Module 1

Introduction to Profiling Equipment
Overview

Introduction to Profiling Equipment

- Internally recording instruments
  – Data recorded in semiconductor memory
- Real-time instruments
  – Data telemetered back to the ship
- Auxiliary sensors
  – Dissolved oxygen
  – pH, ORP
  – Fluorometers, transmissometers, etc.
- Water sampling equipment

In this module we are going to present Sea-Bird’s equipment offerings for profiling. We will present internally recording instruments first, followed by the real-time instruments and then water sampling equipment.

At the end of this module you should be:

- Familiar with Sea-Bird’s product line.
- Aware of the difference between real-time and internally recording instruments.
- Familiar with the water sampling options available.
- Able to install Seasoft.
Sea-Bird offers 3 profiling instruments; the internally recorded SBE 19\textit{plus} and SBE 25 and the real time SBE 9\textit{plus}/11\textit{plus} system. The capabilities of these instruments are contrasted in the following pages.
Sea-Bird’s flagship CTD is the SBE 9 plus and SBE 11 plus. The 9 plus is the underwater part of the system; it houses acquisition, telemetry, and power supply circuitry. The 9 plus receives power from the 11 plus deck unit and will operate over more than 10 kilometers of sea cable. It is capable of operating all types of water samplers and may be configured with a serial port multiplexed into the data stream, to accommodate instruments with serial output rather than the traditional voltage or frequency. It comes standard with pressure, 2 temperature and 2 conductivity channels, and 8 voltage inputs.

The SBE 25 features internal recording at up to an 8 Hz sample rate. It supports temperature, conductivity, and pressure, plus 7 voltage channels. The 25 makes a smaller instrument package and is battery powered with semiconductor memory.

The SBE 19 has been in the field since 1987, and there are over 2500 instruments in use at present. The SBE 19 plus is an enhancement of the venerable SBE 19. It is also battery powered with internal memory. It features independent temperature and conductivity channels, an integral T-C duct (hardware to improve the flow of water past the sensors), and an improved sampling protocol. The 19 plus will sample up to a rate of 4 Hz and average 1 to 32767 scans (decreases the sample rate).
Real-Time Profiling

Real-time profiling means that you are viewing and storing data on your computer at almost the same time that the measurement is being made at the end of the winch cable. The almost part is because there is some time involved in packaging the bits up and sending them up the wire to the deck unit and then onto your computer.

The system consists of sensors that convert environmental parameters to electrically measurable quantities like voltage or frequency. The data acquisition component measures the sensors’ outputs and telemeters them up the sea cable. The deck unit receives the telemetered data, does some minor manipulation, and transmits the data to your computer for display and storage. In the middle of all this is the winch and slip ring, which provide the mechanical means of getting the instrument package down into the ocean and the electrical data stream up to the deck unit.
Internally recorded profiling means that the measurements are stored in semiconductor memory inside the instrument and are downloaded to your computer and viewed after the equipment is on deck. The ship is not required to have a sea cable with an internal conductor.

The measurement system consists of sensors that convert environmental parameters to electrically measurable quantities. The data acquisition portion of the system converts the sensor output to digital data and stores it internally.
Conductivity, Temperature, and Pressure Sensors

Conductivity, Temperature and Depth

- Depth is derived from pressure sensors.
- These are typically internal to the main pressure housing of the CTD
- Conductivity and temperature may be mounted internally or externally
SBE 19 Versus SBE 19\textit{plus}, Sensor Placement

The SBE 19 has side-by-side temperature and conductivity sensors. The SBE 19\textit{plus} features inline sensors and an integral ducting system, which ensures that water that passes the thermometer goes into the conductivity cell.
Calculating Memory Capacity in Scans

Memory Capacity in Scans for Internal Recorders

- Standard memory size is:
  - 1 Mbyte for SBE 19
  - 8 Mbytes for SBE 19plus
  - 1, 2, 4, or 8 Mbytes for SBE 25

- Scan length is:
  - 6 to 15 bytes for SBE 19
  - 8 to 24 bytes for SBE 19plus
  - 8 to 19 bytes for SBE 25

\[
\text{Memory Capacity In Scans} = \frac{\text{Memory available – Scratch Pad}}{\text{Bytes per Scan}}
\]

For the SBE 25:
- No external voltages sampled: ttttccccccsppp
- Seven external voltages sampled: ttttccccccpppuuuuvvvvvwwwwxxxyyyzzz0aaa

