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BEAR BUOY: THE ENGINEERING DOCUMENTATION FOR SCIENTIFIC APPLICA--ETC(U)
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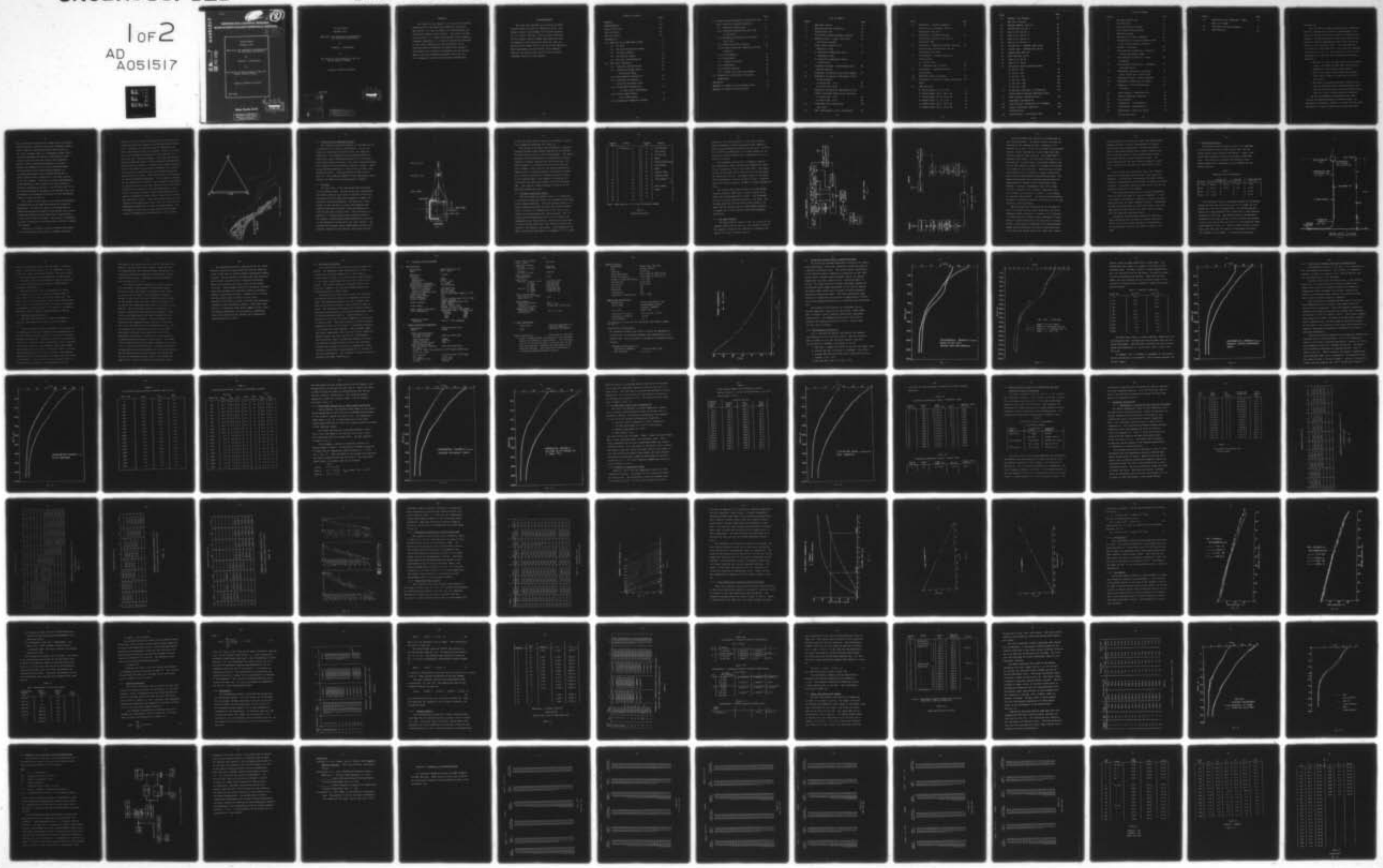

