911plus CTD SYSTEM OPERATING AND REPAIR MANUAL

SBE 9plus UNDERWATER UNIT

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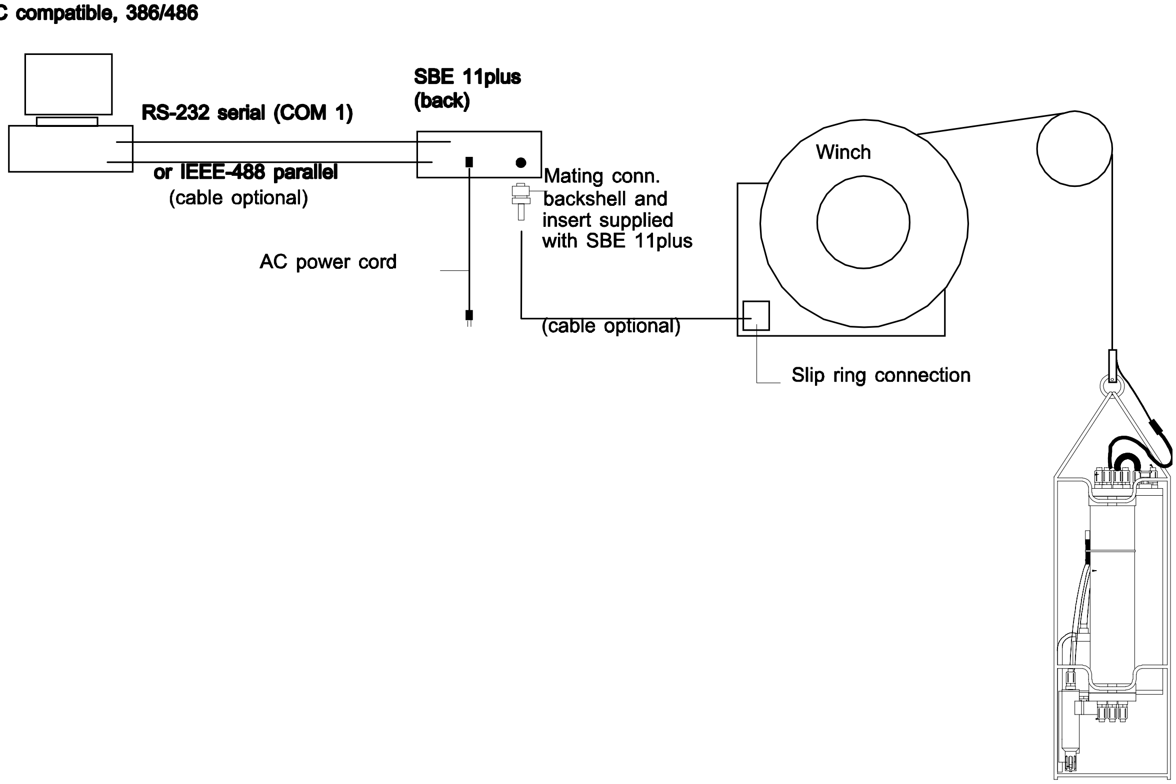
Figure 1



The Sea-Bird 911*plus* CTD system consists of the SBE 9*plus* Underwater Unit and the SBE 11*plus* Deck Unit (for real-time readout using conductive wire). Optionally, the SBE 17*plus* SEARAM Memory Module can be interfaced to the SBE 9*plus* to allow self-contained, internal recording operation when a conducting sea cable is not available. When a deck unit is employed, underwater unit power is supplied down the same single conductor armored wire used to carry data up to the surface. The deck unit decodes the serial data and passes it to a computer for display and logging to disk.

For internal recording, power to the 9plus is supplied from batteries in the SEARAM housing. The data is stored in SEARAM's semiconductor memory and may be extracted upon recovery of the instrument via a RS-232 serial link.

This manual describes the operation and use of the SBE 9*plus* CTD Underwater Unit. For information about the SBE 11*plus* Deck Unit or SBE 17*plus* SEARAM, consult the appropriate manual.

See the SYSTEM CONFIGURATION SHEET at the front of this manual which describes the features of your particular CTD underwater unit.

1-2 SYSTEM COMPONENTS

The Sea-Bird underwater hardware consists of a main pressure housing comprising power supplies, acquisition electronics, telemetry circuitry, and a suite of modular sensors all mounted within a stainless steel guard cage (SBE 9*plus* CTD Underwater Unit). Surface hardware includes the SBE 11*plus* Deck Unit and a computer; the user must supply conductive wire and a slip ring-equipped winch to connect the two together.

For internal recording (9*plus* / 17*plus* integrated package), the only surface equipment required will be a PC compatible computer with one RS-232 serial-port, and a SEARAM data I/O cable supplied with the SEARAM.

1-2.1 SBE 9*plus* CTD UNDERWATER UNIT

Figure 2. Primary components of the SBE 9*plus*.

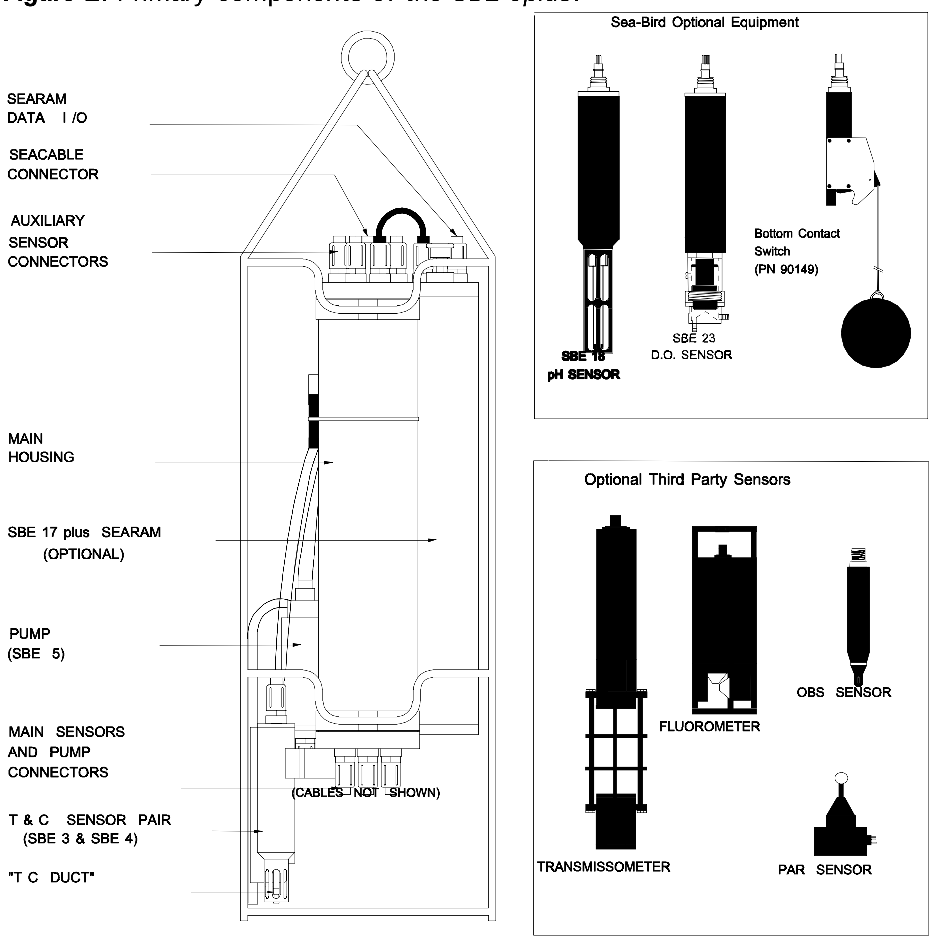


Figure 2 illustrates the main components of the underwater unit and shows some examples of optional equipment. The SBE 9*plus* uses Sea-Bird's standard modular temperature and conductivity sensors (SBE 3*plus* and SBE 4) which are mounted with a single clamp and "L" bracket to the lower end cap of the underwater unit. The conductivity cell is under the SBE 4's rectangular aluminum guard and is mounted parallel to the module housing. The conductivity cell and the temperature sensor are connected by a two-piece "TC Duct" assembly. The tip of the temperature sensor element's protective steel sheath is enclosed inside the clear plastic "Temperature Duct" which is connected to the conductivity cell by an L shaped "Conductivity Duct". If secondary temperature and conductivity sensors are installed, they also mount with a single clamp and "L" bracket, similarly to the primary sensors. The depth (pressure) sensor is mounted inside the underwater unit main housing and is ported to outside pressure through the oil-filled plastic capillary tube seen protruding from the main housing bottom end cap.

A pump is used to provide optimum and constant speed flushing of the temperature and conductivity sensors via the TC Duct. In current designs, the pump is mounted in one of two configurations, depending on whether the CTD will be used vertically, or mounted horizontally under a water sampler.

In the vertical configuration (Figure 3), the pump is mounted with its electrical connector downward. Tubing leads upward from the top of the conductivity cell, (through the oxygen sensor plenum if an optional D.O. sensor has been installed) to a 'Y' connection containing an air bleed-valve. Another length of tubing leads downward to the pump intake, and a third piece of tubing connected to the pump exhaust port leads downward along one leg of the cage to a point even with the opening of the Temperature Duct.

Figure 3
PLUMBING CONFIGURATION - VERTICAL

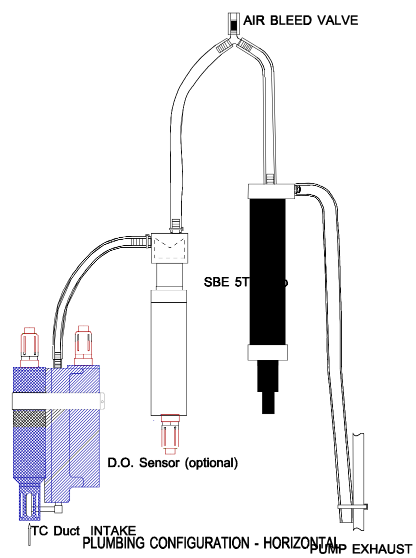


Figure 4 shows the horizontal configuration (CTD lying on its side), with the pump is mounted with its electrical connector toward the top end cap of the CTD. Tubing leads from the conductivity cell, (through the oxygen sensor plenum if an optional D.O. sensor has been installed) to the intake of the pump. The pump exhaust port is oriented so it points upward allowing air to escape as the CTD is submerged.

PLUMBING CONFIGURATION - HORIZONTAL

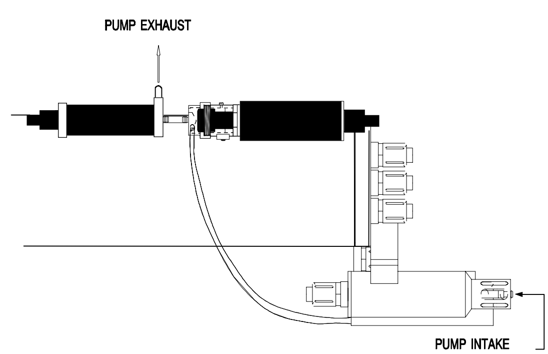


Figure 4

To protect the pump bearings from excessive wear when they are not water-lubricated, control circuitry inside the main housing keeps the pump from running until salt water enters the conductivity sensor, i.e., the pump does not run when then the CTD is in air. To facilitate priming of the pump, this circuitry also forces a 60 second delay before providing pump power.
Accordingly, the CTD should be 'soaked' just under the water surface for about two minutes before actually beginning the descent (see DEPLOYMENT, Section 2-1.6 below).

