressure frequency with a 32-bit ripple counter. Each time the 26*plus* wakes up, the ripple counters are latched into registers and then reset. The wake-up times are set by a continuously powered, real-time clock with an accuracy of ± 5 seconds/month. Wave burst measurements are made with a period counter, with its time base generated from a temperature-compensated, precision quartz crystal oscillator.

For the 26*plus* with Strain Gauge pressure sensor, a 24-bit A/D converter digitizes the output of the pressure sensor for the wave and tide measurements.

The standard 26*plus* includes:

- Plastic housing for depths to 600 meters (1960 ft)
- 20 meter (45 psia) Digiquartz temperature-compensated pressure sensor
- Accurate temperature sensor – aged thermistor embedded in end cap
- Frequency input channel and bulkhead connector for optional SBE 4M conductivity sensor
- 32 MB FLASH memory
- RS-232 interface
- 12 alkaline D-cell batteries (Duracell MN1300, LR20); battery compartment is separated from electronics by a moisture-proof seal
- Impulse glass-reinforced epoxy bulkhead connectors

26*plus* options include:

- Digiquartz temperature-compensated pressure sensor in ranges from 0.2 to 680 meters (15 to 1000 psia)
- Druck strain gauge pressure sensor, with a temperature-compensated strain gauge element, in ranges from 20 to 600 meters (45 to 880 psia)
- SBE 4M conductivity sensor, interfaced via bulkhead connector and clamped to SBE 53 housing. SBE 4M comes equipped with expendable AF24173 Anti-Foulant Devices.
- High accuracy external temperature sensor (0.002 °C accuracy, 0.0001 °C resolution) in place of standard internal thermistor (0.01 °C accuracy, 0.001 °C resolution)
- Wet-pluggable (MCBH) bulkhead connectors in place of standard connectors
- Mounting fixture
- RS-422 / RS-485 (full duplex) interface in place of RS-232 interface
- Lithium batteries (six DD drop-in batteries with buttons) for longer deployments (lithium batteries **not** supplied by Sea-Bird). Note that one lithium DD battery is shorter than two alkaline D batteries, so a different battery cover plate is required if using the lithiums (cover plate available from Sea-Bird).

The 26*plus* is supplied with a modular Windows 95/98/NT/2000/XP software package, SEASOFT for Waves. The software provides pre-deployment planning, communication with the 26*plus* for setup and uploading of data, separation of the uploaded data into separate wave and tide files, removal of barometric pressure from tide data, statistical analysis, and data plotting.

Notes:

- Help files provide detailed information on SEASOFT for Waves.
- **SEASOFT for Waves data processing modules cannot process real-time data from the 26*plus*.**
- Sea-Bird supplies the current version of our software when you purchase an instrument. As software revisions occur, we post the revised software on our FTP site. See our website (www.seabird.com) for the latest software version number, a description of the software changes, and instructions for downloading the software from the FTP site.
- **Sea-Bird also has a DOS program, SEASOFT for Waves – DOS. However, the DOS program is not compatible with the 26*plus*.**

Specifications

Note:
The pressure sensor is mounted on the titanium connector end cap, with the pressure conveyed from the pressure port to the sensor via an oil-filled tube. The pressure reading is position sensitive as a result of the oil pressure head.

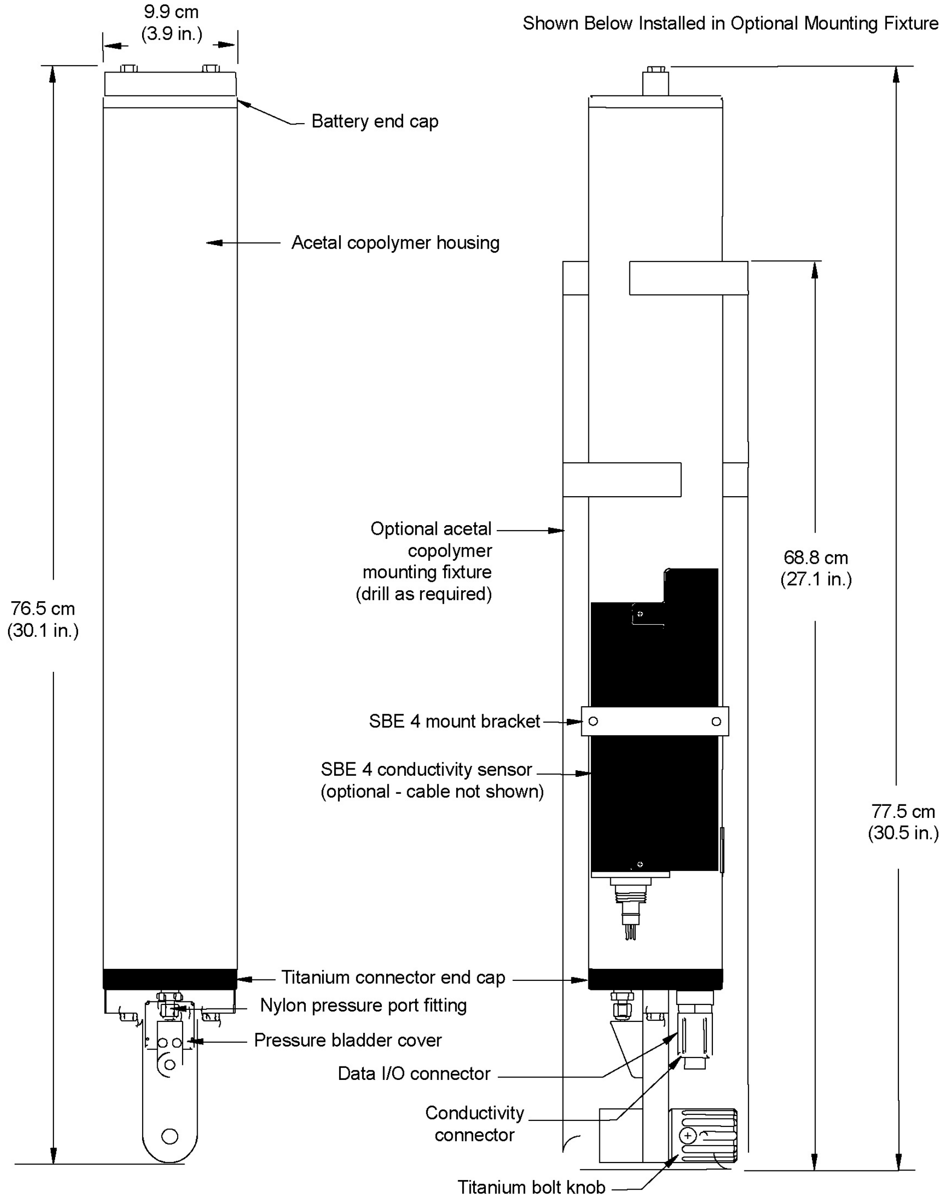
Quartz Pressure (standard)	
Range	0 to 0.2 /5 /10 /20 /60 /130 /200 /270 /680 meters (15 /23 /30 /45 /100 /200 /300 /400 /1000 psia)
Accuracy	0.01% of full scale (3 mm for 45 psia [20 m] range *)
Repeatability	0.005% of full scale (1.5 mm for 45 psia [20 m] range *)
Hysteresis	0.005% of full scale (1.5 mm for 45 psia [20 m] range *)
Calibration	0 psia to full scale pressure
Resolution *	*Tide:* 0.2 mm for 1-minute integration; 0.01 mm for 15-minute integration *Wave:* 0.4 mm for 0.25-second integration; 0.1 mm for 1-second integration
Strain Gauge Pressure (optional, in place of Quartz pressure)	
Range	0 to 20 / 100 / 350 / 600 meters (45 / 160 / 520 / 900 psia)
Accuracy	0.1% of full scale (30 mm for 45 psia [20 m] range *)
Repeatability	0.03% of full scale (9 mm for 45 psia range *)
Hysteresis	0.03% of full scale (9 mm for 45 psia range *)
Calibration	0 psia to full scale pressure
Resolution *	*Tide:* 0.2 mm for 1-minute integration; 0.01 mm for 15-minute integration *Wave:* 0.4 mm for 0.25-second integration; 0.1 mm for 1-second integration
Standard Temperature (internal thermistor)	
Range	-5 to +35 °C
Accuracy	0.01 °C
Resolution	0.001 °C
Calibration	+1 to +32 °C (measurements outside this range may be at slightly reduced accuracy due to extrapolation errors)
Optional High Accuracy Temperature (external thermistor)	
Range	-5 to +35 °C
Accuracy	0.002 °C
Resolution	0.0001 °C
Calibration	+1 to +32 °C (measurements outside this range may be at slightly reduced accuracy due to extrapolation errors)
Conductivity (optional SBE 4M conductivity sensor)	
Range	0.0 to 7 S/m
Accuracy	±0.0003 S/m/month (typical); ±0.001 S/m/month (guaranteed; not applicable in areas of high bio-fouling or contamination or if Application Note 2D procedures are not followed)
Resolution	0.00002 S/m
Calibration	2.6 to 6 S/m plus zero conductivity (air)

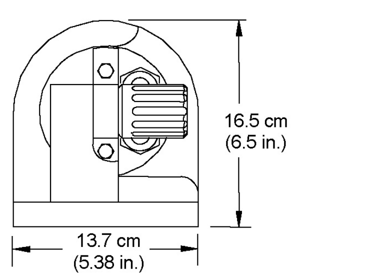
*Stated values in mm for accuracy, repeatability, hysteresis, and resolution are for 45 psia (20 m) pressure sensor. Scale for other ranges, multiplying by (actual sensor range in psia / 45 psia).

Other Specifications	
Clocks	***Counter Time Base*** (for conductivity, Quartz pressure temperature, & Quartz wave burst data): Quartz TCXO ± 1 ppm per year aging; ± 15 ppm (-20 to +70 °C) ***Real-Time Clock*** (for Quartz tide pressure data): Quartz TCXO watch-crystal type 32,768 Hz; accuracy ± 2 ppm (5 seconds/month). Battery-backed for minimum of 2-year operation, without the main batteries installed.
Memory	32 MB Flash RAM
Data Storage	If conductivity not enabled: Bytes/day = 9N + W (36 + 3M) If conductivity enabled: Bytes/day = 12N + W (48 + 3M) (N = tide samples/day, W = wave bursts/day, M = wave measurements/burst)
Power Requirement – 26*plus* with Quartz Pressure Sensor	***Quiescent (sleep)***: 0.0005 Watt ***Communications***: 0.10 Watt ***Data Upload***: 0.16 Watt ***Wave Burst***: *Wave burst*: 0.11 Watt *Real-time wave statistics*: 0.2 Watt * 0.06 sec/sample * # of samples/burst ***Tide Sample***: *Pressure sensor integration*: 0.01 Watt *Turn-on for each sample (if going to sleep between samples)*: 0.30 Watt-seconds = 0.30 Joules *Tide sample (including temperature, but not conductivity)*: 0.30 Watt-seconds = 0.30 Joules *Conductivity sample*: 0.40 Watt-seconds = 0.40 Joules
Power Requirement – 26*plus* with Strain Gauge Pressure Sensor	***Quiescent (sleep)***: 0.0005 Watt ***Communications***: 0.13 Watt ***Data Upload***: 0.19 Watt ***Wave Burst***: *Wave burst*: 0.14 Watt *Real-time wave statistics*: 0.2 Watt * 0.06 sec/sample * # of samples/burst ***Tide Sample***: *Turn-on/off for each tide sample*: 0.36 Watt-seconds = 0.36 Joules *Tide sample (including temperature, but not conductivity)*: 0.14 Watt *Conductivity sample*: 0.71 Watt-seconds = 0.71 Joules
Power Supply	***Standard*** 12 alkaline D-cell batteries (Duracell MN1300, LR20): Typical capacity 756,000 Joules. Sea-Bird recommends derating 15% for safety, and 5% per year for battery self-discharge. Consider derating further for cold water applications. ***Optional:*** 6 lithium DD-cell batteries (Electrochem BCX85-3B76-TC) with buttons (lithiums **not** supplied by Sea-Bird). Note that 1 lithium DD is shorter than 2 alkaline Ds, so different battery cover plate required (cover plate available from Sea-Bird). Typical capacity 2,332,800 Joules. Sea-Bird recommends derating 15% for safety, and 3% per year for battery self-discharge. ***Optional*** external power source: 12 - 20 VDC.
Housing Materials	600-meter acetal copolymer (plastic) housing, titanium end cap
Weight	***Plastic housing with alkaline batteries:*** 6.8 kg (15 lbs) in air, 2.3 kg (5 lbs) in water ***Optional mounting fixture***: 3.6 kg (8 lbs) in air, 1.4 kg (3 lbs) in water

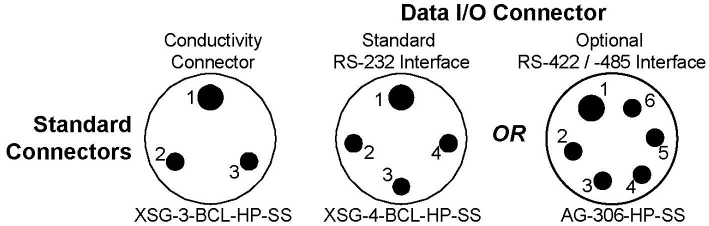
Note:
See *Section 4: Pre-Deployment Planning – Plan Deployment and Battery and Memory Endurance*.

Dimensions and End Cap Connectors

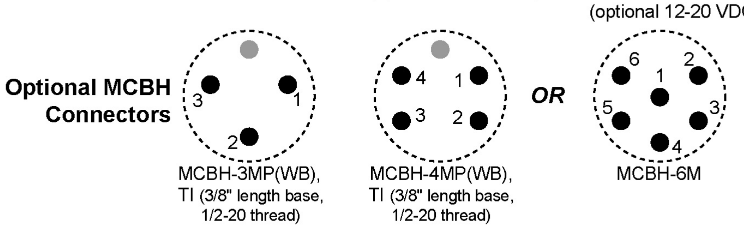




Data I/O Connector



XSG-3-BCL-HP-SS	XSG-4-BCL-HP-SS	AG-306-HP-SS
1 Common	1 Common	1 Common
2 Signal	2 RS-232 Receive	2 RS-422 / 485 Transmit +
3 Power	3 RS-232 Transmit	3 RS-422 / 485 Transmit -
	4 External Power (optional 12-20 VDC)	4 RS-422 / 485 Transmit +
		5 RS-422 / 485 Transmit -
		6 External Power (optional 12-20 VDC)



Power Supply

> **Notes:**
> - For battery endurance calculations, see *Section 4: Pre-Deployment Planning – Plan Deployment and Battery and Memory Endurance*.
> - The cut-off voltage is 10.4 volts. If the voltage falls below that, the 26*plus* provides a warning message in response to the status (**DS**) command, and will not take measurements.

The main batteries for a standard SBE 26*plus* are 12 D-cell alkaline batteries (Duracell MN 1300, LR20). The 26*plus* can also be powered by 6 DD-cell batteries with buttons (batteries **not** supplied by Sea-Bird).

The 26*plus* can be powered from an external 12-20 VDC source. The internal batteries are diode-OR'd with the external source, so power is drawn from whichever voltage source is higher.

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, exhaustion, or removal. The main batteries can be replaced without affecting either the real-time clock or the memory. If the main power supply falls below 9 VDC, the 26*plus* will draw power from the back-up lithium batteries.

External Power and Cable Length

> **Note:**
> See *Real-Time Setup* below for baud rate limitations on cable length if transmitting real-time data.

There are two issues to consider if powering the SBE 26*plus* 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 current ***during communication*** times the power common wire resistance is more than 1 volt, because the difference in ground potential of the 26*plus* and ground controller prevents the 26*plus* from transmitting real-time data.

$V_{limit} = 1 \text{ volt} = IR_{limit}$

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

where I = maximum current required by 26*plus* during communication.

From *Specifications*, upload power required is 0.16 Watt for 26*plus* with Quartz pressure or 0.19 Watt for 26*plus* with Strain Gauge pressure. Conservatively use 0.20 Watts for both, and use 12 V (minimum input voltage) to calculate:

I * V = Watts

I = 0.20 Watts / 12V = 0.017 Amps

> *Example 1* – For 20 gauge wire, what is maximum distance to transmit power to 26*plus* if transmitting real-time data?
> For upload current, $R_{limit} = V_{limit} / I$ = 1 volt / 0.017 Amps = 58.8 ohms
> For 20 gauge wire, resistance is 0.0107 ohms/foot.
> Maximum cable length = 58.8 ohms / 0.0107 ohms/foot = 5495 feet = 1675 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 / (0.017 Amps * 4 instruments) = 14.7 ohms
> Maximum cable length = 14.7 ohms / 0.0107 ohms/foot = 1373 feet = 418 meters (to 26*plus furthest* from power source).

Supplying Enough Power to SBE 26*plus*

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, to power the SBE 26*plus* externally.

Power required for the conductivity measurement is 0.3 Watt for 26*plus* with Quartz pressure or 0.33 Watt for 26*plus* with Strain Gauge pressure; conservatively use 0.33 Watts for both. If not integrating a conductivity sensor with the 26*plus*, the next highest power draw is 0.225 Watts for 26*plus* with Quartz pressure or 0.2 Watts for 26*plus* with Strain Gauge pressure; conservatively use 0.225 Watts for both. Use 12 V (minimum input voltage) to calculate:

I * V = Watts
With conductivity: I = 0.33 Watts / 12V = 0.028 Amps
Without conductivity: I = 0.225 Watts / 12V = 0.019 Amps

Example 1 – For 20 gauge wire, what is maximum distance to transmit power to 26*plus* with an integrated conductivity sensor from a 12 VDC power supply?

The 26*plus* external power specification is 12 – 20 VDC. The battery cut-off (point at which 26*plus* stops taking measurements) is 10.4 V. Therefore, a 1.6 V IR drop (12 V – 10.4 V) would still provide enough power to the 26*plus*.

V = IR   1.4V = 0.028 Amps * (0.0107 ohms/foot * cable length)
Maximum cable length = 4670 ft = 1420 meters
Note that 1420 meters <1675 meters (maximum distance if 26*plus* 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.
1.4V = 0.028 Amps * 4 instruments * (0.0107 ohms/foot * cable length)
Maximum cable length = 1168 ft = 356 meters (to 26*plus furthest* from power source)

Data I/O

The SBE 26*plus* receives setup instructions and outputs diagnostic information or previously recorded data via a three-wire RS-232 link (optional RS-422 / RS-485 full duplex). The 26*plus* is factory-configured for 9600 baud, 8 data bits, 1 stop bit, and no parity. The communications baud rate can be changed using **Baud=** (see *Section 5: SBE 26plus Setup, Installation, and Data Upload – SeatermW*). Standard ASCII data upload from memory is done at the communications baud rate. Binary data upload from memory can be accomplished at rates of up to 115,200 baud, regardless of the setting for the communications baud rate.

Real-Time Setup

Baud Rate and Cable Length – Standard RS-232 Interface

The length of cable that the SBE 26*plus* can drive is 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
16.7	57600 *
13.3	115200 *

* 57600 and 115200 baud are available only for binary upload, and are not applicable to real-time data output.

Notes:
- Set:
  Baud rate with **Baud=**.
  TxTide=Y for real-time tide data.
  TxWave=Y for real-time wave data.
  TXWAVESTATS=Y in **SetSampling** prompt for real-time wave statistics.
  See *Section 5: SBE 26plus Setup, Installation, and Data Upload – SeatermW* for command details.
- If using external power, see *External Power and Cable Length* above for power limitations on cable length.

Baud Rate and Cable Length – Optional RS-422 / RS-485 (full duplex) Interface

The SBE 26*plus* can transmit data at up to 38,400 baud over up to 1200 meters of twisted pair wire cable, 26 AWG or smaller gauge (larger diameter). When uploading data, higher baud rates for binary upload (57,600 and 115,200 baud) may not work with long cables.

Real-Time Data Acquisition

Real-time data (tides, waves, and/or wave statistics) can be acquired by clicking Capture in SeatermW before you begin logging. The data displayed in SeatermW will be saved to the designated file. Process the data as desired. Note that this file **cannot be processed by SEASOFT for Waves, as it does not have the required headers and format for Sea-Bird's processing software**.

Section 3: Software Installation and Use

Notes:

- **SEASOFT for Waves data processing modules cannot process real-time data from the 26*plus*.**
- Sea-Bird supplies the current version of our software when you purchase an instrument. As software revisions occur, we post the revised software on our FTP site. See our website (www.seabird.com) for the latest software version number, a description of the software changes, and instructions for downloading the software from the FTP site.
- **Sea-Bird also has a DOS program, SEASOFT for Waves – DOS. However, the DOS program is not compatible with the 26*plus*.**

This section describes the installation and use of SEASOFT for Waves.

The SBE 26*plus* is supplied with a modular Windows 95/98/NT/2000/XP software package, **SEASOFT for Waves**. The software provides pre-deployment planning, communication with the 26*plus* for setup and uploading of data from the 26*plus*, separation of the uploaded data into separate wave and tide files, removal of barometric pressure from tide data, statistical analysis, and data plotting.

The 26*plus* is supplied with one additional program, **Extract Tide**. Extract Tide splits uploaded data from multiple logging sessions into separate files before converting and processing the data. ExtractTide.exe is a separate program, but is installed in the same directory as SEASOFT for Waves; see *Section 6: Conversion into Tide and Wave Files – Extract Tide and Convert Hex* for details.

Software Installation

Recommended minimum system requirements for software:
Pentium 90 CPU, 64 Mbyte RAM, Windows 98 or later.

Note:
Help files provide detailed information on SEASOFT for Waves.

SEASOFT for Waves

If not already installed, install SEASOFT for Waves on your computer using the supplied software CD-ROM:

1. In the CD-ROM drive, double click on **SeasoftWaves_V*_**.exe** (*_** = software version).

2. Follow the dialog box directions to install the software.

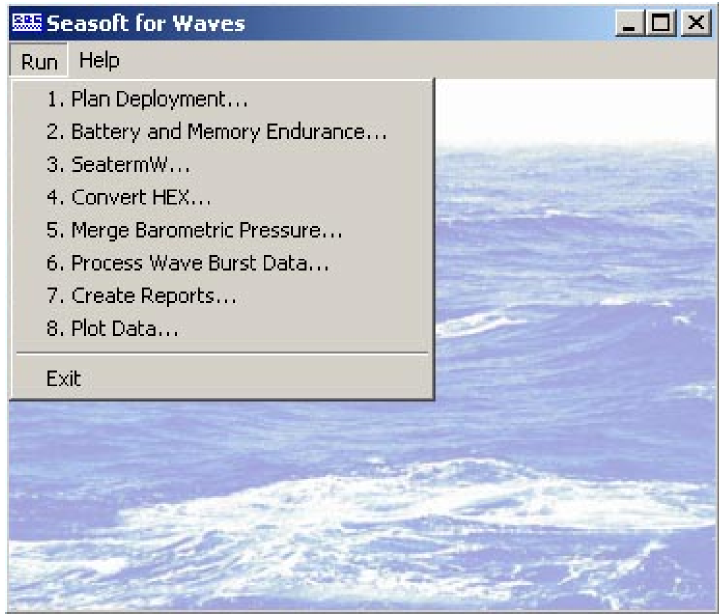
The default location for the software is
c:/Program Files/Sea-Bird/SeasoftWaves.

Extract Tide

When you install SEASOFT for Waves, ExtractTide.exe is automatically installed in the same location.

SEASOFT for Waves Use

Start SEASOFT for Waves by double clicking on SeasoftWavesLaunch.exe. The main screen looks like this:



The Run menu lists each program module:

Type	Module Name	Module Description
Pre-deployment planning See *Section 4*	**Plan Deployment**	Calculate ratio of pressure amplitude measured by instrument to pressure amplitude at surface. Predict number of frequency bands calculated, width of each band, and frequency span.
	Battery and Memory Endurance	Calculate nominal battery and memory endurance for user-specified sampling scheme.
Terminal program See *Section 5*	**SeatermW**	Send commands for status, data acquisition setup, diagnostics, and data upload.
Data conversion See *Section 6*	**Convert Hex**	Convert uploaded data file into separate wave and tide files, with output data in engineering units.
Tide data processing See *Section 7*	**Merge Barometric Pressure**	Remove barometric pressure from tide data.
Wave data processing See *Section 8*	**Process Wave Burst Data**	Compute wave statistics.
	Create Reports	Output one line of surface wave time series and/or wave burst auto-spectrum statistics for each processed wave burst.
Data plotting See *Section 9*	**Plot Data**	Plot data from a .tid, .wb, .was, .wts, and/or .wt file; plots can be printed. Plot Data can plot data at any point after uploaded hex data is converted into separate wave and tide files in Convert Hex.

File Types

File extensions are used by SEASOFT for Waves to indicate the file type:

Extension	Description
.bmp	Bitmap graphics file created by Plot Data.
.bp	Barometric pressure data, used by Merge Barometric Pressure to remove barometric pressure from the tide data (.tid) file.
.cap	Real-time data and/or diagnostics captured using SeatermW.
.hex	Data uploaded from 26*plus* memory using SeatermW. Also, data from multiple logging sessions split into separate files by Extract Tide.
.ini	There are three .ini files used in SEASOFT for Waves: • Convert Hex uses a .ini file containing the pressure sensor slope and offset (for making small post-deployment corrections for pressure sensor drift). Each time you save a .ini file, Convert Hex copies the file to CNVHex.ini, in your Windows directory. You may copy and rename the file if desired; this will not affect the results. The next time you open Convert Hex, it automatically opens CNVHex.ini; you can use that file or select a different .ini file. • SeasoftWaves.ini, in your Windows directory, contains the location and file name of the last saved Program Setup (.psa) file and options settings for each module with a .psa file (Merge Barometric Pressure, Process Wave Bursts, Create Reports, and Plot Data). • SeatermW.ini, in your Windows directory, contains the last instrument type (SBE 26 or 26*plus*), COM port, and baud rate used in SeatermW for communicating with the instrument.
.jpg	JPEG graphics file created by Plot Data.
.psa	Program Setup file, used by Merge Barometric Pressure, Process Wave Bursts, Create Reports, and Plot Data to store setup information (input and output file names and locations, and processing instructions).
.r26	File containing one line of surface wave time series and/or wave burst auto-spectrum statistics for each processed wave burst, created by Create Reports.
.rpt	Summary report, created by Process Wave Burst Data.
.tid	Tide measurements in engineering units, created from uploaded .hex file by Convert Hex. Also, file format for tide data that has had barometric pressure removed by Merge Barometric Pressure.
.was	Statistics and results from auto-spectrum analysis, created by Process Wave Burst Data.
.wb	Wave measurements in engineering units, created from uploaded .hex file by Convert Hex.
.wmf	Windows metafile graphics file created by Plot Data.
.wss	Fast Fourier Transform coefficients, created by Process Wave Burst Data if selected.
.wt	Surface wave time series, created by Process Wave Burst Data if selected.
.wts	Statistics from surface wave zero crossing analysis, created by Process Wave Burst Data.

See *Appendix III: Data Formats* for details on the format of each file.

Section 4: Pre-Deployment Planning – Plan Deployment and Battery and Memory Endurance

This section covers:

- Planning the required wave burst parameters and placement of the SBE 26*plus*, using the Plan Deployment module in SEASOFT for Waves.
- Calculating battery and memory endurance for the desired sampling scheme, using the Battery and Memory Endurance module in SEASOFT for Waves.

Plan Deployment

> **Note:**
> See *Appendix VI: Wave Theory and Statistics* for a detailed discussion of the theory and equations for wave calculations.

Plan Deployment solves the wave dispersion relation to calculate and plot the pressure attenuation ratio:

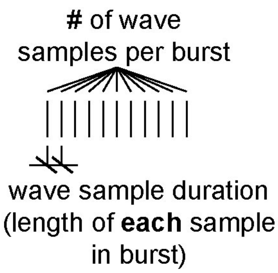
$$\text{Pressure attenuation ratio} = \frac{\text{pressure amplitude measured by 26}plus}{\text{pressure amplitude at surface}}$$

given:

water depth (meters)
height of pressure sensor above bottom (meters)
wave period (seconds)

Pressure attenuation with depth is a strong function of the wave period; short period waves are attenuated much faster with depth than longer period waves. This implies that for a pressure sensor deployed at a fixed depth z, there is a high frequency cut-off *fmax* for which waves with f > fmax are not measurable. Above the high frequency cut-off, any noise in the subsurface pressure record is mapped by the transfer function into unrealistic surface wave height values.

The default high-frequency cutoff (fmax) for processing wave data in Process Wave Burst Data is the frequency where the ratio of pressure measured by the 26*plus* to pressure at the surface is less than (0.0025 / wave sample duration). Frequencies greater than fmax are typically not processed by Process Wave Burst Data.



Plan Deployment also predicts these surface wave analysis parameters:

- number of frequency bands calculated
- width of each frequency band (Hz)
- frequency span (Hz)

given:

water depth (meters)
height of pressure sensor above bottom (meters)
wave sample duration (time between successive wave pressure measurements)
wave samples per burst (multiple of 4; for example, 4, 8, 16, etc.)
number of spectral estimates for each frequency band

> **Note:**
> If planning to calculate wave statistics, Sea-Bird recommends the following for meaningful, valid results:
> - Samples per burst ≥ 512, and
> - Samples per burst = power of 2 (for example, 512, 1024, etc.)

The maximum frequency in the frequency span is the lesser of:

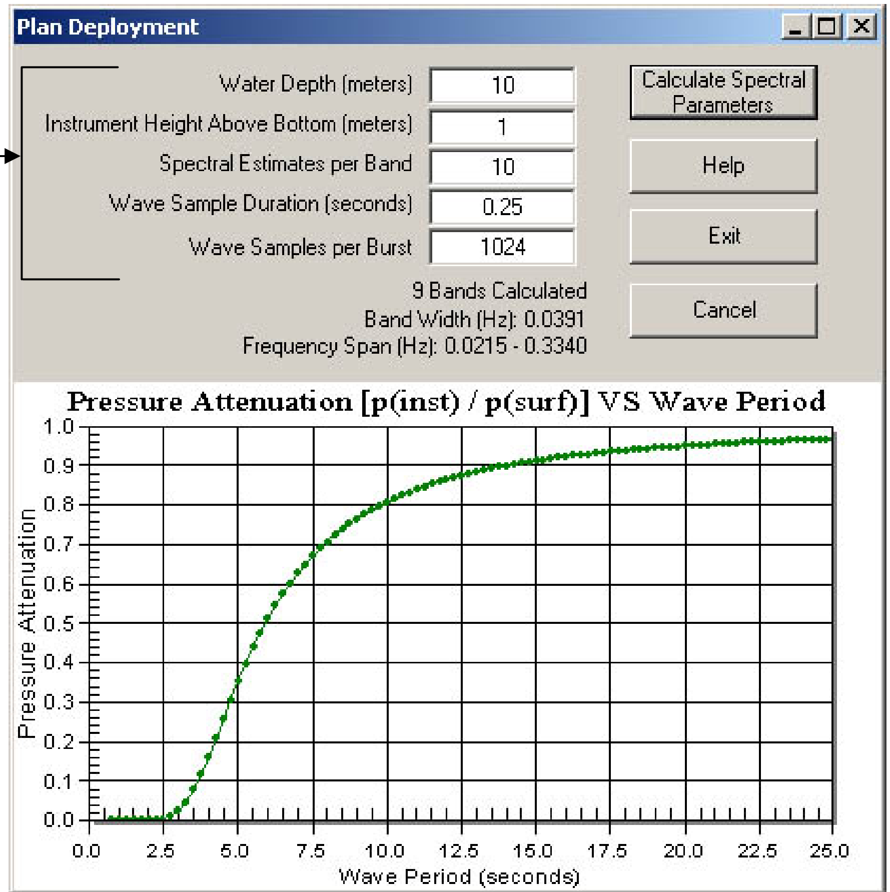
- 0.5 / sample duration (called the Nyquist frequency), or
- frequency (fmax described above) where ratio of pressure measured by 26*plus* to pressure at surface is less than (0.0025 / sample duration)

Appendix VI: Wave Theory and Statistics provides detailed discussion on band averaging.

In SEASOFT for Waves' Run menu, select Plan Deployment. The dialog box looks like this:

Enter values and then click *Calculate Spectral Parameters* to calculate bands, band width, and frequency span, and calculate and plot pressure attenuation. Note that wave sample duration and wave samples per burst are programmed into 26*plus* with **SetSampling**.

Pressure attenuation is wave pressure amplitude measured by instrument divided by wave pressure amplitude at surface.



Example:
Water depth is 10 meters. You are interested in measuring waves with frequencies up to 0.36 Hz (period = 1 / 0.36 = 2.8 seconds). You plan to sample waves 4 times per second (wave sample duration = 0.25 seconds) with 1024 samples/wave burst, and to process data with 10 spectral estimates/band. Can you place the 26*plus* at 1 meter above the bottom and accomplish your goals?

Running Plan Deployment with the above parameters (see dialog box above), the Frequency Span is 0.0215 to 0.3340 Hz. Since 0.3340 < 0.36, you cannot accomplish your goals.

Iterating on a solution by changing the instrument height in Plan Deployment, you find that placing the 26*plus* at 2.5 meters above bottom will allow you to measure the desired frequencies. Alternatively, you could consider modifying other sampling parameters while maintaining the instrument height.

Battery and Memory Endurance

> **Note:**
> See *Specifications* in *Section 2: Description of SBE 26plus* for power and memory specifications.

Power and memory endurance calculations for the SBE 26*plus* are complex, and are dependent on the sampling scheme. Use Battery and Memory Endurance to calculate the endurance for a user-specified sampling scheme.

In SEASOFT for Waves' Run menu, select Battery and Memory Endurance. Click on one of the SBE 26plus tabs in the dialog box. The dialog box looks like this:

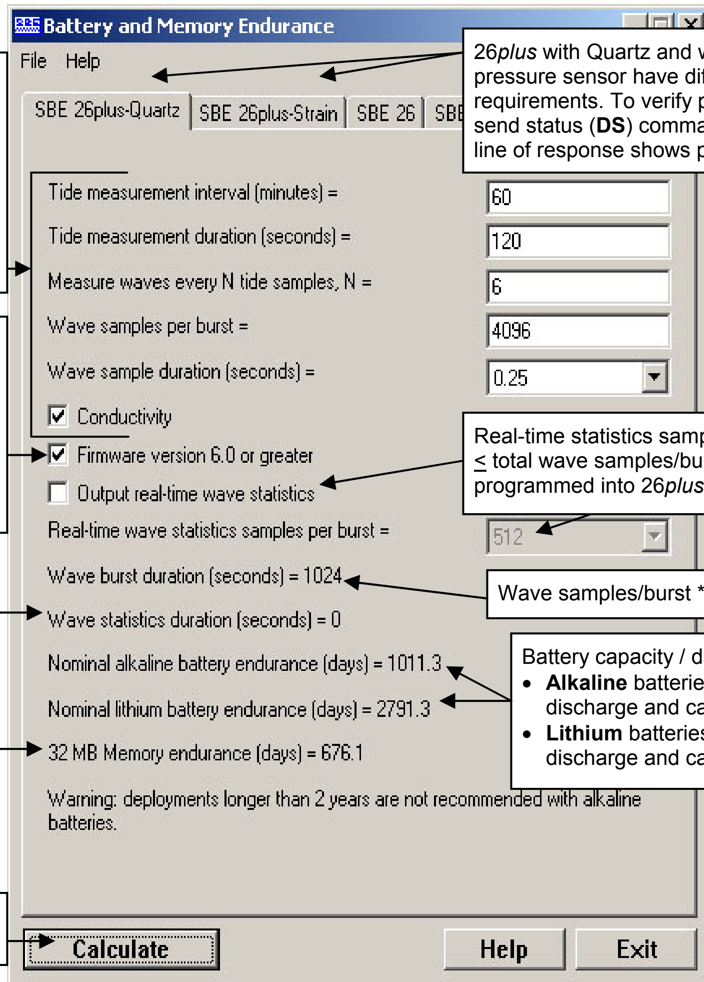
Enter tide measurement interval, tide measurement duration, number of tide measurements between each wave burst, wave samples/burst, wave sample duration, and whether conductivity is also measured. Sampling setup is programmed into 26*plus* with **SetSampling** and **Conductivity=**.

26*plus* firmware ≥ 6.0 allows for output of real-time wave statistics. Earlier versions could only output real-time wave burst pressure frequencies. To verify firmware version, send status (**DS**) command in SeatermW; first line of response shows firmware version.

Time required to calculate real-time wave statistics

Based on input sampling scheme and memory storage requirements.

Click *Calculate* to calculate battery endurance and memory endurance.



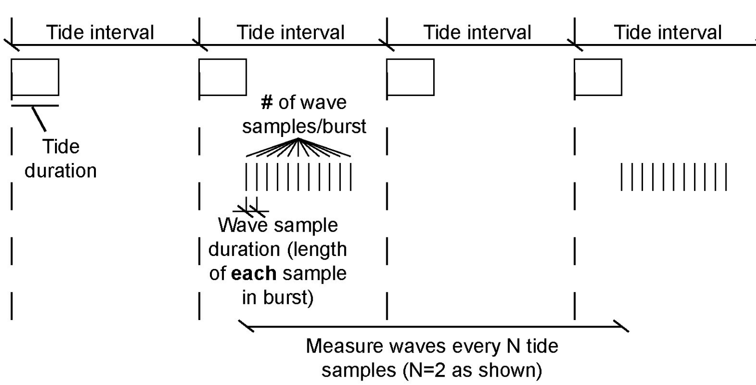
26*plus* with Quartz and with Strain Gauge pressure sensor have different power requirements. To verify pressure sensor type, send status (**DS**) command in SeatermW; third line of response shows pressure sensor type.

Real-time statistics samples/burst must be ≤ total wave samples/burst. Real-time setup is programmed into 26*plus* with **SetSampling**.

Wave samples/burst * Wave sample duration

Battery capacity / daily power consumption

- **Alkaline** batteries: 5% / year battery discharge and capacity derated 15%
- **Lithium** batteries: 3% / year battery discharge and capacity derated 15%



Notes:

- This drawing is schematic only, intended to define the sampling scheme terminology. See *Appendix II: Sample Timing* for timing details.
- See *Command Descriptions* in *Section 5: SBE 26plus Setup, Installation, and Data Upload – SeatermW* for programming desired sampling scheme in 26*plus*.
- If only interested in tide data, see *Using SBE 26plus as a Tide Recorder* in *Section 5: SBE 26plus Setup, Installation, and Data Upload – SeatermW*.
- If only interested in wave data, see *Using SBE 26plus as a Wave Recorder* in *Section 5: SBE 26plus Setup, Installation, and Data Upload – SeatermW*.

Notes:
- See *Specifications* in *Section 2: Description of SBE 26plus* for power requirements and alkaline and lithium battery ratings.
- 1 Watt-second = 1 Joule

Discussions follow of the data and equations used in Battery and Memory Endurance; use this information to perform your own calculations if desired.

Battery Endurance – with Quartz Pressure Sensor

- **Tide sample**
  If (tide duration < tide interval – 20 sec), the SBE 26*plus* goes to sleep between tide measurements, drawing only quiescent power (0.0005 Watt) while *sleeping*.

  If sleeping between tide samples (tide duration < tide interval – 20 sec)
  Quiescent = 0.0005 Watt * (tide interval – tide duration – 10 sec – 2 sec)
  Pressure sensor integration = 0.01 Watt * (tide duration + 10 sec)
  Turn-on for each sample = 0.30 Watt-sec
  Tide sample (including temperature) = 0.30 Watt-sec
  Conductivity sample = 0.40 Watt-sec

  If not sleeping between tide samples (tide interval = tide duration)
  Pressure sensor integration = 0.01 Watt * tide duration
  Tide sample (including temperature) = 0.30 Watt-sec
  Conductivity sample = 0.40 Watt-sec

- **Wave burst measurement**
  Wave burst duration
  = [number of wave samples * wave sample duration (sec)]
  Wave burst = 0.11 Watt * wave burst duration (sec)
  Real-time wave statistics =
  0.2 Watts * 0.06 sec/sample * real-time statistics samples/burst

Example: 26*plus* with quartz pressure sensor, conductivity sensor, and standard alkaline batteries. Measure tides every 60 minutes (24 measurements/day), with measurement duration of 120 seconds. Measure waves after every 6 tide samples (24 / 6 = 4 wave bursts/day). Take 4096 wave measurements per burst, at 0.25-second integration time per measurement. Do not output real-time wave statistics. (Note: This is same sampling scheme as shown in Battery and Memory Endurance dialog box above.)

Tide sample:
26*plus* is sleeping between samples because *tide duration < tide interval – 20 seconds* (120 < 3600 – 20)
Pressure integration = 0.01 Watt * (120 sec + 10 sec) = 1.3 Joules/measurement
Turn-on = 0.30 Joules/measurement
Tide sample (including temperature) = 0.30 Joules/measurement   Conductivity sample = 0.4 Joules/measurement
Quiescent between samples = 0.0005 Watt * (3600 sec – 120 sec – 10 sec – 2 sec) = 1.74 Joules /measurement
(Note: This provides a small over-estimate of quiescent power, because quiescent time is reduced during each tide interval that includes a wave burst.)
Tide power/measurement = 1.3 + 0.3 + 0.3 + 0.4 + 1.74 = 4.04 Joules/measurement
Total tide power/day = 4.04 Joules/measurement * 24 measurements/day **= 97.0 Joules/day**

Wave sample:
Wave burst duration = 0.25 seconds * 4096 measurements = 1024 seconds/burst
Wave burst = 0.11 Watt * 1024 seconds/burst = 112.64 Joules/burst
Total wave power/day = 112.64 Joules/burst * 4 bursts/day = **450.6 Joules/day**

Alkaline battery capacity = 756,000 Joules * 0.85 (derate for safety) = 642,600 Joules
Derating 5% per year for battery self-discharge: 0.05 * 642,600 Joules / 365 days per year = **88 Joules/day**
Total power consumption = 97.0 Joules/day + 450.6 Joules/day + 88 Joules/day = **635. 6 Joules/day**
Number of days of battery capacity = 642,600 Joules/ 635.6 Joules/day = **1011 days =** 2.77 years

As a check, compare with the output of Battery and Memory Endurance on the 26plus-Quartz tab; the program shows the same results. Although the battery capacity is 2.77 years, the program provides a warning that deployments longer than 2 years are not recommended with alkaline batteries. Additionally, the program calculated that the memory endurance is only 676 days (1.85 years), which is the limiting factor in deployment length for this sampling scheme (see *Memory Endurance* for example calculation).

Battery Endurance – with Strain Gauge Pressure Sensor

Note:
1 Watt-second = 1 Joule

- **Tide sample (for intervals *without* a wave burst)**
  Quiescent = 0.0005 Watt * (tide interval – tide duration – 2.6 sec)
  Turn-on/off for each tide sample = 0.36 Watt-sec
  Tide sample (including temperature) = 0.14 Watt * tide duration
  Conductivity sample = 0.71 Watt-sec

- **Tide sample + Wave burst (for intervals *with* a wave burst)**
  Wave burst duration = [number of wave samples * wave sample duration (sec)]
  Conductivity sample = 0.71 Watt-sec
  Real-time wave statistics =
  0.2 Watts * 0.06 sec/sample * real-time statistics samples/burst

  If (tide duration + wave duration + 5 < tide interval)
  Quiescent =
  0.0005 Watt * (tide interval – tide duration - wave duration – 2.6 sec)
  Turn-on/off for each tide sample = 0.36 Watt-sec
  Tide (including temperature) and wave sample (Watt-sec) =
  0.14 Watt * [tide duration (sec) + wave duration (sec)]

  If (tide duration + wave duration + 5 ≥ tide interval)
  Turn-on/off for each tide sample = 0.36 Watt-sec
  Tide (including temperature) **and** wave sample =
  0.14 Watt * wave duration (sec)

Example: 26*plus* with strain gauge pressure sensor, conductivity sensor, and standard alkaline batteries. Measure tides every 60 minutes (24 measurements/day), with measurement duration of 120 seconds. Measure waves after every 6 tide samples (24 / 6 = 4 wave bursts/day). Take 4096 wave measurements per burst, at 0.25-second integration time per measurement. Output real-time wave statistics on 512 of the 4096 wave measurements/burst.

Tide sample (for intervals *without* a wave burst):
Quiescent between samples = 0.0005 Watt * (3600 sec – 120 sec – 2.6 sec) = 1.74 Joules /measurement
Turn-on = 0.36 Joules/measurement
Take tide sample = 0.14 Watt * 120 seconds = 16.80 Joules/measurement
Take conductivity sample = 0.71Joules/measurement
Tide power/measurement = 1.74 + 0.36 + 16.80+ 0.71 = 19.61 Joules/measurement
# of tide measurements/day without a wave burst = 24 measurements/day – 4 wave bursts/day = 20 measurements/day
Total tide power/day = 19.61 Joules/measurement * 20 measurements/day **= 392.2 Joules/day**

Tide sample + Wave sample (for intervals *with* a wave burst):
Wave burst duration = 0.25 seconds * 4096 measurements = 1024 seconds/burst
Tide duration + wave duration + 5 = 120 + 1024 + 5 = 1149 seconds < tide interval = 3600 seconds
Quiescent between samples = 0.0005 Watt * (3600 sec – 120 sec – 1024 sec – 2.6 sec) = 1.23 Joules /measurement
Turn-on = 0.36 Joules/measurement
Take tide and wave sample = 0.14 Watt * (120 sec + 1024 sec) = 160.2 Joules/measurement
Take conductivity sample = 0.71Joules/measurement
Tide and wave power/measurement = 1.23 + 0.36 + 160.2 + 0.71 = 162.5 Joules/measurement
Total tide and wave power/day = 162.5 Joules/measurement * 4 measurements/day = **650 Joules/day**

Real-time wave statistics
Power consumption (Watt-sec) = 0.2 Watts * 0.06 sec/sample * 512 samples/burst = 6.14 Joules/wave burst
Total statistics/day = 6.14 Joules/wave burst * 4 wave bursts/day = **24.6 Joules/day**

Alkaline battery capacity = 756,000 Joules * 0.85 (derate for safety) = 642,600 Joules
Derating 5% per year for battery self-discharge: 0.05 * 642,600 Joules / 365 days per year = **88 Joules/day**
Total power consumption = 392 Joules/day + 650 Joules/day + 25 Joules/day + 88 Joules/day = **1155 Joules/day**
Number of days of battery capacity = 642,600 Joules/ 1155 Joules/day = **556 days =** 1.52 years

As a check, compare with the output of Battery and Memory Endurance on the 26plus-Strain tab; the program shows the same results. The program calculated that the memory endurance is 676 days (1.85 years), which is not the limiting factor in deployment length for this sampling scheme (see *Memory Endurance* for example calculation).

Memory Endurance

The SBE 26*plus* comes standard with a 32 MB memory. Memory used for storing logged data is:

If conductivity not enabled:	Bytes/day = 9N + W (36 + 3M)
If conductivity enabled:	Bytes/day = 12N + W (48 + 3M)

where
N = number of tide samples/day
W = number of wave bursts/day
M = number of wave measurements/burst

Example: 26*plus* with conductivity sensor.
Measure tides every 60 minutes (1/hour * 24 hours = 24 measurements/day). Measure waves after every 6 tide samples (24 / 6 = 4 wave bursts/day). Take 4096 wave measurements per burst.
(Note: This is same sampling scheme as shown in Battery and Memory Endurance dialog box above, and in power endurance calculation examples.)

N = 24, W = 4, M = 4096
Bytes/day = 12N + W (48 + 3M) = (12 * 24) + 4 * (48 + 3 * 4096) = 49,632 bytes/day
Memory capacity ≈ 32 MB * 1024 * 1024 = 33,554,432 bytes
Memory endurance ≈ 33,554,432 / 49,632= 676 days

As a check, compare with the output of Battery and Memory Endurance; the program shows the same results.
Note that for this example the 26*plus* power capacity exceeds the memory capacity.

