技術手冊第027號

溫鹽深儀系統：校正及修護手冊(I)
SBE 11Plus Deck Unit
SBE 9Plus Underwater Unit

撰 寫 人：陸 澍 華
諮詢教授：劉 倬 騰

國科會海研一號貴重儀器使用中心

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目錄

SBE 對責任限制之聲明

使用與維護此設備需極小心及多加熟悉，並且由受過操作保養訓練之專門人員使用之。

SBE 公司拒絕保證任何由於使用不當而損壞之產品。因為 SBE 公司無法管制及選擇使用設備之操作者，所以對於法律上所附帶之產品要求保證無法全數應允，其中包含當使用者對設備進行有危險性之操作時提出警告。

所以當顧客接收此設備後，在持有 SBE 公司產品之保證的同時亦應承諾對所擁有之設備，注意使用安全及維護作業。

使用深度警告

以下列舉設備之組件使用深度限制，使用該項設備元件不可超過其深度限制。

CTD 主體	6,800 meters
壓力 sensor (10,000 psia)	6,885 meters
溫度 sensor (SBE 3)	6,800 meters
電導度計 (SBE 4)	6,800 meters
泵浦 (SBE 5)	6,800 meters

附註：海研壹號上所使用之透光度計型號與使用深度範圍

透光度計	(sea Tech SN611)	2,000 meters
	(sea tech SN980)	4,000 meters

系統參數

最大深度(CTD 與 sensor 主體)	6,800 meters
壓力計範圍	0−10,000 psia
	0−6885 d−Bar
數位石英壓力計(with temp comp)	S/N 2675
modulo 12P	S/N MOD12P−0180
AD590 M(enter in seacon)	0.01156
AD590 B(enter in seacon)	−8.67340
溫度計(SBE 3-02/F)	S/N 03(cfe)
電導度計(SBE 4-02/0)	S/N 04(cfe)
泵浦 (SBE 5-02)	S/N 050131
A/D 輸入電壓範圍	0−5 伏特 DC
邏輯板 EPROM Version 1.0	
Modem 界面建入安裝	
Modem 微控制器 Version 2.0A P/N 11124	
GO 1015 Rosette 界面建入安裝	

資料格式(原廠安裝 sensor 時所設定之 Frequency)：

Frequency 0	Temperature
Frequency 1	Conductivity
Frequency 2	Pressure

原廠規格表：

911plus CTD

GENERAL SPECIFICATIONS

Measurement Range	Conductivity	0 to 7 Siemens/meter (0-70 mmho/cm)
	Temperature	-5 to + 35° C
	Pressure	up to 15,000 psia, depending on configuration
	A/D inputs	0 to +5 volts
Initial Accuracy	Conductivity	0.0003 S/m (0.003 mmho/cm)
	Temperature	0.002 °C
	Pressure	0.015% of full scale
	A/D inputs	0.005 volts
Typical Stability (per month)	Conductivity	0.0002 S/m (0.002 mmho/cm)
	Temperature	0.0003 °C
	Pressure	0.0015% of full scale
	A/D inputs	0.001 volts
Resolution (at 24 Hz)	Conductivity	0.00004 S/m (0.0004 mmho/cm)
	Temperature	0.0002 °C
	Pressure	0.001% of full scale
	A/D inputs	0.0012 volts
Time Response	Conductivity	0.040 second
	Temperature	0.060 second
	Pressure	0.001 second
	A/D inputs	5.5 Hz 2-pole Butterworth Low Pass Filter
Weight in air, lbs (kg)	SBE 9*plus* (aluminum)	55 (25)
	SBE 9*plus* (titanium)	64.7 (29.4)
	SBE 11*plus*	23 (10.4)
	SBE 17*plus* (aluminum)	18 (8.2)
	SBE 17*plus* (titanium)	26 (11.8)
Weight in water, lbs (kg)	SBE 9*plus* (aluminum)	35 (16)
	SBE 9*plus* (titanium)	45 (20.5)
	SBE 17*plus* (aluminum)	8.2 (3.7)
	SBE 17*plus* (titanium)	16.1 (7.3)
Dimensions, inches (mm)	SBE 9*plus*	45 (1143) X 13 (330) X 12 (305)
	SBE 11*plus*	5.2 (132) X 17 (432) X 17 (432)
	SBE 17*plus*	28 (711) X 3.9 (99)

MISCELLANEOUS SPECIFICATIONS

SBE 9*plus* power available for auxiliary sensors	1 amp at +15 volts
SBE 11*plus* AC power requirement	130 watts at 115 or 230 VAC 50-400 Hz
Seacable inner conductor resistance	0 to 350 ohms
Subcarrier modem baud rate	300 baud (30 characters per second, full duplex)

SBE SEA-BIRD ELECTRONICS, INC. Telephone (206) 643-9866
1808 136th Place NE, Bellevue, WA 98005 Telex 292915 SBEI UR Telefax (206) 643-9954

軟硬體之規劃說明

第四版軟體是提供 SBE 911 Plus CTD 系統使用的。這份軟體是設計使用於 IBM-PC/AT/386/486 或是相容之電腦硬碟上，此份手冊將會說明軟體中各程式之正確應用方法。

SBE 911 Plus CTD 系統是一種"即時"資料系統，透過 9 Plus 之 CTD 水下主體部份（如前圖），將所搜集之資料經由 cable 傳送至 SBE 11 Plus Deck Unit。 SBE 11 Plus 將資料隨時編譯與平均後，再傳至電腦，儲存於磁碟檔案中。

〔seasave.exe〕程式是用來顯示與儲存 CTD 之即時資料用的。如果以 SBE 17 Plus SEARAM 配合 CTD 系統使用，則資料經由 SBE 9 Plus 之 CTD 水下主體部份而儲存於 SEARAM 內部。一旦 CTD 被取回研究船上，〔Term17〕程式可用來 upload SBE 17 Plus SEARAM 的資料於磁碟檔案中。

SEA-BIRD 設備在接收到它們所掛載的探測計器偵測之訊號後，依據所送出之電壓與頻率之變化，轉換後以 binary 之型式儲存並傳輸之。

計算過程若需要將"RAW"轉換成"工程單位"，此項工作可於搜集"即時資料"狀態下或完成資料搜集儲存於磁碟檔案後進行之。

要成功的儲存資料於磁碟檔案中，與其他的轉換工作，軟體必需知道所使用之設備的型式（見後圖）、環境規劃、sensor 之係數、所有獨立之設備。而以上所有之訊息均寫入〔seasoft.con〕參數檔中，此文字檔案可以建立之並更動其內容。例如每次某設備係數校正後或添加其它 sensor 設備時。

〔seasoft.con〕會被〔seasave.exe〕或其它如〔Datcnv〕、〔Derive〕等程式使用；當〔seasave.exe〕被要求自一設備進行儲存或顯示"即

SEASOFT.CON

The correct instrument type for your instrument is SBE 911plus CTD System.

```
SEACON   4.201                          Wednesday  July 14, 1993  3:28 pm

                    Select Instrument Type

                 SBE 911plus CTD System
                 SBE 911e CTD System
                 SBE 9/11 CTD System
                 SBE 16 SEACAT
                 SBE 19 SEACAT Profiler
                 SBE 21 Thermosalinograph
                 SBE 25 SEALOGGER CTD
                 SBE 31 Multi-Channel Counter

   <F1> Help; <Enter> Select the Instrument; <Esc> Return to the Main Menu.
```

The correct settings for the configuration of your instrument are documented below:

```
SEACON   4.201                               Friday  July 30, 1993  2:10 pm

               SBE 911plus CTD System (12 words, 24 Hz)

Number of Frequency Channels to Suppress =        2
Number of Voltage Words to Suppress =             4
Computer Interface =                              RS-232
Surface PAR Voltage Word Added by SBE 11plus =    No
NMEA Interface Installed =                        No
Data Format =                                     <Press Enter to Modify>

Frequency  0  temperature
Frequency  1  conductivity
Frequency  2  pressure

           <F1> Help; <Enter> Edit the Field; <Esc> Exit Editing.
```

時資料” 時亦會使用到〔seasoft.con〕檔案，而〔seasoft.con〕可藉由執行〔seacon.exe〕來產生，並可以任何名稱命名，但副檔名均為〔.con〕的型態。一組 CTD 設備可能包含許多各別組合之元件，而程式會以個別組合元件之 S/N 中最後四碼命名為〔****.con〕，例如：1234.con。

要成功的自 SBE 17 Plus SEARAM 記憶體中 upload 資料至電腦硬碟內，則〔Term17〕必需儲存有 SBE 17 Plus 之硬體規劃訊息以及有關電腦被用來 upload 和儲存資料之訊息，以上之內容將被存放於〔Term17.cfg〕檔案內。當進行 upload 資料時，請先執行〔Term17〕程式，並按下〔F2〕鍵，檢查〔Term17.cfg〕的內容，您可以依照您所使用的電腦設備與環境來改變設定。

〔seasoft.con〕與〔Term17〕內的設定容稍後述明。而 sensor 係數之校正，請參考 "SBE 9 Plus 軟體之操作手冊" 中 "係數校正" 一節之部份。

備註：

當執行時，若現行目錄下沒有正確的〔Term17.cfg〕檔案，則〔Term17〕程式無法正確地 upload 資料；若現行目錄下沒有正確的〔seasoft.con〕檔案，則〔seasave〕、〔Derive〕、〔Datcnv〕將無法正常地解譯資料。

1-1 系統描述

SBE 911 Plus CTD 系統包含了 SBE 9 Plus 水下主體部份與 SBE 11 Plus Deck Unit 或 SBE 17 Plus SEARAM 記憶體模組，而 SEARAM 固定於 SBE 9 Plus，進行 "內置紀錄" 資料。

使用 Deck Unit 時，水下部份之電源與信號均藉由一電纜線，遙控並操作之，且將資料送至水面，而 Deck Unit 將所得之串列訊號轉譯後送至電腦顯示出來並檔案化。

在 SEARAM 內部之電力是靠電池供應，而資料是存於 SEARAM 內之半導記憶體內，並可藉聯接串列埠將資料解出。

以上是描述 SBE 9 Plus 水下部份之操作情形。

1-2 系統之組成

水下部份硬體，包括了一個抗壓的外殼，內部有電力供應器，資料搜集用電子元件，遙控電路等。另外有模組化 sensor 固定於不銹鋼製的架子上。

水面上之硬體則包含了 SBE 11 Plus Deck Unit 和電腦。

當作內置記錄時（9 Plus/17 Plus 組合時），水面上之設備僅需要一條 I/O 線（DB-25S 到 RGM-4FS）和一個俱備串列埠之電腦。

1-2.1 SBE 9 Plus CTD 水下部份

如圖所示

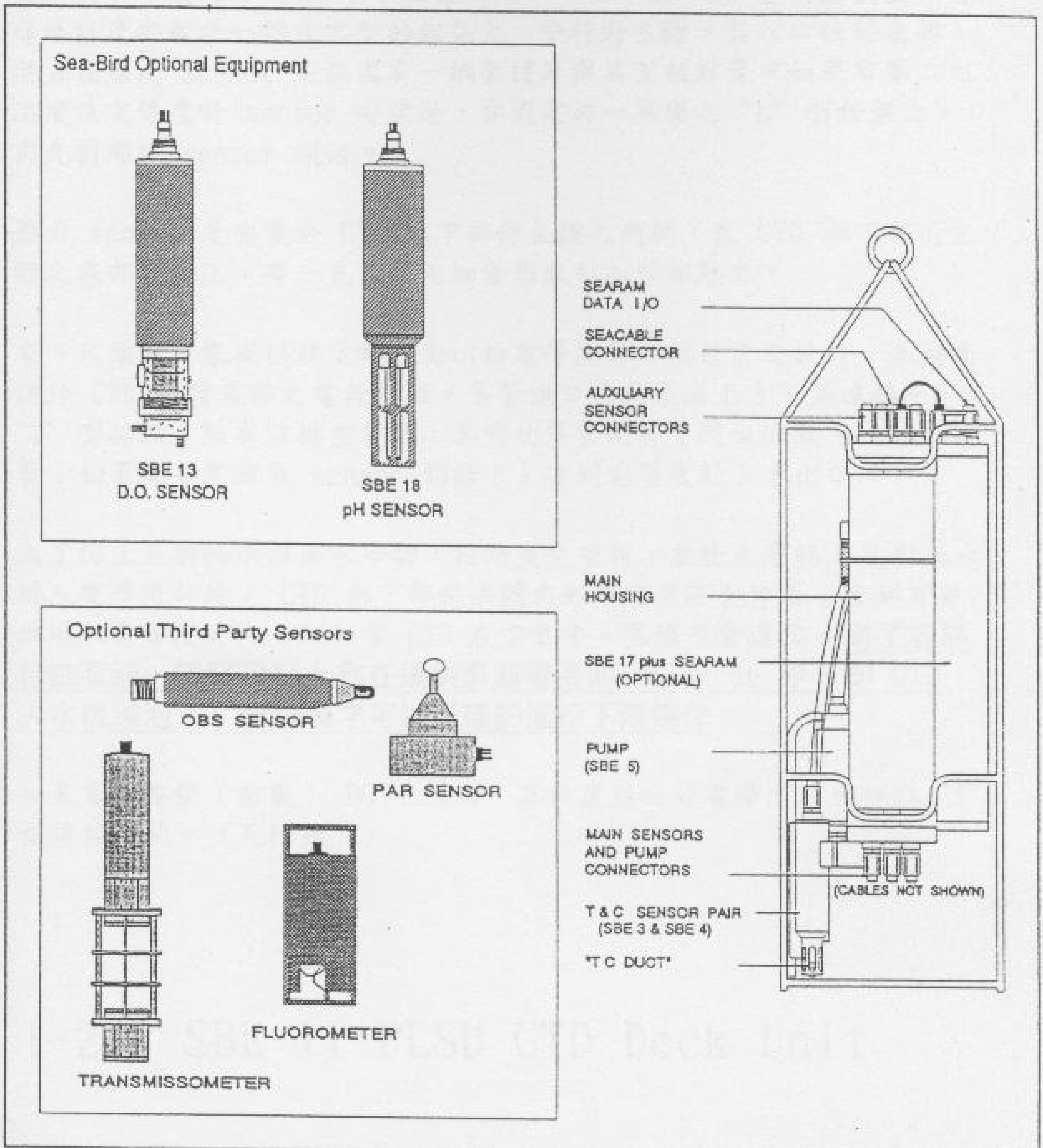


Figure 1. Primary components of the SBE 9*plus*.

(through the oxygen sensor manifold if a DO sensor has been installed) to the top (exit) of the conductivity cell. 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

SBE 9 Plus 使用 SBE 公司標準模組之溫度計（SBE 3）及電導度計（SBE 4），固定於 CTD 水下主體之底部，在一個 "L" 型的鉗架上，電導度計是安裝於一個長方型的鋁架上，平行於主體，其入口位於底部，並且在溫度 sensor 尖端處有一銅套護罩與其互相對齊。如果有第二組溫度及電導度計 sensor 安裝著，亦固定於一單獨之 "L" 型鉗架上，與先前那組 sensor 類似。

壓力 sensor 是安裝於 CTD 水下部份主體之內部，在 CTD 水下部份主體之底部外殼上，有一充油之毛細管用來引入外部壓力。

有一只泵浦用來提供穩定輸送海水給電導度計，依目前之設計，泵浦是連於 CTD 主體底部之電源接頭。導管進口位於泵浦上方，並連接一 "Y" 型接頭，附有濾排空氣孔，其它的導管尚有（經由溶氧 sensor 歧管；如果有安裝溶氧 sensor 的話！）連到電導度計上方出口。

為了防止泵浦軸承因無水冷卻，因而產生空轉，並發生磨耗，故當無水進入電導度計時， CTD 水下部份主體內部電路便不會作用，直到有鹽水進入電導度計內。例如當 CTD 在空氣中，泵浦不會運作，**為了容易起動泵浦、電路設計上會在提供泵浦電源前 delay 60 秒，即 CTD 入水後浸泡 1 分鐘後才可以正確的進行下降操作**。

如果需要安裝（溶氧） DO sensor，其位置應位於電導度計出口與 "Y" 型接頭之間。（見附錄 F）

1-2.2 SBE 11 PLSU CTD Deck Unit

SBE 11 Plus 是一種“Rack-Mountable 架上固定”界面單元，除供應直流 DC 電源給 CTD 主體外，亦用來編譯串列資料流，在微處理器控制下格式化資料，並傳送資料到電腦，SBE 11 Plus 背後有開關可以選擇使用 120 volt AC 或 240 volt AC 50/400 Hz 電源，並且有一數位顯示器，可顯示經由姆指轉動輪盤所選擇之 Raw data 以及 8 位數之 LED 燈。

資料輸出可提供由 IEEE-488 或 RS-232 所需之格式，另有磁帶機界面可供磁帶機記錄數位資料。

SBE 11 Plus 可以 "Average 平均"水下主體資料，以減少電腦處理時所需之空間。

1-2.3 SBE 17 Plus SEARAM

SEA 插座進入 SBE 9 Plus 水下主體是是經由一專用接頭，其使用是經過一種傳導線與滑環接到 SBE 11，理論上 Deck Unit 所提供之電力與編譯串列資料，是受限於 SEARAM；SEARAM 之電力來源是來自 12 個可充電式之鎳鎘電池，並儲存資料於 CMOS 記憶體內，當 CTD 被拆開，記憶體內的資料可以經由 RS-232 連接到電腦。

1-3 一般操作理論

有關 CTD 之操作理論細節在英文手冊附錄之公報上 (STD 84)，有詳細說明，而電路部分之說明，請參閱英文手冊第 4 部份。

1-3.1 CTD 探針

電導度計、溫度計與壓力 sensor 均會輸出一種頻率變化信號，例如溫度上升，則頻率也上升等，探針之頻率探測是用一種高速並列埠計器，並產生"計總"之數位訊號，藉串列埠傳送至 SBE 11 Plus Deck Unit，由 Deck Unit 再轉換至數位化之原始頻率訊號。

SEA-BIRD 電導度計與溫度探針之校正是將其浸入不同之導電度與溫度的液體內時，壓力 sensor 以一淨壓產生器來校正，sensor 之輸出頻率以表列方式列出，沿著已知之物理輸入條件 C.(電導度) T.(溫度) 與 P.(壓力) 來獲取一串校正係數；同理，sensor 已有之輸出訊號作為 Deck Unit 之輸入訊號，經由校正係數與原相同轉換公式，可以反算出正確的 sensor 輸入訊號，並以科學單位表示其產生之結果。

有關 SBE 4（近似於 SBE 3）操作理論之詳細說明，請參閱英文手冊最後之"電導度計內置結構"。（見附錄 A）

SBE 9 Plus CTD 上安裝之 SBE 3 與 SBE 4 sensor，安裝有 SEA-BIRD 之 TC 管，此項設備用來使泵浦提供單一穩流之海水到溫度與電導度 sensor，物理條件上，此管會導致溫度計與電導度計間之測量上有一已知，且為穩定常數之時間差，當同一部份的水用來作測量鹽度計算上，此時間差是被允許的。

英文手冊附錄"應用部分"第 15 條，將描述 TC 管之安裝與使用方法。（見附錄 B）

1-3.2 輔助 sensor

在 CTD 主要的 channel 上，操作 DO、pH、螢光、透光度計等，並不需要非常高層次之分析，而去使這些 sensor 改變其輸出之頻率。因此，從這些 sensor 出來之訊號只需要使用傳統之交流輸入，利用複合 A/D 轉換器，其範圍在 0 到 +5 volt，而 A/D 輸出之二進位碼換為自 0 到 4095，相對於 0 到 +5 volt 之電壓變化。A/D 二進位數值混合

編入 CTD 之串列資料中是可以有效的以"不可變"的格式來顯示或傳送。

2-1 預先檢查與安裝

以下將建議一些預先檢查的項目以確保在收到 CTD 後，CTD 系統可正常作用，在完成後面所列檢查之內容後，使用者應具備一具 IBM PC/AT 或相容之電腦，並**請參閱 seasoft 手冊中"Quick Start"資料。**

Seasoft 支援了有"即時"Deck Box 與"內置"記錄器 SEARAM 系統，且使用者無須太詳細知道 1/0 約定，命令結構及 CTD 資料結構，但若是使用者欲寫自己的程式處理 CTD 輸出資料，**請查閱 SBE 11 Plus Deck Unit 與 SEARAM 手冊上，電腦命令與控制的方法。**

2-1.1 檢查 SEA 11 Plus Unit

連接水下主體之 cable 接頭(2-pin XSG-2BCL "JT1" ON TOP END CAP)至 Deck Unit "sea cable" 後側面板連接器，使用 P/N 80591 test cable (RMA-2FS to MS)，並檢查後側電源開關是否在正確位置，**請注意！當選擇 120V 狀態下連接 SBE 11 Plus 至 240 V 電壓將導致嚴重傷害**，當電源送進 Deck Unit，觀察"data"燈是否亮的，以及"error"是否是熄的，如此可以確定 CTD 水下部分是否正常的傳送資料，且被 Deck Unit 正常接收，此時導電度計如果未進入海水，泵浦是不會轉動的。

* 將 Deck Unit 上之指輪開關撥至 0，顯示器將可以讀到溫度 sensor 產生之頻率數值，典型上是 9000 至 11000 Hz （室溫下），當溫度上升，則頻率亦上升。

* 將指輪開關設定於 1，則可顯示電導度計之頻率，在空氣下(0 導電度)，大約在 2800 Hz。

* 將指輪開關設定至 2，則顯示器會顯示壓力 sensor 之頻率，範圍在 32000 到 40000 Hz。

* 將指輪設定到 3 或 4，將顯示第二組溫度、電導度計之頻率，如果尚未安裝 sensor 將會顯示為 0。

* 將指輪開關設定在 5，則顯示器小數點左邊 4 位數代表 A/D 轉換器之 channel 0，右邊的數字為 channel 1，剩下 3 個開關位置(6-8)將代表剩下的 A/D channel，當設定的 channel 沒有讀到 sensor 訊號，將顯示 4095，此時 A/D 轉換器將之視為 0 volt 輸入。

