

VALEPORT LIMITED
Operating Manual
Model 808
Electromagnetic Current Meter

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1 INTRODUCTION

This document covers the operation of the Valeport Model 808 Electromagnetic Current Meter and EMLog PC software.

Flow charts covering the basic steps in operating the Model 808 are given in Section 2; for a more detailed description of how to use the instrument from configuration through deployment to recovery and data extraction, please refer to Sections 3, 4 and 5.

1.1 DESCRIPTION

The Model 808 Electromagnetic Current Meter has been developed to meet the needs of oceanographers, hydrographers, engineers and surveyors who require an accurate, easy to use instrument which outputs recorded and real time data direct to a PC.

The standard instrument is fitted with a Valeport Model 802 2-axis electromagnetic sensor and an integral gimballed flux gate compass. During sampling, the flow and compass heading are read every 2 seconds and are vector averaged to provide a final output of speed and direction in polar format [note the convention for flow is the direction the water is flowing to, which is the opposite of the convention for wind]. The Model 808 may be optionally fitted with the following additional sensors:

- Pressure
- Temperature [option of Thermistor or PRT]
- Conductivity
- Pitch and Roll
- Up to 5 auxiliary analogue channels for sensors such as D.O., turbidity, pH and optical sensors
- Optional direct reading analogue output version measuring speed & direction, and/or pressure.

Valeport's own "EMLog" software allows the user to setup the instrument sampling regime with a choice of 3 different modes, and to set a delay start feature, enabling users to define a date and time when recording starts. EMLog also allows display of both real time and recorded data in tabulated and graphical formats. Further, since the data is available in ASCII text format, it may easily be imported into other standard software packages.

Valeport offer a range of EM flow sensor types and the 808 can be supplied in either a mooring frame or a bottom mounted frame.

1.2 SPECIFICATION

Data acquisition

Sample Modes:

Time Instrument continually samples all sensors every 2 seconds, and displays/logs the average over a user settable period.

Burst Average Instrument will sample sensors a user settable number of times, and display/log the average. The unit will then enter a sleep mode for a user defined time, before beginning the cycle again. The minimum cycle time is 20 seconds.

Burst Sample Similar to Burst Average, but the unit will display/log all the samples in a burst, rather than just the average of those samples. The minimum cycle time is 20 seconds.

Switch on

If using internal batteries, switch on by using connector pro-cap with flashing LED to indicate unit operational. If external power is used, switch on by applying power.

Delay start:

Operator defined date and time to start.

Calibration	Held in EEPROM in unit.
Memory	Solid state. Standard 128 kbytes memory [optional 1 Mbyte] providing over 8,500 records of Speed, Direction, Pitch, Roll, Conductivity, Temperature & Pressure [60 days at 10 minute sampling]. Header contains setup, calibration and site information. Separate files for each time unit is switched on.
Power Supply <i>Battery pack:</i>	Integral 8 "D" cells [alkaline] in removable battery compartment [electronics remain sealed during battery change]. At 10V the current consumptions are [approximately]:

Quiescent:	0.45 mA
Data acquisition:	240 mA
During PC comms:	30 mA

Capacity, assuming new alkaline cells with nominal 18Ah capacity and 75% efficiency, is, for unit with CTD:

Burst Duration [secs]	Burst period	Life [days]
2	20 secs	8.1
10	1 min	11.9
20	10 min	70
30	10 min	51
10	20 min	210
20	20 min	134
30	20 min	99
Continuous Sampling		3.1

Use of external sensors on the analogue channels will reduce capacity, depending on the power requirements of the particular sensor used

External:

If the data needs to be recovered using external power, then the cable has a switch that enables external DC power (10 to 24 VDC) to be applied. Maximum current at 14 VDC is 190mA for unit with flow, heading, pressure, conductivity and temperature sensors

Communications	RS232 fitted as standard. RS485 communications are also built in to the 808, but are selected by a link on an internal PCB. The RS485 link is usually made at the factory at the time of supply, but can also be carried out by approved service personnel – contact factory for details.
Set up/data recovery	Uses Valeport's EMLog Windows based software. Reads real time data. Extracts data from SR versions and logs header, raw and translated data into spreadsheet compatible PC files. Software provides scroll and graphical displays of real time and recovered data.
Analogue Output	All analogue output channels are 0 – 2.5V

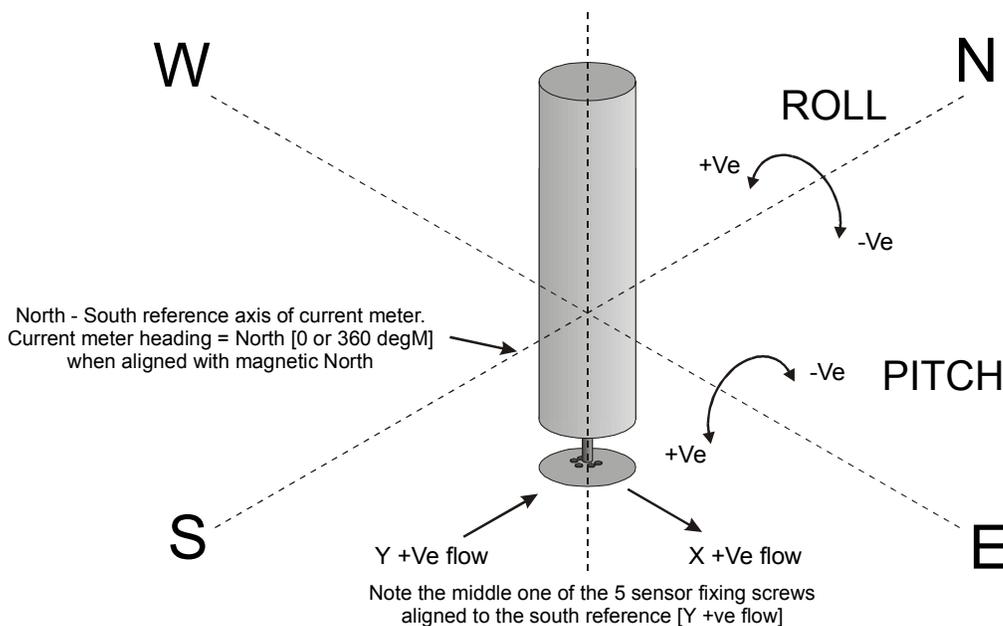
Sensor specifications

Parameter	Type	Range	Accuracy	Resolution
X and Y axis velocity	Valeport Series 802 2 axis electromagnetic current meter with 11 cm discus sensor	±2.5 m/sec	±0.01 plus 1% reading m/sec	0.001 m/sec
Body heading	Valeport gimballed flux gate compass	0 to 360 degM [up to 20 deg gimbal]	± 1 degM	0.25 degM
Current speed	Derived vector average	0 to 5m/sec	± 0.01 plus 1% reading m/sec	0.001m/sec
Current direction	Derived vector average	0 to 360 degM	± 2 degM	0.5 degM

Optional sensors

Parameter	Type	Range	Accuracy	Resolution
Pitch	Capacitive bubble	± 30 deg	± 1 deg	0.25 deg
Roll	Capacitive bubble	± 30 deg	± 1 deg	0.25 deg
Conductivity	Valeport inductive	0.1 to 60 mS/cm	±0.05 mS/cm	0.003 mS/cm
Temperature	Thermistor	-5 to +35 degC	±0.1 degC	0.002 degC
Temperature	PRT	-5 to +35 degC	±0.02 degC	0.002 degC
Pressure	Strain gauge	35, 100, 200, 600, 1000, 3000, 6000 dBar Abs or gauge	±0.1% FS	0.005% FS
Pressure [optional]	Resonant silicon	35 dbar Abs	±0.01% FS	0.001% FS
Auxiliary 1		0 to 5 V	± 1 mV	0.25 mV
Auxiliary 2		0 to 5 V	± 1 mV	0.25 mV
Auxiliary 3		0 to 5 V	± 1 mV	0.25 mV
Auxiliary 4		0 to 5 V	± 1 mV	0.25 mV
Auxiliary 5		0 to 5 V	± 1 mV	0.25 mV
Salinity	Derived [SAL78]		±0.1 PSU	0.003 PSU
Speed of Sound	Derived [user selectable formula]		±0.25 m/sec	0.02 m/sec
Density Anomaly Gamma	Derived [EOS-80]		±0.06 kg/m ³	0.01 kg/m ³

FLOW, PITCH & ROLL CONVENTION



The Oceanographic Flow Convention is that current direction is defined as direction towards which water is flowing, e.g. A Northerly current is a flow towards the North. This is opposite to the convention for Wind Direction and Wave Direction

2 INSTALLATION AND OPERATION

2.1 EQUIPMENT SUPPLIED

The equipment supplied is defined in the equipment checklist, Appendix 3.

2.2 SOFTWARE AND PC SET UP

2.2.1 INSTALLING EMLOG

It is recommended that an IBM compatible PC of 486 DX2 level or above is used, with Windows 3.1 or above, or Windows 95. With Windows 3.1 it is advisable to have at least 8Mb RAM fitted, and with Windows 95 at least 16Mb RAM. Although the software will operate with less, opening too many windows may cause the system to "hang up". In order to show complete displays it is recommended that the PC screen should be SVGA [1024 * 768 resolution]. The PC will need to have a 3.5" floppy disk drive and RS232C serial port, and a mouse will enable more convenient control of the software.

To install EMLog follow the procedures as described below.

- Place the installation disk 1 in drive A.
- in Windows 3.1 select Program Manager : File : Run
or In Windows 95 select Run in the Startup Menu
- In the command line type A:SETUP followed by <CR>.
- Insert Disk 2 when requested.
- After a few seconds you will be asked to select the path and directory in which to install EMLog.
- Select Continue to select default EMLog directory.

The installation will now commence. When finished an OK prompt will appear with the message **INSTALLATION IS COMPLETE**. The EMLog program is now available for use.

2.2.2 PC SETUP

In order for EMLog to operate correctly, the format of the date, time and numbers must be correctly set within the Windows Control Panel.

Function		Format	Example
<i>Date</i>		DD/MM/yy	23/09/96
<i>Time</i>		HH:mm:ss (24 hr clock)	16:37:20
<i>Numbers:</i>	Decimal Mark	.	1.25
	Thousands separator	,	1,321,000

Failure to set the above parameters correctly may result in the software being unable to read data from the instrument.

2.3 HARDWARE

2.3.1 ELECTRICAL CONNECTIONS

Over short lengths of cable and for setting up recording scenario and replay of data, the instrument RS232 communications can be used.

If external power is being used it must be in the range 10V to 24VDC. The red lead should be connected to the +ve terminal and the black lead should be connected to the -ve terminal of the power supply or external battery. If a power supply is being used, it should have sufficient capacity to allow for small surges in current at switch on.

The data lead should be plugged into a serial port on the PC.

Pin allocations for the unit and "Y" lead are included in Appendix 2.

NOTE: Some PCs have 25 way serial ports, in which case it will be necessary to use a 9 to 25 way adaptor.

2.3.2 CHANGING BATTERIES

The batteries are housed within the instrument at the opposite end to the sensor. The procedure to replace the batteries is as follows:

1. Remove the three M5 screws in the side of the main housing at the connector end.
2. Withdraw the connector end cap, revealing the battery assembly which is attached to the connector end cap.
3. The battery cage accepts 8 "D" cells. Alkaline [1.5V nominal voltage] cells must be used. The batteries should be inserted -ve [negative] end first against the spring and then clipped into place.
4. Before replacing the connector end cap, check the condition of the O-rings, which should be free of cuts or perishing. Also check the condition of the sealing bores of the main housing which should be free of scratches. Finally smear a light coating of silicon grease on the O-rings and main housing sealing bores to aid refitting and subsequent removal.
5. Further reassembly is a reversal of the disassembly process.

