

## ELECTRONIC BATHYTHERMOGRAPH

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### ABSTRACT

An instrument for recording sea temperature and pressure on static RAMs to a depth of 256 meters is described. A Copper resistance temperature sensor and a strain gauge pressure sensor were used to sense these parameters. The sensitivity and repeatability for temperature was  $0.1^{\circ}\text{C}$  and for pressure was 1.0 decibar. Results from casts at several oceanographic stations showed close correlation with standard instruments.

### INTRODUCTION

Most of the marine instruments used in the country are presently imported. As these instruments are used extensively at sea, indigenous development of such instruments would save costs and ease service problems encountered in future. The Electronics Commission funded an indigenous development project in two phases wherein development of several marine instruments were taken up at NIO, Goa. One of the instruments developed under this program was the Electronic Bathythermograph (henceforth referred to as EBT) and described in this paper.

Temperature/Depth (T/D) profile at sea is the most fundamental and frequently measured parameters to determine:

i) salinity, (ii) density profiles, (iii) air-sea interaction & atmospheric dependence over the sea and many other parameters. An in-house developed profiling EBT would therefore enable study of the above parameters and being in-house, any special phenomenon of interest could be studied by incorporating the desired modifications in the instrument. Normal recording T/D profilers can be represented under two main categories namely:

(i) Mechanical and (ii) Electrical types.

The scope of the present work was to design and develop an EBT. The instrument was to be calibrated and simulation tested in the laboratory and finally field tested from Research Vessel Gaveshani.

The Mechanical Bathythermograph was the first recording type of T/D profiler and is still in use. Though it is a rugged and traditional instrument, the data is inscribed on a small glass slide, and has to be read through a magnifying glass and digitized which is both laborious and prone to errors. Among the electrical types, the Expendable Bathythermograph (ref.1) is recommended for use while the ship is under move. Though it saves on ship's time, it is expendable and expensive for extensive use. Furthermore, data is in analog form. The Digitally Recording Bathythermograph (DBT, Ref.2), had the advantage of digitized data and was reuseable. Commercially available DBTs(ref.3) today have typical depth ranges upto 1000 meters and temperature ranges from 0-35°C and the acquired data is printed or plotted.

The EBT was designed to record T/D data at every meter with an accuracy of 0.1°C on CMOS RAMs. In addition, heading data was to be recorded. A microprocessor was used as it was seen to be most appropriate in view of the facilities that were to be offered. The design endeavoured to:

- i) Check status of the instrument, and report to the user.
- ii) Allow the user to enter heading data from a deck unit via a serial RS232C line. This allowed any intelligent terminal to be used and the system therefore grew in terms of re-recording data on magnetic tape, printer or plotter.
- iii) A mechanism was incorporated that allowed a single 4 contact connector to charge the internal batteries, communicate serially and electrically isolate itself from the instrument during a cast.
- iv) On recovery from a cast, the instrument would respond to preset commands and display or print data.

An 8 bit Intel 8085 microprocessor was used. Data storage was maintained with a back-up battery during the power-down mode.

A Copper resistance thermometer was used as it exhibits a linear resistance/temperature relationship thus minimizing the electronic circuitry. A strain gauge bridge was chosen as the pressure sensor. The EBT was tested extensively in the field against DBT, XBT and Nansen casts and the form of results obtained agreed well. This was most evident in the rapid response obtained in the thermocline region.

#### METHODOLOGY

The instrument consisted of a sea unit which acquired and stored the data and a deck unit which enabled the user to read data from the sea unit and to connect it to peripherals.