Section 5: SBE 26*plus* Setup, Installation, and Data Upload - SeatermW

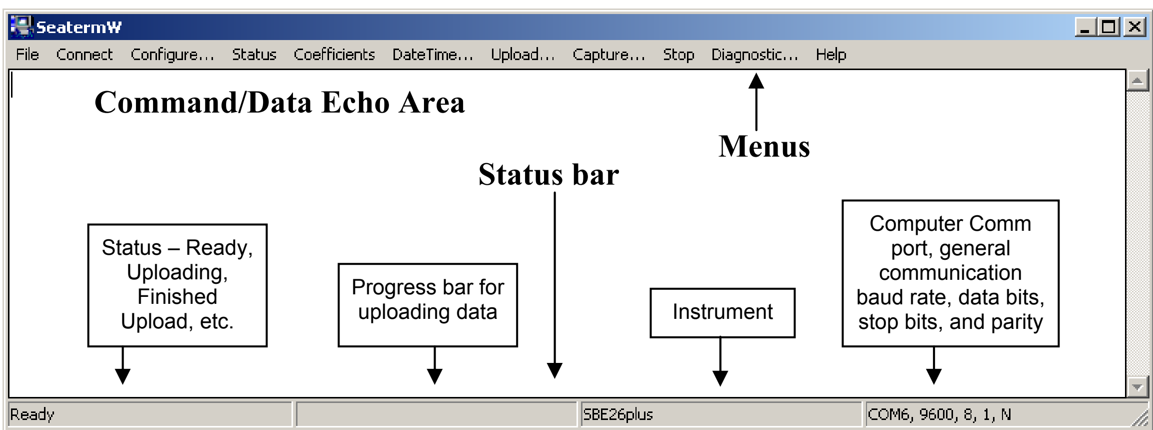
Note:
Instrument commands and responses are identical for the 26*plus* with Quartz pressure sensor or Strain Gauge pressure, ***except as noted***.

This section covers:
- Programming the SBE 26*plus* for deployment using SeatermW
- Command descriptions
- Programming SBE 26*plus* for use only as a tide recorder or only as a wave recorder
- Installing and deploying the SBE 26*plus*
- Recovery and uploading data from memory using SeatermW

Programming for Deployment - SeatermW

1. Connect the 26*plus* to the computer using the data I/O cable:
   A. By hand, unscrew the locking sleeve from the 26*plus* I/O connector (4-pin for standard RS-232; 6-pin for optional RS-422 / RS-485). If you must use a wrench or pliers, be careful not to loosen the I/O connector instead of the locking sleeve.
   B. Remove the dummy plug from the 26*plus* I/O connector by pulling the plug firmly away from the connector.
   C. **Standard Connector** - Install the Sea-Bird I/O cable connector, aligning the raised bump on the side of the connector with the large pin (pin 1 - ground) on the 26*plus*. **OR**
   MCBH Connector – Install the cable, aligning the pins.
   D. Connect the I/O cable connector to your computer's serial port.

2. In SEASOFT for Waves Run menu, select SeatermW.
   The main screen looks like this:



Note:
Once the system is configured and connected (Steps 3 and 4 below), to update the Status bar, click Status. SeatermW sends the status command (**DS**), which displays in the Command/Data Echo Area, and updates the Status bar.

- Menus – Contains tasks and frequently executed instrument commands.
- Command/Data Echo Area – Echoes a command executed using a Menu, as well as the 26*plus* response. Additionally, a command can be manually typed in this area, from the available commands for the 26*plus*. The 26*plus* must be *awake* for it to respond to a command (use Connect to wake up the 26*plus*).
- Status bar – Provides status information.

Note:
You must be *connected* to the instrument (Connect) when using Status, Coefficients, Upload, Stop, or Diagnostic.

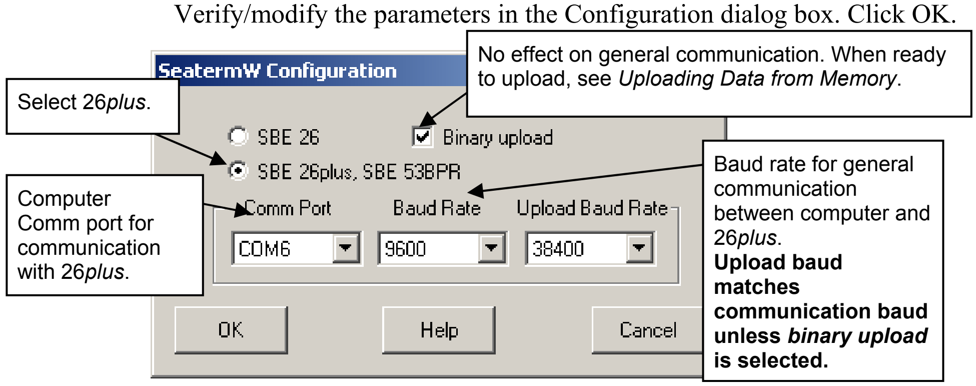
Following is a description of the menus:

Menu	Description	Equivalent Command*
File	Exit SeatermW.	-
Connect	Re-establish communications with 26*plus*. Computer responds with S> prompt. 26*plus goes to sleep* after 2 minutes without communication from computer have elapsed.	(press Enter key)
Configure	Establish communication parameters (instrument, Comm port, and baud rate).	**-**
Status	Display 26*plus* setup and status (logging, samples in memory, etc.).	**DS**
Coefficients	Display pressure, temperature, and optional conductivity sensor calibration coefficients.	**DC**
DateTime	Set 26*plus* date and time based on time in computer. See *Setting Time in SBE 26plus to Synchronize Sampling of Multiple Instruments* for details.	**DateTime=x**
Upload	Upload data stored in memory, in format our data processing modules can use. Uploaded data has .hex extension. Before using, verify 26*plus* has stopped logging (send **Stop** unless you had input and enabled a pre-programmed stop time before beginning logging).	Upload with **DD** or **DBbaud,b,e** (use Upload if you will be processing data with SEASOFT for Waves)
Capture	Capture 26*plus* responses on screen to file; to save real-time data or may be useful for diagnostics. File has .cap extension. Click Capture again to turn off capture. Capture status displays in Status bar.	-
Stop	Interrupt and end current activity, such as uploading data or running diagnostic test (such as **FR**, **VR**, **TT**, **TTR)**. Note: This does not stop logging – use **Stop** command to stop logging.	(press Esc key several times)
Diagnostic	Perform diagnostic tests on 26*plus*. Tests are non-destructive – they do not write over any existing settings.	**DS** (status); **DC** (calibration coefficients); **DD0,10** (upload and display tide samples 0 – 10, along with wave burst data logged during that period of time); **FR** (display frequencies)

*See *Command Descriptions* in this section.

Note:
SeatermW's general communication baud rate must be the same as the 26*plus* baud rate (set with **Baud=**). Baud is factory-set to 9600, but can be changed by the user (see *Command Descriptions*). Other communication parameters – 8 data bits, 1 stop bit, and no parity – cannot be changed.

3. Click Configure. The dialog box looks like this:
   Verify/modify the parameters in the Configuration dialog box. Click OK.



4. Click Connect. The display looks like this:

```
SBE 26plus
S>
```

This shows that correct communications between the computer and 26*plus* has been established.
If the system does not respond with the S> prompt:

- Click Connect again.
- Verify the correct instrument, Comm port, and baud rate were entered in the Configuration dialog box.
- Check cabling between the computer and 26*plus*.

5. Display 26*plus* setup information by clicking Status; SeatermW sends the **DS** command. The display looks like this:

Note:
The 26*plus* automatically enters quiescent (sleep) state after 2 minutes without receiving a command. This timeout algorithm conserves battery energy if the user does not send **QS** to put the 26*plus* to sleep. If the system does not appear to respond, click Connect to reestablish communications.

```
SBE 26plus V 6.1c  SN 12345    10 Dec 2006  13:35:13
user info=test setup
quartz pressure sensor: serial number = 90319, range = 1000 psia
internal temperature sensor
conductivity = YES
iop =  6.0 ma  vmain = 15.3 V  vlith =  9.3 V
last sample: p = 21.9520, t = 21.0250, s = 34.3799

tide measurement: interval = 60.000 minutes, duration = 120 seconds
measure waves every 6 tide samples
4096 wave samples/burst at 4.00 scans/sec, duration = 1024 seconds
logging start time =  do not use start time
logging stop time =  do not use stop time

tide samples/day = 24.000
wave bursts/day = 4.000
memory endurance = 676.1 days
nominal alkaline battery endurance = 1011.3 days
deployments longer than 2 years are not recommended with
alkaline batteries
total recorded tide measurements = 0
total recorded wave bursts = 0
tide measurements since last start = 0
wave bursts since last start = 0

transmit real-time tide data = YES
transmit real-time wave burst data = YES
transmit real-time wave statistics = NO

status = stopped by user
logging = NO, send start command to begin logging
```

6. Send the desired commands to set up the 26*plus* (see *Command Descriptions* below). Verify the setup by clicking Status again.

Notes:
- See *Appendix II: Sample Timing* for a detailed description of when tide and wave measurements are made and stored in memory.
- When transmitting real-time tide data, each tide measurement record displays **after** the tide duration is complete. For example, if the tide duration is 10 minutes, the first tide data displays 10 minutes after logging starts.

7. Test the setup by typing **Start** and pressing the Enter key to begin logging.

If the **DS** response shows `logging start time = do not use start time` (***use start time?*** in **SetSampling** prompt is ***No***), the 26*plus* responds:

```
logging will start in 10 seconds
```

If the **DS** response shows `transmit real-time tide data = YES` (real-time tide data was enabled with **TxTide=Y**), each time the 26*plus* completes a tide measurement, the display looks like this:

```
Tide: start time = 26 Jan 2006 13:40:01, p =14.2135,
pt = 21.952, t = 21.0250, c = 4.81952, s = 34.3799
```

where:
- start time = start of tide measurement.
- p = calculated and stored pressure (psia).
- pt = calculated pressure temperature (not stored) (°C).
- t = calculated and stored temperature (°C).
- c = calculated and stored conductivity (S/m) and s = calculated salinity (not stored) (psu). Note that c and s display only if **DS** response shows `conductivity = YES` (conductivity acquisition is enabled with **Conductivity=Y**).

Note:
This wave data was obtained while the instrument was on land, so the output is indicating essentially 0 wave height.

If the **DS** response shows `transmit real-time wave burst data = YES` (real-time wave data transmission was enabled with **TxWave=Y**), each time a wave burst measurement is made, the display looks like this:

```
wave: start time = 26 Jan 2006 13:43:13
wave: ptfreq = 172046.343     or    wave: ptRaw = 1.278
14.5599
14.5598
14.5597
. . .
14.5598
wave: end wave burst
```

where:
- start time = start of wave measurement.
- ptfreq = pressure temperature frequency (Hz); displays only for 26*plus* with Quartz pressure sensor.
- ptRaw = calculated pressure temperature number; displays only for 26*plus* with Strain Gauge pressure sensor.
- Remaining displayed values are calculated and stored pressures (psia).

If the **DS** response shows `transmit real-time wave statistics = YES` (real-time wave statistics was enabled with `TXWAVESTATS=Y` in the **SetSampling** command prompt), each time a wave burst is completed, the display looks like this (if `Show progress messages = n`):

```
Auto-Spectrum Statistics:
   nAvgBand = 5
   total variance = 1.7509e-08
   total energy = 1.7137e-04
   significant period = 4.2667e+01
   significant wave height = 5.2928e-04

Time Series Statistics:
   Wave integration time = 128
   Number of waves = 0
   Total variance = 1.6868e-08
   Total energy = 1.6512e-04
   Average wave height = 0.0000e+00
   Average wave period = 0.0000e+00
   Maximum wave height = 5.9477e-04
   Significant wave height = 0.0000e+00
   Significant wave period = 0.0000e+00
   H1/10 = 0.0000e+00
   H1/100 = 0.0000e+00
```

where:

- Auto-Spectrum Statistics -
  nAvgBand = user-input number of spectral estimates for each frequency band, and
  next 4 lines are calculated (not stored) auto-spectrum statistics
- Time Series Statistics -
  wave integration time (sec) = wave burst duration
  = user input number of samples / burst * sample duration, and
  remaining lines are calculated (not stored) time series statistics

Note:
See *Appendix VI: Wave Theory and Statistics* for a description of calculation of wave statistics.

8. End the test by typing **Stop** and pressing the Enter key to stop logging. You may need to press the Esc key before entering **Stop** to get the 26*plus* to stop if it is in the middle of sampling. Verify that logging has stopped by clicking Status and checking that the last line of the **DS** response shows `logging = no`.

9. (if ready for deployment)
   A. Type **InitLogging** and press the Enter key to make the entire memory available for recording. If **InitLogging** is not sent, data will be stored after the last recorded sample.
   B. To begin logging now: Type **Start** and press the Enter key. The 26*plus* should display:
   `logging will start in 10 seconds.`
   C. To begin logging at a delayed start date and time:
   - Type **SetStartTime**, press the Enter key, and respond to the prompts to establish a delayed start date and time.
   - Type **SetSampling** and press the Enter key, and answer yes to the ***use start time?*** prompt to enable logging at the delayed start date and time.
   - Type **Start** and press the Enter key. The 26*plus* should display:
   `logging will start at . . ..`

10. (if not ready for deployment) Type **QS** and press the Enter key to command the 26*plus* to go to sleep (quiescent state).

Command Descriptions

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

General Command Notes

- Input commands in upper or lower case letters and register commands by pressing the Enter key.
- The 26*plus* sends `? CMD` if an invalid command is entered.
- If the 26*plus* 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 completion of a command, the 26*plus* returns to quiescent (sleep) state and the display indicates `time out`.
- If in quiescent state, re-establish communications by clicking Connect or pressing the Enter key to get an `S>` prompt.
- The 26*plus* cannot have samples with different tide sample scan lengths (more or fewer data fields per sample) in memory. If the scan length is changed, the 26*plus* must initialize logging. Initializing logging sets the tide sample number and wave sample 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**. **Conductivity=**, which enables/disables acquisition and storing of optional conductivity data, changes the scan length. Therefore, **Conductivity=** prompts the user for verification before executing, to prevent accidental overwriting of existing data.
- The 26*plus* does not respond at all while making a wave burst measurement. If you need to establish communications during a wave burst, press the Esc key or click Stop to interrupt the wave burst (this interrupts the current wave burst but does not stop logging). The 26*plus* will fill out the remaining data in the interrupted wave burst with 0's.
- 26*plus* ***with Quartz Pressure Sensor***: The 26*plus* responds only to **DS**, **DC**, **QS**, **SL**, **SLO**, and **Stop** while making a tide measurement. If you wake up the 26*plus* while it is logging (for example, to send **DS** to check on logging progress), it does not interrupt logging.
- 26*plus* ***with Strain Gauge Pressure Sensor***: The 26*plus* does not respond at all while making a tide measurement. If you need to establish communications during a tide measurement, press the Esc key or click Stop to interrupt the tide measurement (this interrupts the current tide measurement but does not stop logging). If you are communicating/requesting data (for example, sending **DS**, **QS**, **SL**, or **SLO**) from the 26*plus* when it should be starting the next tide measurement, it delays the start of the next tide measurement. **If feasible** (depending on the value of tide duration and tide interval), the 26*plus* makes the following tide interval shorter to return the time series to the expected timing. For example, if the tide interval is 1 minute, tide sample start times are:
  10:20:15
  10:21:15
  10:22:25 (26*plus* delayed sample because user sent **DS**)
  10:23:15 (26*plus* made interval shorter to return to expected timing)
  10:24:15

Note:
Interrupting a wave burst and/or tide measurement by pressing the Esc key or clicking Stop will affect the quality of your data. For high quality data, Sea-Bird recommends the following to allow querying the 26*plus* during logging without interrupting measurements:
- Set sampling parameters with enough time between measurements, and
- Schedule/time queries when the 26*plus* is not measuring tides (of concern only for 26*plus* with Strain Gauge pressure sensor) or waves.

- The 26*plus* responds only to **DS**, **DC**, **QS**, and **Stop** while *waiting to start logging* (***use start time?*** prompt in **SetSampling** command is ***Yes***, and **Start** was sent, but sampling has not started yet).
  To send any other commands:
  1. Send **Stop**.
  2. Send the desired commands to modify the setup.
  3. Send **Start** again.

- Click Upload to upload data that will be processed by SEASOFT for Waves. Manually entering a data upload command does not produce data with the required header information for SEASOFT for Waves.

- If the 26*plus* is uploading data and you want to stop it, press the Esc key or click Stop. Press the Enter key to get the `S>` prompt.

Entries made with the commands are permanently stored in the 26*plus* and remain in effect until you change them.

- The only exception occurs if the electronics are removed from the housing and the two PCBs are separated or the lithium jumper (JP7) is removed (see *Appendix IV: Electronics Disassembly/Reassembly*). Before beginning disassembly, upload all data in memory. Upon reassembly, reset the date and time (**SetTime**) and initialize logging (**InitLogging**).

Commands

Status Command

Notes:
- If the battery voltage is below the cut-off voltage (10.4 volts), the following displays in response to **DS**: `WARNING: LOW BATTERY VOLTAGE!!` Replace the batteries before continuing.
- With Quartz pressure sensor: You can wake up the 26*plus* during a tide measurement and display status (press Enter key to get `S>`, then click Status) without interrupting logging.
- With Strain Gauge pressure sensor: Waking up the 26*plus* during a tide measurement and displaying status interrupts logging. See *General Command Notes* above.

Note:
- **Memory** endurance is based on ***total*** memory capacity, taking into account the setup (tide measurement interval, wave burst interval, etc), but not considering the measurements already in memory.
- **Battery** endurance is based on ***original***, nominal alkaline battery capacity, taking into account the setup (tide measurement interval, wave burst interval, etc). It is not based on a measurement of remaining battery voltage or the number of measurements already taken. If calculated battery endurance is greater than 730 days, status response shows `deployments longer than 2 years are not recommended with alkaline batteries.`

Memory and battery endurance output with **DS** matches that calculated in Battery and Memory Endurance (but Battery and Memory Endurance outputs lithium battery endurance as well as alkaline). See *Section 4: Pre-Deployment Planning – Plan Deployment and Battery and Memory Endurance*.

Note:
After sending **Start**, logging status should be one of the following if the 26*plus* is operating correctly:
- `logging started` - if ***use start time*** in **SetSampling** prompt is ***No*** (26*plus* started logging 10 seconds after receipt of **Start**).
- `waiting to start at . . .` - if ***use start time*** in **SetSampling** prompt is ***Yes*** (26*plus* waits to start logging at time set with **SetStartTime**).

DS

Display operating status and setup parameters. Equivalent to Status menu.

List below includes, where applicable, command used to modify parameter.
- Firmware version, serial number, date and time [**SetTime** or **DateTime=**]
- User-input description [**UserInfo=**]
- Pressure sensor type (quartz or strain gauge), serial number, and full scale range
- Enable high-accuracy external thermistor [**ExternalTemperature=**]?
- Enable conductivity sensor [**Conductivity=**]?
- Main operating current, main and back-up lithium battery voltages
- Last measured pressure (psia) and temperature (ºC); calculated salinity (only if conductivity enabled, psu)
- Wave and tide sampling setup [**SetSampling**]:
  - Interval between tide samples and tide sample duration
  - Interval between wave bursts
  - Number of wave measurements/burst, wave sampling frequency, and calculated wave sampling duration
  - Start time for logging (if enabled)
  - Stop time for logging (if enabled)
- Calculated number of tide samples/day [based on **SetSampling**]
- Calculated number of wave bursts/day [based on **SetSampling**]
- Calculated memory endurance [based on **SetSampling**]
- Calculated battery endurance [based on **SetSampling**]
- Number of tide measurements in memory
- Number of wave bursts in memory
- Number of tide measurements since logging was last started
- Number of wave bursts since logging was last started
- Transmit real-time tide data [**TxTide=**]?
- Transmit real-time wave data [**TxWave=**]?
- Transmit real-time wave statistics [**SetSampling**]? If yes, real-time wave statistic settings, entered with **SetSampling**, display.
- Logging status is one of following: `never started`, `waiting to start at . . .`, `logging started`, `stop: out of memory`, `stop: low battery`, `stop time reached`, `stopped by user`, `unknown`
- Logging is one of following:
  - `NO, send start command to begin logging` (if **Start** has not been sent)
  - `YES` (if **Start** has been sent and 26*plus* is currently logging)
  - `YES, waiting to start` (if **Start** has been sent but 26*plus* is programmed to start logging at a future date/time)

Status Command (*continued*)

Example: (user input in bold; parameter used to change value in parentheses).

```
S>DS
SBE 26plus V 6.1c   SN 12345    10 Dec 2006  13:35:13                  [SetTime or DateTime=]
user info=test setup                                                   [UserInfo=]
quartz pressure sensor: serial number = 90319, range = 1000 psia
internal temperature sensor                                            [ExternalTemperature=]
conductivity = NO                                                      [Conductivity=]
iop =  6.0 ma  vmain = 15.3 V  vlith =  9.3 V
last sample: p = 14.3727, t = 2.924

tide measurement: interval = 60.000 minutes, duration = 120 seconds    [SetSampling]
measure waves every 6 tide samples                                     [SetSampling]
4096 wave samples/burst at 4.00 scans/sec, duration = 1024 seconds     [SetSampling]
logging start time =  29 Jan 2006  00:00:00                            [SetSampling and SetStartTime]
logging stop time =  30 Jan 2006  00:00:00                             [SetSampling and SetStartTime]

tide samples/day = 24.000                                              [based on SetSampling]
wave bursts/day = 4.000                                                [based on SetSampling]
memory endurance = 676.1 days                                          [based on SetSampling]
nominal alkaline battery endurance = 1026.8 days                       [based on SetSampling]
deployments longer than 2 years are not recommended with alkaline batteries   (see Note 1)
total recorded tide measurements = 0
total recorded wave bursts = 0
tide measurements since last start = 0
wave bursts since last start = 0

transmit real-time tide data = YES                                     [TxTide=]
transmit real-time wave burst data = YES                               [TxWave=]
transmit real-time wave statistics = NO  (see Note 2)                  [SetSampling]

status = stopped by user  (see Note 3)
logging = NO, send start command to begin logging
```

Notes:

1. Although calculated battery endurance for this example is 1026.8 days (2.81 years), Sea-Bird does not recommend planning deployments longer than 2 years with alkaline batteries.
2. If `transmit real-time wave statistics = YES`, following lines appear below it (all statistics parameters are entered with **SetSampling**):

```
number of wave samples per burst to use for wave statistics = 512
do not use measured temperature and conductivity for density calculation
average water temperature above the pressure sensor (deg C) = 15.0
average salinity above the pressure sensor (PSU) = 35.0
height of pressure sensor from bottom (meters) =  0.0
number of spectral estimates for each frequency band = 5
minimum allowable attenuation = 0.0025
minimum period (seconds) to use in auto-spectrum = 0.0e+00
maximum period (seconds) to use in auto-spectrum = 1.0e+06
hanning window cutoff = 0.10
show progress messages
```

3. You must send **Start** to start logging at programmed start time. After you send **Start**, status line should show:

```
status = waiting to start at 29 Jan 2006  00:00:00
```

General Setup Commands

SetTime — Set real-time clock date and time. 26*plus* prompts for desired date and time.

Example: Set current date and time to 31 January 2006 12:35:00 (user input in bold).

```
S>SETTIME
set current time:
month (1 - 12) = 1
day (1 - 31) = 31
year (4 digits) = 2006
hour (0 - 23) = 12
minute (0 - 59) = 35
second (0 - 59) = 0
```

DateTime=x — **x=** real-time clock date and time (mmddyyyyhhmmss). Command is sent automatically when using SeatermW's DateTime menu. DateTime menu provides greater accuracy in setting time than can be achieved with **SetTime**; this may be important for synchronizing sampling among multiple instruments. See *Setting Time in SBE 26plus to Synchronize Sampling of Multiple Instruments*.

Note:
The 26*plus* baud rate for general communication (set with **Baud=**) must be the same as SeatermW's baud rate (set in the Configure menu).

Baud=x — **x=** baud rate for general communication (600, 1200, 2400, 4800, 9600, 19200, or 38400). Default 9600.

ExternalTemperature=x — **x=Y**: 26*plus* has optional high-accuracy external thermistor.

x=N: 26*plus* has standard internal thermistor. Default.

Note:
When **Conductivity=** is sent, the 26*plus* must initialize logging, setting tide and wave sample numbers to 0, so the entire memory is available for recording data with the new scan length. **This should only be done after all previous data has been uploaded.** Therefore, the 26*plus* requires verification when **Conductivity=** is sent; the 26*plus* responds: `this command will change the scan length and initialize FLASH memory. Proceed Y/N?` Press Y and the Enter key to proceed.

Conductivity=x — **x=Y**: Enable conductivity logging (if 26*plus* has optional SBE 4M conductivity sensor).

x=N: Disable conductivity logging.

UserInfo=x — **x=** user-defined string that displays in status (**DS**) reply. Up to 59 characters (including spaces); 26*plus* drops any characters after 59. No carriage returns allowed. Allows user to include information describing deployment, conditions, etc. as permanent part of data set, because **DS** reply is included in uploaded .hex file when SeatermW's Upload is used to upload data (see *Uploading Data from Memory*).

General Setup Commands (*continued*)

Notes:
- SEASOFT for Waves data processing modules cannot process real-time tide or wave data from the 26*plus*.
- **TxWave=Y does not control output of real-time wave statistics**. To output real-time wave statistics, use **SetSampling** and respond to the `TXWAVESTATS` prompt with `Y`.

TxTide=x

x=Y: Transmit real-time tide data while logging. Does not affect storing data to memory. 26*plus* transmits tide measurement start time, pressure (psia), pressure temperature (°C), and temperature (°C). If **Conductivity=Y**, it also transmits conductivity (S/m) and salinity (psu).

x=N: Do not transmit real-time tide data.

TxWave=x

x=Y: Transmit real-time wave data while logging. Does not affect storing data to memory. 26*plus* transmits wave burst start time, pressure temperature frequency (Quartz pressure) or pressure temperature number (Strain Gauge pressure), and pressures (psia).

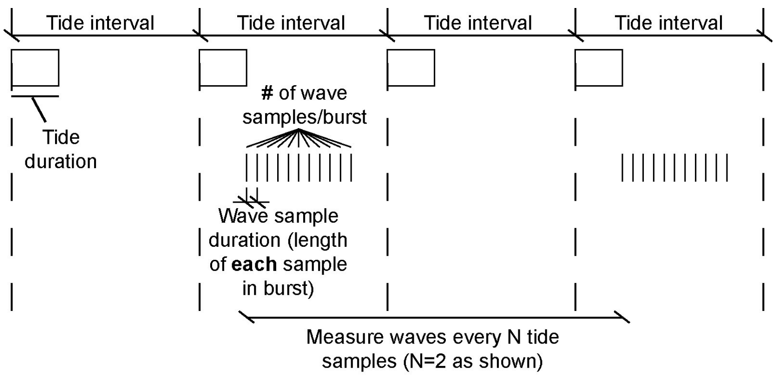
x=N: Do not transmit real-time wave data.

QS

Quit session and place 26*plus* in quiescent (sleep) state. Main power is turned off. Memory retention is not affected.

Wave and Tide Setup Command

Note:
Drawing is schematic only, intended to define the sampling scheme terminology. See *Appendix II: Sample Timing* for timing details.



SetSampling Set sampling parameters. 26*plus* displays present value and asks for new value for each parameter. Type in desired value and press Enter key. To accept present value without change, press Enter key. 26*plus* prompts as follows:

> **Notes:**
> - An alternate form for this command is **SetSample**; both have the same function.
> - If only interested in tide data, see *Using SBE 26plus as a Tide Recorder* for guidelines.
> - If only interested in wave data, see *Using SBE 26plus as a Wave Recorder* for guidelines.
> - With Quartz pressure sensor: Time required for each wave burst (= wave samples/burst * wave sample duration + time for real-time statistics calculation) must be < (tide interval - 20 sec). If the setup does not meet this requirement, the 26*plus* increases the tide interval to meet the requirement.
> - With Strain Gauge pressure sensor: Time required for each wave burst (number of wave samples/burst * wave sample duration) must be < (tide interval – 10 sec). If the setup does not meet this requirement, the 26*plus* increases the tide interval to meet the requirement.
> - See *Appendix II: Sample Timing* for a detailed description of when tide and wave measurements are made.

tide interval (integer minutes) = 30, new value =
Time from start of tide measurement to start of next tide measurement. Range 1 - 720 minutes (12 hours); user-input outside range is set to minimum or maximum allowable value, as appropriate.

tide measurement duration (seconds) = 30, new value =
Length of tide measurement (26*plus* integrates over this time, counting signal continuously and computing average pressure). Range 10 – 43,200 sec (12 hours).

With Quartz pressure:
If tide duration < (tide interval – 20 sec), 26*plus* goes to sleep between tide samples and wakes up and latches power onto pressure sensor 10 sec before start of next tide sample.
If tide duration > (tide interval – 20 sec), tide duration is set to tide interval, and 26*plus* samples tides continuously.

With Strain Gauge pressure: 26*plus* always goes to sleep between measurements.
If tide duration > (tide interval – 10 sec), tide duration is set to (tide interval – 10 sec).

> **Note:**
> Since a minimum of 512 samples/burst is ***required*** for ***real-time*** wave statistics calculations, and this must be ≤ total number of samples/burst, the 26*plus* resets the total number of wave samples/burst to 512 if:
> - a smaller number is entered, **and**
> - real-time wave statistics is enabled (see `TXWAVESTATS` prompt below).

measure wave burst after every N tide samples: N = 4, new value =
Wave burst is sampled every (N * tide interval). Range 1 – 10,000.

number of wave samples per burst (multiple of 4) = 512, new value =
Number of measurements/wave burst. If entered number is not multiple of 4, 26*plus* rounds down to make it multiple of 4. Range 4 - 60,000. **To calculate wave statistics on uploaded data, Sea-Bird recommends following for meaningful, valid results:**
-- wave samples/burst ≥ 512, and
-- wave samples/burst = power of 2 (512, 1024, etc.).

wave sample duration (0.25, 0.5, 0.75, 1.0 seconds) = 1, new value =
This parameter can be used to reduce wave burst sampling rate and increase integration time per measurement.

Wave and Tide Setup Command (*continued*)

use start time (y/n) = n, new value =
If yes, 26*plus* responds to **Start** by starting logging at date and time set with **SetStartime**.
If no, 26*plus* starts logging 10 seconds after **Start** is sent.

use stop time (y/n) = n, new value =
If yes, 26*plus* stops logging at date and time set with **SetStopTime**.
If no, 26*plus* continues logging until **Stop** is sent.

Notes:

- Wave statistics can also be calculated on uploaded data using the Process Wave Burst Data module in SEASOFT for Waves. The real-time wave statistics parameter values entered with **SetSampling** are not used in Process Wave Burst Data.
- See *Section 8: Wave Data Processing – Process Wave Burst Data and Create Reports* and *Appendix VI: Wave Theory and Statistics* for details on wave statistic input parameters and calculations.

TXWAVESTATS (real-time wave statistics) (y/n) = n, new value =
If yes, 26*plus* calculates and outputs real-time wave auto spectrum statistics (total variance, total energy, significant period, significant wave height) and time series statistics (number of waves, total variance, total energy, average wave height, average wave period, maximum wave height, significant wave height, significant wave period, H1/10, and H1/100) at the end of every wave burst. Does not affect storing data to memory.

The remaining prompts apply to real-time wave statistics
Following prompts appear only if you enter `Y` for `TXWAVESTATS`, and ***only apply to real-time wave statistics***.

Show progress messages (y/n) = y, new value =
If yes, 26*plus* outputs progress messages as it performs real-time calculations.

Number of wave samples per burst to use for wave statistics = 512, new value =
Entered value must meet following:

≥ 512. If entered number does not meet this criterion, 26*plus* sets it to 512.

= power of 2 (512, 1024, etc.). If entered number does not meet this criterion, 26*plus* rounds down to nearest power of 2.

≤ total number of wave samples/burst. If entered number does not meet this criterion, 26*plus* rounds down to nearest power of 2 that is less than total number of wave samples/burst.

26*plus* calculates real-time statistics on samples at beginning of burst (for example, if set up for 4096 samples/burst and real-time statistics on 512 samples/burst, 26*plus* uses first 512 out of 4096 samples in real-time calculations).

Wave and Tide Setup Command (*continued*)

Use measured temperature and conductivity for density calculation (y/n) = n, new value =
If Y, 26*plus* uses measured T and C to calculate density, which is used in wave statistics algorithm.

Average water temperature above the pressure sensor (Deg C) = 15.0, new value =

Average salinity above the pressure sensor (PSU) = 35.0, new value =
These 2 prompts appears only if you enter N for using measured T and C for density calculation. 26*plus* uses average water temperature and salinity to calculate density for wave statistics algorithm.

Height of pressure sensor from bottom (meters) = 0.0, new value =
Height of pressure sensor from bottom affects attenuation and calculation of fmax (frequencies > fmax are not processed).

Number of spectral estimates for each frequency band = 5, new value =
You may have used Plan Deployment to determine desired value; see *Section 4: Pre-Deployment Planning – Plan Deployment and Battery and Memory Endurance*.

Minimum allowable attenuation = 0.0025, new value =

Minimum period (seconds) to use in auto-spectrum = 0.0e+00, new value =
26*plus* defines high frequency cutoff, fmax, as smaller of:
-- frequency where (measured pressure / pressure at surface) < (minimum allowable attenuation / wave sample duration).
-- (1 / minimum period).
Frequencies > fmax are not processed.

Maximum period (seconds) to use in auto-spectrum = 1.0e+06, new value =
Low frequency cutoff fmin = (1 / maximum period).
Frequencies < fmin are not processed.

Hanning window cutoff = 0.10, new value =
Hanning window suppresses spectral leakage that occurs when time series to be Fourier transformed contains periodic signal that does not correspond to one of exact frequencies of FFT.

Use **DS** to verify that 26*plus* is set up to sample as desired.

Wave and Tide Setup Command (*continued*)

Example (user input in bold): Set up 26*plus* with quartz pressure sensor to take 2-minute tide measurement (tide measurement duration = 120 seconds) every 60 minutes (tide interval = 60), measure waves after every 6 tide samples (wave burst after every N tide measurements = 6), and take 4096 wave samples per wave burst (wave samples/burst = 4096) at 1 sample per 0.25 second (wave sample duration = 0.25). Set up 26*plus* to start and stop sampling on command, rather than at pre-set start and stop times. Set up 26*plus* to output real-time wave statistics on 512 wave samples per burst. Then send **DS** to verify setup.

```
S>SETSAMPLING
tide interval (integer minutes) = 1, new value = 60
tide measurement duration (seconds) = 60, new value = 120
measure wave burst after every N tide samples: N = 3, new value = 6
number of wave samples per burst (multiple of 4) = 80, new value = 4096
wave Sample duration (0.25, 0.50, 0.75, 1.0) seconds = 0.25, new value = 0.25
use start time (y/n) = y, new value = n
use stop time (y/n) = n, new value = n
TXWAVESTATS (real-time wave statistics) (y/n) = n, new value = y
the remaining prompts apply to real-time wave statistics
show progress messages (y/n) = n, new value = n
number of wave samples per burst to use for wave statistics = 512, new value = 512
use measured temperature and conductivity for density calculation (y/n) = y, new value = n
average water temperature above the pressure sensor (deg C) = 15.0, new value = 15.0
average salinity above the pressure sensor (PSU) = 35.0, new value = 35.0
height of pressure sensor from bottom (meters) = 0.0, new value = 0.0
number of spectral estimates for each frequency band = 5, new value = 6
minimum allowable attenuation = 0.0025, new value = 0.0025
minimum period (seconds) to use in auto-spectrum = 0.00e+00, new value = 0.00e+00
maximum period (seconds) to use in auto-spectrum = 1.00e+06, new value = 1.00e+06
hanning window cutoff = 0.10, new value = 0.10

S>DS
SBE 26plus V 6.1c  SN 12345    10 Dec 2006 13:21:13
user info=test setup
quartz pressure sensor: serial number = 90319, range = 1000 psia
internal temperature sensor
conductivity = YES
iop =  6.0 ma  vmain = 15.3 V  vlith =  9.3 V
last sample: p = 21.9520, t = 21.0250, s = 34.3799

tide measurement: interval = 60.000 minutes, duration = 120 seconds
measure waves every 6 tide samples
4096 wave samples/burst at 4.00 scans/sec, duration = 1024 seconds
logging start time =  do not use start time
logging stop time =  do not use stop time

tide samples/day = 24.00
wave bursts/day = 4.00
memory endurance = 676.1 days
nominal alkaline battery endurance = 973.6 days
deployments longer than 2 years are not recommended with alkaline batteries
total recorded tide measurements = 0
total recorded wave bursts = 0
tide measurements since last start = 0
wave bursts since last start = 0

transmit real-time tide data = YES
transmit real-time wave burst data = YES
transmit real-time wave statistics = YES
real-time wave statistics settings:
        number of wave samples per burst to use for wave statistics = 512
        do not use measured temperature and conductivity for density calculation
        average water temperature above the pressure sensor (deg C) = 15.0
        average salinity above the pressure sensor (PSU) = 35.0
        height of pressure sensor from bottom (meters) =  0.0
        number of spectral estimates for each frequency band = 5
        minimum allowable attenuation = 0.0025
        minimum period (seconds) to use in auto-spectrum = 0.0e+00
        maximum period (seconds) to use in auto-spectrum = 1.0e+06
        hanning window cutoff = 0.10
        do not show progress messages

status = stopped by user
logging = NO, send start command to begin logging
```

Note:
Do not initialize logging until all data has been uploaded. InitLogging does not delete data; it resets the data pointer. **If you accidentally initialize logging before uploading**, recover data as follows:

For Standard ASCII Upload:
1. Set **TideCount=a**, where **a** is your estimate of number of tide samples in memory.
2. Upload data. If **a** is more than actual number of tide samples, data for non-existent samples will be bad, random data. Review uploaded data carefully and delete any bad data.
3. If desired, increase **a** and upload data again, to see if there is additional valid data in memory.

For Binary Upload:
1. Set ***ByteCount=a**, where **a** is your estimate of number of bytes in memory.
2. Upload data. If **a** is more than actual number of bytes, data for non-existent samples will be bad, random data. Review uploaded data carefully and delete any bad data.
3. If desired, increase **a** and upload data again, to see if there is additional valid data in memory.

Initialize Logging (Reset Memory) Commands

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 tide sample number and wave sample number to 0 internally. If not set to 0, data will be stored after last recorded sample. **Do not send InitLogging until all existing data has been uploaded.**

The following two commands are typically used only if you accidentally initialize logging before uploading the data in memory.

TideCount=x

x= sample number for first tide measurement when sampling begins. Use **TideCount=** to recover data if you accidentally initialize logging before uploading, and will be doing an ASCII upload.

***ByteCount=x**

x= byte number for first byte when sampling begins. Use ***ByteCount=** to recover data if you accidentally initialize logging before uploading, and will be doing a binary upload.

Logging Commands

To start logging, send **Start**:
- If ***Use start time?*** in **SetSampling** prompt is ***No***, logging starts approximately 10 seconds after receipt of **Start**.
- If ***Use start time?*** in **SetSampling** prompt is ***Yes***, logging starts at the delayed time set with **SetStartTime**.

The first time logging starts after receipt of initialize logging (**InitLogging**), data recording starts at the beginning of memory and any previously recorded data is written over.

To stop logging:
- Send **Stop**, or
- Before starting logging, set a delayed stop time with **SetStopTime**, and set ***Use stop time?*** in **SetSampling** prompt to ***Yes***.

Each time the 26*plus* is commanded to start logging again, recording continues, with new data stored after previously recorded data.

Notes:
- With Quartz pressure sensor: You can wake up the 26*plus* during a tide measurement and display status (press Enter key to get `S>`, then click Status) without interrupting logging.
- With Strain Gauge pressure sensor: You **cannot** wake up the 26*plus* during a tide measurement and display status. See *General Command Notes* above.
- You may need to send **Stop** several times to get the 26*plus* to respond.
- You must stop logging before uploading data.
- If ***Use start time?*** in the **SetSampling** prompt is ***Yes***, and **SetStartTime** is less than 10 seconds in the future when **Start** is sent, the 26*plus* ignores the programmed start time and starts logging in 10 seconds.
- If ***Use stop time?*** in the **SetSampling** prompt is ***Yes***, and **SetStopTime** is less than 1 hour after logging begins, the 26*plus* ignores the programmed stop time and continues logging until **Stop** is sent.
- See *Setting Time in SBE 26plus to Synchronize Sampling of Multiple Instruments* below to set multiple instruments to start logging at the same time.

Start — If ***Use start time?*** in **SetSampling** prompt is ***No***: Start logging now (in approximately 10 seconds).
OR
If ***Use start time?*** in **SetSampling** prompt is ***Yes***: Wait to start logging at time set with **SetStartTime**.

Stop — Stop logging.

SetStartTime — Set date and time to start logging. 26*plus* prompts you to enter desired date and time. Upon receipt of **Start**, 26*plus* waits to starts logging at this date and time if ***Use start time?*** in **SetSampling** prompt is ***Yes***.

SetStopTime — Set date and time to stop logging. 26*plus* prompts you to enter desired date and time. 26*plus* stops logging at this date and time if ***Use stop time?*** in **SetSampling** prompt is ***Yes***.

Logging Commands (*continued*)

Example 1: Start and stop logging on command (user input in bold).

```
S>SETSAMPLING
 . . . (Respond to prompts, changing tide and wave sampling setup as desired.)
use start time (y/n) = y, new value = n
use stop time (y/n) = y, new value = n
S>START
Logging will start in 10 seconds
```

(If **TxTide=Y**, tide data displays on screen. If **TxWave=Y**, wave data displays on screen.
If TXWAVESTATS prompt in **SetSampling** command is Y, real-time wave statistics display on screen.
See *Programming for Deployment - SeatermW* for a description of screen displays while logging.)

(To stop logging, press Enter key several times to get S> prompt.)

```
S>STOP
```

Example 2: Program 26*plus* to start logging on 20 May 2006 12:35:00 and stop logging on 21 May 2006 12:35:00 (user input in bold).

```
S>SETSAMPLING
 . . . (Respond to prompts, changing tide and wave sampling setup as desired.)
use start time (y/n) = n, new value = y
use stop time (y/n) = n, new value = y
S>SETSTARTTIME
Set time to start logging:
Month (1-12) = 5
Day (1 - 31) = 20
Year (4 digits) =2006
Hour (0 - 23) = 12
Minute (0 - 59) = 35
Second (0 - 59) = 0
S>SETSTOPTIME
Set time to stop logging:
Month (1-12) = 5
Day (1 - 31) = 21
Year (4 digits) =2006
Hour (0 - 23) = 12
Minute (0 - 59) = 35
Second (0 - 59) = 0
S>START
Logging will start at 20 May 2006 12:35:00
Logging will stop at 20 May 2006 12:35:00
```

(When logging starts: If **TxTide=Y**, tide data displays on screen. If **TxWave=Y**, wave data displays on screen.
If TXWAVESTATS prompt in **SetSampling** command is Y, real-time wave statistics display on screen.
See *Programming for Deployment - SeatermW* for a description of screen displays while logging.)

(Logging stops at time set with **SetStopTime**.)

Send Last Sample Commands

Note:
See *General Command Notes* above for issues relating to sending commands while the 26*plus* is making a tide or wave measurement.

These commands cause the 26*plus* to transmit pressure, temperature, and salinity (if optional conductivity sensor installed) from the last tide measurement. These commands are functional only while the 26*plus* is logging (after **Start** has been sent to start logging now or at a future date/time).

- If **Start** has not been sent, the 26*plus* responds with `? CMD`.
- If **Start** has been sent, but there is not yet a completed tide measurement in memory, the 26*plus* responds with:
  `p = -99.0000, t = -99.0000, s = -99.0000`

SL Send pressure, temperature, and salinity (if optional conductivity sensor installed) data from last tide measurement and do not go to sleep (do not enter quiescent state).

SLO Send pressure, temperature, and salinity (if optional conductivity sensor installed) data from last tide measurement and go to sleep (enter quiescent state). Equivalent to sending **SL** and then sending **QS**.

Example: (user input in bold).
```
S>SL
p = 14.5266, t = 22.7003, s = 29.05335
```

Data Upload Commands

Notes:
- **Use SeatermW's Upload menu to upload data in ASCII or binary to a .hex file that will be processed by SEASOFT for Waves** (see *Uploading Data from Memory* below). Manually entering **DD** or **DBbaud,b,e** does not produce data with the required header information for processing by SEASOFT for Waves. These commands are included here for reference for users who are writing their own software.
- To save manually uploaded data to a file, click Capture before entering the upload command.

Stop logging before uploading data.

ASCII Upload:

DD Upload all data from memory **in ASCII** at baud rate set for general communication with **Baud=**.

Binary Upload:

Binary upload, useful for large data sets, is inherently faster than ASCII upload, because each byte is transmitted as one character instead of two. Additionally, the SBE 26*plus* supports binary upload at rates up to 115,200 baud, compared to ASCII upload at rates up to 38,400. SeatermW uploads the data in binary and then converts to ASCII, **resulting in a .hex file with the same format as from an ASCII upload.**

Note:
When SeatermW's Upload menu is used for binary upload, SeatermW automatically tests that the selected upload baud rate is compatible with your computer, sends **ByteCount**, and sends **DBbaud,b,e** as many times as needed to upload all the data in memory in blocks of 500,000 bytes.

DBbaud,b,e Upload data **in binary** at baud rate of **baud** (1200, 2400, 4800, 9600, 19200, 28800, 38400, 57600, or 115200) from byte **b** to byte **e**. First byte number is 0. 26*plus* can upload data in blocks of up to 500,000 bytes at one time. **Sending this command manually does not provide useful information.**

ByteCount Display total number of bytes in memory.

Diagnostic Commands

Data from these tests is not stored in FLASH memory.

TS Take 1 sample of pressure, pressure temperature, temperature, and optional conductivity, and output **converted** data (pressure psia, pressure temperature °C, temperature °C, conductivity S/m, and salinity psu).

Note:
Conductivity and salinity are output only if conductivity is enabled (**Conductivity=Y**).

TSR Take 1 sample of pressure, pressure temperature, temperature, and optional conductivity, and output **raw** data. Output varies, depending on pressure sensor type:

- Quartz pressure sensor: pressure frequency Hz, pressure temperature frequency Hz , temperature A/D counts, and conductivity frequency Hz.
- Strain Gauge pressure sensor: pressure A/D counts, pressure temperature number, temperature A/D counts, and conductivity frequency Hz.

TT Sample temperature, and output **converted** data (°C). 26*plus* runs continuously during test, drawing current. Press Esc key or click Stop to stop test.

TTR Sample temperature, and output **raw** data (A/D counts). 26*plus* runs continuously during test, drawing current. Press Esc key or click Stop to stop test.

FR Measure and display frequencies (Hz).

Column	Output
1	**tf** = pressure frequency (displays only if Quartz pressure sensor)
2	**pf** = pressure temperature compensation frequency (displays only if Quartz pressure sensor)
3	**cf** = conductivity frequency (displays only if conductivity enabled with **Conductivity=Y**)

26*plus* runs continuously during test, drawing current. Press Esc key or click Stop to stop test.

Diagnostic Commands (*continued*)

VR

Measure and display power:

Column	Output
1	Main battery voltage / 11.18
2	Back-up lithium voltage / 4.8187
3	Operating current (mA) / 20.04
4	Ground voltage

26*plus* runs continuously during test, drawing current. Press Esc key or click Stop to stop test.

***FlashInit**

Map bad blocks and erase FLASH memory (2048 blocks), **destroying all data.** 26*plus* requires you to enter ***FlashInit** twice, to provide verification before it proceeds. All data bits are set to 1. Tide and wave sample number are set to 0. **Test takes approximately 1 hour, and cannot be interrupted once it has started.**

Send ***FlashInit** (after uploading all data) if there are FLASH Read errors in Status (**DS**) response. If not encountering errors, use of command is optional, as 26*plus* writes over previously recorded information when **InitLogging** is used before beginning sampling. However, knowledge of initial memory contents (i.e., all 1's) can be a useful cross-check when data is retrieved.

***FlashGood**

Display number of good blocks in FLASH memory (should be 2008 to 2048 blocks, with each block 16K bytes).
If number of good blocks not in this range, consult factory.

Calibration Coefficients Commands

Notes:
- Dates shown are when calibrations were performed. Calibration coefficients are initially factory-set and should agree with Calibration Certificates shipped with 26*plus*.
- See individual commands below to modify calibration coefficients.
- Calibration coefficients are applied to the raw data to output real-time and queried (**SL**, **SLO**, and some testing commands) data in engineering units.
- Pressure, temperature, and conductivity are stored in memory as raw data, before application of calibration coefficients.
- Data is uploaded from memory to a .hex file as raw data and/or partially processed data, depending on the parameter and whether the data is for waves or tides (see *Appendix III: Data Formats*). The .hex file also contains the **DC** command and response. Convert Hex uses the calibration coefficients in the **DC** response to convert the raw data to engineering units. Pressure slope, and ***an additional pressure offset***, are entered in Convert Hex's Coefficient Configuration dialog box to make small post-deployment corrections for pressure sensor drift. Note that the pressure offset entered in Convert Hex is *in addition to* the offset shown in the **DC** response.