2.3.3 DEPLOYMENT FRAME

The stainless steel deployment frame is designed to locate and protect the Model 808. The unit is held by two polypropylene saddle clamps.

For bottom mounted versions, extension bars are supplied with the frame and these should be fitted underneath the frame at either end to prevent the frame assembly rolling over.

2.4 OPERATION

Flow charts on the next two pages indicate the principle steps in operating Model 808 in Self Recording and Direct Reading modes. For more detailed instructions please refer to Sections 3, 4 & 5.

Figure 1 Operation of Model 808 in Logging Mode

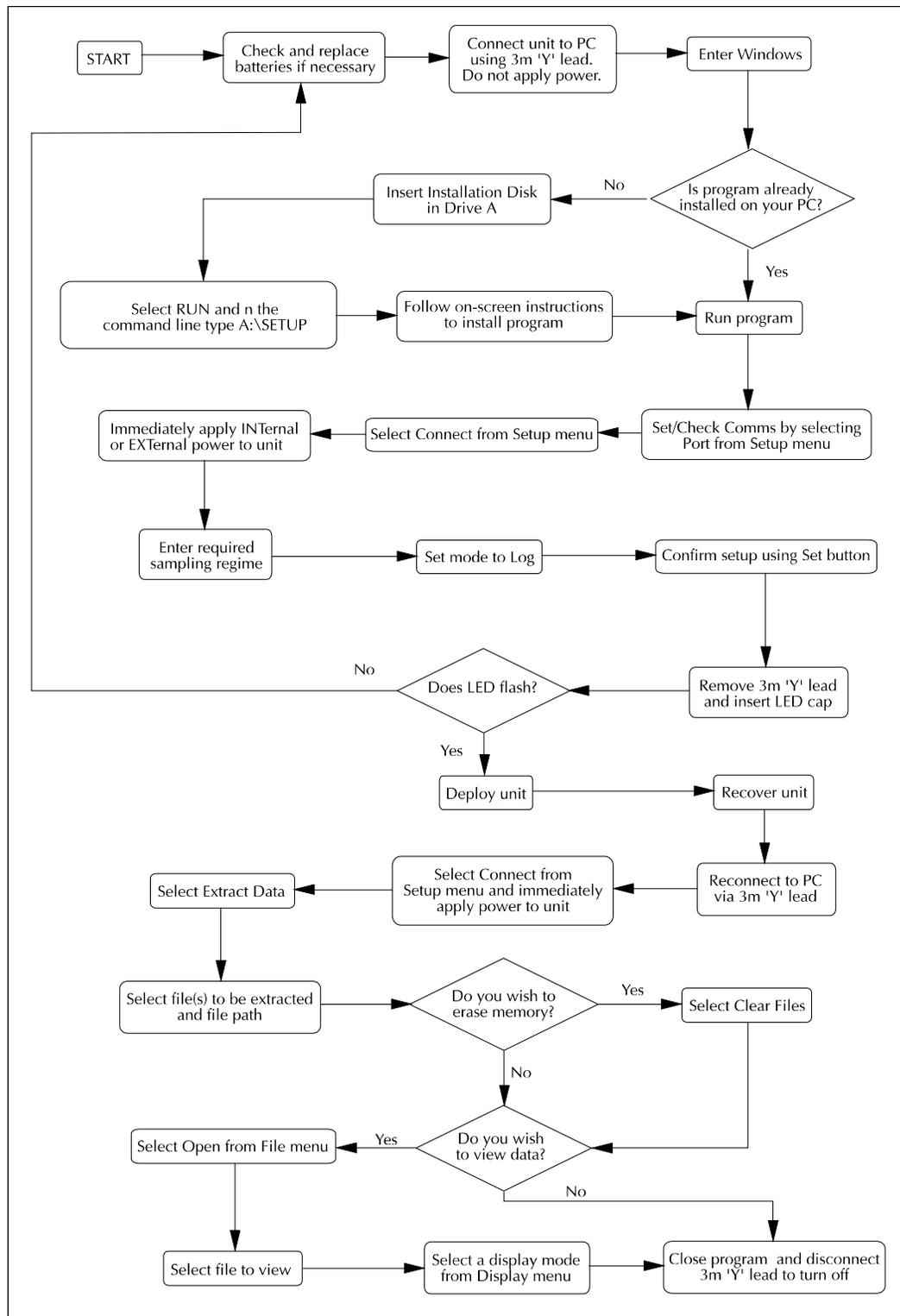
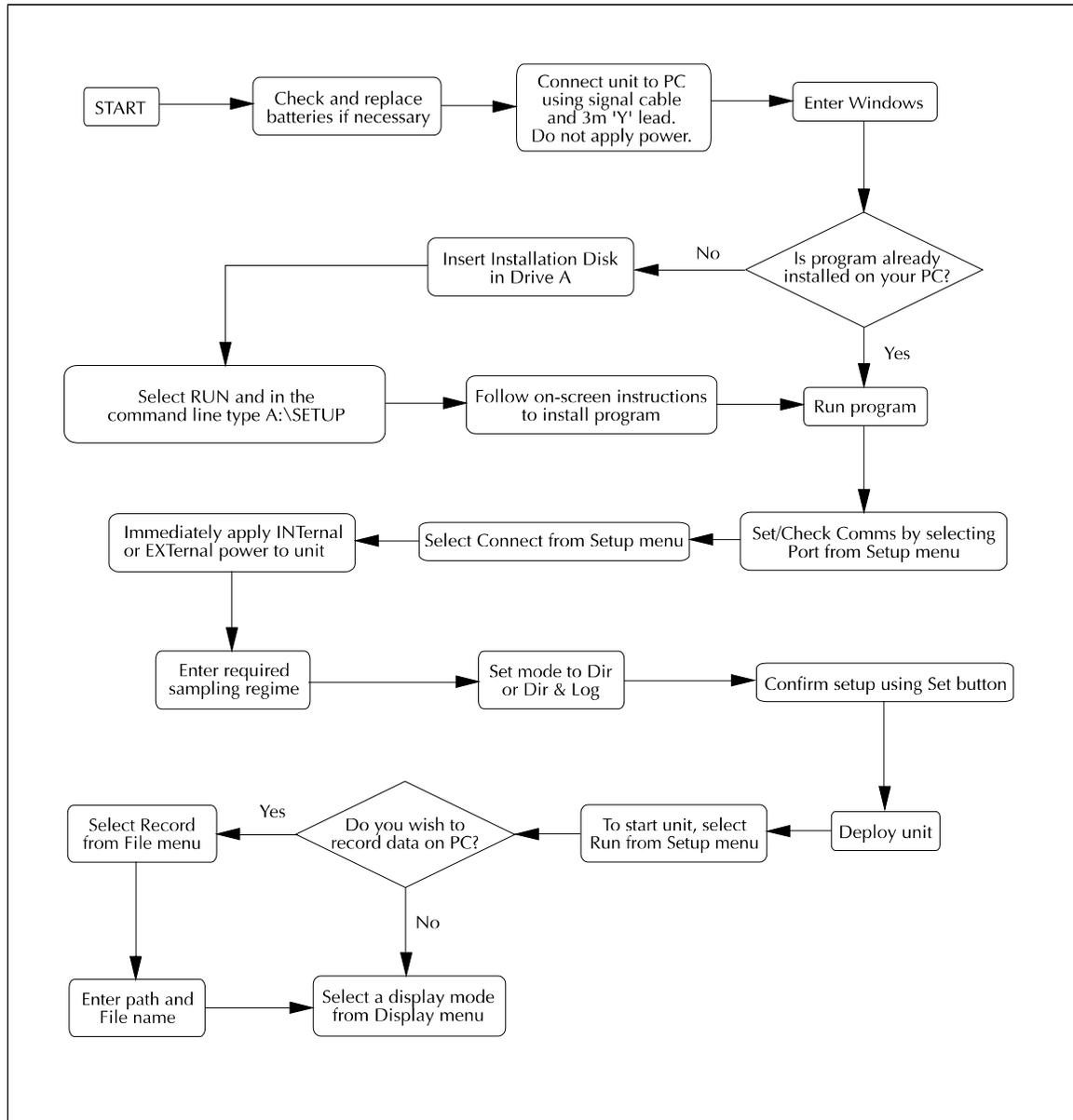
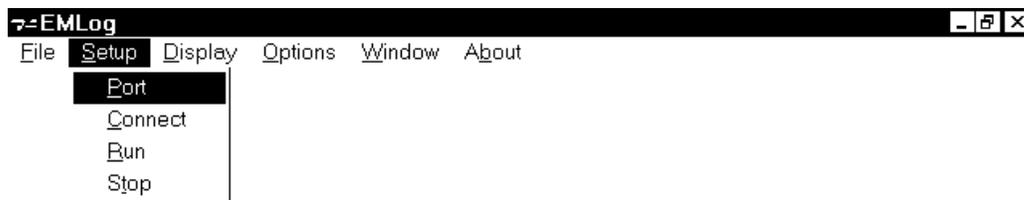


Figure 2 Operation of Model 808 in Direct Reading Mode



3 SETUP

In order to operate the unit, the first step is to correctly configure it using the *Setup* pull down menu in the opening EMLog screen.

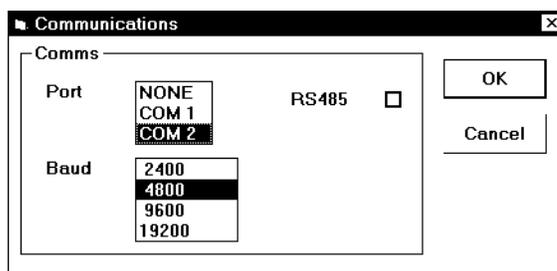


09. October 1997 17:01:19 R

This menu contains all controls necessary for communication with the instrument, setup of sampling regime, and data extraction.

3.1 PORT

Communications are normally via an RS232 comms port. It is necessary to set the comms port configuration before any communications can be achieved. Do this by selecting *Port* from the *Setup* menu. The following display will be shown:



Select the correct comms port number using the mouse and set the baud rate to 4800. For reference, the communications are pre-set to 8 data bits, 1 stop bit and no parity; these are not user changeable.

Note the presence of the check box marked RS485. The Model 808 has this alternative communications method when the unit is being used with long cables [requires internal link to be made on PCB].

3.2 CONNECT

Having correctly configured the comms port, it is possible to communicate with the instrument. Select **Connect** from the **Setup** menu.

A Dialog box similar to that shown below will appear. Confirmed in the title block are the instrument type and the serial number of the unit (e.g. 17859). This box allows changes to be made to the unit's setup. The different options are detailed below.

NOTE:

If the **Set** command is not implemented after inputting changes, the changes will **not** be made in the instrument.

It is also possible to return to **Connect** stage from **Run** mode, if changes need to be implemented, the unit must be switched off and on again to re-connect.

3.3 PROBE CONFIGURATION

The following information is displayed:

- Header text
- Total memory fitted
- Memory free
- Probe Date and Time
- Battery voltage [or external voltage supplied]

3.4 SAMPLE MODE

The 808 operates in Time, Burst Average or Burst Sampling modes.

3.5 SAMPLE SETUP

Time Mode Data is sampled every 2 seconds. User must set the averaging period. To record every data point, set the average to 1. Only averaged data will be logged/displayed.

Burst Average User must set number of samples in a burst, and the burst cycle time. Only the average value of data in a burst will be logged/displayed.

Burst Sample User must set number of samples in a burst, and the burst cycle time. All of the data in a burst will be logged/displayed

EMLog will not allow the user to set inappropriate values.

