

# **A Temperature Profiler**

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## **ABSTRACT**

An instrument developed for measuring temperature profiles at sea in depth or time scales is described. PC-based programming offers flexibility in setting up the instrument for the mode of operation prior to each cast. A real time clock built into the instrument enables setting up the desired time interval for data acquisition when moored at a particular place. Data acquired in either mode is stored in the memory of the sea-probe instrument. At the end of each cast, data is downloaded into the PC for processing and further analysis. Data acquired during a recent cruise has been processed and analysed, and the instrument behaviour studied *vis-a-vis* on-board CTD system. The performance data are presented.

## **INTRODUCTION**

A bathythermograph has been designed and developed to record the temperature in time series or vertical profiling mode [3]. The salient features of the instrument are :

- (i) A user programmable menu driven system that sets operating parameters and can be accessed by a personal computer (PC).
- (ii) A sea-activated switch that switches the instrument ON automatically when it enters seawater and turns it OFF either at the end of data acquisition or when the instrument comes out of water, as desired by the user.

Before lowering the instrument in water for data collection, all the necessary operational settings are set up from the PC and stored in instrument memory. A high stability pressure protected platinum resistance thermometer is used to measure the water temperature [4]. A strain gauge pressure transducer senses the pressure of the water column above its diaphragm as the instrument is lowered into the sea. Both sensors are calibrated against high accuracy laboratory standards, such as the Guidelines Digital thermometer (used in a variable temperature stabilised waterbath) and the Paroscientific Digiquartz pressure sensor. The

calibration data are incorporated in the data processing software permitting higher accuracies to be achieved from lower cost sensors. After data acquisition is completed, the instrument is brought to deck, serially linked to the PC and raw data from the instrument is transferred to the PC for further processing.

The initial field test results conducted onboard *R.V. Sagar Kanya* using the instrument are presented in this paper. The results of calibration tests and parallel field tests conducted with the Sea-Bird CTD are discussed.

### CALIBRATION OF THE INSTRUMENT

The instrument (Fig. 1), henceforth referred to as the sea-probe, was calibrated in the laboratory by pressure and temperature cycling. During pressure cycling, temperature around the sea-probe was maintained at ambient. During temperature cycling, atmospheric pressure was considered as the reference point. Details of the calibration procedure are given below.

*Pressure channel calibration* — The ISRO pressure transducer used in the sea-probe for depth measurements has an accuracy of  $\pm 0.5\%$  FS over the range 1-1000 psi. To enhance the accuracy of the instrument, the ISRO pressure was cross-calibrated with a high accuracy 0.04% FS Digiquartz pressure transducer.



Fig. 1 — The instrument 'Sea-probe'

which, in turn, was calibrated against a transferred secondary standard by the manufacturer. A Heitz pressure gauge and the standard weights supplied with it were used to develop high pressures *via* the oil medium. The ISRO and Digiquartz sensors were mounted on the Heitz pressure gauge and the corresponding pressures on. The pressure ports of both the transducers were simultaneously equalised *via* the oil medium. Outputs of the transducers for various input pressures were recorded. In the case of the ISRO transducer, the final digital output of the sea-probe was measured and calibrated against the Digiquartz transducer output. Regression calculation was carried out on the calibration data and a first order linear fit was computed. From this, the slope 'm' and constant 'c' were derived. These two calculated values were used to process the raw data from the sea-probe. As a 0-900 psi Digiquartz transducer was used during calibration, the sea-probe pressure channel has a one-to-one calibration for the depth range 0-600 m. Data beyond this range were extrapolated. The results of laboratory requirements are presented in Figs 2 and 3.

*Temperature channel calibration* — The temperature sensor used in the sea-probe is a high stability Rosemount Platinum resistance thermometer with a 66.6% response time of 310 ms and an accuracy of 0.02 °C.