Sea unit: The sea unit was a stainless steel cylindrical housing containing the battery and the electronics package. The pressure and temperature sensors and a main 4 pin underwater connector were mounted at the bottom end of the housing within an open steel cage. The main connector enabled the resident batteries to be charged, and data to be

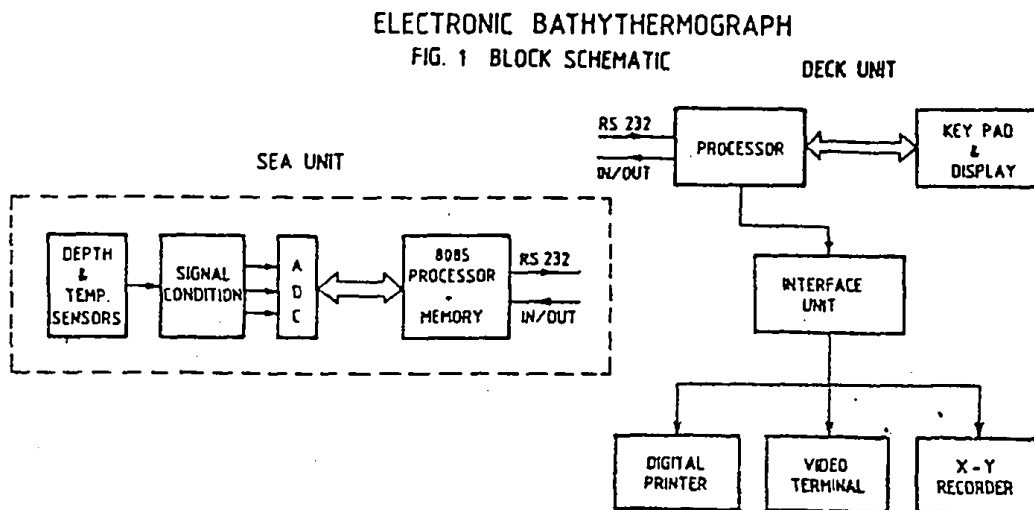
entered into and read from the system memory. The unit contained a magnet and switch assembly at the top end to enable system functions to be set up without opening the unit. The magnet had three external operating positions. In position 1, the 12 volts from the battery was connected to the electronic circuits and data acquisition was enabled. During this operation, the external connector was electrically isolated from the internal circuitry thereby preventing any possibility of the connector terminal short circuiting the internal circuitry due to the surrounding sea water. In position 2, the main connector was used to transfer commands/data between the unit's storage and the deck unit and the internal batteries could be charged. Position 3 switched off the system. Back-up batteries powered the data storage irrespective of magnet position ensuring protection of acquired data.

Deck unit: The deck unit consisted of a hex-decimal keypad, a pair of 4 LEDs and associated electronics which enabled communication with the sea unit and display the respective functions. The unit also enabled interfacing a BCD printer and an RS232C communication terminal to process the data received from the sea unit.

### SYSTEM ELECTRONICS

The power supply consisted of 6 sealed rechargeable cells giving a total of 12 volts. One of these cells continuously powered the data storage.

The electronics was distributed over 4 boards containing the voltage regulators and reference sensor excitation, the signal conditioners, the digitiser & data storage, and the processor. The block schematic of the sea unit is shown in Fig.1.



The pressure transducer was energised by 7 volts DC derived from an LM723. Similarly, a 3 volts DC derived from a resistance ladder at the output of the LM723 was used to generate a constant current of 3ma to energise the temperature sensor. Both the sensor outputs were amplified and adjusted to represent the full scales of 0 to 256 meters and 10°C to 35°C for depth and temperature respectively. Amplification was carried out by precision auto-zero amplifiers whose output was fed to a multiplexer-digitiser, ADC 0809. The digitiser output was connected to the microprocessor data bus, which controlled the analog to digital conversion. The digitiser also sampled the different monitor voltages, battery level etc. and converted these to digital signals for storage in the system memory. The digitiser was programmed to sample each channel 32 times, and store the average. This ensured that signal variations were averaged out leading to stable readings. During data acquisition, the digitiser continuously monitored depth, and on detection of an LSB change (corresponding to one meter), the corresponding temperature was recorded. Both data were alternately stored in CMOS RAMs. The microprocessor used was Intel's 8085 with 2K program and 4K data storage. Necessary decoding logic formed the remaining digital section.