3.6 MODE

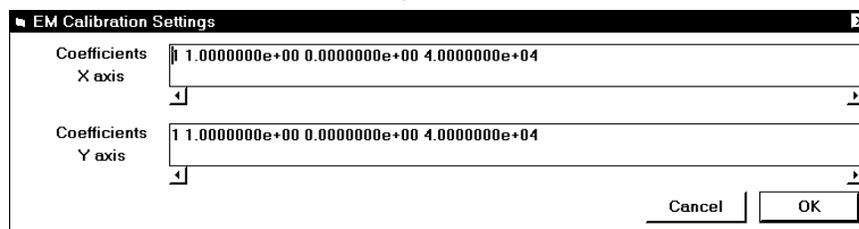
Three modes for data collection are available:

- i) **Dir** This is Direct reading where data are transmitted in real time mode in intervals defined by the sampling setup. **No data are recorded in the unit.**
- ii) **Log** This Logging mode stores averaged data in the instrument RAM in intervals defined by the sampling setup. **No data will be transmitted in this mode.**
- iii) **Dir & Log** This mode performs i) and ii) i.e. real-time data is transmitted and stored to internal RAM.

The desired operating mode is selected by clicking on the relevant option with the mouse.

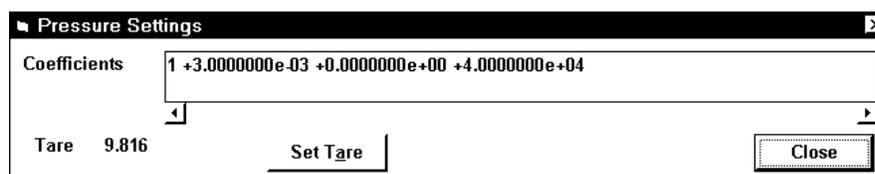
3.7 SENSOR CONFIGURATION

Selecting the appropriate button in this box will lead to the following type of display which will confirm the type of sensor fitted and its calibration. The spare boxes are for additional sensors when fitted.



3.7.1 PRESSURE TARE

On selecting the “pressure” sensor under the Sensor configuration, the following display appears which enables users to set the pressure tare value which will be used for all logged data.

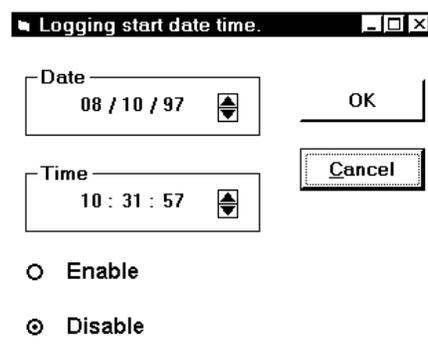


Set Tare instructs the instrument to take a pressure reading at that point in time, and then all data is referred to that pressure as a datum. The measured Tare value is then displayed. Normally this would be taken prior to a deployment. Note that pressure the unit is calibrated to measure absolute pressure, so that

in air the Tare value is going to be in region of 10 dBar. Note that in the translation process of recorded data, the user can choose to use either this value, or enter a value.

3.8 DELAY START

Selecting the “Delay Start” feature brings up the following display.



Logging start date time.

Date 08 / 10 / 97

Time 10 : 31 : 57

Enable

Disable

OK

Cancel

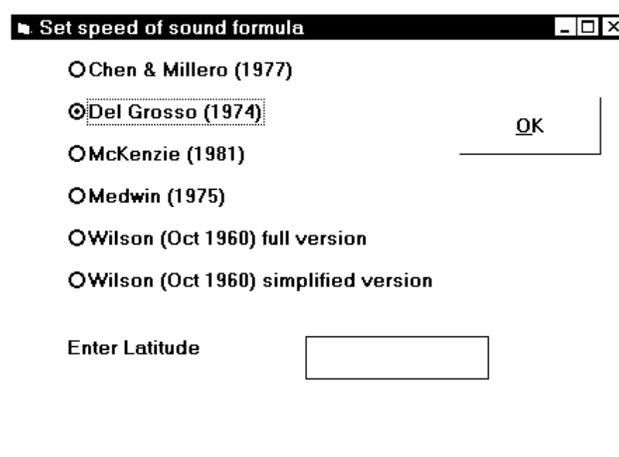
To activate the Delay Start, enter the Date and Time for the start of the first record, and select “Enable”. After “Run” has been selected or the LED pro-cap fitted [putting the unit into “Run”], the unit goes into sleep mode until the start time. The unit automatically brings the start time forward by a few seconds, so that the first record is taken at the start time allowing for an initialisation period. Because of this feature, when the delay start time is viewed again, the time will read slightly differently [e.g. a requested start of 11:00:00 might read as 10:59:55]. The actual start time may also be different from the requested start by up to 5 seconds.

3.9 SET TIME

The 808 Date and Time is reset to PC time by selecting this button. When rechecking PC and 808 times, it should be borne in mind that PC clocks can vary much more than the 808 internal clock, even in the short term.

3.10 SET SPEED OF SOUND FORMULA

Selecting this button brings up a display that allows the user to select the Speed of Sound Formula which is to be used. Note that this feature is only applicable when the unit is fitted with CTD sensors.



Set speed of sound formula

Chen & Millero (1977)

Del Grosso (1974)

McKenzie (1981)

Medwin (1975)

Wilson (Oct 1960) full version

Wilson (Oct 1960) simplified version

Enter Latitude

OK

Many formulae have been put forward over the years for calculating Speed of Sound, and opinion varies as to which is the best. It is generally accepted that Chen & Millero (1977) is the most accurate for depth ranges over which Valeport units operate, and for this reason, this is the formula that is used as default. However, EMLog gives the user the option to use a different formula for calculating Speed of Sound. If any formula other than Chen & Millero is selected, the formula will use the latitude that has been set. See Appendix 1.3 for an explanation of this, full details of each formula, and a short discussion on the merits of each.

3.11 LOGGED DATA

3.11.1 CLEAR FILES

Click on the *Clear Files* button to erase the memory of the unit. A confirmation request message is displayed, and clicking on *OK* erases memory.

3.11.2 SET FILE INFORMATION

This control specifies the Site Information for each File contained within the unit's memory. Clicking on this button reveals the following display:

File Information

Change file name

Old file name

New file name

Current site information

File name FILE0

Site info NO SITE INFORMATION

Set site information

File name

Site info

File name list

- FILE0=13
- FILE1=13
- FILE2=0
- FILE3=0
- FILE4=0
- FILE5=0
- FILE6=0
- FILE7=0
- FILE8=0
- FILE9=0
- FILE10=0
- FILE11=0
- FILE12=0
- FILE13=0
- FILE14=0
- FILE15=0
- FILE16=0
- FILE17=0
- FILE18=0
- FILE19=0
- FILE20=0

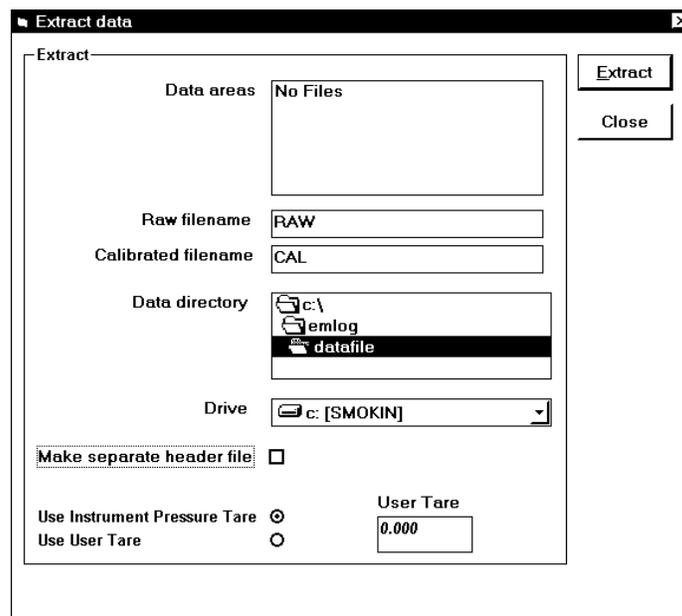
On the right hand side is a list of all files contained within the unit's memory, and their sizes. The next file to be used will be the first one with 0 bytes in memory. To input, change or view the file name or header information of any file, that file should be selected with the mouse.

Having selected a File, the user has the option to rename the file [4 characters maximum] and input header information text. Clicking *Set Info* sets the new information. This information is contained within a header record for each File within the unit's internal memory.

3.11.3 EXTRACT

Data are stored in internal battery backed RAM in binary format. Each time the unit is switched on or 'RUN', a new data file is created with its own header information containing averaging period, etc. following which the data is recorded. These data files can be uploaded and saved to disk by selecting **Extract**. A binary file is created initially which mirrors the requested stored data files; the default name is RAW, and this file is then translated using the calibration information.

The Display will now show the following:



- i) Data Areas: Scrollable text box containing file allocation within the instrument.
- ii) Raw filename: Binary format files are stored in non-engineering units. The default filename RAW may be changed; it should be restricted to 8 characters.
- iii) Calibrated filename: The default calibrated filename is CAL. It can be changed [8 characters max]
- iv) Data directory Standard Windows type dialog box to allow alternative directory paths to be set. The default path is c:\EMLog.
- v) Drive Standard Windows type dialog box to select the drive.
- vi) Pressure Tare The Pressure tare value to be used in translation is set to either "Use Instrument Pressure Tare" in which case the value used at Setup is used, or the user can set a "User Tare" which is set in dBars.

As many files as required can be selected at once with the mouse by holding down Ctrl while using the mouse to click on each file. Once the desired files have been highlighted, select **Extract**.

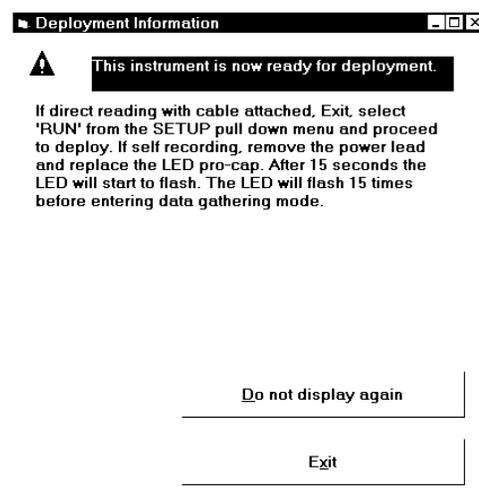
Note that the data in the instrument is not erased after uploading, further logging will occur after the last record.

The Calibrated data files are created using the same extension as the binary files from which they were created [.000, .001 etc.]

4 RUN MODE

4.1 RUNNING THE INSTRUMENT

After all the instrument configurations have been set as required, the following message is displayed:



If the instrument is being used in Logging Mode only, once the unit has been setup, the "Y" lead should be removed. The unit is then switched on into Run mode by fitted the LED pro-cap, after which a 15 second period of LED cap flashing ensues. The unit will then either start logging immediately or, if the Delay Start has been set, it will go into sleep until the start time is reached.

If the instrument is being used in Direct Reading or Both Mode, switching on is achieved by selecting *Run* from the *Setup* menu.

Note that if the unit is logging, either in **Log** or **Dir & Log** modes, then a new data file is created each time the unit is switched on.

