核廢料儲存場建立即時水文觀測系統及場址特性分析 (I)

完成報告

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中文摘要

本計畫為二年的研究計畫，第一年計畫之目的，在建立一即時水文觀測系統，以長期記錄低階核廢料儲存場附近的降雨、地下水位、及大氣壓力等數據；蒐集得的資料將在第二年的計畫中，利用頻譜分析方法，進行場址水文地質參數分析。本計畫執行的結果，將可提供台電公司，作為日後設置、管理最終核廢料處置場址監測系統的參考。

去年底在蘭嶼的核廢料儲存場內，我們已架設各項水文觀測儀器及訊號傳遞系統，並完成系統運作測試工作。蘭嶼儲存場水文的資料，包括降雨量、大氣壓力、及地下水位等，可由監控人員撥電話經數據機連線，每週定時傳送下載並儲存在個人電腦內。惟部分現場儀器如太陽能板及地下水位計，於今年三月份因環境因素，如鹽害、雷擊、或颱風等因素造成損壞，地下水位計已經由美國原廠檢修完畢送回。預定於八月初，再赴蘭嶼儲存場，安裝新的太陽能板和修好的水位計，並進一步做儀器校正與系統運作測試工作。本年度計畫內其他各項工作，均已按照預定進度執行，並已著手執行下年度計畫內，現地資料分析工作；分析結果顯示，蘭嶼地下水位除受降雨與氣壓影響外，其水位的漲落變動主要受全日潮與半日潮的影響。

關鍵字：即時水文觀測系統，低階核廢料儲存場。

Abstract

This is a two –year research project. The objective of the first-year project is to establish a real-time hydrological monitoring system at Lanyu low-level nuclear waste disposal site . This system will record long-term hydrological data on precipitation, groundwater level, and atmospheric pressure in disposal site. In the second year, the recording data will be analyzed for the hydrgeological parameters using the spectral analysis. The results of this project may provide the Taiwan Power Company a useful reference for the establishment and management of a real-time hydrological monitoring system at the final disposal site of the low-level nuclear waste.

A real-time hydrological monitoring system including the data acquisition and transfer system had been established at Lanyu in last November. Meanwhile, the testing of the newly installed system had completed. However, some instruments were possibly damaged by sea-salt effect, thunder, or typhoon. Those instruments have been fully repaired by the manufacturers recently. We plan to go to Lanyu in the near future to reinstall and test the operation of the system. In conclusion, the first-year tasks of this project have been executed on schedule and we are working on the analyses of field data which are part of second year research works. According to the results, the periodic fluctuations of groundwater level at Lanyu are mainly influenced by diurnal and semi-diurnal ocean tides.

Keywords: real-time hydrological monitoring system, low-level nuclear waste disposal site.

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一、前言

蘭嶼低階核廢料儲存場於民國七十一年開始運作，儲存由放射性待處理物料管理處（簡稱物管處）負責接收全國各醫、農、工業及研究單位所產生並處理之低階放射性廢料。至民國七十九年，物管處依「放射性廢料管理方針」之規定，將蘭嶼儲存場移交台電公司經營。由於低階放射性廢料的放射性較低、半衰期較短，故採用淺地層掩埋，並利用工程設施將廢料桶予以封存，本現場的照片，列於圖一。目前，低放射性廢料最終處置場尚在評選作業中，而蘭嶼儲存場仍是低放射性廢料的暫時儲存場址。為了確保放射性廢料處置的安全，有必要掌握與放射性核種遷移路徑有關的地層水文特性參數。因此，應進一步蒐集研究儲存場的地質及水文環境等基本資訊。

物管處曾於民國八十年舉辦「蘭嶼儲存場地下水示蹤劑試驗觀摩會」，根據與會專家研究討論的結果，認為蘭嶼儲存場相關的水文資料仍然不足，有必要在場區內設置專屬的水文站，做長期資料的蒐集。為避免加重工作人員的負擔、並保證數據的品質，本計畫全面採用自計式儀器，在蘭嶼儲存場的場區內設置雨量計、地下水位計、及氣壓計等。但蘭嶼位於台灣東南端且為離島，交通甚為不便，自計式儀器雖然可以自動連續記錄水文資料，但仍需要解決儀器長期供電問題及下載監測數據；如果無法解決前述的兩個難題，除了不能掌握即時水文資料的變化外，對於儀器故障、數據誤差、或記錄中斷等突發事件，也無法把握時效予以處理，影響數據品質與日後數據分析工作。因此，將這些觀測數據記錄並且同步、正確的傳送至監管單位，供專業人員判讀、整理、及分析，是本第一年計畫最主要工作。為達到上述目標，本計劃著手規劃設置電源供應系統與訊號傳遞、接收系統；其中，電源系統包括一個太陽能板及與它串接的蓄電池，作為地下水位計及氣壓計的電源，而訊號系統能遠端傳送蘭嶼儲存場周圍的降雨、地下水位、及大氣壓力等觀測數據，並於新竹端下載儲存、分析。本計畫於蘭嶼儲存場規劃、建立之水文觀測系統，以及資料之觀測、整理、分析的經驗與結果，可提供台電公司將來規劃低階廢料最終處置場水文監測系統的參考。

本計畫的工作分為兩年，第一年工作的目的，是利用近幾年發展成熟的電子資訊產品，配合自動量測系統，建立蘭嶼儲存場水文觀測資料的即時傳送系統，以掌握環境現況，並提昇放射性核種遷移研究的時效性，確保儲存場周圍環境品質。第二年工作的目的，乃針對即時觀測系統傳送回來的水文數據，透過序率理論的統計分析，推求代表水層特性的水文地質參數，而這些現地水層的參數值，將可應用於地下水流與傳輸模式，作為低階核廢料儲存場環境安全評估工作之參考。

圖一　蘭嶼低階核廢料儲存場

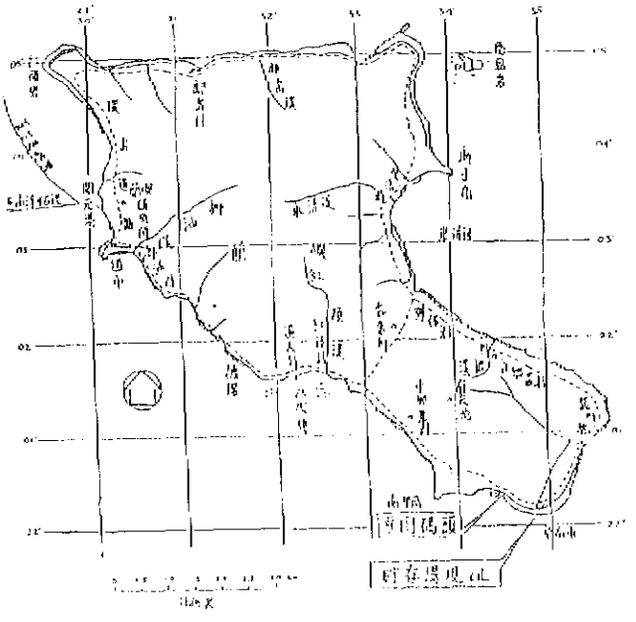
二、現場描述

本計畫的現地實測場址，位於蘭嶼核廢料儲存場的場區內。蘭嶼島位於台東市東方 49 浬之太平洋上，儲存場位於島東南端的龍門地區，其地理位置示意圖，示於圖二。場區北、西、及南側緊鄰陡峭山壁，東側臨海，海岸為礁石灘。依中興工程顧問社(1987)在蘭嶼儲存場之地質鑽探報告，場區地質可概分為三層，由地表向下分別為覆蓋層、珊瑚礁石灰岩、及碎屑安山岩。

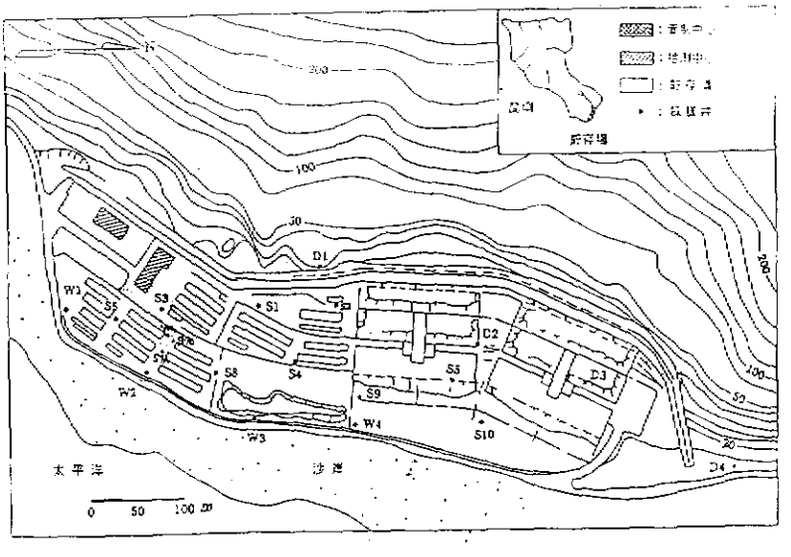
在儲存場場區內設置的自記式地下水水位計，依距海岸不同距離，分別選在 W_0、W_1、W_2、S_3、及 S_6 等五口現有監測井內，其位置如圖三所示，以了解不同距離反應潮位影響之程度。各個觀測井之水位計，架設於井底上方至少 30 公分處，以避免水井水質採樣作業傷及水位計，同時也可避免井底淤泥掩埋水位計影響水位計功能；各水位計之架設基本資料，列於表一，其中架設時水深指架設當時水位計至水面之高度，而架設時水面深指架設當時水面至井口之高度。氣壓計、雨量計、太陽能板、蓄電池、數據記錄器、及數據機皆裝在一個儀器箱內，並置於 W_0 井旁。自計式潮位計則與台電人員合作，設置在儲存場專用港的北側碼頭邊，位於東經 121 度 34 分 54 秒、北緯 22 度 00 分 16 秒處，該碼頭約距儲存場一公里遠，故潮汐數據傳送系統不與儲存場的訊號系統相連。

表一 蘭嶼儲存場各監測井位置及架設基本資料

監測井	經度(東經)	緯度(北緯)	架設時 水深(cm)	架設時 水面深(cm)
W_0	121°35'33.90"	22°00'15.35"	1005	1049
W_1	121°35'29.29"	22°00'10.40"	79	1060
W_2	121°35'34.37"	22°00'13.15"	103	1066
S_3	121°35'29.76"	22°00'16.26"	52	853
S_6	121°35'35.22"	22°00'13.38"	42	755