The Guideline digital thermometer, recommended as a laboratory calibration standard, is used to cross-calibrate the sea-probe temperature sensor. The calibration standard is accurate to  $\pm 0.002^\circ\text{C}$ . A temperature controlled bath, (Model 2160 from M/s Forma Scientific) permits setting the temperature of water in the bath from 2° to 40°C with a simple thermoregulator setting. The bath temperature

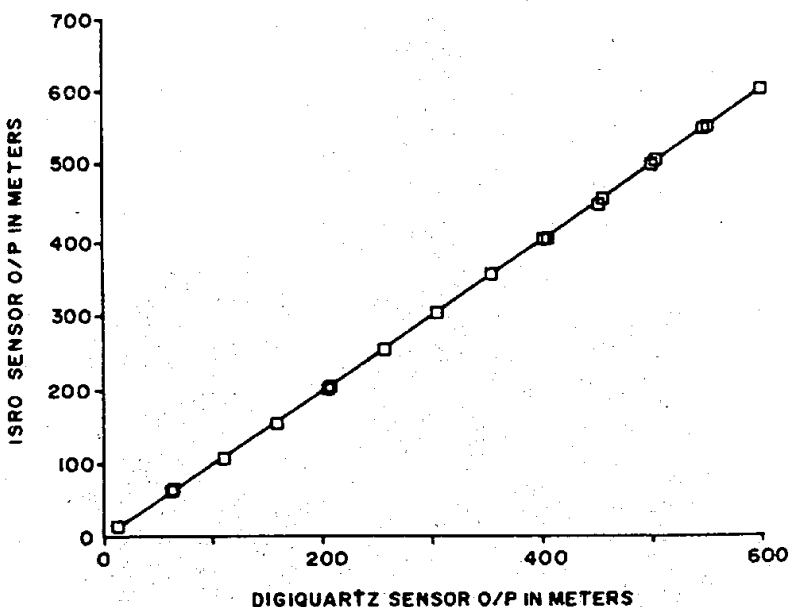


Fig. 2 — Calibration graph of ISRO vs Digiquartz sensor

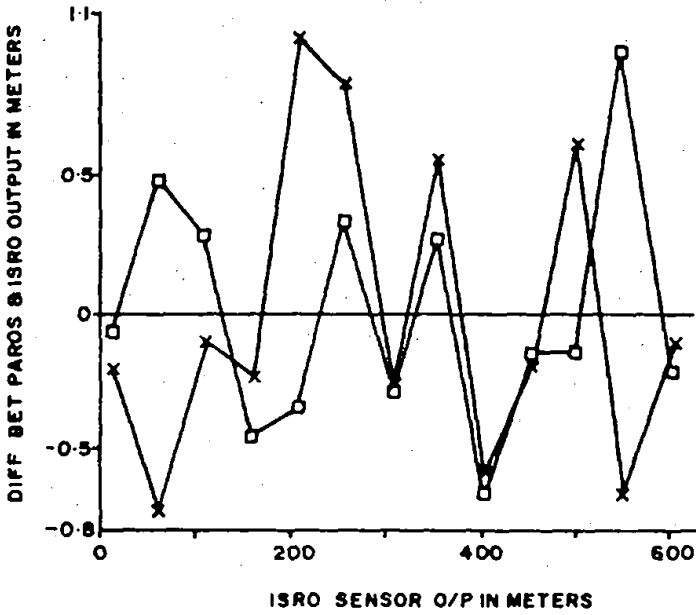


Fig. 3 — Error graph of ISRO sensor vs error

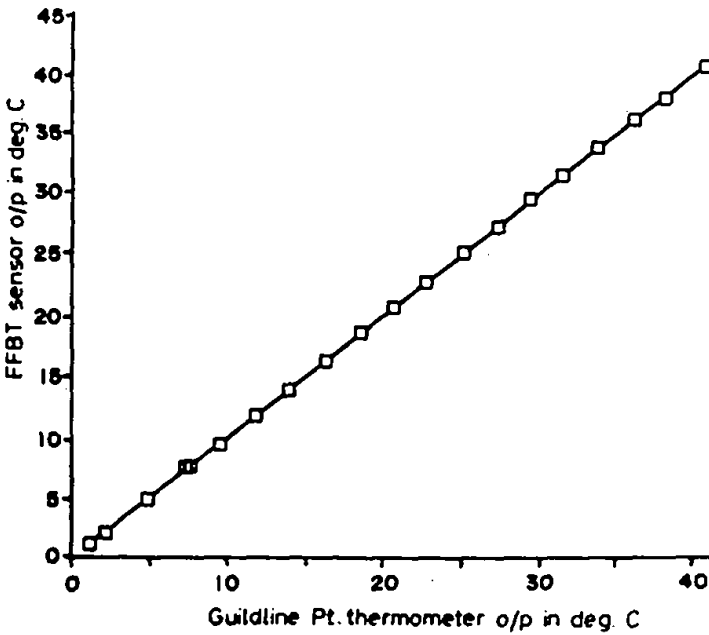


Fig. 4 — Regression calibration graph of guideline Pt thermometer vs FFBT sensor

is stable to  $\pm 0.02^\circ\text{C}$  of the thermoregulator setting. The sea-probe temperature sensor and the Guideline thermometer were immersed in the bath and water temperature was varied from  $2^\circ$  to  $40^\circ\text{C}$ . The outputs of the sea-probe and the calibrator were recorded at various temperatures. Regression calculation was carried out on the calibration data and a first order linear fit was computed. Values of slope 'm' and constant 'c' were derived from the equation used to process the raw temperature data from the sea-probe. Results of laboratory calibration are presented in Figs 4 and 5.

*Field trial* — The instrument was tested at sea during *ORV Sagar Kanya* cruise no. 70 in November-December 1991. Pressure testing of the EBT casing was successfully carried out up to 1200 m. Data was collected at 15 stations along the cruise track. During these operations, the sea-probe was operated immediately after the on-board CTD system DEEP CAST. Temperature/depth data acquired from the sea-probe was compared with the on-board CTD system data qualitatively. Temperature/pressure profiles of the last two stations, F11 and G11, that are discussed in greater detail are presented and the EBT and respective CTD system data represent the two different graphs on each plot (Fig. 6). To compare the EBT data with the data provided by the on-board CTD system in real-time, both the instruments were cast together with a drop rate of approximately 1.3 m/sec in the above two stations of the cruise track.