1-2.2 SBE 11*plus* CTD DECK UNIT

The SBE 11*plus* is the rack-mountable interface unit which supplies DC power for the underwater unit, decodes the serial data stream, formats the data under microprocessor control, and passes the data to a companion computer. Push buttons and status lights for control of a water sampler are provided on the front panel. The SBE 11*plus* has a rear panel selector switch permitting operation from either 115 VAC or 230 VAC 50/400 Hz power and contains provision for numeric display of selected frequency and voltage data via a thumbwheel switch and 8 digit LED readout. Output data is provided in both IEEE-488 and RS-232 format. A tape recorder interface permits recording of the digital data stream (See SBE 11plus manual). The SBE 11*plus* can average the data underwater unit data to reduce the processing or archiving demands placed on the accompanying computer. (See SBE 11plus Manual for more detail)

1-2.3 SBE 17*plus* SEARAM

The optional SEARAM memory module plugs into the SBE 9*plus* Underwater Unit via a dedicated connector and is used in lieu of a connection via conductive wire and slip-rings to the SBE 11plus. The principle deck unit functions of supplying power and decoding the serial data stream are imitated by the SEARAM, which is powered by 12 rechargeable nickel-cadmium batteries, and stores the data in CMOS memory. When the CTD is recovered, the memory contents are read out via an RS-232 link to a computer.

1-3 GENERAL THEORY OF OPERATION

Electronics inside the SBE 9plus housing provide three primary functions including regulation of the several voltage levels required by the internal circuits, external sensors, and pump; acquisition (digitization) of sensor signals; and data telemetry.

Unlike CTD systems in are powered from a fixed *current*, the SBE 9plus receives a *voltage* impressed by the Deck Unit onto the seacable, (minus the seacable I-R drop), regulates it to a constant value, and presents it to a high-efficiency DC/DC converter that generates the system supply voltages (±15, +8, and +5). Two advantages derive from this method; less power is lost in the seacable and more delivered to the underwater unit, and the underwater unit is not required to dissipate unneeded power thus freeing the user of the need to monitor and adjust the surface sea cable supply.

Bulkhead connectors on the SBE 9plus lower end cap supply +15 volt power to (and receive variable frequencies from) the modular conductivity and temperature sensors. The C and T variable frequencies plus the internal Digiquartz® frequency are routed to separate counters that are allotted exactly 1/24 second to derive 24 bit binary values representative of each sensor frequency. Sea-Bird's hybrid counter technique combines integer and period counting to produce digital results that are simultaneous (time coincident) integrals of C, T, and P. Binary data from the entire suite of C, T, P, and auxiliary sensors are transmitted serially 24 times per second using a 34560 Hz carrier differential-phase-shift-keyed technique. This telemetry system is suitable for all single and multi-conductor cables having a conductor resistance of 350 ohms or less.

A 300 baud full-duplex FSK sub-carrier modem (2025/2225 Hz downlink; 1070/1270 Hz uplink) provides a separate communications channel for control of the Sea-Bird Carousel or other common water samplers. Bottles can be fired with SBE 11plus front panel push buttons, through SEASOFT©, or via a separate computer connected directly to the modem port on the SBE 11plus back panel. There is no interruption of CTD power or data during the bottle firing process. An optional interface card in the SBE 9plus permits control of older multi-bottle sampler types, and the modem channel is also available as a general purpose RS-232 interface for custom user applications.

A more detailed discussion of the basic theory of operation of the Sea-Bird CTD is in the published paper (STD 84) in the appendix. Detailed information on the electronic circuitry is given in Section 4.

1-3.1 CTD SENSORS

The **temperature sensor** (model SBE 3plus) is a compact module containing a pressure-protected high-speed thermistor and 'Wein bridge oscillator' interface electronics. The thermistor is the variable element in the Wein-bridge, while a precision Vishay resistor and two ultra-stable capacitors form the fixed components. The **conductivity sensor** (model SBE 4C) is similar in operation and configuration to the temperature sensor, except that the Wein-bridge variable element is the cell resistance. The Digiquartz® **pressure sensor** also provides a variable frequency output. The sensor frequencies are measured using high-speed parallel counters and the resulting digital data in the form of count totals are transmitted serially to the SBE 11*plus* deck unit. The deck unit reconverts the count totals to numeric representations of the original frequencies.

Sea-Bird conductivity and temperature sensors are calibrated by immersing them in a variable conductivity/temperature bath, while the pressure sensor is calibrated using a dead-weight pressure generator. The sensor output frequencies are tabulated along with the known physical input conditions of C, T, and P and the results used to obtain a series of calibration coefficients. The sensor frequency as output by the CTD deck unit is then the input to a conversion equation which - along with the original calibration coefficients - gives results in scientific units.

Embedded in the pressure sensor is a semiconductor temperature sensor used to compensate the small ambient temperature sensitivity of the Digiquartz®. The calibration information for each sensor (C, T, and P) is contained in a series of numeric coefficients used in equations relating frequency to the measured parameter.

SBE 9*plus* CTDs are shipped with SBE 3*plus* and SBE 4C sensors equipped with Sea-Bird's TC duct. This accessory, in addition to the SBE 5 pump provides uniform and constant flow of sea water past the temperature and conductivity sensors. The physical configuration of the duct causes the time interval between temperature and conductivity measurements to be known and constant. Knowledge of the time interval between measurements allows salinity calculations to be made with measurements from the same parcel of water.

For a detailed discussion of the theory of operation of the SBE 4 (and by close analogy, the SBE 3*plus*), refer to the paper 'Development of a Small *in-situ* Conductivity Instrument' at the end of this manual. Application Note 38 describes the TC duct; refer to the 'app notes' section of this manual for more information. See also, individual specification sheets for SBE 3plus Premium CTD Temperature sensor and SBE 4 Conductivity sensor, also located at the end of this manual.

1-3.2 AUXILIARY SENSORS

Optional sensors for dissolved oxygen, pH, light transmission, fluorescence, etc., do not require the very high levels of resolution needed in the primary CTD channels, nor do these sensors generally employ variable frequency outputs. Accordingly, signals from the auxiliary sensors are acquired using a conventional voltage-input multiplexed A/D converter. The A/D output is a binary number between 4095 and 0 corresponding to voltages in the range of 0 to +5 volts. The A/D binary values are incorporated into the CTD serial data stream and are available in unconverted form for display or transfer to the system computer. The SBE 9plus provides four bulkhead connectors for optional auxiliary sensor inputs. Each connector provides +15 volts power and permits access to two differential input / low pass filtered digitizer channels.

2-1 PRELIMINARY CHECKOUT AND INSTALLATION

A preliminary checkout is recommended to confirm system functionality after receipt of the CTD.

After completing the preliminary checkout described here, those who have PC/compatible computers should consult the SEASOFT instruction manual. SEASOFT supports both real time (deck unit) and *in-situ* recording (SEARAM) systems and minimizes the need for detailed knowledge of the I/O protocol, command structure, and data formats associated with Sea-Bird CTD equipment.

Those users who intend to write their own software should consult the SBE 11*plus* Deck Unit or SEARAM Manuals for descriptions of the computer commands needed to implement control and to process the output data.

2-1.1 CHECKOUT WITH SBE 11*plus* DECK UNIT

Connect the Underwater unit seacable bulkhead connector (2-pin "JT-1", see top end cap drawing 50076) to the Deck Unit 'Sea Cable' rear-panel connector using the P/N 80591 Test Cable (RMG-2FS to MS) supplied. **Do not confuse JT-1 on the top end cap with either 2-pin connectors on the CTD bottom end cap (sensor end). JB-3 is the pump connector, and JB-6 (in the center of the end cap) is for a bottom contact switch (see bottom end cap drawing 50078). Connecting power via the test cable to either JB-3 or JB-6 will cause serious damage to the 9plus.**

Check that the rear-panel power selector switch is in the correct position for your AC power source. **CAUTION: CONNECTING AN SBE 11*plus* SET FOR 120 VOLTS to 240 VOLT POWER WILL CAUSE IMPORTANT DAMAGE**. Apply power to the Deck Unit. Observe that the 'Data' light comes on and the 'Error' light is off. This confirms that the Underwater Unit is transmitting data and that the data is being correctly received by the Deck Unit. The pump should not be running since the conductivity cell is not yet in salt water.

Set the Deck Unit thumbwheel switch to position 0. The display should read the frequency being generated by the temperature sensor and will typically be 3000 to 4000 Hz for room temperature conditions. Warming the sensor increases the frequency.

Set the thumbwheel switch to position 1. The display will show the frequency being output by the conductivity sensor. This should be about 2800 Hz, depending on the air (zero conductivity) output of the sensor.

Set the thumbwheel switch to position 2. The display will show the pressure sensor frequency, which should be in the range of 32,000 to 40,000 Hz.

Thumbwheel switch positions 3 and 4 will display the frequency of secondary temperature and conductivity sensors (if installed). If these sensors are not installed, the display will read 0.

Set the thumbwheel switch to position 5. The four digits to the left of the decimal point represent A/D converter channel 0; the right digits, channel 1. The next 3 switch positions (6 - 8) will show the remaining A/D channels in the same fashion. Channels that have no sensors attached to them will read 4095, the A/D converter output for 0 volts input.

With the thumbwheel set to position B, the digits to the left of the decimal point represent the pressure sensor compensation temperature. The right hand digits will show the incrementing modulo count. Since the deck unit defaults on power up to average 8 scans together but the modulo count is transmitted for the most recent scan only, this number will increase in steps of 8. Modulo count is a scan identifier in the form of an 8 bit number which increases 0, 1, 2, 3, etc up to 255 and then rolls over to 0, 1, 2 etc. It is generated in the CTD underwater unit and can be used for diagnostic purposes.

Thumbwheel position C shows the number of bytes available in the IEEE-488 buffer (initially 20500). When recording data via the IEEE-488 interface, this number will decrease as the deck unit places data in the data buffer and will increase as the computer processes and stores CTD data. It will be important to ensure that the buffer count periodically resets to 20500 otherwise the buffer will eventually fill and data loss will occur. The computer display update rate (set in SEASOFT) is used to prevent the occurrence of overflow. Thumbwheel position D performs in the same manner but relates to the RS-232 output; the buffer length for RS-232 data is 8000 bytes.

Units equipped with the optional modem should have the modem carrier detect light lit. This indicates that the modem in the deck unit is receiving a signal from the modem in the underwater unit. With the thumbwheel switch in position E, the left most status bit should be 0, indicating that the modem in the underwater unit is receiving a signal from the deck unit.

2-1.2 CHECKING SBE 9plus WITH SBE 17*plus* SEARAM - OVERVIEW

If factory installed, the SBE 17*plus* SEARAM is mounted parallel to the SBE 9*plus* main housing. There are two connectors on the SEARAM top end cap: one is already connected via a short jumper to the main housingThe second connector (with waterproof dummy cover) is used for set-up and data extraction. A start/stop switch (white mushroom-shaped plastic plunger) is also mounted to the SEARAM top end cap. To test the CTD/SEARAM, connect a computer to the SEARAM and establish communication using the TERM17 program (see SEARAM manual). Verify the SEARAM status, command SEARAM into quiescent (sleep) mode, and push the plunger firmly down to start SEARAM. After about 5 seconds dots will appear on the screen. The dots will continue to appear at a steady interval until the memory is full, the internal batteries have become depleted, or SEARAM is switched off (plunger is pulled upwards to its original position).

Consult the SEARAM Manual for further information on the checkout and application of SEARAM-equipped CTDs.

2-1.3 SHIPBOARD ELECTRICAL HOOKUP (CTD WITH DECK UNIT)

A 2-pin (RMG-2FS connector) pigtail cable (PN 17027) supplied with the CTD is connected to the sea cable connector (JT-1) on the CTD top end cap at time of shipment (see top end cap drawing 50076).

Do not confuse JT-1 on the top end cap with either 2-pin connectors on the CTD bottom end cap (sensor end). JB-3 is the pump connector, and JB-6 (in the center of the end cap) is for a bottom contact switch (see bottom end cap drawing 50078). Connecting power via the sea cable to either JB-3 or JB-6 will cause serious damage to the 9plus.

If your sea cable is not terminated with an equivalent connector, make a waterproof splice to connect the pigtail to your sea cable. Positive power (+, cable inner conductor) goes to the small pin (black wire on the pigtail), and negative (-, cable armor) power goes to the large pin (white wire on the pigtail). In case you should ever inadvertently connect the power with the wrong polarity, no damage will be done, since there is a protective diode in series with the + power line. The CTD will not work, however, until the condition is corrected.

FOR SAFETY REASONS, AND FOR MOST RELIABLE PERFORMANCE, SEA-BIRD STRONGLY RECOMMENDS USE OF THE CABLE ARMOR FOR THE CTD POWER/DATA RETURN.