For the SBE 19:
- No external voltages sampled:
  - With Paine pressure sensor -- ttttccccpppp
  - With Digiquartz pressure sensor -- ttttccccppppppddddd
- Four external voltages sampled:
  - With Paine pressure sensor -- ttttccccuuuvvvxxxyyypppp
  - With Digiquartz pressure sensor – ttttccccppppppuuuvvvwwwwxxxyyyddddd

where:
- ttttt = 3 bytes of temperature frequency
- cccccc = 3 bytes of conductivity frequency
- s = sign character for pressure
- ppp = 12 bits representing pressure
- uuu through zzz and aaa = 12 bits representing stored voltages
- 0 = 4 bits all zero (used to make an even number of characters)

For the SBE 19plus
- SBE 19plus in Profiling mode with strain-gauge pressure sensor, strain gauge temperature as a voltage, and two external voltages sampled:
- example scan = ttttccccccppppvvvvvvvvvv

where:
- ttttt = 3 bytes of temperature frequency
- cccccc = 3 bytes of conductivity frequency
- ppppppp = 3 bytes of pressure data for Paine strain gauge pressure sensor
- vvvv = 2 bytes representing stored voltage
Calculating Memory Capacity in Time

Memory Capacity in Time for Internal Recorders

- Sample rates:
  - SBE 19 = 2 scans / second or less
  - SBE 19plus = 4 scans / second or less
  - SBE 25 = 8 scans / second or less

Memory endurance in time is the ratio of memory capacity in scans divided by the instrument sample rate. The SBE 19 sample rate can vary from 2 samples per second to 4 minutes between samples. The SBE 19plus sample rate is 4 Hz; however, you can average between 1 and 32767 samples, for a range of 4 Hz to 2.3 hours between samples. The SBE 25 samples at 8 Hz and can average between 1 and 8 scans.
Calculating Battery Endurance in Time

Battery Endurance

- Each battery has 1.6 amp hours of power
- **Battery capacity depends on ambient temperature**
- Batteries come in 6, 9, or 12 cell packs… 9, 14, or 19 amp hour capacity
- Battery endurance is nominally the capacity in amp hours divided by the current consumption of the instrument package in amps
- For a 9-cell battery pack:

\[
\text{Battery Endurance} = \frac{14 \text{ Amp Hours}}{\sum \text{Currents}}
\]
Battery Endurance Examples

- SBE 19plus, 9-cell battery pack
  - 0.065 amps for the 19plus
  - 0.095 amps for the 5T pump
  - Maximum sampling time $\approx \frac{14}{0.065 + 0.095} \approx 87$ hours
- SBE 25, 9-cell battery pack
  - 0.160 amps for the 25
  - 0.010 amps for the SBE 3 and SBE 4
  - 0.095 amps for the SBE 5T pump
  - 0.006 amps for the SBE 43
  - Maximum sampling time $\approx \frac{14}{0.366} \approx 12$ hours

Battery endurance is difficult to estimate, because a battery’s life depends on the ambient temperature. Moreover, NiCad batteries tend to lose their capacity as they age. The slide above is a good rule of thumb. However, for critical work, consider that batteries are cheap, so you might as well start with a new set.
SBE 9plus/11plus Telemetry Channels

The 9plus / 11plus CTD has two standard telemetry channels, the data channel and the water sampler control channel (often referred to as the modem channel). The data channel is for uplink only; the data flows from the 9plus to the 11plus. The water sampler control channel is duplex; data flows both ways, from the 9plus to the 11plus and from the 11plus to the 9plus.

The data channel operates at 8640 bits per second and transmits from the 9plus as a Differential Phase Shift Keyed (DPSK) signal. Binary data is packaged into standard 10-bit serial frames (8 data bits, 1 start bit, 1 stop bit, and no parity); it is modulated to 34.5 kHz and a 0 bit is represented as 0 degree phase, a 1 bit as 180 degree phase. The 11plus demodulates the telemetry and standard serial receivers (UART) accept the serial frame.

The water sampler channel is a 300 bit per second Frequency Shift Keyed (FSK) duplex channel, modulated to 1 kHz for the downlink and 2 kHz for the uplink. This data channel is meant for water sampler control and for communications with user instrumentation. Water sampler control information has the 8th bit in a 7 bit ASCII character set. Any data without the 8th bit set is assumed to be meant for a remote instrument and is passed to the center bulkhead connector of the top end cap.
The data transmission rate of the 9plus is constrained by the 24 Hz scan rate. Of the 30 bytes that make up a scan, 29 of them are transmitted in standard asynchronous format, 1 start bit, 8 data bits, and 1 stop bit. The 30th byte is all zeros; it is not transmitted. This lack of a data byte is used by the 11plus and the 17plus to synchronize the data acquisition. Synchronization occurs with each data scan. As an option, the data transmission speed can be doubled and serial data at 9600 baud from a remote instrument can be time dimension multiplexed into the telemetry stream. This option requires a hardware change; it finds use with some optical instrumentation that transmits data at 9600 baud. The disadvantage to deploying this option is the data transmission is not as robust, and some lower quality sea cables will not allow transmission to occur over the whole 10 km.
SBE 9plus/11plus Water Sampler Telemetry