See *Section 6: Conversion into Tide and Wave Files – Extract Tide and Convert Hex*; also see *Sensor Calibration* in *Section 10: Routine Maintenance and Calibration*.

DC — Display calibration coefficients. Examples are shown for 26*plus* with quartz pressure sensor and strain gauge pressure sensor.

Example: 26*plus* with Paroscientific Digi**quartz** sensor (user input in bold).

```
S>DC
Pressure coefficients:  15-apr-2004
  U0 = 5.818158e+00
  Y1 = -3.912547e+03
  Y2 = -1.192010e+04
  Y3 = 0.000000e+00
  C1 = -6.273148e+03
  C2 = 1.688132e+02
  C3 = 1.655105e+04
  D1 = 7.040300e-02
  D2 = 0.000000e+00
  T1 = 2.992117e+01
  T2 = 6.588880e-01
  T3 = 4.158092e+01
  T4 = 1.073818e+02
  M = 12582.9          (calculated by 26plus based on factory-input pressure sensor range)
  B = 838.8            (calculated by 26plus based on factory-input pressure sensor range)
  Offset = 0.000000e+00                                                            (psia)
Temperature coefficients:  05-nov-2004
  TA0 = -1.653843e-05
  TA1 = 2.800270e-04
  TA2 = -2.759926e-06
  TA3 = 1.646110e-07
Conductivity coefficients:  05-nov-2004                       (only if Conductivity=Y)
  CG = -8.000000e+00
  CH = 1.483257e+00
  CI = -1.931111e-04
  CJ = 9.170722e-05
  CTCOR = 3.250000e-06
  CPCOR = -9.570000e-08
  CSLOPE = 1.000000e+00
```

Example: 26*plus* with **Strain Gauge** sensor (user input in bold).

```
S>DC
Pressure coefficients:  15-apr-2004
  PA0 = -7.912454e-02
  PA1 = 7.317688e-05
  PA2 = -1.01280e-12
  PTCA0 = 3.446204e+02
  PTCA1 = -4.617518e+01
  PTCA2 = -1.236197e-01
  PTCB0 = 2.488438e+01
  PTCB1 = 2.275000e-03
  PTCB2 = 0.000000e+01
  PTEMPA0 = -8.059255e+01
  PTEMPA1 = 8.183057e+01
  PTEMPA2 = -1.878352e+00
  M = 279620.2         (calculated by 26plus based on factory-input pressure sensor range)
  B = 18641.3          (calculated by 26plus based on factory-input pressure sensor range)
  OFFSET = 0.00                                                                    (psia)
Temperature coefficients:  05-nov-2004
  TA0 = -1.653843e-05
  TA1 = 2.800270e-04
  TA2 = -2.759926e-06
  TA3 = 1.646110e-07
Conductivity coefficients:  05-nov-2004                       (only if Conductivity=Y)
  CG = -8.000000e+00
  CH = 1.483257e+00
  CI = -1.931111e-04
  CJ = 9.170722e-05
  CTCOR = 3.250000e-06
  CPCOR = -9.570000e-08
  CSLOPE = 1.000000e+00
```

Note:
F = floating point number
S = string with no spaces

The individual Coefficients Commands listed below are used to modify a particular coefficient or date:

Quartz Pressure

PCalDate=S	**S**=calibration date.
PU0=F	**F**=U0.
PY1=F	**F**=Y1.
PY2=F	**F**=Y2.
PY3=F	**F**=Y3.
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.
POffset=F	**F**=pressure offset (psia).

Strain Gauge Pressure

PCalDate=S	**S**=calibration date.
PA0=F	**F**=A0.
PA1=F	**F**=A1.
PA2=F	**F**=A2.
PTCA0=F	**F**=PTCA0.
PTCA1=F	**F**=PTCA1.
PTCA2=F	**F**=PTCA2.
PTCB0=F	**F**=PTCB0.
PTCB1=F	**F**=PTCB1.
PTCB2=F	**F**=PTCB2.
PTEMPA0=F	**F**=PTEMPA0.
PTEMPA1=F	**F**=PTEMPA1.
PTEMPA2=F	**F**=PTEMPA2.
POffset=F	**F**=pressure offset (psia).

Temperature

TCalDate=S	**S**=calibration date.
TA0=F	**F**=A0.
TA1=F	**F**=A1.
TA2=F	**F**=A2.
TA3=F	**F**=A3.

Conductivity

CCalDate=S	**S**=calibration date.
CG=F	**F**=G.
CH=F	**F**=H.
CI=F	**F**=I.
CJ=F	**F**=J.
CTCOR=F	**F**=TCOR.
CPCOR=F	**F**=PCOR.
CSlope=F	**F**=Slope correction.

Using SBE 26*plus* as a Tide Recorder

Note:
It is not possible to completely eliminate wave measurements in the 26*plus*.

If you are not interested in wave data, the SBE 26*plus* can be set up to minimize the number of wave measurements. Respond to the prompts in the **SetSampling** command as follows:

- *measure wave burst after every N tide samples*: Set to 10,000, which is the largest allowable number.
- *number of wave samples per burst (multiple of 4)* = : Set to 4, which is the smallest allowable number.
- *TXWAVESTATS (real-time wave statistics) (y/n)* = : Set to N, which disables calculation of real-time wave statistics.
- *Remaining parameters*: Set as desired.

With this sampling scheme, the 26*plus* will do a wave burst consisting of 4 measurements after every 10,000 tide samples. The wave measurement will have minimal effect on power and memory consumption, allowing you to maximize the number of tide samples.

Using SBE 26*plus* as a Wave Recorder

Note:
It is not possible to completely eliminate tide measurements in the 26*plus*.

If you are not interested in tide data, the SBE 26*plus* can be set up to minimize the number of tide measurements. Respond to the prompts in the **SetSampling** command as follows:

- *tide interval (integer minutes)* = : Set to the interval at which you want to take wave bursts.
- *tide measurement duration* = : Set to 10 sec, which is the smallest allowable number.
- *Measure wave burst after every N tide samples*: Set to 1.
- *Remaining parameters*: Set as desired.

With this sampling scheme, the 26*plus* will do a tide measurement lasting for 10 seconds each time it does a wave burst. The tide measurement will have minimal effect on power and memory consumption, allowing you to maximize the number of wave bursts.

Setting Time in SBE 26*plus* to Synchronize Sampling of Multiple Instruments

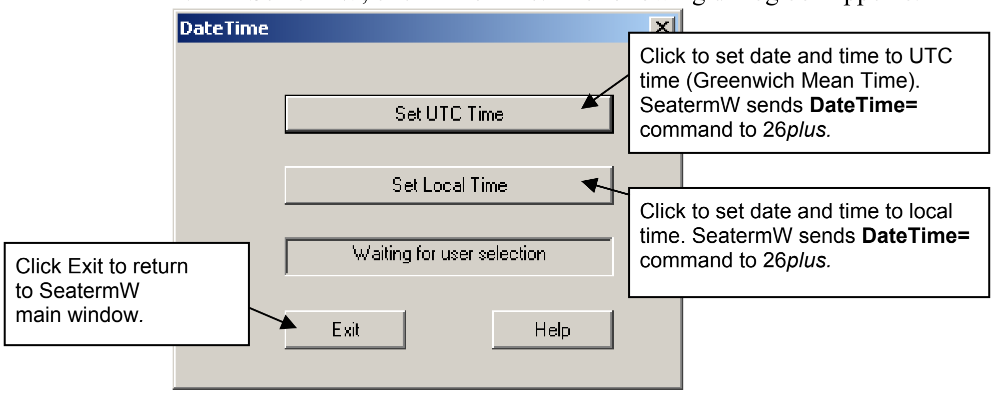
Note:
Software to provide accurate time on your computer is not supplied by Sea-Bird.

If you are running software on your computer that provides the computer with an accurate real-time stamp, the DateTime menu in SeatermW allows you to set the date and time in the SBE 26*plus* to an accuracy of ± 25 msec of the time provided by the timekeeping software. This may be useful if you plan to deploy several instruments, and want to coordinate sampling so that each 26*plus* measures tides and waves on exactly the same schedule. Coordinating sampling can be accomplished by:

- Setting the time in each instrument accurately, using the DateTime menu,
- Setting up each instrument to sample at the same intervals and durations, and
- Setting up each instrument to start sampling at a delayed date and time – using the same start date and time for each instrument.

Set accurate time and coordinate sampling as follows:

1. In SeatermW, click DateTime. The following dialog box appears:



   Click the desired time setting (UTC or local time). SeatermW sends the **DateTime=** command to the 26*plus*, using the computer date and time. Click Exit.

2. If desired, set up the 26*plus* to start logging at some time in the future, allowing you to coordinate sampling to begin in multiple instruments at the same time:
   - Send the **SetStartTime** command to the 26*plus*. The 26*plus* prompts you to enter the desired start date and time.
   - Send the **SetSampling** command. Set up the desired sampling scheme, and enter Y in response to the ***Use start time?*** prompt.

Installing and Deploying SBE 26*plus*

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

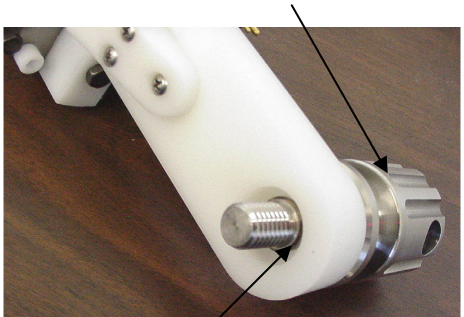
1. Install a cable (if transmitting real-time tide and/or wave data) or dummy plug for the data I/O connector (4-pin for standard RS-232, 6-pin for optional RS-422 / RS-485) on the 26*plus* end cap:
   A. Lightly lubricate the inside of the cable connector/plug with silicone grease (DC-4 or equivalent).
   B. **Standard Connector** - Install the connector/plug, aligning the raised bump on the side of the plug with the large pin (pin 1 – ground) on the 26*plus*. Remove any trapped air by *burping* or gently squeezing the plug near the top and moving your fingers toward the end cap.
   OR
   MCBH Connector – Install the connector/plug, aligning the pins.
   C. Place the locking sleeve over the connector/plug. Tighten the locking sleeve finger tight only. **Do not overtighten the locking sleeve and do not use a wrench or pliers**.

2. If not using the SBE 4M conductivity sensor, install a dummy plug and locking sleeve on the 26*plus* 3-pin bulkhead connector. Use the technique described in Step 1 for lubricating and burping a standard connector.

Note:
Acquisition of conductivity data must be enabled by sending **Conductivity=Y** in SeatermW when programming the 26*plus* for deployment.

3. (Optional) Install the SBE 4M conductivity sensor:
   A. Mount the SBE 4M to the 26*plus* with the supplied mounting bracket, positioning the SBE 4M connector towards the conductivity connector on the 26*plus*.
   B. Connect the SBE 4M to the 26*plus* with the supplied cable, using the technique described in Step 1 for lubricating and burping a standard connector, and then installing the locking sleeve.
   C. Remove the Tygon tubing that was looped end-to-end around the SBE 4M conductivity cell to keep the cell clean while stored.
   D. See *Application Note 70: Installing Anti-Foulant Device Mount Kit on SBE 4, 16, 19, and 21 Conductivity Cells* and *Appendix V: AF24173 Anti-Foulant Device*.

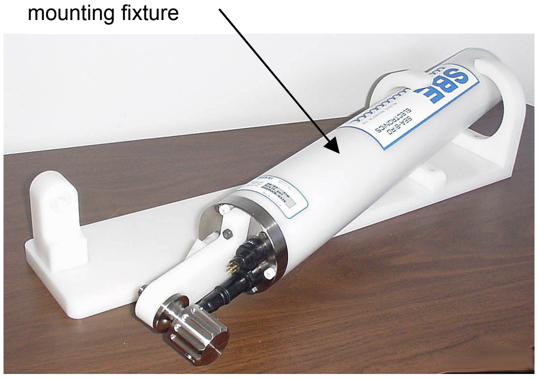
Mooring pin

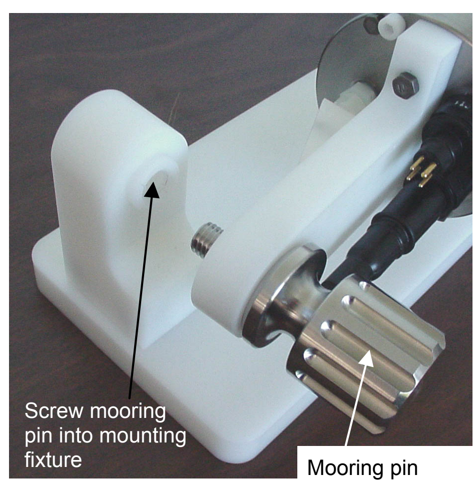


Install retaining ring in recess after inserting mooring pin

4. (Optional) Mount the 26*plus* in the Sea-Bird mounting fixture:
   A. Slide the mooring pin through the 26*plus* lift eye hole in the direction shown.
   B. Install the retaining ring in the lift eye hole recess, to hold the mooring pin to the 26*plus*. Push part of the retaining ring into the recess, and hold it in place with a small tool (such as tweezers or small screwdriver). Using another pair of tweezers, work your way around the retaining ring, pushing it into the recess.
   C. Rotate the 26*plus* into the mounting fixture as shown.
   D. Screw the mooring pin into the mounting fixture.

Rotate 26*plus* into mounting fixture





Mooring pin

Recovering SBE 26*plus*

WARNING!
If the 26*plus* stops working while underwater, 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 600 meters depth holds an internal pressure of more than 800 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 26*plus* is flooded, point the 26*plus* in a safe direction away from people, and loosen the 3 screws on the connector end cap about ½ turn. If there is internal pressure, the end cap will *follow* the screws out, and the screws will not become easier to turn. In this event, loosen 1 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.

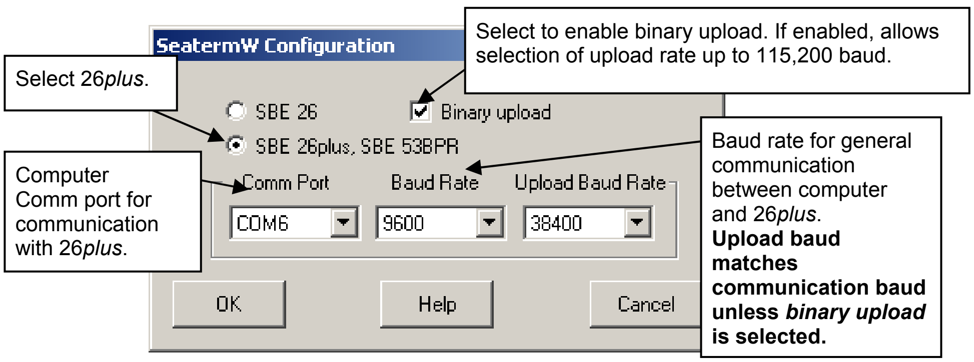
Rinse the 26*plus* with fresh water. See *Section 10: Routine Maintenance and Calibration* for (optional) conductivity cell cleaning and storage.

Uploading Data from Memory

The SBE 26*plus* can upload data in ASCII at baud rates up to 38,400, or in binary at baud rates up to 115,200. Binary upload at 115,200 is approximately **six times faster** than ASCII upload at 38,400, because each byte is one character in binary but two characters in ASCII. Binary upload of the full memory (32 MB) at 115,200 baud requires approximately 3.5 hours.
If binary upload is selected, SeatermW uploads the data in binary and then converts the data to ASCII, resulting in a .hex data file that is identical to one uploaded in ASCII.

1. In SEASOFT for Waves' Run menu, select SeatermW. SeatermW appears.

2. Click Configure. The Configuration dialog box appears. Verify/modify the instrument, Comm port, and baud rate, and whether to upload in binary (if *binary upload* is selected) or in ASCII. Click OK.



3. Click Connect. The S> displays. This shows that correct communications between the computer and 26*plus* has been established.
   If the system does not respond with the S> prompt:
   - Click Connect again.
   - Verify the correct instrument, Comm port, and baud rate were selected.
   - Check cabling between the computer and 26*plus*.

4. If the 26*plus* is still logging, command it to stop logging by typing **Stop** and pressing the Enter key. You may need to press the Esc key before entering **Stop** to get the 26*plus* to stop if it is in the middle of sampling.

5. Display 26*plus* status information by clicking Status. The status response should indicate `logging = no`.

Note:
The 26*plus* communicates at 9600 baud (factory-set default), 8 data bits, 1 stop bit, and no parity, as documented on the instrument Configuration Sheet. Baud rate can be changed with **Baud=**; other parameters cannot be modified.

Note:
Although SeatermW sends **DBbaud,b,e** to upload data in binary, the uploaded .hex file shows the **DD** command, so the file looks exactly the same, regardless of whether ASCII or binary upload was used.

6. Click Upload to upload stored data in a form that SEASOFT for Waves' data processing modules can use. SeatermW responds as follows:
   A. SeatermW sends the status (**DS**) command, displays the response, and writes the command and response to the upload file, with each line preceded by *****. **DS** provides information regarding the number of samples in memory, tide interval, etc.
   B. SeatermW sends the calibration coefficients (**DC**) command, displays the response, and writes the command and response to the upload file, with each line preceded by *****. **DC** provides information regarding the sensor calibration coefficients.
   C. In the Save As dialog box, enter the desired upload file name and click OK. The upload file has a .hex extension.
   D. **ASCII Upload** (if binary upload was not selected in Step 2) – SeatermW sends the data upload command (**DD**). SeatermW writes the data to the upload file. The Status bar at the bottom of the SeatermW window displays the progress of the upload, indicating the number of uploaded lines of data.
   E. **Binary Upload** (if binary upload was selected in Step 2) – SeatermW tests that the selected binary upload baud rate is supported by your computer. If it is not, the upload is aborted.
      SeatermW sends **ByteCount** to determine how many bytes of data are in memory, because only 500,000 bytes can be uploaded in one block.
      SeatermW sends the data upload command (**DBbaud,b,e**), as many times as needed to upload all the data in memory in blocks of 500,000 bytes.
      SeatermW converts the binary data back to ASCII, and writes the data to the upload file. The Status bar at the bottom of the SeatermW window displays the progress of the upload, indicating the number of uploaded lines of data.

7. Type **QS** and press the Enter key to put the 26*plus* in quiescent (sleep) state until ready to redeploy.

8. Ensure all data has been uploaded by processing the data. See *Section 6: Conversion into Tide and Wave Files – Extract Tide and Convert Hex*.

Section 6: Conversion into Tide and Wave Files – Extract Tide and Convert Hex

This section covers:

- Splitting uploaded data from multiple logging sessions into separate data files using ExtractTide.exe.
- Converting uploaded hex (.hex) data into separate wave data (.wb) and tide data (.tid) files, with data in engineering units, using Convert Hex in SEASOFT for Waves. The data must be converted and split into separate wave and tide files before further processing by SEASOFT for Waves.

Extract Tide

Note:
Extract Tide is not accessed through SEASOFT for Waves. It is a separate program that is automatically installed when SEASOFT for Waves is installed, in the same directory as SEASOFT for Waves.

The SBE 26*plus* memory can hold data from multiple logging sessions. Each time logging is started, a beginning tide record is stored, to designate the start of the logging session. **If the uploaded file includes data from multiple logging sessions, run Extract Tide to separate each session into a separate file before converting the data with Convert Hex.** If you try to run Convert Hex on a file containing data from multiple sessions, Convert Hex provides an error message directing you to run Extract Tide.

If you are not certain if the 26*plus* memory holds data from multiple sessions, send **DS** and review the response. If the total number of tide measurements in memory does not equal the number of tide measurements since the last start, the memory holds data from multiple sessions.

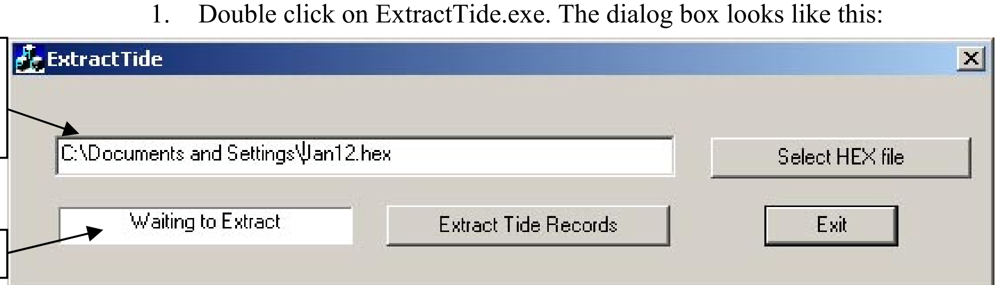
Example: 26*plus* memory holds data from multiple logging sessions. Status response shows 5 tide measurements since last logging start, but 10 total tide measurements in memory.

```
S>DS
SBE 26plus V 6.1a  SN 12345    26 Jan 2006 13:21:13
. . . .
total recorded tide measurements = 10
total recorded wave bursts = 2
tide measurements since last start = 5
wave bursts since last start = 1
. . . .
```

Since these are not equal, memory holds data from multiple logging sessions.

1. Double click on ExtractTide.exe. The dialog box looks like this:

.hex file uploaded from 26*plus* memory. Click *Select HEX file* to search for file, or type in path and file name.



Status bar

2. Click *Extract Tide Records* to process the data; when completed, the Status bar shows *Finished, x files created*, where x is the number of logging sessions in the uploaded data. Extract Tide creates a separate file for each time logging was started, with -1, -2, etc. appended to the file name. For example, if there are 3 logging sessions recorded in Jan12.hex, the output file names will be Jan12-1.hex, Jan12-2.hex, and Jan12-3.hex. Run Convert Hex on each file created by Extract Tide.

Convert Hex

Note:
If the uploaded file includes data from multiple logging sessions, run Extract Tide before you run Convert Hex.

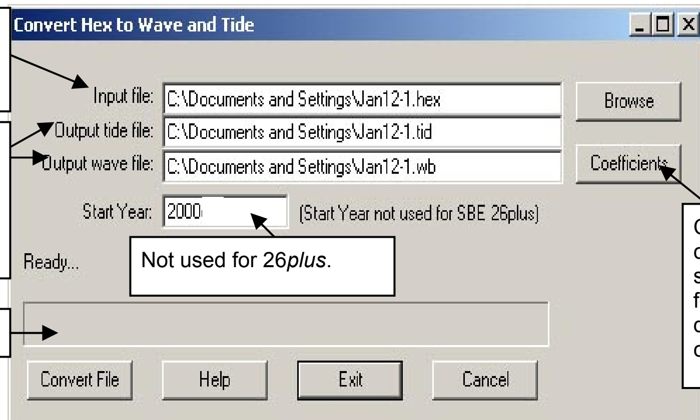
Convert Hex converts uploaded hex (.hex) data into separate wave (.wb) and tide (.tid) files, with data in ASCII engineering units. Convert Hex must be run before further processing by SEASOFT for Waves.

1. In SEASOFT for Waves' Run menu, select Convert Hex. The dialog box looks like this:

.hex file uploaded from 26*plus* memory or output from Extract Tide. Click Browse to search for file, or type in path and file name.

Desired path and file names for output tide (.tid) and wave (.wb) file. Default paths and file names are same as input .hex file.
If desired, type in path and file name to change it from default.

Conversion status bar.

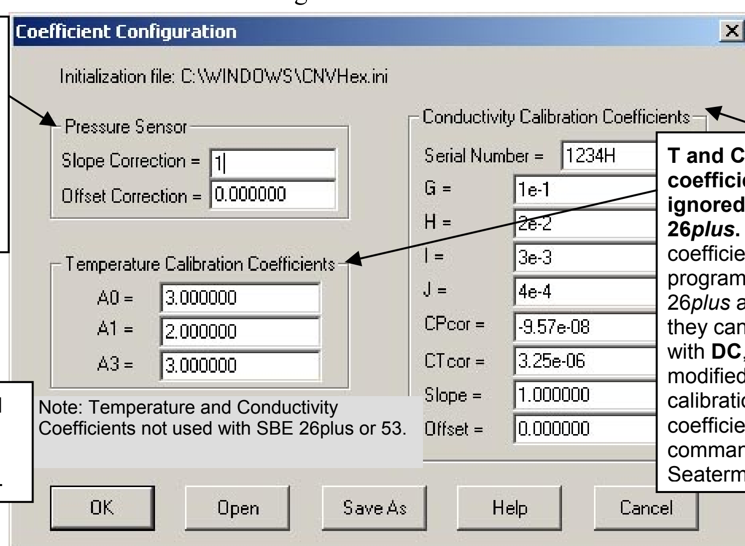


Calibration coefficients to make small corrections for pressure sensor drift between calibrations.

Enter information in the dialog box. Click Coefficients to enter / verify calibration coefficients for converting hex data to engineering units.

2. The Coefficients dialog box looks like this:

Slope and offset (psia) used to make small corrections for pressure sensor drift between calibrations. Other P coefficients are programmed into 26*plus* at Sea-Bird; they can be viewed with **DC**, and modified with calibration coefficient commands, in SeatermW. Note that offset entered here is *in addition to* offset shown in **DC** response.



T and C coefficients are ignored for 26*plus*. T and C coefficients are programmed into 26*plus* at Sea-Bird; they can be viewed with **DC**, and modified with calibration coefficient commands, in SeatermW.

OK to return to Convert Hex to Wave and Tide dialog box.
Open to select a different .ini file.
Save As to save updated .ini file settings.

Make desired changes. Click OK to return to Convert Hex to Wave and Tide dialog box.

Note:
Each time you save the .ini file, Convert Hex copies it to CNVHex.ini, in your Windows directory. You can copy and rename the .ini file if desired, to save the slope and offset entered for a particular instrument. Next time you open Convert Hex, it automatically opens CNVHex.ini; you can select a different .ini file if desired.

3. Click *Convert File* to process the data. The Status bar at the bottom of the dialog box shows the progress of the calculations; when completed, the Status bar shows *Finished conversion*.
   - If you have a .hex file with multiple logging sessions, and did not run Extract Tide, Convert Hex provides the following error message:
     ```
     Can not process a file with multiple tide records,
     run EXTRACTTIDE.EXE to separate the records.
     ```
     Run Extract Tide, and then run Convert Hex for each of the files created by Extract Tide.

Section 7: Tide Data Processing – Merge Barometric Pressure

Merge Barometric Pressure reads in a tide (.tid) file (created with Convert Hex) and a barometric pressure (.bp) file, and subtracts barometric pressure from the tide data. The time in the files does not need to be aligned – Merge Barometric Pressure uses linear interpolation to align the data in time before subtracting barometric pressure. Merge Barometric Pressure can also convert tide pressure to water depth in meters, using average density and gravity.

Both the input tide data and output adjusted file have a .tid extension. However, Merge Barometric Pressure will not process a .tid file that it has already processed, preventing a user from erroneously removing barometric pressure multiple times from the tide data.

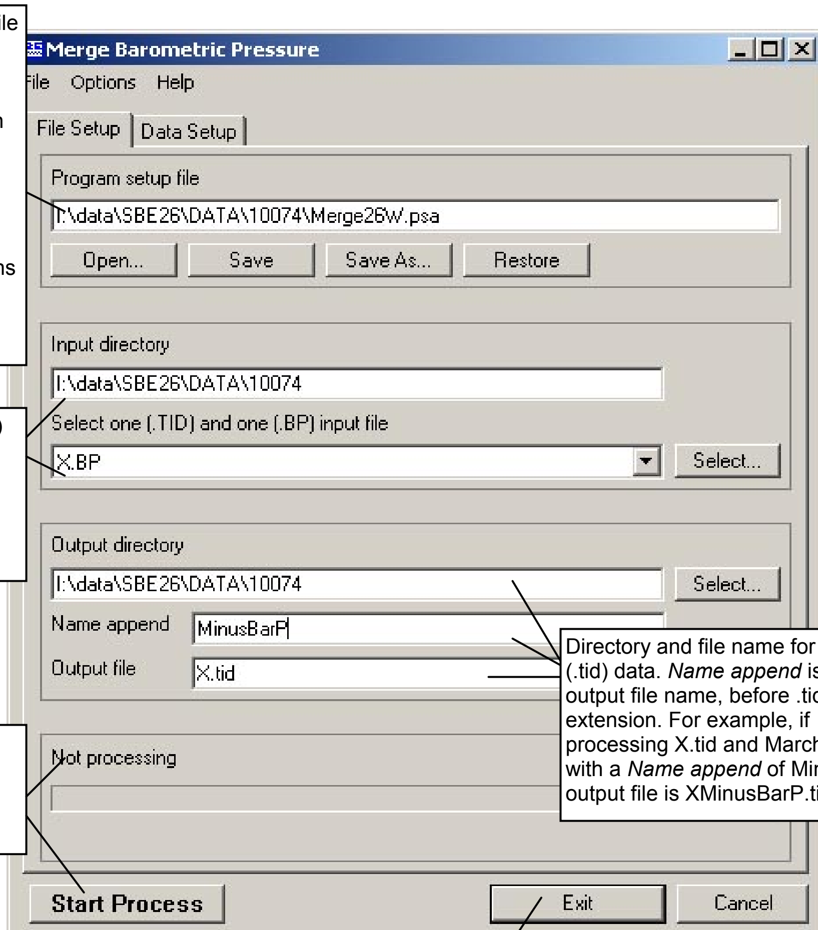
Remove barometric pressure as follows:

1. In SEASOFT for Waves' Run menu, select Merge Barometric Pressure. The File Setup tab looks like this:

File to store all information input in File Setup and Data Setup tabs. **Open** to select a different .psa file, **Save** or **Save As** to save current settings, or **Restore** to reset all settings to match last saved version. As a default, .psa file is stored in same directory as SeasoftWavesLaunch.exe (default is c:/Program Files/Sea-Bird/ SeasoftWaves). SeasoftWaves.ini, located in Windows directory, contains location and file name of last saved .psa file and options settings for each module.

Directory and file names for tide (.tid) data and barometric pressure (.bp) data. Note that both .tid and .bp files must be in same directory, but they can have different names. **Select** to pick different files.

Click **Start Process** to begin processing data. Status field shows *Processing complete* when done.

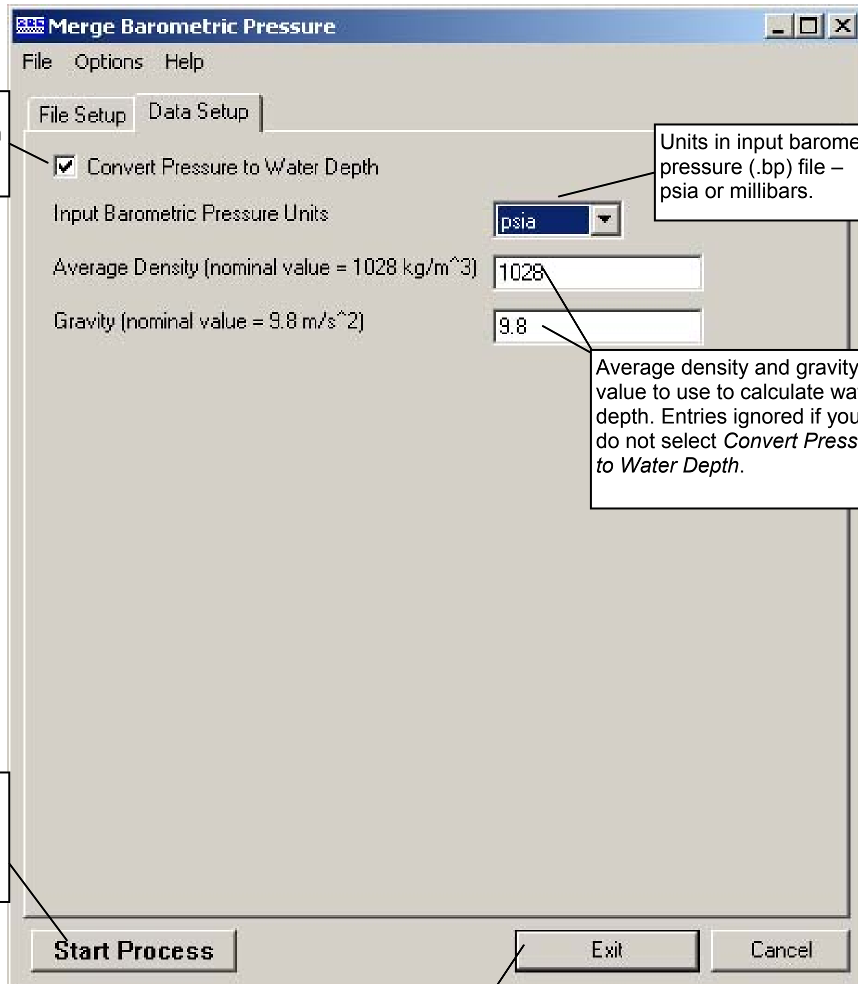


Directory and file name for output (.tid) data. *Name append* is added to output file name, before .tid extension. For example, if processing X.tid and March03.bp with a *Name append* of MinusBarP, output file is XMinusBarP.tid.

Return to SEASOFT for Waves window.
- If *Confirm Program Setup Change* was selected in Options menu - If you made changes and did not Save or Save As, program asks if you want to save changes.
- If *Confirm Program Setup Change* was not selected in Options menu - This says **Save & Exit**. If you do not want to save changes, click Cancel to exit.

Make the desired selections.

2. Click on the Data Setup tab. The Data Setup tab looks like this:



If selected, output .tid file contains water depth *in place of* pressure.

Units in input barometric pressure (.bp) file – psia or millibars.

Average density and gravity value to use to calculate water depth. Entries ignored if you do not select *Convert Pressure to Water Depth*.

Click **Start Process** to begin processing data. Status field on File Setup tab shows *Processing complete* when done.

Return to SEASOFT for Waves window.

- If *Confirm Program Setup Change* was selected in Options menu - If you made changes and did not Save or Save As, program asks if you want to save changes.
- If *Confirm Program Setup Change* was not selected in Options menu - This says **Save & Exit**. If you do not want to save changes, click Cancel to exit.

Make the desired selections and click *Start Process* to process the data.

Note:
Merge Barometric Pressure adds descriptive headings to the pressure (or depth), temperature, and optional conductivity and salinity columns. The presence of headings in the .tid file indicates that it has been processed by Merge Barometric Pressure. See *Appendix III: Data Formats*.

Input Barometric Pressure File Format

The required format for the input barometric pressure (.bp) file is:

MM/DD/YY HH:MM:SS P
MM/DD/YY HH:MM:SS P

where

MM = month	DD = day	YY = year
HH = hour	MM = minute	SS = second

P = barometric pressure in psia or millibars
(1 standard atmosphere = 14.7 psia or 1013.5 millibars)

Example .bp File:

```
07/01/94  00:00:00  1015.5
07/01/94  01:00:00  1016.4
07/01/94  02:00:00  1017.3
```

Merge Barometric Pressure Algorithm

The linear interpolation algorithm is:

$p_{bp} = p0 + [(t - t0) * (p1 - p0) / (t1 - t0)]$
corrected pressure = $p - p_{bp}$

where

t = time of tide sample in .tid file
p = pressure in .tid file at time t
t0 = latest time in .bp file that is less than or equal to t
p0 = barometric pressure at time t0
t1 = earliest time in .bp file that is greater than or equal to t
p1 = barometric pressure at time t1
p_{bp} = interpolated barometric pressure

Depth is calculated as:

depth = corrected pressure / (average density * gravity)

See Appendix VII: Pressure-to-Depth Conversion.

Section 8: Wave Data Processing –
Process Wave Burst Data and Create Reports

Notes:
- See *Appendix VI: Wave Theory and Statistics* for details on the calculations made by SEASOFT for Waves.
- The 26*plus* can also be programmed to output real-time wave statistics. See *Command Descriptions* in *Section 5: SBE 26plus Setup, Installation, and Data Upload – SeatermW*.

SEASOFT for Waves includes two wave data processing modules, which are covered in this section:

- Process Wave Burst Data – Compute wave statistics from an input .wb wave burst file. Output .was statistics and results from auto-spectrum analysis, .rpt summary report, .wts statistics from surface wave zero crossing analysis, .wt surface wave time series, and .wss Fast Fourier Transform coefficients.

- Create Reports - Create .r26 file with one line of surface wave time series and/or wave burst auto-spectrum statistics for each processed wave burst, from input .was and .wts files.

Process Wave Burst Data

Process Wave Burst Data computes wave statistics from an input .wb wave burst file (created in Convert Hex). Process Wave Burst Data outputs three (or optionally four or five) files:

- Statistics and results from auto-spectrum analysis to a .was file.

- Summary report from auto-spectrum analysis to a .rpt file.

- Statistics from surface wave zero crossing analysis to a .wts file.

- (optional) Surface wave time series to a .wt file

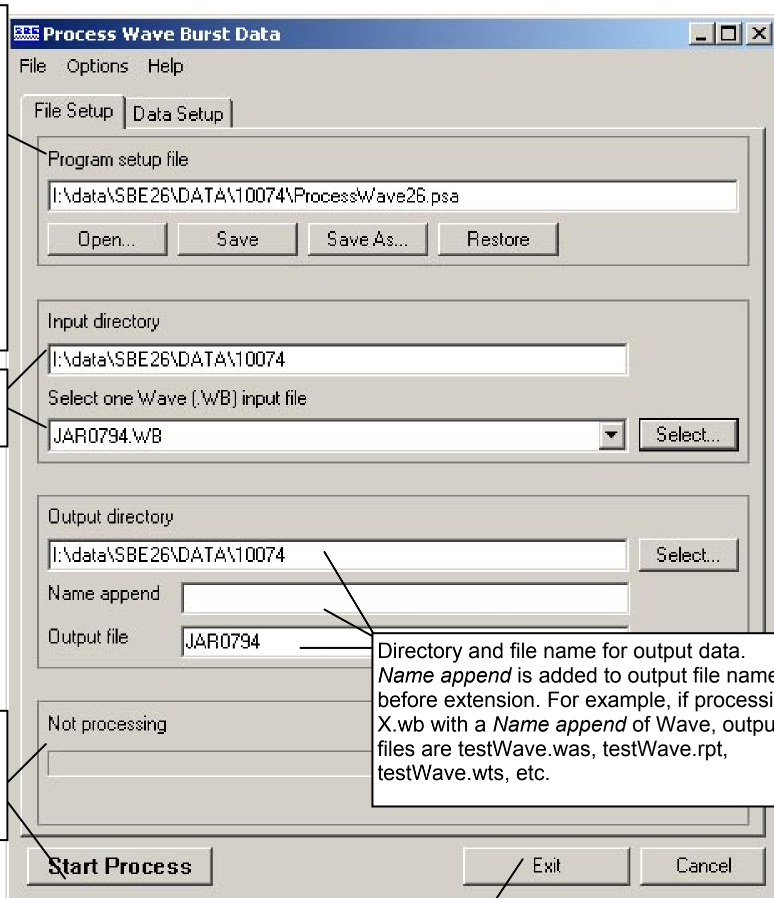
- (optional) Fast Fourier Transform coefficients to a .wss file

Process wave data as follows:

1. In SEASOFT for Waves' Run menu, select Process Wave Burst Data. The File Setup tab looks like this:

File to store all information input in File Setup and Data Setup tabs. **Open** to select a different .psa file, **Save** or **Save As** to save current settings, or **Restore** to reset all settings to match last saved version. As a default, .psa file is stored in same directory as SeasoftWavesLaunch.exe (default is c:/Program Files/Sea-Bird/SeasoftWaves). SeasoftWaves.ini, located in Windows directory, contains location and file name of last saved .psa file and options settings for each module.

Directory and file name for wave (.wb) data. **Select** to pick different file.



Directory and file name for output data. *Name append* is added to output file name, before extension. For example, if processing X.wb with a *Name append* of Wave, output files are testWave.was, testWave.rpt, testWave.wts, etc.

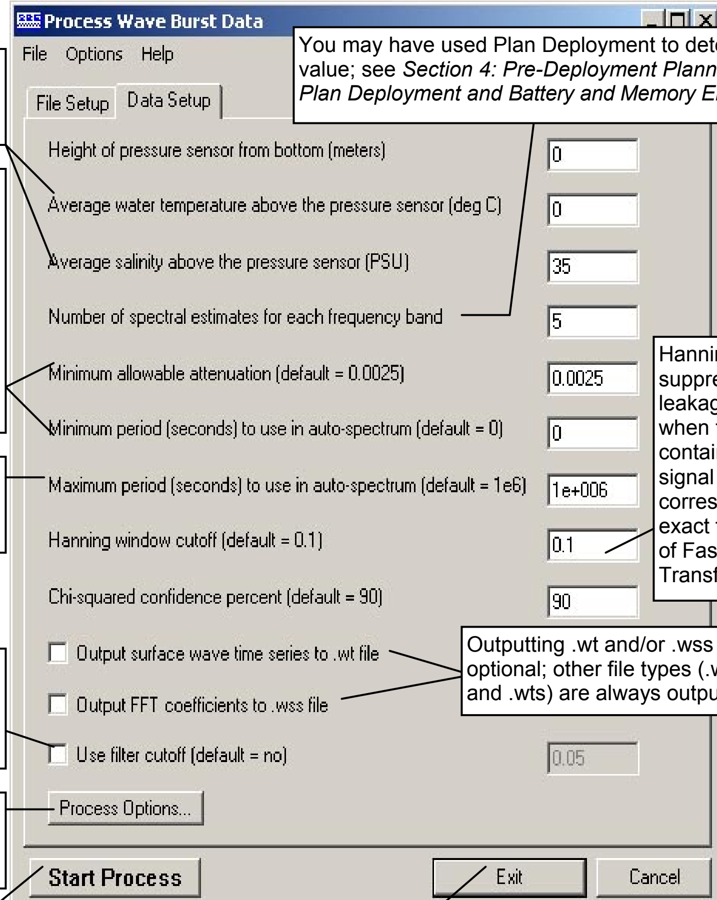
Click **Start Process** to begin processing data. Status field shows *Processing complete* when done.

Return to SEASOFT for Waves window.

- If *Confirm Program Setup Change* was selected in Options menu - If you made changes and did not Save or Save As, program asks if you want to save changes.
- If *Confirm Program Setup Change* was not selected in Options menu - This says **Save & Exit**. If you do not want to save changes, click Cancel to exit.

Make the desired selections.

2. Click on the Data Setup tab. The Data Setup tab looks like this:



You may have used Plan Deployment to determine desired value; see *Section 4: Pre-Deployment Planning – Plan Deployment and Battery and Memory Endurance*.

Average temperature and salinity used to calculate density, required for wave statistics algorithm.

High frequency cutoff for processing wave data, fmax, is smaller of:
- frequency where (measured pressure / pressure at surface) < (minimum allowable attenuation / wave sample duration).
- 1 / minimum period

If getting high frequency noise in output, adjust minimum allowable attenuation and/or minimum period. Frequencies > fmax are not processed unless *Use filter cutoff* is selected.

Low frequency cutoff fmin = (1 / maximum period). Frequencies < fmin are not processed unless *Use filter cutoff* is selected.

Hanning window suppresses spectral leakage that occurs when time series contains periodic signal that does not correspond to one of exact frequencies of Fast Fourier Transform.

If **not** selected, all Fourier coefficients for frequencies > fmax and < fmin are set to 0. If selected, filter ramps Fourier coefficients down to 0 for frequencies > fmax and < fmin.

Outputting .wt and/or .wss files is optional; other file types (.was, .rpt, and .wts) are always output.

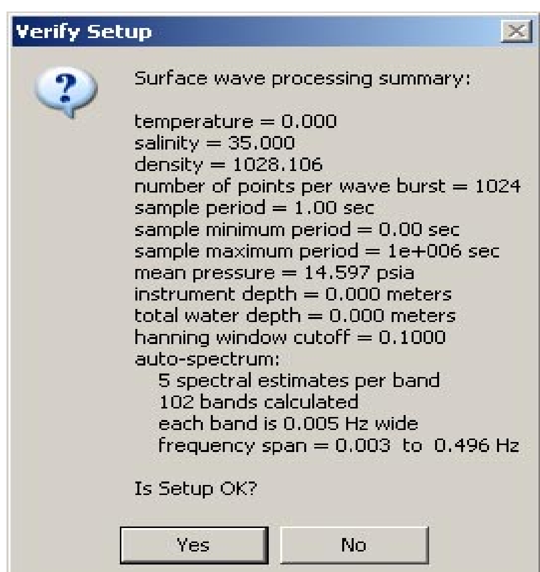
Select number of wave bursts to process and number of wave bursts to skip at start of data file. Default - process all bursts.

Begin processing. Status field on File Setup tab shows *Processing complete* when done.

Return to SEASOFT for Waves window.
- If *Confirm Program Setup Change* was selected in Options menu - If you made changes and did not Save or Save As, program asks if you want to save changes.
- If *Confirm Program Setup Change* was not selected in Options menu - This says **Save & Exit**. If you do not want to save changes, click Cancel to exit.

Make the desired selections and click *Start Process* to process the data.

3. The Verify Setup dialog box appears:



The dialog box summarizes data from the input .wb file and user inputs from the Data Setup tab, and shows calculated values for density, number of bands, band width, and frequency span. Review the summary; click *Yes* to process data.

Process Wave Burst Data Algorithm

For each wave burst, Process Wave Burst Data performs an auto spectrum analysis:

- Reads burst into an array.
- Removes mean, saves mean value.
- Uses mean value, and average water temperature and average salinity (input by user) to compute density.
- Removes trend.
- Makes array a power of two.
- Applies Hanning window to suppress side-lobe leakage.
- Adjusts scale factor to account for tapering by Hanning window.
- Fast Fourier Transforms to create raw spectral estimates of subsurface pressure.
- Computes maximum frequency to process.
- Sets Fourier coefficients greater than maximum frequency or less than minimum frequency to 0; **or**
  (if Use filter cutoff is selected) applies a filter that ramps the Fourier coefficients down to 0 for frequencies greater than maximum frequency or less than minimum frequency
- Saves Fourier coefficients.
- Band averages raw spectral estimates to create auto-spectrum.
- Applies dispersion transfer function to band center frequencies.
- Calculates wave statistics from auto-spectrum: variance, energy, significant wave height, and significant period.

Using the saved (non-band-averaged) Fourier coefficients, Process Wave Burst Data performs a surface wave zero crossing analysis:

- Applies dispersion transfer function to each frequency.
- Inverse Fast Fourier Transforms to create surface wave time series.
- Applies inverse Hanning window and adjusts scale factor.
- Zeroes all elements where inverse Hanning factor is greater than 10.
- Performs zero crossing analysis of surface wave time series to create an array of individual waves and their corresponding periods.
- Sorts wave array in ascending order.
- Calculates wave statistics from surface wave time series:
  average wave height, average period, maximum wave height, significant period, significant wave height $H_{1/3}$, $H_{1/10}$, $H_{1/100}$.