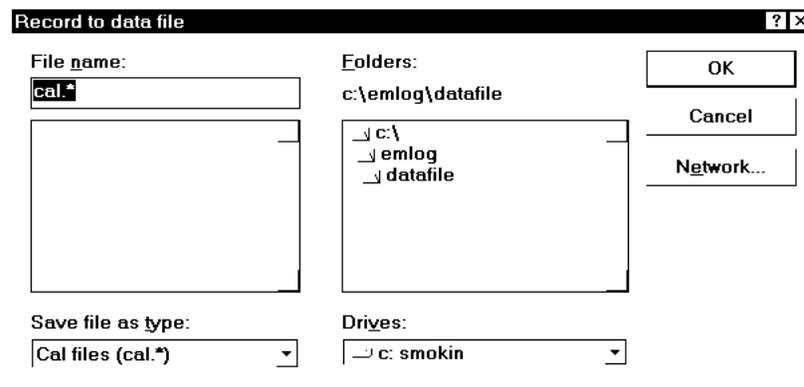
Users should also check that the correct *Speed of Sound Formula* is set in the *Connect* screen.

The unit enters an interrupt period for 15 seconds, during which the message *Initialising* is displayed in the bottom left hand corner of the Window.

Real time Direct Reading data is displayed using one of the display modes detailed in Section 5, by selecting the appropriate command from the Display pull down menu.

4.2 RECORDING DIRECT READING DATA

It is possible for Direct Reading data to be recorded on computer disc by selecting *Record* from the *File* pull down menu. The following display appears.



The required filename should be entered and the desired destination drive and directory selected. The data will automatically be recorded as it is produced.

In order to view direct reading data, a display mode must be selected from the *Display* pull down menu. Full details on these modes are in Section 5.1.

4.3 STOP

Stopping the unit Running in **Dir** or **Dir & Log** modes is achieved by turning off the power and re-connecting. Once interrupted, selecting *Stop* from the *Setup* pull down menu will prevent the unit going into RUN mode. The unit will also stop if *Connect* is selected.

In **Log** mode, the unit is stopped by removing the LED cap.

The unit must be stopped in order to allow certain functions to be used in the displaying of data. See Section 5 for further details.

4.4 DIRECT READING ANALOGUE OUTPUT

Apply power to the Subsea cable (10 to 24V DC) and the instrument will output analogue voltages corresponding to speed and direction. These will be updated at the rate of the Sample period set.

See calibration sheet for actual range set.

5 DATA DISPLAY & HANDLING

The following table indicates the options available for displaying the data from the 808:

Data and Source	EMLog Display			User Spreadsheet
	Single	Scroll	Graph	
Real Time	✓	✓	✓	
Real time logged to PC (.log files)		✓	✓	✓
Logged in 808 and extracted to PC		✓	✓	✓

5.1 EMLOG DISPLAYS

Data files that are held in the PC are opened by selecting *Open* from the *File* menu, selecting the desired drive, directory and file and selecting Enter. The correct file will then be opened.

5.1.1 FULL

Selecting *Full* from the *Display* Menu will show all the parameters transmitted by the instrument in real time mode only. Data stored on disk cannot be displayed in this format.

The Salinity, Density Anomaly and Sound Speed are calculated by EMLog and not by the instrument, provided that the optional Conductivity, Temperature and Pressure sensors are fitted. Parameters which are not fitted to the instrument are shown in italics and not updated.

The screenshot shows a window titled '(Full)' with a 'Data' header. It displays a list of parameters with their current readings and units. The parameters shown are:

Parameter	reading	units
Conductivity	12.123	mS/cm
Temperature	12.123	°C
Pressure	1234.123	dBar
Salinity	9.284	PSU
Density anomaly	12.4	kg/m ³
Sound speed	1486.8	m/s
Flow	3.543	m/s
Direction	324.20	*Mag
Pitch	356.98	°
Roll	223.55	°
<i>Aux1</i>		
<i>Aux2</i>		
<i>Aux3</i>		
<i>Aux4</i>		
<i>Aux5</i>		

At the bottom left of the window, the date and time are displayed as '10/10/97 17:29:29'. At the bottom right, there is a 'Close' button.

5.1.2 SCROLL

Selecting *Scroll* from the *Display* Menu brings up the Scrolled displays shown below. The most recent data is displayed at the top [the opposite of the spreadsheet records]. For real time data and direct data logged to PC the time stamp for the data is when the PC receives the data. For data logged by the 808 and then extracted to the PC, the time stamp is the start of the data burst.

Logged data scroll display:

The screenshot shows the EMLog software interface. At the top, there is a menu bar with 'File', 'Setup', 'Display', 'Options', 'Window', and 'About'. Below the menu bar, there are two input fields: 'File name' containing 'CAL.000' and 'Battery Voltage' containing '0V'. Underneath is a 'Site Information' section with the text 'NO SITE INFORMATION'. The main part of the window is a table with the following data:

Time-stamp	Conductivity	Temperature	Pressure	Salinity	Density anomaly	Sound speed	Flow
	mS/cm	°C	dBar	PSU	kg/m3 (EOS-80)	Chen & Millero m/s	m/s
09/10/97 16:01:49	0.000	0.000	31154.000	0.000	0.0	0.0	2.361
09/10/97 16:01:29	0.000	0.000	31154.000	0.000	0.0	0.0	0.305
09/10/97 16:01:09	0.000	0.000	31154.000	0.000	0.0	0.0	2.203
09/10/97 16:00:49	0.000	0.000	31154.000	0.000	0.0	0.0	0.400
09/10/97 16:00:29	0.000	0.000	31154.000	0.000	0.0	0.0	4.266

At the bottom of the window, there is a status bar showing 'File: C:\EMLOG\DATAFILE\CAL.000' and '09. October 1997 17:27:08 R'.

Real Time scroll display:

The screenshot shows the EMLog software interface. At the top, there is a menu bar with 'File', 'Setup', 'Display', 'Options', 'Window', and 'About'. Below the menu bar, there is a status bar showing 'File: C:\EMLOG\DATAFILE\CAL.000' and '09. October 1997 17:27:08 R'. The main part of the window is a table with the following data:

Time-stamp	Conductivity	Temperature	Pressure	Salinity	Density anomaly	Sound speed	Flow	Direction	Pitch	Roll
	mS/cm	°C	dBar	PSU	kg/m3 (EOS-80)	Chen & Millero m/s	m/s	*Mag	*	*
09/10/97 17:11:33	12.123	12.123	1234.123	9.284	12.4	1486.8	3.543	324.20	356.98	223.55
09/10/97 17:11:32	12.123	12.123	1234.123	9.284	12.4	1486.8	3.543	324.20	356.98	223.55
09/10/97 17:11:32	12.123	12.123	1234.123	9.284	12.4	1486.8	3.543	324.20	356.98	223.55
09/10/97 17:11:32	12.123	12.123	1234.123	9.284	12.4	1486.8	3.543	324.20	356.98	223.55
09/10/97 17:11:31	12.123	12.123	1234.123	9.284	12.4	1486.8	3.543	324.20	356.98	223.55
09/10/97 17:11:31	12.123	12.123	1234.123	9.284	12.4	1486.8	3.543	324.20	356.98	223.55

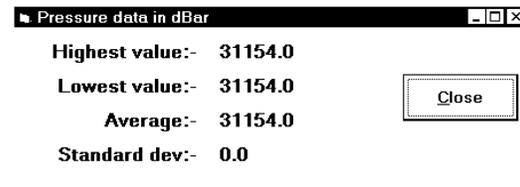
At the bottom of the window, there is a status bar showing '808:P=1234.123IT=12.123IC=12.123ID=324.2IS=3.543IPITCH' and '09. October 1997 17:11:49 R'.

The left/right arrows are used to move across the display to show the other columns.

5.1.2.1 DATA ANALYSIS

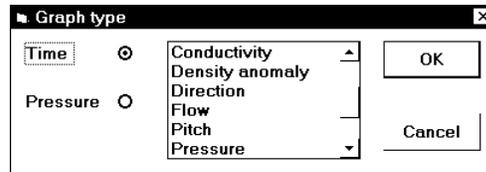
A display of average data values can be obtained from this screen. While the unit is stopped (or with recorded/uploaded data), the Scroll table has the property of allowing values within the table to be highlighted. This can be done either by dragging the mouse over the desired values, or by clicking on a column header to select the entire column. By selecting *Data Analysis* from the *Display* menu a table is displayed, showing high and low values, the mean value and the Standard Deviation of the data.

NOTE: It is not possible to perform Data Analysis on more than one parameter at once.

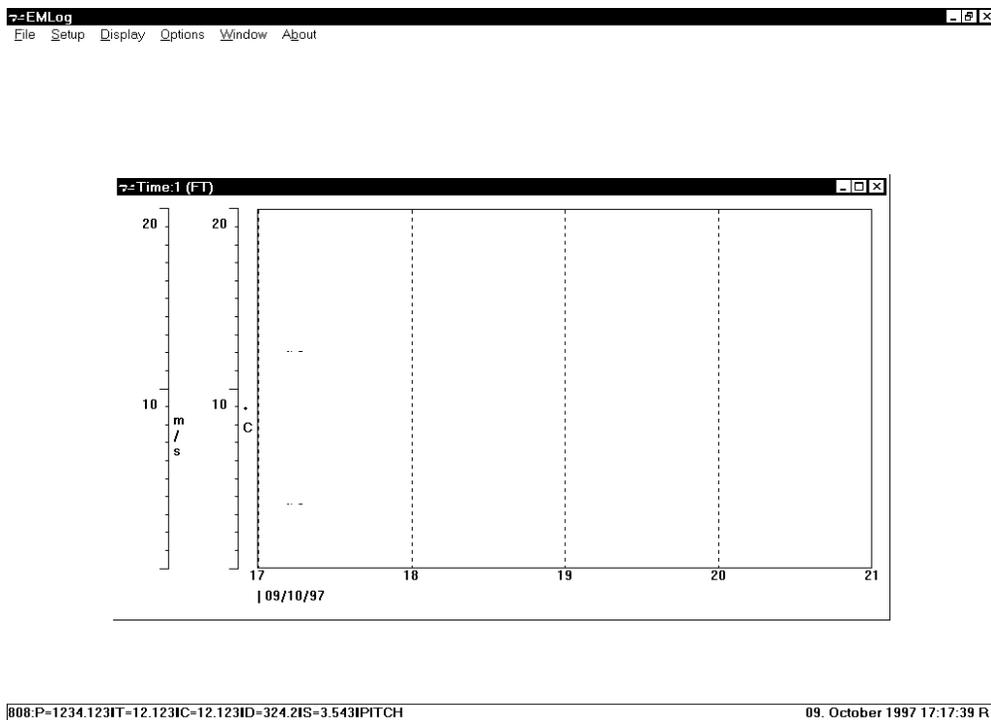


5.1.3 GRAPH

The Graphical display function can be used for either real time or recorded data, and allows each parameter from the instrument to be displayed as a function of time. The 'Y' axes can be scaled individually. More than one parameter can be displayed on the same graph, use **Ctrl** and the mouse to click on each in the Dialog box.