SBE 9plus / 11plus
Water Sampler Channel

- Channel is 300 bps, 8 data bits, 1 stop; water sampler commands are transmitted with 8th bit set
- Other data is passed to connector JT7 on top end cap for use by instrument
- Successful bottle closure confirmation is sent back via SBE 11plus to computer

All water sampler communications are carried out over the 300-baud FSK modem channel. This is a separate, full-duplex communication channel that is frequency domain multiplexed onto the single conductor sea cable. You have the option of commanding water sampler closures with the buttons on the deck unit or via the computer keyboard. If you want to use the computer, you must have two serial ports installed on your computer.
**SBE 9plus Frequency Acquisition**

**SBE 9plus Frequency Counters**

- 24-bit signal acquisition for T, C, and P
- Resolution in terms of degrees C / bit or Siemens/meter/bit depend on the magnitude of temperature or conductivity
- Equations for determining resolution and examples are included in the notes

Frequency counters require a reference frequency to count the sample frequency against. Consider that if you want to measure frequency in Hertz (cycles/second), you need to know how long a second is. The resolution of the type of counters employed in the 9plus depends on the frequency of the sample, the scan rate, and the frequency of the reference.

\[
Resolution \ (\text{Hz} \ / \ \text{Bit}) = \frac{\text{Scan Rate}}{\left(\frac{F_s}{F_r}\right)}
\]

Where:
- \(F_s\) is the sensor frequency
- \(F_r\) is the CTD reference frequency (6,912,000Hz for C & T; 27,648,000 for P)

To find resolution in scientific units, we need to divide resolution by sensitivity (Hz/scientific unit). Approximate values can be obtained from the sensor calibration sheet. Some examples follow. These are for illustration only; your computer will use higher precision math and the appropriate calibration equations for your sensors.

**Temperature:**
- At -1°C, \(F_s = 2100\) Hz, Sensitivity = 48 Hz°C
  - Resolution = 0.00015°C per bit
- At 31°C, \(F_s = 4000\) Hz, Sensitivity = 76 Hz°C
  - Resolution = 0.00018°C per bit

**Conductivity:**
- At 1.4 Siemens/meter (S/m), \(F_s = 5000\) Hz, Sensitivity = 1900 Hz/(S/m)
  - Resolution = 0.000091 S/m per bit
- At 5.8 S/m, \(F_s = 11000\) Hz, Sensitivity = 960 Hz/(S/m)
  - Resolution = 0.0000398 S/m per bit

**Pressure (10,000 psi range Digiquartz sensor, with a conversion factor of 1.46 psi/ubar):**
- At 0 dbar, \(F_s = 33994\) Hz, Sensitivity = 0.614 Hz/ubar
  - Resolution = 0.041 dbar per bit
- At 6800 dbar, \(F_s = 38,480\) Hz, Sensitivity = 0.614 Hz/ubar
  - Resolution = 0.054 dbar per bit
SBE 9plus Voltage Acquisition

SBE 9plus Voltage Channels

- 0 - 5V signal input, 12-bit A/D
- Each bit = 0.0012V
- Each of 8 channels has a 5.5 Hz low pass filter on input, allowing us to resolve features that change at a rate of 2.75 Hz
Modular Sensors, SBE and Others

Sea-Bird offers a variety of modular sensors of our own manufacture and also many from other manufacturers. These sensors have various outputs: voltage, frequency, or serial ASCII data. In addition to temperature and conductivity, dissolved oxygen and pH are offered, as are oxidation potential, light, transmittance, fluorescence, and turbidity.
The top end cap of the 9plus has bulkhead connectors for all auxiliary sensors. Auxiliary sensors are those that are not temperature, conductivity, or pressure. Each auxiliary bulkhead has inputs for two 0 – 5V differential input channels. In addition, there is a 2-pin connector for the sea cable and a 3-pin connector for a GO 1015 rosette sampler. The center connector connects to the SBE 17plus (a memory module), a remote instrument, or an SBE 32 carousel sampler.