WARNING! Life threatening voltage (+250 volts DC) is present on the sea cable when the CTD Deck Unit is powered. Make sure the sea cable is disconnected from the Deck Unit when splicing the pigtail to the sea cable.

Make sure there is a secure mechanical connection between the cable armor and the CTD's lifting eye. When connecting the Underwater Unit to the sea cable, use care to dress the cable termination in such a way that it will not be pinched by the shackle or clevis. Install a cotter pin or seize the shackle securely.

The lead wires from the winch slip-rings must be terminated with an MS connector (type MS3106A-12S-3P SBE P/N 50086 as supplied with the SBE 11*plus*) Refer to the SBE 11plus manual, section 2-1.2, for instruction on connecting the sea cable to the Deck Unit.

WARNING! Life threatening voltage (+ 250 volts DC) is on pin B of the sea cable connector when the CTD Deck Unit is powered. Be sure Deck Unit power is OFF before connecting the sea cable to the Deck Unit.

To minimize cable-induced noise, insure that the connection between the sea cable armor and the MS pin A does not touch the ship.

When the CTD Deck Unit power is turned on the 'DATA' light should almost immediately come on if the Underwater Unit is properly connected and there are no other problems. A quick run-through of the Preliminary Checkout procedures as described earlier in this section will serve to confirm the functionality of the system.

2-1.4 CONNECTING THE SBE 9*plus* TO A WATER SAMPLER

The SBE 9*plus* can be optionally equipped with a modem and a dedicated interface to a General Oceanics (G.O.) model 1015 Rosette® (without EG&G or G.O. tone fire). With the modem card installed, you can control a Sea-Bird Carousel or G.O. Model 1016 Intelligent Rosette pylon via the SBE 11 front panel or via computer. With *both* the modem and the Model 1015 interface card installed, a G.O. 1015 pylon can be controlled in the same way. (Note: use of the 9plus modem channel requires the SBE 11plus Deck Unit to be equipped with the corresponding optional modem board).

The Model 1015 Rosette pylon is connected to the SBE 9*plus* JT-4. G.O. Rosettes have 2 polarity setting, "normal" and "reverse", which refer to the polarity of the seacable. Most commonly, they are set to "reverse", especially when used with MK III CTDs. The 9*plus* can be used with the Rosette in either setting by choosing the appropriate interface cable; PN 17196 for "reverse" or PN 17533 for "normal". If you have only one interface cable, the polarity setting of the Rosette can be changed to correspond with your cable. Application Note 35 gives detailed instructions regarding mounting the SBE 9*plus* and cabling the pylon to the CTD.

The Sea-Bird Carousel Water Sampler or G.O. Model 1016 Intelligent Rosette is connected to the SBE 9*plus* JT-7.

2-1.5 BALLAST WEIGHTS

When making deep casts or when working on large ships with heavy duty winches it is desirable to use additional weight on the Underwater Unit. 13 or 26 kilograms of bolt-on weights can be supplied by Sea-Bird Electronics; they should be bolted to the side rails of the cage as close to the bottom as possible. **BALLAST WEIGHTS SHOULD BE REMOVED FROM THE CAGE FOR SHIPPING**.

2-1.6 DEPLOYMENT

The Underwater Unit is fully assembled and tested. Before putting the unit in the water, remove the Tygon tubing (used to keep the cell clean) from the inlet of the TC Duct. Make sure the air bleed-hole has not become clogged with biological or other matter (a small wire can be used to clear the hole). If using a SEARAM-equipped CTD, fresh batteries should be installed, or the unit's nickel-cadmium battery should be re-charged. See the SEARAM Manual for information on battery installation/charging. If the SEARAM main battery is too low, communication with the SEARAM is prevented until new or recharged batteries are installed.

CTDs shipped after 1 January 1990 have a "hard-wired" pump delay to facilitate pump priming. With this feature, the pump turn-on is enabled only after two conditions are met. First, the conductivity cell must be filled with seawater which causes the conductivity frequency to rise above the 0 conductivity frequency. Second, when the CTD senses the proper increase in frequency, it starts a 60 second delay timer. This delay allows sufficient time for the air in the tubing to escape through the air bleed-hole. Be sure to hold the CTD just under the surface with the top of the tubing underwater for at least a full minute before beginning the profile. Failure to observe this requirement will result in poor quality salinity and density data at the top of the profile.

Note: The control logic for this feature only functions on the "Primary" conductivity channel. If the CTD

is equipped with redundant T & C sensors and pumps, and you wish to deploy it with the "Primary" conductivity sensor removed, be sure to swap the "Secondary" T & C sensor pair to the "Primary" T & C channel bulkhead connectors.

Note: with old water sampler systems that interrupt CTD power when tripping a bottle, wait 60 seconds after bottle firing for the pump to restart (it is not necessary to wait when using the Sea-Bird subcarrier modem / rosette interface system).

Best results will be obtained with down-cast data, as the sensors will be continually entering new and undisturbed water. When the SBE plus is deployed in vertical orientation, the sensors will be in the wake of the main housing and upcast data will be of lesser quality. When the SBE 9plus is mounted horizontally (as under a SBE 32 Carousel Water Sampler) the upcast data will be improved some what because the sensors are mounted as close as possible to the outside edge of the package. The severity of data contamination is proportional to the magnitude of dynamic motion imparted from the ship though the sea cable.

For maximum possible accuracy, it is possible to mount redundant T & C sensors and pumps remotely on the upper and lower outboard extremities of the CTD/Carousel frame. One TC sensor pair can "see" undisturbed water on the down cast and the other on the upcast.

The SBE 9*plus* is optimized for profiling rates of less than 0.5 to more than 2 meters/second. Generally, in rougher seas a faster lowering rate will help offset effects of ship induced "shed wakes".

If using a dissolved oxygen sensor, the highest quality results will depend on keeping the sensor membrane clean. Fouling from surface contamination (i.e. oil) can be minimized or avoided by placing a large drop of non-ionic liquid detergent on the membrane (a sample of the detergent Triton-X 100 is provided with the CTD). A large drop of Triton-X 100 is easily placed with a syringe in the concave well immediately above the membrane, but be very careful not to touch the membrane. As the CTD passes through the surface water, the detergent will be intact and will prevent any surface oil from attaching to the membrane. When the pump turns on (safely below the surface), the vigorous flushing will quickly remove the detergent. Note: with old rosette systems that interrupt CTD power when tripping a bottle, wait at least 2 minutes before resuming the profile. This allows the oxygen sensor to re-polarize (and also provides the delay necessary for pump turn-on as describe above). It is not necessary to wait when using the Sea-Bird subcarrier modem / rosette interface system.

If you are using a PAR (photosynthetically-active-radiation) sensor, remember to remove its protective cover. The 'soaker' bottle used with pH sensors must also be removed before beginning a CTD cast.

2-1.7 RECOVERY AND STORAGE

Unless another cast is to be performed immediately, hose down the CTD underwater unit with fresh water. When there is no likelihood the CTD will experience freezing temperatures during storage, keep a solution of distilled (or deionized) water and detergent inside the conductivity cell during periods of non-use by following the methods described in Application Note 34. Also read Section 2-2.3. If a dissolved oxygen sensor is installed, fill both the conductivity cell and the D.O. sensor plenum.

2-1.8 PROTECTION FROM GALVANIC CORROSION

The Sea-Bird CTD underwater units for 3400 or 6800 meter depths have painted aluminum housings which are insulated from the stainless steel guard cage, and from the sea cable power circuits. This insulation is important to prevent heavy corrosion of the housing. Any direct attachments of metal objects to the CTD housing must be avoided.

Auxiliary equipment powered from Sea-Bird CTDs should ideally have a 'floating' housing relative to their power circuits. It is permissible to have the CTD power and/or signal common lines connected to the auxiliary housing. However, it is mandatory that the auxiliary equipment housing not be connected to the CTD's 15 volt power source as this will destroy the conductivity cell electrodes.

2-2 MAINTENANCE

The most important element in the effective maintenance of the Sea-Bird CTD (or most any other oceanographic instrument) is to avoid storing the unit wet with salt water, or in a salt-spray environment. Additional steps which will help to increase the life of the CTD are outlined below.

2-2.1 CORROSION PRECAUTIONS

Aluminum CTDs have three large zinc anodes screwed into the upper end cap of the underwater unit main housing. These anodes should be checked from time to time to see that they are securely fastened, and that they have not been eaten away. All the stainless steel screws used on the underwater unit which are exposed to salt water have been generously lubricated with NeverSeez®, a molybdenum lubricant containing nickel powder and zinc oxide. After a cruise, it would be a good idea to remove these screws and re-lubricate them with a similar compound. This compound is electrically conductive, so care should be used not to get it on circuit boards. The modular sensors have ring-shaped anodes which should be checked and replaced if seriously depleted.

The underwater unit should be hosed down with fresh water after use and dried with a clean rag prior to storage.

Periodic (yearly) removal of the stainless steel hose clamps and PVC mounting chocks will permit cleaning of the entire housing surface and will prevent long-term breakdown of the hard-coated surface. Replacement of the stainless steel clamps, while usually not mandatory, is a good investment in the long run. Be sure to use teflon tape or similar material between the steel clamps and the anodized housing surfaces.

2-2.2 CONNECTOR MATING AND MAINTENANCE

Mated connectors do not require periodic disassembly or other attention. When connectors are unmated, they should be inspected for signs of corrosion residue around the pins. When re-mating, apply a light coating of silicon grease (Dow Corning DC-4 or equal) around the shoulder 'O'-ring area of the bulkhead connector. Grasp the female rubber-molded connector firmly, and press it straight down onto the bulkhead, noting the alignment of the large pin with the raised nub on the side. Squeeze the mated connector to force out any entrapped air. **Failure to eject entrapped air can cause the connector to leak**.

2-2.3 CONDUCTIVITY CELL STORAGE

When possible, keep distilled water on the conductivity cell during periods of non-use by following the methods described in Application Note 34. It is normally not necessary to do any cleaning of the conductivity cells during a cruise, unless you have evidence that the sensors have been fouled by passing through an oil slick on surface of the water, for example.

If it is not practical to leave the conductivity cell stored with distilled or deionized water in it (due to the danger of freezing, for example) merely rinse the cell with distilled water after each use (to remove salt water), then blow lightly through the cell to insure that no water is trapped inside. This is easily done using the Tygon tubes supplied. Loop the tubing from one end to the other end of the cell to keep out airborne contaminants. If the cell has been stored dry, wet with a 1% solution of Triton X-100 (or other non-ionic detergent) before use.

The Triton solution is also an effective cleaner for cells that have been exposed to oil slicks or mild biologic fouling and can be used to minimize or prevent fouling at the beginning of a cast where it may be necessary to lower the CTD through surface contamination. (refer to Application Note 2D for use and sourcing of Triton X-100). Do not use organic solvents (especially alcohol) for cell cleaning.

2-2.4 DISSOLVED OXYGEN SENSOR MAINTENANCE

The dissolved oxygen sensor should be kept in a 100% relative humidity environment. The best way to do this when the CTD is not in active use is to loop a length of Tygon tubing containing distilled water from port to port on the sensor manifold. The tubing need not be completely full of water, as the humidity within the tube will soon be very nearly 100%. A longer piece of tubing may be looped to encompass the conductivity sensor also, thereby protecting it against contamination or other degradation as well.

The Triton solution described in 2-2.3 may also be used to clean the dissolved oxygen sensor. Organic solvents should not be used for this purpose.

When it is no longer possible to obtain stable calibrations (after 1 to 2 years of use), the dissolved oxygen sensor module must be replaced.

2-2.5 pH SENSOR STORAGE AND MAINTENANCE

When the pH sensor is not in use, remove the metal guard and replace the 'soaker' bottle over the plastic pH electrode. The procedure for doing this is to first remove the soaker bottle cap, slide it along the plastic pH electrode as far as it will go, then thread the bottle up into the cap. Remove the bottle by reversing the sequence. There should be enough fluid in the bottle to cover at least the glass electrode and teflon reference junction.

The 'soaker' fluid is saturated KCl solution buffered to pH 4. Additional solution, if required, may be made using commercially available buffer capsules and saturated KCl solution.