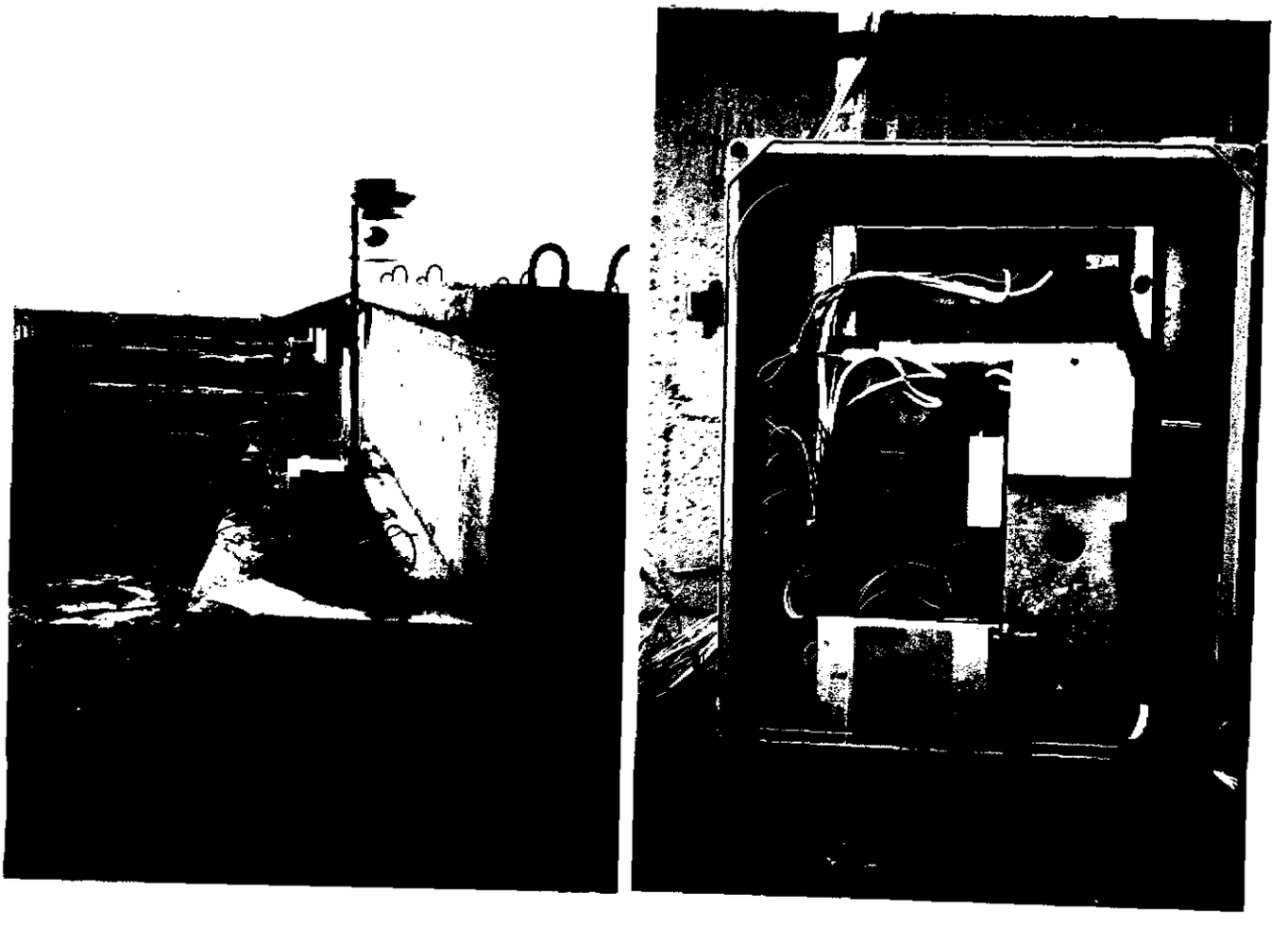
圖二 蘭嶼儲存場位置示意圖



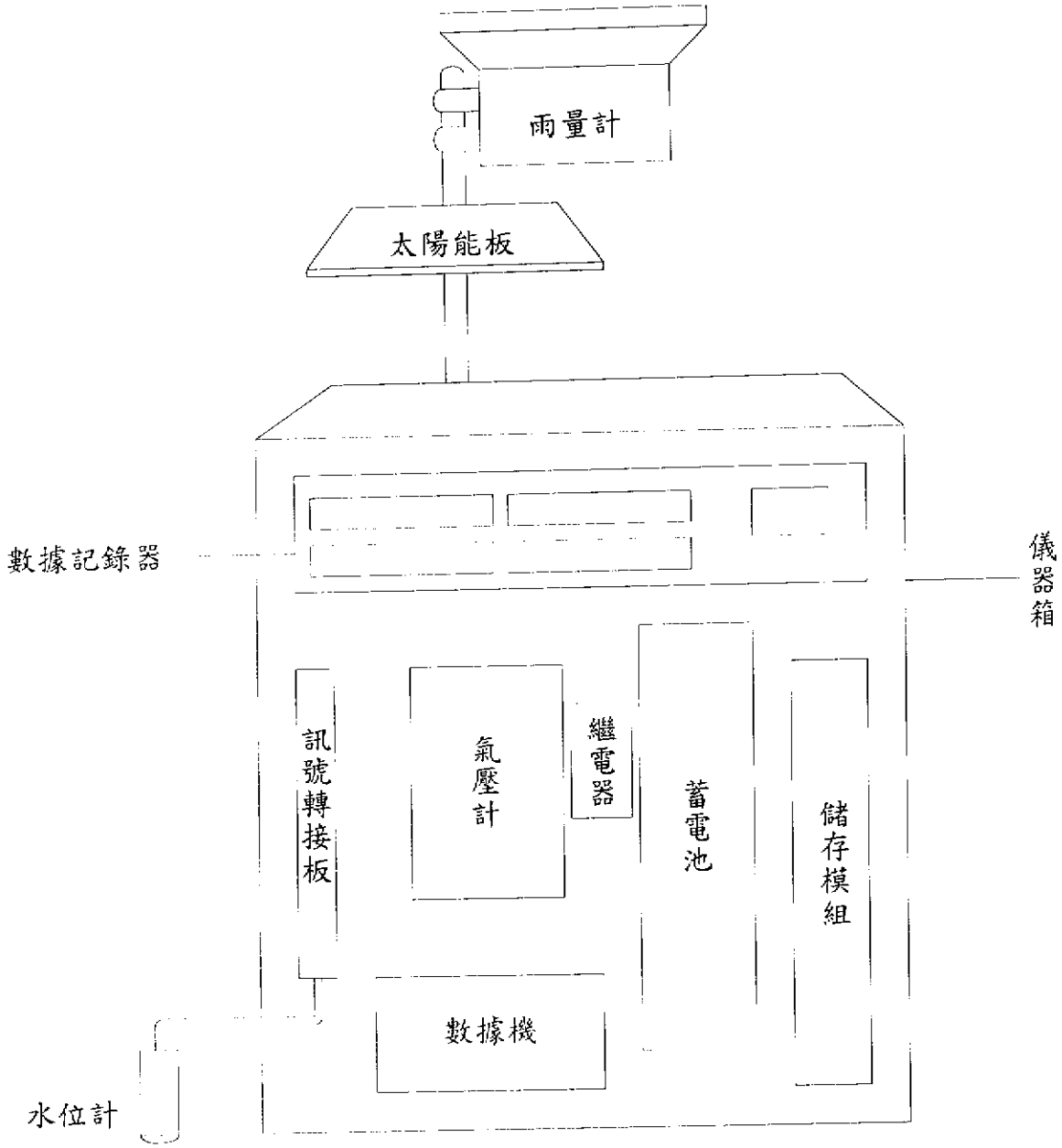
圖三 蘭嶼儲存場設施、監測井位置、及地表等高線圖

三、系統與儀器

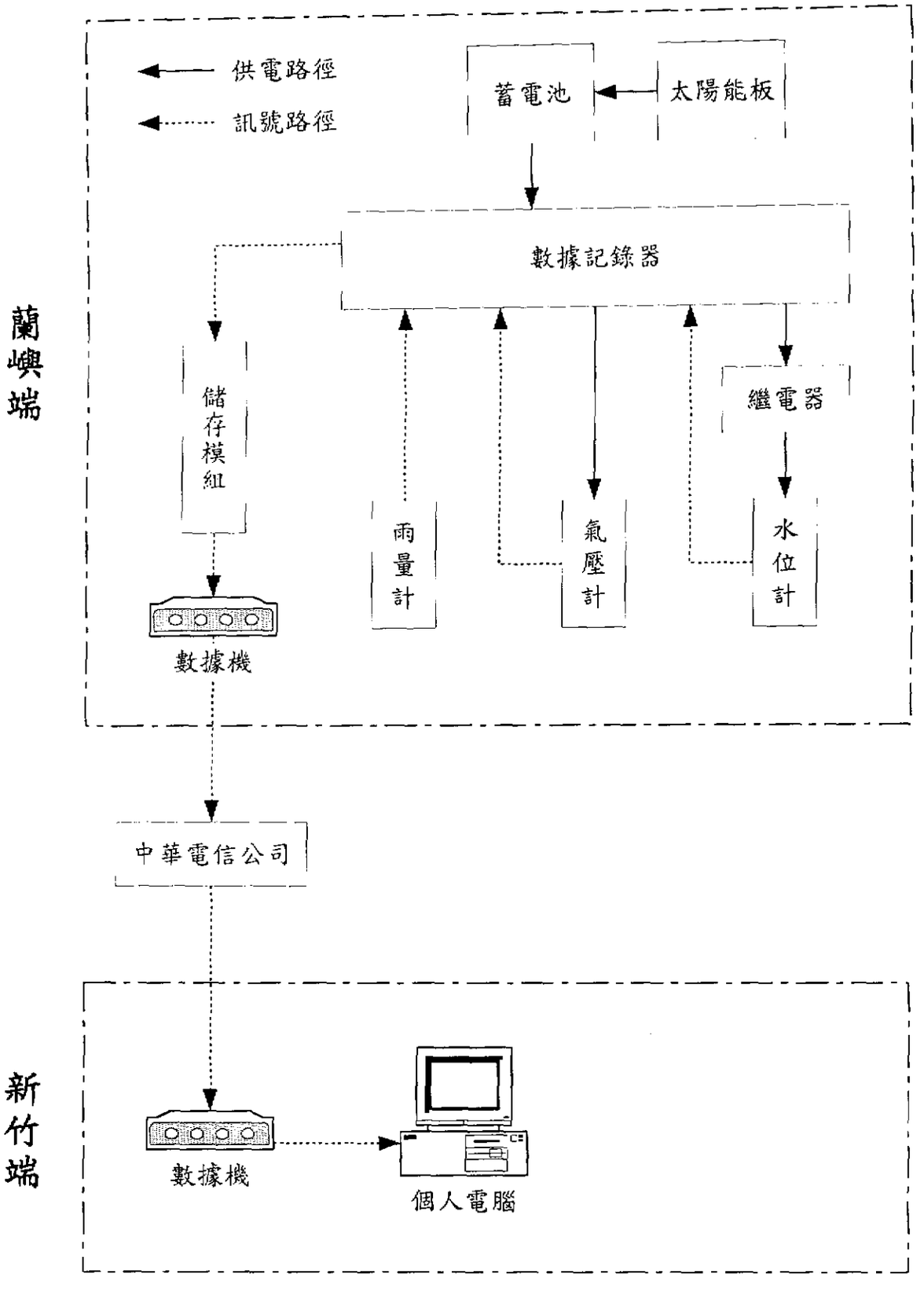
本計畫第一年的工作，即在建立一個遠端即時水文監控系統。經評估現地狀況與儀器間的相容性後決定，主站（蘭嶼儲存場）與各個觀測儀器利用 RS-232 連接，每小時觀測資料將自動記錄於 Campbell Scientific 公司的工業級數據記錄器(datalogger)中，並轉儲存於儲存模組(storage module)內；遠端（新竹）則由個人電腦與 56K 電話數據機組成。軟體部分為兼顧個人電腦作業系統及訊號收集器之相容性，本計劃使用 Campbell Scientific 公司設計之 PC208W Datalogger Support Software 做為人機界面監控軟體。主站與遠端間的電訊網路，是利用中華電信公司在全省各地及外島的電話網路系統，遠端透過 56K 電話數據機，經由市外專線與蘭嶼儲存場儀器箱內的數據機連接，並由遠端監控人員將下載的水文資料，轉換為 MS-EXCEL 格式，按日期加以儲存，以為日後進一步分析使用。整個即時水文觀測系統外觀照片，列於圖四，系統之架構示意圖繪於圖五，而供電及訊號路徑示意圖繪於圖六。



圖四 蘭嶼即時水文觀測系統



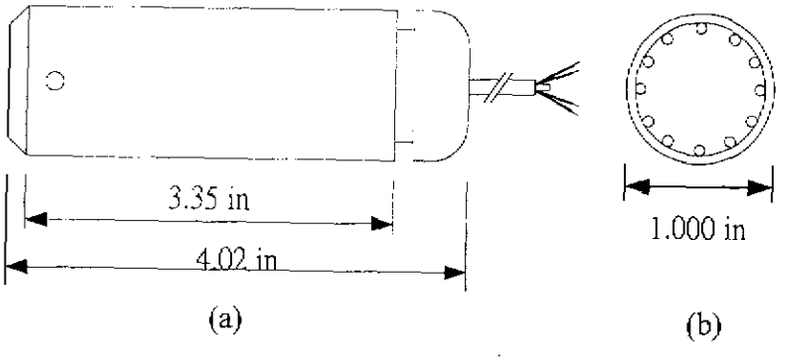
圖五 即時水文觀測系統架構示意圖



圖六 即時水文觀測系統電路與訊號路徑示意圖

本系統中之水位計，乃採用 Pressure Systems 公司的 Series 730 水位計(Pressure Transducer)，此水位計之特性為體積小、堅固、防水性好、相容於多種數據記錄器、並且適用於各種環境溫度，攝氏每度的溫度效應小於讀數之 0.05% ；其最大量測範圍可達到 300 psi，而設計精確度可至 0.5% ，其尺寸規格示於圖七，水位計輸入電源為 12 VDC，輸出訊號為 4-20mA，若經過數據記錄器電阻可轉換成 400-2000mV 之訊號，並進一步儲存於儲存模組內。由於水位計非常耗電，故在數據記錄器與水位計之間，加裝一個繼電器，每隔 10 秒供電 2 秒給水位計，以節省蓄電池的耗電量。本計畫之水位數據為將每小時所得 360 筆資料，取其平均值作為每小時水位數據；水位計的儀器介紹列於附錄 A。雨量計則選用 Campbell Scientific 公司的 TE525 傾斗式雨量計，它係改良自美國氣象局所使用的標準傾斗式雨量計，並可與 CR-10 數據記錄器相容，其最大容許雨量強度為每小時 50 公釐，而設計準確度可達到 1% ，其實物照片列於圖八，其儀器介紹列於附錄 B。至於氣壓計部分，在考慮相容性與準確性後，本系統採用 Met One Instruments 公司的 Model 090D 氣壓計 。Model 090D 為一主動式電晶體設計，以維持氣壓計正常運作與訊號放大功能，適用於攝氏 50 度至零下 40 度範圍的環境中，並可達到 0.125% 的準確度，氣壓計輸出訊號範圍為 0-1000mV，相當於 800-1100mbar，其操作手冊列於附錄 C。

由於蘭嶼為一離島，交通不便，維修人員無法定期至儀器設置現地作檢測。為了能長時間、並且可靠的提供電源給予儲存場內的各項水文觀測儀器，本監測系統乃採用 CHRONAR 公司的 CM 1-1A 太陽能板，供電功率為 5 瓦特，它與一 12V 蓄電池串聯，整個監測系統包括水位計與氣壓計，由蓄電池供電，而太陽能板作為蓄電池之充電器，蓄電池之電壓亦傳入數據記錄器內，若蓄電池電壓小於 12VDC 時，即反應供電系統出了問題，必需至現地對供電系統作檢修。



圖七 水位計尺寸規格示意圖；(a)外觀，(b)橫斷面。

圖八 雨量計

四、數據分析理論

根據序率(stochastic)理論(*Gelhar*，1993)，二個隨機且 stationary 的 stochastic process $\{x_k(t)\}$與$\{y_k(t)\}$，在任意時間 t 時，其平均值與相關變異數函數分別以 μ 與 C 表示，可以下列方程式表示：

$$\mu_x(t) = E\left[x_k(t)\right] = \int_{-\infty}^{\infty} xp(x)dx = \mu_x \tag{1}$$

$$\mu_y(t) = E\left[y_k(t)\right] = \int_{-\infty}^{\infty} yp(y)dy = \mu_y \tag{2}$$

$$C_{xx}(\tau) = E\left[\left\{x(t) - \mu_x\right\}\left\{x(t+\tau) - \mu_x\right\}\right] \tag{3}$$

$$C_{yy}(\tau) = E\left[\left\{y(t) - \mu_y\right\}\left\{y(t+\tau) - \mu_y\right\}\right] \tag{4}$$

$$C_{xy}(\tau) = E\left[\left\{x(t) - \mu_x\right\}\left\{y(t+\tau) - \mu_y\right\}\right] \tag{5}$$