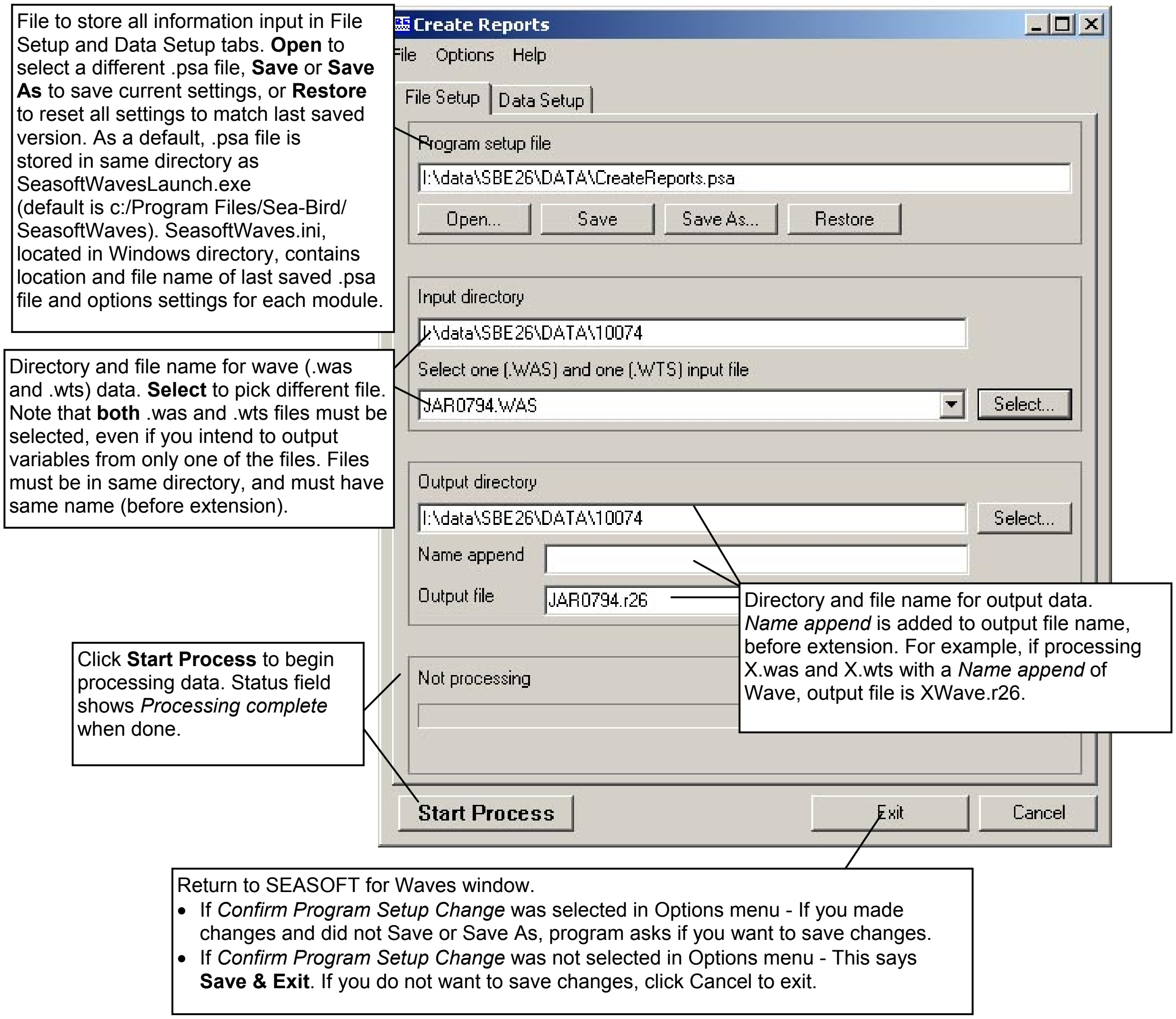
Create Reports: Summarize Wave Data

Create Reports creates a file containing one line of surface wave time series and/or wave burst auto-spectrum statistics for each processed wave burst. The input .wts file contains surface wave time series statistics and the input .was file contains wave burst auto spectrum statistics (these files are created in Process Wave Burst Data). The output .r26 file format is user-defined and can contain one or more of the following variables:

	Variable	Column Label
From Surface Wave Time Series Statistics (.wts) File	time	time
	burst number	burst
	pressure sensor depth	depth
	number of waves	nwaves
	variance	var-wts
	Energy	energy-wts
	average wave height	avgheight
	average wave period	avgper
	maximum wave height	maxheight
	significant wave height	swh-wts
	significant wave period	swp-wts
	$H_{1/10}$	H1/10
	$H_{1/100}$	H1/100
From Wave Burst Auto-Spectrum Statistics (.was) File	variance	var-was
	energy	energy-was
	significant wave height	swh-was
	significant wave period	swp-was

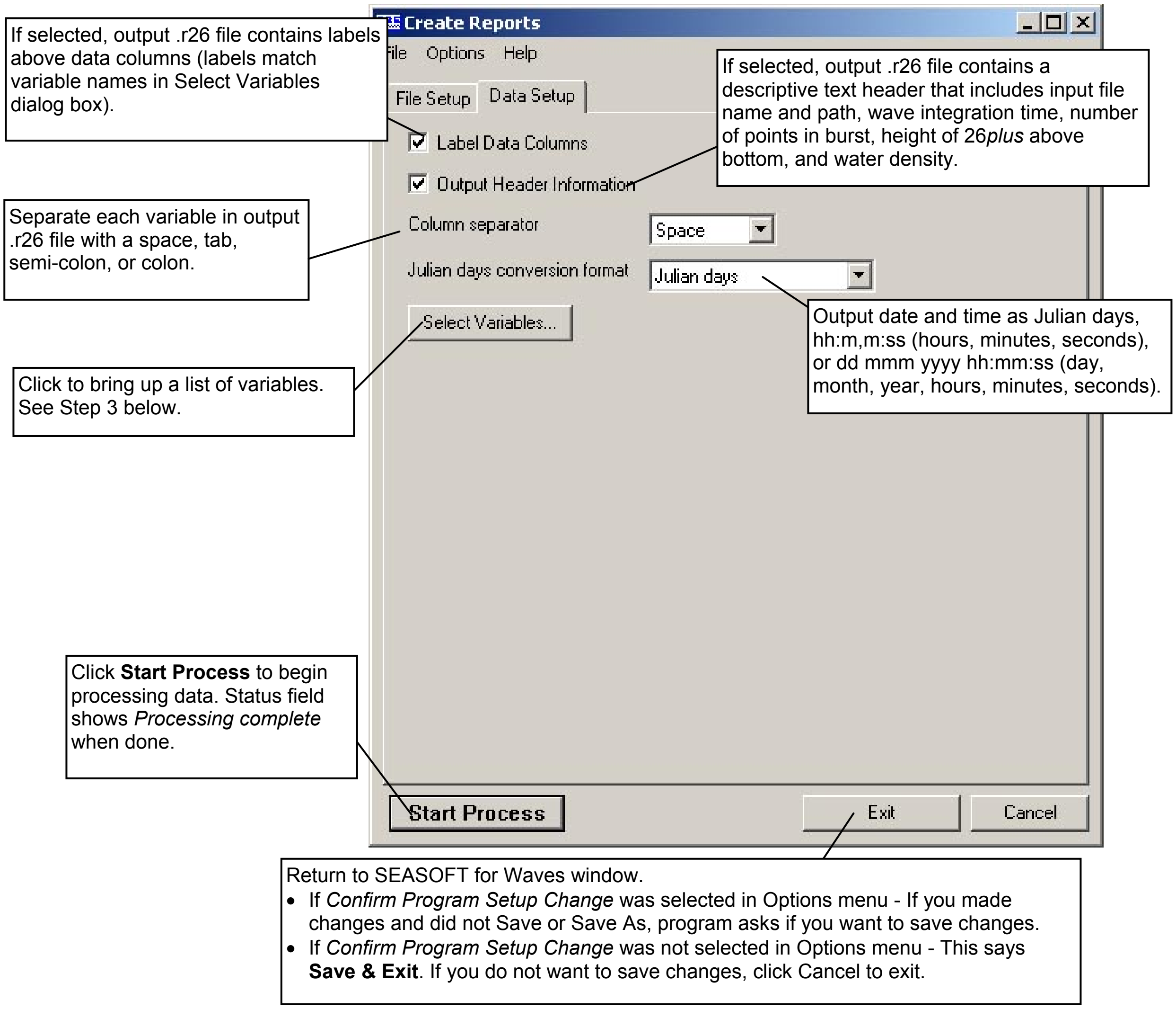
Proceed as follows:

1. In SEASOFT for Waves' Run menu, select Create Reports. The File Setup tab looks like this:



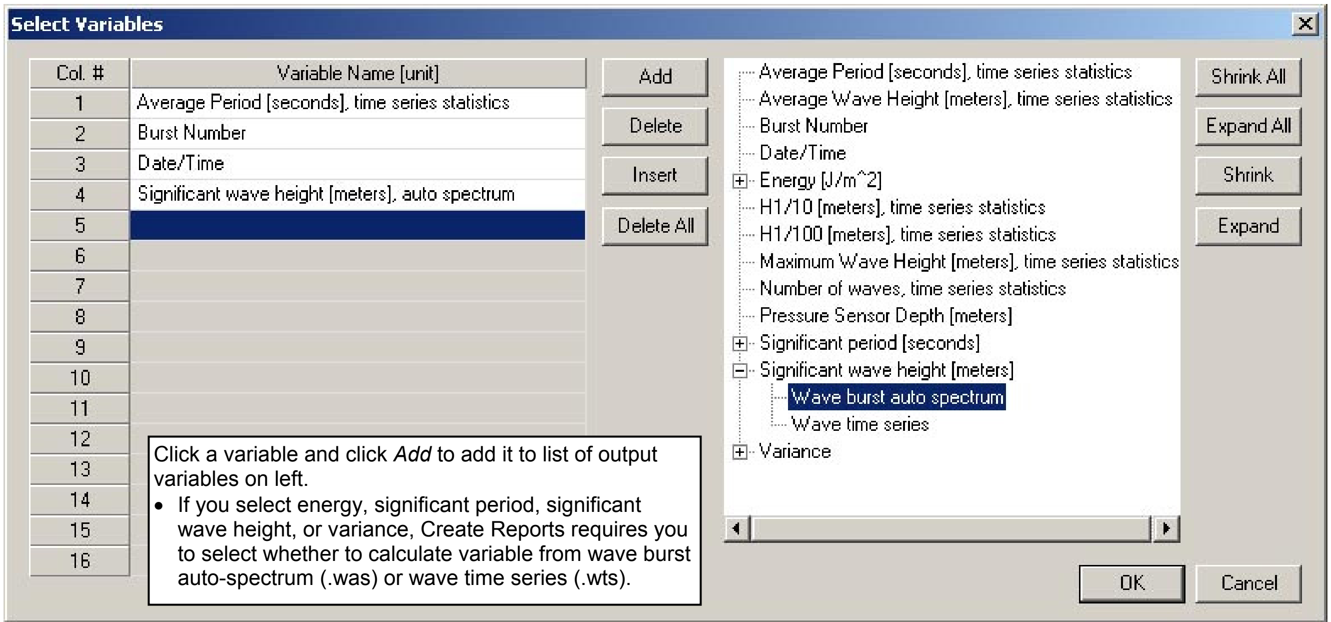
Make the desired selections.

2. Click on the Data Setup tab. The Data Setup tab looks like this:



Make the desired selections.

3. Click *Select Variables*. The Select Variables dialog box looks like this:



Make the desired selections and click *OK* to return to the Create Reports data setup tab.

4. Click *Start Process* to process the data.

Section 9: Data Plotting – Plot Data

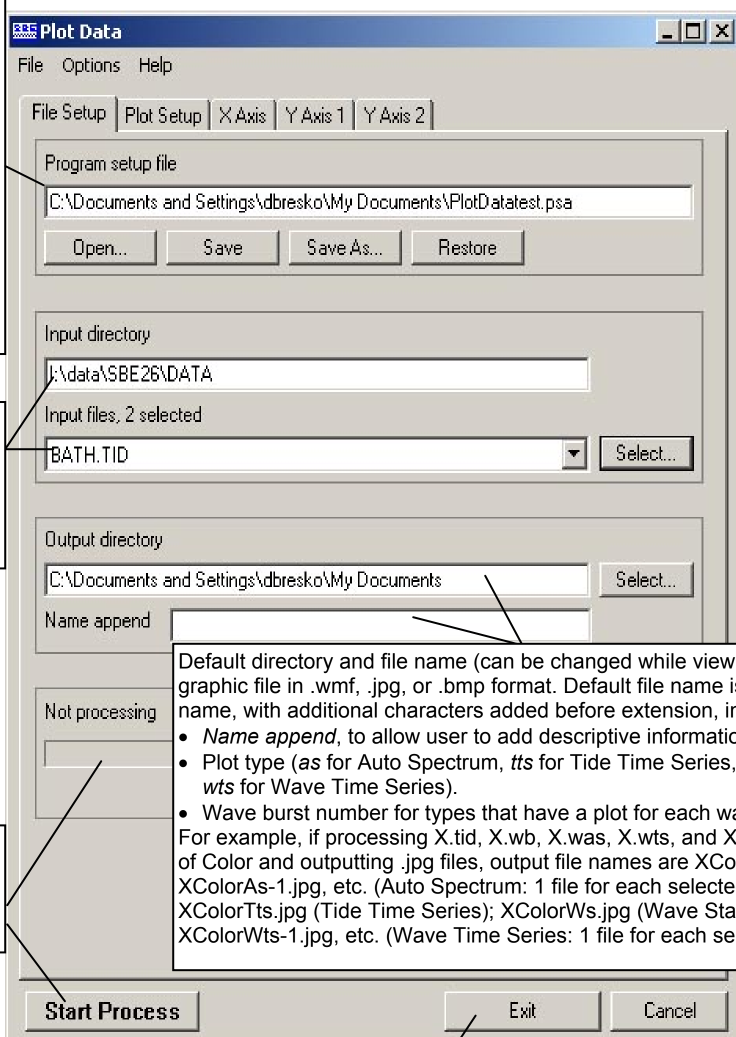
Plot Data displays and plots data from files with a .tid, .wb, .was, .wts, or .wt file extension. Plot Data:

- Plots up to five variables on one plot, with one X axis and up to four Y axes.
- Zooms in on plot features.
- Sends plots to a printer, saves plots to the clipboard for insertion in another program (such as Microsoft Word), or saves plots as graphic files in bitmap, metafile, or JPEG format.

In SEASOFT for Waves' Run menu, select Plot Data. Each tab of the dialog box is described below, as well as options for viewing, printing, and saving plots.

File Setup Tab

The File Setup tab defines the Program Setup file, input data file(s), and output plot file name. The File Setup tab looks like this:



File to store all information input in File, Plot, and Axis tabs. **Open** to select a different .psa file, **Save** or **Save As** to save current settings, or **Restore** to reset all settings to match last saved version. As a default, psa file is stored in same directory as SeasoftWavesLaunch.exe (default is c:/Program Files/Sea-Bird/SeasoftWaves). SeasoftWaves.ini, located in Windows directory, contains location and file name of last saved .psa file and options settings for each module.

Directory and file names for input data files (.tid, .wb, .was, .wts, and / or .wt files). All files must be in same directory and have same name before extension. **Select** to pick different files.

Default directory and file name (can be changed while viewing plot) for outputting graphic file in .wmf, .jpg, or .bmp format. Default file name is set to match input file name, with additional characters added before extension, in order listed below:

- *Name append*, to allow user to add descriptive information to file name.
- Plot type (*as* for Auto Spectrum, *tts* for Tide Time Series, *ws* for Wave Statistics, or *wts* for Wave Time Series).
- Wave burst number for types that have a plot for each wave burst

For example, if processing X.tid, X.wb, X.was, X.wts, and X.wt with a Name Append of Color and outputting .jpg files, output file names are XColorAs-0.jpg, XColorAs-1.jpg, etc. (Auto Spectrum: 1 file for each selected wave burst); XColorTts.jpg (Tide Time Series); XColorWs.jpg (Wave Statistics); XColorWts-0.jpg, XColorWts-1.jpg, etc. (Wave Time Series: 1 file for each selected wave burst).

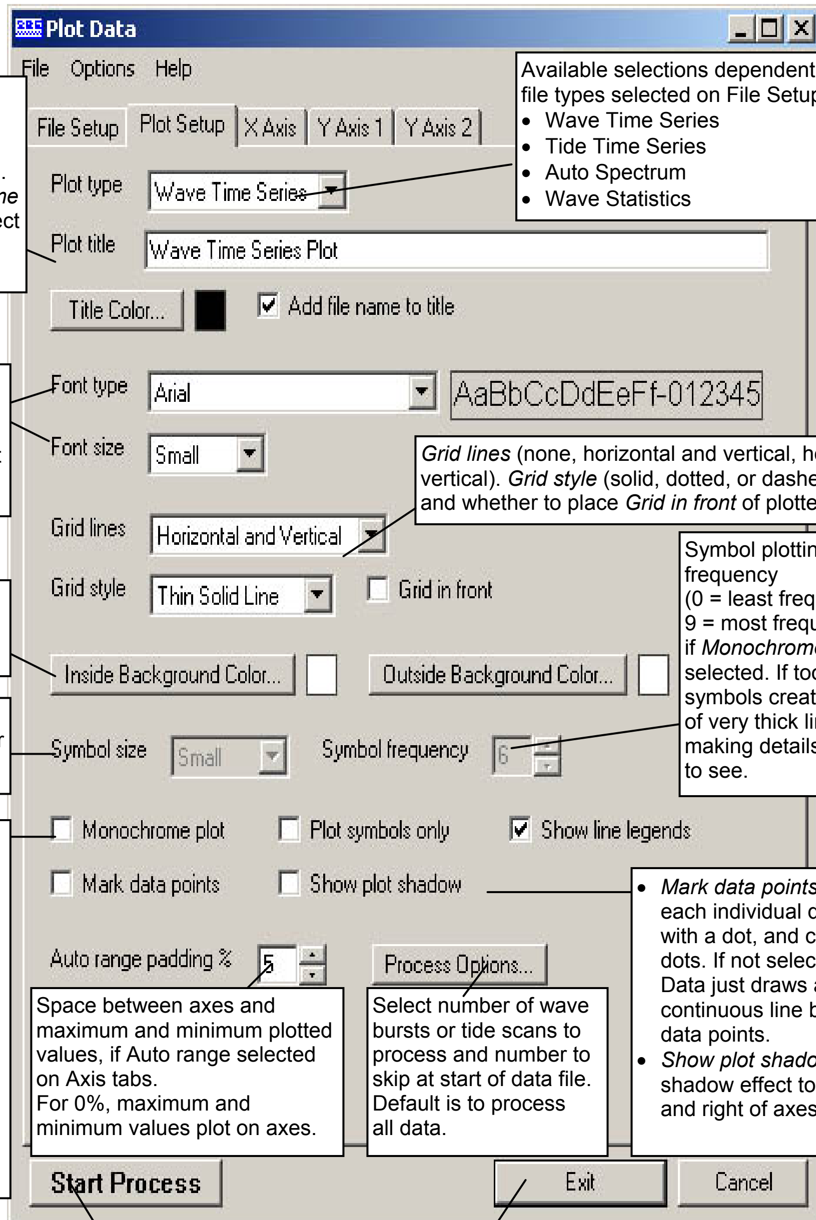
Click **Start Process** to begin processing data. Status field shows *Processing complete* when done.

Return to SEASOFT for Waves window.

- If *Confirm Program Setup Change* was selected in Options menu - If you made changes and did not Save or Save As, program asks if you want to save changes.
- If *Confirm Program Setup Change* was not selected in Options menu - This says **Save & Exit**. If you do not want to save changes, click Cancel to exit.

Plot Setup Tab

The Plot Setup tab defines the plot type, data to be included, and plot layout (title, color, font, grid lines, etc.). The Plot Setup tab looks like this:



- User input *Plot title*.
- User selected *Title color*.
- Select *Add file name to title* to add input data file name to user input title. For example, for a plot title *Wave Time Series* with input file *X.wb*, if you select *Add file name to title*, title is *Wave Time Series, X.wb*.

Available selections dependent on input file types selected on File Setup tab:
- Wave Time Series
- Tide Time Series
- Auto Spectrum
- Wave Statistics

Plot *Font type* and *Font size* (small, medium, or large). Plot Data displays example of font type to right of selection. List of fonts depends on what fonts are installed on your computer.

Grid lines (none, horizontal and vertical, horizontal, vertical). *Grid style* (solid, dotted, or dashed line), and whether to place *Grid in front* of plotted data.

Inside Background Color defines color within axes. *Outside Background Color* defines color outside axes.

Symbol plotting frequency (0 = least frequent, 9 = most frequent), if *Monochrome plot* selected. If too frequent, symbols create illusion of very thick line, making details difficult to see.

Size (small, medium, large) of symbol for each variable, if *Monochrome plot* or *Plot symbols only* selected.

- *Monochrome plot*: Substitute black lines with symbols for colors (colors and symbols defined on Axis tabs). Allows you to set up axes with colors for viewing on screen, and then switch to black lines with symbols for black and white printing.
- *Plot symbols only*: Mark each individual data point with a symbol, and do not connect symbols with a line (symbols defined on Axis tabs).
- *Show line legends*: Show legends below plot title. Legend indicates line color or symbol, as applicable.

- *Mark data points*: Mark each individual data point with a dot, and connect dots. If not selected, Plot Data just draws a continuous line between data points.
- *Show plot shadow*: Create shadow effect to bottom and right of axes.

Space between axes and maximum and minimum plotted values, if Auto range selected on Axis tabs.
For 0%, maximum and minimum values plot on axes.

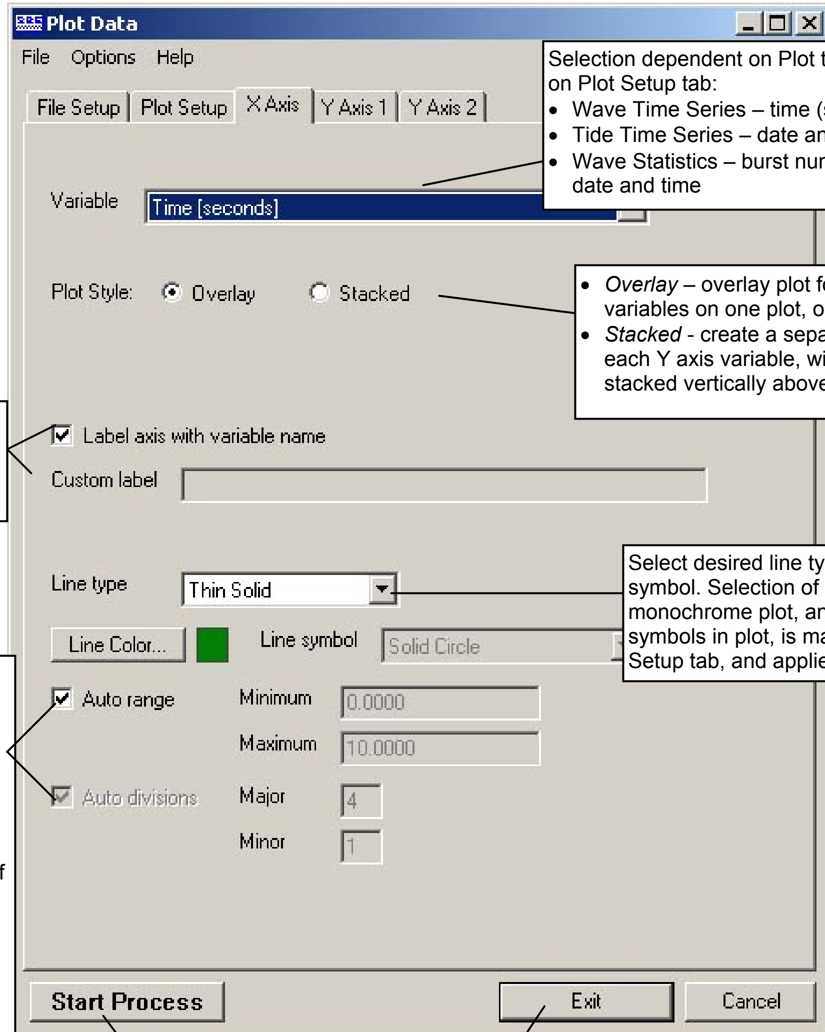
Select number of wave bursts or tide scans to process and number to skip at start of data file. Default is to process all data.

Click **Start Process** to begin processing data. Status field shows *Processing complete* when done.

Return to SEASOFT for Waves window.
- If *Confirm Program Setup Change* was selected in Options menu - If you made changes and did not Save or Save As, program asks if you want to save changes.
- If *Confirm Program Setup Change* was not selected in Options menu - This says **Save & Exit**. If you do not want to save changes, click Cancel to exit.

X Axis Tab

Click on the X Axis tab. The X Axis tab defines the plot style as well as the X axis variable, scale, and line type.
The X Axis tab looks like this for **Wave Time Series**, **Tide Time Series**, or **Wave Statistics**:



Selection dependent on Plot type selected on Plot Setup tab:

- Wave Time Series – time (seconds)
- Tide Time Series – date and time
- Wave Statistics – burst number or date and time

- *Overlay* – overlay plot for all Y axis variables on one plot, or
- *Stacked* - create a separate plot for each Y axis variable, with plots stacked vertically above each other.

Select to label axis with variable name as listed in drop down Variable list, or enter Custom label for axis.

Select desired line type, color, and symbol. Selection of color or monochrome plot, and inclusion of symbols in plot, is made on Plot Setup tab, and applies to all axes.

- *Auto range* - Plot Data selects axis Minimum and Maximum values, number of Major divisions on axis, and number of Minor divisions between Major divisions.
- *Auto divisions* - Plot Data selects number of major divisions on axis, and number of minor divisions between major divisions. User selects axis Minimum and Maximum values.

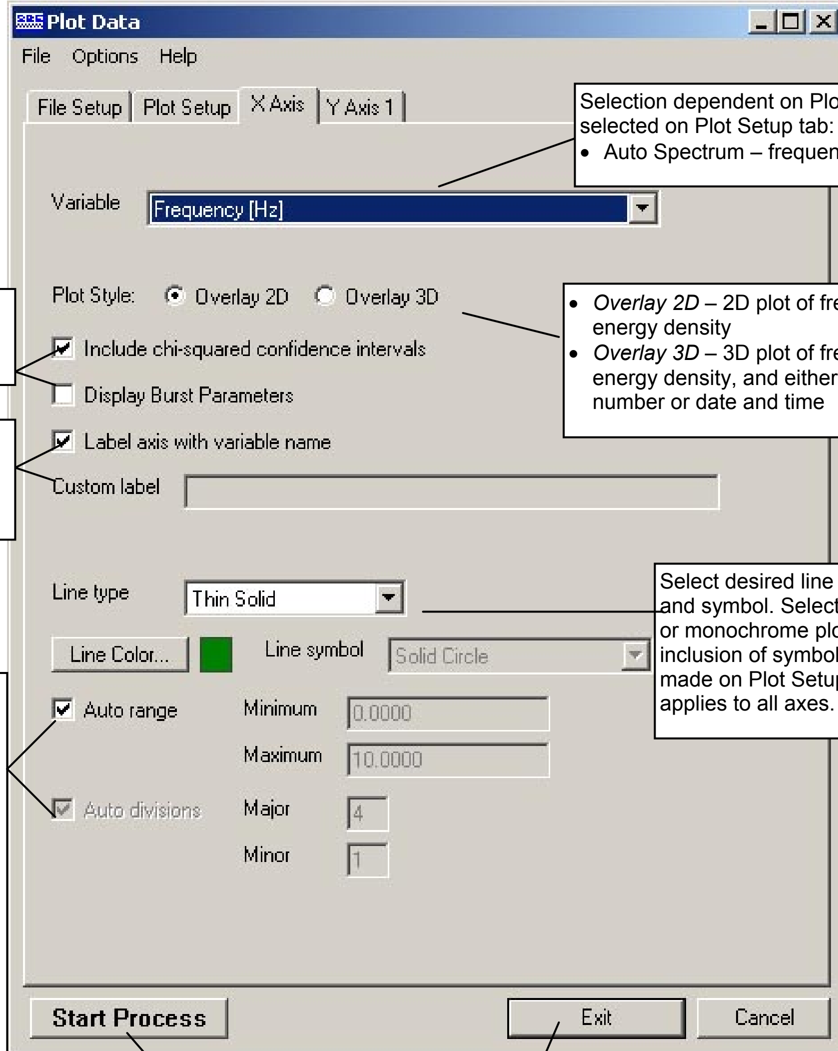
Any values that fall outside user-selected Minimum to Maximum range will plot at minimum or maximum, as applicable.

Click **Start Process** to begin processing data. Status field shows *Processing complete* when done.

Return to SEASOFT for Waves window.

- If *Confirm Program Setup Change* was selected in Options menu - If you made changes and did not Save or Save As, program asks if you want to save changes.
- If *Confirm Program Setup Change* was not selected in Options menu - This says **Save & Exit**. If you do not want to save changes, click Cancel to exit.

The X Axis tab looks like this for **Auto Spectrum**:



Selection dependent on Plot type selected on Plot Setup tab:

- Auto Spectrum – frequency (Hz)

If selected, confidence intervals and burst parameters display in text at right of a 2D plot.

- *Overlay 2D* – 2D plot of frequency and energy density
- *Overlay 3D* – 3D plot of frequency, energy density, and either burst number or date and time

Select to label axis with variable name as listed in drop down Variable list, or enter a Custom label for axis.

Select desired line type, color, and symbol. Selection of color or monochrome plot, and inclusion of symbols in plot, is made on Plot Setup tab, and applies to all axes.

- *Auto range* - Plot Data selects axis Minimum and Maximum values, number of Major divisions on axis, and number of Minor divisions between Major divisions.
- *Auto divisions*: - Plot Data selects number of major divisions on axis, and number of minor divisions between major divisions. User selects axis Minimum and Maximum values.

Any values that fall outside user-selected Minimum to Maximum range will plot at minimum or maximum, as applicable.

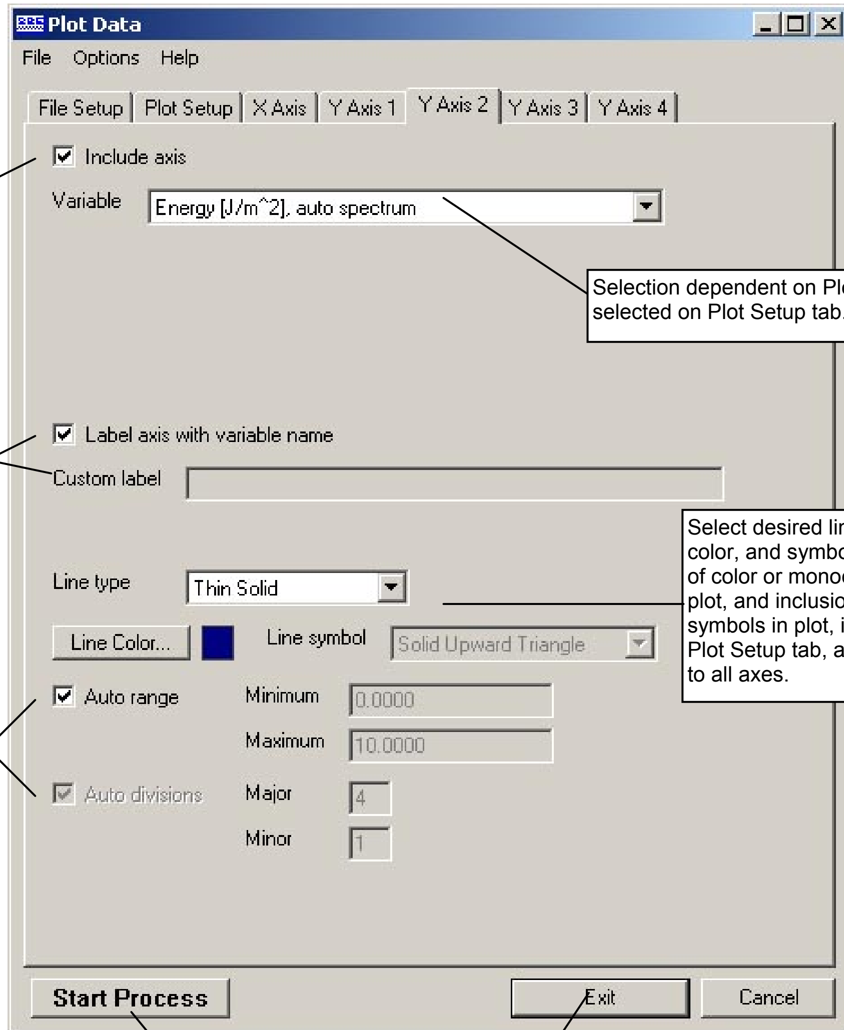
Click **Start Process** to begin processing data. Status field shows *Processing complete* when done.

Return to SEASOFT for Waves window.

- If *Confirm Program Setup Change* was selected in Options menu - If you made changes and did not Save or Save As, program asks if you want to save changes.
- If *Confirm Program Setup Change* was not selected in Options menu - This says **Save & Exit**. If you do not want to save changes, click Cancel to exit.

Y Axis Tab

The Y Axis tabs define the Y axis variables, scales, and line types.



Include this axis in plot. Plot Data can plot 1 X and up to 4 Y axes. At least 1X and 1 Y variable is required, so this selection is available only on Y Axis 2, 3, and 4.
Note: If you deselect an axis, all axes numbered *above* that axis are automatically deselected.

Selection dependent on Plot type selected on Plot Setup tab.

Select to label axis with variable name as listed in drop down Variable list, or enter a Custom label for axis.

Select desired line type, color, and symbol. Selection of color or monochrome plot, and inclusion of symbols in plot, is made on Plot Setup tab, and applies to all axes.

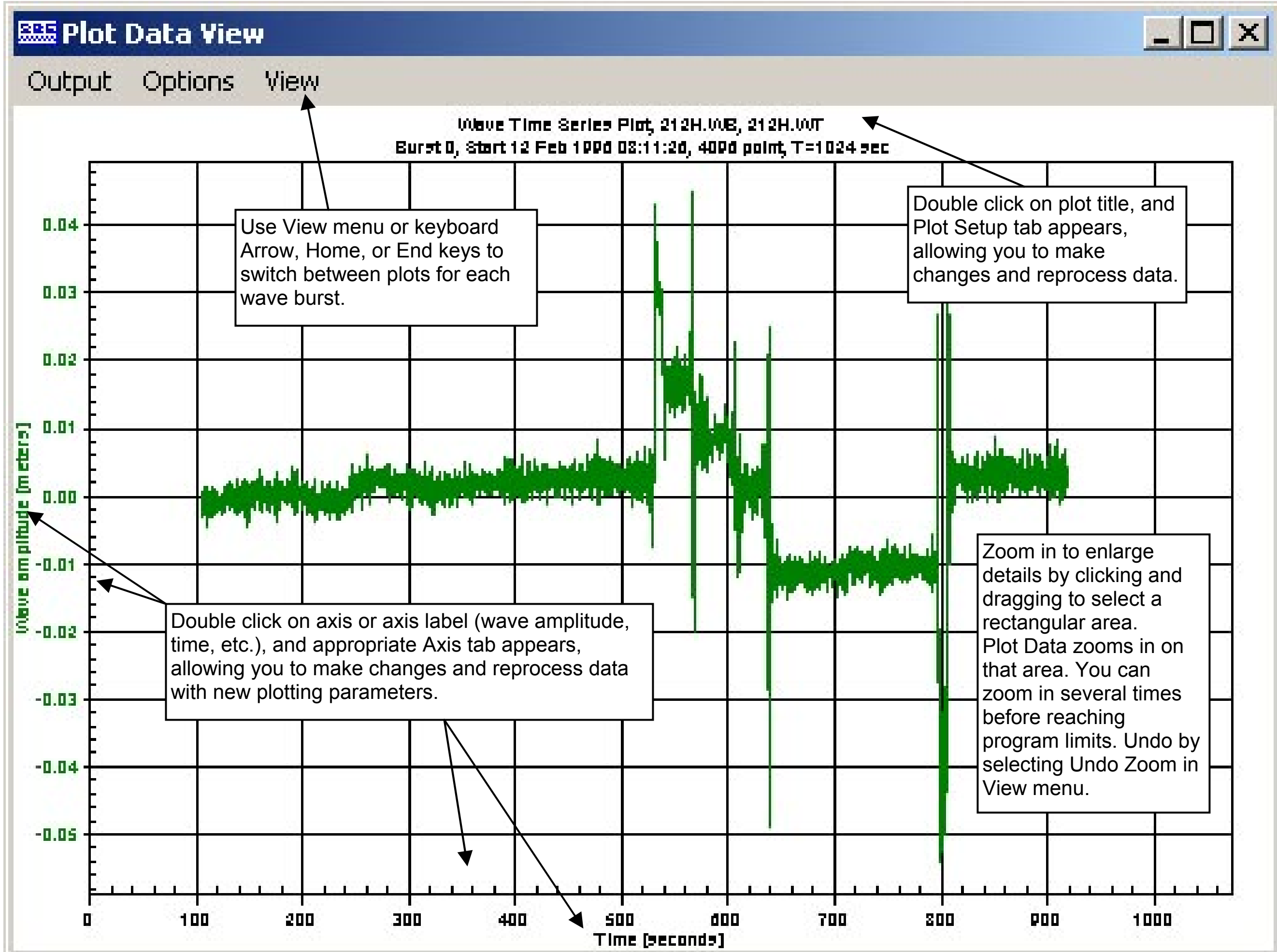
- *Auto range* - Plot Data selects axis Minimum and Maximum values, number of Major divisions on axis, and number of Minor divisions between Major divisions.
- *Auto divisions* - Plot Data selects number of major divisions on axis, and number of minor divisions between major divisions. User selects axis Minimum and Maximum values.

Any values that fall outside user-selected Minimum to Maximum range plot at minimum or maximum, as applicable.

Click **Start Process** to begin processing data. Status field shows *Processing complete* when done.

Return to SEASOFT for Waves window.
- If *Confirm Program Setup Change* was selected in Options menu - If you made changes and did not Save or Save As, program asks if you want to save changes.
- If *Confirm Program Setup Change* was not selected in Options menu - This says **Save & Exit**. If you do not want to save changes, click Cancel to exit.

Viewing and Outputting Plots



The Plot Data View window's menus are described below:

Output – Output the plot to printer, clipboard, or a file.

- *Print* – Print the single plot that is displayed on screen. In the dialog box, select printer, orientation, color, etc.; these selections override selections you made in Plot Data and in the Plot Data View **Options** menu.
- *File* – Output to file the single plot that is displayed on screen, in the selected format (.wmf, .jpg, or .bmp). In the dialog box, select the desired directory and output file name; these selections override selections you made in Plot Data and in the Plot Data View **Options** menu.
- *Clipboard* – Output to the clipboard the single plot that is displayed on screen, in the selected format (.wmf, .jpg, or .bmp). The selected format overrides the selection you made in the Plot Data View **Options** menu.
- *Print Range* (for wave time series and auto spectrum plots) – Print plots for several wave bursts for the series that is displayed on screen. In the dialog box, select the wave burst print range. Orientation and size are as selected in the Plot Data View **Options** menu. Plots output to your system's default printer; to output to a different printer you must select a new default printer before you select *Print Range*.
- *File Range* (for wave time series and auto spectrum plots) – Output to file the plots for several wave bursts for the series that is displayed on screen, in the selected format (.wmf, .jpg, or .bmp). In the dialog boxes, select the wave burst file output range, and the desired directory and output file name. Directory and file name selections override selections you made in Plot Data and in the Plot Data View **Options** menu.

Notes:
- The first wave burst is labeled 0.
- To change the default printer in Windows XP: Click Start / Printers and Faxes. A list of printers installed on your system appears, with a check mark next to the default printer. Right click on the desired printer, and select Set as Default Printer.

Options – Sets up defaults for *how* the plot is output to the printer, file, or clipboard.

- *Print* –
  - Orientation – landscape, portrait, or (printer) driver default. If driver default is selected, orientation is determined by the default for the printer you select in Output / Print (if printing a single plot) or the system default printer (if printing multiple plots using Output / Print Range).
  - Print full page – If selected, scale plot to fit 8 ½ x 11 inch page. If not selected, Size determined by -
    Plot Data View Dimensions – plot dimensions as shown on screen.
    Values Entered Below – Units, Width, and Height entered here.
- *File* –
  - Data format – Metafile (.wmf), Jpeg (.jpg), or Bitmap (.bmp).
  - Size determined by -
    Plot Data View Dimensions – plot dimensions as shown on screen.
    Values Entered Below – Units, Width, and Height entered here.
- *Clipboard* –
  - Data format – Metafile (.wmf), Jpeg (.jpg), or Bitmap (.bmp).
  - Size determined by -
    Plot Data View Dimensions – plot dimensions as shown on screen.
    Values Entered Below – Units, Width, and Height entered here.

View – Sets up viewing options.

- *First Burst*, *Last Burst*, *Next Burst*, *Prior Burst*, *Go to Burst* (applicable to wave time series and auto spectrum plots) – Switch the plot on screen to a different wave burst.
- *Undo Zoom* –Return the plot to the original ranges specified on the Axis tabs. *Undo Zoom* is grayed out unless you have zoomed in (by clicking and dragging to select a rectangular area) to enlarge details.
- *Set Zoomed Ranges* – Substitute the current zoomed ranges of the plot for the Minimum and Maximum plot ranges on the Axis tabs. This allows you to save the ranges of the zoomed view, so you can go to exactly the same view the next time you run Plot Data. *Set Zoomed Ranges* is grayed out unless you have zoomed in (by clicking and dragging to select a rectangular area) to enlarge details.

Section 10: Routine Maintenance and Calibration

This section reviews corrosion precautions, connector mating and maintenance, battery replacement, pressure sensor maintenance, optional conductivity cell storage and cleaning, and sensor calibration. The accuracy of the SBE 26*plus* is sustained by the care and calibration of the sensors and by establishing proper handling practices.

Corrosion Precautions

Rinse the SBE 26*plus* with fresh water after use and prior to storage.

The SBE 26*plus* has a plastic housing with a titanium end cap. No corrosion precautions are required, but avoid direct electrical connection of the titanium end cap to dissimilar metal hardware.

The optional SBE 4M conductivity cell has a titanium housing. No corrosion precautions are required, but avoid direct electrical connection of the titanium to dissimilar metal hardware.

Connector Mating and Maintenance

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

A mated connector does not require periodic disassembly or other attention. Inspect a connector that is unmated for signs of corrosion product around the pins. 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 26*plus*. 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.**

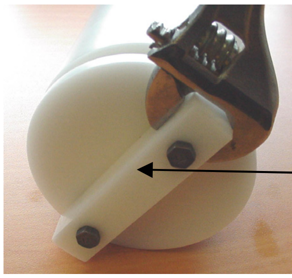
Verify that a cable or dummy plug is installed for each connector on the system before deployment.

Battery Replacement

Alkaline D-cell (MN1300, LR20)

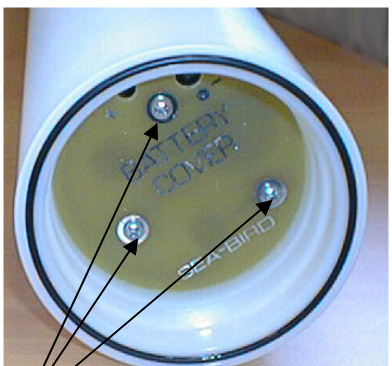
The SBE 26*plus* uses 12 alkaline D-cells (Duracell MN1300, LR20) or 6 lithium DD-cells (Electrochem BCX85-3B76-TC), dropped into the battery compartment.

Leave the batteries in place when storing the 26*plus* to prevent depletion of the back-up lithium batteries by the real-time clock. Even *exhausted* main batteries power the clock (less than 25 microamperes) almost indefinitely. If the 26*plus* is to be stored for long periods, leave the batteries in place and replace them yearly.



Unthread cap by rotating counter-clockwise

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. Remove 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.



Remove Phillips-head screws and washers

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 26*plus* 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.

Note: Alkaline and lithium batteries require different cover plates, because 1 lithium DD cell is shorter than 2 alkaline D cells.

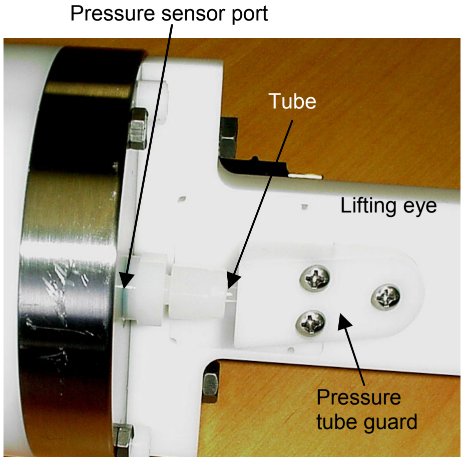
For **lithium DD** cells For **alkaline D** cells

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. For standard alkaline D cell batteries, it should be approximately 18 volts. For lithium DD cell batteries, it should be approximately 21 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 screw the end cap into place. Use a wrench on the white plastic bar to ensure the end cap is tightly secured.

Pressure Sensor Maintenance



Connector End Cap

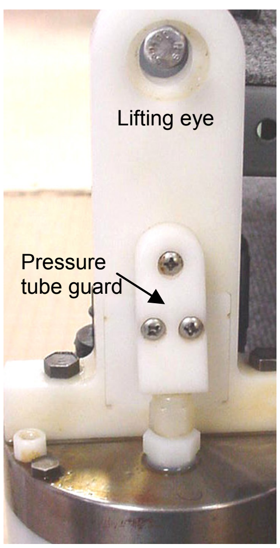
The pressure fitting – which includes a pressure port fitting, external tube, and polyurethane bladder bag – is filled with silicone oil at the factory. The oil transmits hydrostatic pressure via internal, capillary tubing to the pressure sensor inside the instrument, and prevents corrosion that might occur if the sensor diaphragm was exposed to water. The bladder bag is vacuum back-filled.

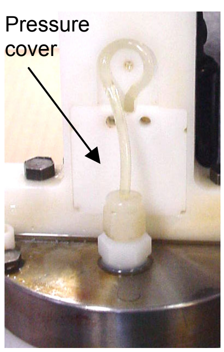
The bladder bag can develop tears and leaks over time. If the fitting has been damaged, or investigation due to poor data shows that the bag has torn, replace the fitting and bag and refill the oil. **Sea-Bird highly recommends that you send the SBE 26*plus* back to the factory for this repair, as it is difficult to completely remove all air from the system in the field, resulting in potential pressure errors.** However, if you must do the repair to meet a deployment schedule, contact Sea-Bird to purchase the needed parts.

Parts required:

Part Number	Description	Quantity
30551	Pressure port bladder bag	2 *
50025	Pressure sensor oil refill kit (provided with 26*plus* shipment)**	1
50029	Nylon capillary assembly	2 *
30002	Swagelock, nylon, NY-200-1-OR	2 *
30521	Syringe, 60 cc, DURR #899069, MFG #309663 (18 gage needle ground)	1

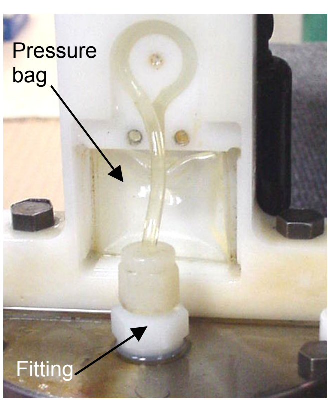
* Only 1 is required, but we recommend that you purchase a spare in case you have difficulty with the procedure.
** If you have a bell jar, use it to de-gas the oil in the oil refill kit.





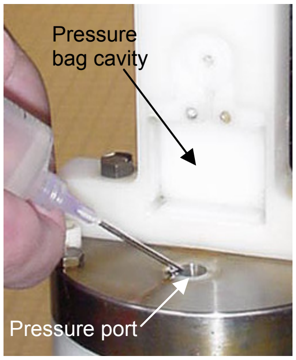
1. Securely mount the 26*plus* vertically (connector end cap up).

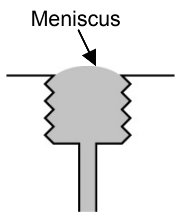
2. Remove the 3 Phillips-head screws attaching the pressure tube guard to the lifting eye. Remove the pressure tube guard and the pressure cover that is under it.



3. Remove the fitting from the end cap with a 9/16 inch wrench. Discard the fitting, tubing, and pressure bag.

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

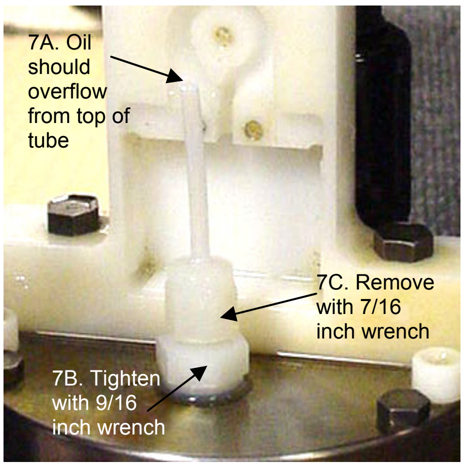




4. Clean the pressure bag cavity in the lift eye and the removed pressure tube guard and pressure cover, removing all residue/grit. Ensure that the holes in each corner of the pressure bag cavity in the lift eye are free of obstructions.