* 當指輪設定到 B 時，小數點至左側之數目代表 sensor 之補償溫度，右手邊的數目字會顯示出"modulo"計量之增加量，當 Deck Unit 開機時，Deck Unit 自動同時一起分配電力至 8 個 scan，但"modulo Count"只傳送最近一個掃描器訊息，數字的增加有 8 次步驟。

"modulo Count"是一個掃描識別器，格式上是 8 位元數字由 0 增加至 255，然後反覆 0、1、2…等，它是由 CTD 主體所產生，其目的是用來診斷系統。

* 指輪撥到 C，所顯示為 IEEE-488 之暫存器容量(初始值為 20500，當 CTD 資料經過 IEEE-488 界面，Deck Unit 將資料移入 buffer 時，數字會減少，當電腦把資料存入 CTD 內，則數字會上升。

要確保暫存器之數字會於每過一段時間會回到 20500，不然暫存器可能會突然滿溢而造成資料流失。

電腦資料更新速率（可在 seasoft 內設定）可用來防止暫存器溢位的。

* 指輪指向 D，是指相同的處理情形，但是在描述 RS-232， 輸出串列埠 RS-232 之暫存器容量為 8000 byte。

Deck Unit 另設有 modem 與採水瓶控制器，並附有 modem 傳輸接觸燈，那是用來指示 Deck Unit 上的 modem 是否收到 CTD 水下主體內 modem 傳來之訊號。

Rosette 的輪盤控制器連接至水下主體接頭 JT4，當“enable”鍵按下，於 15 秒後，綠色 LED 燈會亮，一旦輪盤作用，“fire”按鍵會使輪盤之步計馬達激動，（放出一聲敲擊聲），且紅色的 LED 燈會亮，並持續到“enable” key 再一次按下為止，或是由 seasave 軟體中控制操作。

2-1.2 檢查 SBE 17 Plus SEARAM

SEARAM 為一 3.9 吋 (99 mm) 直徑之圓桶型物體，平行安裝於 SBE 9 Plus 之主架上，在其頂底蓋上有二個接頭，其中一個已連接於一個短的跳接器而接到主體，另一端接頭被蓋住，用來設定與釋出資料用。固定在 SEARAM 頂邊蓋上是一個菇型塑膠插座，要測試 CTD/SEARAM，可以一電腦與之連接，按下 plunger，在 5 秒後螢幕會出現一個點，並連續的出現直到記憶體滿了為止，或是內部電池耗盡電力或直到 plunger 再按一次回到原來之位置。

有關其他資訊與 SEARAM 設備之檢查應用，請參閱 SEARAM 手冊。

2-1.3 船上電路接線說明（CTD 與 Deck Unit）

您所使用 CTD 之 sea cable 的底端是做成 2-pin 之辦狀，正極電源(+,cable 之內部接頭) 經由小支的 pin (黑色)，負極電 (一, cable armor) 經由大支之 pin (白色)。

假若你因未仔細檢查而誤接到錯誤之電極，也不會有任何的危險發生，是因為在 (+) 極上有串接一保護用二極體真空管，除非 cable 被正確的連接，不然此時 CTD 是不會作動的。

為了安全的理由與更可靠的運作，SEA-BIRD 強烈建議您使用 cable armor。

請確定有機械接頭連接於 cable armor 與 CTD 之拉環之間，當您連接水下部分到 sea cable，請小心套上 cable 末端，使其不會被鐵鍊夾到或壓到，並把鐵鍊或纜線以 cotter 扭住，並安全地固定之。

sea cable 引導經過絞機滑環必須於終端接一 MS 接頭 (型式：MS 3106A 12 S-3P SBE P/N 17529，與 SBE 11 Plus 同時提供)，cable armor (一) 負極應接於 MS pin A,同時 cable 接頭 (+) 正極應接於 MS pin B。

注意!!! (+) 250 volts DC 是在 sea cable 接頭之 pin B.

為減少 cable 引起的雜訊，請確保 sea cable armor 與 MS pin 間之連線不會接觸到船身。

當 CTD Deck Unit 電源打開至 "ON" ,而 "data" 燈應幾乎立刻亮起來，(如果水下部份已正確的聯接，且無其他問題)，此時應採取一快速之檢查全部的系統，依先前所述之步驟完成之，以確保系統一切正常。

2-1.4 安裝 SBE 9 Plus 於 General Oceanics Rosette (採水裝置)

SBE 9 Plus 也可能安裝有一只 modem 與 Rosette 界面，使得控制 輪盤採水器塔門 (General Oceanics Rosette Pylon)，可經由 SBE 11 正面面板上或相容電腦上進行控制。

Rosette 塔門連接 SBE 9 Plus JT4，以一 cable 線直接連接，pin 對 pin，塔門必須轉到負 (Negative) 的二極。

<u>英文手冊應用部分第 35 項 (Note 35) 會提到有關連接 SBE 9 Plus 與塔門間連接之細節。(見附錄 D)</u>

2-1.5 壓載重量

當進行深海探測或工作在大船上，使用較重負荷之絞機，則它需要附加重量於水下主體，13 或 26 公斤之直立加掛重物可由 Sea Bird 電子公司提供，它們可以固定在 CTD 護架外緣軌上，靠近底部的地方，在運輸護架之過程中，加掛之重物應取下。

2-1.6 佈置

水下主體經過組合為一體後並測試，在其放入水中之前，請移除 Tygon 管(用來維持 cell 清潔用)，確定空氣排放孔未被其他物質或雜物阻塞，如果於 CTD 上使用了 SEARAM，應已安裝了新的電池，或已將鎳鎘電池充滿了電。

請查閱 SEARAM 手冊或電池安裝說明。

水下主體應懸吊於自護架之上方之掛環處起。

1990 年 1 月 1 日後出廠之 CTD 均有泵浦延時之電路設計，以便較易趨動泵浦。

由於此項功能在電導度計入水後，泵浦電源會 delay 60秒，此段時間延遲是可用來使管內空氣由排放孔排出，請確定 CTD 入水後，固定於水表層 1 分鍾之後才開始下放收集樣品資料，若未注意此項要求，則在資料收集之初期會生較差之資料密度與鹽度資料。

備註：

使用採水瓶系統（Rosette）當 fire 採水瓶之時，會中斷 CTD 電力，採水瓶 fire 之後 60 秒才會再起動泵浦，如果您使用的是 SBE-BIRD 潛載 modem 之 Rosette 界面系統則無需等待 60 秒。

欲獲得最佳之量測結果為下放過程(down cast)，此時流經 sensor 的海水是穩定新鮮的海水。而在上升(up cast)過程中，sensor 會處於主體架構之流跡上，其結果將會不可預測。

SBE 9 Plus 之最佳採樣施放速率為 0.5~1.5 M/S，如果您有溶氧 sensor，要獲得最高品質之結果，可以放置一大滴之液態清潔劑於其膜片上(清潔劑是容易以注射器置於膜面上之凹面，但小心勿碰觸到薄膜表面)。

當 CTD 穿過海面時，清潔液會完整地避免任何浮油接觸到薄膜面上。

當泵浦啓動(在水面以下)後，快速的激動沖刷水流會快速的沖去清潔液。

備註：

當採水瓶系統 fire 時，中斷 CTD 電源後，在重新收集樣品前，需等待至少 2 分鐘。

這是為了允許溶氧 sensor 進行“重置極性”(與提供泵浦啓動延遲所需之時間)。相同的，若您使用 SBE-BIRD 潛載 modem/Rosette 界面系統時，是無需等待的。

如果您使用-PAR (Photosynthetically Active Radiation) sensor，記得移除它的保護蓋。

註：目前海研壹號並無此項 sensor。

若使用 'soaker'瓶與 'pH' sensor 須於 CTD cast 作業前移去護罩。

2-1.7 回收與貯放

除非下一個 cast 很快用到 CTD，否則應拆下 CTD 主體浸於淡水中，去除所有泵浦與電導度計間之 Tygon 管與彎曲管路內，自一端至另一端內之蒸發水分或滷水。如果 CTD 上有溶氧 sensor，彎曲的管線上也應會經過之。

2-1.8 電流腐蝕之保護

SEA BIRD CTD 水下主體若是深海型(3400 或 6800 M 之間)，其表面均塗有一層 aluminum 以隔絕內部 sea cable 電源電流與外側不鏽鋼架之接觸。

這隔離措施是預防主體外殼遇到嚴重之腐蝕，任何之物體均應避免直接接觸到主體外殼。

由 CTD 供應電力之附屬設備，不同於其電力電路，理想上有可移動之外殼。這是被允許其 CTD 電力與信號普通線接到附件外殼，但卻千萬不可使附屬設備外殼接觸到 CTD 之 15 volt 電源，如此是會損壞電池電極的。

2-2 保養

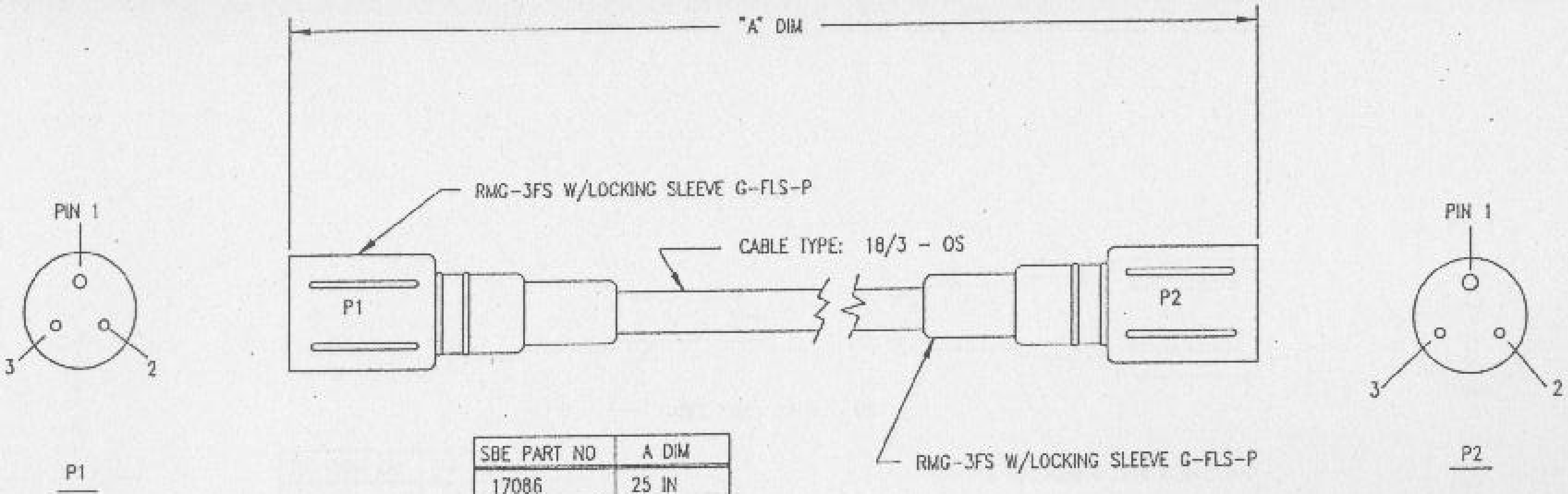
最主要之有效保養 CTD 系統方法是避免置於潮溼且於鹽水處或受海水濺溼處，其餘步驟如後列舉出，可延長 CTD 之壽命。

2-2.1 腐蝕預防

在鋁製水下主體之頂蓋上有 3 個塊狀的正極鋅板以螺栓鎖住，這些陽極板應時時檢查是否栓牢，以及是否被吃掉了。所有在水下主體上外露於鹽水中之不鏽鋼螺絲均應以 Never Seez 潤滑。Never Seez 為一種潤滑劑，內中含有鎳粉與氧化鋅，每航次後，最好卸下這些螺絲並以近似組合成份之潤滑劑潤滑之，由於其成份是會導電的，所以使用時要小心不要碰觸到電路板。

模組化 sensor 均有環型陽極板，應時時檢查，若有腐蝕嚴重者應更換之。

水下部分主體每次用後應垂直置於淡水中，並以乾布擦乾後，才收藏之。定期（每年）移除不鏽鋼架上的鉗夾與 PVC 墊片，以便進行清潔外殼表面，並預防因長時間之緊壓而損壞表面。一般來說並無強制性規定，於長時間使用下，您可更換不鏽鋼夾。



SBE PART NO	A DIM
17086	25 IN
17087	31 IN
17196	98 IN
17257	36 IN
17288	158 IN
17291	40 IN
17353	72 IN
17395	18 IN
17396	20 IN
17397	22 IN
17418	120 IN
17589	48 in
17695	11 in

P1	P2
PIN 1	PIN 1
PIN 2	PIN 2
PIN 3	PIN 3

DATE	SYM	REVISION RECORD	AUTH.	DR.	CK.

SEA-BIRD ELECTRONICS, INC

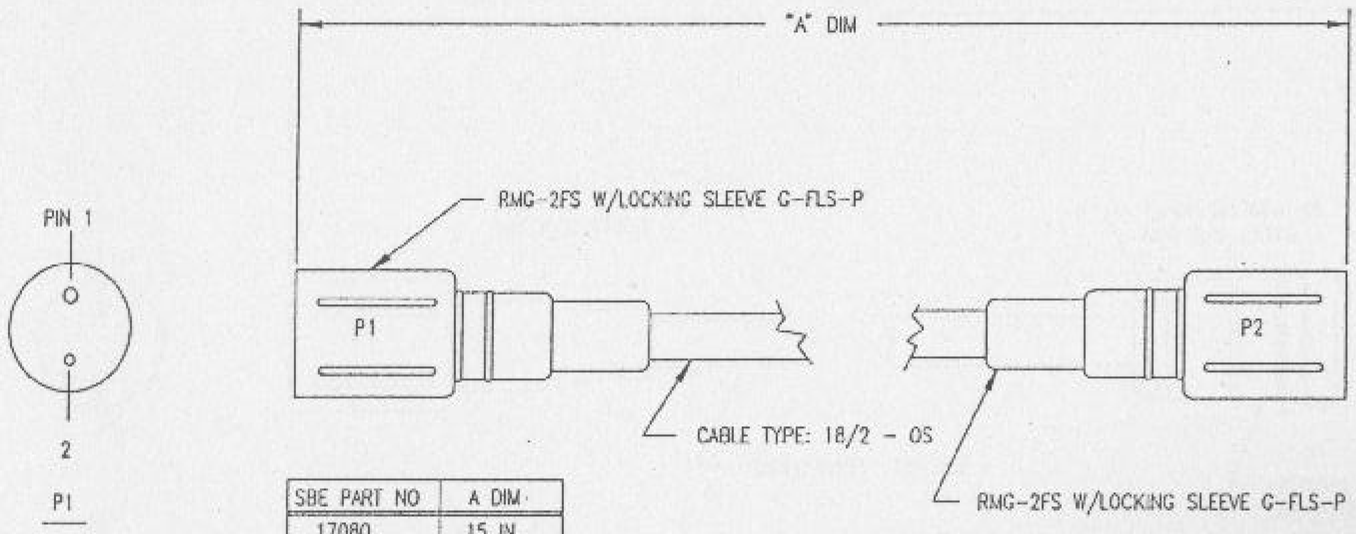
TOLERANCES: FRACTIONAL / DECIMAL / ANGULAR

P/N SEE TABLE — SCALE 1:1 — DRAWN BY BMC — APPROVED BY P.G.

TITLE: CABLE, 3PIN/3PIN RMG-3FS + LS

DATE 1/20/92 — DRAWING NUMBER 30566 — REV

REDRAWN ON ACAD NO CHG



SBE PART NO	A DIM
17080	15 IN
17100	40 IN
17101	6 FT
17127	60 IN
17133	44 IN
17159	36 IN
17188	34 IN
17200	79 IN
17259	120 IN
17285	12 IN
17394	29 IN
17450	24 IN
17584	48 IN

P1	P2
PIN 1	PIN 1
PIN 2	PIN 2

DATE	SYM	REVISION RECORD	AUTH.	DR.	CK.

SEA-BIRD ELECTRONICS, INC

TOLERANCES / FRACTIONAL / DECIMAL / ANGULAR

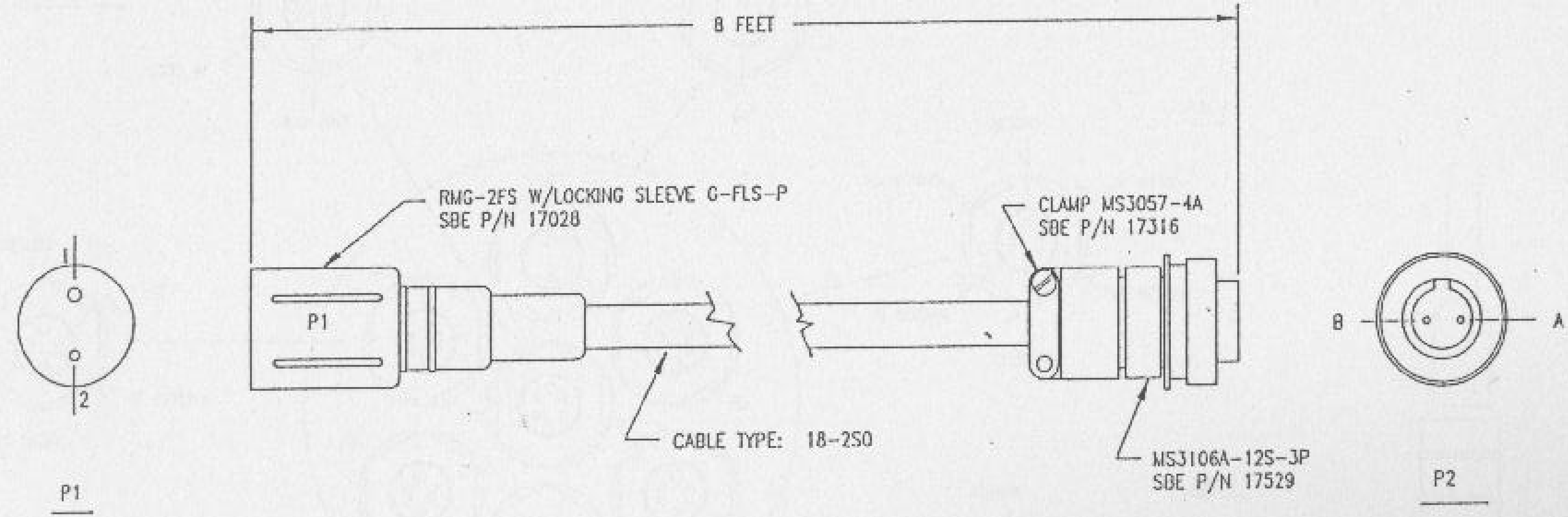
P/N SEE TABLE — SCALE 1:1 — DRAWN BY RMC — APPROVED BY P.G.

TITLE CABLE, 2 PIN / 2PIN RMG-2FS + LS

DATE 3/1/89 — DRAWING NUMBER 30565 — REV

REDRAWN ON ACAD NO CHG

DATE	SYM	REVISION RECORD	AUTH.	DR.	CK.
1/92	A	DELETE BUSHING		BMC	
6/92	B	ADD DIM TABLE			



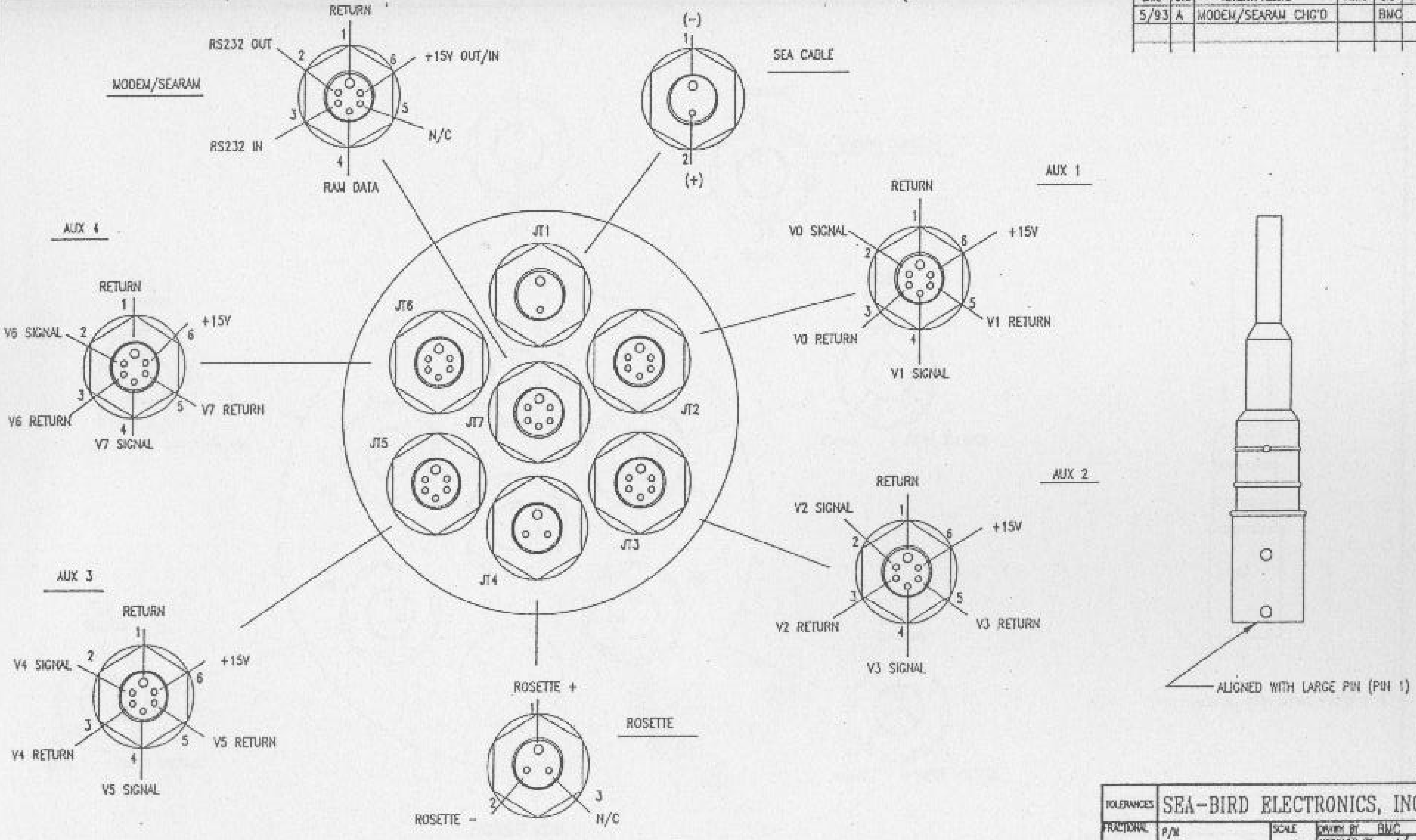
PART NO	DIM A
80591	8 FT
80620	50 FT

WIRING CONNECTIONS		
P1	COLOR	P2
PIN 1	WHITE	A
PIN 2	BLACK	B

TOLERANCES	SEA-BIRD ELECTRONICS, INC		
FRACTIONAL	P/N SEE TABLE	SCALE 1:1	DRAWN BY BMC / APPROVED BY FDL
DECIMAL	TITLE TEST CABLE, SBE 911 PLUS		
ANGULAR	DATE 12/91	DRAWING NUMBER 31314	REV B