其中，，E 為期望值，p 為機率密度函數，而 C_{xx} 與 C_{yy} 定義為 autocovariance functions，C_{xy} 則定義為 cross-covariance function。 此外，相關函數可定義為：

$$R_{xx}(\tau) = E\left[x(t)x(t+\tau)\right] \tag{6}$$

$$R_{yy}(\tau) = E\left[y(t)y(t+\tau)\right] \tag{7}$$

$$R_{xy}(\tau) = E\left[x(t)y(t+\tau)\right] \tag{8}$$

其中，τ為延滯時間，而 R_{xx} and R_{yy} 稱為 autocorrelation functions，R_{xy} 則稱為 cross-correlation function，而 autospectrum、cross-spectral 與相關函數的關係，可表示為：

$$S_{xx}(\omega) = \frac{1}{2\pi}\int_{-\infty}^{\infty} e^{-i\omega\tau} R_{xx}(\tau)d\tau \tag{9}$$

$$S_{yy}(\omega) = \frac{1}{2\pi}\int_{-\infty}^{\infty} e^{-i\omega\tau} R_{yy}(\tau)d\tau \tag{10}$$

$$S_{xy}(\omega) = \frac{1}{2\pi}\int_{-\infty}^{\infty} e^{-i\omega\tau} R_{xy}(\tau)d\tau \tag{11}$$

其中，S_{xx}與S_{yy}為 autospectrum，S_{xy}為 cross-spectrum，ω為角頻率。

由(9)-(11)三式可知，若要知道數據的頻譜(spectrum)，需要利用到傅利葉轉換(Fourier transform)，然而原始數據（raw data）往往會有雜訊或趨勢(trend)，因此推算

數據的頻譜前，通常需要做前處理(*Bendat and Piersol*，1991)。若潮汐或地下水位數據不是以小時為單位做記錄，通常要利用 Godin(1972，p.65)所建議的 low-pass filter 做過濾(filtering)前處理。在 detrend 方面，最簡單的方法有線性趨勢移除(linear trend removal)(*Priestley*，1992)。此外，常見使用的 low-pass filter 為 ED6，定義為(*Mooers and Smith*，1980)：

$$y_i = 0.75 \cdot \left(x_{i-1} + x_{i+1}\right) - 0.30 \cdot \left(x_{i-2} + x_{i+2}\right) + 0.05 \cdot \left(x_{i-3} + x_{i+3}\right) \qquad (12)$$

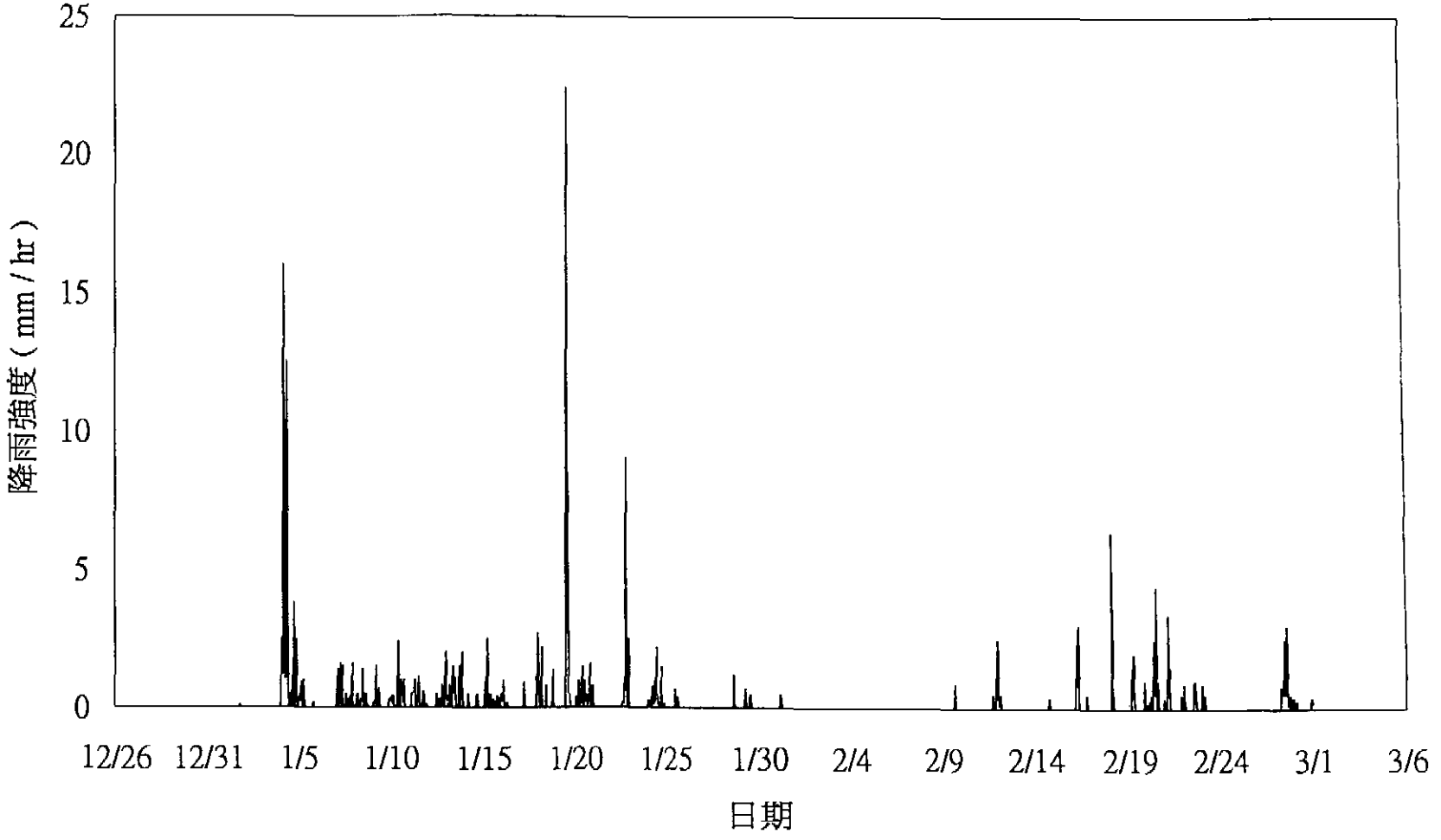
式中，x_i 為原始數據，y_i 為經過 ED6 過濾的數據，i 代表時間系列。

利用上述理論，發展的計算機程式名稱為 Spectrum，其中包含移除線性趨勢和用 ED6 過濾數據，並利用 *Press et al.* (1992)書中的快速傅利葉轉換(FFT)副程式，以計算數據的頻譜，此 Spectrum 程式列於後當附錄 D。

五、結果與討論

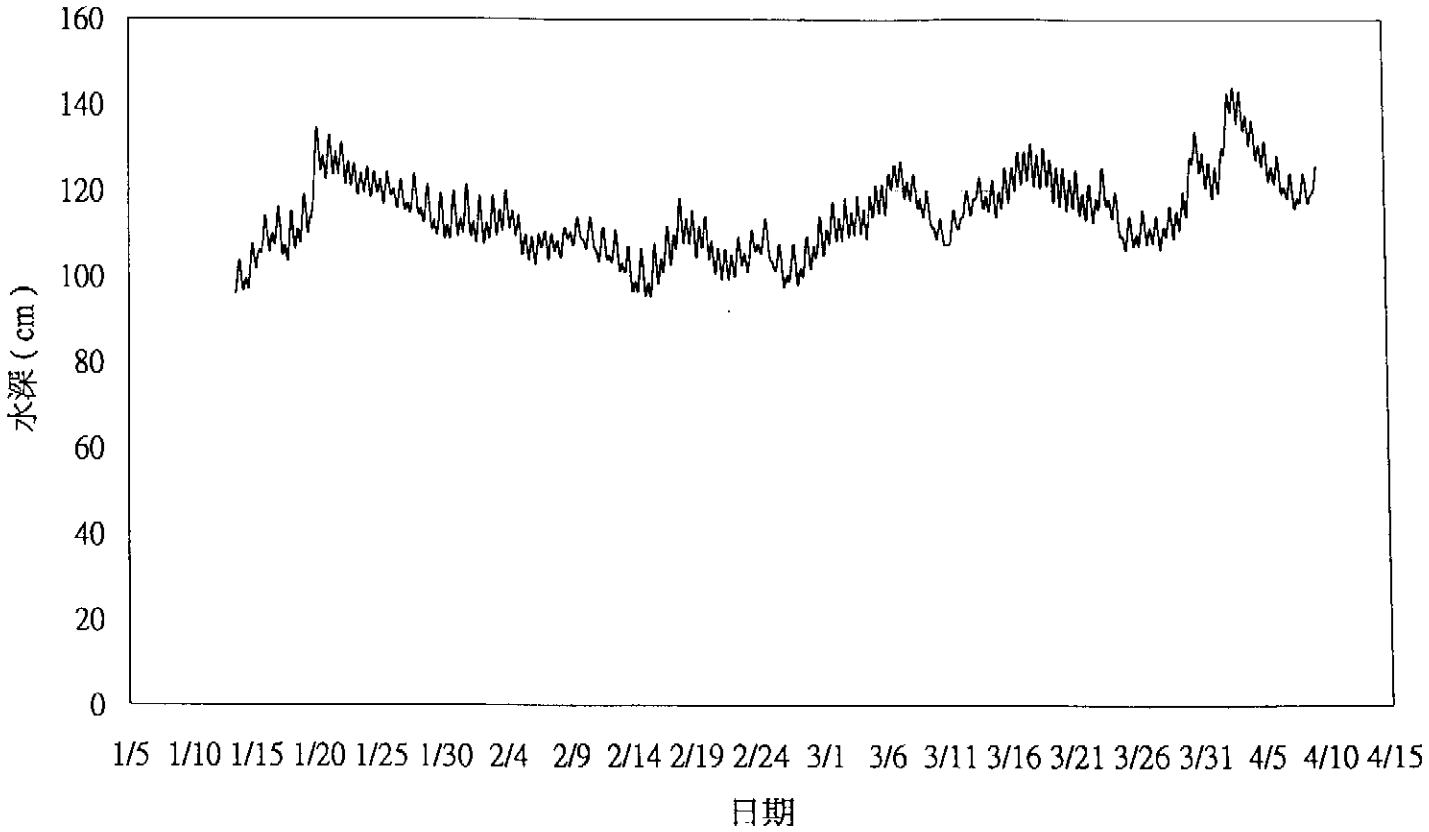
本計劃之水文監測系統，已於民國八十七年十一月架設完成，並已完成測試工作。蘭嶼儲存場水文資料的傳輸，設定於每週二、五下午 4 時至 5 時，由新竹遠端連線下載，資料均由監控人員將下載檔案，按日期轉換成 MS-EXCEL 格式儲存。雨量計與氣壓計經測試，工作性良好，一月上旬至三月上旬的記錄，其結果分別繪於圖九與圖十。水位計並自動記錄各監測井之逐時水位，結果以 W_0 井為例，一月中旬至四月上旬的記錄繪於圖十一。惟部分水位計，於今年三月份時故障，經送回美國原廠檢修完畢以寄回台灣，我們預定於八月初，派員赴蘭嶼儲存場，做進一步的儀器安裝與校正工作。

三月中旬時，我們發現監測系統有故障，整個監測系統無法正常運作，除立即進行系統檢修工作外，並著手進行第二年的研究工作，就現地傳回的資料，利用我們發展的 Spectrum 程式進行數據分析工作。首先，比對圖九的雨量記錄與圖十一的 W_0 井地下水位實測記錄，發現在一月二十日及二月十九日的二場降雨，會使 W_0 井的地下水位很快的漲升，而後，隨時間增加而遞減，這個降雨的影響，對地下水位數據而言，或可視為週期較長的趨勢(long-term trend)。其次，針對現地氣壓及 W_0 井地下水數據，將週期超過 24 小時之資料濾出，其結果分別繪於圖十二與圖十三。隨後，將濾出資料與原始資料相減，依此方法可將長週期趨勢移除，結果分別繪於圖十四與圖十五。接著，再作頻譜分析，並將所得結果繪於圖十六與圖十七。地下水位的頻譜顯示，於頻率 1 與 2（週/日）時，有較大的能量出現，此結果顯示，地下水位主要受全日潮與半日潮的影響較大，此與蘭嶼潮汐特性吻合。蘭嶼儲存場大氣壓力的頻譜顯示，於頻率 2 週/日時，亦有較大能量出現，此結果顯示，地下水位於半日潮處，也可能受大氣壓力的影響。這些結果顯示，日後在執行第二年計畫，進行地下水位頻譜分析時，須檢討降雨與大氣壓力對地下水位的影響，並將其效應從水井水位數據中移除，才能在應用序率分析理論推算含水層參數，得到較精確的結果。