5. Clean the sensor end cap, being careful to remove any residue/grit near the pressure port.

6. From the 50025 pressure sensor oil refill kit, fill the small syringe with the supplied oil. Fill the pressure port, forming a meniscus on the surface of the end cap. Keep the SBE 26*plus* in the vertical position for at least 30 minutes before proceeding, to allow any bubbles in the internal plumbing to rise to the surface. Add oil from the small syringe as necessary to maintain the meniscus.

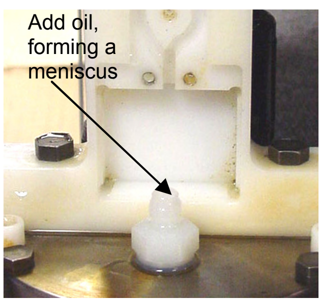


7. Install the supplied capillary fitting (50029) in the pressure port.

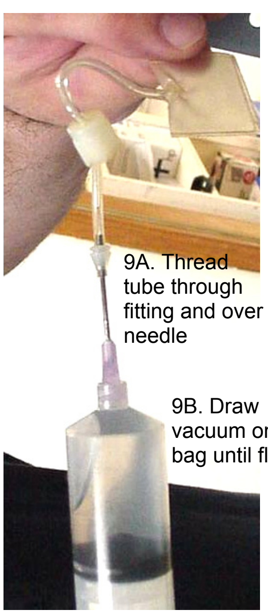
   A. As the fitting is installed, oil should rise the length of the tube and overflow. Wipe up the excess oil with a paper towel.

   B. Gently tighten the lower portion of the fitting with a 9/16 inch wrench - **DO NOT OVERTIGHTEN**.

   C. Remove the upper portion of the capillary fitting and tube using a 7/16 inch wrench. Store it for possible use another time.



8. Using the small syringe, add oil to the lower portion of the fitting, forming a meniscus.

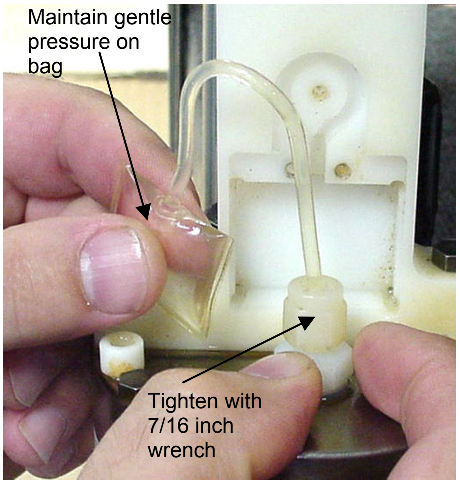


9. Fill the large syringe (30521) ¼ full with oil.

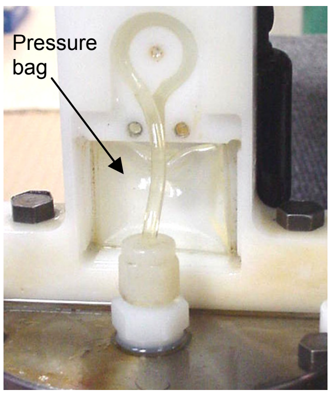
   A. Thread the tube from the pressure bag (30551) through the Swagelock fitting (30002), and install the pressure bag tube over the needle.

   B. Pull the plunger back on the syringe, drawing a vacuum on the pressure bag until it is completely flat. Maintain the vacuum on the bag.

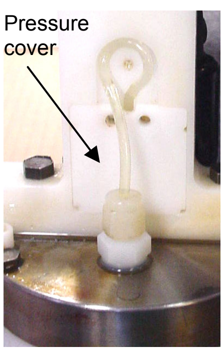
   C. Hold the syringe vertically with the bag down and slowly release the plunger, allowing the vacuum to be released. The bag should slowly fill with oil. There is enough oil in the bag when the bag looks like a *small pillow*. It is very important that there are no air bubbles in the pressure bag; you may have to perform this step several times to ensure that there are no bubbles.

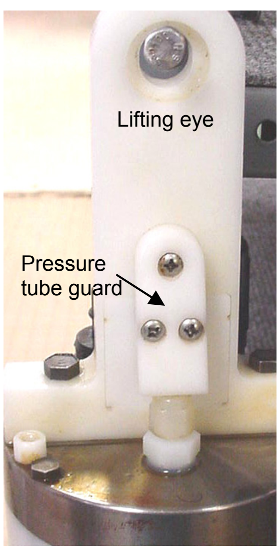


10. After the bag is filled, gently remove the tube from the needle, keeping the bag at or below the level of the end of the tube to prevent air from entering the bag. Maintaining gentle pressure on the bag to keep the oil at the end of the tube and prevent air from entering the bag, insert the end of the tube into the lower portion of the fitting on the end cap and screw the Swagelok fitting down, using a 7/16 inch wrench. Oil should overflow from the fitting, preventing air from entering the bag; the overflow should stop when the fitting is tightened. When completed, the bag should be approximately ½ full of oil and contain no air.



11. Install the pressure bag in the pressure bag cavity. Place the tubing in the indent, going counter-clockwise from the bag to the fitting.





12. Reinstall the pressure cover, pressure tube guard, and 3 Phillips-head screws, being careful not to pinch the tubing or the bag.

13. Log data on the SBE 26*plus*, and download the data. Compare the pressure readings to a local barometer. A pinched or overfilled bag will give pressure readings that are higher that the correct values.

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 SBE 4M 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 26*plus'* optional conductivity cell (SBE 4M) 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 SBE 4M, which is intended for use as a moored instrument.

Sensor Calibration

Note:
After recalibration of the pressure, temperature, and/or optional conductivity sensor, Sea-Bird enters the new calibration coefficients in the 26*plus* EEPROM, and ships the instrument back to the user with Calibration Certificates showing the new coefficients. For the conductivity sensor, Sea-Bird also provides the user with an updated .ini file (for use in Convert Hex).

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 pressure, temperature, and optional conductivity sensors on the SBE 26*plus* are supplied fully calibrated, with coefficients printed on their respective Calibration Certificates (in manual).

We recommend that the 26*plus* be returned to Sea-Bird for calibration.

Pressure Sensor Calibration

Note:
Although the pressure sensor manufacturer can re-calibrate the pressure sensor by duplicating the original procedures, the sensor must be removed from the 26*plus*, the cost is relatively high, and lead times can be considerable.

The pressure sensor is capable of meeting the 26*plus* error specification with some allowance for aging and ambient-temperature induced drift.

The pressure sensor coefficients are entered into the 26*plus* EEPROM with the calibration coefficient commands. The coefficients can be viewed using **DC** in SeatermW. Values for slope (default = 1.0) and offset (default = 0.0) can be entered in Convert Hex's Coefficient Configuration dialog box to make small post-deployment corrections for sensor drift. Note that the offset entered in Convert Hex is *in addition to* the offset entered in the 26*plus* EEPROM. Techniques are provided below for making small corrections using the slope and offset terms by comparing 26*plus* pressure output to:

- Readings from a barometer
- Readings from a dead-weight pressure generator – provides more accurate results, but requires equipment that may not be readily available

Before using either of these procedures, allow the 26*plus* to equilibrate (with power on) 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 26*plus* to equilibrate before starting will provide the most accurate calibration correction.

Calculating Offset using a Barometer

1. Place the 26*plus* in the orientation it will have when deployed.
2. In SeatermW, connect to the 26*plus*.
3. **Quartz pressure sensor**: Send **FR** to display the pressure and pressure sensor temperature compensation frequencies. Click Stop to end the test. Compute pressure in psia from the frequencies with the formula shown on the calibration sheet.
4. **Strain Gauge pressure sensor**: Send **TS** a number of times to measure pressure (as well as pressure temperature and optional conductivity) and transmit converted data in engineering units (pressure in psia).
5. Compare the 26*plus* output to the reading from a good barometer. Calculate *Offset* = barometer reading – 26*plus* reading.
6. Enter the calculated offset (positive or negative) in Convert Hex's Coefficients Configuration dialog box.

Offset Correction Example – Quartz Pressure Sensor
Pressure measured by barometer is 1010.50 mbar. Pressure calculated from 26*plus* pressure frequency is 14.06 psia.
Convert barometer reading to psia using relationship: mbar * 0.01 dbar/mbar * 1 psia / 0.689476 dbar = psia
Barometer reading = 1010.50 mbar * 0.01 / 0.689476 = 14.66 psia *Offset* = 14.66 – 14.06 = +0.60 psia
Enter offset in Convert Hex's Coefficient Configuration dialog box.

Calculating Slope and Offset using a Dead-Weight Pressure Generator

Tests show that room-temperature-derived *slope* and *offset* corrections to the initial quartz calibration can account for long-term drift to within less than 0.01% of the sensor's full scale range. To perform this correction:

1. Use a suitable dead-weight pressure generator to subject the sensor to increments of known pressures. The end cap's 5/16-24 straight thread permits mechanical connection to a pressure source. Use a fitting that has an o-ring face seal, such as Swagelok-200-1-OR. See *Application Note 12-1: Pressure Port Oil Refill Procedure & Nylon Capillary Fitting Replacement*.
2. In SeatermW, connect to the 26*plus*.
3. **Quartz pressure sensor**: Send **FR** to display the pressure and pressure sensor temperature compensation frequencies. Click Stop to end the test. Compute pressure in psia from the frequencies with the formula shown on the calibration sheet.
4. **Strain Gauge pressure sensor**: Send **TS** a number of times to measure pressure (as well as pressure temperature and optional conductivity) and transmit converted data in engineering units (pressure in psia).
5. Enter the calculated slope and offset (positive or negative) in Convert Hex's Coefficient Configuration dialog box.

Pressure Slope and Offset Correction Example – Quartz Pressure Sensor
A 45 psia sensor has drifted and its responses are low, as shown below:

Actual Pressure (psia)	Indicated Pressure (psia)
0.000	-0.057
9.000	8.939
18.000	17.936
27.000	26.932
36.000	35.929
45.000	44.925

Linear regression (best straight-line fit) *pcorrected = (pindicated * slope) + offset*
yields *slope* = +1.00039381 and *offset* = +0.057. Enter these correction coefficients, originally set to 1.0 and 0.0 respectively, in Convert Hex's Coefficient Configuration dialog box.

Temperature Sensor Calibration

The primary source of temperature sensor calibration drift is the aging of the thermistor element. Sensor drift is usually 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.

Note:
Temperature sensor calibration coefficients in Convert Hex's Coefficient Configuration dialog box are ignored (software will be updated in future to eliminate these entries from dialog box).

The temperature sensor coefficients are entered into the 26*plus* EEPROM with the calibration coefficient commands. The coefficients can be viewed using **DC** in SeatermW.

Conductivity Sensor Calibration

The optional SBE 4M 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 conductivity sensor calibration certificate shows the following coefficients: g, h, i, j, Cpcor, and Ctcor. View and/or modify these coefficients in Convert Hex's Coefficient Configuration dialog box and in the 26*plus* EEPROM.

- Cpcor makes a correction for the highly consistent change in dimensions of the conductivity cell under pressure. The default is the compressibility coefficient for borosilicate glass (-9.57×10^{-8}). Some sensors fabricated between 1992 and 1995 (serial numbers between 1100 and 1500) exhibit a compression that is slightly less than pure borosilicate glass. For these sensors, the (hermetic) epoxy jacket on the glass cell is unintentionally strong, creating a composite pressure effect of borosilicate and epoxy. For sensors tested to date, this composite pressure coefficient ranges from -9.57×10^{-8} to -6.90×10^{-8}, with the latter value producing a correction to deep ocean salinity of 0.0057 PSU in 5000 dbars pressure (approximately 0.001 PSU per 1000 dbars). Before modifying Cpcor, confirm that the sensor behaves differently from pure borosilicate glass. Sea-Bird can test your cell and calculate Cpcor. Alternatively, test the cell by comparing computed salinity to the salinity of water samples from a range of depths, calculated using an AutoSal.

Note:
See Application Note 31 for computation of slope correction coefficient from pre- and post-cruise calibrations supplied by Sea-Bird or from salinity bottle samples taken at sea during profiling.

Enter the value for slope (default = 1.0) in the SBE 26*plus* EEPROM to make small corrections for conductivity sensor drift between calibrations:

Corrected conductivity = (slope * computed conductivity)
where
slope = true conductivity span / instrument conductivity span

> *Conductivity Slope and Offset Correction Example*
> At true conductivity = 3.5 S/m, instrument reading = 3.49965 S/m
> Calculating the slope:
> Slope = 3.5 / 3.49965 = + 1.000100010001000100010001

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 (slope of the calibration curve), typically resulting in lower conductivity readings over time. Offset error (error at 0 S/m) is usually due to electronics drift, and is typically less than ± 0.0001 S/m per year. Because offsets greater than ± 0.0002 S/m are a symptom of sensor malfunction, Sea-Bird recommends that drift corrections be made by assuming no offset error, unless there is strong evidence to the contrary or a special need.

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.

Section 11: Troubleshooting

This section reviews common problems in operating the SBE 26*plus*, and provides the most common causes and solutions.

Problem 1: Unable to Communicate with SBE 26*plus*

The `S>` prompt indicates that communications between the SBE 26*plus* and computer have been established. Before proceeding with troubleshooting, attempt to establish communications again by clicking Connect in SeatermW or hitting the Enter key several times.

Cause/Solution 1: The I/O cable connection may be loose. Check the cabling between the 26*plus* and computer for a loose connection.

Cause/Solution 2: The instrument, Comm port, and/or baud rate may not have been entered correctly in SeatermW. Click Configure and verify the settings.

Cause/Solution 3: The I/O cable may not be the correct one. The I/O cable supplied with the 26*plus* permits connection to the DB-9P input connector on a standard RS-232 interface.

- 26*plus* Pin 1 (large pin on standard connector) goes to DB-9 pin 5 (ground)
- 26*plus* pin 2 (counter-clockwise from pin 1) goes to DB-9 pin 3
- 26*plus* pin 3 (opposite pin 1) goes to DB-9 pin 2

Cause/Solution 4: If attempting to communicate with the 26*plus* after you started logging, the 26*plus* may be making a wave burst measurement. You cannot communicate with the 26*plus* while it is making a wave burst measurement. Wait until you think the wave burst is complete, and try to establish communications again. If you have programmed a long wave burst and need to establish communications now, press Esc to interrupt the wave burst (this interrupts the current wave burst but does not stop logging). The 26*plus* will fill out the remaining data in the interrupted wave burst with 0's.

Note:
Interrupting a tide measurement and/or wave burst by pressing the Esc key will affect the quality of your data. For high quality data, Sea-Bird recommends the following to allow querying the 26*plus* during logging without interrupting measurements:

- Set sampling parameters with enough time between measurements, and
- Schedule/time queries when the 26*plus* is not measuring tides (of concern only for 26*plus* with Strain Gauge pressure sensor) or waves.

Cause/Solution 5: If attempting to communicate with the 26*plus* with **Strain Gauge** pressure sensor after you started logging, the 26*plus* may be making a tide measurement. You cannot communicate with the 26*plus* while it is making a tide measurement. Wait until you think the tide measurement is complete, and try to establish communications again. If you need to establish communications now, press Esc to interrupt the tide measurement (this interrupts the current tide measurement but does not stop logging). The 26*plus* will calculate the tide pressure based on the collected data.

Cause/Solution 6: In rare cases, the program that controls the 26*plus* 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:

> **Note:**
> Using the reset switch does not affect the 26*plus* memory - data in memory and user-programmable parameter values are unaffected.

1. **As a precaution, upload all data before proceeding**.
2. Open the battery end cap and remove the batteries (see *Replacing Batteries* in *Section 10: Routine Maintenance and Calibration* for details).
3. There is a toggle reset 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. Set the switch to the reset position for at least 5 minutes.
4. Reinstall or replace the batteries, and close the battery end cap.
5. Establish communications with the 26*plus* (see *Section 5: SBE 26plus Setup, Installation, and Data Upload - SeatermW* for details). Send the status command (**DS**) to verify that the setup is unaffected.

Problem 2: Nonsense or Unreasonable *Uploaded* Data

The symptom of this problem is an uploaded file that contains unreasonable values (for example, values that are outside the expected range of the data).

Cause/Solution 1: An uploaded data file with unreasonable values for pressure, temperature, or optional conductivity may be caused by incorrect calibration coefficients in either of the following places:

- In the instrument EEPROM - pressure, temperature, and conductivity sensor coefficients. View the coefficients by sending **DC** in SeatermW. If necessary, modify calibration coefficient(s) by sending the appropriate coefficient command(s) (see *Command Descriptions* in *Section 5: SBE 53 Setup, Installation and Data Upload – SeatermW*).
- In the instrument .ini file – pressure sensor slope and offset (this offset is in addition to the offset programmed in the instrument EEPROM). View/modify the coefficients by clicking the Coefficients button in Convert Hex's dialog box.

Verify that the calibration coefficients match the instrument Calibration Certificates.

Problem 3: Nonsense or Unreasonable *Real-Time* Data

> **Note:**
> If real-time or queried **pressure** values are unreasonable, note that a pressure slope and offset can be entered in Convert Hex's Coefficient Configuration dialog box to make small post-deployment corrections for pressure sensor drift on the uploaded data.

The symptom of this problem is real-time data that contains unreasonable values (for example, values that are outside the expected range of the data).

Cause/Solution 1: Real-time data with unreasonable values for pressure, temperature, or optional conductivity and salinity may be caused by incorrect pressure, temperature, and conductivity calibration coefficients in the instrument EEPROM. View the coefficients by sending **DC** in SeatermW; verify that the calibration coefficients match the instrument Calibration Certificates. If necessary, modify calibration coefficient(s) by sending the appropriate coefficient command(s) (see *Command Descriptions* in *Section 5: SBE 26plus Setup, Installation and Data Upload – SeatermW*).

.

Glossary

Battery and Memory Endurance – SEASOFT for Waves module for calculating power endurance and memory endurance for a user-specified sampling scheme.

Convert Hex – SEASOFT for Waves module for converting uploaded .hex file into separate wave (.wb) and tide (.tid) files.

Create Reports – SEASOFT for Waves module for outputting one line of surface wave time series and/or wave burst auto-spectrum statistics for each processed wave burst.

Extract Tide – Program to split uploaded data from multiple deployments into separate files before converting and processing the data. ExtractTide.exe is not incorporated in SEASOFT for Waves' Run menu, but is automatically installed when you install SEASOFT for Waves, in the same directory as SEASOFT for Waves.

Fouling – Biological growth in the conductivity cell during deployment.

Merge Barometric Pressure – SEASOFT for Waves module for removing barometric pressure from tide data.

PCB – Printed Circuit Board.

Plan Deployment – SEASOFT for Waves module for calculating the ratio of pressure amplitude measured by the instrument to pressure amplitude at the surface, and predicting number of frequency bands calculated, width of each band, and frequency span.

Plot Data – SEASOFT for Waves module for plotting wave and tide data.

Process Wave Burst Data– SEASOFT for Waves module for computing wave statistics.

SEAGAUGE – High-accuracy wave and tide recorder with a quartz or strain gauge pressure sensor, precision thermometer, and optional SBE 4M conductivity sensor.

SEASOFT for Waves - DOS – Modular DOS program for use with the SBE 26. **SEASOFT for Waves –DOS is not compatible with the 26*plus*.**

SEASOFT for Waves – Modular Win 95/98/NT/2000/XP program for pre-deployment planning, communication with the 26*plus* for setup, uploading of data from the 26*plus*, separation of uploaded data into separate wave and tide files, removal of barometric pressure from tide data, statistical analysis, and data plotting. Modules include Plan Deployment, Battery and Memory Endurance, SeatermW, Convert Hex, Merge Barometric Pressure, Process Wave Burst Data, Create Reports, and Plot Data.

SeatermW – SEASOFT for Waves module for communication with the 26*plus* for setup and uploading of data from the 26*plus*.

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 Mallinckrodt Baker (see http://www.mallbaker.com/changecountry.asp?back=/Default.asp for local distributors).

Appendix I: Command Summary

Note:
See *Command Descriptions* in *Section 5: SBE 26plus Setup, Installation, and Data Upload - SeatermW* for detailed information and examples.

CATEGORY	COMMAND	DESCRIPTION
Status	**DS**	Display status and setup parameters.
Setup	**SetTime**	Set real-time clock date and time.
	DateTime=x	**x**= real-time clock date and time. See *Setting Time in SBE 26plus to Synchronize Sampling of Multiple Instruments* in *Section 5*.
	Baud=x	**x**= baud rate for general communication (600, 1200, 2400, 4800, 9600, 19200, or 38400). Default 9600.
	ExternalTemperature=	**x=Y**: Optional external thermistor. **x=N**: Standard internal thermistor. Default.
	Conductivity=x	**x=Y**: Enable conductivity logging (if optional conductivity sensor included). **x=N**: Do not.
	UserInfo=x	**x**= user-defined string. Displays in **DS** reply.
	TxTide=x	**x=Y**: Transmit real-time tide data. **x=N**: Do not.
	TxWave=x	**x=Y**: Transmit real-time wave data. Note: See **SetSampling** to transmit real-time wave statistics. **x=N**: Do not.
	QS	Enter quiescent (sleep) state. Main power turned off, memory retention unaffected.
Wave and Tide Setup	**SetSampling** (or **SetSample**)	Set tide and wave sampling parameters: • Tide interval (1 – 720 minutes). • Tide duration (10 – 43,200 seconds). • Number of tide measurements between wave bursts (1 – 10,000). • Wave samples/burst – multiple of 4 (4 - 60,000). Set to power of 2 and minimum of 512 for meaningful wave statistics. • Wave sample duration – 0.25, 0.5, 0.75, or 1 second. • At receipt of **Start**, start logging at **SetStartTime** or immediately? • Stop logging at **SetStopTime** or wait for user to send **Stop**? • Calculate and output real-time wave statistics? If yes, 26*plus* prompts for real-time wave statistics parameters.
Initialize Logging (Reset Memory)	**InitLogging**	**After all data uploaded**, send this before starting to sample to make entire memory available for recording. If not sent, data stored after last sample.
	TideCount=x	**x=** tide sample number for first tide measurement when sampling begins. Use to recover data if you accidentally initialize logging before **ASCII** uploading.
	***ByteCount=x**	**x=** byte number for first byte when sampling begins. Use to recover data if you accidentally initialize logging before **binary** uploading.
Logging	**Start**	Start logging now (if ***use start time?*** in **SetSampling** prompt is ***No***), *or* Start waiting to start logging (if ***use start time?*** in **SetSampling** is ***Yes***).
	Stop	Stop logging now.
	SetStartTime	Set date and time to start logging. At receipt of **Start**, 26*plus* starts logging at this date and time if ***Use start time?*** in **SetSampling** is ***Yes***.
	SetStopTime	Set date and time to stop logging. 26*plus* stops logging at this date and time if ***Use stop time?*** in **SetSampling** is ***Yes***.

Note:
Use the Upload menu to upload data that will be processed by SEASOFT for Waves. Manually entering a data upload command does not produce data in the required format for processing by SEASOFT for Waves.

CATEGORY	COMMAND	DESCRIPTION
Send Last Sample	**SL**	Send pressure, temperature, and salinity from last tide measurement and do not go to sleep (do not enter quiescent state).
	SLO	Send pressure, temperature, and salinity from last tide measurement and go to sleep (enter quiescent state).
Data Upload	**DD**	Upload data **in ASCII** at baud set for general communication with **Baud=**.
	DBbaud,b,e	Upload data **in binary** at **baud** (1200, 2400, 4800, 9600, 19200, 28800, 38400, 57600, or 115200) from byte **b** to **e**. First byte is 0. Can upload up to 500,000 bytes at one time.
	ByteCount	Display total number of bytes in memory.
Diagnostic (data from these tests not stored in FLASH memory)	**TS**	Take 1 sample of pressure, pressure temperature, temperature, and conductivity, and output **converted** data.
	TSR	Take 1 sample of pressure, pressure temperature, temperature, and conductivity, and output **raw** data.
	TT	Sample temperature, and output **converted** data. 26*plus* runs continuously, drawing current. Press Esc key or click Stop to stop test.
	TTR	Sample temperature, and output **raw** data. 26*plus* runs continuously, drawing current. Press Esc key or click Stop to stop test.
	FR	Measure and output frequencies: quartz pressure, quartz pressure temperature, and conductivity. 26*plus* runs continuously, drawing current. Press Esc key or click Stop to stop test.
	VR	Measure and output: • main battery voltage / 11.18 • back-up lithium battery voltage / 4.8187 • operating current (mA) / 20.04 • ground voltage 26*plus* runs continuously, drawing current. Press Esc key or click Stop to stop test.
	***FlashInit**	Map bad blocks and erase FLASH memory, **destroying all data**.
	***FlashGood**	Display number of good blocks in FLASH memory.
Calibration Coefficients (F=floating point number; S=string with no spaces) Dates shown are when calibrations were performed. Coefficients are initially factory-set and should agree with Calibration Certificates shipped with 26*plus*.	**DC**	Display sensor calibration coefficients.
	PCalDate=S	**S**=pressure calibration date.
	PU0=F	**F**=*quartz* pressure U0.
	PY1=F	**F**=*quartz* pressure Y1.
	PY2=F	**F**=*quartz* pressure Y2.
	PY3=F	**F**=*quartz* pressure Y3.
	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.

CATEGORY	COMMAND	DESCRIPTION
Calibration Coefficients (*continued*)	**PA0=F**	**F**=*strain gauge* pressure A0.
	PA1=F	**F**=*strain gauge* pressure A1.
	PA2=F	**F**=*strain gauge* pressure A2.
	PTCA0=F	**F**=*strain gauge* pressure PTCA0.
	PTCA1=F	**F**=*strain gauge* pressure PTCA1.
	PTCA2=F	**F**=*strain gauge* pressure PTCA2.
	PTCB0=F	**F**=*strain gauge* pressure PTCB0.
	PTCB1=F	**F**=*strain gauge* pressure PTCB1.
	PTCB2=F	**F**=*strain gauge* pressure PTCB2.
	PTEMPA0=F	**F**=*strain gauge* pressure PTEMPA0.
	PTEMPA1=F	**F**=*strain gauge* pressure PTEMPA1.
	PTEMPA2=F	**F**=*strain gauge* pressure PTEMPA2.
	POffset=F	**F**=pressure offset (psia) – applicable to both quartz and strain gauge pressure.
	TCalDate=S	**S**=temperature calibration date.
	TA0=F	**F**=temperature A0.
	TA1=F	**F**=temperature A1.
	TA2=F	**F**=temperature A2.
	TA3=F	**F**=temperature A3.
	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.
	CTCOR=F	**F**=conductivity TCOR.
	CPCOR=F	**F**=conductivity PCOR.
	CSLOPE=F	**F**=conductivity slope correction.

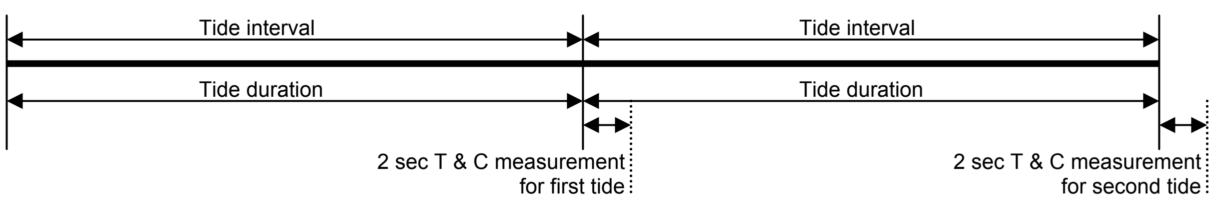
Appendix II: Sample Timing

General Sample Timing Notes

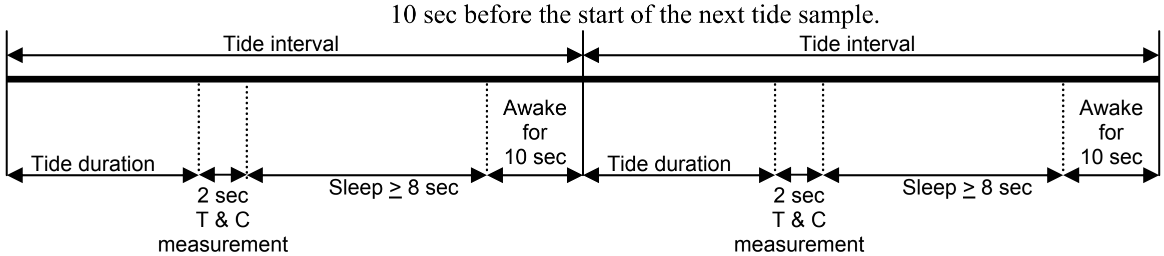
- When **Start** is sent:
  - If ***Use start time?*** in the **SetSampling** prompt is ***No***, the 26*plus* starts logging 10 seconds after receipt of **Start**.
  - If ***Use start time?*** in the **SetSampling** prompt is ***Yes***, the 26*plus* starts logging at **SetStartTime**.
- If ***Use start time?*** in the **SetSampling** prompt is ***Yes***, and **SetStartTime** is less than 10 seconds in the future when **Start** is sent, the 26*plus* ignores the programmed start time and starts logging in 10 seconds.
- If ***Use stop time?*** in the **SetSampling** prompt is ***Yes***, and **SetStopTime** is less than 1 hour after logging begins, the 26*plus* ignores the programmed stop time and continues logging until **Stop** is sent.
- Tides: The 26*plus* integrates the pressure sensor output over the entire tide duration, calculating and storing an average pressure for that time period. The 26*plus* measures the temperature and optional conductivity (T and C) associated with the tide *after* the tide duration. The time stamp (the time reported with the tide pressure, temperature, and conductivity data) is the time at the **beginning** of the tide duration.
- Waves: The time stamp (the time reported with wave burst data) is the time at the **beginning** of the wave burst.

Sample Timing with Quartz Pressure Sensor

- If tide duration > (tide interval – 20 sec), tide duration is set to tide interval, and the 26*plus* samples tides continuously.



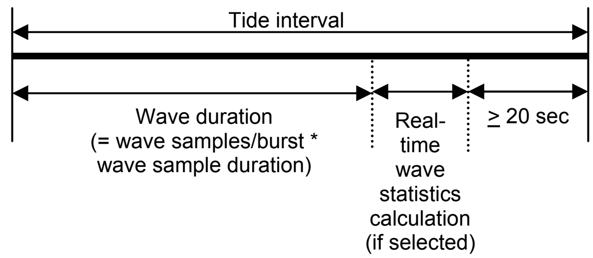
- If tide duration < (tide interval – 20 sec), 26*plus* goes to sleep between tide samples and wakes up and latches power onto the pressure sensor 10 sec before the start of the next tide sample.



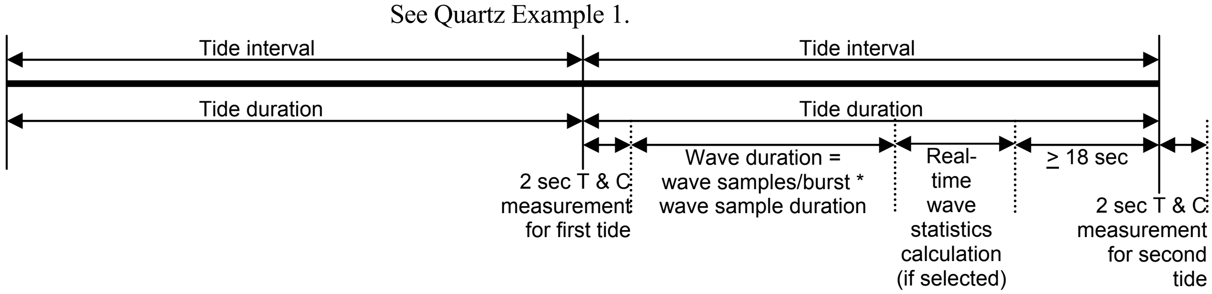
> **Note:**
> Sea-Bird recommends the following for meaningful wave statistics:
> - Wave samples/burst ≥ 512, and
> - Wave samples/burst = power of 2 (512, 1024, etc.)

- If
  (wave burst duration + real-time wave statistics calculation) > (tide interval - 20 sec),
  the 26*plus* increases the tide interval so that
  wave burst duration + real-time wave statistics calculation = (tide interval - 20 sec).
  Note that real-time wave statistics can be calculated on a subset of the total number of wave samples/burst; the real-time statistics calculation requires 0.06 sec/wave sample to be processed.

  The drawing only shows the relationship between the maximum allowable wave burst duration, real-time wave statistics calculation, and tide interval; see other drawings below for sequencing of wave and tide measurements.



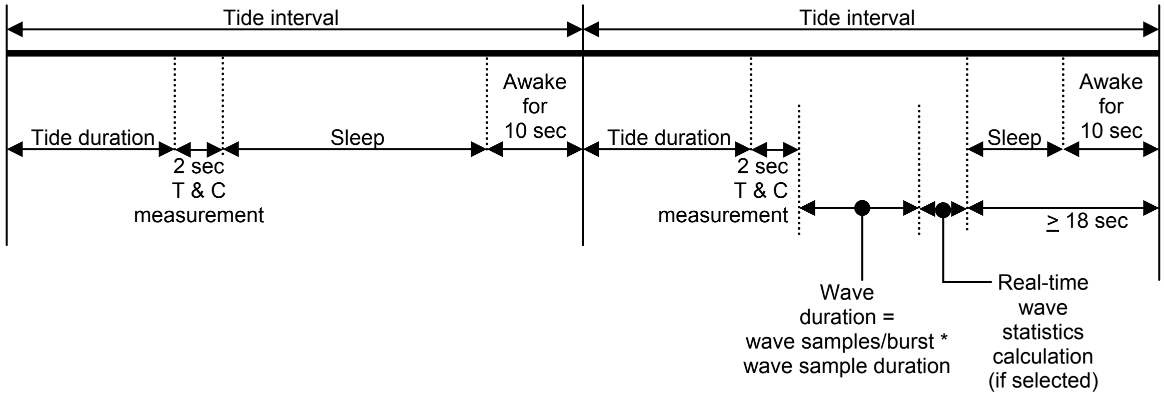
- If tide duration = tide interval, wave burst sampling is done during the applicable tide measurement, and the 26*plus* samples tides continuously. See Quartz Example 1.



Quartz Example 1: Tide interval = tide duration = 15 minutes = 900 sec.
1024 samples/wave burst at 0.25 sec/sample (1024 x 0.25 = 256 sec) every 2 tide measurements.
Calculate real-time wave statistics on 512 samples/wave burst (512 x 0.06 sec/calculation = 30.7 sec required at end of wave burst).
Set **SetStartTime** to 12:00:00.
Checking setup:
wave burst duration + real-time wave statistics calculation = 256 + 30.7 = 287 sec < tide interval - 20 sec = 900 – 20 = 880 sec

Time	Time Stamp for Tide #	Begin P for Tide #	End P for Tide #	Begin T & C for Tide #	End T & C for Tide #	Time Stamp for Wave Burst #	Begin Wave Burst #	End Wave Burst # & Begin Wave Statistic Calculation #	End Wave Statistic Calculation #
12:00:00	#1	#1	-	-	-	-	-	-	-
12:15:00	#2	#2	#1	#1	-	-	-	-	-
12:15:02	-	-	-	-	#1	#1	#1	-	-
12:19:18	-	-	-	-	-	-	-	#1	-
12:19:49	-	-	-	-	-	-	-	-	#1
12:30:00	#3	#3	#2	#2	-	-	-	-	-
12:30:02					#2	-	-	-	-
12:45:00	#4	#4	#3	#3	-	-	-	-	-
12:45:02	-	-	-	-	#3	#2	#2		-
12:49:18	-	-	-	-	-	-	-	#2	-
12:49:49	-	-	-	-	-	-	-	-	#2
13:00:00	#5	#5	#4	#4	-	-	-	-	-

- If tide duration < (tide interval – 20 seconds), and wave burst duration + real-time wave statistics calculation < (tide interval – tide duration – 20 seconds): Wave burst sampling is done **after** the applicable tide measurement. For example, if the 26*plus* is set up to sample a wave burst every 2 tide measurements, the first wave burst starts 2 seconds after the second tide measurement is complete. See Quartz Example 2.

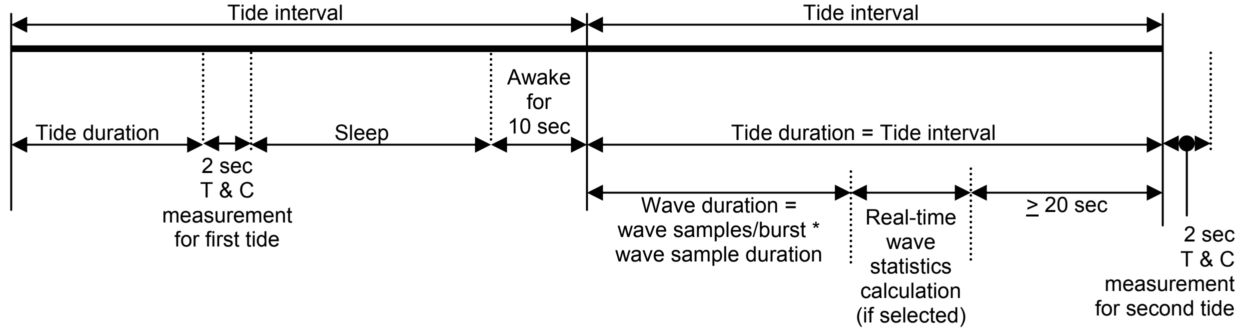


Quartz Example 2: Tide interval = 15 minutes = 900 sec; tide duration = 5 minutes = 300 sec.
512 samples /wave burst at 0.25 sec/sample (512 x 0.25 = 128 sec) every 2 tide measurements.
Calculate real-time wave statistics on 512 samples/wave burst (512 x 0.06 sec/calculation = 30.7 sec required at end of wave burst).
Set **SetStartTime** to 12:00:00.
Checking setup:
tide duration = 300 sec < tide interval – 20 sec = 900 – 20 = 880 sec
wave burst duration + real-time wave statistics = 128 + 30.7 = 159 sec < tide interval – tide duration - 20 sec = 900 – 300 - 20 = 580 sec

Time	Time Stamp for Tide #	Begin P for Tide #	End P for Tide #	Begin T & C for Tide #	End T & C for Tide #	Time Stamp for Wave Burst #	Begin Wave Burst #	End Wave Burst # & Begin Wave Statistic Calculation #	End Wave Statistic Calculation #
12:00:00	#1	#1	-	-	-	-	-	-	-
12:05:00	-	-	#1	#1	-	-	-	-	-
12:05:02	-	-	-	-	#1	-	-	-	-
12:15:00	#2	#2	-	-	-	-	-	-	-
12:20:00	-	-	#2	#2	-	-	-	-	-
12:20:02	-	-	-	-	#2	#1	#1	-	-
12:22:10	-	-	-	-	-	-	-	#1	-
12:22:41	-	-	-	-	-	-	-	-	#1
12:30:00	#3	#3	-	-	-	-	-	-	-
12:35:00	-	-	#3	#3	-	-	-	-	-
12:35:02	-	-	-	-	#3	-	-	-	-
12:45:00	#4	#4	-	-	-	-	-	-	-
12:50:00	-	-	#4	#4	-	-	-	-	-
12:50:02	-	-	-	-	#4	#2	#2	-	-
12:52:10	-	-	-	-	-	-	-	#2	-
12:52:41	-	-	-	-	-	-	-	-	#2

> **Note:**
> As shown, for this scheme the tide duration and T and C timing depend on whether a wave burst occurs during the tide interval. **Consequently, do not use this scheme if you want tide pressure and T and C data at regular intervals**.

- If tide duration < (tide interval – 20 seconds) and
  wave burst duration + real-time wave statistics calculation >
  (tide interval – tide duration – 20 seconds):
  Wave burst sampling is done **during** the applicable tide measurement, and for that tide the tide duration is set to the tide interval (26*plus* does not go to sleep for that tide). See Quartz Example 3.



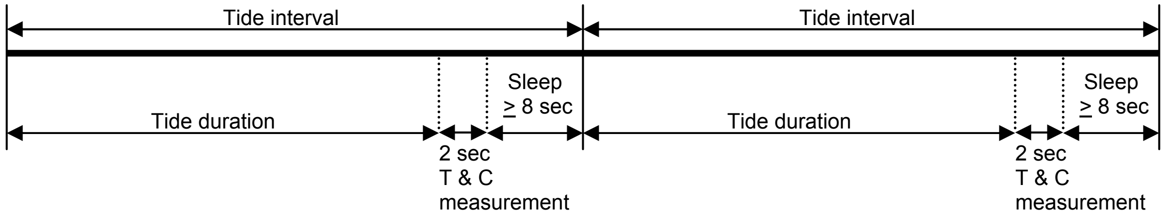
Quartz Example 3: Tide interval = 15 minutes = 900 sec; tide duration = 2 minutes = 120 sec.
Wave burst of 1024 samples at 0.75 sec/sample (1024 x 0.75 = 768 sec = 12 minutes, 48 seconds) every 2 tide measurements.
Calculate real-time wave statistics on 512 samples/wave burst (512 x 0.06 sec/calculation = 30.7 sec required at end of wave burst).
Set **SetStartTime** to 12:00:00.
Checking setup:
tide duration = 120 sec < tide interval – 20 sec = 900 – 20 = 880 sec
wave burst duration + real-time wave statistics = 768 + 30.7 = 799 sec > tide interval – tide duration - 20 sec = 900 – 120 - 20 = 760 sec

Time	Time Stamp for Tide #	Begin P for Tide #	End P for Tide #	Begin T & C for Tide #	End T & C for Tide #	Time Stamp for Wave Burst #	Begin Wave Burst #	End Wave Burst # & Begin Wave Statistic Calculation #	End Wave Statistic Calculation #
12:00:00	#1	#1	-	-	-	-	-	-	-
12:02:00	-	-	#1	#1	-	-	-	-	-
12:02:02	-	-	-	-	#1	-	-	-	-
12:15:00	#2	#2	-	-	-	#1	#1	-	-
12:27:48	-	-	-	-	-	-	-	#1	-
12:28:19	-	-	-	-	-	-	-	-	#1
12:30:00	#3	#3	#2	#2	-	-	-	-	-
12:30:02	-	-	-	-	#2	-	-	-	-
12:32:00	-	-	#3	#3	-	-	-	-	-
12:32:02	-	-	-	-	#3	-	-	-	-
12:45:00	#4	#4	-	-	-	#2	#2	-	-
12:47:48	-	-	-	-	-	-	-	#2	-
12:48:19	-	-	-	-	-	-	-	-	#2
13:00:00	#5	#5	#4	#4	-	-	-	-	-
13:00:02	-	-	-	-	#4	-	-	-	-

Note for Quartz Example 3:
Note the large variation in T & C timing and in the length of the tide pressure measurement using this scheme.

Sample Timing with Strain Gauge Pressure Sensor

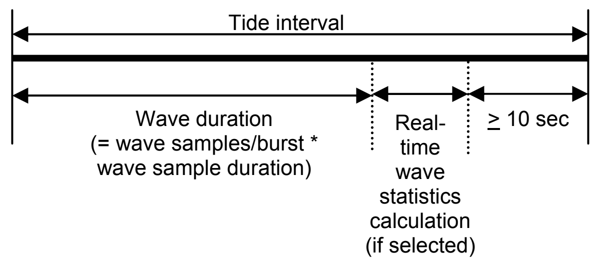
- If tide duration > (tide interval – 10 seconds), tide duration is set to (tide interval – 10). 26*plus* goes to sleep between tide samples.



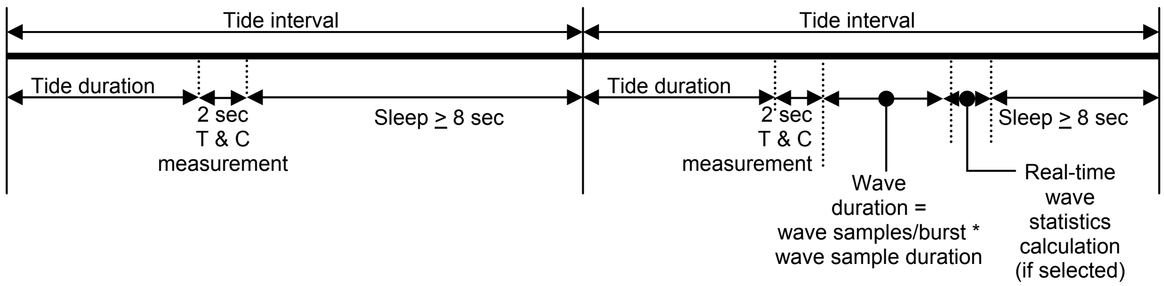
Note:
Sea-Bird recommends the following for meaningful wave statistics:
- Wave samples/burst ≥ 512, and
- Wave samples/burst = power of 2 (512, 1024, etc.)

- If (wave burst duration + real-time wave statistics calculation) > (tide interval - 10 sec), the 26*plus* increases the tide interval so that wave burst duration + real-time wave statistics calculation = (tide interval - 10 sec). Note that real-time wave statistics can be calculated on a subset of the total number of wave samples/burst; the real-time statistics calculation requires 0.06 sec/wave sample to be processed.

  The drawing only shows the relationship between the maximum allowable wave burst duration, real-time statistics calculation, and tide interval; see other drawings below for sequencing of wave and tide measurements.



- If tide duration < (tide interval – 10 sec), and
  (wave burst duration + real-time wave statistics calculation) <
  (tide interval – tide duration – 10 sec):
  Wave burst sampling is done **after** the applicable tide measurement.
  For example, if the 26*plus* is set up to sample a wave burst every
  2 tide measurements, the first wave burst starts 2 seconds after the second
  tide measurement. See Strain Gauge Example 1.

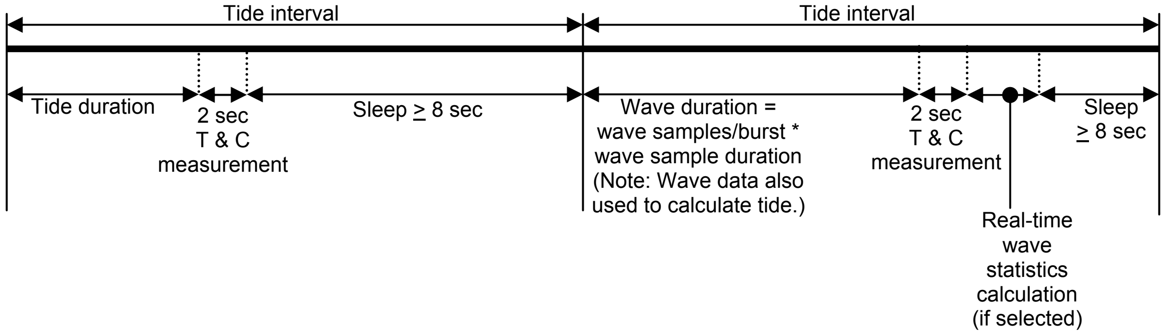


Strain Gauge Example 1: Tide interval = 15 minutes = 900 sec; tide duration = 5 minutes = 300 sec.
512 samples /wave burst at 0.25 sec/sample (512 x 0.25 = 128 sec) every 2 tide measurements.
Calculate real-time wave statistics on 512 samples/wave burst (512 x 0.06 sec/calculation = 30.7 sec required at end of wave burst).
Set **SetStartTime** to 12:00:00.
Checking setup:
tide duration = 300 sec < tide interval – 10 sec = 900 – 10 = 890 sec
wave burst duration + real-time wave statistics = 128 + 30.7 = 159 sec < tide interval – tide duration - 10 sec = 900 – 300 - 10 = 590 sec

Time	Time Stamp for Tide #	Begin P for Tide #	End P for Tide #	Begin T & C for Tide #	End T & C for Tide #	Time Stamp for Wave Burst #	Begin Wave Burst #	End Wave Burst # & Begin Wave Statistic Calculation #	End Wave Statistic Calculation #
12:00:00	#1	#1	-	-	-	-	-	-	-
12:05:00	-	-	#1	#1	-	-	-	-	-
12:05:02	-	-	-	-	#1	-	-	-	-
12:15:00	#2	#2	-	-	-	-	-	-	-
12:20:00	-	-	#2	#2	-	-	-	-	-
12:20:02	-	-	-	-	#2	#1	#1	-	-
12:22:10	-	-	-	-	-	-	-	#1	-
12:22:41	-	-	-	-	-	-	-	-	#1
12:30:00	#3	#3	-	-	-	-	-	-	-
12:35:00	-	-	#3	#3	-	-	-	-	-
12:35:02	-	-	-	-	#3	-	-	-	-
12:45:00	#4	#4	-	-	-	-	-	-	-
12:50:00	-	-	#4	#4	-	-	-	-	-
12:50:02	-	-	-	-	#4	#2	#2	-	-
12:52:10	-	-	-	-	-	-	-	#2	-
12:52:41	-	-	-	-	-	-	-	-	#2

> **Note:**
> As shown, for this scheme the tide duration and T and C timing depend on whether a wave burst occurs during the tide interval. **Consequently, do not use this scheme if you want tide pressure and T and C data at regular intervals**.