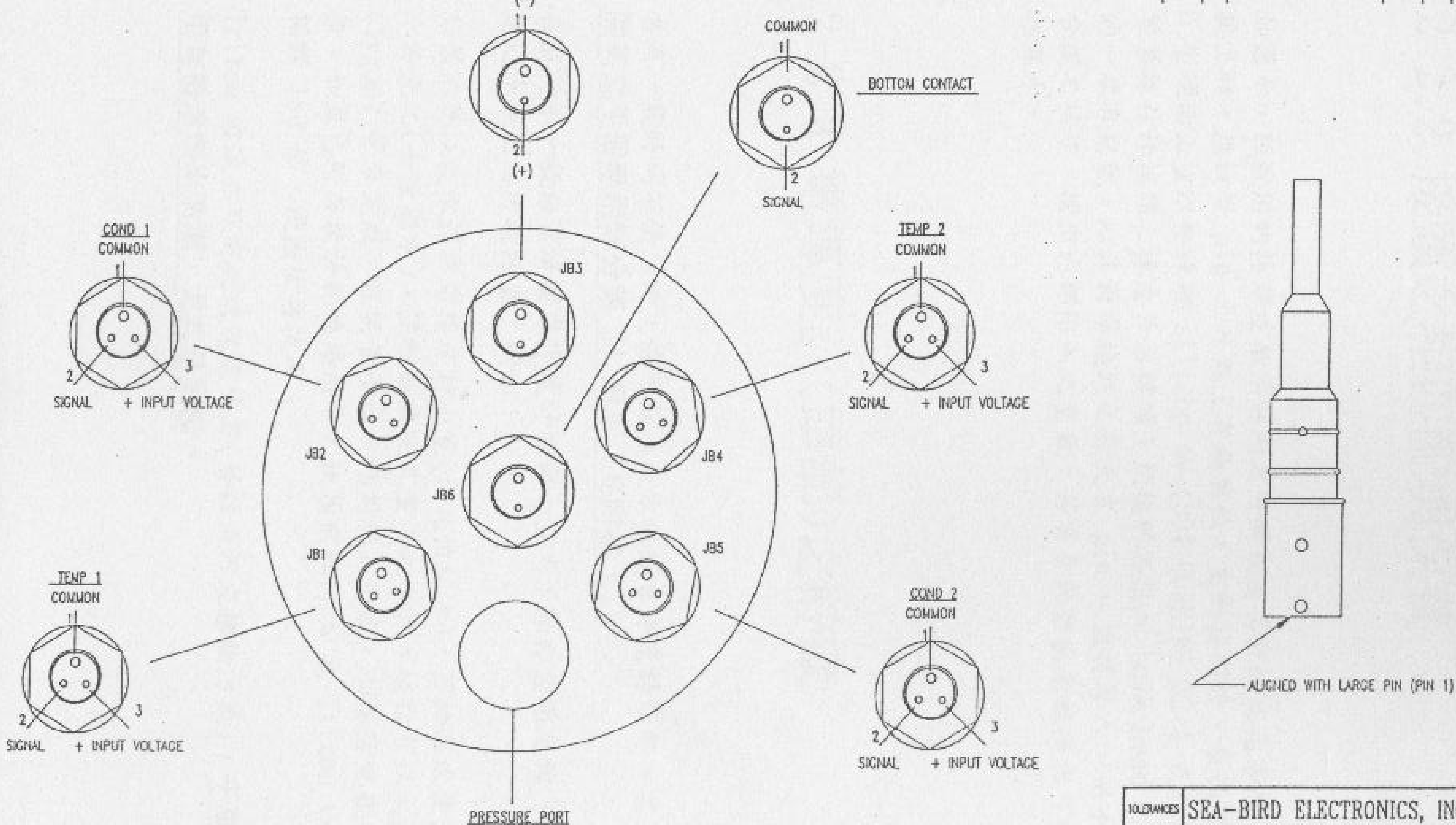
ORIG

DATE	SYM	REVISION RECORD	AUTH.	DR.	CK.
5/93	A	MODEM/SEARAM CHG'D		BMC	



TOLERANCES	SEA-BIRD ELECTRONICS, INC		
FRACTIONAL	P/N	SCALE -	DRAWN BY BMC / APPROVED BY [illegible]
DECIMAL	TITLE TOP END CAP, CONNECTOR— STANDARD		
ANGULAR	DATE 2/23/92	DRAWING NUMBER 50076	REV A

DATE	SYM	REVISION RECORD	AUTH.	DR.	CK.
4/92	A	ADDED JB6	DG	BMc	ds



TOLERANCES	SEA-BIRD ELECTRONICS, INC		
FRACTIONAL	P/N	SCALE –	DRAWN BY BMC / APPROVED BY
DECIMAL	TITLE BOTTOM END CAP CONNECTOR SBE 9+		
ANGULAR	DATE 1/13/92	DRAWING NUMBER 50078	REV A

2-2.2 接頭之相匹配與保養

如圖示，匹配用的接頭並無須週期之分解或有其他的注意事項，若無法接上時，應檢查 pin 之外觀上有無腐蝕。重新接回時，表面可以延著 O 型環面上塗以些許輕 silicon 油 (DOW CORNING DC-4 或相同者)，緊緊抓住母接頭之橡皮外形接頭，然後將其推入 bulk head，在母接頭的一端有記號，以其對準接頭之最大支 pin 以後再壓入，用手夾住接合後之接頭，擠出內部陷入之空氣，若有多餘空氣未被擠出可能導致接頭漏水。

2-2.3 電導度計(頭部)之貯藏

當有一段時間不使用時，儘可能以淡水保護電導度計頭部，其方法**請參閱英文手冊應用部分第 34 項。(見附錄 C)**

在航行中一般無需清潔電導度計頭部小室內，除非您確定該 sensor 曾遭過水表面油污物污染，例如：

如果不使以淡水保存電導度計小室(由於怕結冰)，可於每次使用後以淡水沖洗之(去除鹽水)，並輕輕吹除孔室內之水份，這點可以太港 (Tygon) 管來完成，並將管子以一端對接另一端，以預防空氣中之污染。如果已貯存放於乾燥場所中，使用前以 1 % 之 Triton (化學品名) 稀釋 100 倍，浸溼後再使用。

Triton 溶液亦可有效清潔電導室(若被油污或雜物污染)，**千萬不可使用有機溶劑來清潔，尤其是酒精**。

2-2.4 溶氧 sensor 之保養

溶氧 sensor 應存放於 100% 之相對溼度環境，最好的方法是當 CTD 不使用時，於 DO sensor 之歧管處，用太港管以口對口的方式，充滿淡水後接起來，其管內的水儘可能裝滿，以達 100 % 之相對溼度。

較長的管子如此也可圍繞包含電導度計 sensor 在內，如此亦可防止污染或其他污物的侵蝕。

Triton 亦可以用來清潔 DO sensor，同樣地，不可使用有機溶劑清潔 DO sensor。

當已使用 1、2 年後，它不再可能獲得穩定的調校，此時溶氧 sensor 必須更換之。

2-2.5 pH sensor 之貯放與保養

當 pH sensor 不使用，移除金屬外殼與“soaker”瓶，首先移除瓶蓋，滑動它，沿著塑膠 pH 電極，如此使其可移動，再穿入蓋內，以相反之流程移除瓶子，瓶內應有足的水，遮蓋鐵弗龍參考接合處。Soaker 液是 pH 4 之緩衝液，附加液體時，如果需要可以使用商業用緩衝膠囊和蒸餾水。

2-3 校正

Sea-Bird sensor 之校正，藉由各別模組已知之物理條件下，測量 sensor 之反應，利用適當之方程式算出其參數，用以獲得工程單位之溫度，電導度及壓力資料，Snesor 經完全校正後，其參數會印在個別校正報告內，溶氧 sensor 是校正（術語上）其電子反應，反應至 0 氧度（BOC值）及全刻度大氣壓力範圍下之空氣－飽和水之偏壓值（SOC 值）。

壓力與溫標效果是假設先前使用與研究此 sensor，可能需要修正使用水樣取得當時 CTD 資料，使用 Winkler 滴定法於水樣，並使用 seasoft 所提供之 Oxfit 程式。

pH sensor 以商業之緩衝溶劑來校正（+/- 0.02pH），pH sensor 之使用者建議定期之比較緩衝液(一般在 pH 7-8之範圍)。

SBE 公司設計 sensor 之校正非常快速且廉價，我們之如此設計是考量使用者易忽略於一定之有效之期內進行校正之工作，而其結果往往使得在接收資料之品質標準上失去有力之證據。

sensors 可以透過 SBE 送至 NRCC (Northwest Regional Calibration Center) 進行校正，或以標準實驗室設備方法來校正。

如果選擇後者，則 Sea-Bird 可以提供 PC 電腦相容之係數產生程式。

2-3.1 sensor 之拆換校正

脫開正確之 sensor 連接線，反轉下接頭之塑膠扣蓋，向上拔出其接頭時，抓住接頭之一端，避免扭歪了末端 pin。溫度與電導度計 sensor

以一單獨之不鏽鋼夾固定，放鬆其螺絲使夾子可以彎曲成 90° 直到 sensor 可以移除為止。

使用於溶氧或 pH sensor 的夾子通常是完全除去後再移開 sensor。

2-3.2 電導度計校正

電導度計內組合入一固定之精密電阻器平行於 cell，當 cell 是在空氣中且於乾燥的狀態下，則 sensor 之電路只會輸出電阻器之固定頻率，此頻率應為保持於 1 Hz 內之穩定狀態，電導度計在校正上最主要是機械校正其漂移情形，其原因皆導由於化學，或物質之污染，其結果造成 cell 在幾合上之“移位”。

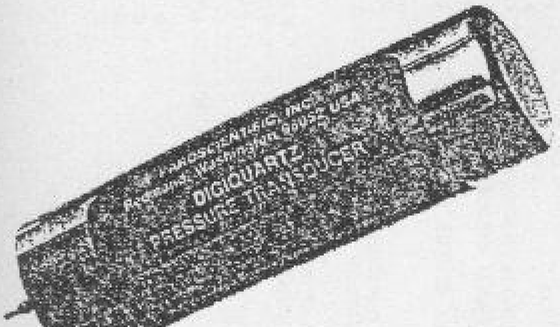
第 2 種之機械偏移原因是電極品質之改變，其結果也會造成資料錯誤，由於以上原因，清潔 cell 就成了很重要的課題，這也是為什麼建議您使用蒸餾水保存之。

我們建議您於每一次重要之航次前先行校正電導度計，特別是當 sensor 曾曝露於有光亮之滑油油污之海水或其他生物污染之物質處。

2-3.3 溫度計之校正

溫度計校正之偏移量主要是由於其熱感元件之老化，在第一年內通常僅為數千分之一度，並且小於後來之間隔，sensor 漂移並不是實際受使用環境之影響一不像白金或銅元素，熱感 sensor 對於衝擊是無感的，故在重要之航次前後進行一容易執行之校正工作，對於求得溫度上之高精確度，其重要性是可理解的。

DIGIQUARTZ® PRESSURE TRANSDUCERS



SERIES 4000

- ABSOLUTE RANGES OF 0-2,000 psia, 0-3,000 psia 0-6,000 psia, 0-10,000 psia

FEATURES

- 0.005% REPEATABILITY
- 1 X 10^{-8} FS RESOLUTION
- LOW POWER CONSUMPTION
- QUARTZ CRYSTAL FREQUENCY OUTPUTS
- CALIBRATED OVER WIDE TEMPERATURE RANGE

APPLICATION AREAS

- OCEANOGRAPHY
- RESERVOIR ANALYSIS
- INTERFERENCE TESTING
- GEOTHERMAL RESEARCH
- LABORATORY STANDARDS
- PRESSURE CALIBRATION SYSTEMS
- ENERGY EXPLORATION AND WELL TESTING

The SERIES 4000 DIGIQUARTZ® HIGH PRESSURE TRANSDUCERS provide laboratory accuracy in a small, low power design. Excellent performance is achieved through the use of a quartz crystal resonator whose frequency of oscillation varies with pressure induced stress. These precision pressure transducers also provide a quartz crystal temperature signal for full thermal compensation over a wide temperature range. Typical accuracy under difficult environmental conditions is 0.02%. Rugged design, small size, and high reliability make the SERIES 4000 ideally suited for field and remote applications. Frequency outputs allow ease of interfacing with counters, computers, or other digital data acquisition and control systems.

The SERIES 4000 DIGIQUARTZ® HIGH PRESSURE TRANSDUCERS are used in applications which require superior repeatability and resolution over a wide pressure range. These sensors can measure pressure changes as small as 0.01 parts per million. They are well suited for interference testing, reservoir analysis, and repeat formation testing, as well as deep sea oceanography and laboratory transfer standards.

When interfaced with the SERIES 700 DIGIQUARTZ® PRESSURE COMPUTER the output of the high pressure transducer is automatically temperature compensated and displayed in engineering units of your choice. These transducers are also available in the standard RS-232 output SERIES 1000 INTELLIGENT TRANSMITTERS.

MODEL	RANGE
42KT	0 to 2,000 psia (13.8 MPa)
43KT	0 to 3,000 psia (20.7 MPa)
46KT	0 to 6,000 psia (41.4 MPa)
410KT	0 to 10,000 psia (69.0 MPa)

PERFORMANCE

Resolution	0.01 ppm
Repeatability	0.005% FS
Hysteresis	0.005% FS
Pressure Conformance	0.005% FS
Acceleration Sensitivity (3 axis average)	0.008% FS/g
Supply Voltage Sensitivity	Negligible

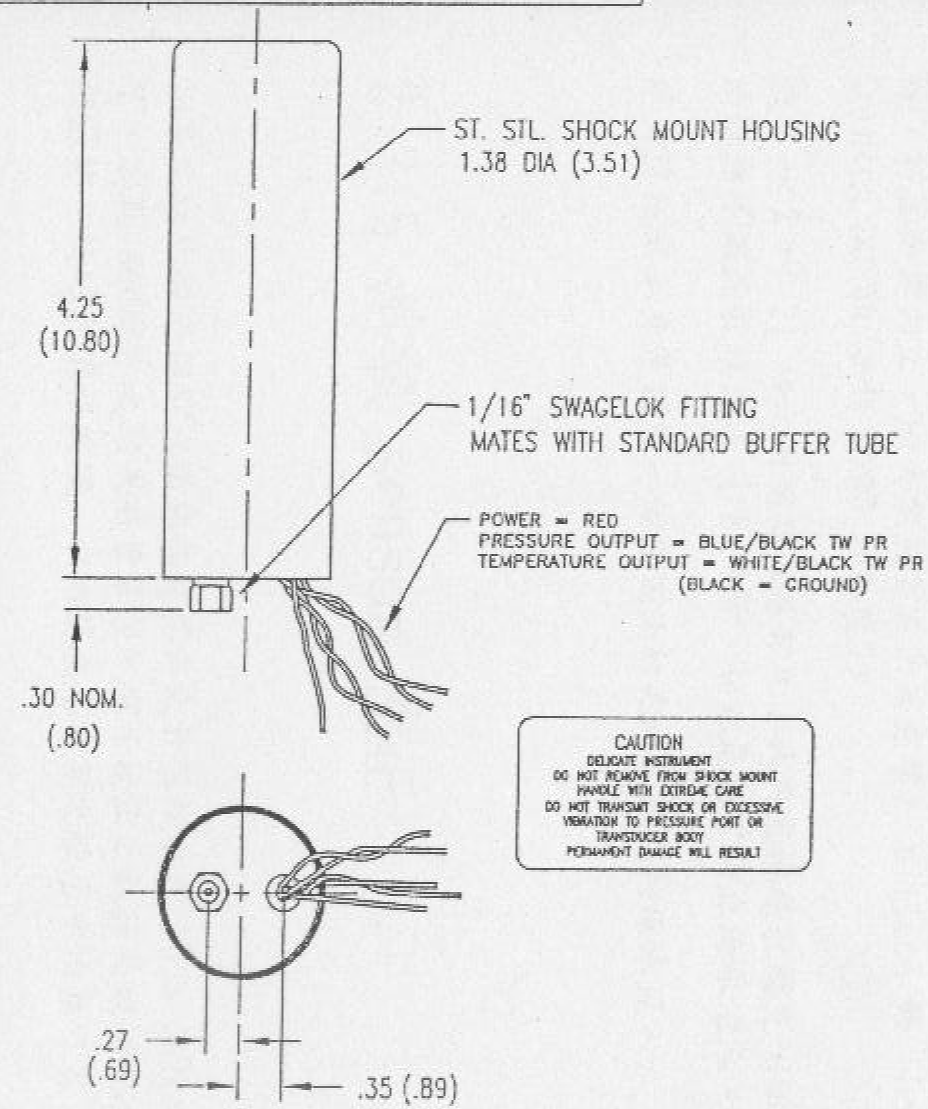
CHARACTERISTICS

Nominal Pressure Frequency (zero to full scale)	34 kHz to 38 kHz
Nominal Temperature Frequency	172 kHz + 50 ppm/°C
Calibrated Temperature Range	0 to 125°C
Power Requirements	6 to 35 vdc, 0.002A
Signal Outputs	Square Wave, 4V p-p
Size (with shock mount)	1.38 in. dia. × 4.25 in. (3.51 cm dia. × 10.8 cm)
Weight (with shock mount)	7 oz. (200 gm)
Overpressure	1.2 × Full Scale

Paroscientific, Inc.
4500 148th AVENUE N.E. REDMOND, WA 98052
(206) 883-8700 TELEX 15290 (PARO RDMD)

Product defined by Specification Control Drawing. Manufactured under one or more of the following U.S. Patents: 3,470,400 - 3,479,536 - 4,089,058 - 4,215,570 - 4,321,500 - 4,372,173 4,382,385 - 4,384,495 - 4,406,966 - 4,454,770 - 4,455,874 - 4,479,391 - 4,531,073 - 4,592,663 Other patents pending

SPECIFICATION CONTROL DRAWING



MODEL NO.	PART NO.	PRESSURE RANGE	
42K-101	1220-001-*	0 TO 2,000 PSIA	(13.79 MPa)
43K-101	1221-001-*	0 TO 3,000 PSIA	(20.68 MPa)
46K-101	1222-001-*	0 TO 6,000 PSIA	(41.36 MPa)
410K-101	1223-001-*	0 TO 10,000 PSIA	(68.94 MPa)

* ADD "0" FOR OIL FILLED

PERFORMANCE

REPEATABILITY . . . . ±0.01% FULL SCALE
HYSTERESIS . . . . ±0.01% FULL SCALE
ACCELERATION SENSITIVITY . . . . . . ±0.008% FULL SCALE/g
(THREE AXIS AVERAGE)

RESIDUAL TEMPERATURE SENSITIVY USING COMPENSATION EQUATION PROVIDED . . . . . . 0.0008% FULL SCALE/DEG C
SUPPLY VOLTAGE SENSITIVITY . . . . . . LESS THAN 0.001% FULL SCALE/V +9 TO +35 VDC

CHARACTERISTICS

NOMINAL PRESSURE SENSOR OUTPUT FREQ. . . . NOMINAL SPAN: 3.5 KHz IN RANGE 30 TO 42 KHz
NOMINAL TEMP. SENSOR FREQUENCY . . . . . . 172 KHz ±10 KHz
AVERAGE TEMP. SENSOR SENSITIVITY . . . . . . 45 ppm/DEG C
WEIGHT . . . . 6 OUNCES (170 gm)
POWER REQUIREMENTS . . . . +9 VDC @ 1.3 MA
(OPERATES FROM +9 VDC MIN TO + 35 VDC MAX)

NOTE: WIDE OPERATING VOLTAGE RANGE IS PERMITTED BY USE OF A CURRENT LIMITING DEVICE IN THE OSCILLATOR CIRCUIT. OUTPUT POWER STAGE IS NOT CURRENT LIMITED AND WILL DRAW CURRENT AS REQUIRED BY THE LOAD ON THE OUTPUT.

OUTPUT SIGNAL IS A NOMINAL SQUARE WAVE OF 4 VOLTS AMPLITUDE PEAK TO PEAK, CAPACITEVLY COUPLED WITH SOURCE IMPEDANCE LESS THAN 750 OHMS.

ENVIRONMENTAL

OVERPRESSURE . . . . 1.2 TIME FULL SCALE
OPERATING TEMPERATURE RANGE . . . . . . 0°C TO +125°C (32°F TO +257°F)
STORAGE TEMPERATURE RANGE . . . . . . -25°C TO +135°C (-13°F TO +275° F)

THE TRANSDUCER BOURDON ELEMENT AND BUFFER TUBE OF OIL FILLED UNITS ARE FILLED UNDER VACUUM WITH DOW-CORNING FS 1265 FLUID. AT 25°C, SPECIFIC GRAVITY = 1.25 AND VISCOSITY = 300 CENTISTOKES.

CAUTION: DO NOT APPLY VACUUM TO PRESSURE PORT. OIL COULD BE WITHDRAWN PERMITTING PRESSURE MEDIUM TO COME INTO CONTACT WITH THE SENSING ELEMENTS.