2-3 CALIBRATION

Sea-Bird sensors are calibrated by subjecting the separate modules to known physical conditions, and measuring the sensor responses. Then coefficients are computed which are used with appropriate algorithms to obtain engineering units of temperature, conductivity, and pressure. The sensors are supplied fully calibrated, with coefficients as printed on their respective Calibration Certificates. Dissolved oxygen sensors are calibrated in terms of electrical response, response to zero oxygen value, and full scale atmospheric partial pressure in air-saturated water. The pressure and thermal lag effects are assumed from previous use and study of this sensor and may require correction using water samples taken concurrently with CTD data, performance of Winkler titrations on the water samples, and use of the OXFIT programs supplied with SEASOFT. pH sensors are calibrated with commercial buffer solutions (+/- 0.02 pH). The user of pH sensors is advised to make periodic corrections by comparison to buffers near the anticipated *in-situ* pH, typically in the 7 - 8 pH range.

For highest accuracy, the temperature and conductivity sensors should be returned to Sea-Bird for calibration. Temperature, conductivity, DO or other sensors may also be calibrated using standard laboratory equipment and methods. If the latter approach is elected, Sea-Bird can supply a PC compatible coefficient generation program for a nominal fee.

2-3.1 SENSOR REMOVAL FOR CALIBRATION

Disconnect the appropriate sensor cables by unscrewing the connector's plastic locking sleeve. Then disconnect the molded connector by pulling straight upward, away from the sensors. Grasp the connector as close to the end as possible to minimize the strain on the connector terminals. The temperature and conductivity sensors are connected together by the TC duct and held onto their mounting block by a single stainless steel clamp. Carefully disconnect the T duct from the C duct (see Application Note 15, TC Duct Installation) by sliding the tubing sleeve toward the T duct to clear the butt joint between the T & C ducts. Loosen the machine screw in the end of the stainless steel clamp until the sensors are loose, then carefully remove them from the mounting block. Finally, carefully remove the T and C ducts from the sensors before calibration.

The clamps used to mount the optional oxygen and pH sensors must usually be fully removed in order to free those sensors.

2-3.2 CONDUCTIVITY SENSOR CALIBRATION

The conductivity sensor incorporates a fixed precision (Vishay) resistor in parallel with the cell. When the cell is dry and in air, the sensor's electrical circuitry will output a frequency representative of the fixed resistor. This frequency is recorded on the calibration certificate and should remain stable (within 1 Hz) over time. The primary mechanism for calibration drift in conductivity sensors is the fouling of the cell by chemical or biological deposits; the effect is to change the cell geometry resulting in a shift in cell constant. A second drift mechanism is associated with change in the quality of the platinized electrodes, and this effect is also induced by fouling. Accordingly, the most important determinant of long-term sensor accuracy is the state of cleanliness of the cell.

We recommend that the conductivity sensors be calibrated before and after important cruises, but particularly when the cell has been exposed to contamination by oil slicks or biological material.

2-3.3 TEMPERATURE SENSOR CALIBRATION

The primary source of temperature sensor calibration drift is the aging of the thermistor element. This will usually be less than 0.002°C during the first year, and less in subsequent intervals. The sensor drift is not substantially dependent upon the environmental conditions of use, and -- unlike platinum or copper elements -- the thermistor sensor is insensitive to shock. The ease of calibration and the importance of very high precision in temperature makes it reasonable to calibrate this sensor before and after important cruises also. **CAUTION - The environment inside the sensor housing was completely desiccated and backfilled with pure argon prior to factory calibration. Opening the housing will introduce humidity (atmospheric water vapor) which will cause an immediate offset to the calibration and temporary drift instability.**

2-3.4 PRESSURE SENSOR CALIBRATION

The Paroscientific Digiquartz pressure sensors are so stable and immune to environmental effects that much less frequent checks will suffice. It will usually be enough to check that the 0 pressure reading closely matches the local barometric pressure. For especially critical work, check the full scale response using a dead-weight tester on an annual schedule. Digiquartz types, show most of their error as zero offset. Since this is easily checked when the CTD is in air (zero depth pressure condition), a periodic arithmetic compensation for the offset value may be used to null the error. SEASOFT makes direct provision for this correction.

To recalibrate the pressure transducer, remove the nylon fitting (with short attached 1/8-inch OD plastic tube) from the lower end cap the main housing. There is silicon oil in this fitting, so there will be some spillage. The end cap is tapped with a 5/16-24 straight thread to accept your pressure fitting. You should use a fitting which has an O-ring face seal, such as Swagelok-200-1-OR. After calibration, turn the instrument so the lower end cap is facing up, remove your fitting and fill the cavity with silicon oil (such as Dow Corning DC200 fluid, with 20 centistokes viscosity). Use a 2-inch long 21 gauge hypodermic needle (supplied, with syringe) inserted as far as it will go into the small hole at the bottom of the cavity. Then replace the nylon fitting. The oil in the cavity should fill the nylon fitting and 1/8-inch tube as the fitting is screwed in. The purpose of the nylon fitting and plastic tube is to prevent any salt water from getting into the end cap penetration. The pressure transducer itself is protected from salt water by the oil-filled stainless capillary tube connecting it to the lower end cap.

2-3.5 DISSOLVED OXYGEN SENSOR CALIBRATION

The dissolved oxygen sensor will give good results if periodically checked against discrete samples and if it is kept in distilled water or a 100% relative humidity environment. The electrical calibrations performed by Sea-Bird are sufficiently precise to assure indefinite operation within specification; they will not require subsequent adjustment unless components are replaced (in any case, the electronic drift will be compensated for during chemical calibrations).

The factory calibration of the dissolved oxygen sensor was performed by measuring the sensor output under zero oxygen conditions and with the sensor in air-saturated water at known temperature and atmospheric pressure. The user may confirm these calibrations by obtaining water samples concurrent with CTD data and performing Winkler titrations, or the original calibrations may be updated using the OXFIT program (part of SEASOFT) and the methods outlined in Application Bulletin 13 in the appendix to this manual.

2-3.6 pH SENSOR CALIBRATION

The pH sensor may be calibrated by use of commercially available buffer solutions, or solutions made using buffer capsules and distilled water. When calibrating the sensor, it is necessary to make an electrical connection between the body of the pH sensor module and the buffer solution. This connection may be made using any convenient piece of wire. Attach one end of the wire to one of the screws holding the pH sensor zinc anode in place. Immerse the other end of the wire in the solution. The initial factory calibration was performed using buffers of +/- 0.02 pH accuracy. In order to obtain readings to this level of precision, it is necessary to know the temperature of the buffer to within about 0.5 °C. The pH electrode should be kept in its soaker bottle at all times when not in actual use or undergoing calibration. As the soaker solution has a pH of about 4, it is important to rinse the sensor thoroughly with distilled or deionized water before attempting calibrations. Rinse between immersions in buffers of differing pH values also.

2-4 PERFORMANCE VERIFICATION

In addition to calibration of the individual system sensors, the CTD should be checked periodically to confirm the accuracy of its internal data acquisition circuitry. These checks should be done by competent technical personnel using electronic equipment of known accuracy and calibration history.

2-4.1 CRYSTAL OSCILLATOR AGING

The frequency of the crystal oscillator in the Underwater Unit will change with time, about 1 ppm in the first year and less than 0.3 ppm in subsequent years.

2-4.2 FREQUENCY CHANNEL PERFORMANCE CERTIFICATION

To check a data channel (or the entire system) for proper operation, disconnect the sensor cable from the sensor and use a frequency generator and counter to put a sine or square wave of 0.5 to 10 volts peak-to-peak amplitude and known frequency into the sensor cable and check this frequency against that computed by the Deck Unit and sent to the computer.

2-4.3 A/D CHANNEL PERFORMANCE CERTIFICATION

Input known voltages in the range 0 to + 5 volts and confirm that the correct voltage (±0.1%) is output via the system post processing software. There are no adjustments in the A/D section, so any inconsistencies will have to be accounted for in software. Calibration of the auxiliary sensors through the entire CTD processing circuitry will automatically correct A/D errors.

3-1 FUNCTIONAL DESCRIPTION OF THE SBE 9*plus*

The conductivity, temperature, and Paroscientific Digiquartz pressure sensors produce variable frequency outputs. To obtain the high encoding speed and resolution required by profiling applications, a 'hybrid' period counting technique is used. Each sensor has its own counting electronics circuit, so that all sensors are sampled simultaneously. Two 12-bit counters are used for each sensor--one counter accumulates the integral number of sensor counts during the sample interval (1/24) second, and the other counter measures the time from the beginning of the measurement period until the first positive-going zero crossing of the sensor frequency, i.e., determines the 'fractional' sensor count.

3-1.1 SENSOR FREQUENCY RANGES ALLOWED

Each counter can handle 4096 counts. The maximum time that the N_r counter will be gated "on" will be $1/F_s$. Since the N_r counter runs at 6,912,000 Hz, the minimum allowable F_s is given by 6,912,000/4096, or 1687.5 Hz. The maximum allowable sensor frequency is determined by the size of the N_s counter--no more than 4096 counts may be accumulated during the measurement interval. Thus F_s max = 4096/(1/24) = 98,304 Hz.

3-1.2 RESOLUTION (CTD CHANNELS)

CTD resolution degrades as the scan rate increases. In the discussion which follows, a scan rate of 24 per second is assumed. For systems with other sampling rates, ratio the given resolution accordingly.

Resolution = Scan Rate x (F_s / F_r) [*Hz / Bit*]

where:
F_s is the sensor frequency, and
F_r is the CTD reference frequency (6,912,000 Hz for C & T; 27,648,000 Hz for pressure).

At 2 kHz and 24 scans per second, the resolution is 0.0069 Hz/bit, and at 98 kHz the resolution is 0.34 Hz/bit. To get resolution in engineering units, we need to divide by "sensitivity", for example, Hz/(Degree Celsius). To compute nominal values of resolution in engineering units, we use the approximate values for sensitivity (Sen) from the sensor specification sheets. The values given here are for illustrative purposes only--the user's computer must use the more exact equations and the specific calibration constants for each sensor installed in order to make the conversions to engineering units (see the SBE 11*plus* Deck Unit or SEARAM Manual).

Temperature: At -1 °C, F_s = 2.1 kHz, and Sensitivity = 48 Hz/°C)
Resolution = 0.00015 °C per bit

At 31 °C, F_s = 4 kHz, and Sensitivity = 76 Hz/°C
Resolution = 0.00018 °C per bit

Conductivity: At 1.4 Siemens/meter (S/m), F_s = 5kHz, and Sensitivity = 1900 Hz/(S/m)
Resolution = 0.0000091 S/m per bit

At 5.8 S/m, F_s = 11 kHz, and Sensitivity = 960 Hz/(S/m)
Resolution = 0.0000398 S/m per bit

Pressure: (10,000 psi range Digiquartz sensor, assuming a conversion factor of 1.46 psi/dbar; resolution with other sensor ranges changes proportionately):

At 0 dbar F_s = 33,994 Hz and Sensitivity = 0.726 Hz/dbar
Resolution = 0.041 dbar/bit

At 6800 dbar, F_s = 38,480 Hz and Sensitivity = 0.614 Hz/dbar
Resolution = 0.054 dbar/bit

3-1.3 ACQUISITION ACCURACY (CTD CHANNELS)

The accuracy of the system is determined by the accuracy of the sensors used and by the accuracy of the crystal oscillator ("master clock") that generates the reference frequency F_r. F_r is stable to within 1 ppm over the temperature range of -20 to 70 °C, and the time drift will be less than 1 ppm for the first year and less than 0.3 ppm per year thereafter. A five-year worst case master clock error budget of 3.2 ppm total yields temperature error of 0.00016 °C, conductivity error of 0.00005 S/m, and pressure error of 0.3 dbar.

3-1.4 A/D CHANNELS (AUXILIARY INPUTS)

Eight voltages in the range of 0 to +5 volts are acquired. The voltages are selected sequentially by a CMOS multiplexer and digitized to 12 bits by successive approximation. The first A/D channel voltage is acquired during an interval of about 50 µs at the beginning of each scan (the same time at which counting of frequency channels begins); the second channel is processed during the next 50 µs, etc. Differential input amplifiers followed by 2-pole Butterworth anti-aliasing filters are used in each A/D channel. Input channels are selected for A/D conversion by a CMOS multiplexer and then passed through a buffer amplifier with a gain of 2 to the A/D converter.