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INSTITUTE FOR ACOUSTICAL RESEARCH
MIAMI DIVISION PALISADES GEOPHYSICAL INSTITUTE

See 1473 in back

Interim Report

November 1976

BEAR Buoy: The Engineering Documentation for Scientific Application

by

Kenneth L. Echternacht

to

The Office of Naval Research, Code 222
Sensor Systems Program

Contract: N00014-74-C-0229

IAR 76002

Miami, Florida 33130

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ABSTRACT

The intent of this report is to serve as the working documentation of the BEAR Buoy System for scientific application. As such the report is oriented toward the engineering aspects of the project. The report includes the following: (1) a general description of the system by component subsystem; (2) a detailed engineering breakdown of the sensor subsystem and the development of the rationale used to determine the operational ranges of the sensors; (3) calibration procedures and the development of the data conversion transfer functions; and (4) a summary of the post-data processing methodology.

ACKNOWLEDGEMENTS

This work was supported by the Office of Naval Research under Contract No. N00014-74-C-0229. The author wishes to acknowledge the following persons: Dr. A.O. Sykes, Code 222, Office of Naval Research, for his support; Robert Marema, Raul Murciano, and the members of the engineering staff for their cooperation and support both in the field and laboratory; Mark Coopersmith and David Smith of the computer section; and James Nangle and the crew of the R/V GULFQUEST during the field phases.

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Introduction

Both the MODE and IWEX experiments were designed to provide information on baroclinic disturbances in the open-ocean region between the islands of Eleuthera and Bermuda. The IAR experiment on the other hand, was designed to provide complementary data from a region adjacent to the continental shelf. The IAR study area is located in close proximity to the island of Eleuthera (position B_2 in Fig. 1). The scientific intent of the experiment is to provide data to study the following questions.

1. What are the relative amplitudes of the internal tides in the MODE and IWEX open-ocean regions compared to the Eleuthera shelf-region?
2. How do the larger scale Rossby wave and mesoscale eddies compare in magnitude at the two locations?
3. Are there long-period baroclinic disturbances, such as meteorologically driven boundary waves, that are characteristic only of the shelf region, and if so, what is their relative magnitude?

The IAR environmental measurement buoy, BEAR (acronym for Bermuda Eleuthera Acoustics Range), was deployed off Eleuthera, Bahamas to provide the data base with which to study the above and related questions.

The measurements include ocean temperatures at discrete depths from near surface to below the permanent thermocline (~1800 m) and mooring tension and inclination. The latter provide input to a mathematical model which is used to determine the mooring configuration under varying conditions and thus predict the thermistor depths. Other engineering parameters are used to monitor the condition of the system and performance. All environmental and engineering parameters are digitized and stored in the on-board memory and on remote command radio telemetered to the shore station, an on-line computer. The buoy is located approximately 40 Km northeast of the northern end of the island of Eleuthera (position B_2 in Fig. 1) at 25° 48'N, 76° 17' W. The anchor position is situated on the abyssal plain approximately 20 Km seaward of the base of the continental slope at a depth of 4797 m.

The intent of this report is to serve as the working documentation for the BEAR Buoy system for scientific application. As such the report is oriented heavily toward the engineering aspects of the project but tedious engineering details are presented only if they pertain to the final scientific product. The intent is establish the basic capabilities and limitations of the data acquisition system.

Section 1.0 provides a general overview description of the buoy system broken down by component subsystem.

Section 2.0 first treats the specifics of the sensor subsystem detailing the engineering specifications by sensor type. Secondly, the rationale used in determining the sensor operational range is presented. Section 3.0 covers the sensor subsystem calibration and the digital to engineering unit conversion method. The first part details both the laboratory and in-field calibration measurements and presents the results. Secondly the transfer functions used in the post-data processing to produce the calibration corrected engineering units are developed and summarized for each sensor. The final section, 4.0 discusses the post-processing methodology. This includes a summary of the calibration correction, the conversion from digital to engineering units, and the correction for sensor depth changes due to changes in mooring configuration. The latter correction utilizes a model which determines the mooring configuration under varying conditions of surface and subsurface forcing. Given the predicted mooring configuration the temperature time series are corrected for temperature changes due to vertical displacements. The development of the mooring model and the displacement correction method will be presented in a later report.