NOTES

1. MAXIMUM TORQUE ON PRESSURE FITTINGS TO BE 25 INCH-POUNDS (29 KG-CM).
2. DIMENSIONS ARE IN INCHES (PARENTHESIZED DIMENSIONS ARE CM).
3. IF TEMP. SENSOR OUTPUT IS NOT REQUIRED, CUT AND INSULATE BOTH WIRES OF THE BLACK/WHITE TWISTED PAIR.
4. PRESSURE MEDIUM MAY COME INTO CONTACT WITH STAINLESS STEEL AND INCONEL 718.
5. STANDARD UNIT SUPPLIED WITH STAINLESS STEEL BUFFER TUBE PN 2161-001. MATES WITH 1/16" SWAGELOK FITTING. SEE SCD 7381-001 FOR SPECIFICATIONS.
6. POWER GROUND AND SIGNAL GROUND ARE CONNECTED TO THE TRANSDUCER HOUSING THROUGH A .10 uF 50 V CAPACITOR.

DRAWN:	CHECKED:	ENGINEER:	APPROVED:	REV:	CHK:	APR:	DATE:	PAROSCIENTIFIC, INC.	TITLE: DIGIQUARTZ ®	FILE:
[signature]	[signature]			G	[initials]	RR	1/92	4500 148th AVE NE REDMOND, WA. 98052 206-883-8700 FAX: 206-867-5407	4000 SERIES PRESSURE	SCD\7271.DWG
1/92	1/92								TRANSDUCER W/TEMP. SENSOR	SH. 1 OF 1

® REGISTERED TRADEMARK OF PAROSCIENTIFIC, INC.

2-3.4 壓力 sensor 之校正

Paroscientific 的數位石英壓力 sensor 受環境之影響作用是可以說極穩定亦可稱為免疫的，所以無須太頻繁的檢查就足夠了。（如圖示）對於重要之作業上，檢查其全範圍之反應是利用每年一次的靜壓試驗。數位石英的型式，可以顯示在 零 offset 時，大部份之誤差訊息，即是當 CTD 在空氣中(零壓的環境)，週期性之算術補償可以藉一數值之 offset 抵消其誤差，這是可以在 seasoft 內直接來做修正。

要重新校正壓力傳送器，先在主體底部蓋上移除其尼龍填充物(一個短的 1/8 吋 OD 塑膠管)，這裏有 silicon 油填入，因此會有些溢出，蓋的末端以一 5/16-24 吋之塞子直線轉入處，剛好適合安裝壓力裝置，此處使用時可以一 O ring 封環，如 Swagelok-200-1-OR，校正後，將蓋面轉向上，除去裝置並在凹刻處填入 silicon 油 (Dow Corning DC200 液態，200 秒黏度)。

使用一 2 吋 21 格之針筒插入底部之小孔內更換尼龍填充，凹刻處之油縫應填滿尼龍填充及 1/8 吋管，如此是為了防止海水溢入。

壓力傳送器本身是藉管一個充滿油的毛細管來預防海水侵入。

2-3.5 溶氧 sensor 校正

如果定期的檢查個別水樣與保持其存放於蒸餾水或 100% 濕度之環境下，溶氧 sensor 之結果將會最佳，電子校正之執行是經過 Sea-Bird 極嚴格、精確之過程處理，以確保在不定期之使用中均為可靠，它們不

需事後之調整、或元件之更換(在任何情況下，電子漂移量均可在化學校正中補償回來)。

在工廠之校正下，是在一已知溫度與大氣壓力下，於空氣一飽和水環境中零氧狀況下，測量其輸出，使用者可以藉同時比較所獲得之 CTD 資料，或於原始校正時，可以使用 Oxfit 程式更新。

2-3.6 pH sensor 校正

pH sensor 可以以有效之商業用緩衝溶劑來校正或以餾水稀釋之，當校正時，必須以一電線聯結緩衝溶劑與 pH sensor 模組，此電線可以任何之電線使用，先以一端固定 sensor 之鋅極板之螺孔上，再將另一端放入溶液中，起初工廠校正之緩衝劑為 +/− 0.02 pH 之精度，為了獲得此項精確度，必須確定溶劑之溫度位於 0.5℃。

pH 電極上之瓶子應保持掛著，無論是不使用時，或是校正中均如此，瓶內溶液應維持 pH 值於 4，在校正前以蒸餾水沖洗，亦在浸入不同 pH 值之緩衝劑前沖洗之。

2-4 執行鑑定

為了校正各別系統之 sensor，CTD 應定期檢查其內部資料收集時之安全性與正確性。

這些檢查應由合適之專門技術人員，使用已知之校正歷史與正確定之電子設備進行之。

2-4.1 (水晶)石英振盪器之老化

水下主體內部之石英振盪器會隨時間而老化，第一年內會小於 1 個 ppm，隨後一年亦會低於 1 ppm，大部份之漂移現象發生在第一年，一般上 10 年內之漂移量約在 3.5 ppm 以內。

2-4.2 頻率頻道執行確認

欲正確的操作資料頻道選擇，除去 sensor 上的 cable，以一示波器連接，並選擇 sine 型波或方形波，範圍 0.5-10 volt 峰對峰值，於已知頻率下接上 sensor cable，檢查其頻率，比較其經由 Deck Unit 計算之結果。

2-4.3 A/D 頻道執行確認

在已知 0 到 +5 V 輸入電壓之情況下，檢查其 ±0.1% V 之輸出電壓經由系統送至處理的軟體，在 A/D 段下，並不必有任何調整工作。所以任何之不一致情形均於軟體內記載之。

輔助 sensor 之校正，經由全部 CTD 之安全處理過程會自動的修正其錯誤。

3-1 SBE 9 Plus 之功能描述

電導度、溫度和 Paroscientific 的數位壓力計，均產生變頻輸出，為獲得高遠之電譯資料與解析度需藉剖面應用方式獲得，故用使了一種混合語言之週期運算技術。

每支 sensor 均有其獨特之電子電流訊號，是故所有之 sensor 均可以同時記錄取樣，每支 sensor 使用 2 個 12 bit 的計數器，一個用來模擬 sensor 每 1/24 秒間隔之間所計數之正整數，另一個則測量由開始收集之間隔直到第一個正 0 穿越 sensor 頻率的時間。

3-1.1 sensor 允許的頻率範圍

每個計數器可以處理至 4096。最大時間 Nr.計數器於 ON 時為 1/FS，當 Nr 在 6,912,000 Hz，最小之 Fs 是 6,912,000/4096，或 1687.5 Hz，最大 sensor 頻率是 Ns 計數之大小－－不超過4096，所以 Fs 最大值=4096/(1/24)=98,304 Hz。

3-1.2 分析（CTD 頻道）

CTD 解析衰減時，掃瞄率上升。掃描率為每秒 24(假設)，則系統其他

之掃瞄比率為，解析度=掃瞄率$\times\frac{Fs}{Fr}\left(Hz/_{BIT}\right)$

其中

Fs 為 sensor 頻率、Fr 為 CTD 參考頻率

(6,912,000Hz,溫度、電導度計)

(27,648,000Hz，壓力)

在 2 kHz，24 掃瞄率/每秒，其解析度為 0.0069 Hz/bit。

在 98 kHz，解析度 0.34 Hz/bit，要獲得工程單位之解析度，我們需要除以"感度"，例如 Hz/°C 要運算工程單位之解析度微小數值，此數僅用來作插圖之目的。

使用者的電腦必須使用較正確之方程式和特別之校正常數來設定安裝每支 sensor 以便轉換為工程單位運算，請查看 SBE 11 Plus Deck unit 及 SBE RAM 手冊。

溫度計：－1℃，Fs = 6 kHz， Sensitivity 感度 = 146 Hz/°C，解析度 = 0.00014 ℃ per bit。

31 ℃,Fs = 12 kHz， Sensitivity 感度 = 233 Hz/°C，解析度 = 0.00018 ℃ per bit。

電導度： 1.4 Siemens/meter(S/M), Fs = 5 kHz， Sensitivity = 1900 Hz/(s/m)

壓力：(10,000 psi 數位 sensor，假設轉換因子為 1.46 psi/meter，解析度隨其 sensor 成比例改變。

在空氣中 (0 M 深)， Fs = 33.994 Hz, Sensitivity 感度 = 0.726 Hz/m，解析度 = 0.041 m/bit 。

3-1.3 精確度

系統之正確性乃決定於所使用 sensor 之精確性與石英振盪器所產生之頻率 Fs,Fs 在 0 到 50 ℃ 以內，穩定於 2 ppm 以內，任何之 Fr 錯誤會影響 Fs，當 Fs = 12,000 Hz 下有 5 ppm 之錯誤 Fr，會導致 0.006 Hz 之偏差，反算後會產生 0.0004 ℃ 之最大溫度誤差，或 0.00007 s/m 之電導度誤差。

較低之 sensor 頻率，誤差也小，40,000 Hz 下，頻率誤差為 0.2 Hz，相對深度誤差為 0.3 M (對10,000 psi 壓力 sensor)。

3-1.4 A/D 頻道(附屬輸入)

需要 8 個由 0 到 +5 volt 的電壓順序，其順序上之選擇由 CMOS 複合處理為連續的近似 12 bit 數位訊號。

第一個 A/D 頻道電壓獲得，於開始的每一次掃瞄，間隔為 50 μs ，第二個頻道於下一個 50 μs 中來掃瞄，以此類推。

每個 A/D 頻道使用一個 2 孔之 Butterworth Anti-Aliasing 過濾器來聯接微分輸入放大器。

A/D 轉換器輸入頻道之選擇是由 CMOS 複合器控制，然後以 2 倍於 A/D 轉換器之增益比通過暫存放大器。

3-1.5 解析度(複合 A/D 頻道)

邏輯電壓輸入範圍於 0~+5 V，其增加量是隨著暫存放大器內處理的 A/D 轉換器之 2 倍增益而變化。

而 A/D 輸入範圍是 0~10 V，經轉換至數位化數值，介於 4095~0 之間，其解析為 10V/4096 = 0.0024 V/bit。

3-1.6 精確性(複合 A/D 頻道)

Micro Networks SN MN5206 A/D 轉換器晶片可提供 12 bit 之精確度，並且無需調整。

其低通量過濾器及微分放大器之設計可使其在收集海洋溫度資料的全範圍內，仍然保持在 0.1% 之精確性。

3-1.7 CTD 之譯碼資料格式

以下將說明 CTD 水下主體之資料輸出順序。

對於由 Deck Unit 上不同之輸出埠 IEEE-488 及 RS-232，其資料輸出方式請參閱 Deck Unit 手冊。 SEARAM 的部份，請參閱 SEARAM 手冊。

第一個 byte 之 8 bit 資料包含了壓力、溫度之補償訊息。第二個 byte，包括了剩下 4 個 bit 的壓力、溫度資料及不同條件狀況下之”旗標”。第三個 byte 則是一個計數，隨著成功 scan 到的資料而增加。其餘 15 個 byte 之資料產生順序依序為溫度、電導度及壓力等。

下一筆之資料是由 12 bit 之 A/D 轉換器產生之，其中每一對頻道分配到 3 個 byte。

自水下主體 output 之資料順序如下：

BYTE	內容
1	8 MSB 之壓力、溫度補償。
2	4 LSBs 之壓力、溫度補償，泵浦、底部接觸、採水器確認、數據機狀態 bit。
3	modulo 計量。
4~6	溫度(主要的)。
7~9	電導度(主要的)。
10~12	壓力。
13~15	溫度(第二個)。
16~18	電導度(第二個)。
19~30	12-bit A/D 頻道 0-7。
31~36	擴充部份(全為 0)。

每一次 scan 產生 36 byte 之資料，對於 IEEE-488 埠之當時資料來說， Deck Unit 是在每一次 scan 結束時輸出 MOLULO byte，而非 scan 之開始。

3-1.8 資料遙測之聯接

SBE 9 Plus 將串列資料送至 SBE 11Plus 市是依 RS-232 NRZ 之資料格式作遙測聯接（ 1 個 "START" bit，8 個 "data" bit，1 個 "END" bit)，並且使用 34560 Hz carrier-modulated differential-phase-shift-keying (DPSK)。

當資料流中的反轉訊號在 Deck Unit 內被偵測到，便開始重建 NRZ 資料， SBE 11 Plus 主 cpu 使用的同時，一只單晶片微控制器會配合其工作，來重新格式化 NRZ 資料。

3-1.9 CTD 水下主體電力

其電源供應是透過一鋼纜之聯接，而來自於 Deck Unit。通常使用內部傳導、外部絕緣之雙鋼絲外甲包裹之電子機械鋼纜。

有一個反兩極保護用極體用來保護水下主體與 sea cable 之 cross-wiring。

sea cable 使用時，無需考慮其長度上之變化，其電力供應是完全自動會自我調整的。

水下主體之外殼、內部電力、與 sea cable 電壓彼此間是絕緣的，如此可防止其與任何一者發生電擊腐蝕。

SBE 9 Plus 有一 "預先一調整器"，可減小 sea cable 電壓至 170 V，而 DC－DC 轉換器可用來產生 ＋15V、＋8V、＋5V、及 －15V 電源。 sea cable 電流約為 200 ma (最大掛載輔助設備時)。

Deck Unit 之 250V DC 使用於 sea cable，可供應使用 (250－170 V)/200 ma ＝ 400 ohms 之 cable。

附錄 A

溫度計、電導度計、泵浦 原廠規格表。

OCEANOGRAPHIC THERMOMETER SBE 3

DESCRIPTION

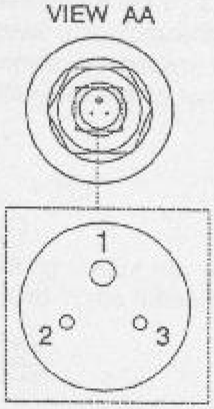
The SBE 3 thermometer is modular and self-contained permitting easy installation, service, and calibration. Two choices of sensor response time (fast or slow) and three depth ratings are offered to suit different application requirements. Model SBE 3 /F provides a "fast" response time of 70 milliseconds and SBE 3 /S has a "slow" response time of 580 milliseconds. The standard aluminum housing is rated to 3,400 meters. Optional aluminum or titanium housings provide 6,800 or 10,500 meter capability. The power/signal cable and CTD mounting hardware are available separately.

The SBE 3 has a proven record of reliability and accuracy with 17 years of field use and calibrations by Northwest Regional Calibration Center (an independent U.S. government contractor). The SBE 3 is a primary sensor for Sea-Bird's SBE 9 CTD Underwater Unit and SBE 25 Sealogger CTD and is also well suited to many custom instrumentation applications.

APPLICATION

Because of the SBE 3's low noise characteristics, hybrid frequency measuring techniques (used in Sea-Bird's CTD instruments) may be used to obtain rapid sampling with very high resolution. A published article [1] describes how a resolution of 40 μ°C per bit may be obtained at a 6 Hz sampling rate.

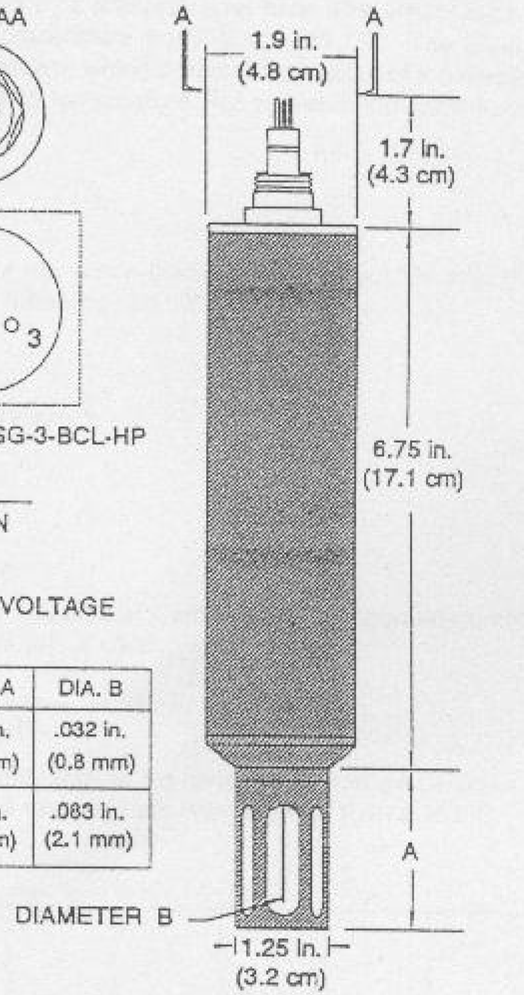
The SBE 3 is an ideal oceanographic tool for obtaining horizontal data with towed systems or vertical data with lowered systems. Its small size makes it especially useful for portable CTD systems and underwater vehicles. Having also found applications in many laboratories, the SBE 3 is beginning to be applied to industrial and environmental temperature monitoring applications, like hydro-turbine inlet and outlet temperature or effluent discharge temperature monitoring.



CONNECTOR : XSG-3-BCL-HP

PIN	SIGNAL
(1)	COMMON
(2)	SIGNAL
(3)	+ INPUT VOLTAGE

MODEL	DIM. A	DIA. B
SBE 3- /F	2.2 in. (5.6 cm)	.032 in. (0.8 mm)
SBE 3- /S	3.3 in. (8.5 cm)	.083 in. (2.1 mm)



Power required: 10 - 20 VDC, 10 ma
Signal output: 0.7 V (rms) sine wave
Materials (3400/6800 m): Anodized aluminum (6061-T6 or 7075-T6)
Materials (10,500 m): Titanium (6Al4V)
Weight (Aluminum): 0.63 kg (1.4 lbs) in air; 0.28 kg (.63 lbs) in water
Weight (Titanium): 0.90 kg (2.0 lbs) in air; 0.55 kg (1.23 lbs) in water

SPECIFICATIONS[1]

Measurement Range: -5.0 to +35 °C.

Accuracy/Stability: ± 0.004 °C per year (typical)
± 0.01 °C per 6 months (guaranteed)

Resolution:[2] 0.0003 °C. @ 24 samples per second

Response Time[3] (Fast): 0.072 sec. (1.0 m/s water velocity)
0.084 sec. (0.5 m/s water velocity)

Response Time[3] (Slow): 0.580 sec. (1.0 m/s water velocity)
0.690 sec. (0.5 m/s water velocity)

Self-heating Error: <0.0001 °C in still water (only 7×10^{-8} watt is dissipated in the thermistor)

Warm-up Time: <2.0 seconds to within 0.005 °C of final value

[1] Typical specifications, referenced to NBS-traceable calibration, and applying over the entire oceanographic range.
[2] Achieved with Sea-Bird's SBE 9 CTD. In custom applications, resolution will depend on the frequency measuring technique used.
[3] Time to reach 63% of final value following a step change in temperature.

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OPERATION

The sensing element is a glass-coated thermistor bead, pressure-protected by a stainless steel tube. The sensor outp frequency ranges from approximately 5 to 13 kHz corresponding to temperature from -5 to +35 °C. The outpu frequency is inversly proportional to the square root of the thermistor resistance which controls the output of a patented Wien Bridge circuit [2]. The thermistor resistance is exponentially related to temperature.The approximate relationship between output frequency and temperature is given by:

$$T = \frac{1790}{\ell n\,(4.34 \times 10^{6}) - \ell n\,(f)} - 273, \qquad [^{\circ}C]$$

where T is temperature [°C] and f is frequency [Hz]. The resulting output has a non-linearity [3] of about 1% over the range of 0 to 25 °C (for precise work, use the equation described in the following CALIBRATION section).

The sensitivity of the circuit is approximately:

$$\frac{\partial f}{\partial T} \approx \frac{7.77 \times 10^{9}}{(273 + T)^{2}}\, e^{\frac{-1790}{273+T}} \qquad [Hz/^{\circ}C]$$

and varies from 146 [Hz/°C] at -1°C to 233 [Hz/°C] at 31°C.

CALIBRATION

Each sensor is calibrated from -1.0 to 31 °C by the Northwest Regional Calibration Center (NRCC), operating under contract to NOAA. The following equation, derived from Bennett's formula [4], is used:

$$T = \frac{1}{A + B\ell n(f_0/f) + C\ell n^{2}(f_0/f) + D\ell n^{3}(f_0/f)} - 273.15, \qquad [^{\circ}C]$$

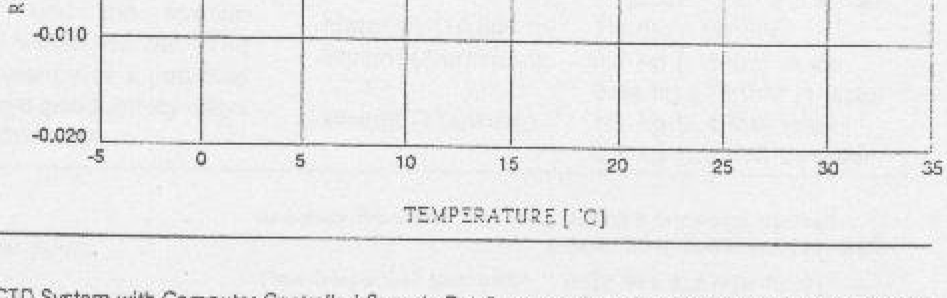
where ℓn is the natural log function, T is temperature [°C.], f_0 is the frequency [Hz] at the lowest temperature calibratic point and the constants A, B, C, and D are determined by computer. The residuals are typically less than 0.002°C.

SAMPLE CALIBRATION DATA FOR SENSOR SERIAL NUMBER 1034

CALIBRATION DATE: 02-09-90

a = 3.67408129e-03   b = 5.98980761e-04
c = 1.50737491e-05   d = 2.45874291e-06
f_0 = 5925.14

BATH TEMP [°C]	INST FREQ [kHz]	INST TEMP [°C]	RESIDUAL (INST - BATH) [°C]
27.0429	10583.73	27.0424	-0.00052
19.0327	9055.77	19.0324	-0.00031
11.0950	7700.56	11.0954	0.00044
3.0268	6475.82	3.0264	-0.00043
31.0788	11417.11	31.0792	0.00038
23.0213	9796.07	23.0212	-0.00010
15.0481	8356.29	15.0488	0.00067
7.0387	7066.36	7.0383	-0.00042
-0.9734	5925.14	-0.9731	0.00029



REFERENCES

[1] A.M. Pederson, "A Modular High Resolution CTD System with Computer-Controlled Sample Rate", proceedings of *International STD Conference and Workshop, pp. 41-47, 1984.*

[2] U.S. Patent Number 3,675,484

[3] Linearity determined by deviation from the best straight line fit

[4] A.S. Bennett, "The Calibration of Thermistors Over the Temperature Range 0-30°C", *Deep Sea Research, Vol. 19, pp.157-163, 1972.*

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CONDUCTIVITY SENSOR

SBE 4

DESCRIPTION

The SBE 4 conductivity sensor is modular and self-contained, permitting easy installation, service, and calibration. The sensor has a frequency output of approximately 3 to 12 kHz corresponding to conductivity from 0 to 7 Siemens/meter [S/m] (optionally 0 to 0.6 S/m), covering the full range of fresh water and oceanic applications. The cell design confines electric fields to the inside of the cell, making measurements and instrument calibration independent of the calibration bath size or proximity to protective cages or other objects; a distinct advantage over inductively coupled or "open" external field cells. 3,400 meter depth capability is standard. Optional housings provide 6,800 or 10,500 meter capability. The power/signal cable and mounting hardware for Sea-Bird CTDs are available separately.