The system was powered-up when the magnet was set to position 2. In this mode, the processor carried out self test routines and sent the results to the deck unit upon receiving appropriate commands. Heading data entered from the deck unit prior to a cast was stored in the sea unit. After satisfactory completion of the check routines, position 1 was selected and the instrument was deployed. When the instrument reached its maximum depth of operation of 256 meters, the data acquisition was completed and the instrument was hauled up to the deck. Selection of switch position 2 established the link between the sea unit and the deck unit and the acquired data was retrieved subsequently from the sea unit into the deck unit at 1.2K baud upon receipt of the appropriate dump command. The data received was initially stored, prior to display on the unit's front panel LEDs, or printing on a digital printer. The data could also be connected to a computer or a chart recorder.

#### CALIBRATION AND TESTING

Prior to field deployment, both sensors were calibrated and rigorously tested in the laboratory. The pressure sensor was calibrated with a dead weight tester (Ref.4) at the manufacturer's and showed an overall linearity of better than 1%. The pressure sensor was then simulated by a resistance bridge with a variable resistance arm. The bridge output voltage represented the sensor output voltage in the range of 0-300 metres. This output was amplified to read one meter equivalent to one LSB on the digitiser. The calibration (simulation) results showed a correlation of better than 1%.

The temperature sensor was simulated by a zero temperature co-efficient resistance box. The resistance was varied from 48.00 to 56.00 representing 10°C to 35°C. The amplifier offset and gain were adjusted such that the digitiser output represented a full scale range of 10°C to 35°C with 0.1°C resolution. The calibration results showed a

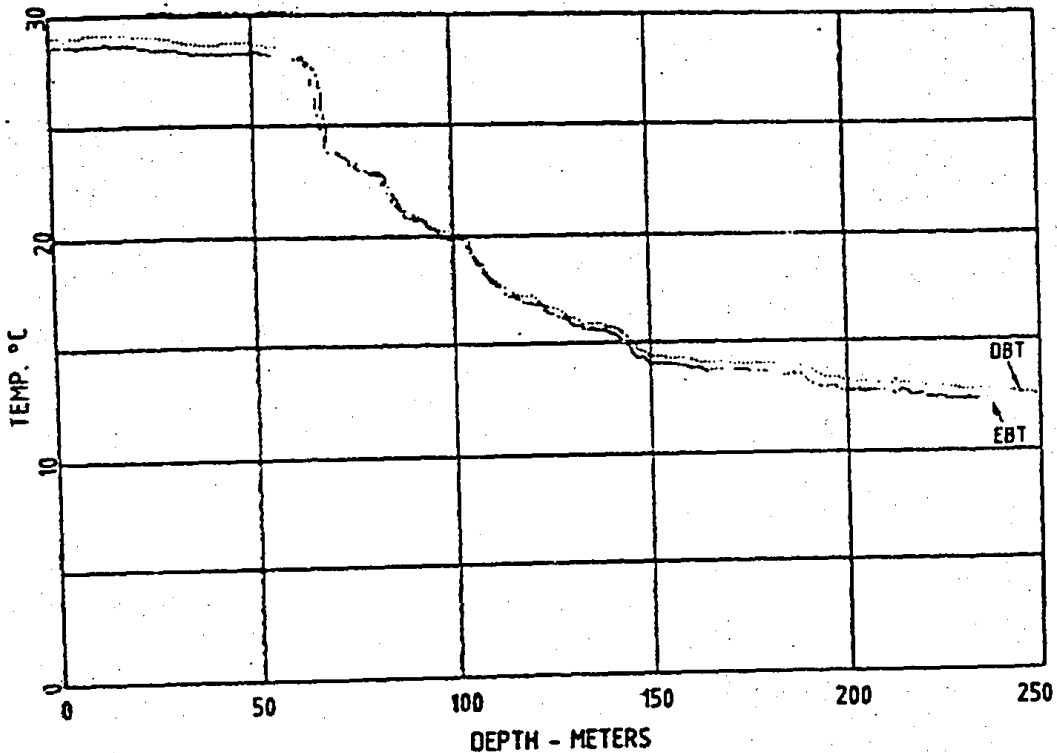
correlation of better than 0.1%. Further calibration in a precision temperature bath (Ref.5) showed the same linearity of 0.1%.