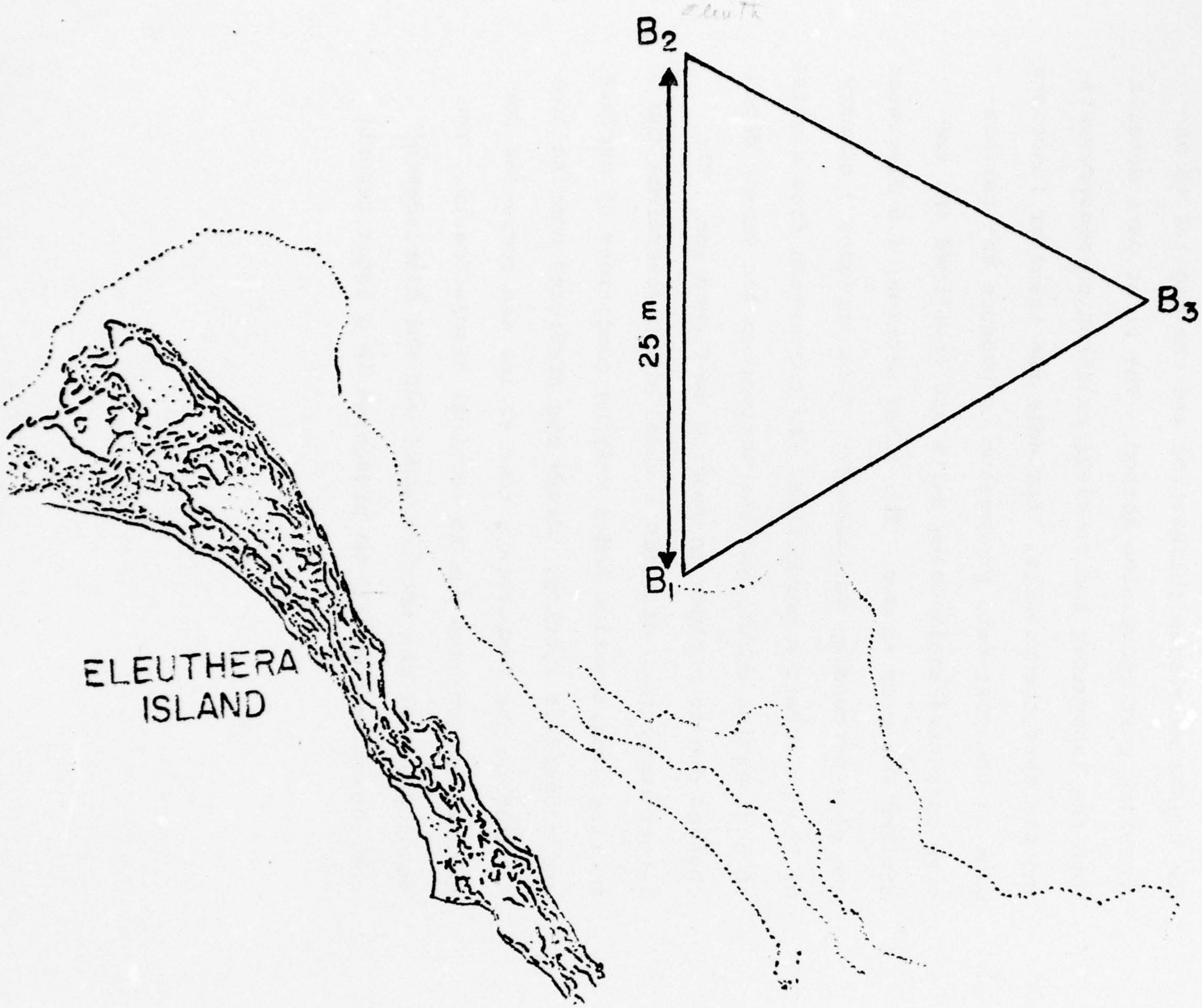


Fig. 1 The Experimental Area

1.0 Overview of the BEAR Buoy System

The following system description is intended for use as reference for scientific application. As such the system is categorized by function into the component subsystems. All components are included but specific operational and/or engineering details are not covered unless they pertain directly to the task of post-processing data reduction and the ensuing scientific analyses. Much of the following material in this section is taken from Kronengold (1976). Reference should be made to that paper if a more complete summary of the operational and/or engineering aspects of the buoy system is needed.

1.1 The Buoy

The buoy (Fig. 2) was fabricated from two NAVAIR cruiser mooring buoys. The two buoys were strengthened and welded together to provide the internal volume for instrumentation and additional buoyancy to support the thermistor string and mooring. The buoy has a total weight of 13061 Kg and is filled with expanded polyurethane foam which provides a positive buoyancy of 10715 Kg per meter of buoy draft. The electronics are mounted in a sealed capsule under positive pressure. The capsule is hard-wired through waterproof connectors to the thermistor string and to the radio antenna. The electronics and power supply compartments contain float switches connected to the digital electronics systems