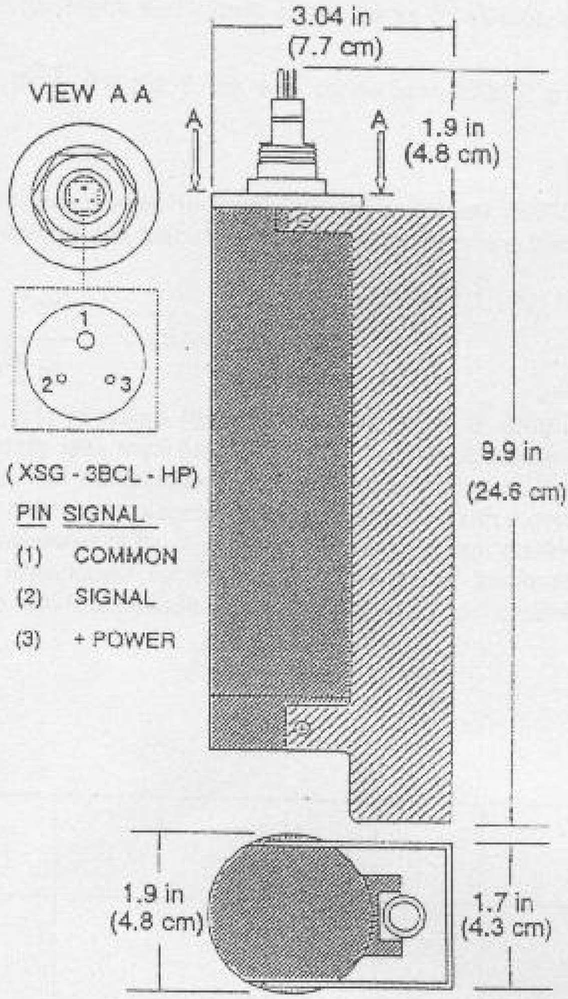
APPLICATION

The SBE 4 is an ideal sensor for vertical profiling with lowered systems or horizontal profiling with towed systems. Its small size is well suited for moorings, portable CTD systems, underwater vehicles or through-the-ice work. It has a proven record of reliability and accuracy with 17 years of field use and calibrations by the Northwest Regional Calibration Center (an independent U.S. government contractor).

The SBE 4 is a primary sensor for Sea-Bird's SBE 9 CTD Underwater Unit and SBE 25 Sealogger CTD and is also easily adapted to custom applications. The SBE 4's low noise characteristics allow the use of hybrid frequency measuring techniques to obtain rapid sampling with very high resolution. A published article [1] describes how a resolution of 1 x 10^{-5} S/m may be obtained at a 6 Hz sampling rate.

OPERATION

The flow-through sensing element is a glass tube (cell) with 3 internal platinum electrodes. The resistance measured between the center electrode and end electrode pair is determined by the cell geometry and the specific conductance (conductivity) of the fluid within the cell. The cell resistance controls the output frequency of a patented Wien Bridge circuit [2]. An internally-fixed conductivity offset enables measurements down to 0 conductivity.



(XSG - 3BCL - HP)

PIN	SIGNAL
(1)	COMMON
(2)	SIGNAL
(3)	+ POWER

Power required: 10 - 20 VDC, 10 ma
Signal output: 0.7 V (rms) sine wave
Materials (3400/6800 m): Anodized aluminum (6061-T6 or 7075-T6)
Materials (10,500 m): Titanium (6Al4V)
Weight (Aluminum): 0.7 kg (1.6 lbs) in air; 0.34 kg (.75 lbs) in water
Weight (Titanium): 1.1 kg (2.4 lbs) in air; 0.7 kg (1.5 lbs) in water

SPECIFICATIONS[1]

Measurement Range:	0.0 to 7 Siemens/meter (S/m) (0.0 to 70 mmho/cm)
Resolution:[2]	0.00004 S/m @ 24 samples per second
Accuracy/Stability:	± 0.0003 S/m/month (typical) ± 0.001 S/m/month (guaranteed)[3]
Time Response[4] (pumped):	0.085 sec. (0.5 m/s drop) 0.070 sec. (1.0 m/s drop)
(no pump):	0.170 sec. (2.0 m/s tow)

[1] Typical specifications, referenced to NBS-traceable calibration, and applying over the entire oceanographic range.
[2] Achieved with Sea-Bird's SBE 9 CTD. In custom applications, resolution will depend on the frequency measuring technique used.
[3] Not applicable in areas of high biofouling activity, highly contaminated waters or if procedures in Application Bulletin 2D are not followed.
[4] Time to reach 63% of final value following a step change in conductivity.

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The approximate relationship between output frequency and conductivity is given by:

$$f = H\,(\sigma + d)^{0.5} \quad \text{[Hz]},$$

where f is output frequency, H is a constant determined by the cell geometry and circuit components (H = 4400), σ is conductivity in [S/m] and d is the conductivity offset (d = 0.4).

The sensitivity of the circuit is approximately: $\partial f/\partial \sigma = 0.5\,H/(\sigma + d)^{0.5}$ [Hz per S/m] and varies from 2700 [Hz per S/m] at 0 S/m to 850 [Hz per S/m] at 6 S/m.

CALIBRATION

All instruments are calibrated from approximately 1.5 to 6 S/m by the Northwest Regional Calibration Center (NRCC), operating under contract to NOAA. Using a least squares fitting technique, the following equation is fitted to the NRCC data and the instrument's zero conductivity frequency:

$$\text{Conductivity} = \frac{af^m + bf^2 + c + dt}{10\,[1 - (9.57\times10^{-8})\,p]} \quad \text{[S/m]}$$

where f is the instrument frequency [kHz], t is temperature [°C], p is pressure [decibars] and a, b, c, d, & m are coefficients listed on the calibration certificate. Residuals are typically less than 0.0003 S/m. A published article [3] describes user experience and also discusses instrument noise level, cell maintenance and calibration methods. Users have since improved performance by using anti-foulant to protect the cell from biological growth. After a 5 month mooring at depths of 80 to 290 meters, four SBE4s with anti-foulant protection showed drifts of <0.0015 S/m over a year's interval between calibrations. An optional anti-foulant device, specifically developed for moorings, consists of anti-foulant impregnated cylinderical attachments at each end of the cell. These anti-foul cylinders are effective for 3 to 12 months in waters with high rates of bio-fouling growth.

SAMPLE CALIBRATION DATA

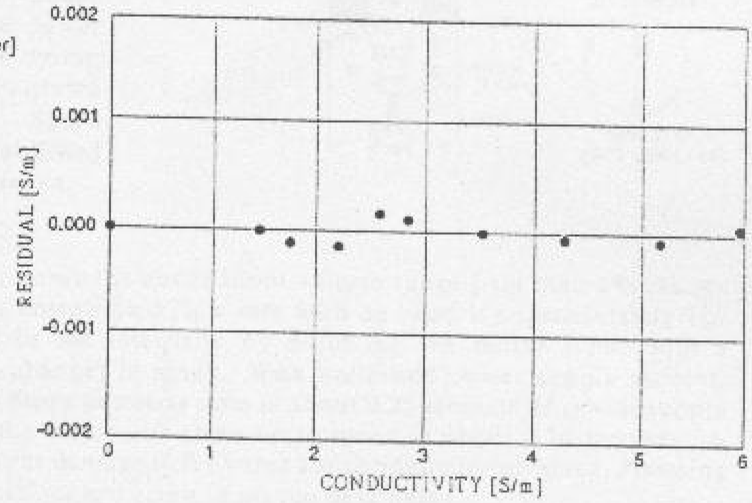
CALIBRATION DATA FOR SENSOR SERIAL NUMBER = 677

CALIBRATION DATE: 9-29-89

Practical Salinity Scale 1978: C(35,15,0) = 4.2914 [Siemens/meter]

a = 2.10166389e-05 b = 3.92391126e-01
c = -3.79740447e+00 d = 1.53484144e-05
m = 3.9

BATH TEMP [°C]	BATH SAL [ppt]	BATH COND [S/m]	INST FREQ [kHz]	INST COND [S/m]	RESIDUAL (INST - BATH) [S/m]
27.1023	15.0406	2.57988	8.67094	2.58007	0.00019
19.1355	15.0404	2.18995	8.08073	2.18980	-0.00015
11.0895	15.0392	1.81543	7.47017	1.81531	-0.00012
3.0062	15.0389	1.46294	6.84567	1.46294	0.00000
31.0877	35.0571	5.96006	12.66879	5.96011	0.00005
23.0432	35.0782	5.11331	11.79726	5.11322	-0.00009
14.9669	35.0776	4.29664	10.98952	4.29660	-0.00004
6.8513	35.0768	3.52152	9.95016	3.52154	0.00002
-1.0729	35.0762	2.81736	9.01093	2.81747	0.00011
0.0000	0.0000	0.00000	3.11027	0.00003	0.00003



REFERENCES

[1] A.M. Pederson, "A Modular High Resolution CTD System with Computer-Controlled Sample Rate", proceedings of International STD Conference and Workshop, pp. 41-47, 1984.

[2] U.S. Patent No. 3,675,484

[3] A.M. Pederson and M.C. Gregg, "Development of a Small In-Situ Conductivity Instrument", IEEE Journal of Ocean Engineering, Vol. OE-4, No 3, pp. 69-75, July 1979.

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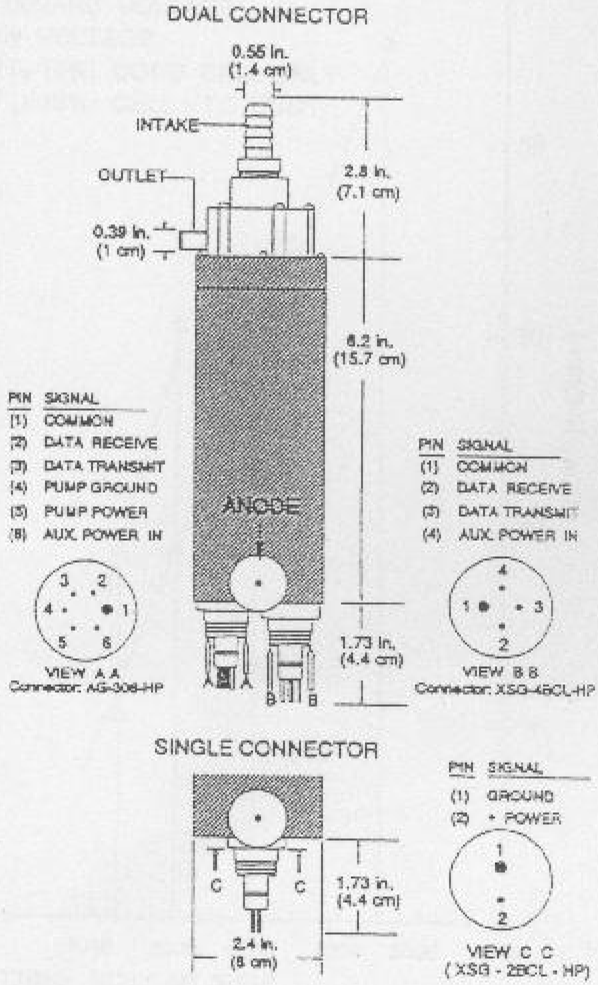
SUBMERSIBLE PUMP

SBE 5

The SBE 5 submersible pump is a compact, modular unit consisting of a centrifugal pump head and a long-life, brushless DC, ball bearing motor contained in an underwater housing. The pump impeller and electric drive motor are coupled magnetically through the pressure housing, eliminating moving seals and providing high reliability.



APPLICATIONS

The SBE 5 is a primary component in Sea-Bird's SBE 9 CTD Underwater Unit and SBE 25 Sealogger CTD. It is also used as optional equipment on the SBE 16 Seacat and SBE 19 Seacat Profiler. The pump flushes water through the conductivity cell at a constant rate, independent of the CTD's motion, improving dynamic performance. The pump is also suitable for many custom applications, where pressure heads are less than 300 cm of water and flow rates are less than 100 ml/sec.

CONFIGURATION

The SBE 5 is configured for various applications by selecting pressure housing, connector, supply voltage, motor power, and speed options. Aluminum and titanium housings are available for depths of 3400, 6800 or 10500 meters. A single connector (as used on the SBE 9) is for pump power. Dual connector pumps are used on SBE 16, 19, & 25 CTDs. Power and data lines from the CTD enter the pump housing through the first connector. The data I/O lines are wired to the other connector which serves as the CTD system's I/O port. Supply voltage options are either "standard" or "low voltage". Motor power options are determined by the windings used on the motor. High power motors use #3 windings, low power motors use #5 windings which draw less current at a given speed. Speed options of 1300, 2000, 3000 or 4500 rpm have been established for most Sea-Bird applications. Other speeds are possible.

OPERATION

Motor speed and pumping rate remain nearly constant over the entire input voltage range (less than 1% change in speed for a 1 volt change in supply voltage). The unrestricted flow rate with no head is approximately 100 ml/second at 2000 rpm. The pumping rate may be set internally by adjusting the motor RPM with a potentiometer. Flow changes are nearly linear with changes in speed. With unlimited power supply current, turn-on surge is about 1.8 amperes (maximum) which drops to steady state in about 0.25 seconds. If power supply current is limited to approximatelty 200 milliamps, the motor will come up to speed in about 0.30 seconds. A series diode is installed in the input power line to prevent damage if the wires are accidentally reversed. Pumping rates and motor current for Sea-Bird's various applications are given in on the next page.

SPECIFICATIONS

Weight (aluminum):	1.1 kilos (2.4 lbs.) in air, 0.5 kilos (1.1 lbs.) in water
Weight (titanium):	1.5 kilos (3.3 lbs.) in air, 0.9 kilos (2.0 lbs.) in water

Standard Voltage input range:	12 - 18 VDC
Low Voltage input range:	6 - 13.5 VDC

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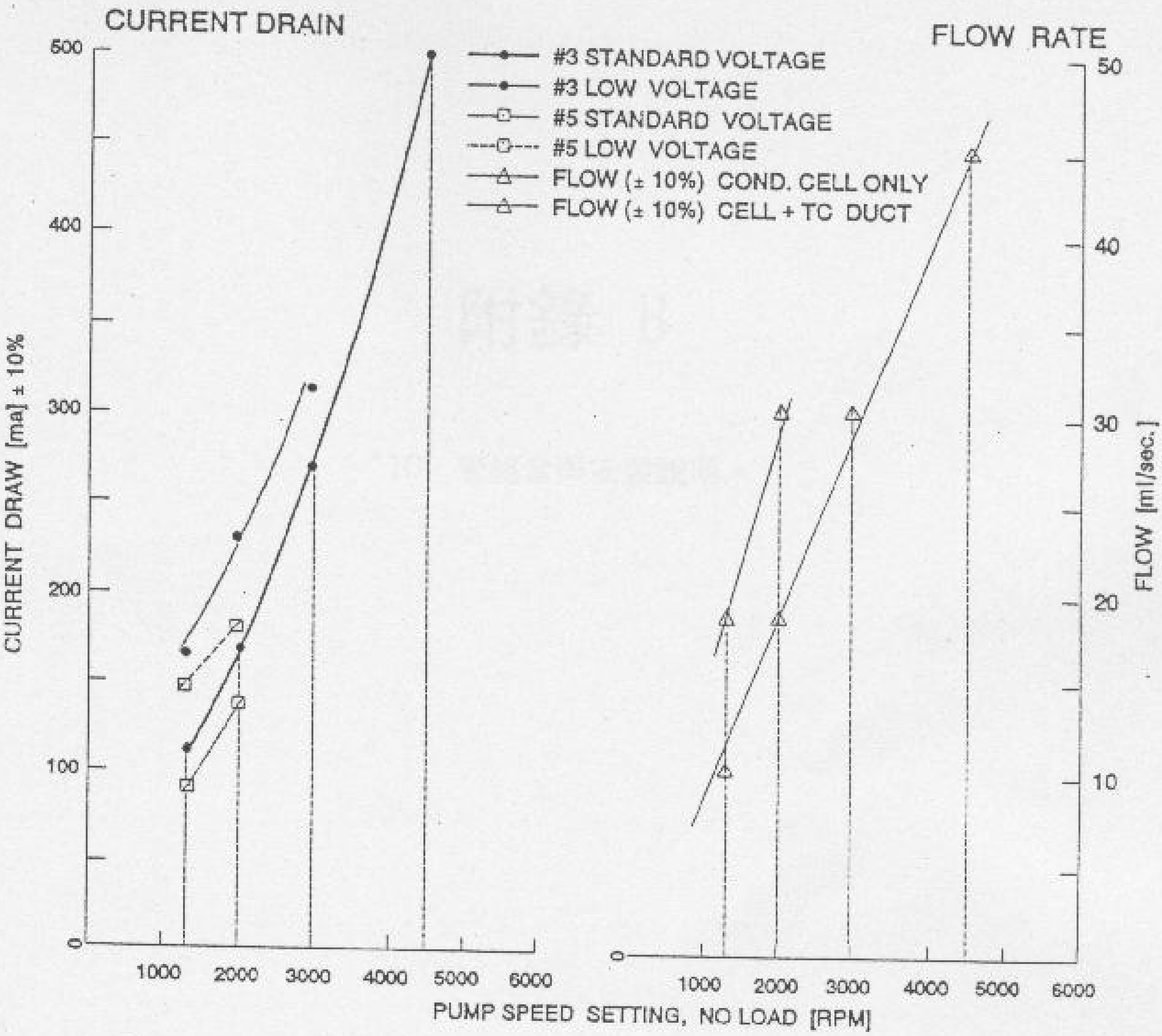

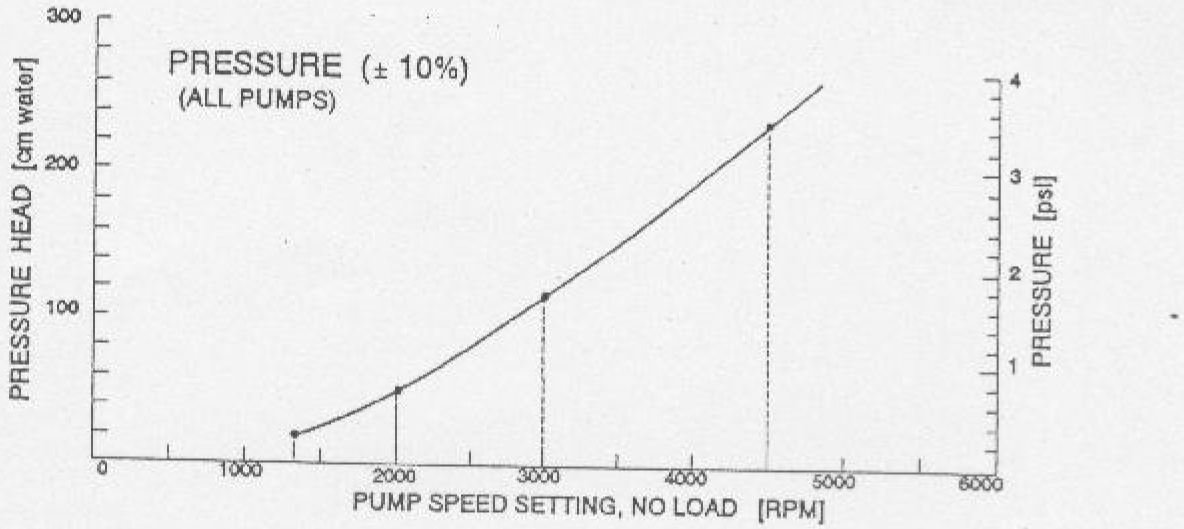

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附錄 B

"TC" 管組合與安裝說明。

SBE SEA-BIRD ELECTRONICS, INC.
1808 - 136th Place Northeast, Bellevue, Washington 98005
Telephone: (206) 643-9866 Fax: (206) 643-9954 Telex: 292915 SBEI UR

APPLICATION NOTE NO. 15

Revised - July 1991

"TC" DUCT ASSEMBLY AND INSTALLATION INSTRUCTIONS

OVERVIEW

The plastic TC duct (Delrin) comes in two pieces; a "T" duct that fits inside the temperature sensor guard over the sensor needle, and a "C" duct that fits into the conductivity cell. The two duct pieces are joined with flexible plastic tubing (Tygon) to form the TC duct assembly. The "TC" duct is designed to fit the SBE 3 temperature and SBE 4 conductivity sensors used on the SBE 9 CTD and SBE 25 SEALOGGER CTD only when equipped with the standard sensor mounting bracket.

SCOPE OF WORK

The "TC" duct Retro-fit Kit can be installed without modification on SBE 3 temperature sensors manufactured after November 1988. Older sensors have a sensor needle of a larger diameter and will require drilling the "T" duct to make it fit the old style sensor.

To retro-fit the TC duct, the temperature sensor must be repositioned in the mounting bracket so the end of the sensor guard extends beyond the end of the conductivity cell guard. On some older SBE 9 systems, the horizontal arm of the "C" duct may need to be trimmed to the proper length before installation. In this case, the bore of the trimmed end should be tapered as shown in the following instructions.

CAUTION - Many of the modification and installation steps described in this instruction require extreme care and precision to insure maximum CTD accuracy and prevent damage to the sensors during installation. Carefully read through these instructions BEFORE beginning work and make sure the appropriate work place and tools are available.