- If tide duration < (tide interval – 10 sec) and
  (wave burst duration + real-time wave statistics calculation) >
  (tide interval – tide duration – 10 sec):
  Wave burst sampling is done **instead of** the applicable tide measurement, and for that tide the data from the entire wave burst is averaged to calculate the tide measurement. See Strain Gauge Example 2.



Strain Gauge Example 2: Tide interval = 15 minutes = 900 sec; tide duration 3 minutes = 180 sec.
Wave burst of 1024 samples at 0.75 sec/sample (1024 x 0.75 = 768 sec = 12 minutes, 48 seconds) every 2 tide measurements.
Calculate real-time wave statistics on 512 samples/wave burst (512 x 0.06 sec/calculation = 30.7 sec required at end of wave burst).
Set **SetStartTime** to 12:00:00.
Checking setup:
tide duration = 180 sec < tide interval – 10 sec = 900 – 10 = 890 sec
wave burst duration + real-time wave statistics = 768 + 30.7 = 799 sec > tide interval – tide duration - 10 sec = 900 – 180 - 10 = 710 sec

Time	Time Stamp for Tide #	Begin P for Tide #	End P for Tide #	Begin T & C for Tide #	End T & C for Tide #	Time Stamp for Wave Burst #	Begin Wave Burst #	End Wave Burst #	Begin Wave Statistic Calculation #	End Wave Statistic Calculation #
12:00:00	#1	#1	-	-	-	-	-	-	-	-
12:03:00	-	-	#1	#1	-	-	-	-	-	-
12:03:02	-	-	-	-	#1	-	-	-	-	-
12:15:00	#2	-	-	-	-	#1	#1	-	-	-
12:27:48	-	-	-	#2	-	-	-	#1	-	-
12:27:50	-	-	-	-	#2	-	-	-	#1	
12:28:21	-	-	-	-	-	-	-	-	-	#1
12:30:00	#3	#3	-	-	-	-	-	-	-	-
12:33:00	-	-	#3	#3	-	-	-	-	-	-
12:33:02	-	-	-	-	#3	-	-	-	-	-
12:45:00	#4	-	-	-	-	#2	#2	-	-	-
12:57:48	-	-	-	#4	-	-	-	#2	-	-
12:57:50		-	-	-	#4	-	-		#2	-
12:58:21	-	-	-	-	-	-	-	-	-	#2
13:00:00	#5	#5	-	-	-	-	-	-	-	-

Notes for Strain Gauge Example 2:

- A separate tide measurement is not made during a tide interval that includes a wave burst; the value reported for that tide is the average of the measurements taken over the entire wave burst.
- Note the large variation in T & C timing and in the length of the tide pressure measurement using this scheme.

Appendix III: Data Formats

Notes:
- See *Section 7: Tide Data Processing – Merge Barometric Pressure* for the barometric pressure file (.bp) format.
- The format for the .wss file, created if *Output FFT coefficients to .wss file* is selected in Process Wave Burst Data, is not detailed.

This appendix provides detailed information on data format for each file type.

Extension	Description
.cap	Capture file of real-time data from 26*plus*.
.hex	Hex data uploaded from 26*plus* memory using SeatermW. Also, Hex data from multiple logging sessions split into separate files by Extract Tide.
.tid	Tide measurements only, created from .hex file by Convert Hex. Also, file output by Merge Barometric Pressure, which removes barometric pressure from an input .tid file.
.bp	Barometric pressure data, used by Merge Barometric Pressure to remove barometric pressure from the tide data (.tid) file.
.wb	Wave measurements only, created from .hex file by Convert Hex.
.was	Statistics and results from auto-spectrum analysis, created by Process Wave Burst Data.
.rpt	Summary report, created by Process Wave Burst Data.
.wss	Fast Fourier Transform coefficients, created by Process Wave Burst data if selected.
.wts	Statistics from surface wave zero crossing analysis, created by Process Wave Burst Data.
.wt	Surface wave time series, created by Process Wave Burst Data if *Output surface wave time series to .wt file* is selected.
.r26	File containing one line of surface wave time series and/or wave burst auto-spectrum statistics for each processed wave burst, created by Create Reports.

Real-Time Data Format (.cap extension)

Real-time data can be saved to a .cap file if you click Capture in SeatermW.
- Real-time tide data is output if **TxTide=Y**.
- Real-time wave data is output if **TxWave=Y**.
- Real-time wave statistics is output if you set `TXWAVESTATS=Y` in the **SetSampling** prompt.

Note:
Each tide measurement record displays **after** the tide duration is complete. For example, if the tide duration is 10 minutes, the first tide data displays 10 minutes after logging starts.

Each time a **tide** measurement is completed, the display looks like this if the **DS** response shows `transmit real-time tide data = YES` (real-time tide data was enabled with **TxTide=Y**):

```
Tide: start time = 21 Nov 2004 13:40:01, p =14.2135,
pt = 21.952, t = 21.0250, c = 4.81952, s = 34.3799
```

where:
- start time = start of tide measurement
- p = calculated and stored pressure (psia)
- pt = calculated pressure temperature (not stored) (°C)
- t = calculated and stored temperature (°C)
- c = calculated and stored conductivity (S/m) and
  s = calculated salinity (not stored) (psu).
  Note that c and s display only if **DS** response shows `conductivity = YES` (conductivity acquisition was enabled with **Conductivity=Y**).

Each time a **wave** measurement is made, the display looks like this if the **DS** response shows `transmit real-time wave burst data = YES` (real-time wave data transmission was enabled with **TxWave=Y**):

```
wave: start time = 21 Nov 2004 13:43:13
wave: ptfreq = 172046.343     or    wave: ptRaw = 1.278
14.5599
14.5598
14.5597
. . .
14.5598
wave: end wave burst
```

where:

- start time = start of wave measurement.
- ptfreq = pressure temperature frequency (Hz);
  displays only for 26*plus* with Quartz pressure sensor.
- ptRaw = calculated pressure temperature number;
  displays only for 26*plus* with Strain Gauge pressure sensor.
- Remaining displayed values are calculated and stored pressures (psia).

Note:
Sample output shown assumes you set `Show progress messages = n` in the **SetSampling** prompt.

Each time a **wave** burst is completed, the display looks like this if the **DS** response shows `transmit real-time wave statistics = YES` (real-time wave statistics was enabled with `TXWAVESTATS=Y` in the **SetSampling** command prompt):

```
Auto-Spectrum Statistics:
   nAvgBand = 5
   total variance = 1.7509e-08
   total energy = 1.7137e-04
   significant period = 4.2667e+01
   significant wave height = 5.2928e-04

Time Series Statistics:
   Wave integration time = 128
   Number of waves = 0
   Total variance = 1.6868e-08
   Total energy = 1.6512e-04
   Average wave height = 0.0000e+00
   Average wave period = 0.0000e+00
   Maximum wave height = 5.9477e-04
   Significant wave height = 0.0000e+00
   Significant wave period = 0.0000e+00
   H1/10 = 0.0000e+00
   H1/100 = 0.0000e+00
```

Note:
See *Appendix VI: Wave Theory and Statistics* for a description of calculation of wave statistics.

where:

- Auto-Spectrum Statistics -
  nAvgBand = user-input number of spectral estimates for each frequency band, and
  next 4 lines are calculated (not stored) auto-spectrum statistics
- Time Series Statistics -
  wave integration time (sec) = wave burst duration
  = user input number of samples / burst * sample duration, and
  remaining lines are calculated (not stored) time series statistics

Hex Data Format with *Quartz* Pressure Sensor (.hex extension)

A .hex file contains hexadecimal data uploaded from SBE 26*plus* memory using SeatermW's Upload.

The beginning of a sample .hex file for a 26*plus* **with Quartz pressure sensor and without conductivity** follows:

```
*Sea-Bird SBE 26plus Data File:
*FileName = C:\26plus\QuartzNoCond.hex
*Software Version 1.07
*DS
*SBE 26plus V 6.1c  SN 1022    10 Dec 2006  10:43:20
*user info= test file
*quartz pressure sensor: serial number = 12345, range = 45 psia
*internal temperature sensor
*conductivity = NO
*iop =  5.9 ma  vmain = 18.5 V  vlith =  9.1 V
*last sample: p = 14.8637, t = 18.8973
*
*tide measurement: interval = 5.000 minutes, duration = 120 seconds
*measure waves every 3 tide samples
*512 wave samples/burst at 4.00 scans/sec, duration = 128 seconds
*logging start time = do not use start time
*logging stop time = do not use stop time
*
*tide samples/day = 288.000
*wave bursts/day = 96.000
*memory endurance = 218.6 days
*nominal alkaline battery endurance = 319.5 days
*total recorded tide measurements = 17
*total recorded wave bursts = 5
*tide measurements since last start = 17
*wave bursts since last start = 5
*
*transmit real-time tide data = NO
*transmit real-time wave burst data = NO
*transmit real-time wave statistics = NO
*
*status = stopped by user
*logging = NO, send start command to begin logging
*S>DC
*Pressure coefficients:
*    U0 = 5.856409e+00
* . . .                      (more pressure sensor calibration coefficients)
*    M = 279620.2
*    B = 18641.3
*    offset = 0.000000e+00
*Temperature coefficients:
*    TA0 = 5.473956e-04
*    TA1 = 1.803112e-04
*    TA2 = 3.899926e-06
*    TA3 = 6.722141e-09
*S>DD
FFFFFFFFFBFFFFFFFF     (flag beginning of tide parameters)
091CB0510000000000     (time of beginning of first tide sample)
012C00010000000000     (tide sample interval, wave integration period)
FFFFFFFFFCFFFFFFFF     (flag end of tide parameters)
3FB78A6CA4091CB051     (tide data – pressure, temperature, and time)
3FB7DE6CEB091CB17D     (tide data – pressure, temperature, and time)
3FB8F66D33091CB2A9     (tide data – pressure, temperature, and time)
000000000000000000     (flag beginning of wave burst)
091CB3220200000000     (time of beginning of wave burst, number of samples in burst)
029B83E80000000000     (pressure temperature compensation number, number of samples in burst)
87CED887CED6           (wave burst pressure data)
. . .                  (wave burst pressure data)
87CEE087CEEA           (wave burst pressure data)
FFFFFFFFFFFFFFFFFF     (flag end of wave burst)
3FB8BE6D77091CB3D5     (tide data – pressure, temperature, and time)
3FB8DA6DBD091CB501     (tide data – pressure, temperature, and time)
3FB9826E01091CB62D     (tide data – pressure, temperature, and time)
000000000000000000     (flag beginning of wave burst)
. . .
```

Note:
If you uploaded data in binary, SeatermW sent **DBbaud,b,e** instead of **DD**. However, the uploaded .hex file ***always*** shows the **DD** command, so the file looks exactly the same, regardless of whether ASCII or binary upload was used.

The beginning of a sample .hex file for a 26*plus* **with Quartz pressure sensor and with conductivity** follows:

> **Note:**
> If you uploaded data in binary, SeatermW sent **DBbaud,b,e** instead of **DD**. However, the uploaded .hex file ***always*** shows the **DD** command, so the file looks exactly the same, regardless of whether ASCII or binary upload was used.

(beginning of file, with **DS** and **DC** response, same as shown above, except **DS** response shows *conductivity = YES*, the calculated memory endurance and battery endurance in **DS** response is reduced, and **DC** response shows conductivity coefficients in addition to pressure and temperature coefficients)

```
*S>DD
FFFFFFFFFFFFFFFBFFFFFFFF   (flag beginning of tide parameters)
091B5BA70000000000000000   (time of beginning of first tide sample)
012C00010000000000000000   (tide sample interval, wave integration period)
FFFFFFFFFFFFFFFCFFFFFFFF   (flag end of tide parameters)
3FF42973A0000000091B5BA7   (tide data – pressure, temperature, conductivity, and time)
3FF59573D6000000091B5CD3   (tide data – pressure, temperature, conductivity, and time)
3FF674740E000000091B5DFF   (tide data – pressure, temperature, conductivity, and time)
000000000000000000000000   (flag beginning of wave burst)
091B5E790200000000000000   (time of beginning of wave burst, number of samples in burst)
029B92F40000000000000000   (pressure temperature compensation number, number of samples in burst)
87CAA787CAA1               (wave burst pressure data)
. . .                      (wave burst pressure data)
87CA9387CAA1               (wave burst pressure data)
FFFFFFFFFFFFFFFFFFFFFFFF   (flag end of wave burst)
3FF71C743F000000091B5F2B   (tide data – pressure, temperature, conductivity, and time)
3FF8F77472000000091B6057   (tide data – pressure, temperature, conductivity, and time)
3FF9BB74A6000000091B6183   (tide data – pressure, temperature, conductivity, and time)
000000000000000000000000   (flag beginning of wave burst)
. . .
```

- Beginning lines - ***** flags header. Header lines contain (in order):
  - Input file name
  - Software version used to upload the data
  - 26*plus* response to status (**DS**) command
  - 26*plus* response to calibration coefficients (**DC**) command

- Following lines - Data follows, with each line followed by a carriage return and line feed. Data is described below.

Setup Parameters and Tide Data – with *Quartz* Pressure

Data (lines after the `*S>DD`) is described below:

Tide Line	**26*plus without* Conductivity** (all flags and tide data are 9 bytes = 18 Hex characters)	**26*plus with* Conductivity** (all flags and tide data are 12 bytes = 24 Hex characters)
1*	`FFFFFFFFFBFFFFFFFF` - Flag start of setup parameters.	`FFFFFFFFFFFFFFFBFFFFFFFF` - Flag start of setup parameters.
2*	`091CB0510000000000` – First 5 bytes is start time (seconds since January 1, 2000) of integration of first tide sample. Remaining bytes are 0's.	`091B5BA7000000000000000` – First 5 bytes is start time (seconds since January 1, 2000) of integration of first tide sample. Remaining bytes are 0's.
3*	`012C00010000000000` - First 2 bytes (`012C`) is tide sample interval (seconds); next 2 bytes (`0001`) is number of 0.25-second periods to integrate wave samples. Remaining bytes are 0's	`012C00010000000000000000` - First 2 bytes (`012C`) is tide sample interval (seconds); next 2 bytes (`0001`) is number of 0.25-second periods to integrate wave samples. Remaining bytes are 0's.
4*	`FFFFFFFFFCFFFFFFFF` - Flag end of setup parameters.	`FFFFFFFFFFFFFFFCFFFFFFFF` - Flag end of setup parameters.
5	`3FB78A6CA4091CB051` - Tide record (pressure, temperature, and time). First 3 bytes (`3FB78A`) is pressure number, next 2 bytes (`6CA4`) is temperature number, and last 4 bytes (`091CB051`) is start time of tide measurement (seconds since January 1, 2000).	`3FF42973A0000000091B5BA7` - Tide record (pressure, temperature, conductivity, and time). First 3 bytes (`3FF429`) is pressure number, next 2 bytes (`73A0`) is temperature number, next 3 bytes (`000000`) is conductivity number, and last 4 bytes (`091B5BA7`) is start time of tide measurement (seconds since January 1, 2000).
6	`3FB7DE6CEB091CB17D` - Tide record (pressure, temperature, and time). First 3 bytes (`3FB7DE`) is pressure number, next 2 bytes (`6CEB`) is temperature number, and last 4 bytes (`091CB17D`) is start time of tide measurement (seconds since January 1, 2000).	`3FF59573D6000000091B5CD3` - Tide record (pressure, temperature, conductivity, and time). First 3 bytes (`3FF595`) is pressure number, next 2 bytes (`73D6`) is temperature number, next 3 bytes (`000000`) is conductivity number, and last 4 bytes (`091B5CD3`) is start time of tide measurement (seconds since January 1, 2000).
7	`3FB8F66D33091CB2A9` - tide record (pressure, temperature, and time). First 3 bytes (`3FB8F6`) is pressure number, next 2 bytes (`6D33`) is temperature number, and last 4 bytes (`091CB2A9`) is start time of tide measurement (seconds since January 1, 2000).	`3FF674740E000000091B5DFF` - Tide record (pressure, temperature, conductivity, and time). First 3 bytes (`3FF674`) is pressure number, next 2 bytes (`740E`) is temperature number, next 3 bytes (`000000`) is conductivity number, and last 4 bytes (`091B5DFF`) is start time of tide measurement (seconds since January 1, 2000).
8	`000000000000000000` - Flag beginning of wave burst. Setup for this example was to measure waves every 3 tide samples, so there are 3 tide records (lines 5 to 7) before wave burst flag.	`000000000000000000000000` - Flag beginning of wave burst. Setup for this example was to measure waves every 3 tide samples, so there are 3 tide records (lines 5 to 7) before wave burst flag.

* An uploaded file that includes multiple logging sessions contains these four records at the start of each logging session, to provide sampling parameters for that logging session.

Note:
You must run ExtractTide.exe before Convert Hex if your uploaded .hex file contains data from multiple logging sessions. See *Section 6: Conversion into Tide and Wave Files – Extract Tide and Convert Hex*.

Convert Hex converts the hex data to pressure, temperature, (optional) conductivity, and time in engineering units when the data is separated into tide and wave burst files. The tide data conversions are described below:

pressure (psia)= [slope correction * (pressure number - B) / M] + offset correction
where

- pressure number is the first 3 bytes (6 characters) of the tide data, converted from Hex to decimal.
- slope and offset corrections are read from the Convert Hex calibration coefficients (.ini) file. Note that the *pressure number* already includes the effect of the offset entered in the 26*plus* EEPROM with the **POffset=** command.
- M and B are scaling parameters that depend on pressure sensor range. They are calculated by the 26*plus* and are read by Convert Hex from the uploaded .hex file header (in the **DC** response).

temperature (°C) = (temperature number / 1000) - 10
where

- temperature number is the next 2 bytes (4 characters) of the tide data, converted from Hex to decimal.

conductivity frequency (Hz) = conductivity number / 256
where

- Conductivity number is the next 3 bytes (6 characters) of the tide data, converted from Hex to decimal.

Conductivity frequency is converted to conductivity using the coefficients and equation found on the calibration certificate for the sensor. These coefficients are entered in the 26*plus* EEPROM at the factory using the calibration coefficient commands, and are read by Convert Hex from the uploaded .hex file header (in the **DC** response).

time = time number = number of seconds since January 1, 2000

- Time is the last 4 bytes (8 characters) of the tide data, converted from Hex to decimal.

Example 1 (no conductivity, from sample file above):
tide record = 3FB78A6CA4091CB051 hex

The first 3 bytes are 3FB78A hex = 4175754 decimal.
For this example, M = 279620.2 and B = 18641.3 (in **DC** response in .hex file)
Assume slope correction = 1.0 and offset correction = 0 in the .ini file.
pressure = [slope correction * (pressure number - B) / M] + offset correction
pressure = [1.0 * (4175754 – 18641.3) / 279620.2] + 0 = 14.8670 psia

The next 2 bytes are 6CA4 hex = 27812 decimal.
temperature = (temperature number / 1000) – 10 = (27812 / 1000) - 10 = 17.812 °C

The last 4 bytes are 091CB051 hex = 152875089 decimal
Time = 152875089 seconds since Jan. 1, 2000 = November 4, 2004, 09:18:09

Example 2 (conductivity enabled, from sample file above):
tide record = 3FF42973A0000000091B5BA7 hex

The first 3 bytes are 3FF429 hex = 4191273 decimal.
For this example, M = 279620.2 and B = 18641.3 (in **DC** response in .hex file)
Assume slope correction = 1.0 and offset correction = 0 in the .ini file.
pressure = [slope correction * (pressure number - B) / M] + offset correction
pressure = [1.0 * (4191273 – 18641.3) / 279620.2] + 0 = 14.9225 psia

The next 2 bytes are 73A0 hex = 29600 decimal.
temperature = (temperature number / 1000) – 10 = (29600 / 1000) - 10 = 19.6 °C

The next 3 bytes are 000000 hex = 0 decimal.
conductivity frequency (Hz) = conductivity number / 256
conductivity frequency (Hz) = 0 / 256 = 0 Hz

The last 4 bytes are 091B5BA7 hex = 152787879 decimal
Time = 152787879 seconds since Jan. 1, 2000 = November 3, 2004, 09:04:39

Wave Burst Data – with *Quartz* Pressure

Data (lines from beginning to end of wave burst) is described below:

Wave Burst Line	**26*plus without* Conductivity** (all wave pressure data is 6 bytes = 12 Hex characters; all flags and other wave data is 9 bytes = 18 Hex characters)	**26*plus with* Conductivity** (all wave pressure data is 6 bytes = 12 Hex characters; all flags and other wave data is 12 bytes = 24 Hex characters)
1	`000000000000000000` - Flag beginning of wave burst.	`000000000000000000000000` - Flag beginning of wave burst.
2	`091CB3220200000000` – First 4 bytes (`091CB322`) is start time (seconds since January 1, 2000) of wave burst. Next byte (`02`) is MSB of number of samples in wave burst. Remaining bytes are 0's.	`091B5E790200000000000000` – First 4 bytes (`091B5E79`) is start time (seconds since January 1, 2000) of wave burst. Next byte (`02`) is MSB of number of samples in wave burst. Remaining bytes are 0's.
3	`029B83E80000000000` - First 4 bytes (`029B83E8`) is pressure temperature compensation number. Next byte (`00`) is LSB of number of samples in wave burst. (For example shown, number of samples in wave burst = 0200 Hex = 512 decimal). Remaining bytes are 0's.	`029B92F40000000000000000` - First 4 bytes (`029B92F4`) is pressure temperature compensation number. Next byte (`00`) is LSB of number of samples in wave burst. (For example shown, number of samples in wave burst = 0200 Hex = 512 decimal). Remaining bytes are 0's.
4 and following	`87CED887CED6` - First 3 bytes (`87CED8`) is pressure number for first wave measurement, last 3 bytes (`87CED6`) is pressure number for second wave measurement. Each subsequent line also contains data for 2 wave measurements. There are a total of [(wave samples/burst) / 2] lines of wave pressure data.	`87CAA787CAA1` - First 3 bytes (`87CAA7`) is pressure number for first wave measurement, last 3 bytes (`87CAA1`) is pressure number for second wave measurement. Each subsequent line also contains data for 2 wave measurements. There are a total of [(wave samples/burst) / 2] lines of wave pressure data.
Last	`FFFFFFFFFFFFFFFFFF` - Flag end of wave burst.	`FFFFFFFFFFFFFFFFFFFFFFFF` - Flag end of wave burst.

Note:
You must run ExtractTide.exe before Convert Hex if your uploaded .hex file contains data from multiple logging sessions. See *Section 6: Conversion into Tide and Wave Files – Extract Tide and Convert Hex*.

Convert Hex converts the hex data to pressure in engineering units when the data is separated into tide and wave burst files. The wave burst data conversions are described below:

Pressure temperature compensation frequency (Hz) = PTCF
= pressure temperature compensation number / 256
Pressure frequency (Hz) = PF = pressure number / 256

Pressure is computed as follows:

U = [(1.0 / PTCF) * 1000000] - U0
C = C1 + (C2 * U) + (C3 * U^2)
D = D1 + D2 but D2 = 0, so D = D1
T0 = (T1 + T2 * U + T3 * U^2 + T4 * U^3) / 1,000,000
W = 1.0 - (T0 * T0 * PF * PF)
pressure (psia)
= slope correction * [{C * W * (1.0 - D * W)} + POffset] + offset correction
where

- U0, C1, C2, C3, D1, T1, T2, T3, T4, and POffset are entered in the 26*plus* EEPROM at the factory using the calibration coefficient commands, and are read by Convert Hex from the uploaded .hex file header (in the **DC** command response).
- Slope and offset corrections are read from the Convert Hex calibration coefficients (.ini) file.

Example (26plus with no conductivity, from sample file above):

`000000000000000000`	(flag beginning of wave burst)
`091CB3220200000000`	(time of beginning of wave burst, number of samples in burst)
`029B83E80000000000`	(pressure temperature compensation number, number of samples in burst)
`87CED887CED6`	(wave burst pressure data)
`. . .`	(wave burst pressure data)
`87CEE087CEEA`	(wave burst pressure data)
`FFFFFFFFFFFFFFFFFF`	(flag end of wave burst)

pressure temperature compensation & number of samples = 029B83E80000000000 hex

Pressure temperature compensation number = 029B83E8 hex = 43746280 decimal
Pressure number for first wave burst pressure data (first 3 bytes)
= 87CED8 hex = 8900312 decimal
Pressure temperature compensation frequency = PTCF
= pressure temperature compensation number / 256 = 43746280 / 256 = 170883.90 Hz
Pressure frequency = PF = pressure number / 256 = 8900312 / 256 = 34766.843 Hz
Using calibration coefficients from uploaded hex file:
U0 = 5.856409e+00, Y1 = -3.987838e+03, Y2 = -1.049603e+04,
Y3 = 0.000000e+00, C1 = 2.305367e+02, C2 = 1.198422e+01,
C3 = -2.401512e+02, D1 = 4.095400e-02, D2 = 0.000000e+00,
T1 = 2.781994e+01, T2 = 6.760780e-01, T3 = 1.761829e+01,
T4 = 6.000932e+00, POffset = 0

U = [(1.0 / PTCF) * 1,000,000] - U0
= [(1.0 / 170883.90) * 1,000,000] - 5.856409e+00 = -0.004482634

C = C1 + (C2 * U) + (C3 * U^2)
= 2.305367e+02 + (1.198422e+01 * U) + (-2.401512e+02 * U^2)
= 2.305367e+02 - 0.05372087 - 0.004825600 = 2.304782e+02

D = D1 + D2 = 4.095400e-02+ 0 = 4.095400e-02

T0 = (T1 + T2 * U + T3 * U^2 + T4 * U^3) / 1,000,000
= (2.781994e+01 + 6.760780e-01* U + 1.761829e+01 * U^2
+ 6.000932e+00 * U^3) / 1000000
= (2.781994e+01 - 3.030610e-03 + 3.540221e-04 - 5.405284e-07) / 1,000,000
= 2.7817266e-05

W = 1.0 - (T0 * T0 * PF * PF)
= 1.0 - (2.7817266e-05 * 2.7817266e-05 * 34766.843 * 34766.843) = 6.468177e-02

pressure = slope correction * [{C * W * (1.0 - D * W)} + POffset] + offset correction
For this example, assume slope correction = 1.0, and offset correction = 0.

pressure = (2.304782e+02) * (6.468177e-02) * (1.0 – [4.095400e-02 * 6.468177e-02])
= 14.868 psia

Hex Data Format with *Strain Gauge* Pressure Sensor (.hex extension)

A .hex file contains hexadecimal data uploaded from SBE 26*plus* memory using SeatermW's Upload.

The beginning of a sample .hex file for a 26*plus* **with Strain Gauge pressure sensor and without conductivity** follows:

```
*Sea-Bird SBE 26plus Data File:
*FileName = C:\sbe26plus\StrainGaugeNoCond.hex
*Software Version 1.07
*DS
*SBE 26plus V 6.1c  SN 1034    10 Dec 2006  12:10:53
*user info= test file
*strain gauge pressure sensor: serial number = 5471, range = 45 psia
*internal temperature sensor
*conductivity = NO
*iop =  7.8 ma  vmain = 18.4 V  vlith =  9.1 V
*last sample: p = 14.9320, t = 21.5951
*
*tide measurement: interval = 5.000 minutes, duration = 120 seconds
*measure waves every 3 tide samples
*512 wave samples/burst at 4.00 scans/sec, duration = 128 seconds
*logging start time = do not use start time
*logging stop time = do not use stop time
*
*tide samples/day = 288.000
*wave bursts/day = 96.000
*memory endurance = 218.6 days
*nominal alkaline battery endurance = 94.9 days
*total recorded tide measurements = 36
*total recorded wave bursts = 12
*tide measurements since last start = 36
*wave bursts since last start = 12
*
*transmit real-time tide data = NO
*transmit real-time wave burst data = NO
*transmit real-time wave statistics = NO
*
*status = stopped by user
*logging = NO, send start command to begin logging
*S>DC
*Pressure coefficients:  05-feb-04
*    PA0 = -7.912454e-02
* . . .          (more pressure sensor calibration coefficients)
*    OFFSET = 0.00
*Temperature coefficients:  05-jan-04
*    TA0 = 2.993769e-04
*    TA1 = 2.397817e-04
*    TA2 = -8.392026e-07
*    TA3 = 1.319386e-07
*S>DD
FFFFFFFFFBFFFFFFFF     (flag beginning of tide parameters)
091B5D370000000000     (time of beginning of first tide sample)
012C00010000000000     (tide sample interval, wave integration period)
FFFFFFFFFCFFFFFFFF     (flag end of tide parameters)
3FC29478FB091B5D37     (tide data – pressure, temperature, and time)
3FC3AE7940091B5E63     (tide data – pressure, temperature, and time)
3FC4F77981091B5F8F     (tide data – pressure, temperature, and time)
000000000000000000     (flag beginning of wave burst)
091B60080200000000     (time of beginning of wave burst, number of samples in burst)
000005000000000000     (pressure temperature compensation number, number of samples in burst)
18FD5B18FD64           (wave burst pressure data)
. . .                  (wave burst pressure data)
18FDCF18FDD5           (wave burst pressure data)
FFFFFFFFFFFFFFFFFF     (flag end of wave burst)
3FC56079C0091B60BB     (tide data – pressure, temperature, and time)
3FC1017A47091B61E7     (tide data – pressure, temperature, and time)
3FC1097AC9091B6313     (tide data – pressure, temperature, and time)
000000000000000000     (flag beginning of wave burst)
. . .
```

Note:
If you uploaded data in binary, SeatermW sent **DBbaud,b,e** instead of **DD**. However, the uploaded .hex file ***always*** shows the **DD** command, so the file looks exactly the same, regardless of whether ASCII or binary upload was used.

The beginning of a sample .hex file for a 26*plus* **with Strain Gauge pressure sensor and with conductivity** follows:

> **Note:**
> If you uploaded data in binary, SeatermW sent **DBbaud,b,e** instead of **DD**. However, the uploaded .hex file ***always*** shows the **DD** command, so the file looks exactly the same, regardless of whether ASCII or binary upload was used.

(beginning of file, with **DS** and **DC** response, same as shown above, except **DS** response shows *conductivity = YES*, the calculated memory endurance and battery endurance in **DS** response is reduced, and **DC** response shows conductivity coefficients in addition to pressure and temperature coefficients)

```
*S>DD
FFFFFFFFFFFFFFFBFFFFFFFF   (flag beginning of tide parameters)
091CAFE70000000000000000   (time of beginning of first tide sample)
012C00010000000000000000   (tide sample interval, wave integration period)
FFFFFFFFFFFFFFFCFFFFFFFF   (flag end of tide parameters)
3F9A816E50000000091CAFE7   (tide data – pressure, temperature, conductivity, and time)
3F9BF36EC1000000091CB113   (tide data – pressure, temperature, conductivity, and time)
3F9D136F47000000091CB23F   (tide data – pressure, temperature, conductivity, and time)
000000000000000000000000   (flag beginning of wave burst)
091CB2BA0200000000000000   (time of beginning of wave burst, number of samples in burst)
000004DC0000000000000000   (pressure temperature compensation number, number of samples in burst)
18F03D18F054               (wave burst pressure data)
. . .                      (wave burst pressure data)
18F07518F063               (wave burst pressure data)
FFFFFFFFFFFFFFFFFFFFFFFF   (flag end of wave burst)
3F9DA26FB4000000091CB36B   (tide data – pressure, temperature, conductivity, and time)
3F9DBE7010000000091CB497   (tide data – pressure, temperature, conductivity, and time)
3F9F1A706A000000091CB5C3   (tide data – pressure, temperature, conductivity, and time)
000000000000000000000000   (flag beginning of wave burst)
. . .
```

- Beginning lines - ***** flags header. Header lines contain (in order):
  - Input file name
  - Software version used to upload the data
  - 26*plus* response to status (**DS**) command
  - 26*plus* response to calibration coefficients (**DC**) command

- Following lines - Data follows, with each line followed by a carriage return and line feed. Data is described below.

Setup Parameters and Tide Data – with *Strain Gauge* Pressure

Data (lines after the `*S>DD`) is described below:

Tide Line	**26*plus* without Conductivity** (all flags and tide data is 9 bytes = 18 Hex characters)	**26*plus* with Conductivity** (all flags and tide data is 12 bytes = 24 Hex characters)
1*	`FFFFFFFFFBFFFFFFFF` - Flag start of setup parameters.	`FFFFFFFFFFFFFFFBFFFFFFFF` - Flag start of setup parameters.
2*	`091B5D370000000000` – First 5 bytes is start time (seconds since January 1, 2000) of integration of first tide sample. Remaining bytes are 0's.	`091CAFE70000000000000000` – First 5 bytes is start time (seconds since January 1, 2000) of integration of first tide sample. Remaining bytes are 0's.
3*	`012C00010000000000` - First 2 bytes (`012C`) is tide sample interval (seconds); next 2 bytes (`0001`) is number of 0.25-second periods to integrate wave samples. Remaining bytes are 0's.	`012C00010000000000000000` - First 2 bytes (`012C`) is tide sample interval (seconds); next 2 bytes (`0001`) is number of 0.25-second periods to integrate wave samples. Remaining bytes are 0's.
4*	`FFFFFFFFFCFFFFFFFF` - Flag end of setup parameters.	`FFFFFFFFFFFFFFFCFFFFFFFF` - Flag end of setup parameters.
5	`3FC29478FB091B5D37` - Tide record (pressure, temperature, and time). First 3 bytes (`3FC294`) is pressure number, next 2 bytes (`78FB`) is temperature number, and last 4 bytes (`091B5D37`) is start time of tide measurement (seconds since January 1, 2000).	`3F9A816E50000000091CAFE7` - Tide record (pressure, temperature, conductivity, and time). First 3 bytes (`3F9A81`) is pressure number, next 2 bytes (`6E50`) is temperature number, next 3 bytes (`000000`) is conductivity number, and last 4 bytes (`091CAFE7`) is start time of tide measurement (seconds since January 1, 2000).
6	`3FC3AE7940091B5E63` - Tide record (pressure, temperature, and time). First 3 bytes (`3FC3AE`) is pressure number, next 2 bytes (`7940`) is temperature number, and last 4 bytes (`091B5E63`) is start time of tide measurement (seconds since January 1, 2000).	`3F9BF36EC1000000091CB113` - Tide record (pressure, temperature, conductivity, and time). First 3 bytes (`3F9BF3`) is pressure number, next 2 bytes (`6EC1`) is temperature number, next 3 bytes (`000000`) is conductivity number, and last 4 bytes (`091CB113`) is start time of tide measurement (seconds since January 1, 2000).
7	`3FC4F77981091B5F8F` - Tide record (pressure, temperature, and time). First 3 bytes (`3FC4F7`) is pressure number, next 2 bytes (`7981`) is temperature number, and last 4 bytes (`091B5F8F`) is start time of tide measurement (seconds since January 1, 2000).	`3F9D136F47000000091CB23F` - Tide record (pressure, temperature, conductivity, and time). First 3 bytes (`3F9D13`) is pressure number, next 2 bytes (`6F47`) is temperature number, next 3 bytes (`000000`) is conductivity number, and last 4 bytes (`091CB23F`) is start time of tide measurement (seconds since January 1, 2000).
8	`000000000000000000` - Flag beginning of wave burst. Setup for this example was to measure waves every 3 tide samples, so there are 3 tide records (lines 5 to 7) before wave burst flag.	`000000000000000000000000` - Flag beginning of wave burst. Setup for this example was to measure waves every 3 tide samples, so there are 3 tide records (lines 5 to 7) before wave burst flag.

* An uploaded file that includes multiple logging sessions contains these four records at the start of each logging session, to provide the sampling parameters for that logging session.

> **Note:**
> You must run ExtractTide.exe before Convert Hex if your uploaded .hex file contains data from multiple logging sessions. See *Section 6: Conversion into Tide and Wave Files – Extract Tide and Convert Hex*.

Convert Hex converts the hex data to pressure, temperature, (optional) conductivity, and time in engineering units when the data is separated into tide and wave burst files. The tide data conversions are described below:

pressure (psia)= [slope correction * (pressure number - B) / M] + offset correction
where

- pressure number is the first 3 bytes (6 characters) of the tide data, converted from Hex to decimal.
- slope and offset corrections are read from the Convert Hex calibration coefficients (.ini) file. Note that the *pressure number* already includes the effect of the offset entered in the 26*plus* EEPROM with the **POffset=** command.
- M and B are scaling parameters that depend on pressure sensor range. They are calculated by the 26*plus* and are read by Convert Hex from the uploaded .hex file header (in the **DC** response).

temperature (°C) = (temperature number / 1000) - 10
where

- temperature number is the next 2 bytes (4 characters) of the tide data, converted from Hex to decimal.

conductivity frequency (Hz) = conductivity number / 256
where

- Conductivity number is the next 3 bytes (6 characters) of the tide data, converted from Hex to decimal.

Conductivity frequency is converted to conductivity using the coefficients and equation found on the calibration certificate for the sensor. These coefficients are entered in the 26*plus* EEPROM at the factory using the calibration coefficient commands, and are read by Convert Hex from the uploaded .hex file header (in the **DC** response).

time = time number = number of seconds since January 1, 2000

- Time is the last 4 bytes (8 characters) of the tide data, converted from Hex to decimal.

> *Example 1 (no conductivity, from sample file above):* tide record = `3FC29478FB091B5D37` hex
>
> The first 3 bytes are `3FC294` hex = 4178580 decimal.
> For this example, M = 279620.2 and B = 18641.3 (in **DC** response in .hex file).
> Assume slope correction = 1.0 and offset correction = 0 in .ini file.
> pressure = [slope correction * (pressure number - B) / M] + offset correction
> pressure = [1.0 * (4178580 – 18641.3) / 279620.2] + 0 = 14.8771 psia
>
> The next 2 bytes are `78FB` hex = 30971 decimal.
> temperature = (temperature number / 1000) – 10 = (30971 / 1000) - 10 = 20.971 °C
>
> The last 4 bytes are `091B5D37` hex = 152788279 decimal
> Time = 152788279 seconds since January 1, 2000 = November 3, 2004, 09:11:19
>
> *Example 2 (conductivity enabled, from sample file above):*
> tide record = `3F9A816E50000000091CAFE7` hex
>
> The first 3 bytes are `3F9A81` hex = 4168321 decimal.
> For this example, M = 279620.2 and B = 18641.3 (in **DC** response in .hex file)
> Assume slope correction = 1.0 and offset correction = 0 in .ini file.
> pressure = [slope correction * (pressure number - B) / M] + offset correction
> pressure = [1.0 * (4168321 – 18641.3) / 279620.2] + 0 = 14.8404 psia
>
> The next 2 bytes are `6E50` hex = 28240 decimal.
> temperature = (temperature number / 1000) – 10 = (28240 / 1000) - 10 = 18.24 °C
>
> The next 3 bytes are `000000` hex = 0 decimal.
> conductivity frequency (Hz) = conductivity number / 256
> conductivity frequency (Hz) = 0 / 256 = 0 Hz
>
> The last 4 bytes are `091CAFE7` hex = 152874983 decimal
> Time = 152874983 seconds since January 1, 2000 = November 4, 2004, 09:16:23

Wave Burst Data – with *Strain Gauge* Pressure

Data (lines from beginning to end of wave burst) is described below:

Wave Burst Line	**26*plus* without Conductivity** (all wave pressure data is 6 bytes = 12 Hex characters; all flags and other wave data is 9 bytes = 18 Hex characters)	**26*plus* with Conductivity** (all wave pressure data is 6 bytes = 12 Hex characters; all flags and other wave data is 12 bytes = 24 Hex characters)
1	`000000000000000000` - Flag beginning of wave burst.	`000000000000000000000000` - Flag beginning of wave burst.
2	`091B60080200000000` – First 4 bytes (`091B6008`) is start time (seconds since January 1, 2000) of wave burst. Next byte (`02`) is MSB of number of samples in wave burst. Remaining bytes are 0's.	`091CB2BA0200000000000000` – First 4 bytes (`091CB2BA`) is start time (seconds since January 1, 2000) of wave burst. Next byte (`02`) is MSB of number of samples in wave burst. Remaining bytes are 0's.
3	`000005000000000000` - First 4 bytes (`00000500`) is pressure temperature compensation number. Next byte (`00`) is LSB of number of samples in wave burst (for example shown, number of samples in wave burst = 0200 Hex = 512 decimal). Remaining bytes are 0's.	`000004DC0000000000000000` - First 4 bytes (`000004DC`) is pressure temperature compensation number. Next byte (`00`) is LSB of number of samples in wave burst (for example shown, number of samples in wave burst = 0200 Hex = 512 decimal). Remaining bytes are 0's.
4 and following	`18FD5B18FD64` - First 3 bytes (`18FD5B`) is pressure number for first wave measurement, last 3 bytes (`18FD64`) is pressure number for second wave measurement. Each subsequent line also contains data for 2 wave measurements. There are a total of [(wave samples/burst) / 2] lines of wave pressure data.	`18F03D18F054` - First 3 bytes (`18F03D`) is pressure number for first wave measurement, last 3 bytes (`18F054`) is pressure number for second wave measurement. Each subsequent line also contains data for 2 wave measurements. There are a total of [(wave samples/burst) / 2] lines of wave pressure data.
Last	`FFFFFFFFFFFFFFFFFF` - Flag end of wave burst.	`FFFFFFFFFFFFFFFFFFFFFFFF` - Flag end of wave burst.

> **Note:**
> You must run ExtractTide.exe before Convert Hex if your uploaded .hex file contains data from multiple logging sessions. See *Section 6: Conversion into Tide and Wave Files – Extract Tide and Convert Hex*.

Convert Hex converts the hex data to pressure in engineering units when the data is separated into tide and wave burst files. The wave burst data conversions are described below:

Pressure temperature compensation = **PTC**
= pressure temperature compensation number / 1000

Pressure = **P** = pressure number / 8

Pressure temperature = **T** =
PTEMPA0 + (PTEMPA1 * PTC) + (PTEMPA2 * PTC^2)

X = P – PTCA0 – (PTCA1 * T) – (PTCA2 * T^2)

N = X * PTCB0 / [PTCB0 + (PTCB1 * T) + (PTCB2 * T^2)]

pressure (psia)
= slope correction * [PA0 + (PA1*N) + (PA2*N^2) + POffset] + offset correction

where

- PA0, PA1, PA2, PTCA0, PTCA1, PTCA2, PTCB0, PTCB1, PTCB2, PTEMPA0, PTEMPA1, PTEMPA2, and POffset are entered in the 26*plus* EEPROM at the factory using the calibration coefficient commands, and are read by Convert Hex from the uploaded .hex file header (in the **DC** command response).
- Slope and offset corrections are read from the Convert Hex calibration coefficients (.ini) file.

Example (no conductivity, from sample file above):

`000000000000000000`	(flag beginning of wave burst)
`091B60080200000000`	(time of beginning of wave burst, number of samples in burst)
`000005000000000000`	(pressure temperature compensation number, number of samples in burst)
`18FD5B18FD64`	(wave burst pressure data)
`. . .`	(wave burst pressure data)
`18FDCF18FDD5`	(wave burst pressure data)
`FFFFFFFFFFFFFFFFFF`	(flag end of wave burst)

Pressure temperature compensation & number of samples = 000005000000000000 hex
Pressure temperature compensation = 00000500 hex = 1280 decimal
Pressure temperature compensation = PTC = pressure temperature compensation number / 1000 =
1280 / 1000 = 1.28

Pressure number for first wave burst pressure data (first 3 bytes) = 18FD5B hex = 1637723 decimal
Pressure = **P** = pressure number / 8 = 1637723 / 8 = 204715.375

Using calibration coefficients from uploaded hex file:
PA0 = -7.912454e-02, PA1 = 7.317688e-05, PA2 = -1.012808e-12,
PTCA0 = 3.446204e+02, PTCA1 = -4.617518e+01, PTCA2 = -1.236197e-01,
PTCB0 = 2.488438e+01, PTCB1 = 2.275000e-03, PTCB2 = 0.000000e+00,
PTEMPA0 = -8.059255e+01, PTEMPA1 = 8.183057e+01, PTEMPA2 = -1.878352e+00, POffset = 0

Pressure temperature = **T** = PTEMPA0 + (PTEMPA1 * PTC) + (PTEMPA2 * PTC^2) =
-8.059255e+01 + (8.183057e+01 * 1.28) + (-1.878352 * 1.28^2) = -80.59255 + 104.7431296 -3.0774919168 =
21.073

X = P – PTCA0 – (PTCA1 * T) – (PTCA2 * T^2) =
204715.375 – 3.446204e+02 – (-4.617518e+01 * 21.073) – (-1.236197e-01 * 21.073^2) = 205398.704
N = X * PTCB0 / [PTCB0 + (PTCB1 * T) + (PTCB2 * T^2)] =
205398.704 * 2.488438e+01 / [2.488438e+01 + (2.275000e-03 * 21.073) + (0 * 21.073^2)] = 205003.753

pressure = slope correction * [PA0 + (PA1 * N) + (PA2 * N^2) + POffset] + offset correction
For this example, assume slope correction = 1.0, and offset correction = 0.
pressure = (-7.912454e-02) + (7.317688e-05 * 205003.753) + (-1.012808e-12 * 205003.753^2) = 14.880 psia

Tide Data Format (.tid extension)

A .tid file is created from the .hex file in Convert Hex. A sample tide data (.tid) file is shown below:

```
1   11/13/92 10:27:16   14.8125    22.102   3.55682    23.909
2   11/13/92 10:28:16   15.0086    14.818   3.48032    27.844
3   11/13/92 10:29:16   15.0836    11.242   3.07901    26.714
4   11/13/92 10:30:16   15.1536     8.951   3.07101    28.376
5   11/13/92 10:31:16   15.2267     7.225   3.06788    29.772
```

Note:
If conductivity logging is not enabled (**Conductivity=N**; status display shows `conductivity = NO`), the sixth and seventh columns are not included in the .tid file.

- Column 1 = Tide measurement number
- Columns 2 and 3 = Date and time of beginning of tide measurement
- Column 4 = Measured pressure in psia
- Column 5 = Measured water temperature in °C
- Column 6= Measured conductivity in S/m
- Column 7 = Calculated salinity in PSU

If Merge Barometric Pressure has been run on the .tid file to remove the effect of barometric pressure, the output .tid file contains descriptive column headings. The presence of headings in the .tid file indicates that it has been processed by Merge Barometric Pressure. Additionally, Merge Barometric Pressure has the ability to replace the pressure in the fourth column with calculated water depth. See *Section 7: Tide Data Processing – Merge Barometric Pressure* for details, and for the required data format for the barometric pressure (.bp) file to input in Merge Barometric Pressure.