3-1.5 RESOLUTION (MULTIPLEXED A/D CHANNELS)

The analog voltage input range of 0 to +5 volts is multiplied by a gain of 2 by the buffer amplifier preceding the A/D converter. The A/D converter input range of 0 to 10 volts is converted to digital values between 4095 and 0. The resolution at the SBE 9*plus* A/D input ports is therefore 5 volts/4096 = 0.0012 volts/bit.

3-1.6 ACCURACY (MULTIPLEXED A/D CHANNELS)

The Micro Networks series MN5206 A/D converter chip provides true 12-bit accuracy without adjustment. The low-pass filters and differential amplifiers have been designed to maintain an overall accuracy of about 0.1% over the range of temperature encountered in ocean profiling.

3-1.7 CTD ENCODED DATA FORMAT

The following is the sequence of the data as output by the underwater unit (Fish). For the (different) output sequence from the Deck Unit's IEEE-488 or RS-232 ports, see the Deck Unit Manual; for the data output from SEARAM, see the SEARAM Manual. The first data byte contains 8 bits of pressure temperature compensation information. The second byte contains 4 remaining bits of pressure temperature data, and status 'flags' for various conditions. The third byte is a count which increments on successive data scans. Frequency information from the temperature, conductivity, and pressure sensors make up the next 15 data bytes. The next data are generated by the 12 bit A/D converter, with each channel pair allocated 3 bytes.

The data sequence from the Underwater Unit is:

Byte 1: 8 MSB of Pressure sensor temperature compensation

Byte 2: 4 LSBs of Pressure sensor temperature compensation; pump, bottom contact, rosette confirm, and modem status bits

Byte 3: Modulo count

Byte 4-6: Temperature (primary)

Byte 7-9: Conductivity (primary)

Byte 10-12: Pressure

Byte 13-15: Temperature (secondary)

Byte 16-18: Conductivity (secondary)

Byte 19-30: 12-Bit A/D Channels 0 to 7

Byte 31-36: expansion (all zeros)

A total of 36 bytes of data are generated for each scan. In its presentation of data to the IEEE-488 port, the Deck Unit outputs the Modulo byte at the end of the scan rather than at the beginning.

3-1.8 DATA TELEMETRY LINK

The serial data from the SBE 9*plus* is sent to the SBE 11*plus* in RS-232 NRZ format (1 start bit, 8 data bits, 1 stop bit) using a 34560 Hz carrier-modulated differential-phase-shift-keying (DPSK) telemetry link. Phase reversals in the data stream are detected in the Deck Unit to recreate the NRZ data. A single chip micro controller reformats the NRZ data as required by the SBE 11*plus* main CPU.

3-1.9 CTD UNDERWATER UNIT POWER

Fish power is supplied from the Deck Unit through a single pair of wires, usually the inner (insulated) conductor and steel jacket of a double-armored single conductor electro-mechanical cable. A reverse-polarity protection diode protects the underwater unit from sea cable cross-wiring.

The sea cable supplies are entirely self-adjusting and require no operator attention irrespective of load on the CTD underwater unit or length of sea cable.

The underwater unit pressure case, internal power, and the sea cable voltages are electrically isolated from one another to prevent galvanic corrosion.

The SBE 9*plus* underwater unit has a pre-regulator which reduces the sea cable voltage to 170 volts; DC-to-DC converters are used to generate + 15, +8, +5, and - 15 volts. Cable current is about 200 milliamperes for a fully loaded (maximum auxiliary equipment) SBE 9*plus*. The deck unit's 250 volt DC sea cable supply can therefore drive about (250 - 170V)/200ma = 400 ohms of sea cable.

4-1 DESCRIPTION OF SBE 9*plus* UNDERWATER UNIT CIRCUITRY

The electronics needed to power the system sensors, acquire and digitize their output frequencies or voltages, and transmit the digital information up the sea cable are located in the main underwater unit housing. The Digiquartz pressure transducer is mounted to the bottom end-cap, at the lower end of the card file. The pressure port connection is via an oil filled capillary tube. A Swagelock SS-200-1-OR fitting is used to connect the capillary tube to the end cap (5/16-24 straight thread).

The other system sensors are located outside the main housing, with a cable connecting power to and bringing signals from each modular sensor.

4-1.1 END CAP WIRING

The 'End Cap Connector' drawing 50076 shows the bulkhead connector arrangement at the upper end cap where the auxiliary sensors, sea cable, SEARAM, and optional rosette connections are made. The sea-cable interface board, modem, and rosette interface boards are mounted to the top end cap. Drawing 31658 shows the wiring of the top end cap assembly. The top end cap interface board determines if the unit is standard (dwg 40598) or has an optional isolated 12 volt power supply (dwg 40581).

Connections to Seacable Interface J1 and J2 are shown, as are connections to SBE 9*plus* Modem J2 and J3, and Rosette Interface J1. Power, data and analog signals are routed to the card file via a ribbon cable that runs between a printed circuit board attached to the bottom of the mounting hardware for the seacable interface and the card file. As mentioned above, an optional isolated 12 volt power supply may be placed on this board.

The 'End Cap Connector' drawing 50078 shows the wiring arrangement at the lower end cap where the temperature and conductivity sensors, pump and bottom contact sensor are connected. Bulkhead connectors for secondary temperature and conductivity sensors are also provided.

4-1.2 CARD FILE WIRING

With the exception of the Seacable Interface which is permanently mounted to the top end cap, and the modem / rosette interface circuits that plug directly to it, the underwater unit electronics are on plug-in circuit cards with printed edge connectors, mounted in slots in the card file rails. The circuit boards are located in the order shown in drawing 31387.

Drawing 31387 sheet 1 shows the backplane wiring, as well as the routing (via J12) of signals, power, and controls to and from the top end cap. Drawing 31387 sheet 2 shows the wiring between the backplane and the lower end cap.

4-1.3 SEACABLE INTERFACE

See schematic 31321. Toroidal transformer T1 is used to couple the DPSK telemetry signal from the Transmitter and Pump Delay Card onto the sea cable. It will pass cable currents up to 0.5 ampere without saturating; T2 couples the optional modem signal to R1. A simple series regulator (D2 and Q1) provides a maximum of 170 volts dc to the underwater unit's primary DC/DC converter (U1, 15 volts at 1.8 amp maximum). +5 volts is generated from U1's 15 volt output by linear regulator U2. Primary power for the SBE 9*plus* is provided by diode OR'ing U1's output with the battery voltage obtained from an (optional) SEARAM. +/- 15 volts for the A/D circuits is developed by a second DC/DC converter, U3 operating via a linear regulator (Q2, Q3, D4) from the diode OR'd main supply.

4-1.4 TRANSMITTER AND PUMP DELAY BOARD

See schematic 31291. NRZ data from the system shift registers (on the AP Counter, Modulo 12P, and AD/CS cards) are DPSK encoded by U2A, U2B, and U1A; the DPSK signal is modulated by the 34560 Hz carrier via U2C. Transistors Q1, Q2, Q3, and Q4 form a complementary line driver. Subsequent to detection of seawater by the conductivity sensor, counter U4 accumulates the 24 Hz scan clock and is decoded by U5A, U5B, and U5C to develop a 60 second delay. U6A then latches and drives Q6 and Q5 to route power to the submersible pump.

4-1.5 LOGIC BOARD

See schematic 31399. This circuit contains a 27,648,000 Hz temperature compensated crystal oscillator and the countdown electronics to generate most of the Underwater Unit control signals. F_r is the buffered 27,648,000 Hz oscillator output that is used by the pressure sensor counting circuit. $F_r/4$ is the 6,912,000 counter reference frequency required by the temperature and conductivity counters. U3 and U5 are frequency dividers that produce a 69120 Hz clock for the telemetry and the 2 frequencies used to clock U6, U7, and U8. Most of the logic waveforms required for system timing are developed by counter-sequencing the address lines of EPROM U7; U7's outputs are then latched by U6. The following is a list of the control signals and their significance.

8640 Hz: System clock, determined by the requirement of transferring 12 words in 1/24th of a second.

69120 Hz: This clock is divided by two on the Transmitter board and modulates the DPSK telemetry.

Shift clock: Shifts data from the data acquisition boards, it is inactive during start bits, stop bits and for a 10 bit period at the beginning of each data scan. This 10 bit period allows the data acquisition boards to transfer their data in parallel to their shift registers.

SE: Sample enable, a 24 Hz clock, this signal goes high at the beginning of each 1/24 second sample interval.

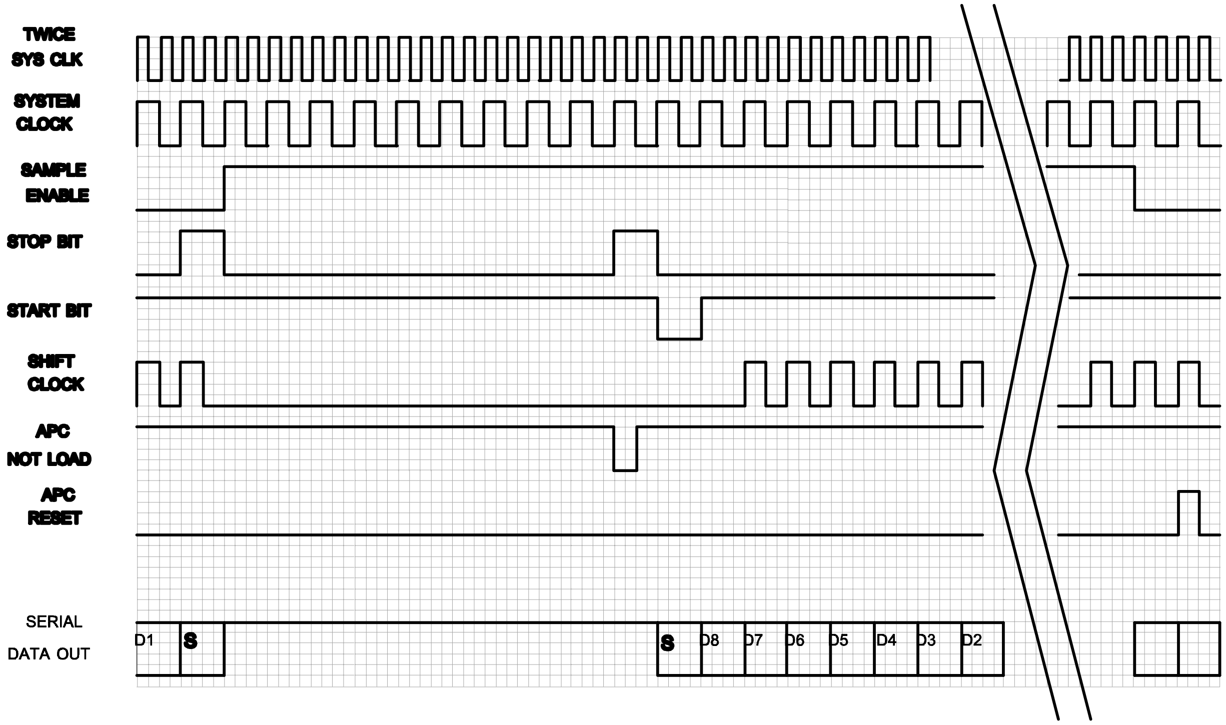
Not Load: This signal occurs just before the end of the 10 bit period mentioned above. It causes the AP counters to end their count and place the contents of their counters in the shift registers. This signal is necessary in the event that no sample frequency is present.

Load: The inverse of the previous signal, it preforms the same function as above for the Modulo P boards.

Reset: This occurs after the falling edge of SE and prepares the AP counters for the next sampling.

Start and stop bits for the serial data stream are also generated by the EPROM. These are OR'ed and AND'ed with the data stream to produce the proper serial data format. Figure 5 is a timing diagram for the logic board.

The frequency of the crystal oscillator, U1, is adjusted by the removing the access screw on the oscillator case and turning the adjusting screw. This adjustment has been made at the factory by comparison to a WWV receiver frequency standard to obtain the most accurate reference frequency.