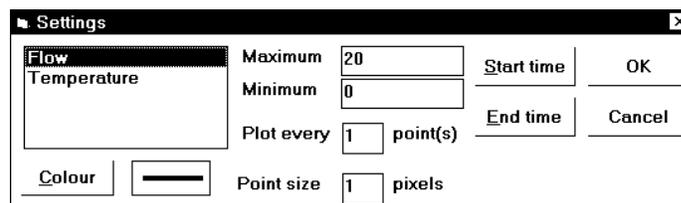


Once selected the following type of graph is displayed:



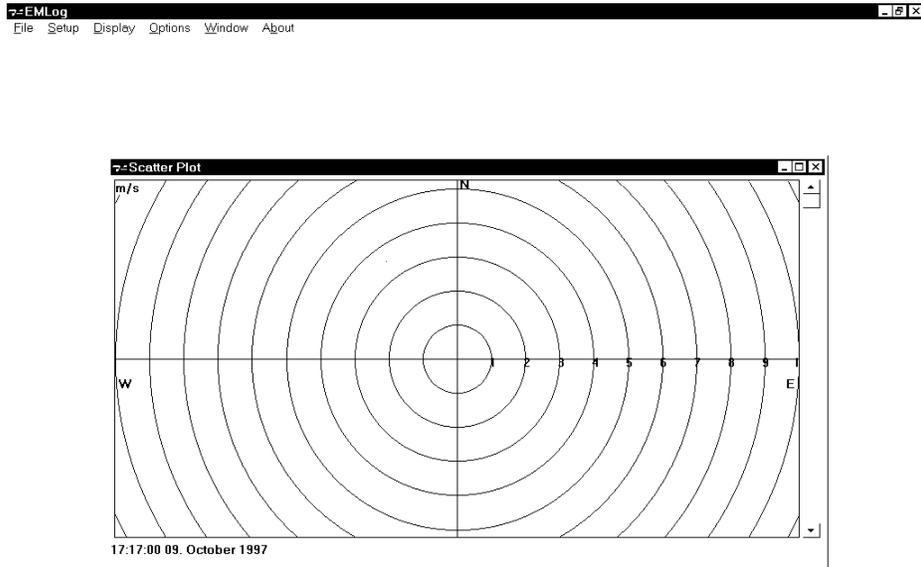
5.1.3.1 GRAPH SETTINGS

Selecting *Graph Settings* from the *Options* menu in graph mode allows the user to change certain features of the display. Shown below is the settings Dialog box, to allow changes to be made to 'X' and 'Y' axes scales, plot interval, point size and parameter display colour. The default scale values are set in another part of the program, covered in Section 5.2.2.



5.1.4 SCATTER

The Scatter display function can be used for either real time or recorded speed and direction data. Zooming in and out is achieved by moving the slide button to the right of the display.



808:P=1234.123IT=12.123IC=12.123ID=324.2IS=3.543IPITCH 09. October 1997 17:20:26 R

5.2 OPTIONS

This function allows the user to set various options as detailed below. Some functions are only available at specific points within the software. At all times, *Options* allows the user to select/de-select the status line at the bottom of the page

5.2.1 CONSTANTS

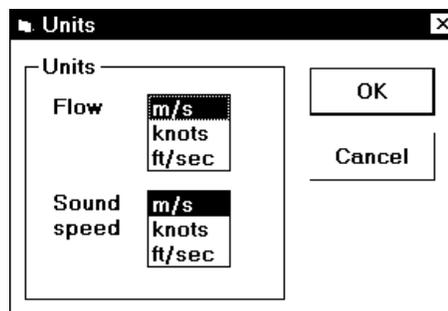
Selecting Constants brings up the following display, allowing the user to select the standard used for the nautical Mile when calculating knots.



Select either a *UK* nautical mile (1853.18 metres) or *International* nautical mile (1852 metres) as required followed by OK to confirm.

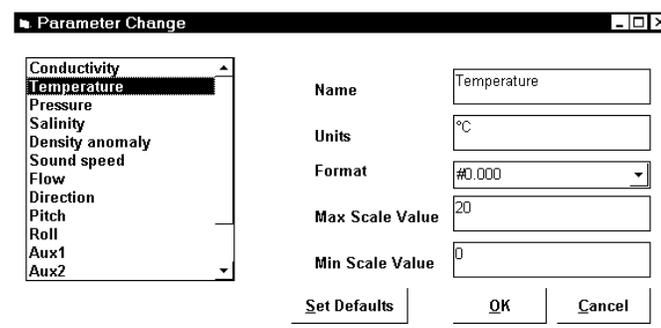
5.2.2 UNITS

The units of speed can be selected as below (OK to confirm).



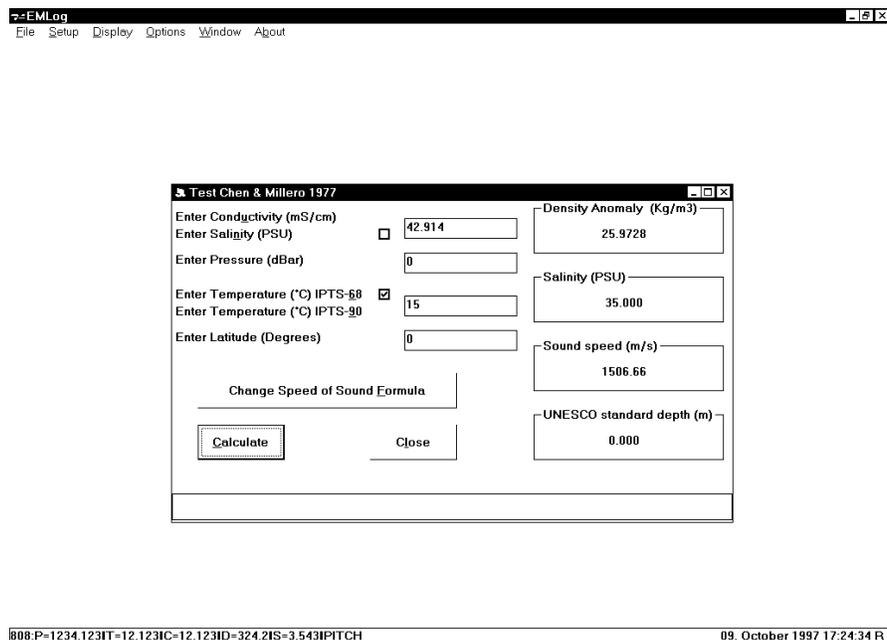
5.2.2 CHANGE PARAMETER DEFAULTS

The user can define the name and units that are displayed for any parameter, and the scale for graphing. Selecting default returns to factory defaults.



5.2.3 TEST FORMULA

Selecting *Test Formula* from the *Options* Menu reveals the following display, which allows the user to calculate Density Anomaly, Salinity/Conductivity, Speed of Sound using a formula of their choice, and to perform a Depth/Pressure calculation.



5.2.3.1 USER INPUT VALUES

CONDUCTIVITY/SALINITY

The user has the option to input either Conductivity (mS/cm) or Salinity (PSU). Click on either to select (highlight), or click the check box. The program will calculate whichever is not input.

PRESSURE

Enter the required pressure in decibars.

TEMPERATURE

It is possible to use either IPTS-68 or IPTS-90 temperature values in the calculations. Simply click on the desired scale or the check box to select.

LATITUDE

This is required to correct for local gravity which is required in depth calculations for Speed of Sound [for all formulae with the exception of Chen & Millero 1977].

CHANGE SPEED OF SOUND FORMULA

The user can select a formula with the Change Speed of Sound Formula button. Note that for all formulae apart from Chen & Millero, geographical latitude must be input. Clicking the Calculate button then reveals the Speed of Sound as calculated using the selected formula.

NOTE: This has no effect on the formula used by the software for the Speed of Sound in Running Mode.

5.2.3.2 CALCULATED PARAMETERS

The formulae used for calculating Density Anomaly γ , Salinity, Depth and Speed of Sound are given in Appendix 1. Conductivity is calculated from Salinity using a Newton Raphson Iteration of the Salinity formula. Salinity and Conductivity are self explanatory functions. Speed of Sound can be calculated using various formulae, and the merits of each are discussed in Appendix 1.3. Density Anomaly γ and Depth require further explanation:

Density anomaly γ This is Density (ρ) - 1000

Depth This is based on the Simple UNESCO Depth formula which is based on assuming a salinity of 35 PSU and temperature of 0 °C. For simple calculations of depth for different densities, the standard depth can be corrected by multiplying it by the ratio of average density over depth of 35 PSU, 0 °C water to the average density of the actual water column.

E.g.

Standard Depth [35,0] for 1000 dBar at 0 latitude = 992.117 metres

Average density [approx.] over 1000 dBar range for [35,0] seawater
 = [Density at 0 dBar + Density at 1000 dBar]/2
 = [1028.1 + 1032.8]/2
 = 1030.45 kg/m³

Average density from data, using Data Analysis function [see section 5.3.3.1]
 = 1027.6 [example number only for calculation]

Density ratio = 1030.45/1027.6
 = 1.0028

Revised depth estimate = 992.117 * 1.0028
 = 994.895 metres

5.2.4 STATUS LINE

The Status line is situated at the bottom of the EMLog window. Real time data/filename and PC time and Date are displayed here. This can be toggled on/off by selecting **Status Line** with the mouse.

5.3 WINDOW

The *Window* pull down menu allows the user to configure the display to either *Cascade*, *Tile* or *Arrange Icons* if showing. It should be noted however that the *Brief* and *Full* displays are not affected by this command as they are created for display outside the EMLog window.

5.3.1 CASCADE

The Cascade display has the different open windows cascaded down, overlapping each other, so that only one is visible

5.3.2 TILE

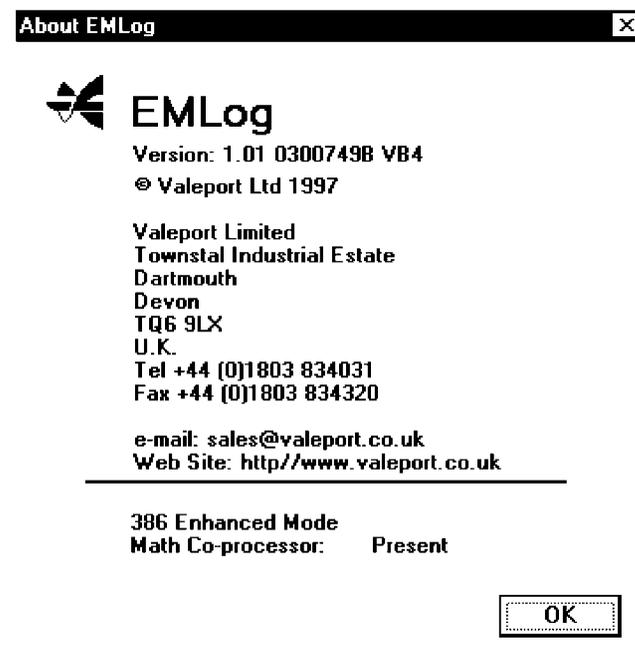
The Tile display has all open windows displayed within one screen.

5.3.3 ARRANGE ICONS

This allows displays to be minimised.

5.4 ABOUT

Selecting the *About* function displays the EMLog software version similar to below:



5.5 SPREADSHEET OUTPUTS

The PC data files are spreadsheet compatible, and in addition to the data also include full header information to verify the data set. It should be noted that the latest data is at the bottom, which is the reverse of the scrolled data.

File header created by EMLLOG on 09/10/97 16:16:35
 Device: 808, Serial number: 9876
 Header text:
 Sampling period (x5 secs): 4, datasets in burst: 1
 File name CAL_000
 Site information NO SITE INFORMATION
 Battery voltage 0V
 Pressure coefficients: 1 1.0000000e+00 1.0000000e+00 4.0001001e+04
 X axis coefficients: 1 1.0000000e+00 0.0000000e+00 4.0000000e+04
 Y axis coefficients: 1 1.0000000e+00 0.0000000e+00 4.0000000e+04
 Pressure tare 1.0000
 Speed of sound formula Chen & Millero

Date	Time	Conductivity mS/cm	Temperature °C	Pressure dBar	Salinity PSU	Density anomaly kg/m3 (EOS-80)	Sound speed m/s	Flow m/s	Direction °Mag	Pitch °	Roll °	Aux1 counts	Aux2 counts	Aux3 counts	Aux4 counts	Aux5 counts	
09/10/97	16:00:29	0	0	0	31154	0	0	4.266	90.86	0	0	0	0	0	0	0	0
09/10/97	16:00:49	0	0	0	31154	0	0	0.4001	88.16	0	0	0	0	0	0	0	0
09/10/97	16:01:09	0	0	0	31154	0	0	2.2027	259.61	0	0	0	0	0	0	0	0
09/10/97	16:01:29	0	0	0	31154	0	0	0.3047	291.74	0	0	0	0	0	0	0	0
09/10/97	16:01:49	0	0	0	31154	0	0	2.3606	306.39	0	0	0	0	0	0	0	0

6 CALIBRATION

The instruments are calibrated at the factory using industry standard methods, and the calibration certificate is in Appendix 5.