Wave Burst Data Format (.wb extension)

A .wb file is created from the .hex file in Convert Hex. A sample wave burst data file is shown below:

Note:
This wave data was obtained while the instrument was on land, so the output is indicating essentially 0 wave height.

```
SBE 26plus
*    0   152875706    0.25  512
         14.842843     14.843052     14.842925     14.842970
         14.842998     14.843070     14.843125     14.843025
         14.843079     14.842952     14.842998     14.842970
. . . .  (remaining data for first wave burst)
*    1   152876606    0.25  512
         14.844642     14.844933     14.844914     14.844851
         14.844942     14.844914     14.844969     14.844787
         14.844833     14.844887     14.844860     14.844887
. . . .  (remaining data for second wave burst)
```

- First line - * flags beginning of data for a wave burst. Line contains (in order):
  - Wave burst number
  - Start of tide measurement (seconds since January 1, 2000)
  - Wave integration period (seconds)
  - Number of points in wave burst

- Second and following lines (until next line with *) - Measured pressures in psia, with four values per line

Wave Burst Auto-Spectrum Statistics (.was extension)

A .was file is created from the .wb file in Process Wave Burst Data. A sample wave burst Auto-Spectrum statistics file is shown below:

```
SBE 26plus
*  0  39714178  1.00 1024  10   5.666  4.466  1024.211  90  0.637  1.843
    51 5.371094e-003 9.765625e-003 5.9946e-003 6.0210e+001 1.0732e+001 3.0970e-001
    3.091334e-003   3.298001e-003   2.160857e-003   7.776975e-004
    5.304750e-003   3.731420e-003   1.790720e-002   2.439886e-002
    8.326155e-002   1.082657e-001   5.056803e-002   5.299359e-002
    2.502890e-002   2.332787e-002   2.122386e-002   1.846813e-002
    3.559706e-002   3.633030e-002   2.943071e-002   8.796323e-003
    8.000838e-003   4.111465e-003   2.995502e-003   6.887020e-003
    2.995481e-003   4.263404e-003   1.317504e-003   3.054346e-003
    1.688730e-003   2.141096e-003   1.688405e-003   3.960159e-003
    1.314685e-003   1.714741e-003   1.393692e-003   1.332473e-003
    3.300501e-004   5.239898e-004   3.741254e-004   1.336304e-003
    5.561366e-004   6.184441e-004   8.887792e-004   4.510226e-004
    5.383913e-004   4.866397e-004   1.003825e-003   5.819744e-004
    7.742675e-004   1.622945e-003   9.336277e-004
*  1  39724978  1.00 1024  10  6.378  5.178  1024.211  90  0.637  1.843
    51 5.371094e-003 9.765625e-003 6.2661e-003 6.2937e+001 1.0732e+001 3.1663e-001
    2.399138e-003   4.958530e-003   5.970532e-003   5.397915e-003
    3.676770e-003   2.406614e-002   1.292470e-002   2.224974e-002
    4.823480e-002   1.086449e-001   7.481066e-002   8.684431e-002
    1.948858e-002   2.912741e-002   3.741619e-002   2.336472e-002
    2.254591e-002   1.218159e-002   1.780615e-002   4.395502e-003
    9.833613e-003   3.936535e-003   5.881464e-003   4.571996e-003
    5.443738e-003   4.163474e-003   3.601095e-003   3.585647e-003
    5.531514e-003   1.835893e-003   1.114426e-003   3.934834e-003
    2.174772e-003   1.469032e-003   1.335585e-003   9.147523e-004
    6.760068e-004   8.808380e-004   5.716856e-004   7.181183e-004
    6.005655e-004   4.775679e-004   1.299268e-003   3.855911e-004
    4.464863e-004   4.614029e-004   6.163178e-004   8.327592e-004
    1.575676e-003   1.628755e-003   4.645250e-003
```

- First line - ***** flags the beginning of the data for a wave burst. Line contains (in order):
  - ➢ Wave burst number
  - ➢ Start of wave burst (seconds since January 1, 2000)
  - ➢ Wave integration time (seconds)
  - ➢ Number of points in the wave burst
  - ➢ Number of spectral estimates for each frequency band
  - ➢ Water depth (meters)
  - ➢ Pressure sensor depth (meters)
  - ➢ Density (kg/m^3)
  - ➢ Chi-squared confidence interval (percent)
  - ➢ Multiplier for Chi-squared lower bound
  - ➢ Multiplier for Chi-squared upper bound

- Second line contains (in order):
  - ➢ Number of frequency bands calculated
  - ➢ Frequency of first frequency band (Hz)
  - ➢ Interval between frequency bands (delta f) (Hz)
  - ➢ Total variance (meters^2)
  - ➢ Total energy (Joules / meters^2)
  - ➢ Significant period (seconds) = frequency band with greatest variance
  - ➢ Significant wave height (meters) = 4 × sqrt (total variance)

- Third and following lines (until next line with *****) -
  Values (beginning with the first frequency) for the Auto-Spectral density function <Gaa>. Units are meters^2 / Hz. To obtain the variance (m^2) in a frequency interval δf (Hz), multiply the value of <Gaa> by δf.

Wave Burst Auto-Spectrum Report (.rpt extension)

A .rpt file is created from the .wb file in Process Wave Burst Data. A sample wave burst Auto-Spectrum report file is shown below:

```
surface wave processing summary:
file = apr12sp.wb
temperature = 15.000
salinity = 33.000
density = 1024.431
number of points per wave burst = 1028
sample period = 1.00 sec
burst # 1:
    mean pressure = 21.207 psia
    instrument depth = 4.466 meters
    total water depth = 5.666 meters
auto-spectrum:
    10 spectral estimates per band
    51 bands calculated
    each band is 0.010 Hz wide
    frequency span = 0.005  to  0.492 Hz

MM/DD HH:MM SIG.HT SIG.PER                  ENERGY (CM.SQ.)
             (CM)   (SEC)   22+  20  17 15  13  11  9   7   5   3
------------------------------------------------------------------
04/05 15:42   31     11      1   0   0   2   2  19  13  10  10   3
04/05 18:42   32     11      2   2   0   1   2  15  18  11   7   4
04/05 21:42   46      3      2   2   0   2   3   7  12  15   8  82
04/06 00:42   39      9      1   3   0   2   5  10  13  14   8  39
04/06 03:42   41     18      3  13   0   6   2   6  17  11   9  41
04/06 06:42   45     10      4   2   0   8   3  10  21  12  13  56
04/06 09:42   49      8      2   2   0  11   2  13  23  27  29  42
04/06 12:42   57     16      1   5   0  28   5   6  28  17  43  71
04/06 15:42   61     16      1   5   0  59   3   9  27  18  60  50
04/06 18:42   67     16      6   2   0  72  37   9  17  12  52  70
```

The energy (centimeters squared) is the sum of the variance over the indicated frequency band:

- The 9 second wave period is the sum of the variances where the frequency is between 1/10 Hz and 1/8 Hz.
- The 20 second wave period is the sum of the variances where the frequency is between 1/22 Hz and 1/18 Hz.
- The 22+ second wave period is the sum of the variances of all the frequencies less than 1/22 Hz.

Significant period = 1 / (band averaged frequency with the greatest variance)

Surface Wave Time Series Statistics (.wts extension)

A .wts file is created from the .wb file in Process Wave Burst Data. A sample surface wave time series statistics file is shown below:

```
SBE 26plus
*  0  39714178  1.00  1024   109   5.666      4.466    1024.431
  6.860774e-003 6.892497e+001 1.972292e-001 7.431193e+000
  6.293907e-001 3.115848e-001 9.138889e+000 4.114119e-001 6.293907e-001
*  1  39724978  1.00  1024   112   6.377      5.177    1024.431
  6.632170e-003 6.662836e+001 1.914052e-001 7.223214e+000
  4.505061e-001 3.078597e-001 9.000000e+000 3.902955e-001 4.505061e-001
```

- First line - ***** flags the beginning of the data for a wave burst. Line contains (in order):
  - Wave burst number
  - Start of wave burst (seconds since January 1, 2000)
  - Wave integration time (seconds)
  - Number of points in the wave burst
  - Number of individual waves found
  - Water depth (meters)
  - Pressure sensor depth (meters)
  - Density (kg/m^3)

- Second line contains (in order):
  - Total variance of time series (meters^2)
  - Total energy of time series (Joules / meters^2)
  - Average wave height (meters)
  - Average wave period (seconds)

- Third line contains (in order):
  - Maximum wave height (meters)
  - Significant wave height (meters) [average height of largest 1/3 waves]
  - Significant period (seconds) [average period of largest 1/3 waves]
  - $H_{1/10}$ (meters) [average height of largest 1/10 waves] - If less than 10 waves, $H_{1/10}$ is set to 0
  - $H_{1/100}$ (meters) [average height of largest 1/100 waves] - If less than 100 waves, $H_{1/100}$ is set to 0

Surface Wave Time Series (.wt extension)

A .wt file is created from the .wb file in Process Wave Burst Data, if *Output surface wave time series to .wt file* is selected. Part of a sample surface wave time series file is shown below:

```
SBE 26plus
*  0   39714178    1.00  32
       -0.1783     -0.2180     -0.1793     -0.0721
       0.0615       0.1677      0.2036      0.1582
       0.0521      -0.0754     -0.1829     -0.2384
```

- First line - * flags the beginning of the data for a wave burst. Line contains (in order):
  - Wave burst number
  - Start of tide measurement (seconds since January 1, 2000)
  - Wave integration period (seconds)
  - Number of points in wave burst

- Second and following lines (until the next line with *) - Measured wave amplitudes in meters, with four values per line.

Wave Burst Statistics Report (.r26 extension)

A .r26 file is created from the .was and .wts file in Create Reports. Part of a sample report file is shown below:

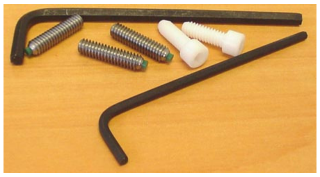
```
# filename = D:\SBE26\951002[.WAS, .WTS]
# wave integration time = 1.00
# number of points in the burst = 1024
# height of SBE 26 above the bottom = 0.300
# density = 1024.153
         Burst    Time-jdays    Time-hours         Depth        Nwaves     Avgheight        Avgper
Maxheight         H1/10        H1/100       Swp-wts       Swh-wts
             0     232.67205         0.000        17.759           211  4.600717e-01  3.838863e+00
3.384997e+00  1.441726e+00  3.134322e+00  4.200000e+00  8.141103e-01
             1     232.75538         2.000        17.679           185  2.278769e-01  4.383784e+00
8.741022e-01  7.083250e-01  8.741022e-01  6.344262e+00  5.092874e-01
```

- Beginning lines - # flags header. Header lines contain (in order):
  - Input file name
  - Wave integration period (seconds)
  - Number of points in the wave burst
  - Height of pressure sensor above bottom
  - Water density

- Column heading line and data – Data varies, depending on user-selected variables to be output.

Appendix IV: Electronics Disassembly/Reassembly

Jackscrew kit



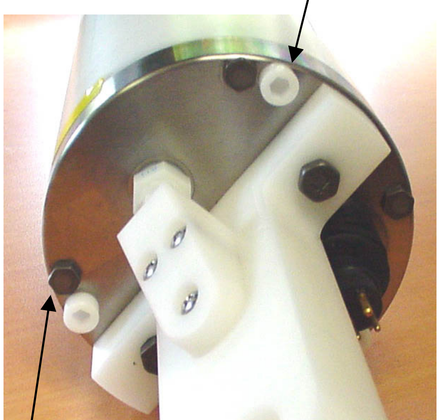
Sea-Bird provides a jackscrew kit with the SBE 26*plus*, to assist in removal of the connector end cap. The kit contains:

- 2 Allen wrenches
- 3 jackscrews
- 2 spare plastic socket hex-head screws

Disassembly

CAUTION:
Disconnect and dismount the optional SBE 4M conductivity cell from the 26*plus* before disassembly to avoid breaking the conductivity cell.

Plastic hex-head screw (typical, 3 places)



Titanium hex-head screw (typical, 4 places)

1. Establish communications with the 26*plus* (see *Section 5: SBE 26plus Setup, Installation, and Data Upload - SeatermW* for details).
   As a precaution, click Upload to upload any data in memory before beginning.

2. Wipe the outside of the end cap and housing dry, being careful to remove any water at the seam between them.

3. Remove the four titanium hex-head screws securing the connector end cap to the housing.

4. Remove the three plastic hex-head screws from the end cap using the larger Allen wrench. Insert the three jackscrews in these three holes in the end cap. When you begin to feel resistance, use the smaller Allen wrench to continue turning the screws. Turn each screw 1/2 turn at a time. As you turn the jackscrews, the end cap will push away from the housing. When the end cap is loosened, pull it and the PCB assembly out of the housing.

5. Remove any water from the O-ring mating surfaces inside the housing with a lint-free cloth or tissue. Be careful to protect the O-rings from damage or contamination.

6. Disconnect the Molex connector connecting the PCB assembly to the battery compartment bulkhead.

7. Remove the jackscrews from the end cap.

Reassembly

Note:
Before delivery, a desiccant package is inserted in the housing and the electronics chamber is filled with dry Argon gas. These measures help prevent condensation. To ensure proper functioning:

1. Install a new desiccant bag each time you open the electronics chamber. If a new bag is not available, see *Application Note 71: Desiccant Use and Regeneration (drying)*.
2. If possible, dry gas backfill each time you open the housing. If you cannot, wait at least 24 hours before redeploying, to allow the desiccant to remove any moisture from the housing.

Note that opening the battery compartment does not affect desiccation of the electronics.

1. Remove any water from the O-ring and mating surfaces with a lint-free cloth or tissue. Inspect the O-ring 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-ring and mating surfaces.

2. Reconnect the Molex connector to the PCB assembly. Verify the connector holds and pins are properly aligned.

3. Carefully fit the PCB assembly into the housing, aligning the holes in the end cap and housing.

4. Reinstall the 4 hex-head screws to secure the end cap to the housing.

5. Reinstall the 3 plastic hex head screws in the end cap.

6. Establish communications with the 26*plus* (see *Section 5: SBE 26plus Setup, Installation, and Data Upload - SeatermW* for details). Reset the date and time (**SetTime**) and initialize logging (**InitLogging**) before redeploying. No other parameters should have been affected by electronics disassembly (send **DS** to verify).

Appendix V: 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 VI: Wave Theory and Statistics

Surface Gravity Waves - Description

Types of Waves and Restoring Forces

The most characteristic physical feature of any kind of wave is the restoring force. If a medium at rest (such as still water) is disturbed in some way (by the wind, for example, or by dropping a rock into a pond), the restoring force acts to return the medium to its initial still state.

Compressibility is the restoring force for sound waves. Surface tension acts as the restoring force at any surface of contact between any two different fluids (like air and water), and produces very high frequency capillary waves. Gravity waves arise through the restoring force of gravity on water particles displaced from equilibrium levels. If the equilibrium level is a free surface (the boundary between water and air), surface gravity waves are formed. If the equilibrium level is an internal surface in a stratified fluid, internal gravity waves are formed. These internal waves tend to have longer periods (minutes to hours) than surface gravity waves (seconds). Finally, planetary effects such as rotation introduce restoring effects such as the Coriolis force and potential vorticity, yielding very long period waves called inertial waves, Rossby, and planetary waves.

Spectrum of Surface Waves in the Ocean

Surface waves in the ocean occupy a broad range of wavelengths and periods.

- At extremely short periods, the spectrum is dominated by capillary waves, followed by a broad (1 - 20 second) band of surface gravity waves, mostly wind driven.
- Longer period (> 10 minutes) gravity waves may occur in association with earthquakes and large-scale meteorological systems (storm surges).
- Tides, which are another type of forced gravity wave, dominate the spectrum in the 12 - 36 hour band.
- At longer periods, *inertial* and *planetary* waves are prevalent; gravity does not play a dominant role any longer.

See Pond and Picard (Figure 12.1, Table 12.1) (*Appendix VIII: References*).

Definition of Terms

a = wave amplitude, [m]

D_w = density of water, [Kg/m^3]

E = W_w H^2 / 8, total wave energy per unit area, [J/m^2]

f = 1 / T, wave frequency, [Hz], [cycles/sec]

g = 9.80665, acceleration of gravity, [m/sec^2]

h = water depth, [m]

H = 2a, wave height, [m]

k = 2 π / L, wave number, [rad/m]

L = wave length, [m]

φ = phase angle, [radians]

σ = 2 π / T, radian frequency, [rad/sec]

t = time, [sec]

T = wave period, [sec]

T_b = total time of the wave burst series (total sample period), [sec]

W_w = D_w g, specific weight of water, [Kg/(m^{2}sec^2] = [Pa/m]

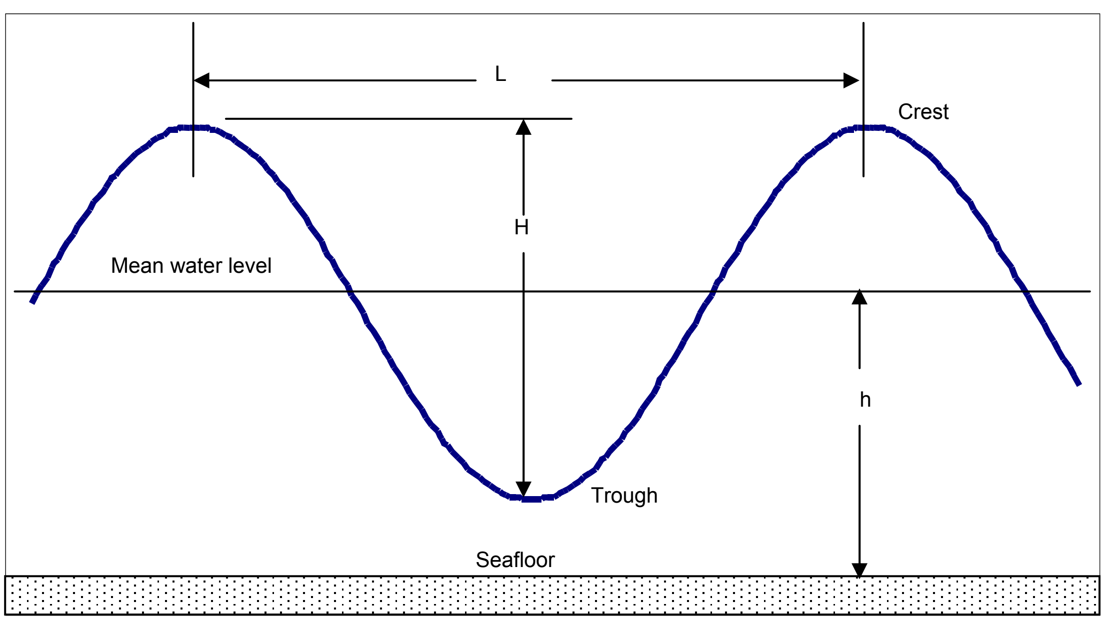
x = horizontal distance, [m]

z = instrument depth, [m]

Basic Linear Wave Description

A traveling disturbance of the sea surface is commonly represented as a linear simple harmonic wave traveling in the x horizontal direction:

$$A(x,t) = a \cos(kx - \sigma t + \varphi) \quad [1]$$



Simple-Harmonic Linear Wave Traveling on the Sea Surface

Phase Angle

The phase angle φ represents a shift of the wave relative to some reference time. This is useful for describing the relationships between a group of waves of different frequencies. When a time series is separated by spectral analysis methods into frequency components defined by [1], the two numbers that are computed for each frequency are:

amplitude	a(f)
phase	φ(f)

The physical time lag associated with a given phase depends on the wave period (T). For example, a phase of π radians implies a time lag of 5 seconds for a wave with a period of 10 seconds (T = 10 sec), while the same phase implies a lag of 2.5 sec for a wave with T = 5 sec.

Dispersion Equation

For surface gravity waves described by [1], there is a special relationship between wave period and wave length. This relationship, which depends on water depth, is called the dispersion relation and is given by:

$$\sigma^2 = gk \tanh(kh) \qquad [2]$$

Implications of Linear Theory

Equation [1] represents a single frequency-wavenumber component of a sea surface that usually contains a whole group of waves of different sizes, lengths, and propagation directions. One of the major assumptions of linear theory is that we can take this jumbled combination and treat each frequency component (or frequency band) separately by using [1].

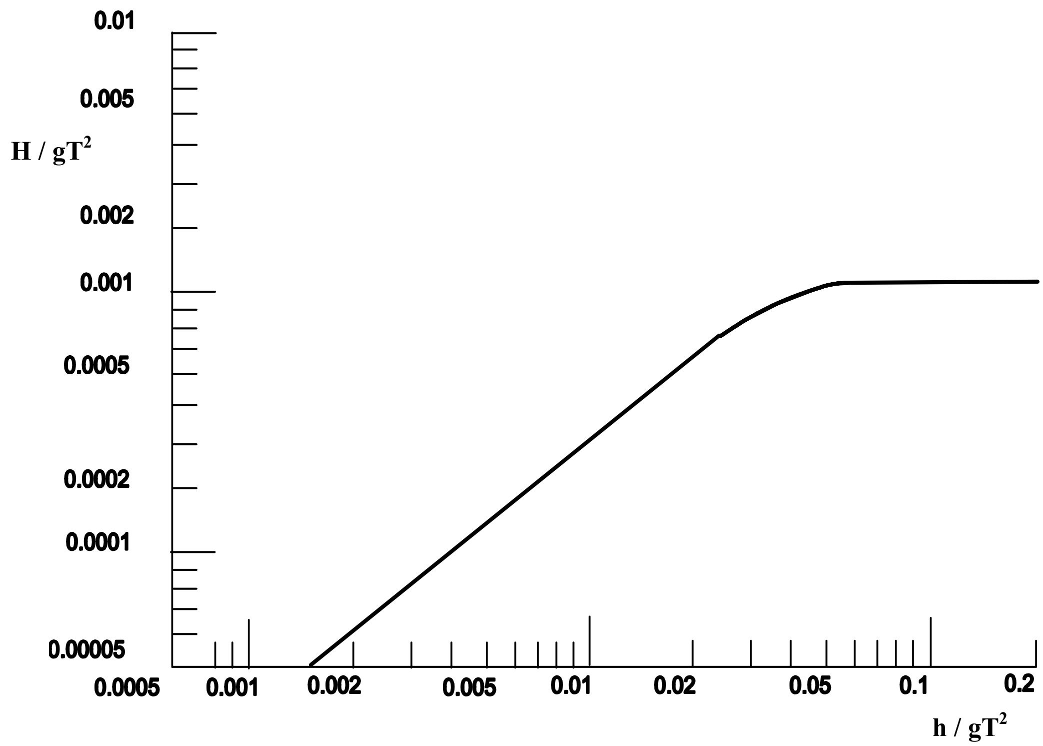
First order linear *small amplitude* theory is the simplest and most direct solution to a very complex general set of equations and boundary conditions for surface gravity waves. The simple results are based on a set of approximations that are strictly valid only over a restricted range of conditions. Small amplitude wave theory is not a good model of steep or breaking waves, or waves traveling in very shallow water. The theory is a good model of long ocean waves away from viscous boundary layers and horizontal boundaries.

Assumptions

For the linear theory to be valid, a major requirement is that the wave height H be small compared with both the wavelength L and the water depth h. These conditions are usually expressed as:

H / L	$<< 1$	(wave steepness)
$H L^2 / h^3$	$<< 1$	(Ursell parameter)

Another measure of the effect of wave steepness on the validity of the small amplitude theory, based on laboratory measurements, is shown below. For the theory to be valid, you must be below the curve indicated. For example, if the wave period of interest T is 10 sec and the water depth h is 100 meters, the parameter $h / gT^2 = 0.1$. This means that H / gT^2 must be less than 0.001 for the theory to be valid, which translates into a maximum wave height of 1 meter.



Range of Validity of Linear Wave Theory
(Theory Valid for Values Below Curve)

A final rule of thumb is that estimates of surface wave heights should be accurate within ± 5% provided:

$z / L < 0.3$ to 0.5,

where z is the depth of the instrument below the surface and L is the wavelength of the observed waves.

Subsurface Pressure Due to Surface Gravity Waves

As a surface wave passes over a subsurface position, the elevation and depression of the sea surface causes a differential subsurface pressure disturbance. This pressure disturbance decays with depth according to the relation:

$$p = W_W A(t) K(f,z) \quad [Pa] \qquad [3]$$

where the vertical pressure response function is:

$$K(f,z) = \cosh[k(h - z)] / \cosh(kh) \quad [dimensionless] \qquad [4]$$

where
A(t) (defined by [1]) = water surface displacement, which varies between +a and -a meters
W_w = specific weight of water near the surface
h = water depth
k = wave number [radians/m], calculated for a given wave period and depth with the dispersion relation [2]
z = vertical distance [m] from the measurement point to the mean (undisturbed) water surface

Equation [3] is the essential result required to relate subsurface pressure to surface wave height. For a given pressure frequency component P(f), the transfer function used to obtain surface wave amplitude a(f) from subsurface pressure is:

$$a(f) = P(f) / W_W K(f,z) \quad [m] \qquad [5]$$

For deep water waves (kh >> 1 and h/L > 0.5) equation [3] takes the form:

$$p \approx W_W A e^{-kz} \quad [Pa] \qquad [6]$$

which clearly represents an exponential decay with depth.

For shallow water waves (hk << 1 and h > L/2) equation [3] takes the form:

$$p \approx W_W A \quad [Pa] \qquad [7]$$

which is simply the hydrostatic equation.

The table below, developed with Plan Deployment, shows pressure attenuation [p(bottom) / p(surface)] vs. bottom depth for waves with T = 2, 5, 10, 20, and 25 seconds.

Water Depth [meters]	Sensor Height above Bottom [meters]	Wave Period [seconds]				
		25	20	10	5	2
2	**0**	0.99	0.99	0.96	0.84	0.25
4	**0**	0.99	0.98	0.92	0.70	0.04
8	**0**	0.97	0.96	0.84	0.45	-----
15	**0**	0.95	0.93	0.72	0.17	-----
20	**0**	0.94	0.90	0.63	0.08	-----
30	**0**	0.91	0.85	0.48	0.02	-----
40	**0**	0.87	0.81	0.35	-----	-----
50	**0**	0.84	0.76	0.25	-----	-----
75	**0**	0.77	0.65	0.1	-----	-----
100	**0**	0.70	0.55	0.04	-----	-----

Pressure attenuation [p(bottom) / p(surface)] for various bottom depths and wave periods (----- = less than 0.001).

High Frequency Cutoff

Note:
Frequencies greater than fmax are processed if *Use filter cutoff* is selected in Process Wave Burst Data.

The table above shows that the pressure attenuation with depth is a strong function of the wave period; short period waves attenuate much faster with depth than longer period waves. This implies that for a pressure sensor deployed at a fixed depth z, there is a high frequency cutoff fmax for which waves with f > fmax are not measurable. Above the high frequency cutoff, any noise in the subsurface pressure record is mapped by the transfer function into unrealistic surface wave height values. The default high frequency cutoff for Process Wave Burst Data is the frequency where the ratio of pressure measured by the SBE 26*plus* to pressure at the surface is less than (0.0025 / wave sample duration) [see equation 20]. Frequencies greater than fmax are not processed by Process Wave Burst Data for most applications.

Example:
Water depth is 10 meters. You are interested in measuring waves with frequencies up to 0.36 Hz (period = 1 / 0.36 = 2.8 seconds). You plan to sample waves 4 times per second (wave sample duration = 0.25 seconds) with 1024 samples per wave burst, and to process data with 10 spectral estimates/band. Can you place the 26*plus* at 1 meter above the bottom and accomplish your goals?

Running Plan Deployment with the above parameters, the Frequency Span is 0.0215 to 0.3340 Hz. Since 0.334 < 0.37, you cannot accomplish your goals.

Iterating on a solution by changing the instrument height in Plan Deployment, you find that placing the 26*plus* at 2.5 meters above bottom will allow you to measure the desired frequencies. Alternatively, you could consider modifying other sampling parameters while maintaining the instrument height.

Wave Processing Steps

To compute surface wave energy spectra and statistics, the frequency dependent attenuation must first be removed from the subsurface pressure data. Fourier analysis techniques are used to decompose the subsurface time series into a group of linear wave components, each with a distinct frequency, amplitude, and phase.

Initial Processing of Pressure Data

First the wave burst data is read into an array. The mean is computed and then the mean and trend are removed from the array. A trend is expected in the wave data due to tides and other low frequency waves. If these trends are not removed, distortions can occur in the processing of spectral estimates; the *ramp* function in the time domain leaks all over the spectrum in the frequency domain.

Density (D_w) is computed from the user-supplied salinity and temperature.

Instrument depth (z) and water depth (h) are computed by:

$$z = 6894.757 \text{ (mean pressure - 14.7) } / D_W g \quad \text{[m]} \qquad [8]$$

$$h = z + \text{height of pressure sensor above bottom} \quad \text{[m]} \qquad [9]$$

where the factor 6894.757 is used to convert the pressure from psi to Pascals.

If the number of wave samples is not a power of two, the array length is made a power of two by filling it with the last de-meaned and de-trended pressure value.

Next, a Hanning window is applied to the time series to suppress the spectral leakage that occurs when the time series to be Fourier transformed contains a periodic signal that does not correspond to one of the exact frequencies of the FFT. Physically, this means that an integral number of waves does not fit in the time series. When this occurs, energy at one frequency leaks to other frequencies. This causes errors when applying the frequency dependent dispersion transfer function to the transformed data. The Hanning window has the form:

$$u(t) = 1 - \cos^2(\pi t / T_b) \quad 0 \leq t \leq T_b \qquad [10]$$

The windowing operation reduces the total energy in the time series so each element is multiplied by the scale factor SF, where

$$SF = (8 / 3)^{1/2} \qquad [11]$$

to obtain the correct magnitudes in later spectral estimates.

Finally, each element in the time series is multiplied by the factor 6894.757 to convert the measured pressure from psi to Pascals.

Surface Wave Auto-Spectrum

The Finite Fourier transform of a time series with N points contains N raw spectral estimates at frequencies given by:

$$F_j = j \mid T_b \quad j = 0, N\text{-}1 \quad [\text{Hz}] \qquad [12]$$

where T_b is the total time of the series (seconds). The first spectral estimate (j = 0) is the mean of the time series, and is 0 since the subsurface pressure time series has been de-meaned.

The interval between spectral estimates (resolution bandwidth) is:

$$\delta f = 1 / T_b = 1 / (N\delta t) \qquad [13]$$

where δt is the time interval between samples in the subsurface pressure time series.

While N raw spectral estimates are computed, only the first (N/2 + 1) are unique. For a real input time series the second (N/2 - 1) values are identical to the first N/2 values. The limiting frequency is the Nyquist frequency, given by:

$$\text{Nyquist} = 1 / (2\delta t) \quad [\text{Hz}] \qquad [14]$$

The forward Fourier transform of the time series is defined by:

$$Z_j = (1 / N) \sum_{n=0}^{N-1} x_n \exp(-i\, 2\, \pi\, n\, j / N) \qquad [15]$$

where
Z_j (the raw spectral estimates) are complex numbers.
$i = (-1)^{1/2}$

The raw spectral estimates are directly related to the single frequency wave described in [1]:

$$a_j = 2 \mid Z_j \mid , \qquad \varphi_j = \arg(Z_j) \qquad [16]$$

The variance at each frequency is:

$$\text{var}_j = \mid Z_j \mid^2 , \qquad j = 1, N\text{-}1 \qquad [17]$$

The total variance of the spectrum:

$$\text{var}_{\text{total}} = \sum_{j=1}^{N-1} \mid Z_j \mid^2 \quad [\text{Pa}^2] \qquad [18]$$

is equal to the variance calculated from the time series [28].

For each frequency up to the Nyquist, the relationship between the single pressure wave variance [1] and [17] is:

$$a_j^{\,2} / 2 = 2\, \text{var}_j \qquad [19]$$

Once the Fourier transform has been obtained, the Fourier coefficients for the frequencies greater than fmax and less than fmin are *typically* set to 0.0:

fmax = minimum of:
frequency where (subsurface / surface pressure = 0.0025 / δ t) [20]
or
1 / user input minimum period [21]

fmin = 1 / user input maximum period [22]

Maximum frequency limits prevent noise in the subsurface time series from being mapped by the dispersion transfer function into unrealistic wave heights.

If the user selected *Use filter cutoff*, a filter is applied that ramps the Fourier coefficients down to 0 for frequencies greater than fmax and less than fmin.

- For frequencies less than fmin:
  fourier coefficient = f * exp ([f – fmin]/ fc)
- For frequencies greater than fmax:
  fourier coefficient = f * exp ([fmax – f]/ fc)

where
f = frequency
fc = user input filter value

A copy of the Fourier transform is saved; it will be used to recover the surface wave time series.

Band Averaging

Each raw spectral estimate contains two degrees of freedom. Band averaging can be used to increase the number of degrees of freedom and reduce the error of the estimate. The number of degrees of freedom (n_d) associated with grouping n_f spectral estimates in a frequency band of width δf is twice the number of frequencies in the band. $\delta f = n_f / T_b$

Band averaging is performed by adding up the total variance in a frequency band and dividing the sum by the width (Hz) of the frequency band (δf). For positive frequencies less than the Nyquist, the estimate of the one-sided subsurface pressure auto-spectral density function for a frequency band centered at f_b is:

$$< G_{pp}(f_b) > = \frac{2 \sum_{k=1}^{n_f} |Z_k|^2}{\delta f} \qquad [\mathrm{Pa}^2\ \mathrm{sec}] \qquad [23]$$

Confidence Intervals (Error Bars)

The properties of a *real-world* (random) time series cannot be precisely determined from sample data. Only estimates of the parameters of interest can be obtained. The method for setting error bars on the estimates of the auto-spectral density function $<G_{pp}>$ is related to the Chi-Square distribution function:X^2.

The confidence interval (1-α; α is the significance) for the *true* auto-spectral value G_{pp} based on an estimate $<G_{pp}>$ is given by:

$$\frac{n_d <G_{pp}>}{X^2\, n_d;\, \alpha / 2} \le G_{pp} (f_b) \le \frac{n_d <G_{pp}>}{X^2\, n_d;\, 1 - \alpha / 2} \qquad [24]$$

where

n_d = 2 * number of frequency bands averaged

$X^2 n_d;\alpha$ = percentage points, Chi-Square distribution with n_d degrees of freedom and significance α

The Chi-Square distribution is described completely in most statistics books (for example, J. E. Freund, Mathematical Statistics, 1962, Prentice Hall, Inc.). For example, if 10 frequencies are averaged per band and we wish to know the error bars corresponding to the 90% confidence interval:

$n_d = 20$ alpha = significance = 0.1

$X^2_{20;0.05} = 31.41$ $X^2_{20;0.95} = 10.85$

Therefore, the error bar is:

$$(0.637 <G_{pp}>) \le G_{pp} \le (1.843 <G_{pp}>)$$

This means that we can say with 90% certainty that the *true* value of G_{pp} lies somewhere between 0.637 and 1.843 times the estimated value of G_{pp}.

When band averaging, the value of the auto-spectral estimate lies somewhere in the band averaged frequency band; the error bars for the frequency are as wide as the band.

Band averaging is a trade-off between *vertical* and *horizontal* error bars. If you average a lot of bands, you get a good estimate of the magnitude of a peak in G_{pp}, but there is a lot of uncertainty as to its precise frequency value. If you band-average only a few bands, the frequency of a peak is precisely defined, but there is a lot of uncertainty as to the value of G_{pp}.

Sometimes a peak in the spectrum stands out from the background if there are few frequencies in the band, but vanishes into the background as the number of frequencies averaged increases. When this happens, an understanding of the physical problem being investigated can help in deciding whether the peak is real or not.

Surface Wave Auto-Spectral Density Function

The one-sided surface wave auto-spectral density function for a frequency band centered at f_b is:

$$G_{aa} (f_b) = | H (f_b) |^2 G_{pp} (f_b) \quad [m^2 \sec] \qquad [25]$$

The transfer function $H (f_b)$ is used to convert the subsurface pressure to surface waves and is computed with equations [2] and [4].

$$H (f_b) = 1 / [W_w K (f, z)] \quad [m / Pa] \qquad [26]$$

A plot of the surface wave auto-spectral density function G_{aa} with error bars is probably the most useful way of describing the sea surface shape due to a surface wave field. A glance at the spectrum shows where the wave variance is in frequency space.

The surface wave spectral density function G_{aa} has units of [m^2 sec]. To find the variance [m^2] in a frequency interval δf (Hz), multiply G_{aa} by δf.

Total Variance and Energy

The total variance Var_{tot} is the sum of all the band-averaged spectral estimates:

$$var_{tot} = \sum_{k=1}^{n_b} G_{aa}(f_k)\,\delta f \qquad [m^2] \qquad [27]$$

where
δf is the number of spectral estimates in the band divided by the total sample period,
n_b is the number of frequency bands computed,
$G_{aa}(f_k)$ is the spectral estimate for the frequency centered at f_k.

The total wave energy (J / m^2) is found by multiplying the total variance by the specific weight of water (W_w).

Significant Wave Height and Period

The significant wave height is the average height of the highest 1/3 of the waves and is estimated from the auto-spectrum as:

$$H_{1/3} = 4\,(Var_{tot})^{1/2} \qquad [m] \qquad [28]$$

The significant wave period estimated from the auto-spectrum is the period corresponding to the frequency with the highest variance.

Surface Wave Time Series

To reconstruct the surface wave time series from the subsurface pressure, the transfer function $H(f_i)$ [see equation 26] is applied frequency by frequency to the scaled raw spectral estimates:

$$A(f_i) = H(f_i)\,P(f_i) \qquad f_i \le \text{Nyquist} \qquad [29]$$

where $A(f_i)$ are the raw spectral estimates of surface wave amplitude and $P(f_i)$ are the spectral estimates of subsurface pressure. The spectral estimates for f_i > Nyquist are given by $A(F_{n-i}) = A(f_i)$.

The Inverse Fast Fourier Transform (IFFT) is taken to construct the surface time series.

The influence of the Hanning window is removed with a deconvolution in the time domain; each point x_i is multiplied by the inverse of the Hanning window w_i corresponding to the same time point. This procedure is unstable near the end points where $w_i \approx 0$. Therefore, the time series is set to 0 at the beginning and end where the window reaches 1% of its maximum value.

Finally, each point in the time series is multiplied by 1 / sqrt (8/3) to compensate for the initial scaling of the time series.

Total Variance and Energy

The unbiased sample variance is a fundamental statistical measure of the time series. Variances from different bursts can be compared to see if the wave field is stationary or changing. The unbiased estimator for the variance is:

$$< \sigma_x{}^2 > = (1 / [N-1]) \sum_{j=0}^{N-1} | x_j - < \mu_x > |^2 \qquad [m^2] \qquad [30]$$

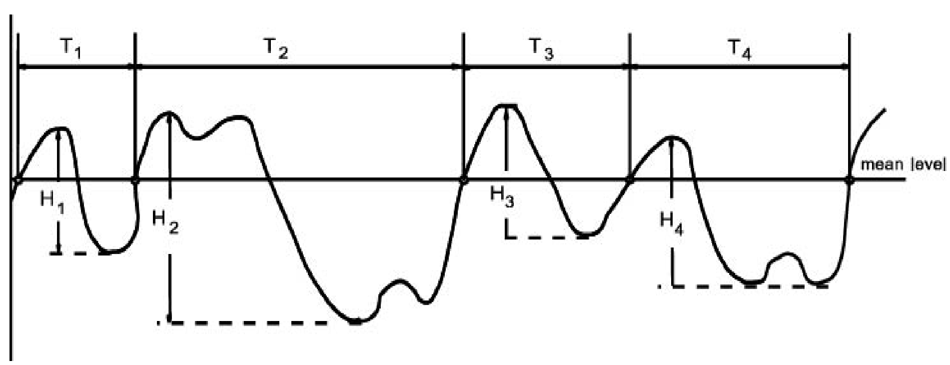
where μ_x is the sample mean. In this case, the mean is zero since the time series has been de-meaned. The variance obtained from the reconstructed time series can be compared with the total variance obtained from the auto-spectrum [25] as a check on the *goodness* of the time series reconstruction.

An estimate of the total wave energy contained in the record is:

$$E = W_w < \sigma_x{}^2 > \qquad [J / m^2] \qquad [31]$$

Average Wave Height and Period: H_{avg}, T_{avg}

Since the wave time series is typically very irregular due to the random nature of the sea surface, the calculation of wave heights and periods can only be approximate and statistical. A standard method for estimating wave heights and wave periods is summarized in the Handbook on Wave Analysis and Forecasting, from the World Meteorological Organization (WMO- No. 446, 1976, Geneva, Switzerland) and illustrated below:



Zero-Crossing Method for Estimating Wave Heights and Periods from a Wave Time Series

Individual *waves* are isolated by identifying the zero *upcrossings*; H and T for each captured wave is stored in an array. Averaging over all the captured waves yields the average wave height H_{avg} (meters) and the average period T_{avg} (seconds). H_{max} is the largest captured wave.

Sea State (Significant Wave Height)

The significant wave height ($H_{1/3}$) and average period (T_{avg}) define the sea state. $H_{1/3}$ is the average height of the highest 1/3 of the waves and has physical significance because it is the approximate wave height picked out visually and reported by trained observers at sea.

$T_{1/3}$ is obtained by picking out the highest 1/3 of the captured waves and averaging their periods.

The parameters $H_{1/10}$ and $H_{1/100}$ are similarly defined as the average height of the highest 10 and 1 percent of the captured waves, respectively.

Appendix VII: Pressure-to-Depth Conversion

Force is mass * acceleration, units are Newtons [N]:

$N = Kg\ m / sec^2$

Density (ρ) is mass / volume, units are [Kg / m^3]:

This is the *in situ* value, and is approximately 1025 Kg / m^3 at the surface.

Specific weight (W) is weight / volume, units are [N / m^3]:

$W = \rho * g$

where g = local gravity [m / sec^2]

Hydrostatic equation:

$p = p_{atm} + W * z$

p_{atm} = atmospheric pressure in Pascals [N / m^2]

p = total pressure in Pascals [N / m^2]

W is average density times gravity [N / m^3]

z = depth [m]

Conversions:

1 Pascal = 10^{-4} decibars

1 psi = 0.6894757 decibars

Example:

average density = 1025 kg / m^3

average gravity = 9.8 m / sec^2

pressure reading = 6000 decibars = 6×10^7 Pascals

atmospheric pressure = 14.7 psia = 1.013529×10^5 Pascals

W = 1025 * 9.8 = 10045 [N / m^3]

$6 \times 10^7 - 1.013529 \times 10^5 = 10045 * z$

$z = 5.989865 \times 10^7 / 10045 = 5963.031$ meters

Appendix VIII: References

Textbooks:

Bendat, J.S. and A.G. Piersol, 1986. *Random Data, Analysis and Measurement Procedures*, 2nd edition, Wiley, NewYork, ISBN 0-471-04000-2.

Bevington, P.R., 1969. *Data Reduction and Error Analysis for the Physical Sciences*, McGraw-Hill, New York.

Freund, J.E., 1962. *Mathematical Statistics*, Prentice Hall, EngleWood Cliffs, N.J.

LeBlond, P.H., and L.A. Mysak, 1978. *Waves in the Ocean*, Elsevier Amsterdam, ISBN 0-444-41602-1.

Neumann and Pierson, 1966. *Principles of Physical Oceanography*, Prentice Hall, EngleWood Cliffs, N.J.

Pond and Picard, 1983. *Introductory Dynamical Oceanography*, 2nd Ed., Pergamon Press, New York, ISBN 0-08-028728-X

Press, W. H., *et. al.*, 1986. *Numerical Recipes*, Cambridge University Press, New York.

Reports:

Earle, M.D. and J.M. Bishop. 1984. *A Practical Guide to Ocean Wave Measurement and Analysis*, Published by: ENDECO, Inc., Marion, MA.

Handbook on Wave Analysis and Forecasting, 1976. World Meteorological Organization, Geneva, ISBN 92-63-10446-8.

Knowles, C.E., 1981. Estimation of surface gravity waves from subsurface pressure records for estuarine basins. UNC Sea Grant College Publication UNC-SG-WP-81-6.

Morang, A, *1990. Quality Control and Management of Oceanographic Wave-Gauge Data*, Instruction Report CERC-90-1, Department of the Army, Waterways Experiment Station, Corps of Engineers, Vicksburg, Mississippi.

Scientific Publications:

Bergan, A.O., A. Torum and A. Tratteberg, 1968. Wave measurements by pressure type wave gauge. Proc. 11th Coastal Eng Conf., ASCE, 1: 19-29.

Bishop, C.T. and M.A. Donelan, 1987. Measuring waves with pressure transducers. *Coastal Eng.*, 11: 309-328.

Forristall, G.Z., 1982. Subsurface Wave-Measuring Systems, *in: Measuring Ocean Waves*, National Academy Press, Washington D.C., pp. 194-209.

Grace, R.A., 1970. How to measure waves. *Ocean Ind.*, 5(2): 65-69.

Hom-ma, M., K. Horikawa and S. Komori, 1966. Response characteristics of underwater wave gauge. Proc. 10th Coastal Eng. Conf., ASCE, 1: 99-114.

Michel, W.H., 1968. Sea Spectra Simplified. *Marine Technology,* January 1968: 17-30.

Wang, H., D. Lee and A. Garcia, 1986. Time series surface wave recovery from pressure gage, *Coastal Engineering*, 10: 379-393.

Appendix IX: Replacement Parts

Part Number	Part	Application Description	Quantity in 26*plus*
22018	Batteries, alkaline D-cell, Duracell MN1300 (LR20)	Power 26*plus*	12
41124B	Battery cover plate	Retains **alkaline** D-cell batteries	1
801575	Battery cover plate/spacer	Retains **lithium** DD-cell batteries with buttons	-
50092	SBE 16/19 Jackscrew Kit	For removing connector end cap	1
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 screw 30145) • 30816 Parker 2-234E603-70 (battery end cap to housing piston seal) • 30090 Parker 2-153N674-70 (battery end cap to housing face seal)	-
50056	Spare parts kit	Assorted hardware and o-rings, 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 screw 30145) • 30447 Bolt ¼-20 x 1¼ Hex, titanium (secures life eye to connector end cap and plastic bar to battery end cap) • 30493 Machine screw, 10-24 x 1¼ Hex, titanium (secures connector end cap to housing) • 30552 Retaining ring (secures mooring pin for optional mounting fixture to lift eye) • 30816 Parker 2-234E603-70 (battery end cap to housing piston seal) • 30090 Parker 2-153N674-70 (battery end cap to housing face seal) • 30815 Parker 2-233E603-70 (connector end cap to housing radial piston seal)	-

Continued on next page

Continued from previous page

Part Number	Part	Application Description	Quantity in 26*plus*
17695	3-pin RMG-3FS to 3-pin RMG-3FS cable, 0.28 m (11 in.) long	From 26*plus* to optional conductivity sensor	1
171752	3-pin to MCIL-3FS (wet-pluggable connector) to 3-pin RMG-3FS cable, 0.28 m (11 in.) long	From 26*plus* to optional conductivity sensor	1
801225	4-pin RMG-4FS to DB-9S data I/O cable, 2.4 m (8 ft) long	From 26*plus* to computer, for standard RS-232 interface	1
801374	4-pin MCIL-4FS (wet-pluggable connector) to DB-9S data I/O cable, 2.4 m (8 ft) long	From 26*plus* to computer, for standard RS-232 interface	1
801584	6-pin AG-206 to DB-9S data I/O cable, 2.4 m (8 ft) long	From 26*plus* to computer, for optional RS-422 / RS-485 interface	1
171888	25-pin DB-25S to 9-pin DB-9P cable adapter	For use with computer with DB-25 connector	-
17043	Locking sleeve	Locks I/O cable or dummy plug in place	2
171192	Locking sleeve (wet-pluggable connector)	Locks I/O cable or dummy plug in place	2
17045.1	3-pin RMG-3FS dummy plug with locking sleeve	For when optional conductivity sensor not used	1
171500.1	3-pin MCDC-3-F (wet-pluggable) dummy plug with locking sleeve	For when optional conductivity sensor not used	1
17046.1	4-pin RMG-4FS dummy plug with locking sleeve	For RS-232 I/O connector during deployment	1
171398.1	4-pin MCDC-4-F (wet-pluggable) dummy plug with locking sleeve	For RS-232 I/O connector during deployment	1
17047.1	6-pin AG-206 dummy plug with locking sleeve	For RS-422 / RS-485 I/O connector during deployment	1
801542	AF24173 Anti-Foulant Device	For use with optional conductivity sensor – Bis(tributyltin) oxide device inserted into anti-foulant device cup in mount kit	1 (set of 2)
50315	Anti-foulant device mount kit	Mounts on ends of conductivity cell to hold AF24173 Anti-Foulant Devices	1
30411	Triton X-100	Octyl Phenol Ethoxylate – Reagent grade non-ionic cleaning solution for conductivity cell (supplied in 100% strength; dilute as directed)	1
50102	Mounting fixture	Optional mounting fixture with mooring lock pin	1

Index

P

Q

R

S

T

U

W

SEAGAUGE Wave & Tide Recorder

SBE 26*plus*

The SBE 26*plus* is the next generation wave and tide recorder, bringing improvements in many areas over its SBE 26 predecessor:

- Deployment length – 32 Mbyte vs 8 Mbyte memory; 12 batteries vs 9 *and* reduced power consumption (6 times longer deployment for a typical sampling scheme of water-level measurements every 30 minutes and 8.5-minute, 4 Hz wave-burst samples eight times a day).
- Sampling flexibility – If desired, measure the tide for only a portion of the tide interval, reducing power consumption. Logging start and stop times can be programmed.
- Real-time output – Output real-time tide data, wave data, and/or wave statistics.
- Upload speed - Binary upload of data in memory at up to 115,200 baud vs. ASCII upload at up to 38,400 baud, providing up to 6 times faster upload.
- Upgrade flexibility - Downloadable instrument firmware upgrades for future enhancements do not require opening the electronics compartment to physically install a new EPROM.