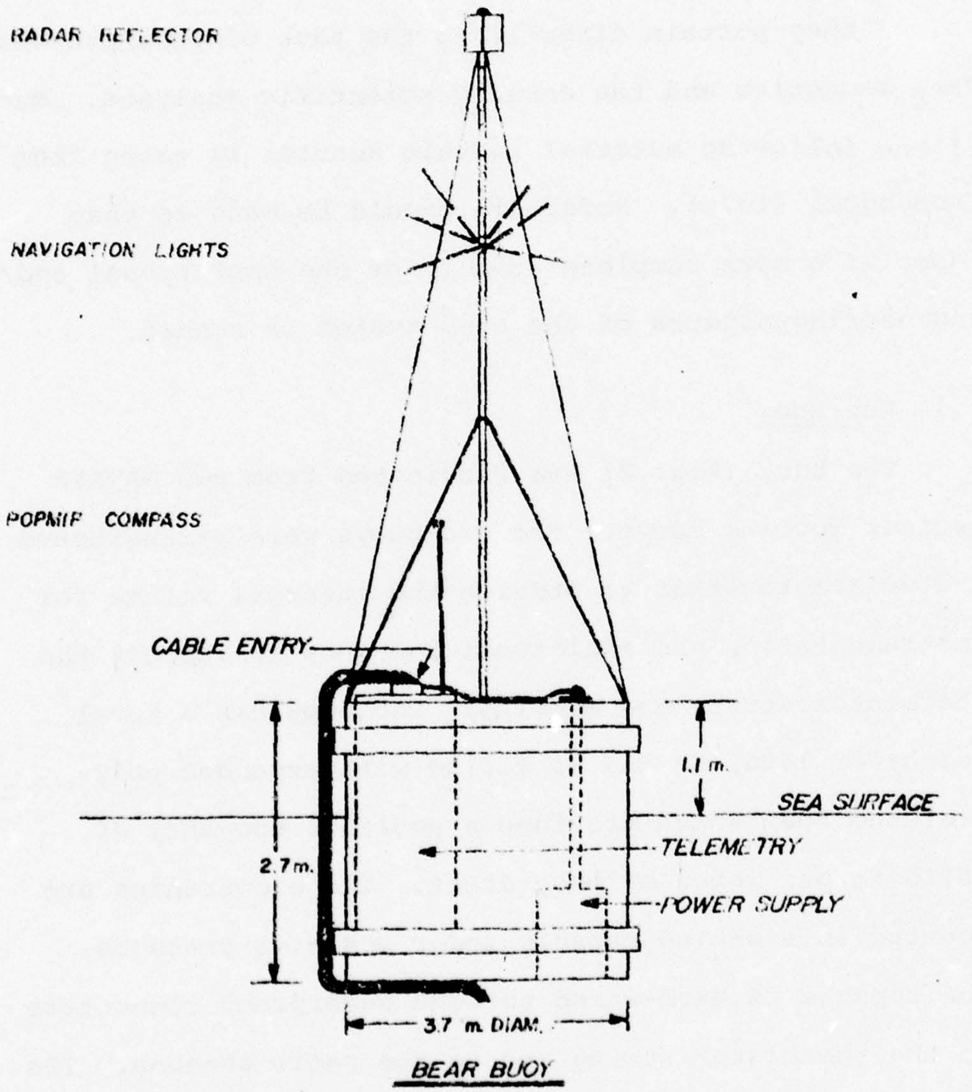

RADAR REFLECTOR
NAVIGATION LIGHTS
POPMIF COMPASS
CABLE ENTRY
1.1 m.
SEA SURFACE
2.7 m.
TELEMETRY
POWER SUPPLY
3.7 m. DIAM.
BEAR BUOY

Fig. 2

so that the shore station system will recognize a potentially dangerous condition and "flag" it.

Buoy motion is measured and recorded by a separate on-board recording data system supplied by the National Data Buoy Office, Bay St. Louis, Mississippi. The system - Portable Ocean Platform Motion Instrumentation Package (POPMIP)- is battery operated and self-contained. The POPMIP remains in a stand-by mode until activated by radio command. After turn-on, the system sequentially samples each of 6 analog sensors 3.82 times per second over a turn-on interval of 2 minutes and then returns to the stand-by mode. Each sample is converted to a three-digit BCD word and recorded on 1/4 inch magnetic tape. The interval format provides a total of 90 independent samples per tape.

1.2 The Buoy Electronics System

The buoy system (as shown in Fig. 3) is comprised of the data acquisition system, the telemetry transceiver, and the power generator. Data are acquired using an interval sampling technique in which each sensor channel (refer to Table 1) is sampled once at the rate of one channel per second during the turn-on period. The interval between sampling periods is 6 or 12 minutes as commanded by the shore station. The data are digitized as 10-bit binary words with 1 bit added for parity and stored in the magnetic core memory. Upon command by the shore station the buoy memory is unloaded, at 3 or 6 hour

Channel No.	Sensor	Channel No.	Sensor
1	Thermistor - 1	17	Cal Resistor
2	" - 2	18	Cable Test
3	" - 3	19	28 Volt Bus
4	" - 4	20	Spare
5	" - 5	21	Bilge Flood Alarm
6	" - 6	22	Tensiometer
7	" - 7	23	Spare
8	" - 8	24	Capsule Temp.
9	" - 9	25	Capsule Press.
10	" -10	26	Inclinometer - 1
11	" -11	27	" - 2
12	" -12	28	Depth Gauge
13	" -13	29	Spare
14	" -14	30	"
15	" -15	31	"
16	" -16		