NOTE: APC not load ensures that the counting cycle ends in case of zero count. APC reset occurs after the falling edge ofsample enable.

Figure 5. Logic board timing diagram.

4-1.6 MODULO 12P BOARD

See schematic 31444. The Sample Enable (SE) control signal causes the CD4040 counter to increment once each scan. This counter is never reset. The LOAD signal from the logic board controls the parallel-load/serial-out modes of the 4021 shift register.

The TSC8702 is a 12-bit A/D converter used to digitize the output of an AD590L temperature sensor which is imbedded within the housing of the Digiquartz pressure sensor. The 590 is a two-terminal, current-output device whose output changes by 1 microampere per °K change (the current output is 0 at -273.2 degrees C). In the drawing, the REF02 (U2) and the upper half of the OP215 (U3A) generates +/- 5 volt reference voltages for the A/D converter. U3B is used to offset and scale the input to the A/D. When the AD590 current is 268.15 µA (corresponding to - 5 degrees), the nominal value of the A/D output word is 385; when the current is 308.15 µA (35 degrees) the output word is 3923 (actual values of N are determined at test and used to create the SEASOFT coefficients M and B). The A/D converter output can be converted to temperature with the equation:

$$\text{Digiquartz Temperature} = T_D = (M)(\text{binary}) - B$$

Typical values for M and B are 0.0126 and -9.844 respectively. The T_D computed can be used in the conversion equation for the Digiquartz to remove most of the temperature-related errors of the sensor (see 'A Temperature Model for Digiquartz Transducers' at the end of this document and the Digiquartz calibration sheet).

4-1.7 AP COUNTER BOARD

See schematic 31366. These boards are used to count the frequencies generated by the temperature, conductivity, and pressure sensors. U1, a LM393 comparator, takes the sine-wave outputs of the sensors and converts it to logic level square waves for input to the counter circuit. The 301K and 3.01K resistors (R2 and R3) provide about 50 millivolts of hysteresis to prevent multiple triggering if there is noise on the signal line (the negative-going threshold point is at about -50 millivolts). The 1N5818 Schotkey diode protects the input of the LM393 from excessive negative input voltage. This diode also causes some unimportant distortion on the negative peak of the sine-wave.

The count sequence is initiated by positive-going SE which opens the F_r counter gate (signal B) and enables the D1 input of the 74AC74 flip-flop. The next positive-going transition of the SQUARED SENSOR FREQUENCY (SSF) causes the 74AC74 flip-flop to be reset, closing the F_r counter gate and triggering the first 4538 one-shot (5 µs). This one-shot delay allows time for the F_s and F_r counters to ripple-through and causes data in the F_r and F_s counters to be parallel-loaded into their respective shift registers (the three 4021's). At the end of the delay, the second 74AC74 is activated, triggering the second 4098 one-shot which resets the F_r and F_s counters to zero. Prior to the arrival of the shift clock, a negative going pulse [not load] ensures that the shift registers are loaded and placed in serial mode. This is only necessary if no F_s counts have occurred, for example if a sensor is missing or malfunctioning. Right after the negative-going transition of SE, a set pulse, RESET arrives at the 74AC74s preparing them for the next sample. Figure 6 shows the timing diagram for this board.

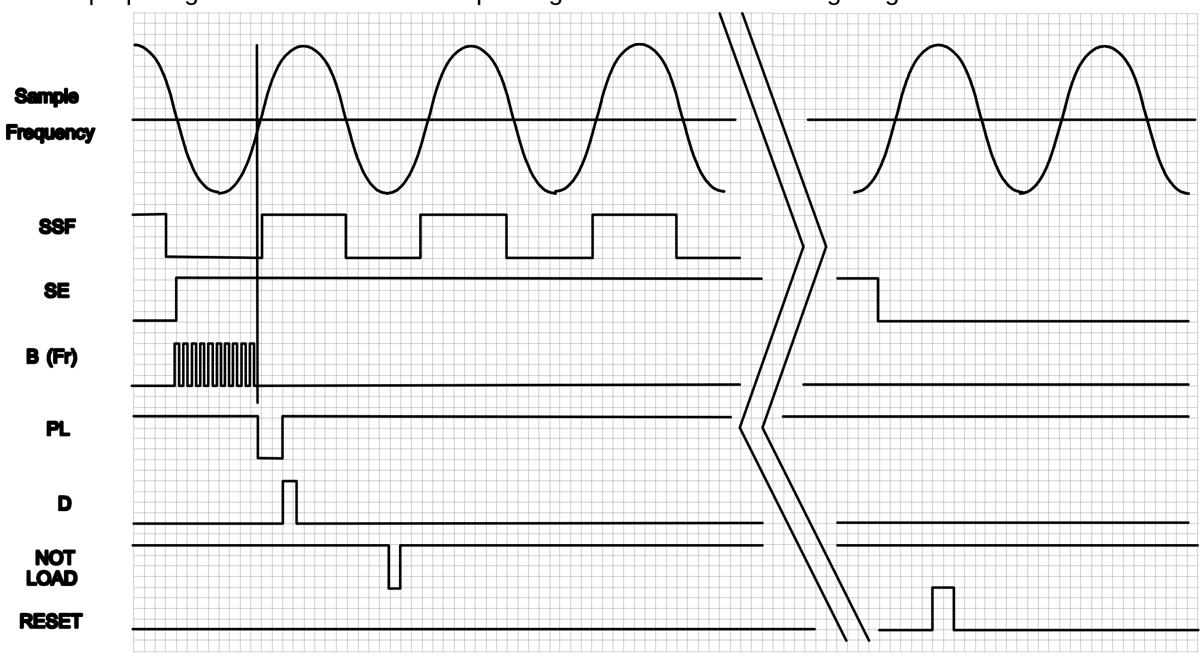


Figure 6. AP counter timing diagram.

The primary conductivity channel is used as the signal source for pump control. U3, a 4538 one-shot, is connected to the squared output of the sensor. It is used in the retriggerable mode to generate a control signal for the pump power switch. The 4050 acts as a filter to smooth the one-shot output, with an average DC output increasing with conductivity. Above about 3500 Hz, the 4050 output will be at +5 volts and the pump power will be turned on. The purpose is to prevent the pump from running when the CTD system is not in the water. The pump impeller bearings are water-lubricated, and should not be run "dry" for extended periods of time. If no water (or fresh water) is in the conductivity cell, its frequency will be low, and the pump will be off. Note that all counter boards are equipped with pump control circuits but only the primary conductivity channel is wired to the pump power switch.

4-1.8 AD/CS BOARD

See schematic 31310. This board contains a 12 bit A/D converter (MicroNetworks MN5206), an eight channel CMOS analog multiplexer, and the logic required for channel switching and data storage. U2 is the eight channel multiplexer (Harris HI-508A), the design of which permits over-voltage (up to 15 volts above the supply rails) without damage. Its output is buffered and amplified (gain of 2) by the OP15 op amp U9. Sample enable (SE) starts the A/D clock (U4), resets the 74HC4040 counter that provides the channel address for the multiplexer chip and initiates the first A/D conversion. When the A/D converter signals that it has finished a conversion the 74HC4040 is incremented and the next conversion begins. The data from each conversion is clocked into the shift register, U7. At the end of the eighth conversion a 1 of 2 multiplexer, U6, shuts off the start convert pulses to the A/D converter and directs the system shift clock and system serial data to the shift register. The A/D clock is disabled on the falling edge of SE. Figure 7 shows the timing diagram for the A/D board.

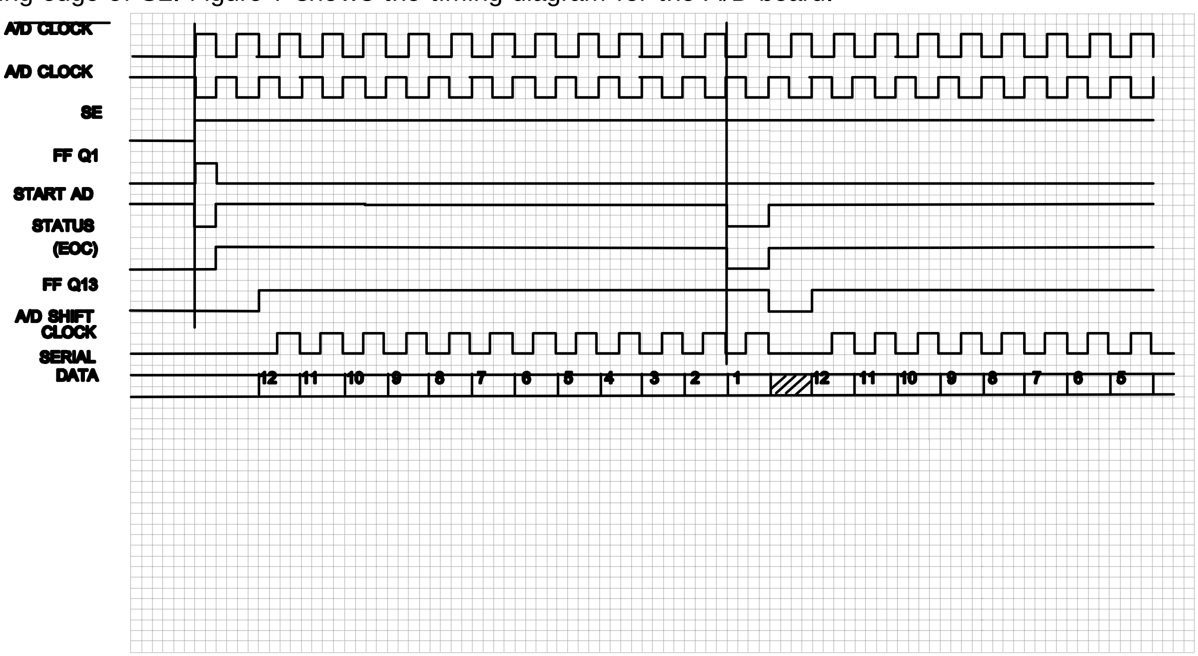


Figure 7. A/D control and store timing diagram.

4-1.9 DIFFERENTIAL AMPLIFIER / LOW PASS FILTER BOARD

See schematic 31399. U1, U3, U4, and U6 are PMI AMP-02 differential amplifiers. The differential outputs are routed to four low-pass filters which are 2-pole Butterworth (maximally flat) types. They have unity gain at dc and a gain of 0.707 at 5.5 Hz. The filters are of the single - amplifier follower type which give extremely good gain accuracy because there are no gain setting resistors.

Components determining the filter frequency transfer characteristic have 1% or 2% tolerances and are stable with ambient temperature, i.e., metal film resistors and mylar capacitors respectively.

4-1.10 MODEM BOARD

See schematic 31292. The modem board mounts on stand-offs to the Seacable Interface board; it can be seen on the top end cap where it is "sandwiched" between the mounting rails. +15 volt power and the modem signals are obtained via interboard connector J1. This is a 300 baud full-duplex circuit based on a Motorola MC145443 modem chip (U5). A 6-pole active bandpass filter (U2 and U4 and associated components) rejects the U3-buffered uplink FSK signal (1070 - 1270 Hz) while passing the downlink signal (2025 - 2225 Hz). The modem chip passes serial data to UART U7 which is controlled by a Signetics single-chip microprocessor 87C51 (U8). A logic to RS-232 level converter chip (U6, LT1081) provides access to the modem channel from a terminal, computer, or serial-output instrument connected to J2 via top end cap JT-6. Control signals for the Rosette Interface are available at J4, while the bottle trip confirm signal is routed to the CTD backplane from J3.