26*plus* being secured in optional mounting fixture - After installation at a mooring site, fixture allows removal and precise repositioning by a diver. Tools are not required, and there are no loose parts to misplace.

The 26*plus* combines Sea-Bird's non-volatile FLASH memory with a stable time base, precision thermometer, and Quartz crystal pressure sensor to provide wave and tide recording of unprecedented resolution and accuracy, along with high-quality temperature information. A second input connector for an optional SBE 4M conductivity sensor is also standard.

The 26*plus* integrates pressure samples to obtain water level measurements unaffected by wave action, and also independently burst-samples pressure at rates up to 4 Hz for wave amplitude calculation. Water level sampling interval and integration duration and wave burst sampling interval and duration are programmable. The tide interval is user-programmable over a range of 1 minute to 12 hours. The 26*plus* can continuously measure pressure (if equipped with Quartz pressure sensor), or can conserve battery power by removing power from the pressure sensor between tide measurements, with user-programmable pressure integration from 10 seconds to the entire tide interval. Temperature data is recorded with each tide integration. Waves are characterized by burst sampling with the number of samples per burst, burst interval, and burst integration time programmed by the user. A tide and temperature measurement consists of 9 bytes (12 bytes with optional conductivity); each sample in a wave burst uses 3 bytes.

The large memory and low power requirements permit frequent water level recording and highly detailed wave characterization. For example, with Quartz pressure sensor, standard alkaline batteries, and optional conductivity sensor, a 445-day deployment could include water level measurements every 30 minutes (integrating pressure for the entire 30 minutes) and an 8.5-minute, 4 Hz wave-burst (2048 samples) eight times a day; a 670-day deployment could be achieved if pressure integration is limited to 11 minutes for each water level measurement.

CONFIGURATION AND OPTIONS

A standard 26*plus* is supplied with:

- Plastic housing for depths to 600 meters (1960 feet)
- 20 meter (45 psia) Digiquartz® temperature-compensated pressure sensor
- Accurate temperature sensor – aged thermistor embedded in 26*plus* end cap
- Frequency input channel and bulkhead connector for optional SBE 4M conductivity sensor
- 32 MB FLASH memory
- 12 alkaline D-cell batteries; battery compartment is separated from electronics by a moisture-proof seal.
- Impulse glass-reinforced epoxy bulkhead connectors

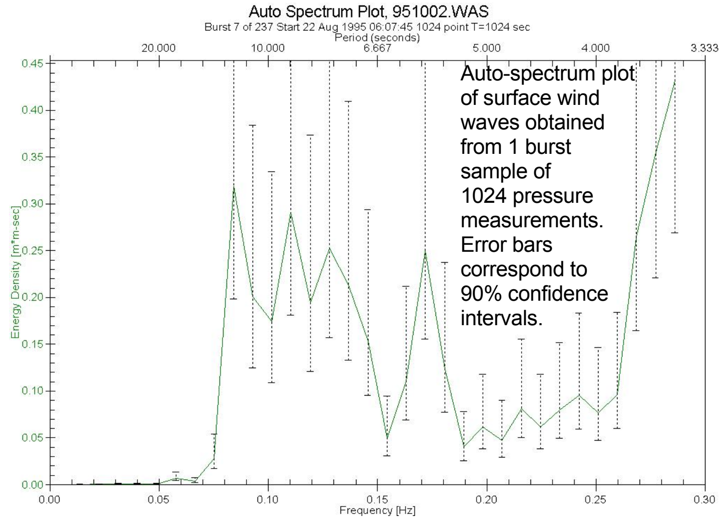
Options include:

- Digiquartz temperature-compensated pressure sensor, in ranges from 0.2 to 680 meters (15 to 1000 psia)
- Lower priced Druck temperature-compensated strain gauge pressure sensor in ranges from 20 to 600 meters (45 to 880 psia), generally intended for wave sampling applications; will not provide highest quality tide data.
- SBE 4M Conductivity sensor, interfaced via bulkhead connector and clamped to 26*plus* housing
- High accuracy external temperature sensor
- RS-485 full duplex interface in place of standard RS-232 interface
- Wet-pluggable (MCBH *Micro*) connectors in place of standard connectors
- Mounting fixture

SEAGAUGE Wave & Tide Recorder SBE 26*plus*

SOFTWARE

The 26*plus* includes *SEASOFT© for Waves*, a comprehensive package of Windows programs including deployment planning, instrument setup and data retrieval, plotting, auto-spectrum and time series analysis, and statistics reporting.



SPECIFICATIONS

Quartz Pressure (standard)

Range: 9 ranges, from 0 - 0.2 m (15 psia) to 0 - 680 m (1000 psia)
Accuracy: 0.01% of full scale (3 mm for 45 psia range *)
Repeatability: 0.005% of full scale (1.5 mm for 45 psia range *)
Hysteresis: 0.005% of full scale (1.5 mm for 45 psia range *)
Calibration: 0 psia to full scale pressure
Resolution *: Tide - 0.2 mm for 1-minute integration; 0.01 mm for 15-minute integration
Wave - 0.4 mm for 0.25-second integration; 0.1 mm for 1-second integration

*Stated values in mm are for 45 psia pressure sensor. Scale for other ranges, multiplying by (actual sensor psia / 45 psia).

Strain Gauge Pressure (optional)

Range: 4 ranges, from 0 - 20 m (45 psia) to 0 - 600 m (880 psia)
Accuracy: 0.1% of full scale (30 mm for 45 psia range *)
Repeatability: 0.03% of full scale (9 mm for 45 psia range *)
Hysteresis: 0.03% of full scale (9 mm for 45 psia range *)
Calibration: 0 psia to full scale pressure
Resolution *: Tide - 0.2 mm for 1-minute integration; 0.01 mm for 15-minute integration
Wave - 0.4 mm for 0.25-second integration; 0.1 mm for 1-second integration

*Stated values in mm are for 45 psia pressure sensor. Scale for other ranges, multiplying by (actual sensor psia / 45 psia).

Standard Temperature [°C]

Range: -5 to +35 Accuracy: 0.01
Resolution: 0.001 Calibration: +1 to +32 [1]

High Accuracy Temperature [°C] (optional)

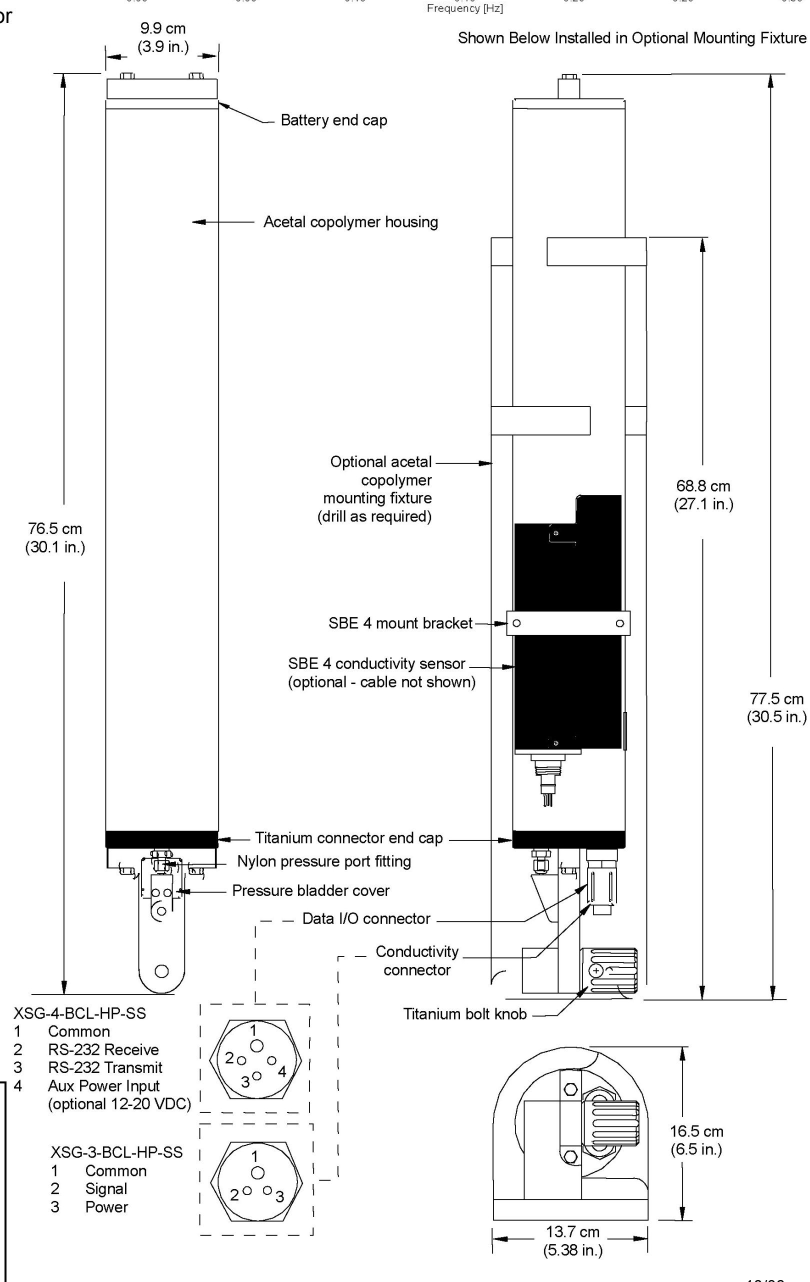
Range: -5 to +35 Accuracy: 0.002
Resolution: 0.0001 Calibration: +1 to +32 [1]

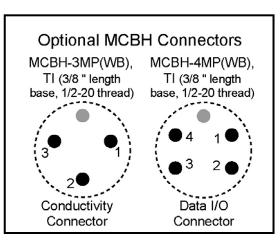
Conductivity [S/m] (optional)

Range: 0 to 7 Accuracy: 0.001
Resolution: 0.00002
Calibration: 2.6 – 6 plus zero conductivity (air) [1]

[1]Measurements outside specified calibration ranges will be at slightly reduced accuracy due to extrapolation errors.

Real-time clock: Quartz TCXO watch-crystal type 32,768 Hz; accuracy ± 2 ppm (5 sec/month). Battery-backed for minimum 2-year operation without main batteries installed.
Memory: 32 MB Flash RAM
Power Supply: Internal: standard 12 alkaline D-cells, External (optional) 12 – 20 VDC
Housing: Acetal copolymer Plastic to 600 m
Weight (with alkaline batteries):
Plastic housing 6.8kg (15 lbs) in air; 6.8kg (15 lbs) in water
Mounting fixture 3.6kg (8 lbs) in air; 1.4kg (3 lbs) in water





10/06

Sea-Bird Electronics, Inc.
1808 136th Place NE, Bellevue, Washington 98005 USA
Website: http://www.seabird.com
E-mail: seabird@seabird.com
Telephone: (425) 643-9866
Fax: (425) 643-9954

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: 1134 SBE 26plus TEMPERATURE CALIBRATION DATA

CALIBRATION DATE: 14-Apr-07

ITS-90 COEFFICIENTS

a0 = 2.511946e-004

a1 = 2.518127e-004

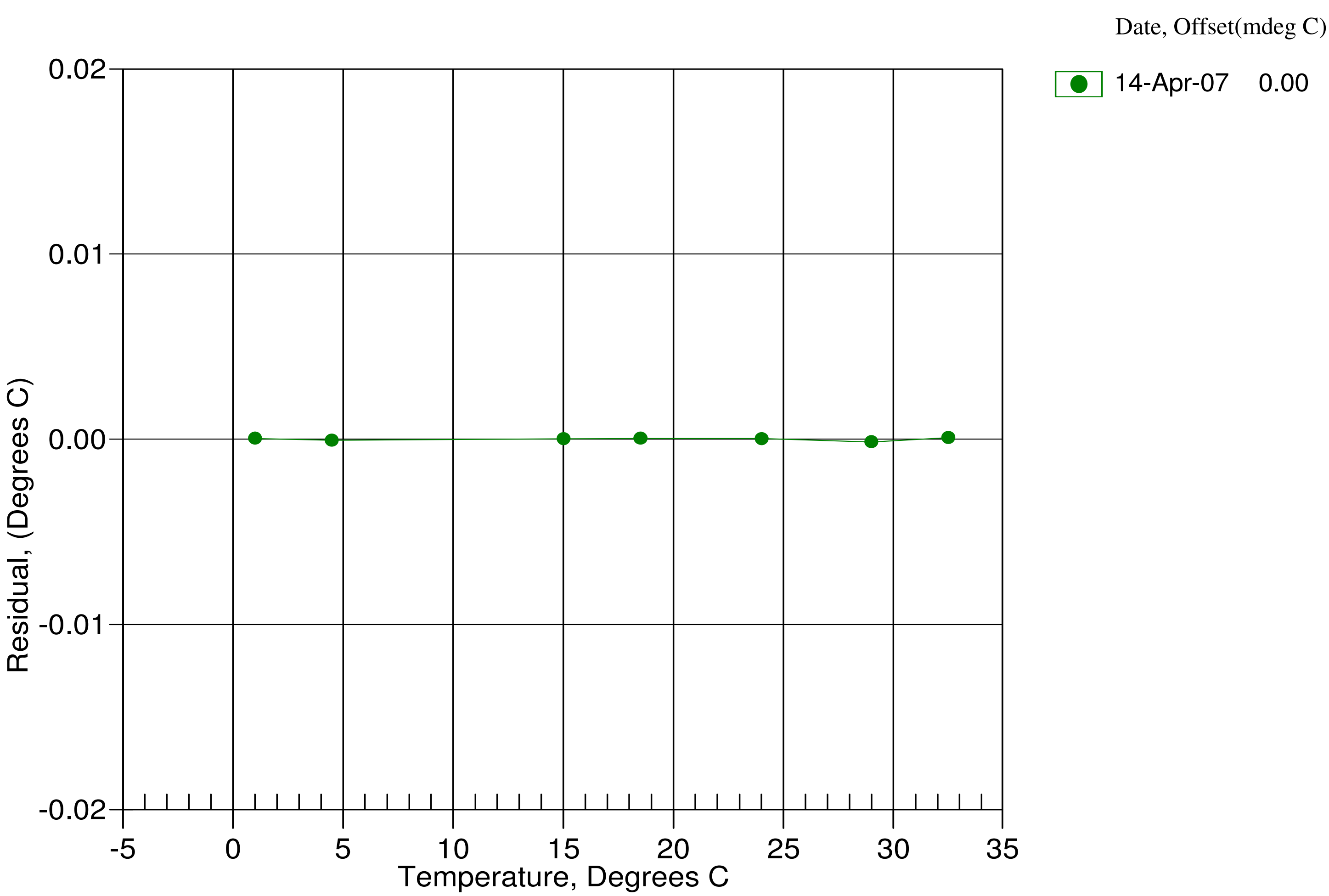
a2 = -1.827306e-006

a3 = 1.578895e-007

BATH TEMP (ITS-90)	INSTRUMENT OUTPUT	INST TEMP (ITS-90)	RESIDUAL (ITS-90)
1.0001	595344.4	1.0001	0.0000
4.5001	507000.9	4.5000	-0.0001
15.0001	319143.0	15.0001	0.0000
18.5001	275174.7	18.5002	0.0000
24.0001	219265.6	24.0001	0.0000
29.0001	179426.0	28.9999	-0.0001
32.5001	156433.5	32.5002	0.0001

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

Residual = instrument temperature - bath temperature



Sea-Bird Electronics, Inc. FAX: (425) 643-9954
1808 136th Place NE, Bellevue, Washington 98005 USA Tel:(425)643-9866
Website: http://www.seabird.com Email: seabird@seabird.com

26P46716-1134 13-June-07
Pressure Range: 100 psia
Pressure sensor Serial Number: 104279
Pressure sensor Type: Digiquartz

Pressure offset correction for SBE 26plus Wave and Tide Recorder

Pressure sensor output in the SBE 26plus Wave and Tide Recorder is sensitive to ambient pressure (including elevation and atmospheric pressure) and orientation of the instrument. As part of the test of this instrument, the output of the pressure sensor was measured in the orientation noted below. This data was averaged and compared to the output of a precision barometer at an elevation of 43 feet above sea level. The difference between these two measurements has been entered into the SBE 26plus as an offset correction. The slope correction for the SBE 26plus is nominally set to 1.0 for new instruments. The offset correction should be recalculated by the end-user in a manner appropriate for the intended use of the instrument.

ATMOSPHERIC CALIBRATION DATA

Orientation: Vertical
Pressure Sensor Range: 100 psia

Reference Pressure (psia)	SBE 26plus pressure (psia)	Difference (psia)
14.6811	14.8419	-0.1608

These coefficients should be entered into the SBE 26plus.

OFFSET = -0.1608
SLOPE = 1

Horizontal Orientation

Vertical Orientation

CALIBRATION COEFFICIENTS

PRESSURE TRANSDUCER

SERIAL NO : **104279**

DATE : 04-04-2007

MODEL :	PRESSURE RANGE :	TEMP. RANGE :	PORT :
2100A-219	0 to 100 psia	-40 to 107 deg C	oil filled

TEMPERATURE COEFFICIENTS

X = temperature period (μsec)

$U = X - U_0$

Temperature : (deg C)

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

U_0	5.817337	μsec
Y_1	-3942.137	deg C/μsec
Y_2	-11613.37	deg C/μsec^2
Y_3	0	

PRESSURE COEFFICIENTS

T = pressure period (μsec)

$$C = C_1 + C_2U + C_3U^2$$

$$D = D_1 + D_2U$$

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

Pressure : (psia)

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

C_1	599.4733	psia
C_2	4.579116	psia/μsec
C_3	-1088.546	psia/μsec^2

D_1	0.028215
D_2	0

T_1	27.91110	μsec
T_2	0.619178	μsec/μsec
T_3	19.91334	μsec/μsec^2
T_4	39.39682	μsec/μsec^3
T_5	0	

(04-04-2007)

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

CUSTOMER : SEABIRD ELECTRONICS, INC.

PARO TEST 12

SALES ORDER : 24128 PREPARED BY : T.C.

CALIBRATION COEFFICIENTS

PRESSURE TRANSDUCER

SERIAL NO : **104279**

DATE : 04-04-2007

MODEL :	PRESSURE RANGE :	TEMP. RANGE :	PORT :
2100A-219	0 to 100 psia	-40 to 107 deg C	oil filled

PRESSURE COEFFICIENTS AT FIXED TEMPERATURE

(only valid at specified temperature)

T = pressure period (μsec)

Pressure equation : (psia)

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

Temperature: 21.0 C

C (psia)	599.4166				
D	0.028215				
T_0 (μsec)	27.90833				

(04-04-2007)

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

CUSTOMER : SEABIRD ELECTRONICS, INC.

PARO TEST 12

SALES ORDER : 24128 PREPARED BY : T.C.

This page intentionally left blank.

PRESSURE TEST CERTIFICATES

Sea-Bird Electronics, Inc.
1808 136th Place NE, Bellevue, Washington 98005 USA
Website: http://www.seabird.com

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

SBE Pressure Test Certificate

Test Date: **5/21/2007** Description **SBE-26 SeaGauge Wave Meter**

Job Number: **46716** Customer Name **UW/APL**

SBE Sensor Information:

Model Number: **26Plus**
Serial Number: **1134**

Pressure Sensor Information:

Sensor Type: **DigiQuartz**
Sensor Serial Number: **104279**
Sensor Rating: **100**

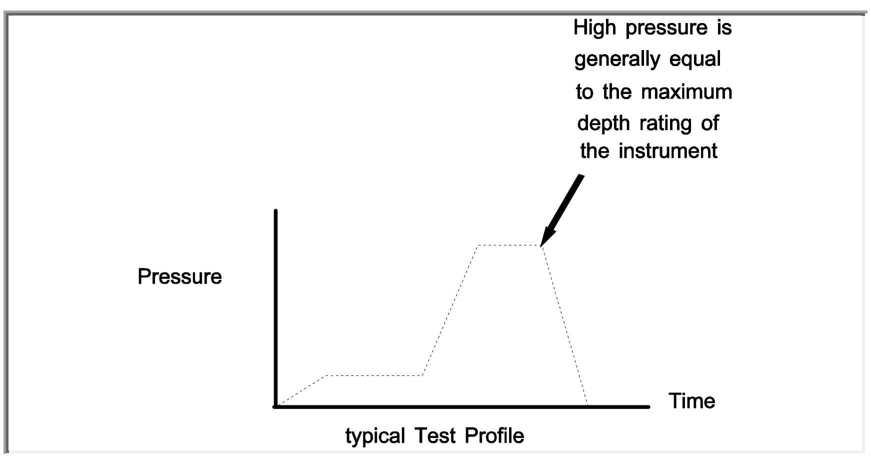
Pressure Test Protocol:

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

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

Passed Test: ☑

Tested By: PC



APPLICATION NOTES

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

Phone: (425) 643-9866
Fax: (425) 643-9954
E-mail: seabird@seabird.com
Web: www.seabird.com

APPLICATION NOTE NO. 42 **Revised September 2001**

ITS-90 TEMPERATURE SCALE

Beginning January 1995, Sea-Bird temperature calibration certificates list a new set of coefficients labeled *g*, *h*, *i*, *j*, and *F0*. These coefficients correspond to ITS90 (T90) temperatures and should be entered by those researchers working with SEASOFT-DOS Versions 4.208 and higher (and all versions of SEASOFT-Win32). For the convenience of users who prefer to use older SEASOFT versions, the new certificates also list *a*, *b*, *c*, *d*, and *F0* coefficients corresponding to IPTS68 (T68) temperatures as required by SEASOFT-DOS versions older than 4.208.

It is important to note that the international oceanographic research community will continue to use 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), SEASOFT-DOS 4.200 and later and all versions of SEASOFT-Win32 convert between T68 and T90 according to the linear relationship:

$$\mathbf{T_{68} = 1.00024 \ * \ T_{90}}$$

The use of T68 for salinity and other seawater calculations is automatic in all SEASOFT programs. However, when selecting **temperature** as a display/output variable, you will be prompted to specify 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 computes T90 temperature directly or calculates it from the Saunders linear approximation, depending on which coefficients were used and which display variable type is selected.

For example, if *g, h, i, j, F0* coefficients (T90) are entered in the .con file and you select temperature variable type as T68, SEASOFT computes T90 temperature directly and multiplies it by 1.00024 to display T68. Conversely, if *a, b, c, d,* and *F0* coefficients (T68) are entered in the .con file and you select temperature variable type as T90, SEASOFT computes T68 directly and divides by 1.00024 to display T90.

Note: The CTD configuration (.con) file is edited using the Configure menu (in SEASAVE or SBE Data Processing in our SEASOFT-Win32 suite of programs) or SEACON (in SEASOFT-DOS).

Also beginning January 1995, Sea-Bird's own temperature metrology laboratory (based upon water triple-point and gallium melt cell, SPRT, and ASL F18 Temperature Bridge) converted to T90. These T90 standards are now employed in calibrating *all* Sea-Bird temperature sensors, and as the reference temperature used in conductivity calibrations. Accordingly, all calibration certificates show T90 (g, h, i, j) coefficients that result directly from T90 standards, and T68 coefficients (a, b, c, d) computed using the Saunders linear approximation.

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

Phone: (425) 643-9866
Fax: (425) 643-9954
E-mail: seabird@seabird.com
Web: www.seabird.com

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

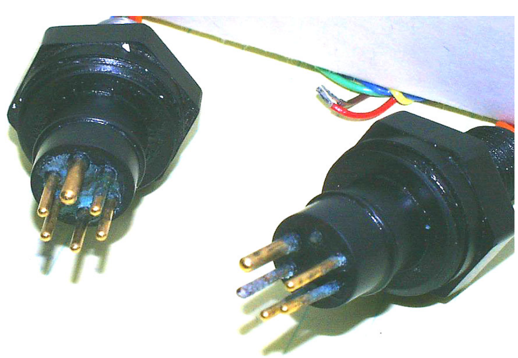
1. Carefully clean the bulkhead connector and the inside of the mating inline (cable end) connector with a Kimwipe. Remove all grease, hair, dirt, and other contamination.


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.

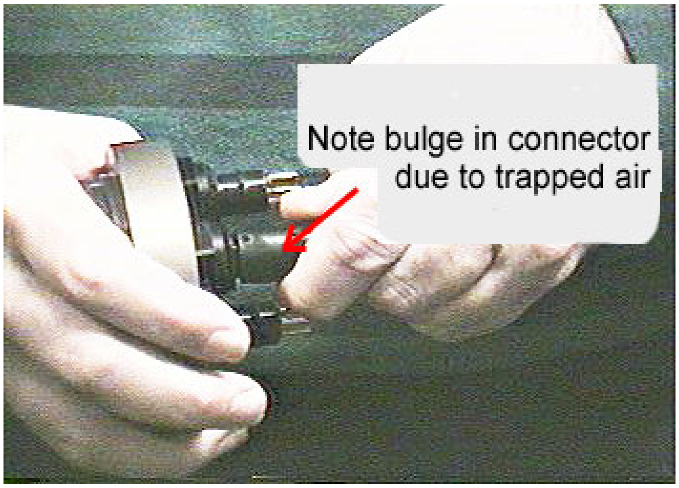
   Replace severely corroded or otherwise damaged connectors - contact SBE for instructions or a Return Authorization Number (RMA number).


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.

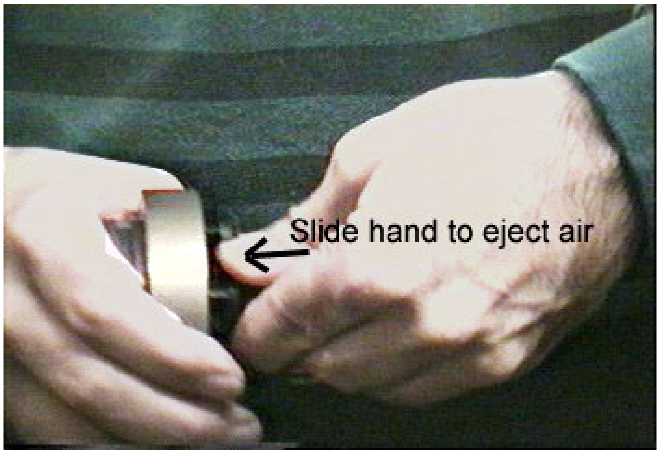


5. Mate the inline connector to the bulkhead, being careful to align the pins with the sockets. Do not twist the inline connector on the bulkhead connector. Twisting can lead to bent pins, which will soon break.

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.



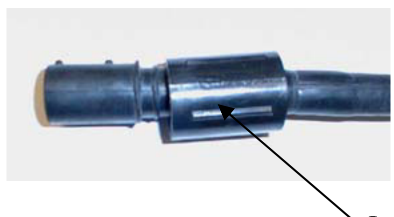
Locking Sleeve Installation

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.



Locking Sleeve

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!

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

Phone: (425) 643-9866
Fax: (425) 643-9954
E-mail: seabird@seabird.com
Web: www.seabird.com

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.

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

Phone: (425) 643-9866
Fax: (425) 643-9954
E-mail: seabird@seabird.com
Web: www.seabird.com

APPLICATION NOTE NO. 68

Revised **November 2006**

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, many 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 three manufacturers on desktop computers at Sea-Bird, and verified compatibility with our instruments. These manufacturers and the tested adapters are:

- **IOGEAR** (www.iogear.com) –
  USB 1.1 to Serial Converter Cable (model # GUC232A).
  Note: This adapter can also be purchased from Sea-Bird, as Sea-Bird part # 20163.

- **Keyspan** (www.keyspan.com) -
  USB 4-Port Serial Adapter (part # USA-49WLC, replacing part # USA-49W)

- **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 have one report from a customer that he could not communicate with his instrument using a notebook computer and the Keyspan adapter listed above. He was able to successfully communicate with the instrument using an XH8290 DSE Serial USB Adapter (www.dse.co.nz).

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.

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

Phone: (425) 643-9866
Fax: (425) 643-9954
E-mail: seabird@seabird.com
Web: www.seabird.com

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:

$$g\ (m/sec^2) = 9.780318 * [\ 1.0 + (\ 5.2788\times10^{-3} + 2.36\times10^{-5} * x) * x\ ] + 1.092\times10^{-6} * p$$

where
$x = [\sin(\text{latitude} / 57.29578)\ ]^2$
p = pressure (decibars)

Then, depth is calculated from pressure:

$$\text{depth (meters)} = [(((-1.82\times10^{-15} * p + 2.279\times10^{-10}) * p - 2.2512\times10^{-5}) * p + 9.72659) * p] / g$$

where
p = pressure (decibars)
g = gravity (m/sec^2)

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

Phone: (425) 643-9866
Fax: (425) 643-9954
E-mail: seabird@seabird.com
Web: www.seabird.com

APPLICATION NOTE NO. 71 — Revised July 2005

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.

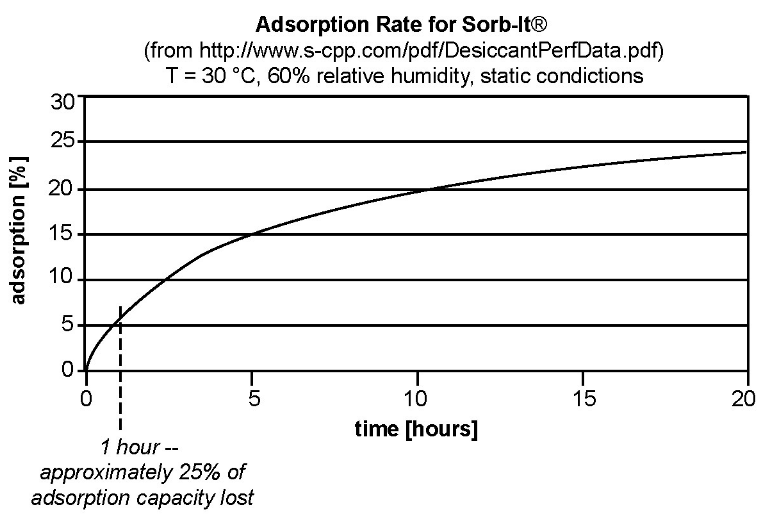
What do we mean by *expose the electronics*?

- For most battery-powered Sea-Bird instruments (such as SBE 16, 16*plus*, 16*plus*-IM, 17*plus*, 19, 19*plus*, 25, 26, 26*plus*, 37-SM, 37-SMP, 37-IM, 37-IMP, 44, 53; 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, 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*-IM, 19*plus*, 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, 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

Sud-Chemie Performance Packaging
101 Christine Dr.
Belen, New Mexico 87002
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%.

SÜD-CHEMIE
Creating Performance Technology
ISO 9002 CERTIFIED

Sud-Chemie Performance Packaging
101 Christine Dr.
Belen, New Mexico 87002
Phone: (505) 864-6691
Fax: (505) 864-9296

MATERIAL SAFETY DATA SHEET – August 13, 2002
SORB-IT®
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.

SÜD-CHEMIE
Creating Performance Technology

ISO 9002 CERTIFIED

Sud-Chemie Performance Packaging
101 Christine Dr.
Belen, New Mexico 87002
Phone: (505) 864-6691
Fax: (505) 864-9296

MATERIAL SAFETY DATA SHEET – August 13, 2002
SORB-IT®
Packaged Desiccant

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.

SÜD-CHEMIE
Creating Performance Technology

ISO 9002 CERTIFIED

Sud-Chemie Performance Packaging
101 Christine Dr.
Belen, New Mexico 87002
Phone: (505) 864-6691
Fax: (505) 864-9296

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.

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

Phone: (425) 643-9866
Fax: (425) 643-9954
E-mail: seabird@seabird.com
Web: www.seabird.com

APPLICATION NOTE NO. 73 — Revised July 2005

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* (RS-232 version)** SEACAT C-T (pressure optional) Recorder, SBE **19*plus*** SEACAT Profiler CTD, and SBE **49** FastCAT CTD Sensor
- SBE **16*plus* (RS-485 version)** SEACAT C-T (pressure optional) Recorder and SBE **16*plus*-IM** SEACAT C-T (pressure optional) Recorder
- SBE **37** MicroCAT (all models – IM, IMP, SI, SIP, SM, SMP)
- 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 software (SEASAVE or SBE Data Processing) uses 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* (RS-232 version), 19*plus*, and 49

Sea-Bird software (SEASAVE or SBE Data Processing) uses 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 (use the **POFFSET=** command in 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* (RS-485 version) and 16*plus*-IM

Sea-Bird software (SEASAVE or SBE Data Processing) uses 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 SEATERM, set the pressure offset to 0.0 (**#iiPOFFSET=0**) and set the output format to converted data in decimal form (**#iiOUTPUTFORMAT=3**).
3. Acquire data using the **#iiTP** command.
4. Calculate *offset* = (0 – instrument reading).
5. Enter the calculated offset in the instrument (use **#iiPOFFSET=** in SEATERM).
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)

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 SEATERM, 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
SBE 37-IM and 37-IMP, and RS-485 version of SBE 37-SM, 37-SMP, 37-SI, and 37-SIP	**#iiPOFFSET=**	**#iiFORMAT=1** or **#iiFORMAT=2**	**#iiTP** (measures and outputs pressure 30 times)
RS-232 version of SBE 37-SM, 37-SMP, 37-SI, and 37-SIP	**POFFSET=**	**FORMAT=1** or **FORMAT=2**	**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 SEATERM, 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 SEATERM, 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 SEATERM, 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	1570
100	145	14.5	0.2	7885
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.

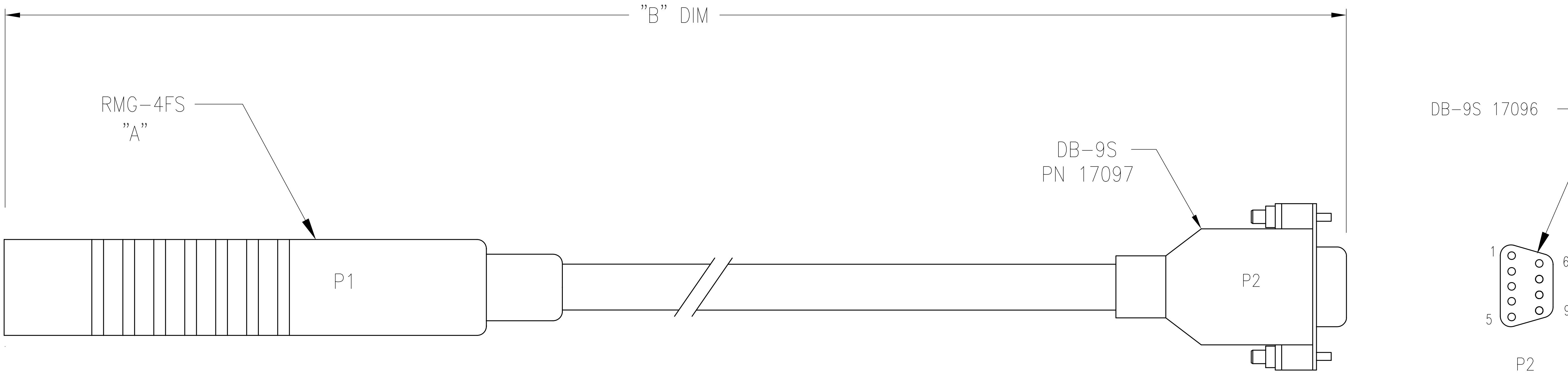
> *Example 1*: You want to deploy the SBE 39 with a 20 m pressure sensor in a mountain lake at 1400 meters (4590 feet). This is lower than 1570 meters shown in the table, so you do not need to adjust the sensor range. After the data is recorded and uploaded, perform post-processing to adjust for the 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 1570 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.

DRAWINGS

DATE	SYM	REVISION RECORD	AUTH.	DR.	CK.
1.4.07	A	ECN 1047: UPDATE SPEC TO 18/4 CABLE	RB	CB	



CABLE TYPE: 18/4-SO OR EQUIV

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	

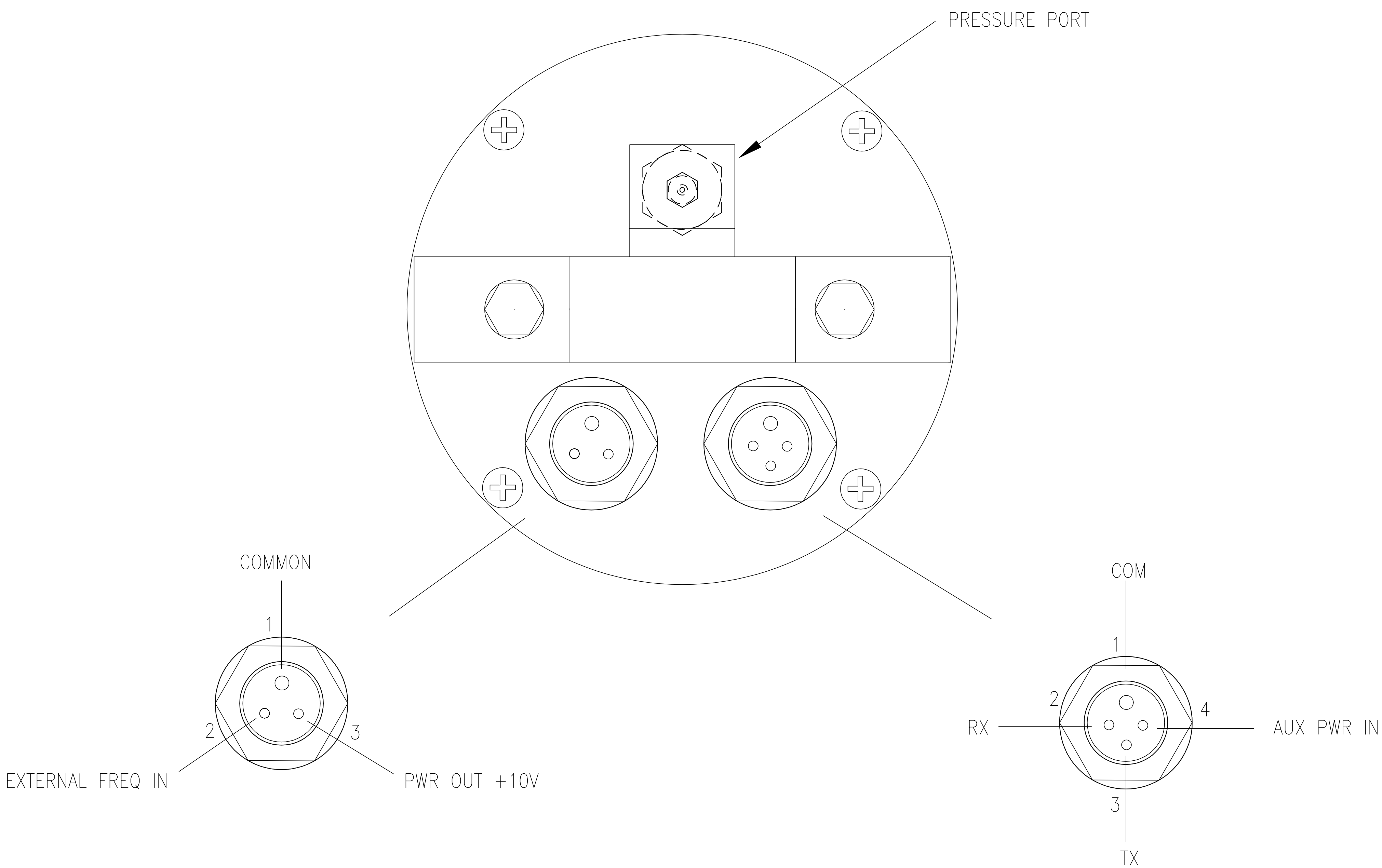
SEA-BIRD ELECTRONICS, INC

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	SYM	REVISION RECORD	AUTH.	DR.	CK.

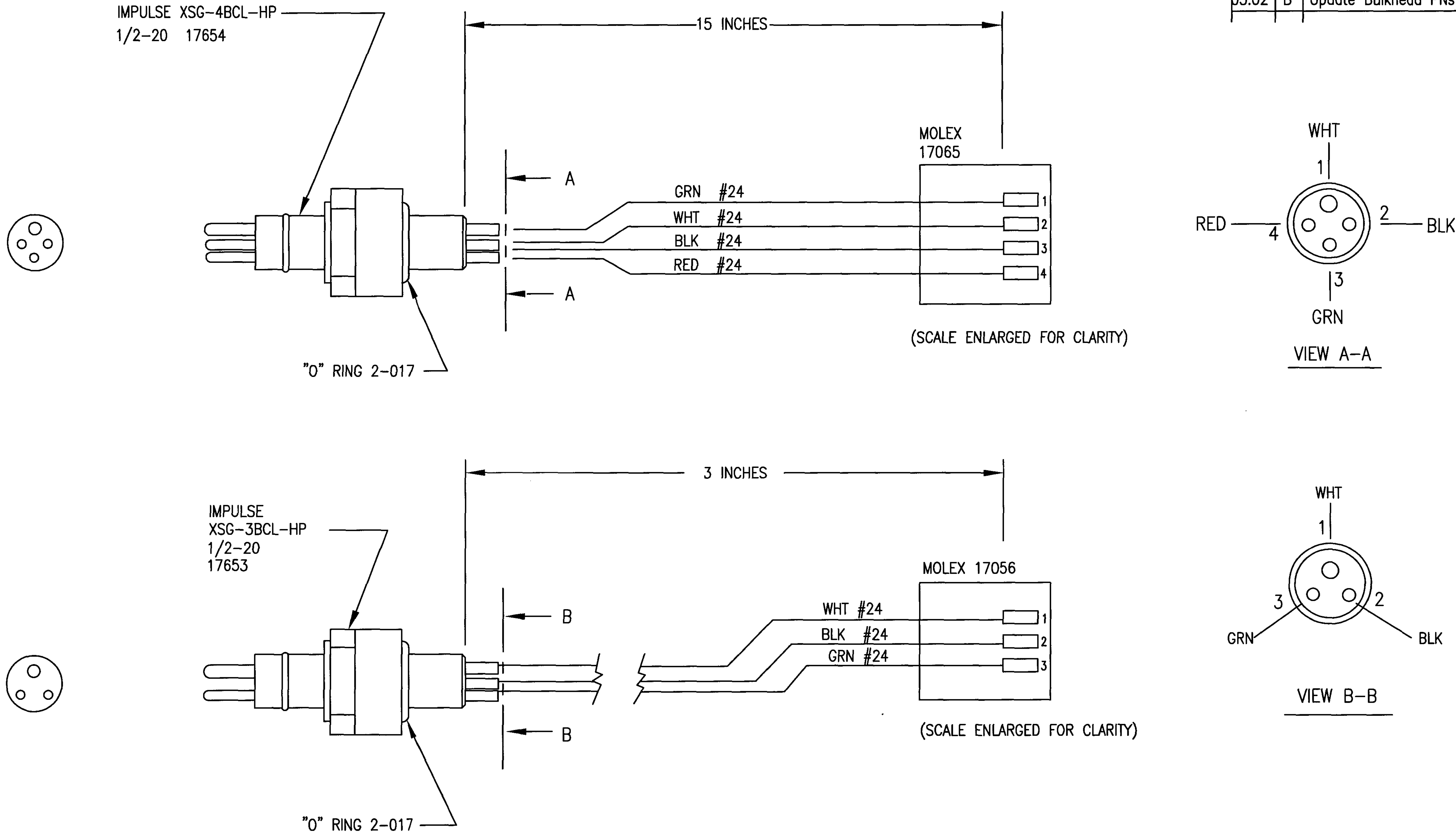


NOTES:

1. LARGE PIN IS NO. 1 (BOTH CONNECTORS)
2. ROTATIONAL ALIGNMENT ON CONNECTORS VARIES

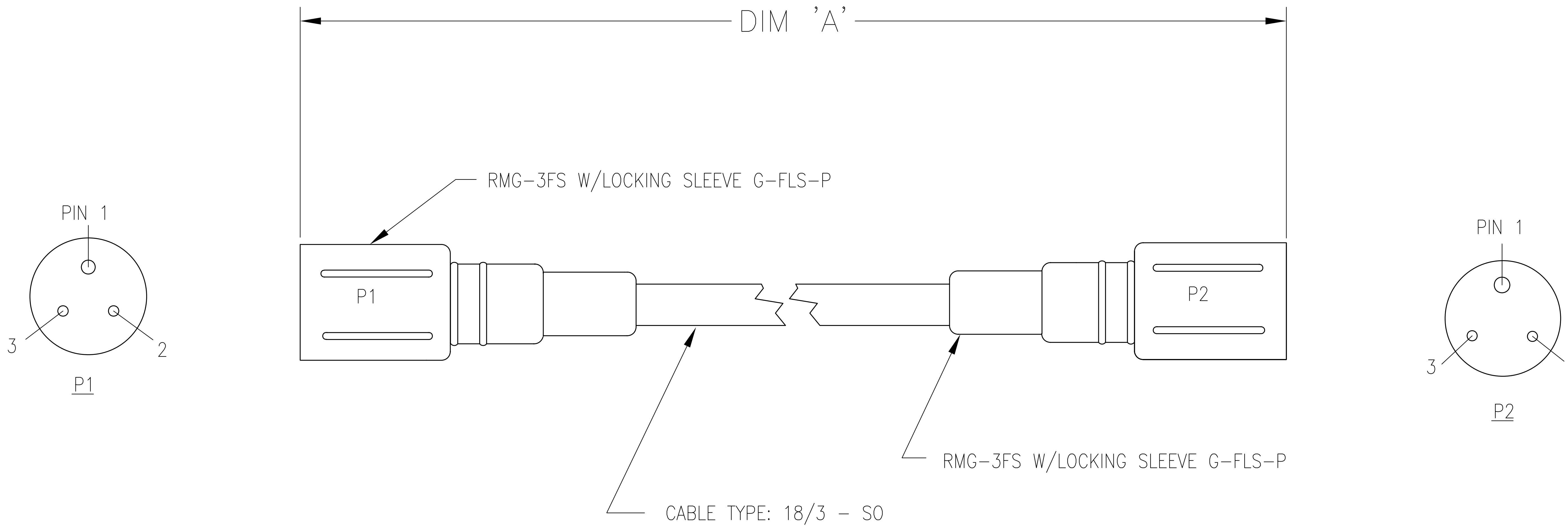
TOLERANCES	SEA-BIRD ELECTRONICS, INC		
FRACTIONAL	P/N	SCALE FULL	DRAWN BY BMC APPROVED BY
DECIMAL	TITLE EXTERNAL I/O WIRING SBE 26 WITH CONDUCTIVITY INTERFACE		
ANGULAR	DATE 12/92	DRAWING NUMBER 50092	REV

DATE	SYM	REVISION RECORD	AUTH.	DR.	CK.
10/93	A	WIRE COLORS CHG B-B		BMC	
03.02	B	Update Bulkhead PNs		MJ	



TOLERANCES	SEA-BIRD ELECTRONICS, INC		
FRACTIONAL	P/N	SCALE –	DRAWN BY BMC APPROVED BY
DECIMAL	TITLE SBE 26 I/O CABLE AND CONDUCTIVITY CABLE ASSEMBLY		
ANGULAR	DATE 11/2/92	DRAWING NUMBER 40609	REV B

DATE	REV	REVISION RECORD	AUTH.	DR.	CK.



SBE PN	DIM 'A'
17086	25 INCHES
17087	31 INCHES
17196	98 INCHES
17257	36 INCHES
17288	158 INCHES
17291	40 INCHES
17353	72 INCHES
17395	18 INCHES
17396	20 INCHES
17397	22 INCHES
17418	120 INCHES

SBE PN	DIM 'A'
17451	24 INCHES
17589	48 INCHES
17695	11 INCHES
17856	60 INCHES
171153	8 INCHES
171248	40 CM
172168	236 INCHES
172298	44 INCHES
172299	79 INCHES

P1	P2
PIN 1	PIN 1
PIN 2	PIN 2
PIN 3	PIN 3

TOLERANCES	SEA-BIRD ELECTRONICS, INC		
FRACTIONAL	P/N SEE TABLE	SCALE N.T.S.	DRAWN BY CEG APPROVED BY P.G.
DECIMAL	TITLE CABLE, 3 PIN/3 PIN RMG-3FS + L.S.		
ANGULAR	DATE 10.13.97	DRAWING NUMBER 30566	REV

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.