TOOLS REQUIRED

- ___ sharp knife or scalpel for cutting short lengths of Tygon tubing
- ___ straight edged ruler for measuring and cutting straight lines
- ___ pin vise for drilling the "T" duct (if necessary)
- ___ fine-toothed backsaw (approx. 50 teeth per inch or finer) for cutting the "C" section (if necessary)
- ___ 10 degree (approx.) tapering tool (ie. sharp pencil)
- ___ 400 grit (very fine) sand paper

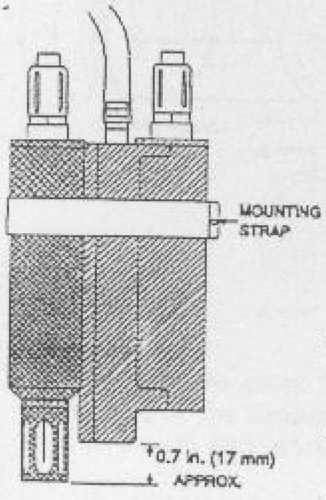
PARTS AND SUPPLIES INCLUDED IN KIT

- ___ new temperature sensor guard with "T" duct installed
- ___ "C" duct
- ___ 0.0492" (1.25mm) drill bit for modifying the "T" duct
- ___ Tygon tubing: 0.25" ID, 0.03" wall, 1 length: 1.0" (25mm) approx.
- ___ Tygon tubing: 0.25" ID, 0.125" wall, 1 length: 1.0" (25mm) approx.
- ___ Tygon tubing: 7/16" ID, 1/16" wall, 1 length: 2.0" (50mm) approx.
- ___ Silicone grease

STANDARD INSTALLATION PROCEDURES

Fitting the "T" Section of the Duct

Figure 1



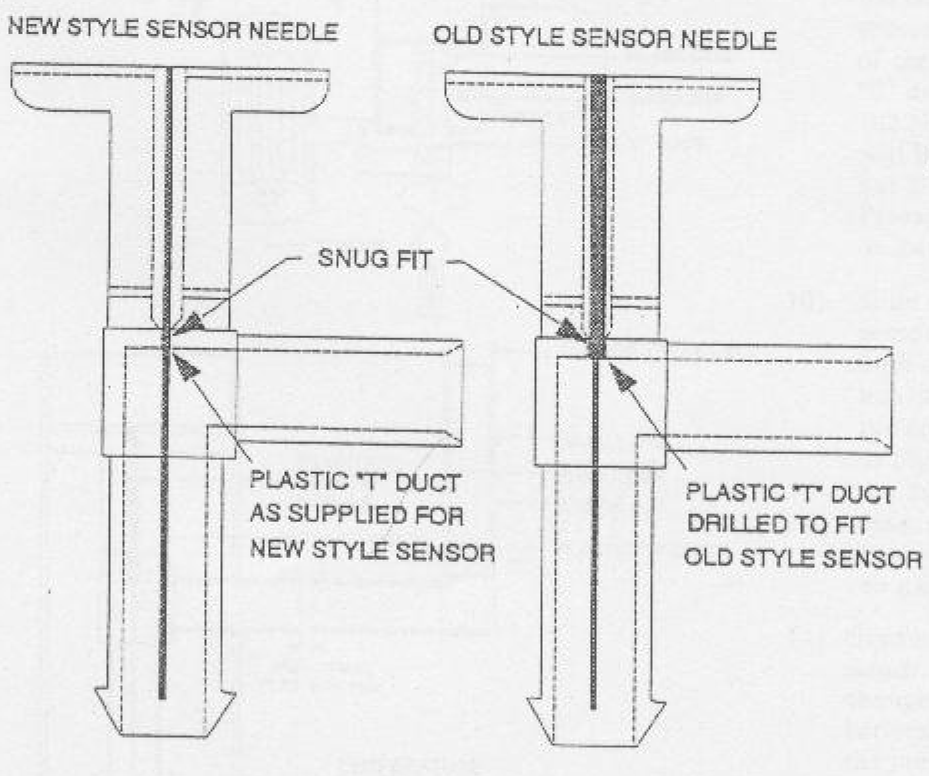
1) Work with the CTD cage lying horizontally so the conductivity and temperature sensors are on top.

2) Loosen the strap that secures the temperature and conductivity sensors in the sensor mounting bracket and slide the temperature sensor so the end of the sensor guard extends beyond the conductivity cell guard about 0.7 inches. Re-tighten the strap enough to secure the sensors but still allow them to be slid and rotated in the mounting bracket.

3) Unscrew the temperature sensor guard. **Avoid touching the fragile temperature sensor needle.**

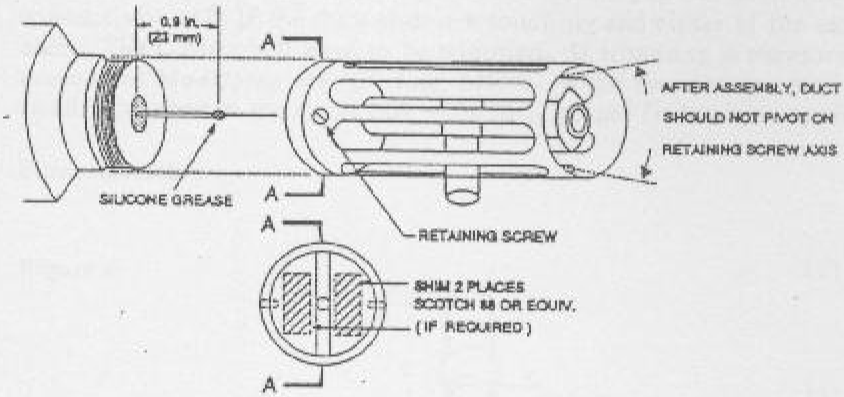
4) Refer to Figure 2; note which type of sensor needle you have.

Figure 2



5) If you have an old style sensor needle with a stepped diameter shaft, go to the Special Installation Procedures, *Modifying the "T" duct*, on page 4. If you have a new style sensor needle with a thin shaft, go to step 6.

Figure 3



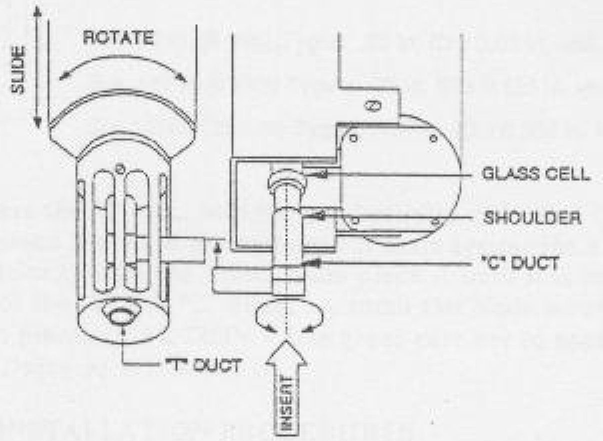
6) Apply a small bead of silicone grease to the temperature sensor needle ONLY where it makes a snug fit in the "T" section (0.9" from the base). DO NOT get grease on the needle tip.

7) Install the new temperature guard (with the "T" duct installed in it) inserting the temperature sensor needle gently into the base of the duct. Do not bend or torque the needle in any way.

8) Make sure the guard is screwed on tightly (by hand only) and the base of the "T" duct seats against the face of the temperature sensor housing and does not move. If it does, shim the base of the duct with Scotch 88 electrical tape (or equiv.) (Shimming is usually not required).

Fitting the "C" Section of the Duct

Figure 4



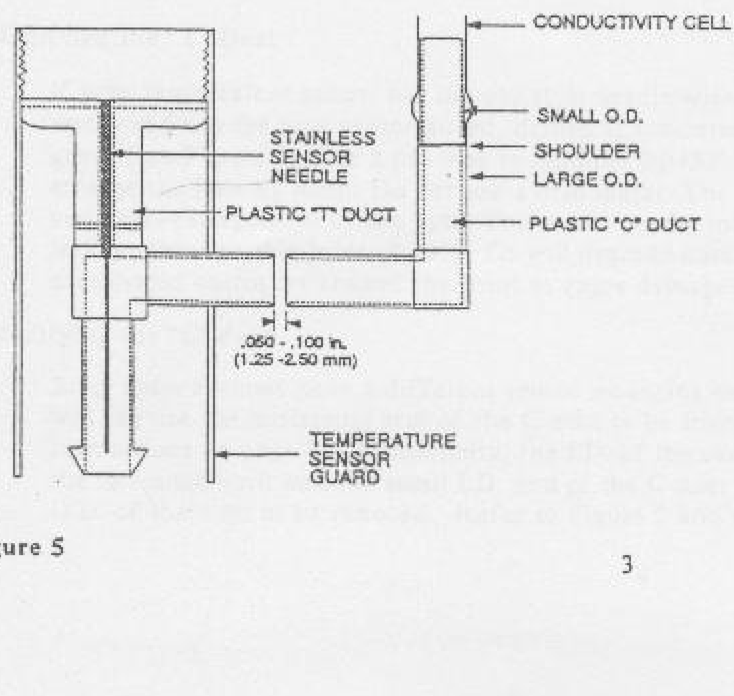


Figure 5

9) Insert the small OD end of the "C" duct into the intake of the conductivity cell until the duct shoulder butts against the end of the cell and rotate the horizontal arm of the duct toward the temperature sensor. Due to variations in the I.D. of the conductivity cell intake, the "C" duct may not fit into some cells. **DO NOT FORCE** the fit. Doing so will break the cell. If the duct does not fit, go to the Special Installation Precedures, *Modifying the "C" duct*, on page 4.

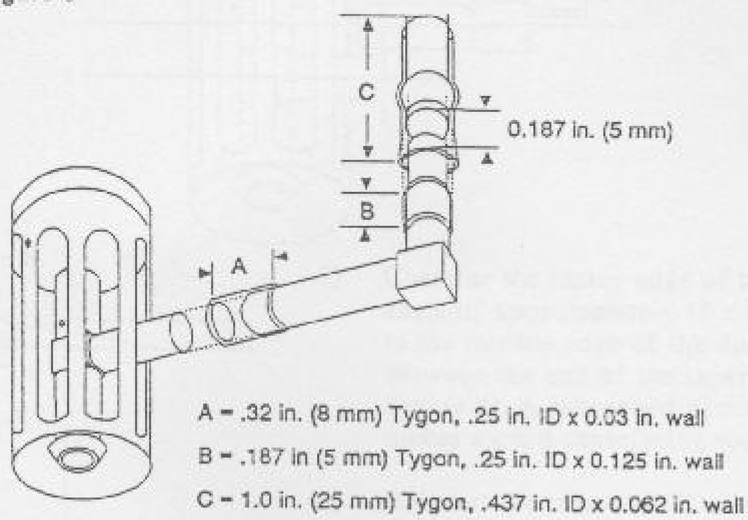
10) Slide and rotate the temperature sensor until the horizontal arms of both ducts are perfectly aligned, leaving a gap of .05 - .10" between the ends of the T and C ducts. Refer to Figure 5. On some older systems, the duct arms will overlap. In this case, go to the Special Installation Precedures, *Modifying the "C" duct*, on page 4.

11) Gradually tighten the screw on the sensor mounting block, checking for changes in alignment and the gap between the T and C duct ends. As the temperature and conductivity sensors are tightened into their mounting block, the "T" and "C"ducts

usually move closer together, reducing or eliminating the gap between the horizontal arms. **DO NOT continue to tighten the mounting block after the gap has been eliminated.** Doing so will break the glass conductivity cell. If the duct ends are touching and either of the sensors are not secure in the mounting block, The C duct will have to be trimmed. If trimming is necesary, go to the Special Installation Precedure, *Modifying the "C" duct*, below. When the sensors are securely tightened and there is still a small gap between the ducts (.02 – .05 in.), proper fit has been verified and final assembly can be done.

Final Assembly

Figure 6



12) Remove the "C" duct and cut the three pieces of Tygon tubing (A,B,C) per Figure 6.

13) Push piece A (.32" x .25" ID x .03 wall) over the large OD end of the "C" duct and flush with the end.

14) Push piece B (.187" x .25" ID x .125 wall) over the small OD end of the "C" duct sliding it over and well past the duct shoulder.

15) Slide piece C (1" x .437 ID x .062 wall) over the end of the conductivity cell. Leave about 0.20 inches hanging off the end of the cell.

16) Reinsert the "C" duct into the conductivity cell. Seat the shoulder of the duct against the cell and slide piece B toward the cell until it seats against the end of the cell and inside piece C. This hermetically seals the joint. Slide piece A until it is centered over the joint between the horizontal arms of the "T" and "C" ducts. A small flat blade screw driver is useful in sliding and mating the Tygon pieces. CAUTION - Use great care not to apply force perpendicular to the end of the glass cell. Doing so will break it!

SPECIAL INSTALLATION PROCEDURES

Modifying the "T" Duct

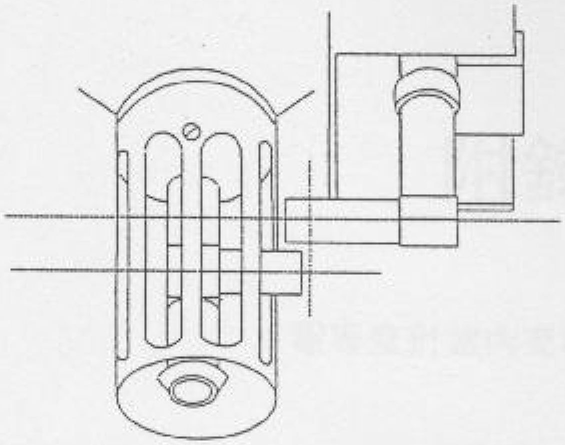
If your temperature sensor has the old style needle with a stepped diameter, the "T" duct must be removed from the new sensor guard, drilled as indicated in Figure 2 and reinstalled in the sensor guard (see Figure 3). Use a pin vise to hold the 0.0492" (1.25mm) drill bit supplied in the kit and enlarge the hole by hand. Do not use a drill motor. The high speed will likely cause poor precision and over-enlargement of the hole. The sensor needle must fit snugly (not tight) to prevent flow leakage through this joint. A loose fit will degrade data quality. A fit that is too tight may cause accelerated corrosion around the joint or cause damage to the sensor needle.

Modifying the "C" duct

Some older systems have a different sensor mounting bracket, causing the duct arms to overlap. This will require the horizontal arm of the C duct to be trimmed. Refer to figures 7 & 8 and the related instructions on page 5. Occasionally, the I.D. of the conductivity cell intake falls on the low side of the tolerance limit and the small I.D. end of the C duct will not fit into the cell. This will require the O.D. of the duct to be reduced. Refer to Figure 9 and the related instructions on page 5.

Trimming the Horizontal Arm of the C Duct

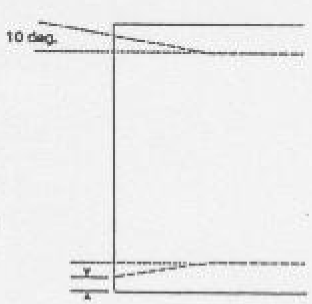
Figure 7



1) Rotate and/or slide the temperature sensor until the center lines of the horizontal duct arms are parallel. Mark the end of the "C" duct for trimming as shown in Figure 7, leaving a gap of 0.05 to 0.1".

2) Remove the "C" duct, trim off the end with a fine-toothed backsaw, sand or file the cut square and flat and remove any burrs. Be careful not to crush the thin walled duct while cutting.

Figure 8

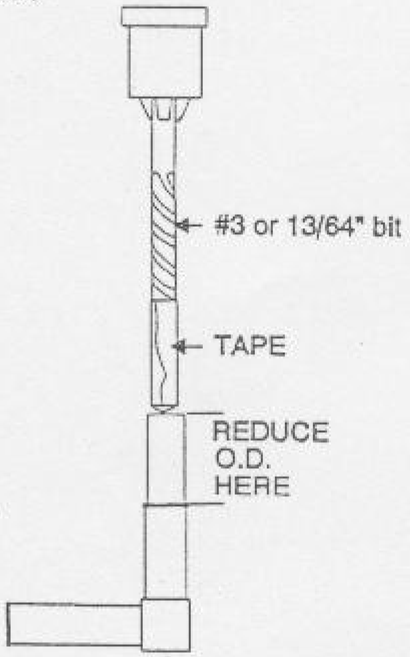


3) Chamfer the inside edge of the trimmed end of the "C" duct at an angle of approximately 10 degrees. Be careful not to taper all the way to the outside edge of the duct. Leave about half the wall thickness between the end of the taper and the outside of the duct wall (see Figure 8). A sharpened pencil, wrapped with 400 grit sandpaper makes a good chamfering tool.

4) Reinsert the trimmed "C" duct into the neck of the conductivity cell and move the temperature sensor until the center lines of both ducts are perfectly aligned (refer to Figure 5). Resume Standard Installation Procedures at step 10. If a second trimming is required, do not remove more than 0.10 inch.

Reducing the O.D. of the "C" Duct

Figure 9



1) Use a #3 or 13/64" drill bit and wrap 1 or 2 layers of Scotch tape (#810 "Magic tape" or equal) around the bit to cover the sharp edges and build up the diameter to create a snug friction fit inside the small O.D. end of the "C" duct.

2) Chuck the bit in a drill press and spin the duct slowly (100–200 rpm). Use 400 grit sand paper with a flat metal backing and light pressure to reduce the small O.D. section of the duct a little at a time. Test the fit in the end of the conductivity cell frequently until the small O.D. of the duct fits all the way into the cell without resistance.

3) Clean the duct with water after sanding to remove dust and grit and resume the Standard Installation Procedure at step 8.

附錄 C

電導度計室內充填與儲存裝置。

SBE SEA-BIRD ELECTRONICS, INC.
1808 - 136th Place Northeast, Bellevue, Washington 98005
Telephone: (206) 643-9866 Fax: (206) 643-9954 Telex: 292915 SBEI UR

APPLICATION NOTE NO. 34

January 1992

CONDUCTIVITY CELL FILLING AND STORAGE DEVICE P/N 50087

INSTRUCTIONS FOR USE

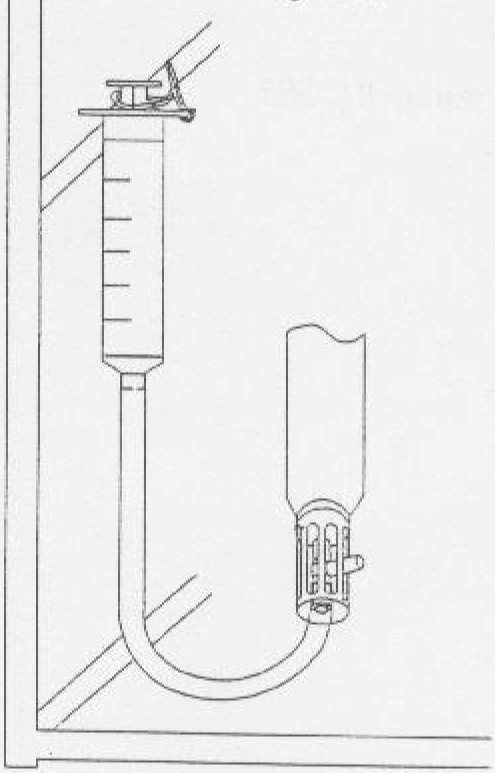


Figure 1

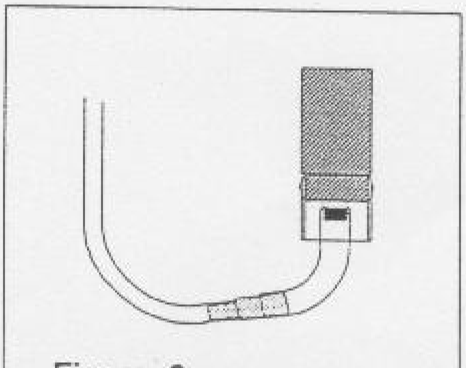


Figure 2

Sea-Bird recommends keeping the conductivity cell full of purified water (except in freezing environments) during periods when the CTD is not being used. This is important in keeping the cell free from contamination and in keeping the electrodes wetted and ready for immediate use.

CTDs with pumped conductivity cells (SBE 911, SBE 25 and some Seacats) are shipped with syringe and tubing assembly (P/N 50087) as an accessory for filling and storing the conductivity cell. The tubing assembly consists of a length of 1/4 inch I.D. tube connected to a short piece of 7/16 inch I.D. tube by a plastic reducing union.

To fill the conductivity cell, draw about 40-60 cc of purified water into the syringe, connect the plastic tubing to the TC duct intake on the temperature sensor [Figure 1], (or to the open end of the conductivity cell on systems without the TC duct [Figure 2]) and inject water into the cell and pump plumbing.

For CTDs with a TC duct, remove the plastic reducing union and connect the smaller diameter tubing directly to the TC duct. For CTDs without a TC duct, leave the reducing union and large diameter tubing attached and carefully connect the tubing directly to the end of the glass conductivity cell [Figure 2].

After filling the conductivity cell, loop the rubber band around a bar on the CTD cage and back over the top of the syringe to secure the apparatus for storage.

REMEMBER TO REMOVE THE SYRINGE AND TUBING ASSEMBLY BEFORE DEPLOYMENT !

附錄 D

SBE 19 plus 與 輪盤採水器之組合使用。

SBE SEA-BIRD ELECTRONICS, INC.
1808 - 136th Place Northeast, Bellevue, Washington 98005
Telephone: (206) 643-9866 Fax: (206) 643-9954 Telex: 292915 SBEI UR

APPLICATION NOTE NO. 35

FEBRUARY 1992

INSTRUCTIONS FOR USE OF SBE 911*plus* CTD WITH GENERAL OCEANICS ROSETTES

The Sea-Bird SBE 911*plus* CTD system is electrically and mechanically compatible with standard, unmodified rosette water samplers made by General Oceanics (G-O). The SBE 911*plus* can be ordered with the optional modem and rosette interfaces. These items allow the SBE 911*plus* to control the operation of the rosette directly and without interrupting the data from the CTD. The use of the SBE 911*plus* in this manner eliminates the need for the G-O deck box.