### FIELD RESULTS

The instrument, when tested at sea showed good results. A typical profile is shown in Fig.2. Plotted on the same graph are results obtained with a commercial Digital Bathythermograph.

### DBT - EBT PLOT

FIG. 2 RV GAVESHANI - STN. NO. 3822



### DISCUSSIONS

The comparative traces produced by the digital and the electronic bathythermograph in Fig.2 show that the basic behaviour of both the instruments are similar. In regions of slow temperature variation, -from 0-60 meters and 150-250 meters, - a temperature difference of 0.4°C is noticeable. In contrast, the large temperature variation of the thermocline from 60-150 meters show good correlation. As the EBT had been rigorously tested and calibrated prior to deployment, it was assumed that its calibration was correct. In order to quantitatively

estimate the results from the DBT & the EBT, an offset was applied to the temperature and pressure scales of the DBT readings. By adding an offset of  $-0.4^{\circ}\text{C}$  and +3 meters to the DBT results, the readings were almost coincident. The calibration of the EBT was rechecked after the sea trials and no shift was detectable with the pre-trial calibration results.

Table 1 shows the readings from different instruments' outputs at surface level taken at different oceanographic stations. From Table 1, it was observed that all the instruments' outputs had differences among themselves. The difference in the EBT output with respect to other instruments are represented in columns 6 to 9. It was observed that this difference was always maintained close to a nominal value which varied from instrument to instrument.

TABLE 1 : TEMPERATURE COMPARISONS AND DEVIATIONS OF XBT,SST,RT & DBT WITH EBT FOR DIFFERENT STATIONS AT SEA SURFACE.

STN. NO.	1 XBT	2 SST	3 RT	4 DBT	5 EBT	1 - 5	2 - 5	3 - 5	4 - 5
3817	--	28.8	28.60	28.35	27.8	--	1.0	0.8	0.55
3820	30.0	29.5	29.53	29.35	28.8	1.1	0.7	0.73	0.55
3821	29.3	29.5	29.30	29.07	28.5	0.8	1.0	0.8	0.57
3822	--	29.4	29.20	29.09	28.6	--	0.8	0.6	0.49
3824	--	29.4	29.21	28.95	28.5	--	0.9	0.71	0.45
3825 A	29.2	--	29.09	28.93	28.4	0.8	--	0.69	0.53
3827	29.1	--	29.07	28.93	28.4	0.7	--	0.67	0.53
3828	--	--	28.86	28.61	28.1	--	--	0.76	0.51

XBT > SST > RT > DBT > EBT

XBT : EXPENDABLE BATHYTHERMOGRAPH      SST : SEA SURFACE THERMOMETER.  
 RT : REVERSING THERMOMETER.              DBT : DIGITAL BATHYTHERMOGRAPH.  
 EBT : ELECTRONIC BATHYTHERMOGRAPH.

The results from this prototype have shown extremely encouraging results. Furthermore, the advantages of an indigenous instrument are that the modifications are easily accomplished, and maintenance capability and spares, are readily available.

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#### REFERENCES

1. M/S Sippicon Ocean Systems Inc. , Marion, MASS, U.S.A.
2. A.E.Gilmours & E.J. Barnes (1979): A Digital BathyThermograph, Marine Science Communications, 5(3), 217-228.
3. M/S Kankyo Keisoku System Co.Ltd., Tokyo, JAPAN.
4. Dead Weight Tester Model 5020, M/S Desgranges & Huot, Aubervilliers, West Germany.
5. Model 2160 Bath & Circulator, M/S Forma Scientific, U.S.A.