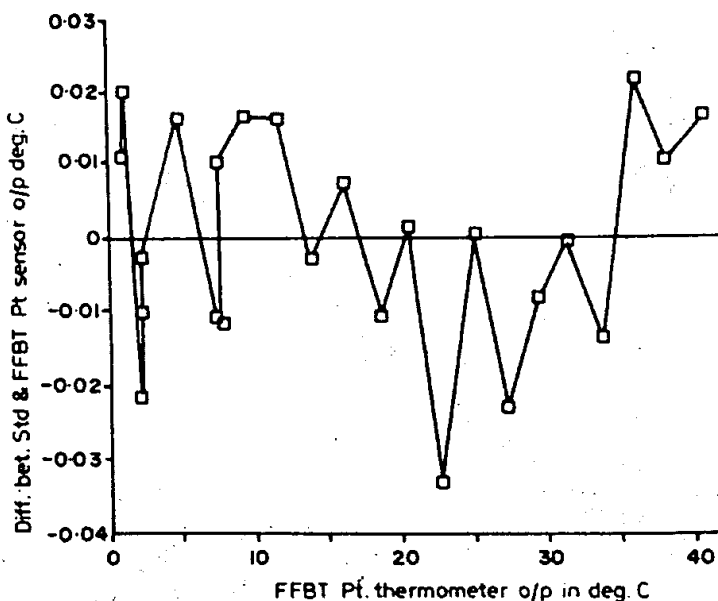


Fig. 5 — FFBT temperature error graph

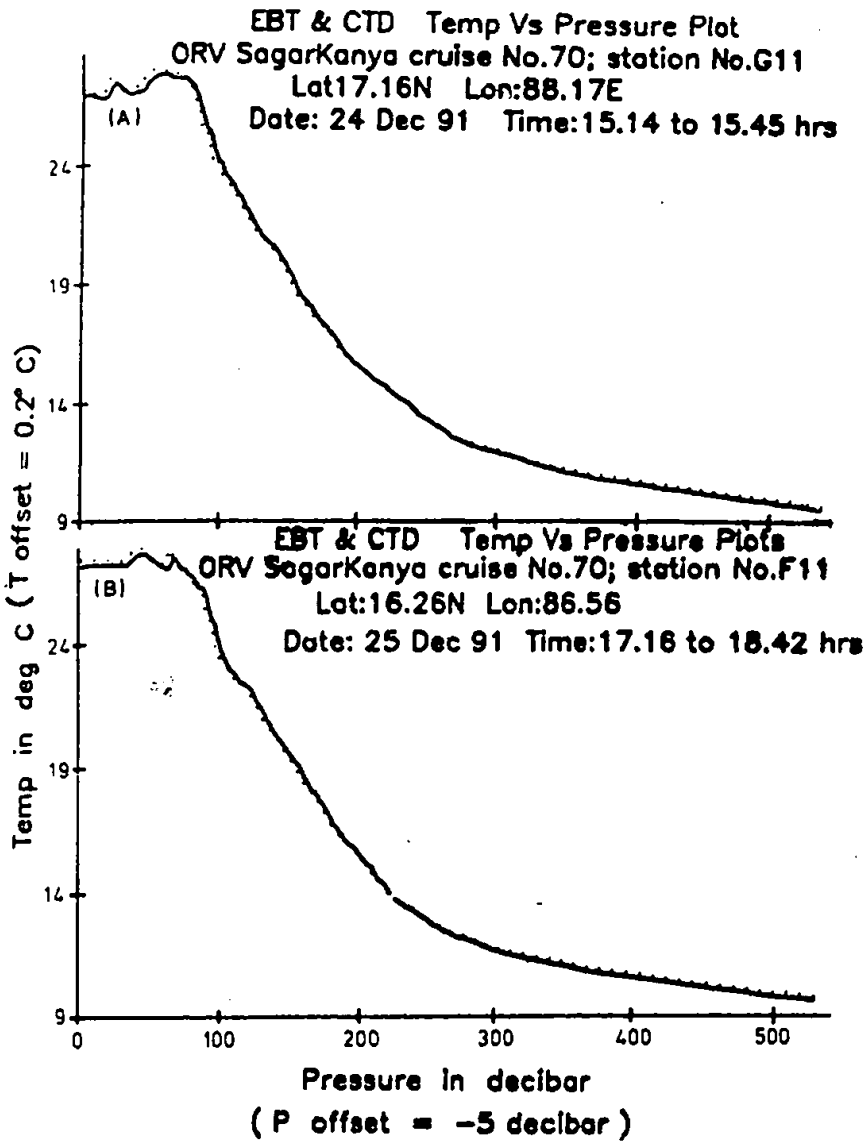


Fig. 6 — Temperature/pressure profiles for stations - G11(A) and F11(B)

### RESULTS AND DISCUSSION

After studying the data in detail, and considering the CTD unit as the standard to be compared against, it was observed that the EBT instrument developed at NIO shows the expected behaviour. This characteristic behaviour is seen in temperature/pressure plots for various stations. Closer scrutiny of the data shows that the difference between EBT and CTD data in the mixed upper layer (0-50 m) and the slow varying deeper (200-600 m) is constant and is within 0.1 °C. In the thermocline region (50-200 m), differences were higher.