4-1.11 G.O. 1015 ROSETTE® INTERFACE BOARD

See schematic 31294. The CTD main power source (15 volts) is obtained at interboard header H1 and applied to DC/DC converter U4 which generates a floating 60 VDC level. If bottle firing is not enabled, Q1 will be "ON" and opto-coupler U6 will be active with its output transistor conducting and clamping Q3's gate low; in this condition, current will not be supplied to the Rosette. Upon receipt of the "enable" command, Q1 will be turned off. Now Op amp U5 controls Q2 and hence the gate voltage on power MOSFET Q3. Q3's gate quickly rises until a voltage equal to reference D3 (1.25 volts) is generated across R13 (18 ohms). Q3's source current is accordingly clamped at 1.25 / 18 = 69 milliamps. Upon receipt of a "fire" command, Q1 is turned on. This again clamps Q3's gate low causing cessation of the 69 milliamp current at which time the Rosette stepper motor will activate. **Note that powering down the CTD system with the rosette pylon in an "enabled" state will cause a cessation of the 69 milliamp current and cause the pylon to trip (fire a bottle).**

The capacitive transient associated with stepper activation is coupled via D5 and R12 to another opto-isolator (U2). The conduction of U2 triggers a one-shot (U1A) which generates a one-second pulse. The pulse is routed via H1 and Modem J3 to an input on one of the data shift registers on the Modulo 12P board and is subsequently transmitted to the surface for decoding by the deck unit and display via SEASOFT. The confirmation pulse is also decoded within the CTD underwater unit and a corresponding character transmitted to the surface via the subcarrier modem.

5-1 TROUBLE DIAGNOSIS AND REPAIR (UNDERWATER UNIT PROBLEMS)

Servicing of the Sea-Bird CTD should only be performed by experienced technicians who have been trained to work with complex mechanical/electrical equipment.

LIFE-THREATENING HIGH VOLTAGES ARE PRESENT IN BOTH DECK UNIT AND UNDERWATER UNIT WHEN POWER IS ON. THESE HAZARDOUS VOLTAGES PERSIST FOR UP TO ONE MINUTE AFTER REMOVAL OF POWER.

THE BEST WAY TO PROTECT AGAINST ELECTRICAL SHOCK IS TO DISCONNECT THE AC POWER CORDS FROM THE REAR PANEL OF THE DECK UNIT, THEN WAIT A FULL MINUTE BEFORE ATTEMPTING SERVICE.

ALWAYS DISCONNECT THE AC POWER CORD BEFORE CHECKING FUSES!!!

For protection of the circuitry, we also recommend that AC power be removed and a 1 minute period for supply capacitor discharge be allowed before opening housings, changing connections, removing or inserting circuit cards, or otherwise working on the equipment.

If the data telemetry is OK (deck unit data light is on and error light off) but one or more channels is faulty, see Section 5-2 (Sensor Problems) before proceeding with work on the underwater unit; the problem may be a defective sensor.

Read Section 4-1 which describes the operation of the underwater unit circuitry. Refer also to the section titled 'schematics' which contains the underwater unit schematic diagrams.

All voltages are measured relative to pin 2 of any plug-in card; this is main signal/power ground for the underwater unit.

5-1.1 UNDERWATER UNIT COMPLETELY INOPERATIVE

Make sure that the deck unit is supplying the proper sea cable voltage (250 volts). If there is no sea-cable voltage, the seacable rear panel fuse may be blown.

With SEARAM units, see that SEARAM is supplying the proper voltage to the CTD (12 - 15 volts).

Look for the presence of the telemetry waveform across the sea cable. **USE EXTREME CAUTION IN PERFORMING THIS OBSERVATION. THE SEA CABLE VOLTAGE IS POTENTIALLY LIFE-THREATENING! ALLOW 1 MINUTE AFTER POWER-DOWN FOR POWER SUPPLY DISCHARGE BEFORE MAKING CONNECTIONS TO THE SEA CABLE OUTPUT CONNECTOR.** If the telemetry waveform is present, the trouble is probably in the deck unit.

If the **telemetry waveform is not present at the deck unit**, measure the sea cable current which will be in the range of 50 to 220 milliamperes depending on the underwater unit configuration.

If the sea cable voltage is present, but no current is being drawn by the underwater unit, there is either a break in the sea cable, or an open circuit in the cable interface circuitry inside the underwater unit.

Assuming that there is no break in the sea cable, turn off the deck unit power, refer to Section 6-1 and open the Underwater Unit housing, but leave the electronics chassis connected to the top end cap. Restore deck unit power and measure the internal supply voltages (relative to pin 2): +5, +15 and -15 at pins 1, 5, and 3 respectively of the Analog interface boards.

If there is **no voltage at any point on the backplane**, the sea cable interface circuitry is either defective or is not receiving power from the sea cable. Check that the Seacable Interface is receiving the correct input voltage (250 volts).

If **no voltage is present at the inputs to the DC/DC converters**, the series pass transistor Q1 on the seacable interface board may be open.

If the +5, +8, +15, or -15 volt levels are absent or in error by more than about 0.5 volts, remove all the underwater unit plug in printed circuit boards. Check the power supply levels again - if these are now ok, the problem is probably in one of the plug-in boards. Start plugging boards in, beginning with the Transmitter (top) board. (Turn off power and wait one minute for supply discharge before plugging in each board). If a board is found which appears to cause the drop in supply voltage, refer to the circuit description in Section 4-1 and the board's schematic diagram.

Check the board for dead shorts at the power input pins - an IC or one of the power supply bypass capacitors may be shorted. Also, carefully examine the board for any metallic material (solder, wire clippings, shavings) which may have inadvertently shorted the printed circuit traces or component pins. With the board in the underwater unit chassis, look at the board outputs and inputs for signal irregularities. The logic levels are 5 volt CMOS and should swing the full 0 to +5 volts.

If the **power supply levels are not ok with the plug-in boards removed**, check the backplane wiring for broken connections or wires, and for any shorted connections. Check that the input voltage to the DC/DC converters is correct. If so, one of the converters may be defective, or one of the by-pass capacitors across the converter outputs may be shorted.

5-1.2 POWER SUPPLIES OK BUT NO DATA

Check Logic Board pin 3 for the NRZ logic level. If this signal is present, check phase-reversing output at Transmitter Board pin 8.

If the **phase-encoded signal is present at the Transmitter Board output**, the problem is in the transformer coupling to the sea-cable, or in the sea-cable wiring itself.

If the **phase-encoded signal is missing** (or wrong in frequency or waveform), check for proper output signals from the Logic 1 Board. The following should be observed:

Pin 5 FR	27,648 kHz (square wave)
Pin 4 FR/4	6,912 kHz (square wave)
Pin H	69120 Hz (square wave)
Pin 6	8640 (square wave)

Pin 9 SE 24 Hz (square wave)

If any of the signals described above are **missing or of improper shape or frequency**, disconnect power from the CTD and remove all the plug-in cards except the Logic Board. If any of the tabulated signals remain faulty, the trouble is on the Logic Board, or is the result of a short in the backplane wiring.

If the signals described above are ok on the Logic Board alone, reinstall the remaining circuit boards one-by-one, checking the suspect signal after each card is installed until the faulty card is located.

5-1.3 ONE OR MORE NON-FUNCTIONING CHANNELS

If a frequency channel is giving improper readings, check that the sensor signal is present on AP counter board (pins 7 and H on the backplane, found on the right edge of the small board that the coax cabling is mounted to). These are 2 volt p-p sine waves in the frequency range of 2800 - 12000 Hz for temperature and conductivity and a 4 volt square wave in the range 35000 to 40000 Hz for the pressure sensor.

If one of the sensor outputs is faulty, remove that channel's AP Counter Board - if this restores the signal, the AP Board has a defective input. Try one of the other AP Counters (the five boards are identical) in the offending channel position.

If the AP Counter inputs are ok, try swapping AP Counter Boards to locate the faulty one. If the problem stays with the same channel, check that the FR, SE, SC, and RESET, inputs are active.

If the problem is a faulty A/D channel, check that the inputs to the A/D Board multiplexer (pins D, F, H, J, L, 10, 8, 7) are as assumed. Check for +15 and -15 volts at the A/D Board. Look for the SE scan clock at pin 9; this starts the (rapid ~ 50 µs/channel) acquisition of A/D channel data. Check that the SC shift clock is present at pin 6, and that serial data is present at pin 4.

5-1.4 PUMP NOT WORKING

CTDs shipped after 1 January 1990 have a "hard-wired" pump delay to facilitate pump priming. With this feature, the pump turn-on is enabled only after two conditions are met. First, the conductivity cell must be filled with seawater which causes the conductivity frequency to rise above the 0 conductivity frequency. Second, when the CTD senses the proper increase in frequency, it starts a 60 second delay timer. This delay allows sufficient time for the air in the tubing to escape through the air bleed-hole. Be sure to hold the pump just under the surface with the top of the tubing underwater for at least a full minute before beginning the profile.

Note: The control logic for this feature only functions on the "Primary" conductivity channel. If the CTD is equipped with redundant T & C sensors and pumps, and you wish to deploy it with the "Primary" conductivity sensor removed, be sure to swap the "Secondary" T & C sensor pair to the "Primary" T & C channel bulkhead connectors.

Note: with old water sampler systems that interrupt CTD power when tripping a bottle, wait 60

seconds after bottle firing for the pump to restart (it is not necessary to wait when using the Sea-Bird subcarrier modem / rosette interface system).

Remember that the pump does not normally run until there is salt water in the conductivity cell. To test the pump, put salt water (a few ppt will be sufficient) in the cell; a faint rattling sound will be heard from the pump (extended operation of the pump when not in water will reduce the life of the bearings). The pump is also not self-priming, so it cannot lift water up through the cell when it itself is in air. The actual pumping of water does not take place until the pump exhaust port (hole on the side of the impeller assembly) is underwater.

Make sure that the pump cable is not cut or otherwise damaged and that the rubber molded plug is fully mated to the pump housing connector. Unplug the pump from its external cable. Apply +12 volts to the pump housing's small connector pin, return to the large pin. Look for a current drain of about 300 milliamperes and listen for the pump running. If the pump passes this test, the problem is in the main housing or in the cabling. Disassemble the underwater unit and perform the following tests.

Unplug the conductivity sensor. Connect a audio signal generator (approximately 2 volts p-p output) at pin 7 (return to pin H) of the AP Counter Board for primary conductivity (C1). Set the generator frequency to about 2500 Hz. Observe the squared signal at U2A output. Measure the voltage at pin L which should be zero. Increase the generator frequency to about 4000 Hz. The voltage at pin L should now be 5 volts. If not, the one-shot U3B or the buffer U2B is defective.

If the voltage at C1 AP Counter Board pin L responds properly, make sure that it also appears at the Transmitter Board pin K. 60 seconds after Transmitter Board pin K goes high, pin L should also go high (to nearly 15 volts). If this is the case, the problem is in the wiring to the pump external connector.

5-2 SENSOR PROBLEMS

Apparent sensor problems may be the result of trouble with the cables or the acquisition circuitry in the underwater unit, or the trouble may be nothing more than an incorrect entry of the sensor calibration coefficients. The conductivity and temperature sensors have identical power and output characteristics, and may be freely interchanged to help localize the fault.

Although repair of these sensors is certainly possible, it is not likely that repairs can be made without affecting the sensor's calibration. The Sea-Bird sensors are small and easily replaced in the field; as they are supplied with calibration coefficients, a spare sensor can get a failed unit into fully operating and calibrated condition with a minimum of trouble. Sea-Bird is also always ready to send replacement sensors by air courier immediately upon notification of a failure.

5-2.1 CONDUCTIVITY AND TEMPERATURE SENSORS

If a sensor is generating conductivity, temperature, or pressure-dependent frequency but the indicated value is significantly erroneous, **check that the coefficients used in the processing software are as stated on the calibration certificates** supplied with the sensor. **CAUTION - The environment inside the sensor housing was completely desiccated and backfilled with pure argon prior to factory calibration. Opening the housing will introduce humidity (atmospheric water vapor) which will cause an immediate offset to the calibration and temporary drift instability.**

Swap the cable connections to the temperature and conductivity sensors to verify the operation of the acquisition circuit (SEASOFT permits the reversal of the channel assignments to permit the proper display of temperature or conductivity when this is done - use the SEACON program to do this).

If no output frequency is being generated, the deck unit will display 0.000 in the defective channel. If a sensor is defective, swapping sensors will put a sensible frequency into the previously 0.000 reading display.

If no frequency indication occurs with the sensors swapped, disconnect the rubber molded plug from the sensor connector. +15 volts should be measured between the large pin and one of the small pins (if the large pin is up when looking into the plug, the +15 should be found on the left side small pin).