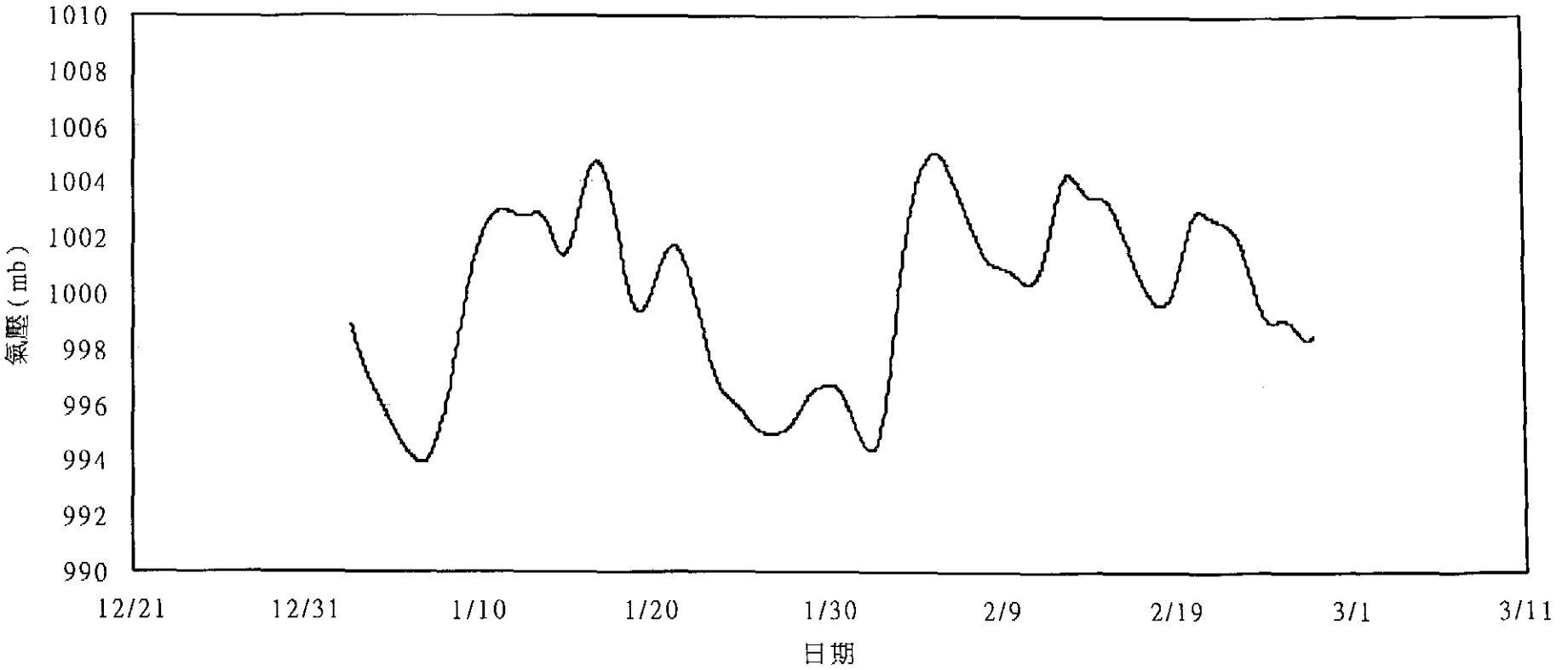


圖九 蘭嶼儲存場降雨實測數據

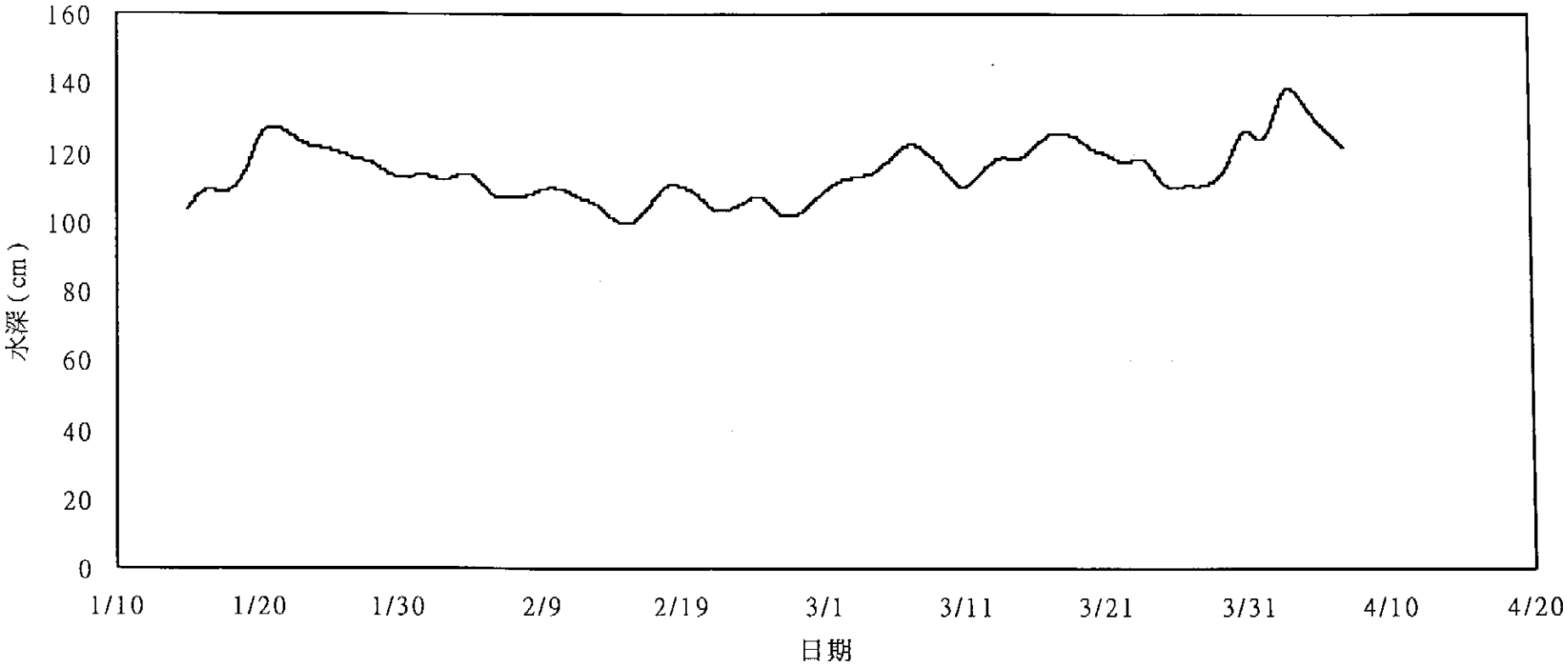
圖十 蘭嶼儲存場氣壓實測數據



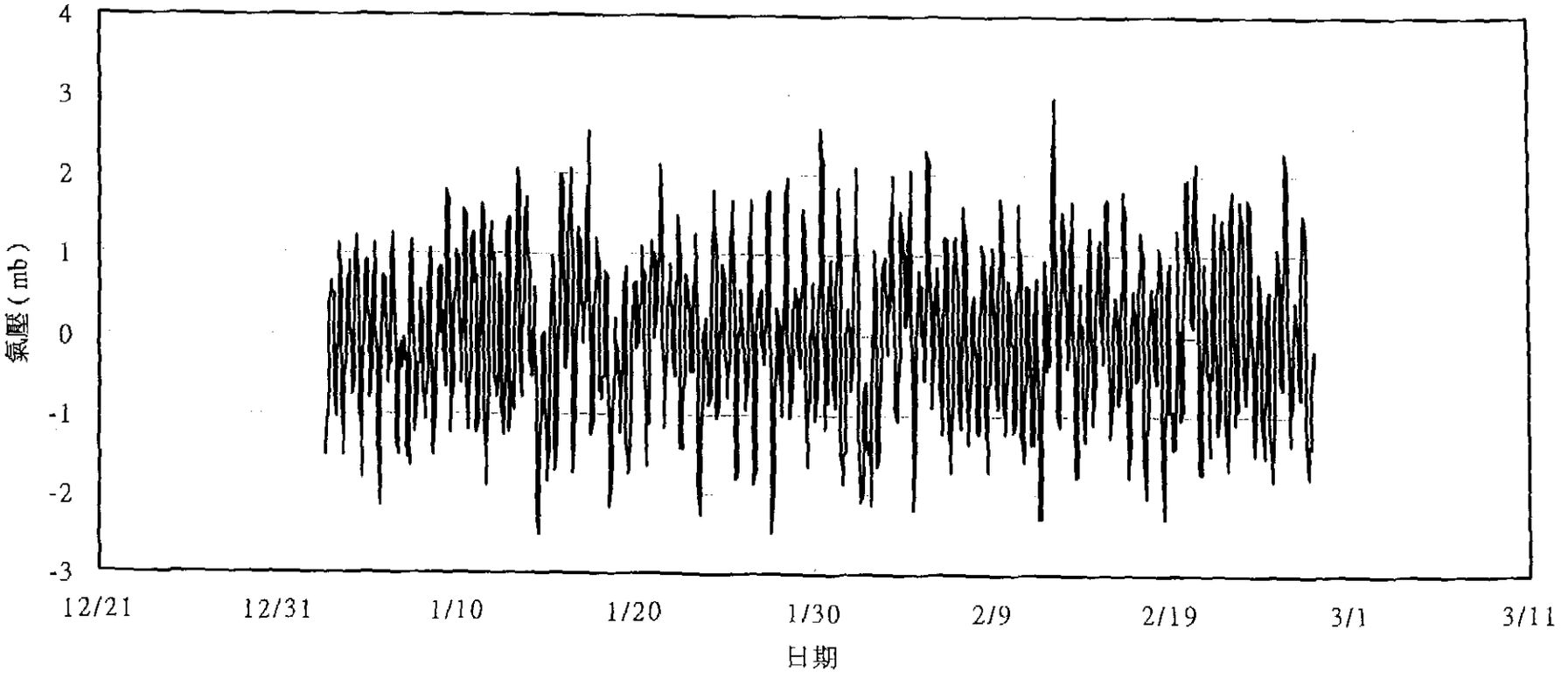
圖十一 W_0 井地下水位實測數據



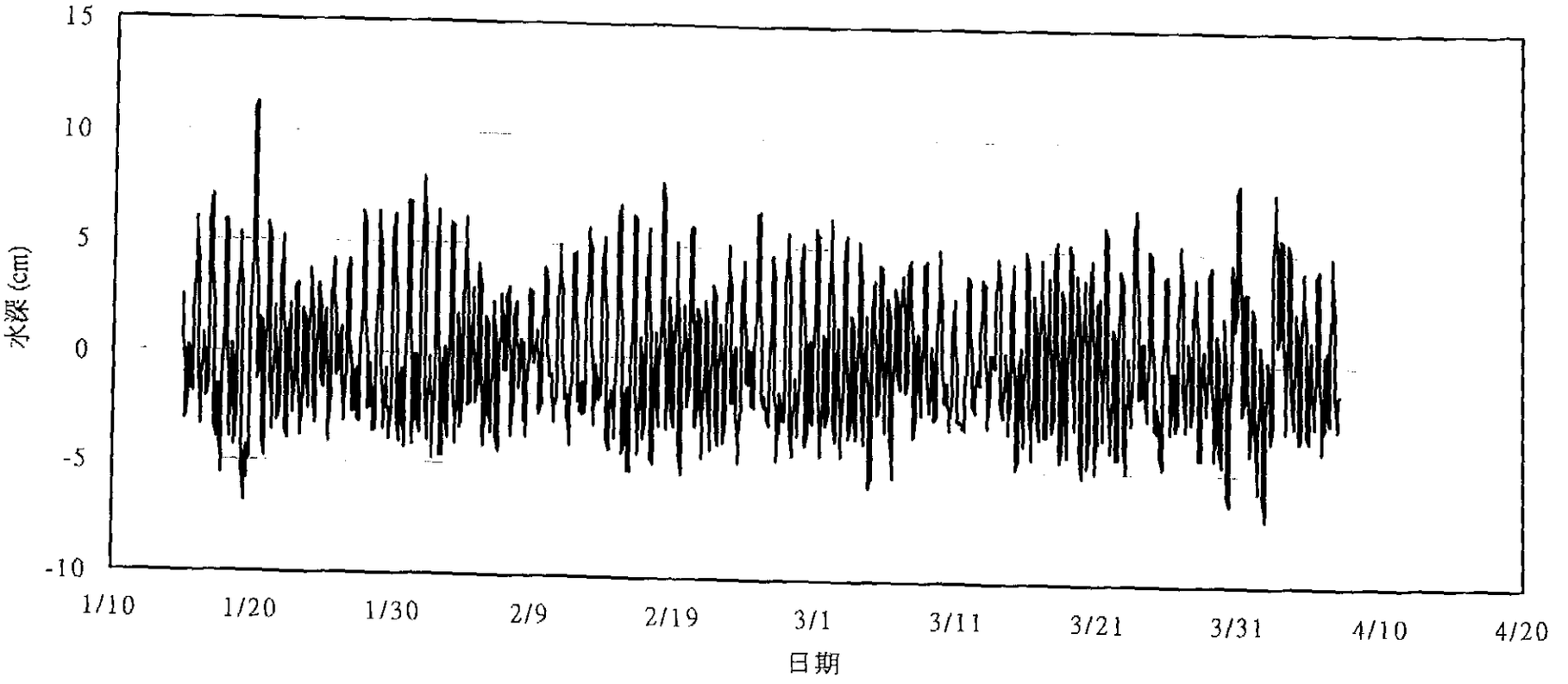
圖十二 長週期(大於 24 小時)氣壓數據



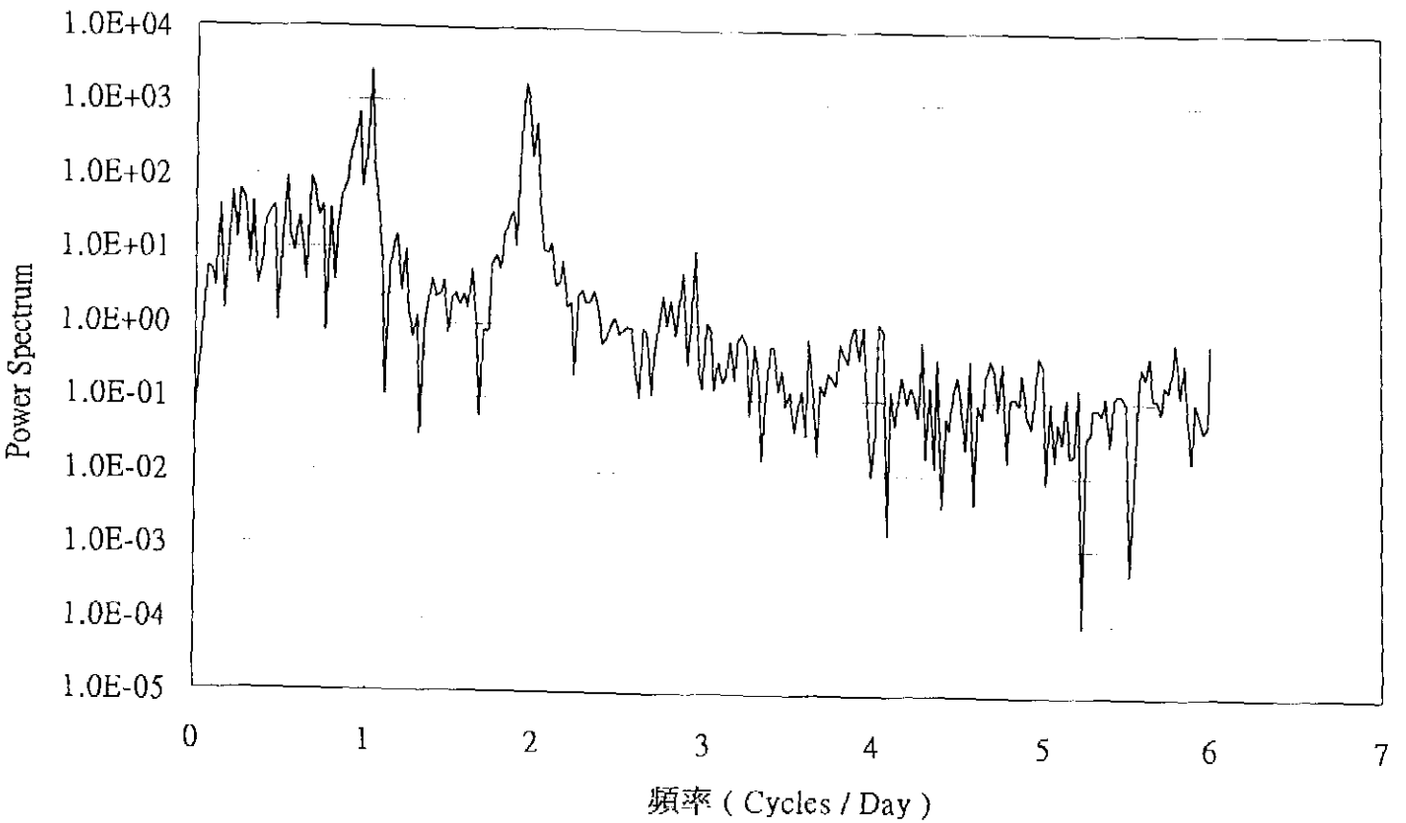
圖十三 長週期(大於 24 小時)W_0 井水位數據



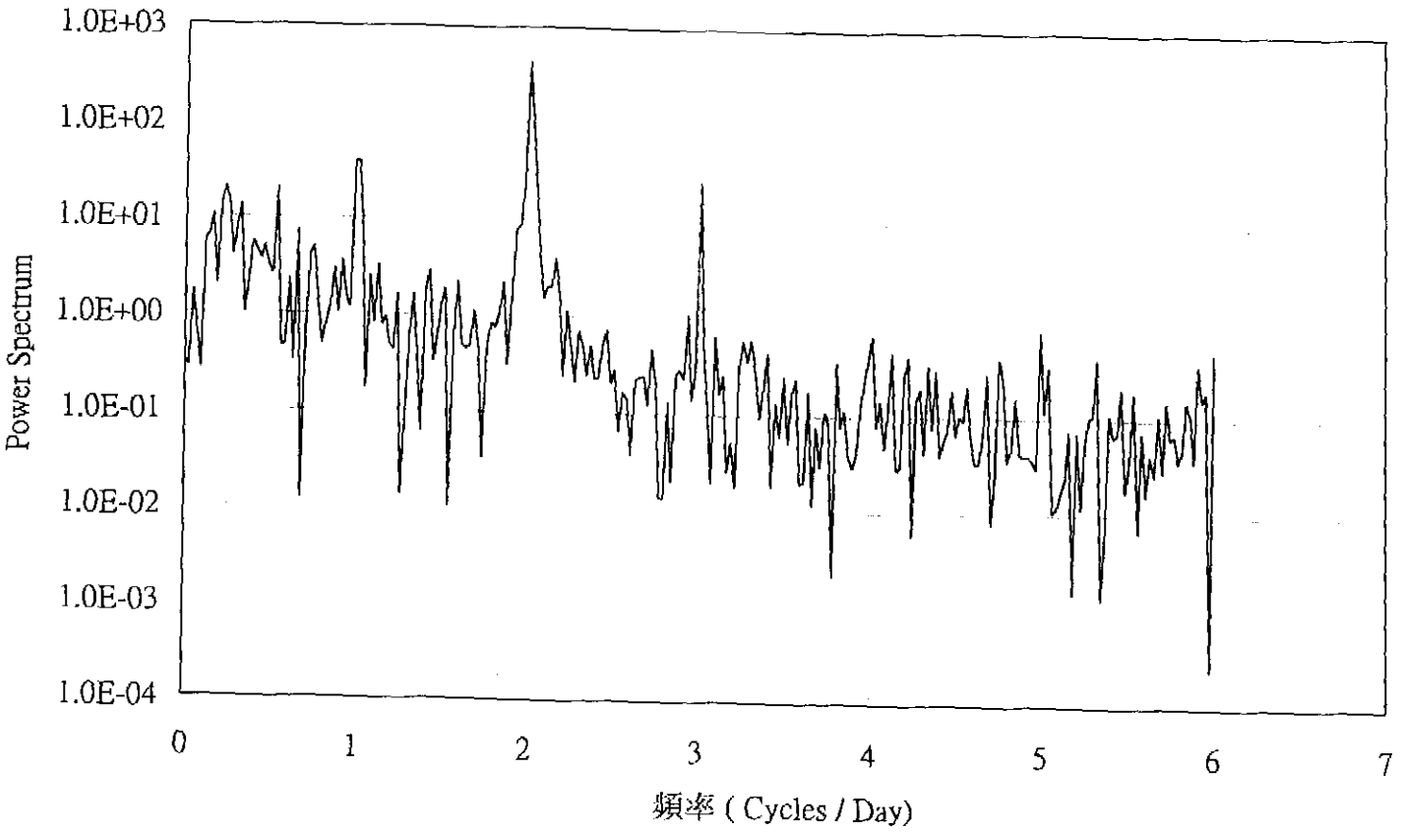
圖十四 過濾後氣壓數據



圖十五 過濾後 W_0 井地下水位數據



圖十六 W_0 井水位之 Autospectrum 與頻率關係圖



圖十七 氣壓之 Autospectrum 與頻率關係圖

六、結語

本計畫執行至今，除完成第一年的各項工作外，並進一步針對觀測得的氣壓及地下水位數據，作過濾與頻譜分析，結果顯示，地下水位週期性的變動，受全日潮與半日潮的影響較大。下年度計畫將應用序率分析理論，來推算受潮汐影響下之地下含水層參數。

七、參考文獻

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附錄

附錄 A

水位計儀器介紹

PRESSURE SYSTEMS

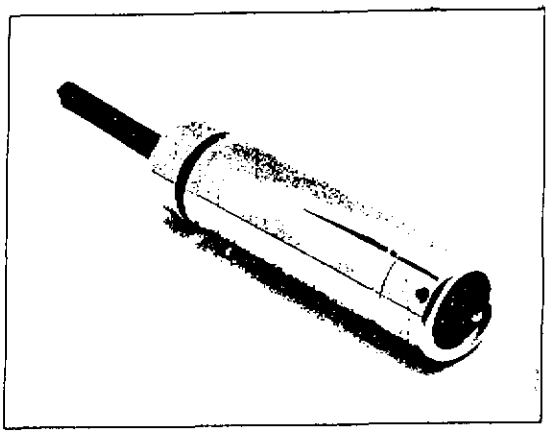
Industrial Submersible Pressure Transducer

ISO-9001 Certified

Series 700, 710, 720, 760

FEATURES

- High Static Accuracy & Repeatability
- Welded 316 SS Construction
- Small Rugged Package
- User-Specified Pressure Ranges Available
- 100% Computer-Tested, Calibrated and Serialized
- Unique Cable Seal System
- Fully Temperature Compensated
- Datalogger Compatible



APPLICATIONS

- Well Monitoring
- Slug Tests
- Pump Control
- Ground Water Monitoring
- Soil Remediation
- Oceanographic Research
- Lift Stations
- Level Control
- Surface Water Monitoring

The Series 700 family of submersible pressure transducers is specifically designed to meet the rigorous environments encountered in liquid level measurement and control. It can be configured to perform to specifications under the most adverse, reactive conditions.

These transducers incorporate the latest advancements in piezoresistive pressure sensing technology. A stability-enhancing charged "Field Shield" is vapor deposited directly to the pressure cell. A welded 316 Stainless Steel diaphragm, with a spring rate ratio of 1000:1 with the piezoresistive pressure cell, is used for contact with the media. The transducer housing is an all-welded design, constructed of corrosion resistant 316 SS. A titanium housing with hastelloy/platinum sensor combination is also offered for extremely corrosive media.

The Series 700 also features state-of-the-art, surface mount internal signal conditioning which provides a power supply rejection of 0.001% and either a 4-20 mAdc, 0-5 Vdc, or mVdc process signal. Approvals to FM, CSA, and UL are available for Class I, Div 1, Groups A, B, C and D, and Class II, Div 1, Groups E, F and G, and Class III, Div 1 hazardous locations. These instruments also meet CE approval according to EN-50081-2 and EN-50082-2. Hazardous locations installation must be to local and national electrical codes and installed with an approved electrical barrier, such as manufactured by R.G. Stahl, Inc.