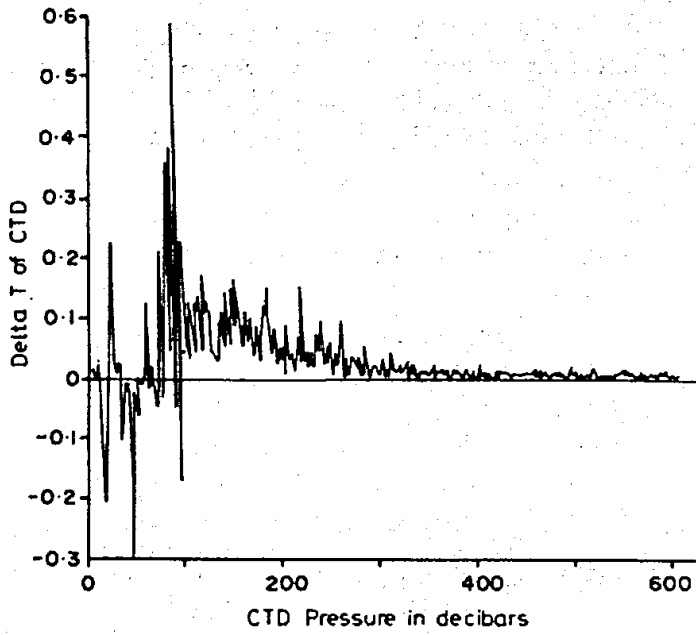


Fig. 7 — CTD T vs pressure response

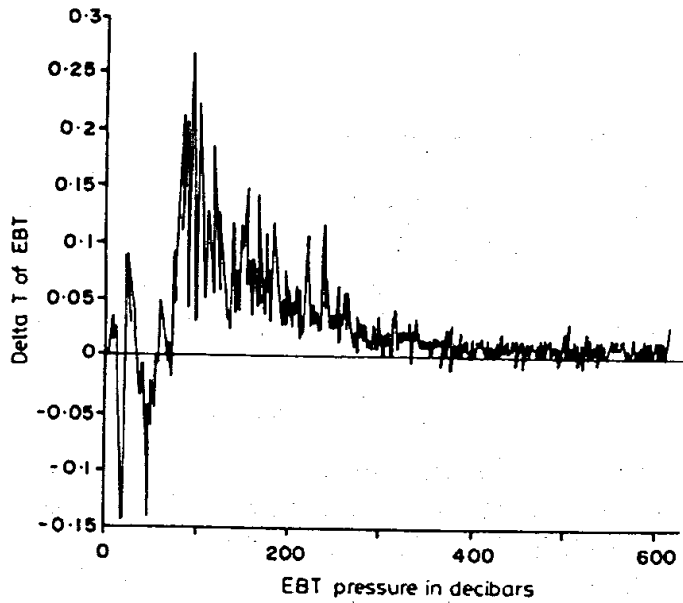


Fig. 8 — EBT T vs pressure response

Apart from the regular temperature/pressure graphs, Figs 7 and 8 representing the variation in temperature ( $\Delta t$ ) with respect to pressure were drawn for the stations F11 and G11. As both the instruments were lowered at the same drop rate and the pressure sensors used in both the instruments have almost the same response time, it was assumed that pressure scale can be substituted with the time scale. This assumption permitted us to analyse the behaviour of the EBT temperature sensor. It is known that the CTD temperature sensor response time (72 ms) is almost five times higher than the response time of the EBT sensor, which is greater than 310 ms at this drop rate. This difference in response time accounted for the major part of the error in the thermocline region of the temperature scale. The high rate combined with its slow response did not permit the EBT temperature sensor to reach the final temperatures within the profiling time [2]. As such, all the smaller variations are filtered out. Uniform differences in temperature in the mixed and deeper layer are, to some extent, attributed to shift in calibration. Further analysis of data by determining regression and calculating standard deviations has yielded some interesting results. A correction of 5 m on depth scale and  $+0.2^\circ\text{C}$  for temperature applicable for all data sets reduces the difference appreciably [1]. Hopefully, the instrument will be used in several forthcoming cruises to establish its reliability and robustness.

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