Mechanical Interfacing

Vertical mounting of the CTD to the rosette pylon is shown in figure 1. The CTD underwater unit (SBE 9) is removed from its stainless-steel guard cage and a special clamp (Sea-Bird #24083, General Oceanics# C1015-SB-2) is fixed just under the CTD's top endcap flange. Four heavy threaded rods pass through this clamp and secure the CTD assembly to the rosette's lower bottle plate. An extension stand must be used to provide sufficient height to protect the CTD sensors when the rosette is on deck. Consult General Oceanics for the extension stand appropriate for your rosette. Note that the CTD will be in the 'wake' of the rosette during the upcast; the rosette will modify the temperature of the water as it passes through, and the CTD will respond accordingly. Optimum data quality cannot be obtained under these conditions and only the downcast data should be used. If the 'TC Duct' is employed, the plumbing connections are the same as without the rosette.

Horizontal mounting of the CTD may be feasible where the rosette frame is of sufficient diameter. (figure 2); a somewhat smaller diameter will suffice if the CTD is removed from its cage and mounted with suitable clamps. Notice that the pump position is altered and the 'return tubing' deleted; in the horizontal configuration there is no vertical component to the water in the system. This makes the system inherently insensitive to ship's motion induced vertical accelerations. By positioning the TC Duct intake close to the rosette frame's periphery and out of the wake of the pylon/bottle assembly, it may be possible to obtain good upcast in addition to downcast data.

Electrical Interfacing

The SBE 9*plus* is connected to the G-O rosette using a three pin jumper cable (P/N 17196, reverse polarity cable). When using this cable the switch in the rosette pylon should be set for 'reverse polarity'. It is possible to use a rosette set for 'normal polarity' by connecting a different cable (P/N 17533, normal polarity cable) between the G-O pylon and the CTD rosette connector.

Note that with the SBE 9*plus* there is no Y-cable between the sea cable termination, the CTD and the rosette as is used with older SBE 9 systems and EG&G CTDs. The sea cable is connected directly to the CTD at connector JT1. A jumper cable is then used between CTD connector JT4 and the connector on the rosette pylon. (see SBE drawing no. 50076 or 50077 and figure 3)

CTD/Rosette Operation

The firing of the bottles on the rosette can be accomplished by three different methods. During the display of real time data using SEASAVE, function keys [CTRL] F3 can be used to enable and fire bottles (if the computer serial port is connected to the modem port on the SBE 11*plus*). The buttons on the front panel of the deck unit can be used in a similar manner whether or not the primary logging computer has its serial port connected to the modem port. A third option is to connect a second computer to the modem communications port on the SBE 11*plus* and use the program TMODEM to control the rosette operation.

If the bottle has been enabled, sending a fire signal will cause the immediate closing of the enabled bottle on the rosette. If the bottle has not been enabled sending a fire command will initiate a 15 second arming sequence followed by the firing of the bottle.

When the SBE 9*plus* underwater unit detects a bottle confirmation from the G-O rosette it:

1) sends a confirm message to the computer connected to the modem port

2) sets a bit high in the modulo word for 1.5 sec. The confirm bit is a permanent mark in the CTD data stream for later ID and processing of the rosette bottle data and is used by SEASAVE to keep track of the number of bottles fired.

Note: If the rosette pylon has been enabled, turning off the deck unit power will cause the pylon to fire. This situation can cause bottles to trip in unexpected locations. Tripping a bottle on deck may be hazardous.

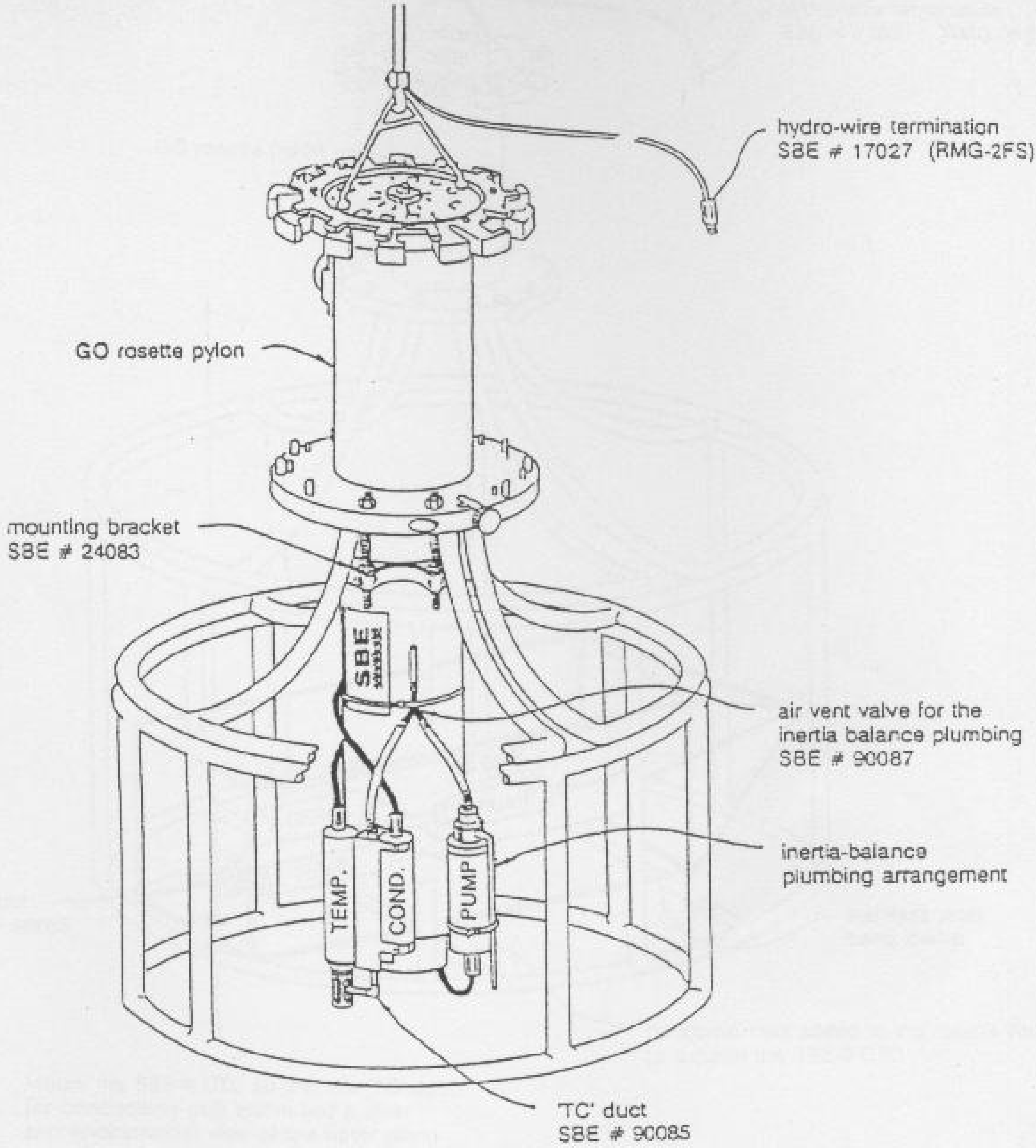


Figure 1 **VERTICAL MOUNTING** of the SBE-9 CTD to the General Oceanics rosette pylon. The CTD is removed from the SBE guard cage and the CTD top end bolted to the bottom of the pylon with a special mounting bracket (SBE #24083). In this figure inertia-balanced plumbing has been installed; the pump is mounted with the pump head up and connected to the conductivity cell through a air vent valve (SBE #90087). The filter and orifice assembly, normally between the conductivity cell and pump have been removed. In addition, the 'TC' duct has been installed on the sensing end of the temperature and conductivity sensors.

Inertia-balanced plumbing removes pump speed fluctuations induced by accelerations of the CTD package. The duct improves salinity by channeling the same water past both sensors, and precisely controlling the dynamic response and time lag between measurements of both sensors.

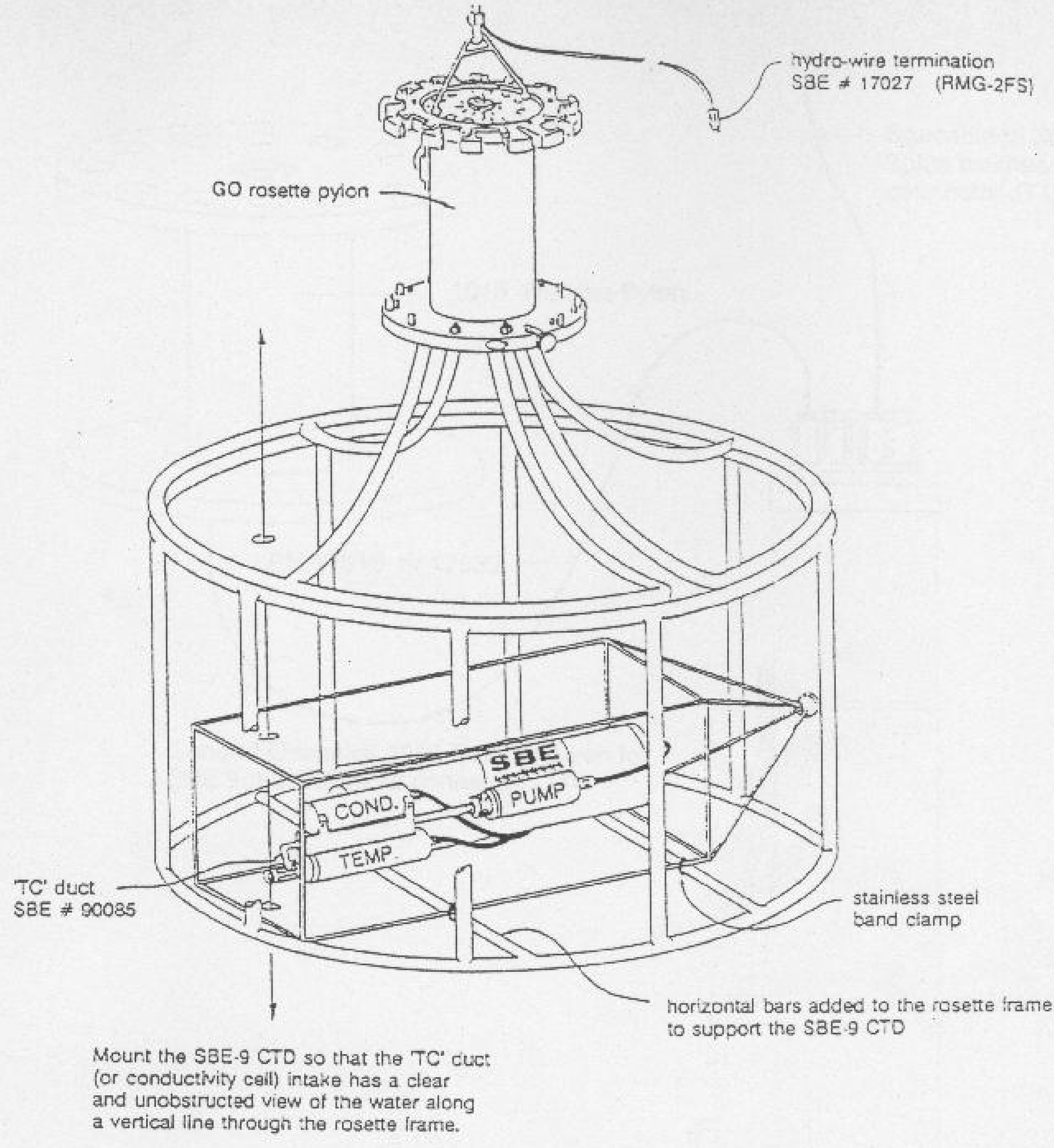


Figure 2 HORIZONTAL MOUNTING of the SBE-9 CTD in a General Oceanics rosette frame. The CTD is left in the SBE guard cage and the guard cage is clamped to horizontal bars at the bottom of the rosette frame. The pump is mounted in a straight line behind the conductivity cell with the base of the pump exhaust port oriented straight up (so that all trapped air in the pump chamber can escape). In this figure a 'TC' duct has been installed on the sensing end of the temperature and conductivity sensors, consequently the filter and orifice assembly between the conductivity cell and pump have been removed.

One advantage of the horizontal mounting is the ability to collect CTD data on both the down and up profiles. To obtain the best data, mount the CTD so that the 'TC' duct (or conductivity cell) intake is as close to the edge of the frame as possible while maintaining an unobstructed view on a vertical line through the intake (so that the frame or rosette bottles do not disturb the water that the CTD samples).

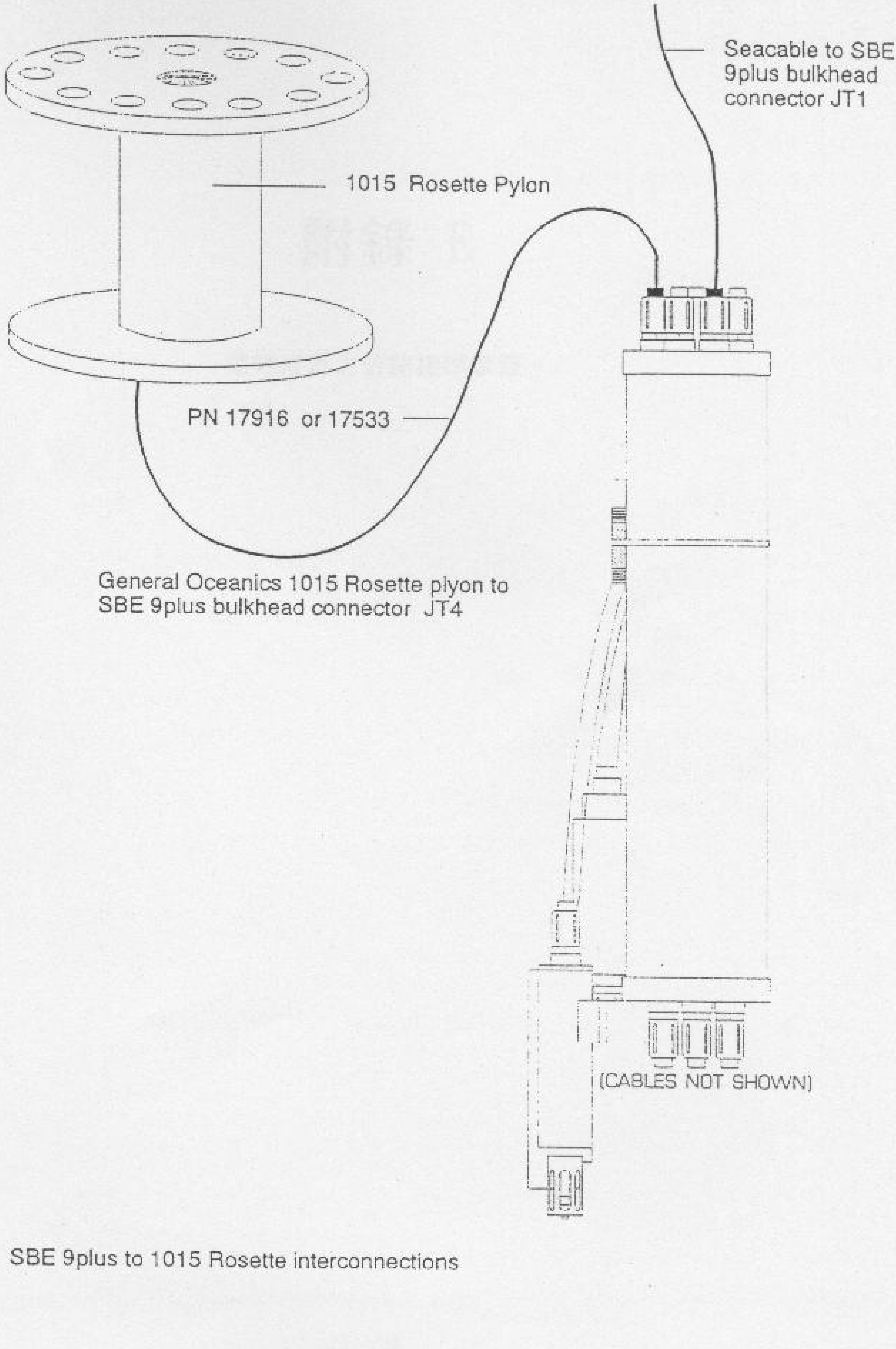


Figure 3 SBE 9plus to 1015 Rosette interconnections

附錄 E

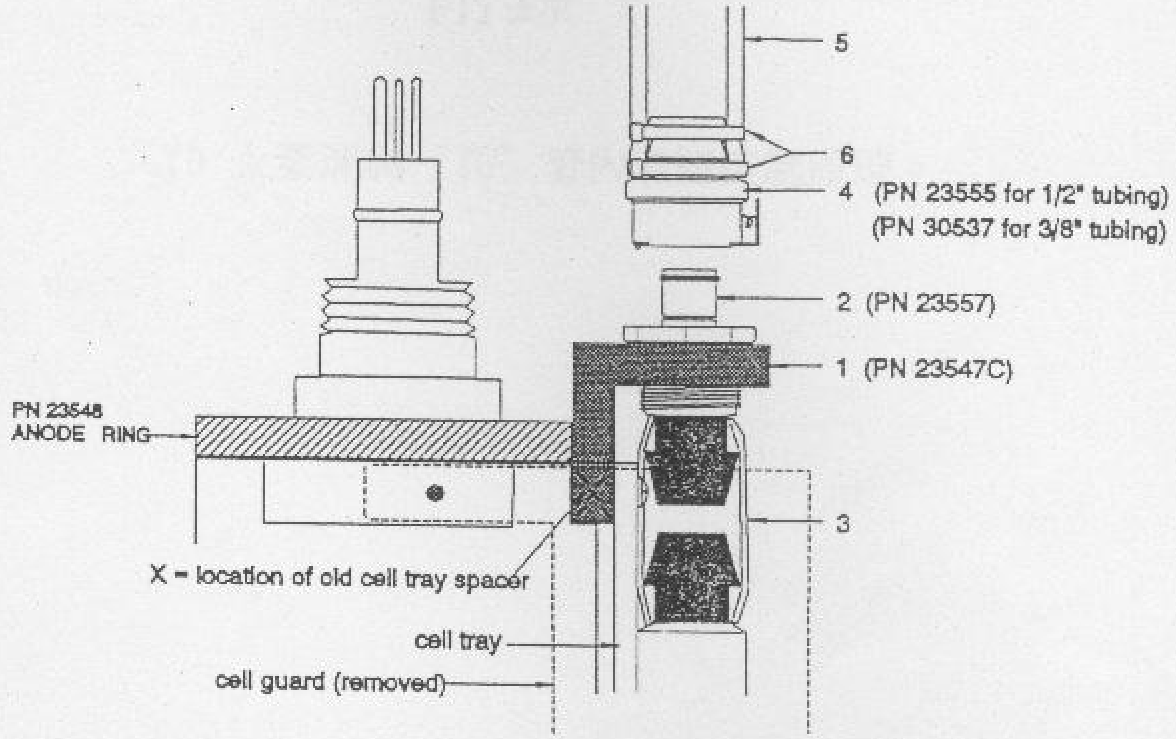
電導度計之管路接頭裝置。

SBE SEA-BIRD ELECTRONICS, INC.
1808 - 136th Place Northeast, Bellevue, Washington 98005-2398
Telephone: (206) 643-9866 Fax: (206) 643-9954 Telex:292915 SBEI UR

APPLICATION NOTE NO. 36A

February 1993

INSTALLATION OF PN 50094 CONDUCTIVITY CELL TUBING CONNECTOR KIT



a. Remove conductivity sensor from the CTD and remove the cell guard from the sensor housing (4 screws).

b. Remove the anode ring from the top of the sensor housing and install the new flat-sided anode ring in its place.

c. Remove the two screws at the top of the cell tray and take the cell tray spacer out from between the cell tray and the sensor housing.

d. Screw the male tubing connector (item 2) into the connector bracket.

e. Insert the connector bracket at the location of the old cell tray spacer and measure the length of tubing (item 3, 7/16 ID x 1/16 wall) required to connect the cell end and the connector.

f. Remove the connector bracket, cut the appropriate length of Tygon tubing (7/16 ID x 1/16 wall) and push one end onto the tubing connector.

g. Reinsert the connector bracket between the cell tray and sensor housing, carefully pushing Tygon tubing onto the end of the conductivity cell. Make sure the tubing is not bulged, out of line, or putting any stress on the cell end.

h. Reinstall the 2 screws through the holes in the cell tray and connector bracket.

i. Replace the cell guard.

j Insert the hose barb end of the female tubing connector (item 4) into the end of the Tygon tubing (item 5) leading from the pump intake. Secure the tubing to the connector with nylon cable ties as shown (item 6).

k. Push the male and female connectors (items 2 and 4) together until they lock. Push the metal tab on the female connector to unlock.

附錄 F

CTD 上泵浦與 "TC" 管內流體控制原理。

SBE SEA-BIRD ELECTRONICS, INC.
1808 - 136th Place Northeast, Bellevue, Washington 98005-2398
Telephone: (206) 643-9866 Fax: (206) 643-9954 Telex:292915 SBEI UR

Application Note 38

December 1992

Fundamentals of the TC duct and pump-controlled flow used on Sea-Bird CTDs

Scientists are interested in salinity and density, but CTD probes measure the pressure, temperature, and electrical conductivity of the ocean water. Because salinity and density are computed from the C, T, and P values, it is obvious that the C, T, and P measurements must be made on the same parcel of water, otherwise the computed salinity and density will be wrong and "spiking" will result (the pressure sensor can be above or below so long as its physical displacement is taken into account).

Many CTD probes fail to measure C and T on the same water parcel because the C and T sensors are physically separated, or because the C and T sensors have different time responses. Especially, the time response of their conductivity cells depends on the CTD drop rate, with more time required to fill the cell at slower speeds. Unless the CTD profiling speed is known and constant (it almost never is constant because of ship motion), the response time of these system's conductivity cell will be continuously changing and serious spiking will result.

To reduce salinity and density spiking to the lowest possible level *with out loss of resolution caused by data averaging*, Sea-Bird uses a TC duct and a pump. These two features ensure that the measurement of temperature and conductivity are made on the *same parcel of water* as follows:

TC duct: all the water sensed by both the temperature and conductivity cell must pass through a single small (0.4 cm) diameter opening.

Pump: the electronically controlled pump forces the seawater to flow at a constant 30 cm^3/second speed to ensure that the C - T time responses are constant.