7 TROUBLESHOOTING

The following table is designed to assist the user with problems commonly experienced while using the instrument.

SYMPTOM	PROBABLE CAUSE	REMEDY
Unable to break in to unit after switch on	Left too long after switch on	Unit must be interrogated within 15 seconds of switch on, or at the end of an averaging period. Either: a: Switch off/on and try again, or b: Wait until end of averaging period.
	Insufficient power	If running on internal batteries, batteries exhausted. If running on external power, voltage too low or external supply current limiting at switch on.
	Incorrectly fitted cable	Check connections and try again.
LED won't flash in logging mode		Check LED Pro-Cap is correctly fitted. Check batteries, and replace if necessary.
Spurious Readings:		
Conductivity	Salt deposits around sensor	Remember to clean meter in fresh water after each use.
Speed	Growth on sensor	Clean sensor head at regular intervals.

Most faults are due to:

1. Failure to successfully interrupt unit operation. Switch off/on and try again.
2. Incorrectly connected leads.
3. Low battery power, low external voltage, current limit on external supply.

If in any doubt about the performance of the unit, please contact the factory at the address shown on the front page of this manual.

8 MAINTENANCE

8.1 CLEANING

The housing is manufactured from stainless steel, but it is still advisable to wash it off in fresh water after use.

The EM sensor calibration will be effected by large amounts of marine growth as the water flow characteristics will be altered.

If the unit is fitted with a conductivity sensor, the conductivity sensor end should be kept clean from mud and debris as the sensor is measuring the conductivity of the water within the sensor. Washing off with clean water is therefore advised after use. If the sensor is not washed off in fresh water after use, then salt crystals may form and on re-immersion, the concentrated salt content will temporarily effect the readings.

8.2 O-RING SIZES

Line connector bore seal	1 x 200-020-4470
Bulkhead Connector/Housing	2 x 200-121-4470
End Cap, sensor end	2 x 200-240-4470
Electronics Cover	4 x 200-043-4470
End Cap, connector end	2 x 200-240-4470
EM stem – End cap	2 x 200-123-4470

Note that where anti-extrusion backing rings are used the O-rings should be placed on the pressure [sea water] side of the anti-extrusion ring.

The Dowty seals used in the sensor end are:

Pressure sensor,	type 010
Temperature sensor,	type 310

8.3 LITHIUM BATTERY FOR MEMORY

The memory back-up lithium battery, (Type T327BA9, 3.7V), should be replaced at least every 5 years. If the memory and or clock settings are lost then the battery should be replaced. It is recommended that the instrument be returned to Valeport Limited for replacement of this battery, however if urgent renewal is required then the replacement procedure is as follows:

1. Open up the housing to reveal the electronics assembly
2. The battery is on board 0300508 and can be un-soldered in-situ. Do not remove the board.
3. Fit the new battery and solder to the board.
4. Further reassembly is a reversal of the disassembly process.

APPENDIX 1 DERIVED CTD FORMULAE

The following extracts are taken and adapted from "Processing of Oceanographic Station Data", published by UNESCO in 1991.

A1.1 SALINITY

The Practical Salinity Scale (PSS-78)

The fundamental step in constructing the practical salinity scale PSS-78 consisted of defining a single reference point ($S=35$) on the scale as having the same electrical conductivity as a reference potassium chloride (KCl) solution at 15°C and atmospheric pressure. The transition from the previous scale was made by selecting a single batch (P79) of Standard Seawater and equating the new scale to the old through the chlorinity relationship $S = 1.80655 C$ for that particular batch. As the salinity on the practical scale is defined to be conservative with respect to addition and removal of water, the entire salinity range is accessible through precise weight dilution or evaporation without additional definitions. However, the practical scale is defined in terms of conductivity ratio and not by its conservative properties. Thus the second part of the definition was constructed by measuring the conductivity ratio to the KCl standard or an equivalent secondary standard over the entire range of salinities (1 to 42) of samples prepared by evaporation or dilution of batch P79 SSW and computing an empirical formula $S = S(R_{15})$, where R_{15} is the conductivity ratio 15°C and atmospheric pressure to the KCl standard. Thus salinities on the PSS-78 scale are defined by conductivity ratios alone. Salinities determined by any other method would not necessarily coincide with the PSS-78 scale and would have to be identified separately. Lewis and Perkin (1981) and Mamayev (1986) discuss differences between PSS-78 and previous scales and provide algorithms and tables to convert existing data to the new scale.

The algorithm for converting conductivity ratio to salinity is constructed in terms of the conductivity ratio R defined as:

$$R = C(S, t, p)/C(35, 15, 0) \quad (1)$$

where $C(S, t, p)$ is the electrical conductivity as a function of salinity S , temperature t and pressure p . The ratio is factored into the functions:

$$R = r_t(t) \cdot R_t(S, t) \cdot R_p(R, t, p) \quad (2)$$

where

$$\begin{aligned} r_t(t) &= C(35, t, 0)/C(35, 15, 0) \\ R_t(S, t) &= C(S, t, 0)/C(35, t, 0) \\ R_p(R, t, p) &= C(S, t, p)/C(S, t, 0) \end{aligned}$$

Salinity is given by the function

$$S = \sum_{n=0}^5 \left[a_n + \frac{\Delta t}{1+k\Delta t} b_n \right] \cdot R_t^{n/2} \quad (3)$$

with coefficients

$a_0 =$	+0.0080	$B_0 =$	+0.0005	$k =$	+0.0162
A1	-0.1692	$B_1 =$	-0.0056	$\Delta t =$	$t - 15$
=					
A1	+25.3851	$B_2 =$	-0.0066		
=					
A1	+14.0941	$B_3 =$	-0.0375		
=					
$a_4 =$	-7.0261	$B_4 =$	+0.0636		
$a_5 =$	+2.7081	$B_5 =$	-0.0144		

At $t = 15^\circ\text{C}$ (3) reduces to the formula defining the practical salinity scale (Perkin and Lewis 1980).

The factors r_t and R_p are given by

$$r_t = \sum_0^4 C_n t^n \quad (4)$$

where

$$\begin{aligned} C_0 &= +0.6766097 & C_3 &= -6.9698\text{E-}7 \\ C_1 &= +2.00564\text{E-}2 & C_4 &= +1.0031\text{E-}9 \\ C_2 &= +1.104259\text{E-}4 & & \end{aligned}$$

and

$$\begin{aligned} R_p &= 1 + \frac{e_1 p + e_2 p^2 + e_3 p^3}{1 + d_1 t + d_2 t^2 + (d_3 + d_4 t) \cdot R} \\ &= 1 + \frac{C}{B + AR} \end{aligned} \quad (5)$$

with

$$\begin{aligned} e_1 &= +2.070\text{E-}5 & d_1 &= +3.426\text{E-}2 \\ e_2 &= -6.370\text{E-}10 & d_2 &= +4.464\text{E-}4 \\ e_3 &= +3.989\text{E-}15 & d_3 &= +4.215\text{E-}1 \\ & & d_4 &= -3.107\text{E-}3 \end{aligned}$$

for temperature in °C and pressure in dBar.

Given a measurement of R , t and p , salinity is computed by solving (2) for R_p ; $R_t = R/(r_t R_p)$ and evaluating S from (3). If conductivity ratio R is required given S , t and p , the ratio R_t can be found by numerical inversion of (2), and R can be found by solving the quadratic equation

$$R = r_t \cdot R_t \cdot R_p = r_t \cdot R_t \cdot \left[1 + \frac{C}{AR + B} \right]$$

or

$$R = \frac{[(Ar_t R_t - B)^2 + 4r_t R_t A(B + C)]^{1/2} + [Ar_t R_t - B]}{2A} \quad (6)$$

This description of PSS-78 has been adapted from Fofonoff (1985)

A1.2 DENSITY ANOMALY GAMMA

Equation of State of Seawater (EOS-80)

The equation of state of seawater is the mathematical expression to calculate density from measurements of temperature, pressure and salinity. Virtually all the computations of density of seawater made since the beginning of the century have been based on the direct measurements of density, chlorinity and salinity made by Knudsen, Forch and Sørensen (1902), and of compression of seawater made by Ekman (1908). This equation was obtained from measurements of density of natural seawater in which the proportions of the various ions are not exactly constant. To be consistent with the new definition of the Practical Salinity, 1978, the new equation of state is based on measurements of density of standard seawater solutions obtained by weight dilution with distilled water and by evaporation. As the absolute density of pure water is not known with enough accuracy, the density of distilled water used for these measurements was determined from the equation of the SMOW (Standard Mean Ocean Water) whose isotopic composition is well defined.

The new equation of state (EOS-80) which was adopted by JPOTS in 1981 (Unesco, 1981c) is:

$$\left. \begin{aligned} v(S, t, p) &= v(S, t, 0)[1 - p/K(S, t, p)] \\ \rho(S, t, 0) &= 1/v(S, t, 0) = A + BS + CS^{3/2} + DS^2 \\ K(S, t, p) &= E + FS + GS^{3/2} + (H + IS + JS^{3/2})p + (M + NS)p^2 \end{aligned} \right\} (7)$$

where the coefficients A, B, \dots, N are polynomials in temperature t . Units: salinity, PSS-78; temperature, °C; pressure (p), bar; density (ρ), kg/m³; specific volume (v), m³/kg. These coefficients are given below.

	A	B	C	D
t ⁰	+999.842594	+8.24493E-1	-5.72466E-3	+4.8314E-4
t ¹	+6.793952E-2	-4.0899E-3	+1.0227E-4	
t ²	-9.095290E-2	+7.6438E-5	-1.6546E-6	
t ³	+1.001685E-4	-8.2467E-7		
t ⁴	-1.120083E-6	+5.3875E-9		
t ⁵	+6.536332E-9			
	E	F	G	
t ⁰	19652.21	+54.6746	+7.944E-2	
t ¹	+148.4206	-0.603459	+1.6483E-2	
t ²	-2.327105	+1.09987E-2	-5.3009E-4	
t ³	+1.360477E-2	-6.1670E-5		
t ⁴	-5.155288E-5			
	H	I	J	
t ⁰	+3.239908	+2.2838E-3	+1.91075E-4	
t ¹	+1.43713E-3	-1.0981E-5		
t ²	+1.16092E-4	-1.6078E-6		
t ³	-5.77905E-7			
	M	N		
t ⁰	+8.50935E-5	-9.9348E-7		
t ¹	-6.12293E-6	+2.0816E-7		
t ²	+5.2787E-8	+9.1697E-10		

Density Anomaly γ is defined as the Density of the water minus 1000 kg/m³.

A1.3 SPEED OF SOUND

The following information, discussion and conclusions are taken from Special Publication No.34 of the Hydrographic Society, prepared by JM Pike and FL Beiboer of METOCEAN plc. The report is entitled "A Comparison Between Algorithms for the Speed of Sound in Seawater".