Each transducer is shipped with a barrier that prevents moisture from entering the cable vent tube and with a traceable calibration card. The card specifies input/output conditions and actual data recorded during manufacture. Optional calibration is available when additional performance characteristics are required. All units are repairable and have low power requirements.

Pressure Systems, Inc.
34 Research Drive
Hampton, VA 23666
USA
Phone: (757) 865-1243
Fax: (757) 766-2644
E-mail: sales@psih.com or kpsi@cts.com
Website: www.psih.com and www.kpsi.com

PSI Ltd.
124, Victoria Road
Farnborough, Hants
GU14 7PW, United Kingdom
Phone: +44 (1252) 510000
Fax: +44 (1252) 510099
E-mail: dcopley@solartron.com

Series 700, 710, 720, 730 Specifications

Parameter	730	720	710	700	Units	Comments
PRESSURE RANGES	0~20PSI					
Pressure Ranges[3]	0 - 5 through 0 - 300 0-35 through 0-21000				psig kPa	any intermediate ranges available
Proof Pressure	1.5				x F.S.	
Burst Pressure	2.0				x F.S.	
STATIC PERFORMANCE						
Static Accuracy[1]	±0.10	±0.25	±0.50	±1.00	%FSO BFSL	
Thermal Error[2]	±0.05			±0.10	%FSO/°C	worst case
Resolution	Infinitesimal					
ENVIRONMENTAL						
Wetted Materials[3]	316 SS, Fluorocarbon					options available
Compensated Temp Range[3]	0 to 50			10 to 30	°C	options available
Operating Temp Range	-10 to 60				°C	options available
ELECTRICAL						
Excitation	2.5 - 10 5 9 - 30				VDC	mVdc output (ratiometric) mVdc output (non-ratiometric) mAdc, Vdc output
Input Current	3.5 20				mA max	mVdc, Vdc output mAdc output
Output	2.5 - 10 0 - 100[4] 0 - 5 4 - 20				mV/V mV VDC mA	ratiometric, depending on range non-ratiometric 3 wire 2 wire
Zero Offset	±5 ±60 ±0.12				mV mV mA	mVdc output Vdc output mAdc output
Output Impedance	< 10				ohms	
Insulation Resistance	100				megaohms	at 50 VDC
Circuit Protection	Polarity, surge/shorted output					
PHYSICAL						
Weight	198				grams	excluding cable
Cable	Polyurethane jacketed shielded cable with polyethylene vent tube. 90 kilograms pull strength. Conductors are 22 AWG. Tefzel jacket optional.				70 g/m	specify cable length as separate line item
Mounting Provisions	Suspended by cable. For turbulent conditions, specify optional mount bracket or conduit fitting.					

Notes:

1 Static accuracy includes the combined errors due to non-linearity, hysteresis and nonrepeatability on a Best Fit Straight Line (BFSL) basis, at 25°C per ISA S51.1.

2 Thermal error is the maximum allowable deviation from the Best Fit Straight Line due to a change in temperature, per ISA S51.1.

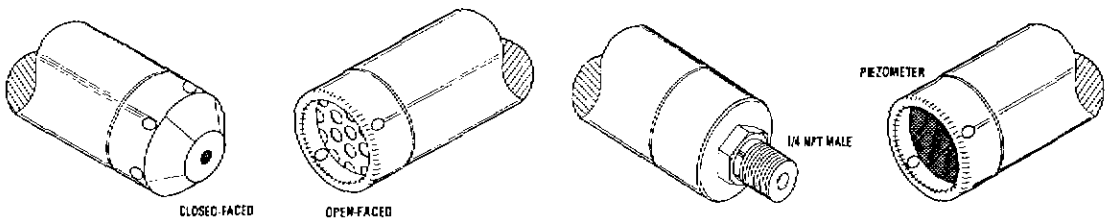
3 Consult factory for highly corrosive media, tighter tolerances on environmental specifications and special low/high pressure applications.

4 0-50 mV FSO for ranges < 10 psi.

Specifications subject to change without notice.