The bottom end cap has connectors for pairs of temperature and conductivity sensors, pump power, and a bottom contact switch. The bottom contact switch is mechanical, with a weight that hangs below the instrument package. When the weight contacts the ocean bottom, a bit is set in the data stream and an alarm in the SBE 11plus deck unit sounds.
Real-Time Options for Internally Recording Instruments

**Telemetering a Recorded Instrument: SBE 36 and PDIM**

- SBE 36 is the deck unit
- PDIM (Power Data Interface Module):
  - receives power from SBE 36
  - converts it to power for SBE 19, 19plus, or 25
  - telemeters data to deck

The SBE 36 and PDIM provide power and telemetry, but no water sampling capability.
Cabling for Real-Time Operation

SBE 36 and PDIM

Diagram showing cabling connections between SBE 19, 19 plus, or 25 (internally recording) to PDIM, slip ring/winches, SBE 36 Deck Unit, and Computer.
As a companion to CTD profilers, Sea-Bird supplies water sampling equipment. Sea-Bird manufactures the framework, mechanism for closing bottles, and deck power supply and sampler control. The water sample bottles themselves are not manufactured by Sea-Bird. The SBE 32 is the portion of the equipment that triggers the bottle closure.

The Carousel trigger mechanism is an electro-mechanical device. It operates by energizing a solenoid magnet that pulls a mechanical trigger, releasing the nylon lanyards that hold the top and bottom caps of the water sampler open.
Water Sampling in Real-Time for Internally Recording Instruments

Telemetering and Water Sampling with a Recorded Instrument: SBE 33

- SBE 33
- Computer
- Slip ring/winch
- Single conductor sea cable
- SBE 19, 19 plus, or 25 (internal memory)
- SBE 32 Carousel with real-time integration option
- For setup & data upload only
- Computer
Water Sampling for Internally Recording Instruments

Water Sampling with Recorded Instruments: AFM and SBE 17\textit{plus} V2

- AFM = Auto Fire Module, closes water sampler by interpreting data from recorded instrument
  - Closes sampler on time or pressure, upcast or downcast
- SBE 17\textit{plus} V2 is a memory module for SBE 9\textit{plus} with auto fire capability
  - Closes sampler on pressure, upcast only

Internally recording instruments output a real time, RS-232 serial data stream. This data stream is suitable for real-time telemetry over short cables only. The data stream is used by the AFM to monitor the depth of the sampling package for the purpose of closing water samplers.
Cabling for Water Sampling with the AFM

The AFM is programmed to close water samplers at the required depths, and then it is armed. It receives pressure data from the CTD; when the closure parameter for a water sample has been met, it actuates the Carousel and records a small amount of CTD data. When the CTD is retrieved, the data in the CTD and AFM are uploaded to the computer. The data in the AFM is used in post-processing to get a table of CTD parameters to go with whatever is gleaned from the water samples.
Battery Power and Internal Recording for the SBE 9\textit{plus}

SBE 17\textit{plus} V2

- SBE 17\textit{plus} V2 provides memory and power for SBE 9\textit{plus}, has 16 Mb of nonvolatile memory, supports conductivity advance and suppression of channels
- Also features Carousel auto fire capability

The SBE 17\textit{plus} V2 acts as battery power and internally recording memory for the SBE 9\textit{plus}. This device has the capability to close water samplers as well. It only closes bottles on the upcast.
SBE 17plus Version 2 (includes auto-fire)
Autonomous Profiling

Autonomous Instruments: SBE 41 and 41cp

- Launched from research vessels, ships of opportunity, and aircraft
- Profiles telemetered via ARGOS satellite

The SBE 41 and 41cp are CTDs that are used with buoyancy engines. After deployment they become negatively buoyant, sinking to ~1000 meters, resting for 10 days, and then making themselves positively buoyant, collecting a profile as they rise through the ocean. Once on the surface, they transmit their data via a satellite back to the scientist who deployed them. Because they receive no handling after deployment and have minimal time on the surface, they provide an excellent example of conductivity sensor drift in an optimum environment.
Activity

Activity: Install Seasoft and Course Data

- Insert the Seasoft CD into your laptop, double click on “Seasoft-Win32.exe”
- Install Seasoft for waves
  – Copy the sswaves.dos folder onto your C:\ drive
  – Open the folder, double click on “Setup26.bat”
- Insert the course materials disk into your laptop
  – Copy the “Data” folder from \Seabird Training Rev 2.1\Data to your C:\ drive.
- Add the following to your Autoexec.bat path statement
  – c:\program files\sea-bird\sbedataprocessing-win32\
  – c:\sswaves.dos\

To add a folder to your MSDOS or command line path do the following:

Click Start

Click Run

Type sysedit

Click on the window that says AUTOEXEC.BAT

Add a the following line:

Path c:\program files\sea-bird\sbedataprocessing-win32\c:\sswaves.dos\

Note that the folder names are separated by a semicolon.

Reboot your computer