The following abbreviations and units are used:

V	Computed speed of sound in seawater (m/s)
T	Temperature (°C)
S	Salinity
ϕ	Latitude in degrees
$g(\phi)$	Gravitational acceleration at the given latitude (m/s ²)
P_b	Hydrostatic pressure (bar) (1bar = 10 ⁵ Pa = 10/g(ϕ) (kg/cm ²))
P_k	Hydrostatic pressure (kg/cm ²)
D	Depth (m)

A1.3.1 STANDARD FORMULAE

A1.3.1.1 PRESSURE/DEPTH RELATIONSHIP

Several relationships are identified by Robertson(l), ranging from the approximate ("1 km of seawater generates a pressure of 101 bar"), to the precise (use of the MacKenzie or UNESCO algorithms).

The accurate relationships require computation of the gravitational field at the latitude in question using an appropriate formula for the gravitational field.

The UNESCO pressure/depth relationship has not been the subject of significant academic debate since its introduction, and is stated as follows:

$$D = \frac{(C_1 * (P_b * 10) + C_2 * (P_b * 10)^2 + C_3 * (P_b * 10)^3 + C_4 * (P_b * 10)^4)}{(g(\phi) + \frac{1}{2} g^1 * P_b)} + \Delta d / 9.8$$

where:

$g(\phi)$	= 9.780318 * (1.0 + 5.2788E-3 * sin ² ϕ + 2.36E-5 * sin ⁴ ϕ)
g^1	= +2.184E-5 m.s ⁻² . bar ⁻¹
C_1	= +9.72659
C_2	= -2.25 12E-5
C_3	= +2.279E-10
C_4	= -1.82E-15, and
P_b	is the hydrostatic pressure (bar)
Δd	is the geopotential anomaly, expressed in J/kg. This term is zero for standard seawater (S = 35, T = 0°C).

The geopotential anomaly term (Δd) contains the correction for the actual density distribution within the water column, and can be evaluated for precise computation (or where there are extremes of temperature or salinity) by integrating the specific volume anomaly over the required pressure range. The procedures for this are also included in UNESCO Technical Paper #44.

The EMLog program, however, does not feature the ability to input Δd (which is therefore assumed to be 0).

This assumption is recognised as being legitimate, with the resultant pressure depth algorithm called 'Simple UNESCO Depth':

$$D = \frac{(C_1 * (P_b * 10) + C_2 * (P_b * 10)^2 + C_3 * (P_b * 10)^3 + C_4 * (P_b * 10)^4)}{(g(\phi) + \frac{1}{2} g^1 * P_b)}$$

This value of D is used in all formulae within EMLog

A1.3.1.2 WOOD (1949)

$$V = 1410 + 4.21 * T - 0.037 * T^2 + 1.14 * S + 0.018 * D$$

This formula was recognised before 1960 as being inadequate, and was replaced (at least in US Navy Hydrographic Office operations) in 1962 by the Wilson formula. It is thus not used in EMLog.

A1.3.1.3 WILSON (OCTOBER 1960)

Full Version

The full version of this formula is:

$V = 1449.14 + V_T + V_P + V_S + V_{STP}$, where

$$V_T = 4.5721 * T - 4.4532E - 2 * T^2 - 2.6045E - 4 * T^3 + 7.9851E - 6 * T^4$$

$$V_P = 1.60272E - 1 * P_k + 1.0268E - 5 * P_k^2 + 3.5216E - 9 * P_k^3 - 3.3603E - 12 * P_k^4$$

$$V_S = 1.39799 * (S - 35) + 1.69202E - 3 * (S - 35)^2$$

$$V_{STP} = (S - 35) * (-1.1244E - 2 * T + 7.7711E - 7 * T^2 + 7.7016E - 5 * P_k - 1.2943E - 7 * P_k^2 + 3.1580E - 8 * P_k * T + 1.5790E - 9 * P_k * T^2) \\ + P_k * (-1.8607E - 4 * T + 7.4812E - 6 * T^2 + 4.5283E - 8 * T^3) \\ + P_k^2 * (-2.529E - 7 * T + 1.8563E - 9 * T^2) \\ + P_k^3 * (-1.9646E - 10 * T)$$

Wilson states that the formula is valid to within ± 0.3 m/s in the ranges:

$$-4^\circ\text{C} < T < 30^\circ\text{C}; 0 < S < 37 \text{ 1 kg/cm}^2; < P_k < 1000 \text{ kg/cm}^2.$$

where $P_k = P_b \cdot \frac{10}{g(\phi)}$

Simplified Version

A simplified version of this formula, which is believed to have been used for a number of offshore surveys, is:

$$V = 1.449.14 + 4.5721 * T - 4.4532E - 2 * T^2 - 2.6045E - 4 * T^3 + (1.39799 - [1.1244E - 2 * T]) * (S - 35) + 1.643E - 2 * D$$

The range of validity is likely to be comparable to the full version, with simplification (and inaccuracy) introduced by replacing the pressure terms with a depth term (of unknown provenance), and ignoring 4th order temperature terms (*inter alia*).

A1.3.1.4 MEDWIN (1975)

This simple formula was based on the Del Grosso equation and is:

$$V = 1449.2 + 4.6 * T - 0.055 * T^2 + 0.00029 * T^3 + (1.34 - 0.010 * T) * (S - 35) + 0.016 * D$$

Medwin states the formula is valid "for realistic combinations of T , S , P " in the ranges $0 < T < 35^{\circ}\text{C}$, $0 < S < 45$, $0 < D < 1000$ m. The fact that the equation was based on the Del Grosso equation, however, leads to the conclusion that the range of validity cannot be superior to the Del Grosso formula itself, which is deemed to be valid only in a limited temperature and salinity range.

The more likely validity of the Medwin formula is indicated in the matrix below, in which the maximum valid pressure (in bar) is indicated for each temperature and salinity:

S	$T (^{\circ}\text{C})$			
	0	5	10	15
33	100	100	100	69
34	100	100	100	100
35	100	100	100	100
36	100	100	100	69
38	69	69	100	100

A1.3.1.5 CHEN AND MILLERO (1977)

This formula was adopted by UNESCO in 1983 and is as follows:

$$V = C_w(t, p) + A(t, p) \cdot S + B(t, p) \cdot S^{3/2} + D(t, p) \cdot S^2$$

where,

$$\begin{aligned} C_w(t, p) = & C_{00} + C_{01} \cdot T + C_{02} \cdot T^2 + C_{03} \cdot T^3 + C_{04} \cdot T^4 + C_{05} \cdot T^5 + \\ & (C_{10} + C_{11} \cdot T + C_{12} \cdot T^2 + C_{13} \cdot T^3 + C_{14} \cdot T^4) \cdot P_b + \\ & (C_{20} + C_{21} \cdot T + C_{22} \cdot T^2 + C_{23} \cdot T^3 + C_{24} \cdot T^4) \cdot P_b^2 + \\ & (C_{30} + C_{31} \cdot T + C_{32} \cdot T^2) \cdot P_b^3 \end{aligned}$$

$$\begin{aligned} A(t, p) = & A_{00} + A_{01} \cdot T + A_{02} \cdot T^2 + A_{03} \cdot T^3 + A_{04} \cdot T^4 + \\ & (A_{10} + A_{11} \cdot T + A_{12} \cdot T^2 + A_{13} \cdot T^3 + A_{14} \cdot T^4) \cdot P_b + \\ & (A_{20} + A_{21} \cdot T + A_{22} \cdot T^2 + A_{23} \cdot T^3) \cdot P_b^2 + \\ & (A_{30} + A_{31} \cdot T + A_{32} \cdot T^2) \cdot P_b^3 \end{aligned}$$

$$B(t, p) = B_{00} + B_{01} \cdot T + (B_{10} + B_{11} \cdot T) \cdot P_b$$

$$D(t, p) = D_{00} + D_{10} \cdot P_b$$

with the coefficients defined in the following matrix:

<i>Subscript</i>	<i>A</i>	<i>B</i>	<i>C</i>	<i>D</i>
00	+1.389	-1.922E-2	+1402.388	+1.727E-3
01	-1.262E-2	-4.42E-5	+5.03711	
02	+7.164E-5		-5.80852E-2	
03	+2.006E-6		+3.3420E-4	
04	-3.21E-8		-1.47800E-6	
05			+3.1464E-9	
10	+9.4742E-5	+7.3637E-5	+0.153563	-7.9836E-6
11	-1.2580E-5	+1.7945E-7	+6.8982E-4	
12	-6.4885E-8		-8.1788E-6	
13	+1.0507E-8		+1.3621E-7	
14	-2.0122E-10		-6.1185E-10	
20	-3.9064E-7		+3.1260E-5	
21	+9.1041E-9		-1.7107E-6	
22	-1.6002E-10		+2.5974E-8	
23	+7.988E-12		-2.5335E-10	
24			+1.0405E-12	
30	+1.100E-10		-9.7729E-9	
31	+6.649E-12		+3.8504E-10	
32	-3.389E-13		-2.3643E-12	

The Chen & Millero expression is based upon comprehensive observations on seawaters in the ranges $0 < T < 40^\circ$, $0 < S < 40$, $0 < P_b < 1000$. Some concern has been expressed, however, at the accuracy of the formula at pressures exceeding 100 bar.

A1.3.1.6 DEL GROSSO (1974)

$V = C_{000} + DC_T + DC_S + DC_P + DC_{STP}$, where

$$C_{000} = 1402.392$$

$$DC_T = 0.501109398873E + 1 * T - 0.550946843172E - 1 * T^2 + 0.221535969240E - 3T^3$$

$$DC_S = 0.132952290781E + 1 * S + 0.128955756844E - 3 * S^2$$

$$DC_P = 0.156059257041 * P_k + 0.244998688441E - 4P_k^2 - 0.883392332513E - 8 * P_k^3$$

$$DC_{STP} = -0.127562783426E - 1 * T * S + 0.635191613389E - 2 * T * P_k \\ + 0.265484716608E - 7 * T^2 * P_k^2 - 0.159349479045E - 5 * T * P_k^2 \\ + 0.522116437235E - 9 * T * P_k^3 - 0.438031096213E - 6 * T^3 * P_k \\ - 0.161674495909E - 8 * S^2 * P_k^2 + 0.968403156410E - 4 * T^2 * S \\ + 0.485639620015E - 5 * T * S^2 * P_k - 0.340597039004E - 3 * T * S * P_k$$

The formula is deemed to be valid only in the temperature and salinity ranges, and up to the pressures (bar), indicated in the matrix below:

<i>S</i>	<i>T</i> (°C)			
	<i>0</i>	<i>5</i>	<i>10</i>	<i>15</i>
33	1034	1034	275	69
34	1034	1034	207	207
35	1034	1034	414	207
36	1034	1034	275	69
38	69	69	414	414

A1.3.1.7 MACKENZIE (1981)

Based upon widespread oceanographic measurements, the MacKenzie formula is:

$$\begin{aligned}
 V = & 1448.96 + 4.591 * T - 5.304E - 2 * T^2 + 2.374E - 4 * T^3 \\
 & + 1.340 * (S - 35) + 1.630E - 2 * D + 1.675E - 7 * D^2 \\
 & - 1.025E - 2 * T * (S - 35) - 7.139E - 13 * T * D^3
 \end{aligned}$$

and is stated to be valid for naturally occurring seawaters in the intervals indicated in the matrix below:

P_k	$T (^{\circ}C)$	S
0	0-30	30-40
50	0-20	32-40
100	0-14	32-34
	0-16	35-38
	10-16	39-40
200	0-12	32-36
	0-16	37
	8-16	38-39
500	0-5	33-36
	12-14	38-39
800	0-5	34-35

A1.3.2 DISCUSSION

A1.3.2.1 DEVELOPMENT OF FORMULAE

A useful overview of the history of seawater speed of sound measurements and formulae is provided by Dulshaw *et al.*

All formulae given above (and the majority of others referred to in the course of this study) were empirically derived from measurements of acoustic velocity of seawater samples whose temperature, salinity and pressure were measured in the oceans and/or varied in the laboratory. The Robertson equation is one of the few attempts to base the equations for the speed of sound on theoretical considerations alone.