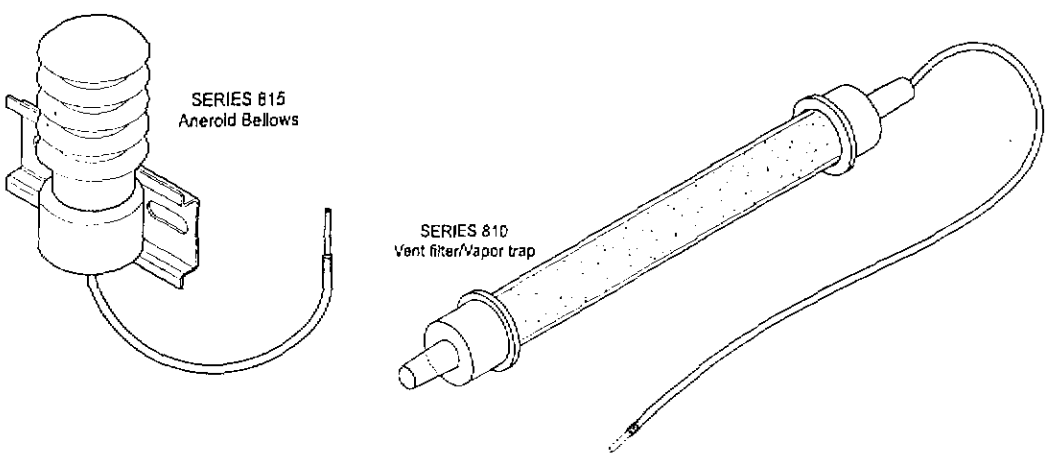
Field Installable Nose Caps

Several different user-installable nose caps are available for the Series 700, 710, 720, 730 submersible pressure transducers. The closed-faced port end cap (PN# 42-01-1314) with #8-32UNC-2B threaded hole is best used where weights are required and for those installations where users may encounter sharp, protruding objects. The open-faced port end cap (PN# 42-01-6481) which allows maximum contact with the liquid media is ideal for wastewater and "greasy" applications where clogging of the sensor is a concern. The ¼" male NPT pressure port end cap (PN# OPTION-017) is not only useful for calibration purposes but also allows the device to be used as a submersible or above ground pressure transducer. The piezometer port end cap (PN# OPTION-006) allows the unit to be buried in the ground without damage to the sensor diaphragm.



Moisture Protection

Our submersible transducers are equipped with custom, vented cable. The vent provides an atmospheric reference for the sensor, which is necessary for insuring the highest possible accuracy when making a level measurement. The downside to the vent is that, if left unprotected, it provides a pathway for water vapor to enter the level transducer. This vapor will condense into liquid water and, at the least, create an offset in the transducer output and at worst, cause damage. For these reasons, a Series 810 desiccant-filled vent filter is provided free of charge with each Series 700 that we ship. These filters must be periodically replaced as the desiccant becomes spent, which is obvious because the desiccant changes from blue to pink. Replacement filters are available from the factory. For those applications where periodic maintenance is not practical, our Series 815 Aneroid Bellows is a direct replacement for the vent filter. This sensitive bellows responds to and transmits changes in atmospheric pressure to the sensor while remaining a maintenance-free, closed system. It should be noted, however, that the Bellows may not be a suitable replacement for the desiccant cartridge in applications where extremely high accuracy is required, usually 0.1% or better. The user is cautioned to evaluate a Bellows in the specific application intended.



Surge/Lightning Protection

Surge protection is offered for 0-5 VDC (PN# OPTION-012) and 4-20 mA (PN# OPTION-009) output for our 700 family of submersible pressure transducers. This is achieved through the use of 2 protectors. One is located in a 4 inch long, 1 inch OD 316 SS housing extension attached directly to the non-pressure sensing end of the transducer while the other is located at the surface and grounded via DIN-rail or ground wire. Whether lightning protection is employed or not, the cable shield is left exposed so that the shield can be attached to an earth ground.

Submersible Cable

Our submersible transducers utilize two different types of custom cable made just for submersible applications. The most common is our polyurethane-jacketed cable, or poly cable for short. This is the cable of choice for most applications, including potable water, sewage, rivers, streams and even leachate. The other choice is our Tefzel-jacketed cable. DuPont Tefzel is a derivative of Teflon, providing the chemical resistance and toughness but at a lower price than Teflon. Tefzel is the better choice when media are expected that are not compatible with polyurethane or when a high degree of abrasion is anticipated. While more expensive than poly cable, it can save money in the long term due to lower maintenance costs. Some applications where Tefzel is utilized include remediation wells, drinking water tanks that are periodically sanitized with chemicals such as sodium hypochlorite and where it is not possible or practical to remove the transducer during the sanitization process. Installations where it is expected that the cable will be subjected to sharp objects and/or abrasion would also be a good candidate for Tefzel. In the case where the user is not sure which material is best, contact the KPSI applications department for assistance. In all installations, care should be taken to ensure no damage occurs to the cable as cable damage represents on of the most frequent causes of transducer failure.

Display Meter

The PD690 is a high performance, easy-to-use, industrial grade digital process meter with many useful features. They include:

- single button scaling
- NEMA 4X front panel
- linearization with square root extraction
- 4-20 mA output option
- 2 or 4 control relay options
- isolated 24 VDC transmitter power supply
- steady 4½ digit + extra zero display
- 4 visual alarm points
- UL approval

Single-button and stand-alone scaling make setups a snap and the internal 24 VDC power supply simplifies your 4-20 mA current loop setups by eliminating the need for an external power supply.

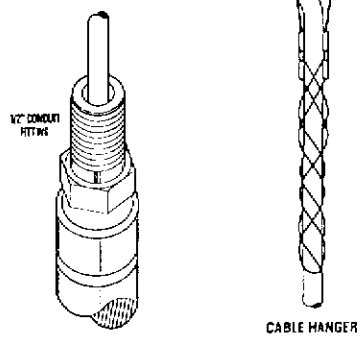
The NEMA 4X front panel allows installation of the PD690 in almost any panel in your plant, including wet, dirty and dusty environments. The PD690's 4½ digit plus extra zero is great for displaying large numbers, like the volume in a 100,000 gallon tank. Even when displaying large numbers, the PD690's display is accurate and steady.

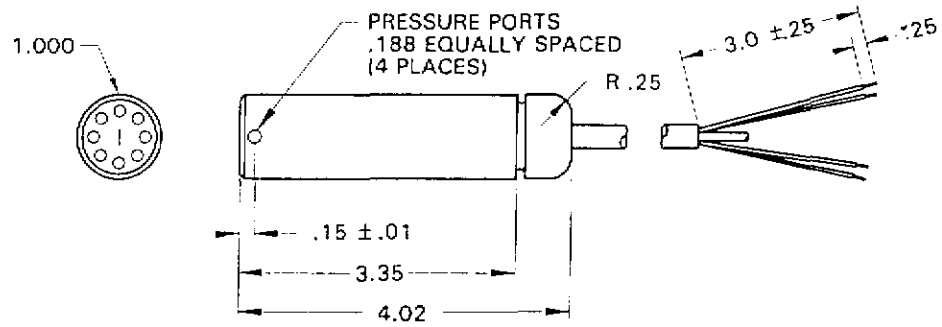
Optional 4-20 mA isolated output provides signal to independent RTU or data logger, while the options for either 2 or 4 control relays means the PD690 can function as a controller. These SPDT relays are rated at 2 amps at 240 VDC and can be programmed for automatic or automatic + manual reset. They can also be programmed for 0-100% deadband.

Installation Tips

Most users either suspend our submersible transducer in a 1" or 2" PVC instrumentation still well or attach the transducer using our optional ½" M NPT fitting to a rigid conduit.

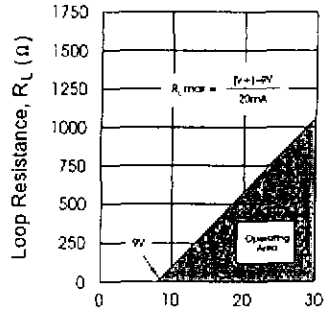
When suspending the cable, users often utilize our cable hanger (PN# 12-90-0931). This device slides onto the cable from the bare-wire end. The cable hanger can be positioned anywhere on the cable by pushing the ends together. Once positioned, the cable hanger contracts to provide a snug grip.





ELECTRICAL TERMINATION		
(2,3 or 4) 24AWG CONDUCTORS IN A SHIELDED CABLE WITH SENSOR BREATHER AND POLYURETHANE JACKET		
(4) 4-20 mA	RED	+ EXCITATION
	BLACK	- EXCITATION
(3) 0-5 VDC	RED	+ EXCITATION
	BLACK	- EXCITATION
	WHITE	+ SIGNAL
(2,5,6) mV	RED	+ OUTPUT
	BLACK	+ EXCITATION
	WHITE	- EXCITATION
	GREEN	- OUTPUT

LOOP RESISTANCE vs.
LOOP POWER SUPPLY



Series 700, 710, 720, 730 Order Information

Standard shipment is 4 weeks upon receipt of order. Expedited 1 and 2 week shipment is available. All orders are shipped FOB from our factory in Hampton, Virginia.

Ordering Information

Model No.

7	0	0	±1.0% FSO Static Accuracy Submersible Pressure Transducer
7	1	0	±0.50% FSO Static Accuracy Submersible Pressure Transducer
7	2	0	±0.25% FSO Static Accuracy Submersible Pressure Transducer
7	3	0	±0.10% FSO Static Accuracy Submersible Pressure Transducer

Pressure Format

1 Gage, vented reference
3 Sealed gage
4 Absolute

Excitation/Signal

2 9-30 VDC Input, mV Output (Non-Ratiometric)
3 VDC Input, VDC Output
4 VDC Input, mA Output
5 VDC Input, mV Output (Ratiometric)
6 5 VDC Input, mV Output (Non-Ratiometric)

Pressure Connection

0 Standard submersible screen (open faced)
2 ¼" - 18 NPT male

Electrical Connections

0 Standard submersible cable exit
4 ½" - 14 NPT Male conduit connection

Pressure Range

0 - 5 psi through 0 - 300 psi

Examples: 0-5 psi = 0005; 0-10 psi = 0010; 0-100 psi = 0100

Warranty: The Series 700 family of products is warranteed against defects in material and workmanship for 12 months from date of shipment. Products not subjected to misuse will be repaired or replaced. THE FOREGOING IS IN LIEU OF ANY OTHER EXPRESSED OR IMPLIED WARRANTIES. We reserve the right to make changes to any product herein assume no liability arising out of applications or use of any product or circuit described. Products described in this Specification are not intended for life support applications.

附錄 B

雨量計儀器介紹

TE525
TIPPING BUCKET RAIN GAGE

REVISION: 2/96

WARRANTY AND ASSISTANCE

The **TE525 TIPPING BUCKET RAIN GAGE** is warranted by CAMPBELL SCIENTIFIC, INC. to be free from defects in materials and workmanship under normal use and service for twelve (12) months from date of shipment unless specified otherwise. Batteries have no warranty. CAMPBELL SCIENTIFIC, INC.'s obligation under this warranty is limited to repairing or replacing (at CAMPBELL SCIENTIFIC, INC.'s option) defective products. The customer shall assume all costs of removing, reinstalling, and shipping defective products to CAMPBELL SCIENTIFIC, INC. CAMPBELL SCIENTIFIC, INC. will return such products by surface carrier prepaid. This warranty shall not apply to any CAMPBELL SCIENTIFIC, INC. products which have been subjected to modification, misuse, neglect, accidents of nature, or shipping damage. This warranty is in lieu of all other warranties, expressed or implied, including warranties of merchantability or fitness for a particular purpose. CAMPBELL SCIENTIFIC, INC. is not liable for special, indirect, incidental, or consequential damages.

Products may not be returned without prior authorization. To obtain a Returned Materials Authorization (RMA), contact CAMPBELL SCIENTIFIC, INC., phone (801) 753-2342. After an applications engineer determines the nature of the problem, an RMA number will be issued. Please write this number clearly on the outside of the shipping container. CAMPBELL SCIENTIFIC's shipping address is:

CAMPBELL SCIENTIFIC, INC.
RMA#_____
815 West 1800 North
Logan, Utah 84321-1784

CAMPBELL SCIENTIFIC, INC. does not accept collect calls.

Non-warranty products returned for repair should be accompanied by a purchase order to cover the repair.

CAMPBELL SCIENTIFIC, INC.

815 W. 1800 N.
Logan, UT 84321-1784
USA
Phone (801) 753-2342
FAX (801) 750-9540

Campbell Scientific Canada Corp.
11564 -149th Street
Edmonton, Alberta T5M 1W7
CANADA
Phone (403) 454-2505
FAX (403) 454-2655

Campbell Scientific Ltd.
14-20 Field Street
Shepshed, Leics. LE12 9AL
ENGLAND
Phone (44)-50960-1141
FAX (44)-50960-1091

TE525 TIPPING BUCKET RAIN GAGE

1. FUNCTION

The TE525 is a smaller adaptation of the standard Weather Bureau tipping bucket rain gage. It measures rainfall at rates up to 2 in. per hour with an accuracy of ±1%. Output is a switch closure for each bucket tip. A tip occurs with each 0.01 inch of rainfall. The metric TE525, available on special request, tips with each 0.1 millimeter of rainfall.

2. SPECIFICATIONS

Range of Indication:
Infinite in increments of 0.01 in. (least count) of rainfall. (Metric version: in increments of 0.1 mm.)

Accuracy:
1.0% at 2 inch/hr. or less.

Signal Output:
Momentary switch closure activated by tipping bucket mechanism. Switch closure is approximately (35 ms.)

Calibration/Cleaning Frequency:
Sensor is factory calibrated and should not require field calibration. Debris filters, funnel orifices, and bucket reservoirs should be kept clean. Section 4 describes field calibration check and factory recalibration.

Environmental Limits:
Temperature: 0° to +50°C
Humidity: 0 to 100%

Physical Data:
Diameter: 6.25 in. overall
Height: 9.5 in. (metric version 12 in.)
Weight: 2.5 pounds
Receiving Orifice: Gold anodized spun aluminum knife edge collector ring and funnel assembly.
Ring Diameter: 6.064 in. (metric version 9.664 in.)
Resolution: 0.01 in. (metric version 0.1 mm)
Calibration: 16.00 fluid oz. (100 bucket tips)
Mounting: Side bracket with clamps for pole or mast mounting
Material: Aluminum
Cable: 2-conductor, shielded cable, 25 ft. standard length.

NOTE: The black outer jacket of the cable is Santoprene® rubber. This compound was chosen for its resistance to temperature extremes, moisture, and UV degradation. However, this jacket will support combustion in air. It is rated as slow burning when tested according to U.L. 94 H.B. and will pass FMVSS302. Local fire codes may preclude its use inside buildings.