The physical arrangement of the Sea-Bird T and C sensors with TC duct is shown in Figure 1. As the CTD descends, water is taken in at the duct opening (the opening points downward) and its temperature is immediately sensed. After a small time delay of 0.073 seconds during which the water flows through the duct, the water enters the conductivity cell. The 0.073 second delay is constant because the pumping speed is fixed. This delay is automatically corrected in real-time by the SBE 11*plus* Deck Unit.

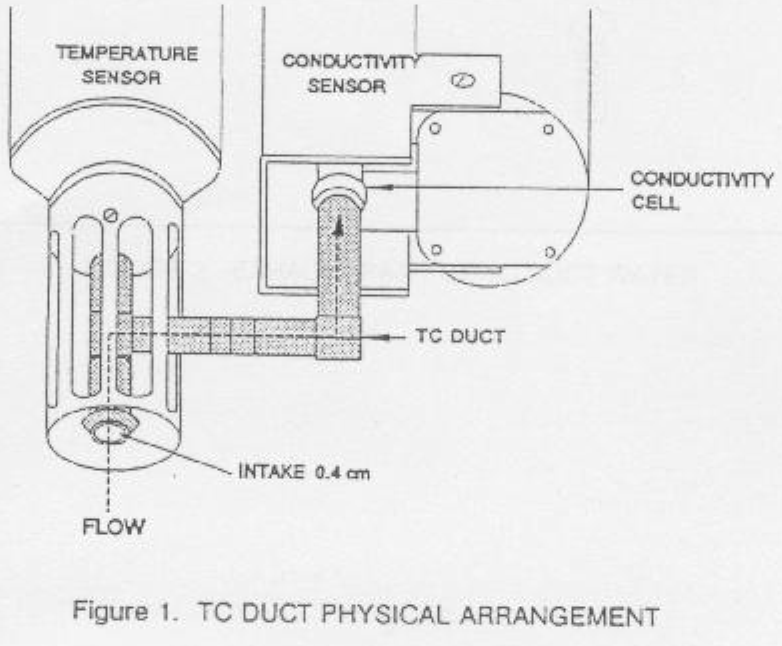


Figure 1. TC DUCT PHYSICAL ARRANGEMENT

Note that the downward exhaust of the pumped water (Figure 2) eliminates any "ram" effect that would cause the flow rate to be affected by profiling speed.

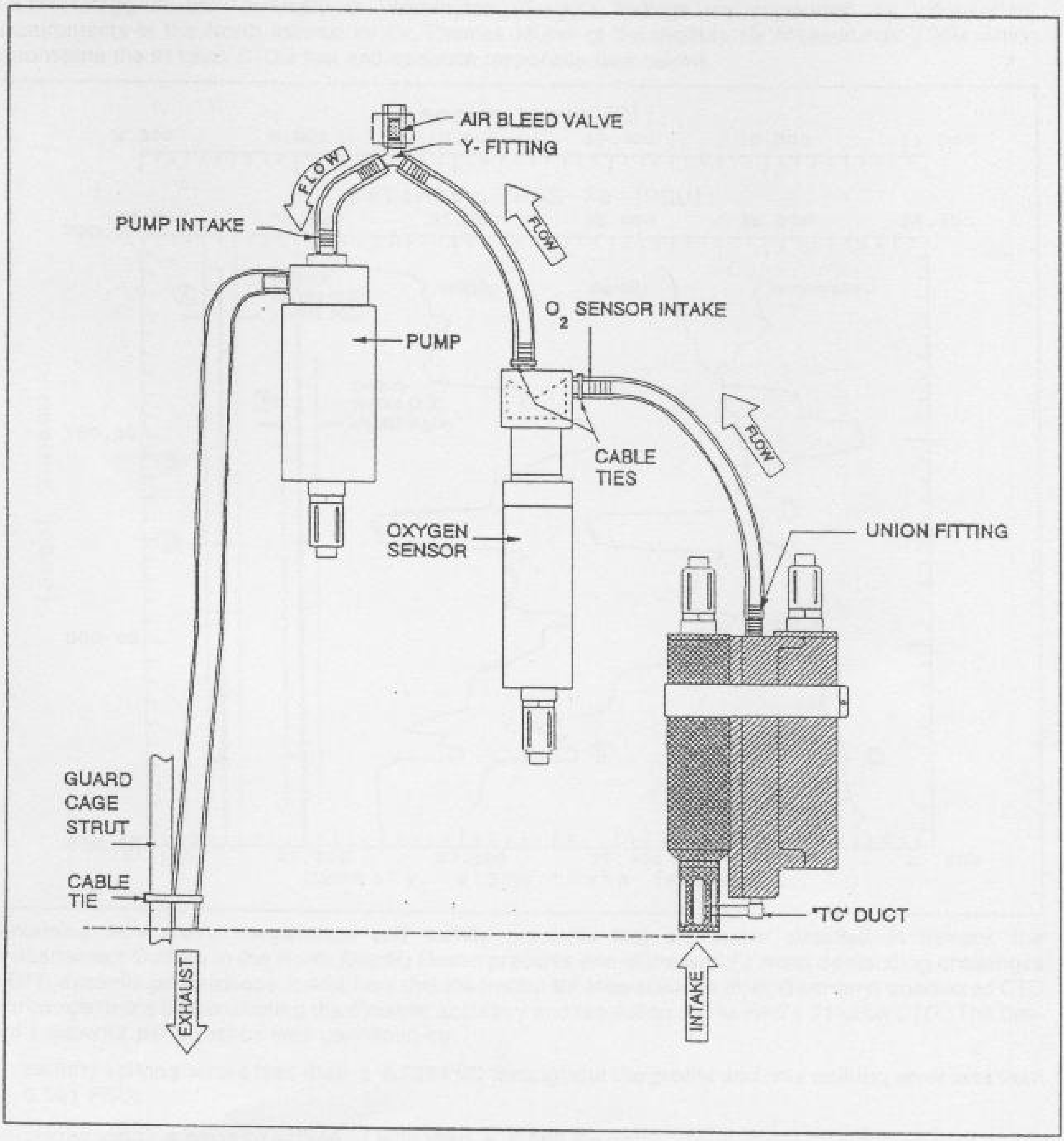
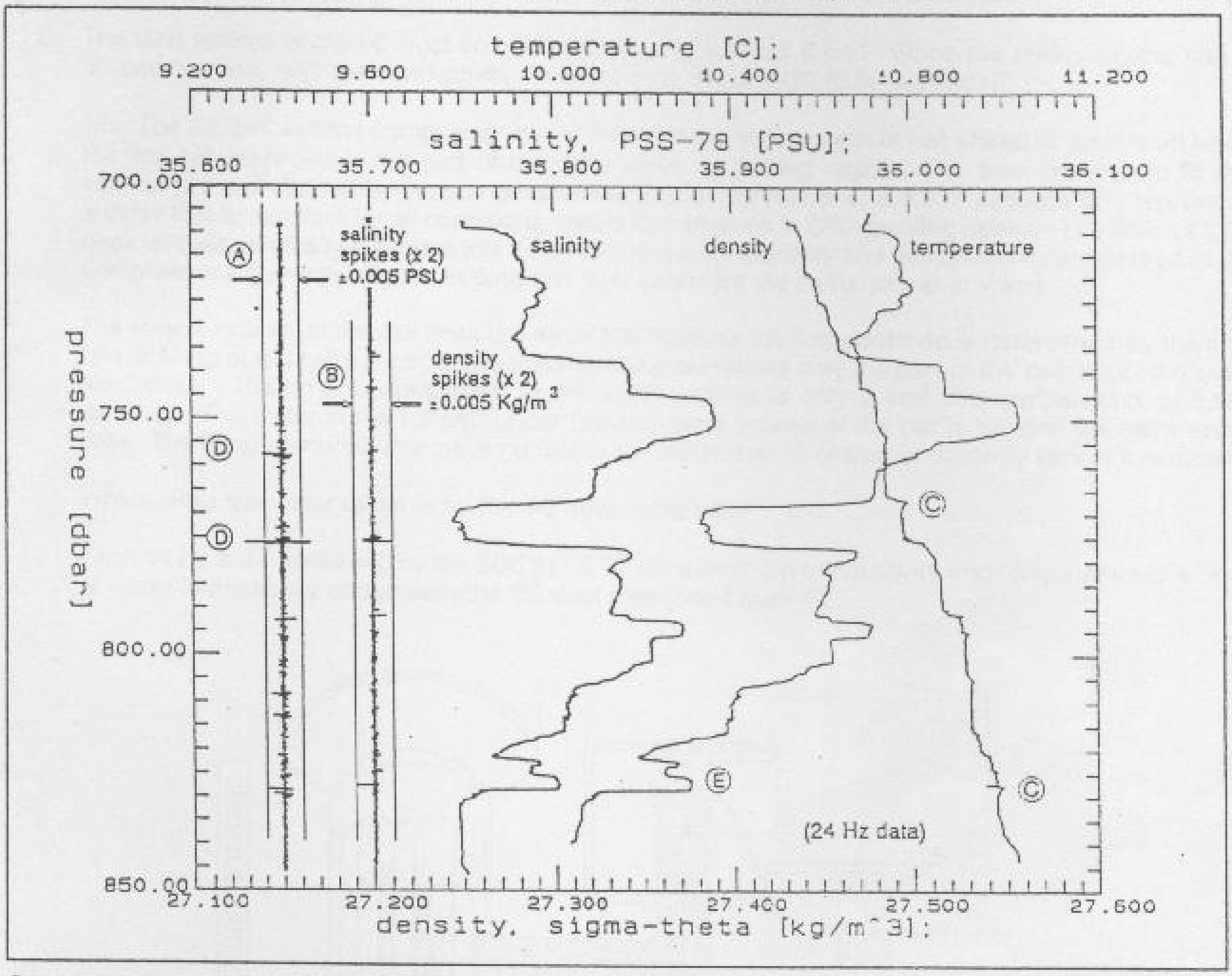


FIGURE 2. EXHAUST PATH OF TC DUCT WATER

Data taken with the Sea-Bird CTD show that the pumped and TC ducted temperature and conductivity sensors both exhibit the *same* time response of about 0.060 seconds. The Sea-Bird time responses have been measured and verified in a series of sophisticated and comprehensive field measurements by Dr. Michael Gregg of the University of Washington (Gregg's findings are supported by independent measurements in the North Atlantic by Dr. Thomas Müller of the Institute für Meerskunde / Kiel which demonstrate the 911plus CTD's fast and accurate responses (see below).



Containing very sharp temperature and salinity gradients that are stably stratified in density, the Mediterranean Outflow in the North Atlantic Ocean presents one of the world's most demanding challenges to CTD dynamic performance. It was here that the Institut für Meereskunde (Kiel, Germany) conducted CTD intercomparisons demonstrating the dynamic accuracy and resolution of Sea-Bird's *911plus CTD*. The Sea-Bird's superior performance was confirmed by:

A salinity spiking errors less than ± 0.005 PSU throughout the profile and rms spiking error less than 0.001 PSU;

B corresponding density spikes of less than ± 0.005 Kg/m^3;

C density inversions in the entire record that are always less than 0.003 Kg/m^3;

D two prominent features identified by an algorithm as salinity spikes that are in fact signatures of active oceanographic mixing and not salinity or density error;

E sensor time-responses of 0.060 seconds (± 0.010) that are confirmed by the spatial resolution of the sharpest TS steps in the record.

The 24 Hz data (processed with SEASOFT 4.0) have been time aligned and corrected for cell thermal mass. No other filtering, averaging or editing was performed and no data have been replaced or removed.

The following questions are often raised about the operations of the Sea-Bird CTD:

1. Does the TC duct act like a filter?

   On conductivity there is a small filtering effect that increases the conductivity time response from 0.035 seconds to 0.06 seconds. The effect of the TC duct on temperature is to improve its time response slightly (also to 0.06 seconds) and make it completely independent of profile rate.

2. The total volume of the TC duct and conductivity cell is about 6 cm^3. Since the pump volume rate is 30 cm^3/second, isn't the conductivity time response about 6/20 (0.20 seconds)?

   No. The 2.2 cm^3 volume comprising the TC duct and the short length of cell ahead of (upstream from) the first cell electrode is not part of the cell's active measuring region. The time required to fill this volume (2.2 cm^3 divided by the pump volume rate of 30 cm^3/second) is 0.073 seconds and represents a delay that is constant for all conditions, including variations in CTD profiling speed. The SBE 11 CTD deck unit automatically subtracts this delay so that the conductivity and temperature data passed to the computer are correctly aligned in time and truly represent the same parcel of water.

   The *time response* of the cell once the water has reached the first electrode is determined by the time rate of filling of the cell's 2 cm^3 active volume which comprises only the part of the cell *inside* the outer electrodes. The time to completely fill the active volume is only 2 cm^3 /30 cm^3/second or 0.067 seconds. The water in the 1.8 cm^3 upper (downstream) volume of the cell is beyond the cell's active area. The filling of this volume plays no role in the determination of the conductivity sensor's response.

3. Where does the water taken in by the TC duct come from?

   Each 24 Hz scan measured by the SBE 911 CTD represents the conductivity and temperature of a "rod" of water immediately underneath the TC duct inlet (see Figure 4).

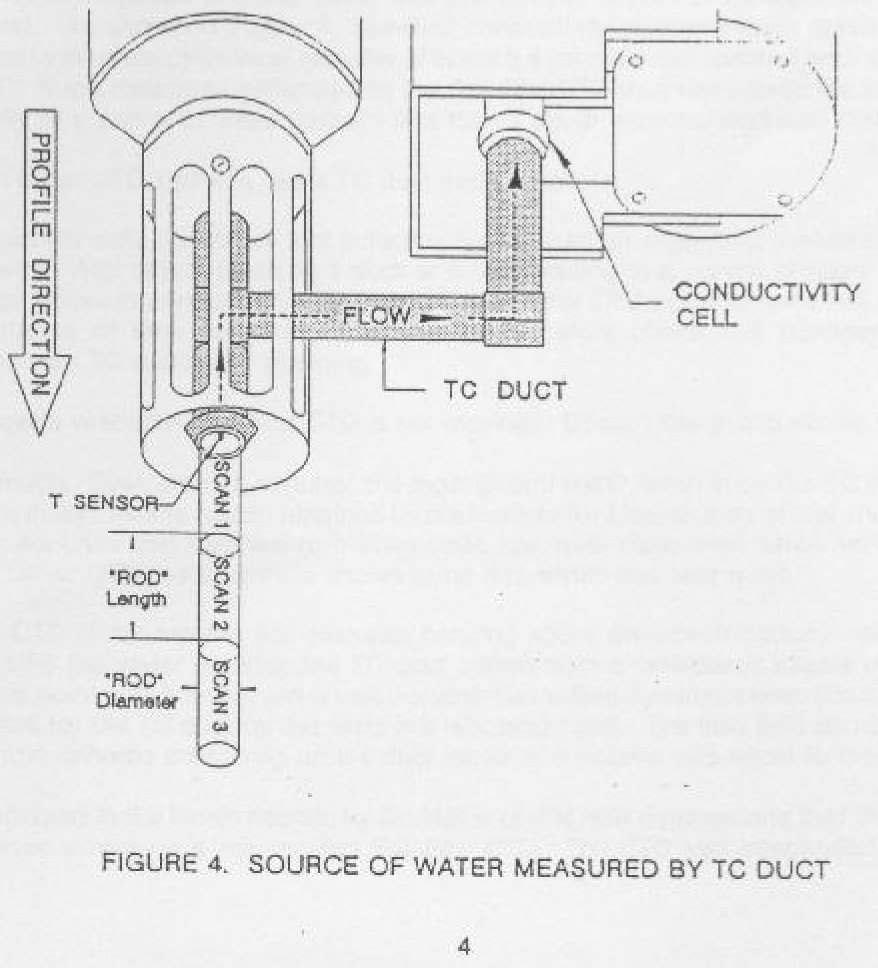


FIGURE 4. SOURCE OF WATER MEASURED BY TC DUCT

The dimensions of the rod depend on CTD profiling speed and are shown in the table below.

Profiling Speed (m/s)	Rod Diameter (cm)	Rod Length (cm)
0.25	1.24	1.04
0.50	0.88	2.08
0.75	0.71	3.13
1.00	0.62	4.20
1.50	0.50	6.25
2.00	0.44	8.33

Using the TC duct, the Sea-Bird CTD provides better spatial resolution than any other CTD.

While the analytical description of the flow is somewhat complicated, the simple cylindrical geometry is easily understood by the following argument: If the pump draws water into the TC duct at exactly the CTD drop speed, then water entering the duct must come from a cylinder having a diameter exactly equal to the inside diameter of the TC duct intake (0.4 cm). The CTD in this case "sweeps" new water at just the rate that its movement downward is causing new water to be "presented". The CTD can also be thought of as falling down a long 0.4 cm diameter "rod" extending from the surface of the water column to the bottom. The volume of water taken from the "rod" each second must equal the volume flow rate imposed by the pump. In the SBE 9 CTD, this volume is 30 cm^3/second. As speed of the CTD changes, the diameter of the "rod" will become larger or smaller to meet the water volume demanded by the pump.

All water that enters the TC duct comes from inside this cylinder and none comes from outside the cylinder. In addition, it is easy to see that for the Sea-Bird's 24 Hz sample rate, each measurement corresponds to a cylinder of ocean water with a length that is 1/24 of the distance that the CTD moves in 1 second. As shown in Figure 4, *Sea-Bird conductivity measurements taken using the TC duct correspond to discrete cylindrical samples of about 0.6 cm diameter stacked end-to-end along the path of the CTD.* Each data scan generated by the Sea-Bird CTD thus represents the true temperature and conductivity of a parcel of water typically less than 1 cm in diameter and less that 5 cm long.

4. Why don't other CTD systems use a TC duct and pump?

The conductivity cells (electrode and inductive types) used on other CTD systems have partly external electric fields. Any object (such as a duct or tubing leading to a pump) brought near these cells will cause large errors in conductivity. The designers of other CTD systems were not completely aware of the importance of time response matching and therefore chose cell configurations that are not compatible with TC ducts and pumping.

5. What happens when the Sea-Bird CTD is not moving? Doesn't the pump stir up the water?

Not very much. Even after 15 minutes, the most distant water taken in by the TC duct will be from less than 20 cm away. At-sea results obtained by the Institute für Meerskunde at Kiel show the Sea-Bird CTD to be very accurate and sensitive (providing quiet, low-noise data) even when held at one depth for 40 minutes. Other CTD systems were shown to be less stable and less quiet.

When the CTD is not moving (for example, hanging above the ocean bottom waiting to close a deep salinity bottle) the water entering the TC duct comes from a collapsing sphere centered on the duct intake. This point-sink flow pattern is well documented in fluid dynamics texts (Batchelor, 1967) and has been verified for the TC duct by dye tests in a laboratory tank. The flow field can be visualized as a set of concentric spheres collapsing on the duct intake at a volume rate equal to the pump rate.

Tests conducted in the North Atlantic by Dr. Müller of IFM/Kiel demonstrate that *the pump and TC duct do not cause errors on a non-moving Sea-Bird CTD.* The CTD was suspended under the ship at a depth of approximately 4635 meters for 43 minutes. All 62,000 measurements of temperature and salinity during this test are plotted in Figure 5 and show that the measurements are within +/- 0.002 °C and +/- 0.0012 PSU of the local mean gradients.

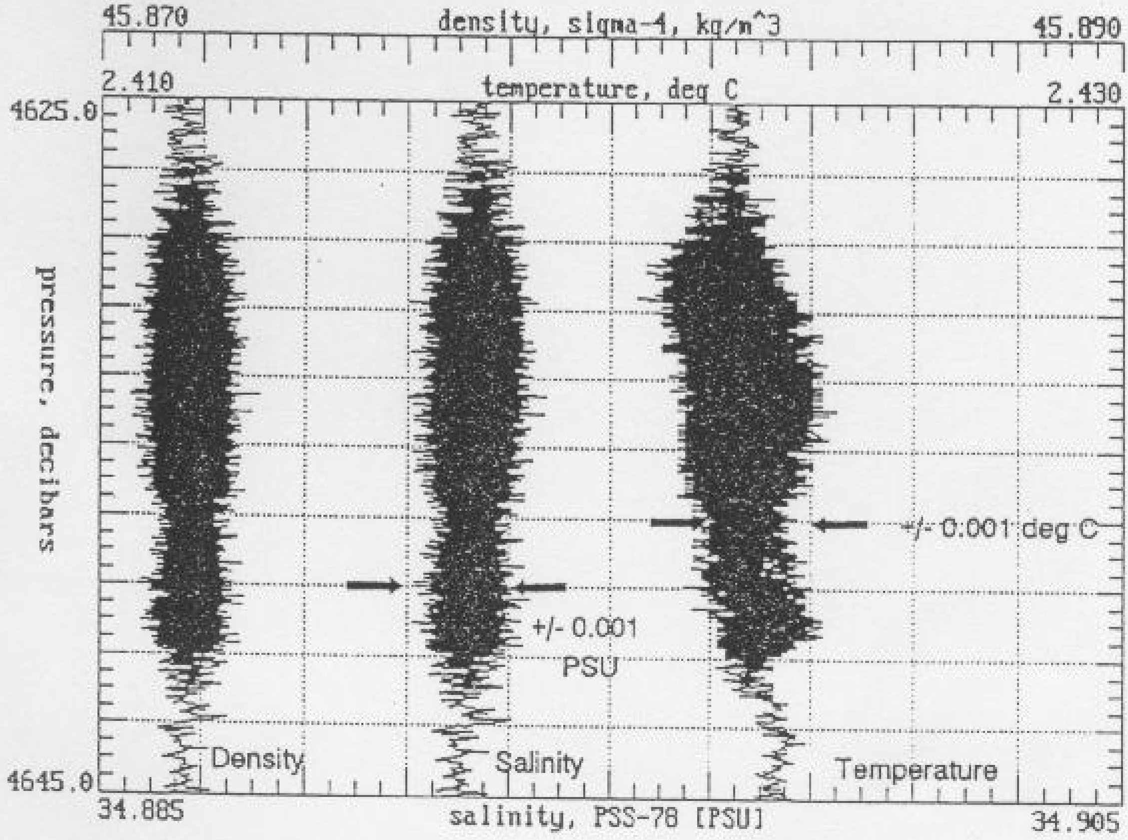


FIGURE 5. QUIET DATA WITH SBE 9 STATIONARY