The Wood formula, while in use even now, was considered as early as 1960 to be unreliable for the advancing technology and requirements of that era, and was superseded by the Wilson formula in 1961.

The recognition of defects in the experimental methods of Wilson, together with the adoption of the practical salinity scale and the international equation of state for seawater (EOS-80) resulted in the Wilson formula being superseded for oceanographic purposes by the Chen & Millero formula, which still represents the formal standard for oceanographic purposes.

The limitations of the Chen & Millero formula in turn were revealed by precise in situ observations of acoustic velocity with depth, and by the advent of tomographic methods to determine seawater physical properties along very large path-lengths (across oceans) and to great depths.

These observations have led in recent years to the realisation that the Chen & Millero formula has distinct limitations at high pressures, and that the Del Grosso equation may be more realistic for such specialist purposes. The wide validity range for salinity and temperature of the Chen & Millero formula is of value for measurements on the continental shelf, however. The quality of fit of the Del Grosso equation to the modern high-pressure data sets (and the corrections that should consequently be applied to the Del Grosso equation) is currently the subject of some debate.

A1.3.2.2 COMPARISON OF FORMULAE

The Wood and Wilson formulae do not fit modern experimental and observational data well, and should no longer be used for precise computations. This probably is the result of improvements in observational and analytical techniques over the years, together with changes in computational methods of salinity and depth.

The remaining algorithms show fairly close agreement with one another, diverging as pressure increases.

The Chen & Millero formula is commonly accepted for oceanographic use, and was derived from measurements over a wide salinity, temperature and pressure range.

At high pressures (>100 bar), however, recent research suggests that the Del Grosso equation is more accurate, although this formula is valid only for a limited range of oceanic waters.

The Del Grosso formula has been used as a benchmark to appraise the accuracy of the other algorithms.

The following order of preference is suggested:

- i) Chen & Millero (only for water depths less than 1000m)
- ii) Del Grosso (only for water depths greater than 1000m)
- iii) MacKenzie (for rapid computations in oceanic waters to 8000m water depth)
- iv) Medwin (for rapid computations in oceanic waters to 1000m water depth)

The Medwin and Wilson (simplified) formulae diverge considerably from the remaining algorithms at temperatures greater than 20°C. This is expected from two simple formulae lacking higher order temperature terms.

There may be some advantages in using the MacKenzie and Medwin formulae where depth is known, and where the computation of pressure for inclusion in the Chen & Millero or Del Grosso formulae would become unnecessarily onerous. The user should be made aware, however, of the limited range of conditions of temperature, salinity and pressure over which these formulae are valid.

A1.3.2.3 THE PRESSURE/DEPTH ALGORITHM

An accurate expression for computing pressure from depth (and *vice versa*) may be desirable:

- a) for its own sake, to enable precise pressure and depth computations to be made for a variety of purposes; and
- b) to enable precise speed of sound computations to be made.

When using speed of sound algorithms with a pressure term (Chen & Millero, Del Grosso), the water pressure can be measured directly, estimated from a known depth and inversion of the UNESCO pressure/depth algorithm (possibly based on a carefully calibrated conductivity/temperature/depth cast), or calculated from standard tables. According to Saunders and Fofonoff, who were the originators of the basic method adopted in the UNESCO formula, these estimates should be carried out at 5 bar pressure intervals near the surface and at 200 bar intervals for greater depths.

When using speed of sound formulae with a depth term (MacKenzie or Medwin), the depth may be estimated or measured by some independent means, or computed from a pressure measurement and a conductivity/temperature depth cast. It is more likely, however, that these methods would not be used for precise purposes; they are in any case valid only for oceanic waters in which the errors in the estimation of depth, introduced through ignoring the geopotential anomaly, would not be excessive.

A1.3.3 CONCLUSIONS

1. It is recommended that use of the Wood and Wilson formulae be discontinued for precise purposes, as they do not provide good agreement with modern data sets and computational methods of salinity and depth.
2. It is of crucial importance to ensure that the formulae (of whatever origin) are used only for observations made within the ranges of temperature, salinity and pressure for which each expression is deemed valid.
3. It is recommended that the Chen and Millero formula be used for seawaters on the continental shelf. This incorporates a pressure term which should be measured directly; evaluated from a known depth using the full UNESCO formula and data obtained either from oceanographic tables or from a conductivity/temperature/depth cast; or the error in using the simplified UNESCO formula deliberately accepted.
4. In deep ocean waters, the Del Grosso formula is currently favoured, especially for long path-lengths. This also uses a pressure term.
5. Where rapid computations are necessary, or where the depth is known (but not pressure), the simple MacKenzie (9 terms) and Medwin (5 terms) formulations may prove of value. These expressions are strictly valid only for normal oceanic waters. Where depth is computed from pressure, the simplified UNESCO equation for the pressure/depth relationship could be used without introducing significant error.
6. Incorporation of the full UNESCO pressure/depth algorithm (incorporating the geopotential anomaly) would be a useful addition to any software package, although there may be little discernible benefit to the accuracy of the speed of sound computations. The complete formula would, however, enable a full suite of precise applications to be available for use worldwide.

APPENDIX 2 ELECTRICAL CONNECTIONS

3m Y Lead Connections

Mil Spec 10 way line connector Pin No. and cable colour	Function	9 way "D" type female	Black Banana plug	Red Banana plug	Wire Colour Power	Wire Colour Comms
A [RED]	C/LOOP IN & EXT SUPPLY	N/C	N/C	1	RED	
B [WHITE]	RS232 IN TO 808 [RX232]	3	N/C	N/C		RED
C [GREEN]	GND & BATT -VE	5	1	N/C	BLACK	GREEN
D [BLUE]	RS232 OUT FROM 808 [TX232]	2	N/C	N/C		YELLOW
E [N/C]	RS485 I/O INVERTED	N/C	N/C	N/C		
F [N/C]	RS 485 I/O NON-INV	N/C	N/C	N/C		
G [[N/C]	FLASHING LED +VE CONN	N/C	N/C	N/C		
H [BROWN]	V_UNIT	N/C	N/C	N/C		
J [ORANGE]	CL_UNIT	N/C	N/C	N/C		
K [YELLOW]	INT BATTERY POSITIVE	N/C	N/C	N/C		
	DTR	PIN 4 LINK TO PIN 6&7				
	DSR	PIN 6 LINK TO 4&7				
	RTS	PIN 7 LINK TO PIN 4&6				

Seapoint Turbidity Sensor Cable (option)

Mil-Spec 8 way Line Connector	Function	Colour
A	0v Supply	White
B	Signal +ve	Black
C	Signal Gnd	Blue
D	+12v Supply	Orange
E	Gain Control A	Green
F	Gain Control B	Red
G	N/C	
H	N/C	

PRODUCT 0808 – ANALOGUE OUTPUT**CABLEFORM NAME 0808 POWER / ANALOGUE OUTPUT, SUBSEA CABLE**

END 1:-15 WAY FEMALE SUBSEA CONNECTOR LMH 00T 12 15 SN		END 2:- BARE BACK CABLE 50mm FOR TESTING / TERMINATION
PIN	WIRE COLOUR	FUNCTION
A	RED & WHITE	+ VE SUPPLY
B	BROWN	RS 232 IN TO UNIT
C	BLACK & YELLOW	GND - PWR & 232
D	ORANGE	RS 232 OUT FROM UNIT
E		
F		
G		
H	LINKED IN CONNECTOR	V_UNIT
J		CL_UNIT
K		
L		
M	PINK	ANALOGUE GROUND
N	BLUE	ANALOGUE SPEED OUTPUT
P	GREY	ANALOGUE DIRECTION OUTPUT
R	GREEN	ANALOGUE PRESSURE OUTPUT

PRODUCT 0808 – ANALOGUE OUTPUT**CABLEFORM NAME 0808 POWER /COMMS / ANALOGUE OUTPUT, SUBSEA BULKHEAD**

END 1:-15 WAY MALE SUBSEA BULKHEAD CONNECTOR, LMH 06T 12 15 PN				END 2:- BATTERY PCB 0730504A	END 3:- BATTERY BULKHEAD, 15w D Type
PIN	WIRE COLOUR		FUNCTION	PIN	PIN
A	PINK		+ VE SUPPLY		1
B	WHITE & RED		RS 232 IN TO UNIT		3
C	GREEN		GND - PWR & 232	-ve	2
D	WHITE & BLACK		RS 232 OUT FROM UNIT		4
E					
F					
G	GREY & BLACK		LED Flash +ve		7
H	ORANGE		V_UNIT		8
J	RED		CL_UNIT		9
K	YELLOW		INT Battery +ve	+ve	10
L					
M	GREEN & SCREEN	Separate Screened Cable	ANALOGUE GROUND		12
N	RED		ANALOGUE SPEED OUTPUT		13
P	YELLOW		ANALOGUE DIRECTION OUTPUT		14
R	BLUE		ANALOGUE PRESSURE OUTPUT		15

APPENDIX 3 EQUIPMENT SUPPLIED

Serial No.	Model No.
Customer:	Con Number:.....
.....	Customer Ref:.....
.....	Del. Note:.....
.....	Calibration Cert.:

ITEM	Items Required		Quantity	Serial Number	Checked By	Date
	Yes	No				
808 Unit [Speed & Direction]						
Pressure Sensor Type Resonant Silicon [0.01 %FS pressure accuracy]						
Pressure Sensor Type Strain Gauge [0.1 %FS pressure accuracy]						
Pressure sensor range						
Conductivity sensor						
Temperature sensor						
Seapoint Turbidity sensor						
Deployment frame						
Extended u/w cable						
9 – 25 way D Type adaptor						
Y lead						
LED pro-cap						
EMLog discs [2]						
Spare set O-rings						
M5 x 12 screws and hex key						
Manual						
Calibration certificate [in manual]						
Transit case						

APPENDIX 4 GUARANTEE CERTIFICATE

GUARANTEE CERTIFICATE

All goods are subject to a 36 month guarantee against faulty materials and bad workmanship.
Any faults to be declared within 36 months from date of despatch, in writing to Valeport Limited, who will replace or repair (at their option) any faulty items caused by bad workmanship or materials, (except transducers, displays and semiconductors which are only guaranteed for a 12 month period).

Valeport Limited shall be under no liability for:

- 1) Any consequential loss or damage of any kind whatsoever.
- 2) For any defect or deficiency judged by Valeport Limited to be caused by wear and tear or of improper or unskilled handling of the goods or by any repair or attempted repair or dismantling by any one other than Valeport Limited or person's authorised to do so by Valeport Limited.
- 3) Batteries and other consumables supplied with the equipment, which are not covered by this guarantee.

Due to the specialised nature of the instrument it should, if possible, be returned to the factory for repair or servicing. The type and serial numbers of the instrument should always be quoted, together with full details of any fault or the service required.

Equipment returned to Valeport Limited for servicing must be adequately packed, preferably in the special box supplied and shipped with transportation charges prepaid. Return transport charges are also to the account of the customer.

Note: Any items supplied as part of a system which are not manufactured by Valeport Limited are covered by the individual manufacturer's guarantee of the equipment supplied.

MODEL NUMBER..... SERIAL NUMBER

DATE OF DESPATCH..... SIGNATURE.....

APPENDIX 5 CALIBRATION CERTIFICATES