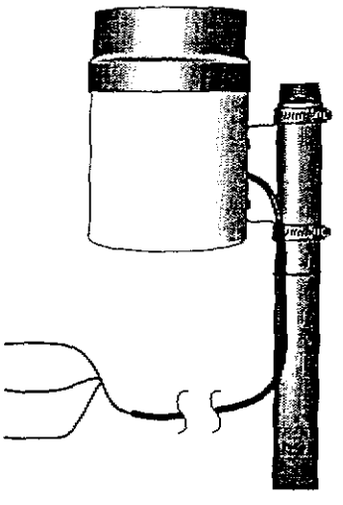


FIGURE 1. TE525 Tipping Bucket Rain Gage

3. INSTALLATION

3.1 LOCATION

The rain gage should be mounted in a relatively level spot which is representative of the surrounding area. The lip of the funnel should be horizontal and at least 30 cm. above the ground. It should be high enough to be above the average snow depth. The ground surface around the rain gage should be natural vegetation or gravel. It should not be paved.

The rain gage should be placed away from objects that obstruct the wind. The distance should be 2 to 4 times the height of the obstruction.

When leveling, be sure that the funnel is properly seated in the body of the gage and that:

- the orifice is level
- the body of the sensor is vertical (plumb).

3.2 MOUNTING

The TE525 rain gage mounts to a 2 inch post or pipe. Set the post or drive the pipe as nearly vertical as possible. Use the enclosed hose clamps to mount the gage as shown in Fig. 1. The lip of the gage should be at least 2 inches above the post or pipe. Level the rain gage after mounting it.

> **NOTE**: Before final leveling, press either end of the bucket down against its stop to make sure the bucket is NOT hung up in the center.

3.3 WIRING

Connect the sensor leads to the CR10, 21X, or CR7 as follows: black to pulse channel; white and shield to ground (G on the CR10).

In a long cable there is appreciable capacitance between the lines. A built up charge could cause arcing when the switch closes, shortening switch life. With long leads, a 100 ohm resistor should be connected in series at the switch. The resistor prevents arcing by limiting the current. Campbell Scientific installs the resistor whenever a cable longer than the standard 25 feet is ordered.

3.4 DATALOGGER INSTRUCTIONS

CR10, 21X, and CR7

The TE525 is measured using Instruction 3 with the switch closure configuration code. A multiplier of 0.01 converts the output to inches. A multiplier of 0.254 converts the output to millimeters.

The metric TE525 uses a multiplier of 0.1 to convert the output to millimeters. A multiplier of 0.00394 converts the output to inches.

4. MAINTENANCE

The funnel and bucket mechanism must be kept clean. Routinely check for and remove any foreign material, dust, insects, etc. The following calibration check is advised every 12 months.

Field Calibration Check:

(1) Secure a metal can that will hold at least one quart of water.
(2) Punch a very small hole in the bottom of the can.
(3) Place the can in the top funnel of the rain gage and pour 16 fluid ounces (1 pint) of water into the can. (A 16 oz. soft drink bottle filled to within 2.5 inches of the top may be used for a rough field calibration. An exact volume will allow for a more precise calibration).
(4) If it takes less than 45 minutes for this water to run out, the hole in the can is too large.
(5) One hundred tips plus or minus three tips should occur.
(6) Adjusting screws are located on the bottom adjacent to the large center drain hole. Adjust both screws the same number of turns. Rotation clockwise increases the number of tips per 16 oz. of water; counter clockwise rotation decreases the number of tips per 16 oz. of water. One half turn of both screws causes a 2% to 3% change.
(7) Check and re-level the rain gage lid.

Factory Calibration:

If factory calibration is required, send the TE525 to:

Texas Electronics
P.O. Box 7225, Inwood-Station
Dallas, Texas 75209
Phone: (214) 631-2490

附錄 C

氣壓計操作手冊

MODEL 090D
BAROMETRIC PRESSURE SENSOR

OPERATION MANUAL

Met One
Instruments

1600 Washington Blvd.
Grants Pass, Oregon 97526
Telephone 503-471-7111
Facsimile 503-471-7116

Regional Sales & Service
3206 Main St., Suite 106
Rowlett, Texas 75088
Telephone 214-412-4747
Facsimile 214-412-4716

1.0 GENERAL INFORMATION

1.1 090D Barometric Pressure Sensor uses an active solid-state device to sense barometric pressure. Self-contained electronics provide a regulated voltage to the solid state sensor and amplification for the signal output.

1.2 A 1169-XX' Sensor Cable is a 3-conductor shielded, vinyl jacketed cable. Length is given in -XX feet on each cable part number label.

TABLE 1-1

Model 090D-26/32-1 Pressure Sensor Specifications

Performance

Calibrated Range	26/32" (standard)*
Calibrated Operating Range	-18°C to +50°C
Operating temperature range	-40°C to +50°C
Resolution	Infinite
Accuracy	±0.04 in Hg (±1.35 mb) or
Accuracy	±0.125% FS
Output	0-1V DC (standard)*

*Refer to model number of sensor. Example: 090D -26/32(-1

Basic Model # | Range ("Hg) | Output Voltage
(In this example, the sensor output is 0-1v for a range of 26 to 32" Hg)

Electrical Characteristics

Power Requirement	11 ma @ 12 VDC
Sensor Output	0-1 VDC Standard
	0-5 VDC Optional

Physical Characteristics

Weight	2 lbs. 5 oz. (1.05 Kg)
Dimensions	5.5" x 5" x 7.5" (14x12x19 cm)

2.0 INSTALLATION

2.1 Mounting the Sensor. Mount sensor in a convenient location with pressure inlet port facing downward. Refer to drawings 6139 and 6140 for mounting details.

2.2 Installing the Cable. The 1169 Cable Assembly contains three wires. Install the cable into the water-tight gland and connect cable as follows:

SIG Terminal = Signal Output (Clr)
COM Terminal = Common (Blk)
+12 Terminal = +12V Power (Red)

3.0 OPERATION

3.1 The Barometric Pressure Sensor has been calibrated at the factory, and will not change unless it is damaged. To check for proper operation of the sensor and module, it is advised that the module's output be checked against a local weather service facility. Exact correlation is not to be expected, due to geographical and meteorological variations. The sensor reads absolute barometric pressure, whereas local weather services readings are normalized to sea level values.

3.2 One should keep in mind that nominal pressure, at sea level, is 30 inches of mercury and that for every 1,000 feet of elevation, the pressure decreases approximately one inch of mercury. EXAMPLE: A weather station at sea level may use a barometer with a range of 26 to 32 inches of mercury to cover all possible weather conditions. However, a weather station, located 4,000 above sea level, would require a range of 22 to 28 inches of mercury.

MODEL 090D BAROMETRIC PRESSURE SENSOR
RANGE SELECTION GUIDE

ELEVATION	RANGE ("Hg)
0 to 1,500	26/32
1,501 to 3,500	24/30
3,501 to 5,500	22/28
5,501 to 8,000	20/26
8,001 to 10,000	18/24
10,001 to 12,500	16/22
12,501 to 15,500	14/20
15,501 to 19,000	12/18

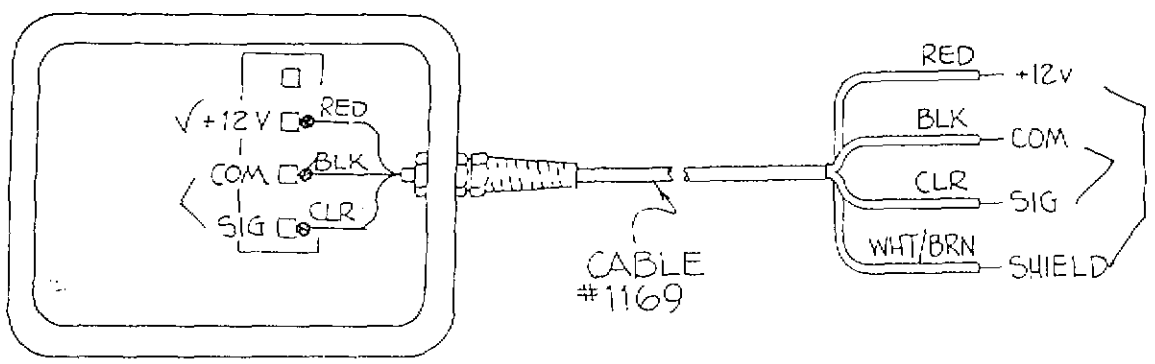
4.0 MAINTENANCE AND TROUBLESHOOTING

4.1 General Maintenance Schedule

A. Inspect pressure inlet port occasionally to insure it is free of obstruction. No other periodic maintenance or calibration is required.

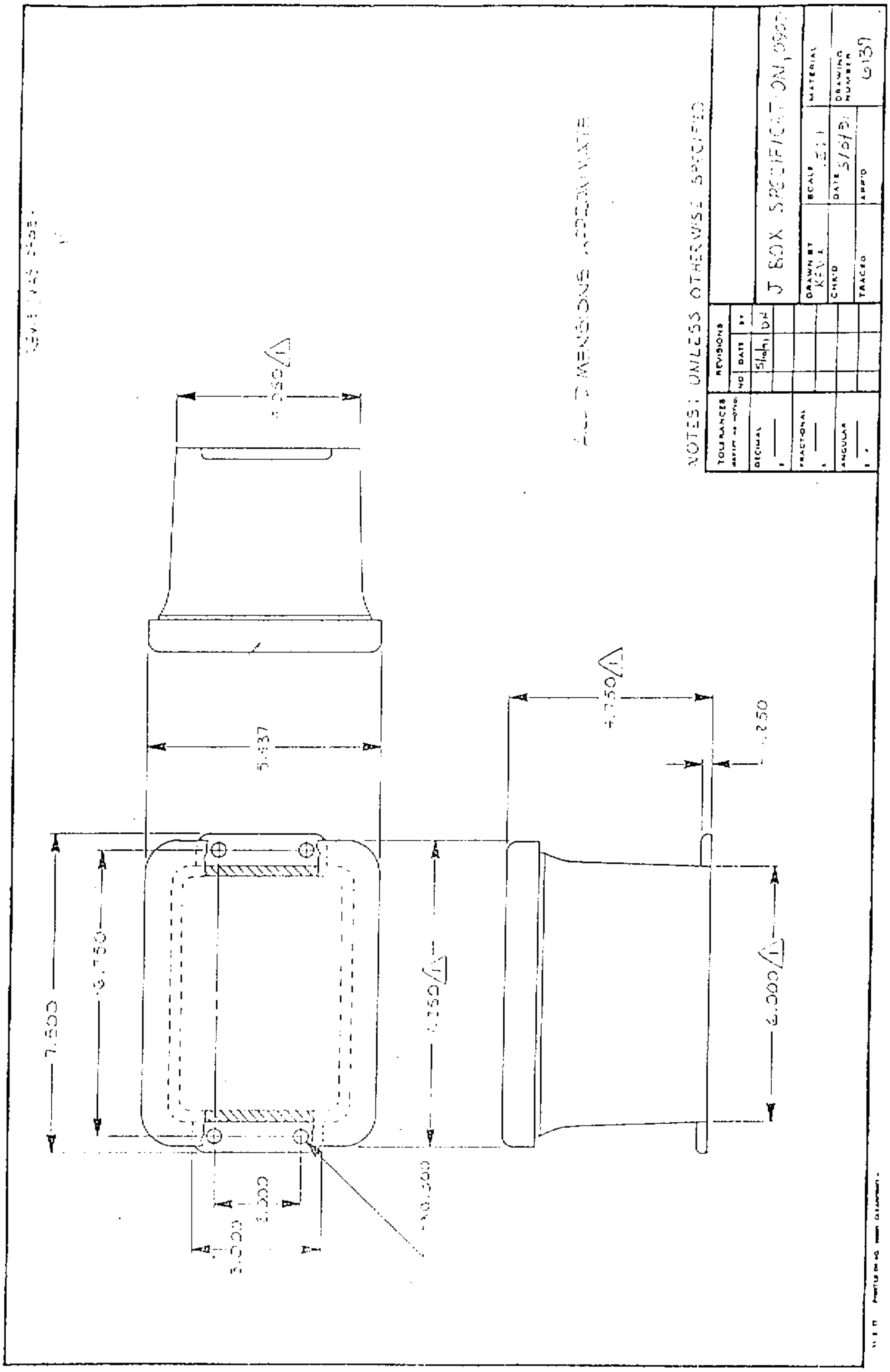
B. Inspect sensor for proper operation per Section 3.1.

4.2 090D Pressure Sensor Maintenance. The pressure sensor is an inherently stable device that does not require periodic service or recalibration. Should service or recalibration become necessary, the sensor must be returned to the factory. Always inspect Model 090D Pressure Sensor to make sure that inlet port is clean and free from obstructions.