The proper functioning of a frequency channel may be confirmed by connecting a frequency source (square or sine wave, 2 - 5 volts p-p) to right side small pin (as defined above) and the large (ground) pin of the sensor cable. The deck unit should read the frequency of the generator.

The sensors may also be checked separately from the CTD by connecting a power source of 10 to 20 volts and observing the frequency output with an oscilloscope.

Application Note No. 3 (in the 'app notes' section of this document) explains temperature/ conductivity sensor disassembly instructions. Look for broken leads or evidence of water leakage.

5-2.2 PRESSURE SENSOR

Internal pressure sensors are mounted inside foam insulation near the bottom of the card file. The red lead should be at +8 volts, the black lead at power common. The blue lead should be connected to Backplane via the small board that the sensor cabling is secured to. A properly operating sensor will exhibit a square wave frequency in the range 32 to 40 kHz at this point. For a discussion of possible fault conditions associated with this and subsequent acquisition circuitry, see Section 5-1.3 above.

It is not possible to perform field repairs on a defective pressure sensor; any repair work must be done at the factory.

The temperature compensation of the pressure makes use of a solid-state (bandgap) temperature sensor embedded in the pressure sensor. This element (Analog Devices type AD590) is a 2-terminal device which generates a current proportional to absolute temperature (1 microampere per °K). The current is input to an op amp on the Modulo 12P board; a current of opposite polarity is derived from the REF02 / Op215 reference and used as an offset source. The current difference is scaled through the 95K ohm precision fixed resistor R19 to create an input to the 12 bit A/D converter, U8. The A/D converter parallel output is strobed into the CD4021 shift registers in preparation for transmission to the deck unit.

The white lead (from the pressure sensor) goes to -15 volts. The orange lead connects to pin 10 of the Modulo 12P board. Disconnect this lead and connect through a microammeter to power common. If the sensor is working correctly, the current should be approximately equal (in microamperes) to the ambient temperature in °K. If the temperature sensor appears to be ok, check the voltage levels associated with Modulo 12P board U3.

5-2.3 DISSOLVED OXYGEN SENSOR

The dissolved oxygen sensor should show a sensor current channel output of approximately +5 volts when the system is powered up. This 'saturation' condition will continue for up to a minute or two, after which the output will steadily decline until a stable reading (typically 2 volts) representative of atmospheric oxygen level is maintained.

If the oxygen current channel voltage is zero upon power up, the sensor is defective. This condition can be caused by the sensor module proper (the small brown plastic element at the top of the DO sensor) breaking contact. See the Disassembly instructions in the 'dissolved oxygen' section which describe how the sense module's electrical contact is made.

The electrical cable connecting the DO probe to the main CTD housing should be checked. Disconnect the cable from the probe and check for +15 volts between the large pin (common) and the left-hand pin (viewed from face with large pin up). Put a voltage source of approximately 5 volts between the large pin and the bottom small pin: the deck unit should read about 1024 (thumbwheel set the 3, left 4 digits of display). Connect to the right small pin: read 1024 on the right hand 4 digits.

The DO probe housing may be disassembled to allow checking for broken wires, water leakage, etc.

6-1 MECHANICAL DISASSEMBLY / REASSEMBLY

Disassembly of Sea-Bird equipment should only be undertaken by personnel trained and experienced in the maintenance of complex oceanographic equipment.

1. **WARNING - HAZARDOUS VOLTAGES EXIST IN BOTH UNDERWATER UNIT AND DECK UNIT WHEN POWER IS ON. THESE VOLTAGES WILL PERSIST FOR 60 SECONDS AFTER POWER DOWN AS A RESULT OF CAPACITOR STORAGE.**

   BEFORE WORKING ON EITHER DECK UNIT OR UNDERWATER UNIT, REMOVE THE POWER CORD FROM THE DECK UNIT AND WAIT 60 SECONDS.

2. **WARNING - IMPROPERLY SEALED PRESSURE HOUSINGS MAY FLOOD IN SUCH A WAY AS TO TRAP AND COMPRESS THE AIR INSIDE. IF THIS HAPPENS, A POTENTIALLY LIFE-THREATENING EXPLOSION CAN OCCUR WHEN THE INSTRUMENT IS BROUGHT TO THE SURFACE. ACCORDINGLY, A MALFUNCTIONING INSTRUMENT SHOULD BE TREATED WITH GREAT CAUTION UNTIL IT HAS BEEN DETERMINED THAT ABNORMAL INTERNAL PRESSURE DOES NOT EXIST, OR HAS BEEN RELIEVED.**

   IF THE CTD STOPS WORKING WHILE UNDERWATER, LOOSEN EACH OF THE 6 SCREWS ON THE TOP END CAP ABOUT 1/2 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 ONE OF THE TOP

END CAP BULKHEAD CONNECTORS AT LEAST ONE TURN TO RELIEVE ANY INTERNAL PRESSURE.

6-1.1 UNDERWATER UNIT DISASSEMBLY

DISCONNECT AC POWER FROM THE DECK UNIT AND THE SEA CABLE FROM THE UNDERWATER UNIT.

OBSERVE THE PRECAUTIONS ABOUT INSTRUMENT INTERNAL PRESSURIZATION STATED ABOVE.

If it is determined that there is a malfunction requiring the pressure housing to be opened:

1) Lay the instrument on its side and disconnect all the cables from the bulkhead connectors on the top and bottom end caps. Then disconnect the cables from the temperature and conductivity sensors (see section 2-3.1 for reference) and disconnect the pump tubing from the conductivity cell. The temperature and conductivity sensors may be left attached to the end cap to avoid disassembly of the TC Duct. To make sure reassembly is done correctly, note (or mark with tape) which cables were removed from which connectors so that so that they can be reassembled correctly. Connecting cables in the wrong location can cause bad or missing data or system damage.

Figure 8

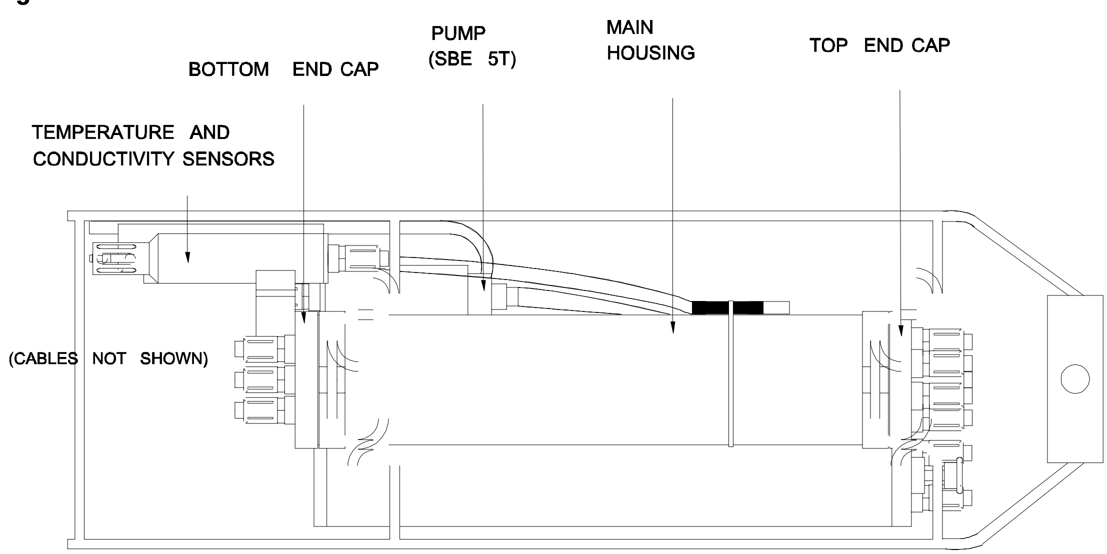
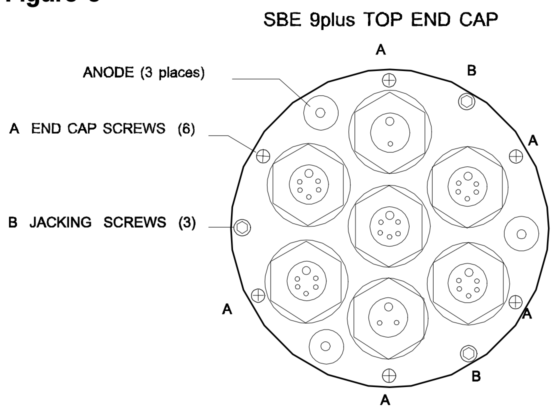


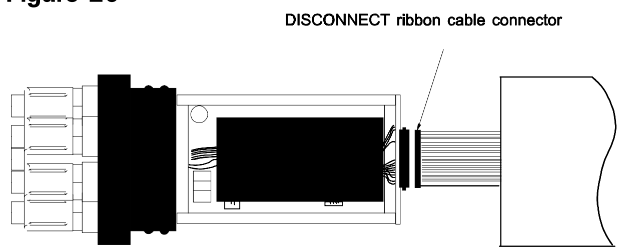
Figure 9



2) Remove the 6 screws which secure the top end cap to the pressure housing. Remove the top end cap using the white plastic "jacking screws" provided. (Figure 9)

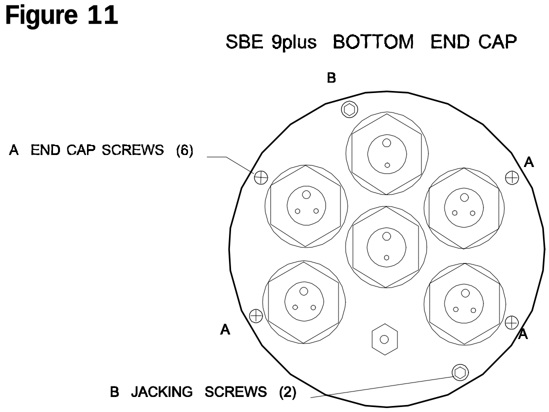
3) The top end cap and power supply are connected to the card file by a ribbon cable; disconnect this from the round PC board mounted to the end of the power supply. (Figure 10)

Figure 10



4) Unbolt the bottom end cap from the housing. Use the "jacking screws" to unseat the end cap (Figure 11). The card file will come out with the end cap, enabling you to work on the electronics.

Figure 11



6-1.2 SENSOR / PUMP DISASSEMBLY

Disassembly of the SBE 3 and 4 (Temperature and Conductivity) sensors is not recommended. These sensors are completely desiccated and filled with pure argon at the factory. Opening the sensor housings **will** invalidate the calibrations and cause a period of unpredictable drift. However, should field service be attempted, instructions for disassembly/reassembly of the SBE 3, and SBE 4 sensors and SBE 5T pump are included in the application notes that accompany this manual.

6-1.3 UNDERWATER UNIT REASSEMBLY - To put the instrument back together, reverse the above procedure.

6-2 O-RING SIZES

Main CTD pressure case (all depths):	Parker 2-241674N-70 (4 required)
All bulkhead connectors at top of CTD case:	Parker 2-017N674-70
All Sea-Bird Sensor bulkhead connectors:	Parker 2-019N674-70
Temperature sensor end cap (3400 m depth):	Parker 2-220N674-70
Temperature sensor end cap (6800 and 10,500 m depth):	Parker TP021
Conductivity sensor end cap (3400 m dept):	Parker 2-219N674-70
Conductivity sensor end cap (6800 and 10,500 m depth):	Parker TP020
Conductivity cell assembly (all depths):	Parker TP001
Pump housing (3400 m depth):	Parker 2-224N674-70
Pump housing (6800 and 10,500 m depth):	Parker TP024
Pump magnet housing (all depths):	Parker 2-219N674-70
Pump housing end cover:	Parker 2-027N674-70
Pump bulkhead connector:	Parker 2-017N674-70
Dissolved oxygen end-cap (3400 m unit):	Parker 2-220N674-70
Dissolved oxygen end-cap (6800 m unit):	Parker TP021
Oxygen Receptacle (XSG):	Parker 2-213N674-70
Oxygen Pressure Balance:	Parker 2-210N674-70
Oxygen sensor:	Parker 2-022N674-70
Oxygen Plenum:	Parker 2-022N674-70
pH sensor end cap:	Parker 2-220N674-70