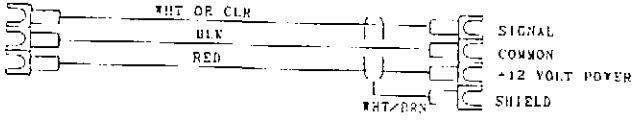


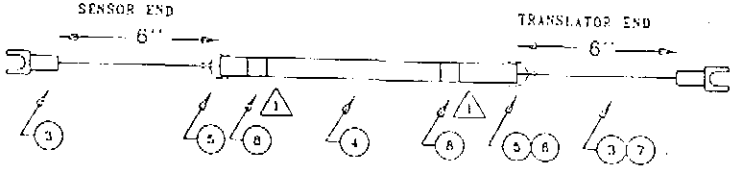
MODEL 090D BAROMETRIC PRESSURE SENSOR.
CABLE CONNECTIONS

(See Section 2.2)


NOTES: UNLESS OTHERWISE SPECIFIED
ALL DIMENSIONS APPROXIMATE
J BOX SPECIFICATION
7.500
6.750
5.437
4.750
6.000
.250

REVISIONS			
REV	DESCRIPTION	DATE	APPROVED
C	REDRAWN W/PARTS LIST	9/16/91	DH





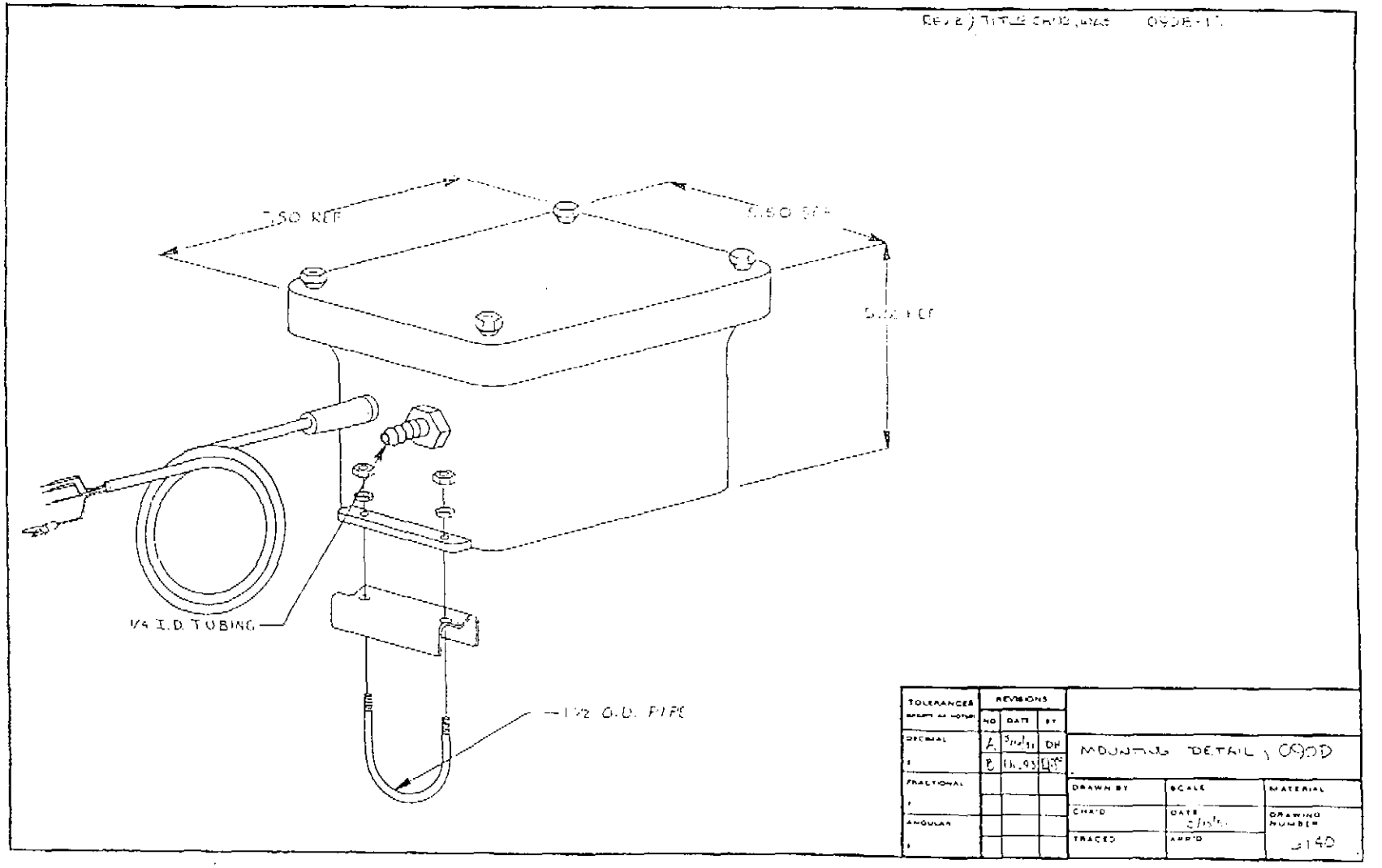
1 IDENTIFY CABLE 18" FROM EACH END. DASH NUMBER = LENGTH IN FEET.

ITEM	PART NO.	DESCRIPTION	QTY.
1			
2			
3	800193	LUG, SPADE, #8	7
4	400011	CABLE, 3 WIRE, SHIELDED	A/R
5	960050	SLEEVING, 1/4", SHRINK	A/R
6			
7	980510	WIRE, 22 AWG, WHT/BRN	6'
8	960060	SLEEVING, 1/4", CLEAR SHRINK	A/R
9			
10			

MET ONE INSTRUMENTS

ASSY, CABLE, BARO PRESSURE

SIZE	FSCM NO.	DWG NO.	REV
		1169	C
SCALE		SHEET 1 OF 1	



TOLERANCES	REVISIONS		
DECIMAL	NO	DATE	BY
.x	A	3rd/11	DH
.xx	B	11.93	DH
FRACTIONAL			
ANGULAR			

MOUNTING DETAIL, 0900

DRAWN BY	SCALE	MATERIAL
CHK'D	DATE 3/11/93	DRAWING NUMBER 3140
TRACED	APP'D	

附錄 D

Spectrum 程式

```
      Program Spectrum
c     This program includes following two functions:
c     1.trend removal:linear trend and low-pass filter(ED6)
c     2.spectrum estimation using FFT from Numerical Recipes
c
      parameter(idata=10000,m=128)
      real data(idata),cut(idata)
      real data1(-2:idata),cut1(-2:idata)
      real w1(m*2),w2(m*2),xi(m*2)
      real ps1(m*2),ps2(m*2)
      real fq(m*2),omaga(m*2)
      complex  ans1(m*2),ans2(m*2)
      character*16 filename,filename1,filename2,filename3
      real window
      window(j)=(1.-abs(((j-1)-facm)*facp))
c     window(j)=1.
c     window(j)=(1.-(((j-1)-facm)*facp)**2)
c
c
      write(*,*) 'Input the file name (time domain) '
      read(*,*) filename
      open(unit=10,file=filename,status='old')
      write(*,*) 'Is the data file atmospheric pressure  ?'
      write(*,*) 'Yes=1, No=0'
      read(*,*) ia
      write(*,*) 'Output the file name (Frequency domain): Spectrum '
      read(*,*) filename
      open(unit=20,file=filename,status='unknown')
      write(*,*)' the first point (it must be greater then 5)'
      read(*,*) if
      write(*,*)' the total length'
      read(*,*) nf
c
       n=nf
       k=nf/m-1
       nh=24
       iovrlap=1
       pi=3.141592654
       isgn=1
       isgn1=-1
       t=real(nf)/real(nh)
       do 110 i=1,if-4
       read(10,*)
 110   continue
c
c  Input data record in time domain
```

```
c
        do 1 i=-2,nf+3
        cut1(i)=0.01
        read(10,*) data(i)
 1      continue
c
c
c  Do you want to overlap the data ?
c
      mm=m+m
      m4=mm+mm
      m43=m4+3
      den=0.
c
c  facm is factors used by the window statement function.
c
      facm=m
      facp=1./m
c
c  sumw is accumulate the squared sum of the weights.
c
      sumw=0.
      do 13 j=1,mm
        sumw=sumw+window(j)**2
 13   continue
c
c Initialize the spectrum to zero.
c
      do 14 i=1,mm
        ps1(i)=0.0
        ps2(i)=0.0
 14   continue
c
      do 20 kk=1,k
        if (iovrlap .eq. 1) then
          do 21 i=1,mm
            nk=(kk-1)*m
            if ((i+nk) .gt. nf) goto 999
            if ((i+nk) .le. nf) io=1
            data1(i)=data(i+nk)
            cut1(i)=cut(i+nk)
            xi(i)=real(i)
 21       continue
        else
          do 22 i=1,mm
            nk=(kk-1)*mm
```

```
            if  ((i+nk) .gt. nf)  goto 999
            if  ((i+nk) .le. nf)  io=1
            datal(i)=data(i+nk)
            cutl(i)=cut(i+nk)
            xi(i)=real(i)
 22       continue
         endif
c
c  Linear Trend Removal
c
          call trend(xi,datal,-2,mm+3,al,bl)
          do 15 j=-2,mm+3
           datal(j)=datal(j)-al*xi(j)-bl
 15       continue
c
c  Taper Function and Filter Used "ED6"
c
         if (ied6 .eq. 1) then
         do 6 i=1,mm
         wl(i)=0.75*(datal(i-1)+datal(i+1))-0.3*(datal(i-2)+
     +          datal(i+2))+0.05*(datal(i-3)+datal(i+3))
         w2(i)=0.75*(cutl(i-1)+cutl(i+1))-0.3*(cutl(i-2)+
     +          cutl(i+2))+0.05*(cutl(i-3)+cutl(i+3))
 6       continue
         else if (ied6 .eq. 0) then
         do 8 i=1,mm
         wl(i)=datal(i)
         w2(i)=cutl(i)
 8       continue
         endif
c
c  Apply the window to the data.
c
          do 23 j=1,mm
            w=window(j)
            wl(j)=wl(j)*w
            w2(j)=w2(j)*w
 23       continue
         call twofft(wl,w2,ans1,ans2,mm)
         do 24 j=1,m
         ps1(j)=ps1(j)+2.*conjg(ans1(j))*ans1(j)
         ps2(j)=ps2(j)+2.*conjg(ans2(j))*ans2(j)
 24      continue
         den=den+sumw
 20      continue
         den=m4*den
```

```
        do 25 j=1,m
        ps1(j)=ps1(j)/den
        ps2(j)=ps2(j)/den
 25     continue
c
        write(20,*)'Autospectrum of ',filename1
        do 41 i=1,m
           fqq=float((i-1)*nh)/real(mm)
        write(20,'(1x,i5,f12.5,2e16.8)') i,fqq,ps1(i)
 41     continue
c
c
        if ((io .eq. 1)) goto 998
 999    write(*,*) 'ERROR'
 998    stop
        end
c
c
c
      SUBROUTINE trend(xi,yi,in,n,a,b)
c
c     y=ax+b
c
       real xi(in:n),yi(in:n),b,a
c
       x2=0.
       y1=0.
       xy=0.
       x1=0.
       b=0.
       a=0.
       do 10 i=1,n
        x2=x2+xi(i)*xi(i)
        x1=x1+xi(i)
        y1=y1+yi(i)
        xy=xy+xi(i)*yi(i)
 10    continue
       d=x2*real(n)-x1*x1
       a=(xy*real(n)-x1*y1)/d
       b=(x2*y1-xy*x1)/d
       return
       end
c
c
      SUBROUTINE correl(data1,data2,n,ans)
      INTEGER n,NMAX
```

```
      REAL data1(n),data2(n)
      COMPLEX ans(n),ans1(n)
      PARAMETER (NMAX=16384)
CU    USES realft,twofft
      INTEGER i,no2
      COMPLEX fft(NMAX)
      call twofft(data1,data2,fft,ans,n)
      no2=n/2
      do 11 i=1,n
        ans(i)=fft(i)*conjg(ans(i))/float(no2)
11    continue
c     ans(1)=cmplx(real(ans(1)),real(ans(no2+1)))
      return
      END
C  (C) Copr. 1986-92 Numerical Recipes Software j30.
C
      SUBROUTINE twofft(data1,data2,fft1,fft2,n)
      INTEGER n
      REAL data1(n),data2(n)
      COMPLEX fft1(n),fft2(n)
CU    USES four1
      INTEGER j,n2
      COMPLEX h1,h2,c1,c2
      c1=cmplx(0.5,0.0)
      c2=cmplx(0.0,-0.5)
      do 11 j=1,n
        fft1(j)=cmplx(data1(j),data2(j))
11    continue
      call four1(fft1,n,1)
      fft2(1)=cmplx(aimag(fft1(1)),0.0)
      fft1(1)=cmplx(real(fft1(1)),0.0)
      n2=n+2
      do 12 j=2,n/2+1
        h1=c1*(fft1(j)+conjg(fft1(n2-j)))
        h2=c2*(fft1(j)-conjg(fft1(n2-j)))
        fft1(j)=h1
        fft1(n2-j)=conjg(h1)
        fft2(j)=h2
        fft2(n2-j)=conjg(h2)
12    continue
      return
      END
C  (C) Copr. 1986-92 Numerical Recipes Software j30.
c
c
      SUBROUTINE four1(data,nn,isign)
```

```
      INTEGER isign,nn
      REAL data(2*nn)
      INTEGER i,istep,j,m,mmax,n
      REAL tempi,tempr
      DOUBLE PRECISION theta,wi,wpi,wpr,wr,wtemp
      n=2*nn
      j=1
      do 11 i=1,n,2
        if(j.gt.i)then
          tempr=data(j)
          tempi=data(j+1)
          data(j)=data(i)
          data(j+1)=data(i+1)
          data(i)=tempr
          data(i+1)=tempi
        endif
        m=n/2
1       if ((m.ge.2).and.(j.gt.m)) then
          j=j-m
          m=m/2
        goto 1
        endif
        j=j+m
11    continue
      mmax=2
2     if (n.gt.mmax) then
        istep=2*mmax
        theta=6.28318530717959d0/(isign*mmax)
        wpr=-2.d0*sin(0.5d0*theta)**2
        wpi=sin(theta)
        wr=1.d0
        wi=0.d0
        do 13 m=1,mmax,2
          do 12 i=m,n,istep
            j=i+mmax
            tempr=sngl(wr)*data(j)-sngl(wi)*data(j+1)
            tempi=sngl(wr)*data(j+1)+sngl(wi)*data(j)
            data(j)=data(i)-tempr
            data(j+1)=data(i+1)-tempi
            data(i)=data(i)+tempr
            data(i+1)=data(i+1)+tempi
12        continue
          wtemp=wr
          wr=wr*wpr-wi*wpi+wr
          wi=wi*wpr+wtemp*wpi+wi
13      continue
```

```
        mmax=istep
      goto 2
      endif
      return
      END
C  (C) Copr. 1986-92 Numerical Recipes Software j30.
```