Note - Data word no. "0" is the ID/sequence number

Table 1

BEAR Buoy Sensors

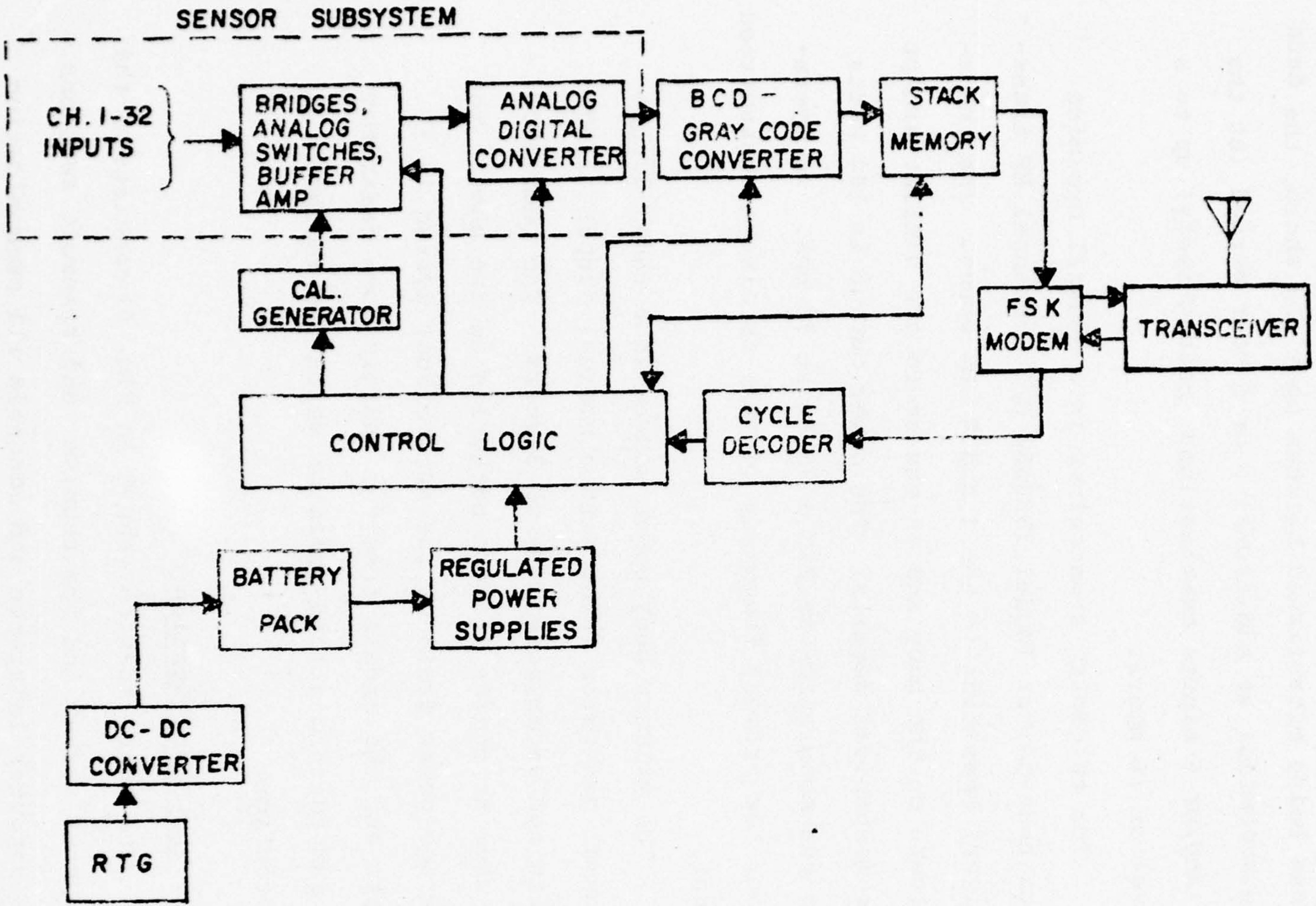
intervals, via radio telemetry to the shore station. Should atmospheric conditions prevent good communications being established between buoy and shore, the data are stored for an additional 3 or 6 hour period (at the 12 and/or 6 minute combinations, respectively) up to a total of 18 hours.

The telemetry transceiver is a General Dynamics data transceiver (Model 2550352 G/D 2-channel HF transceiver) operating in the 4 and 8 mHz bands. The transceivers on the buoy and on the shore are similar except for mechanical details. The power output is 100 watts and the modulation is FSK ± 85 Hz at 75 bps. In operation, the primary frequency (4 mHz) is always transmitted first.

The primary buoy power source is a radioisotope thermal generator (RTG) with a nominal output of 25 watts and an expected life of 3 years. The generator is used to charge storage batteries on the buoy. The average power drain of the entire buoy system is 15 watts and the excess from the radioisotope generator is dumped into a load resistor which has redundant protection.

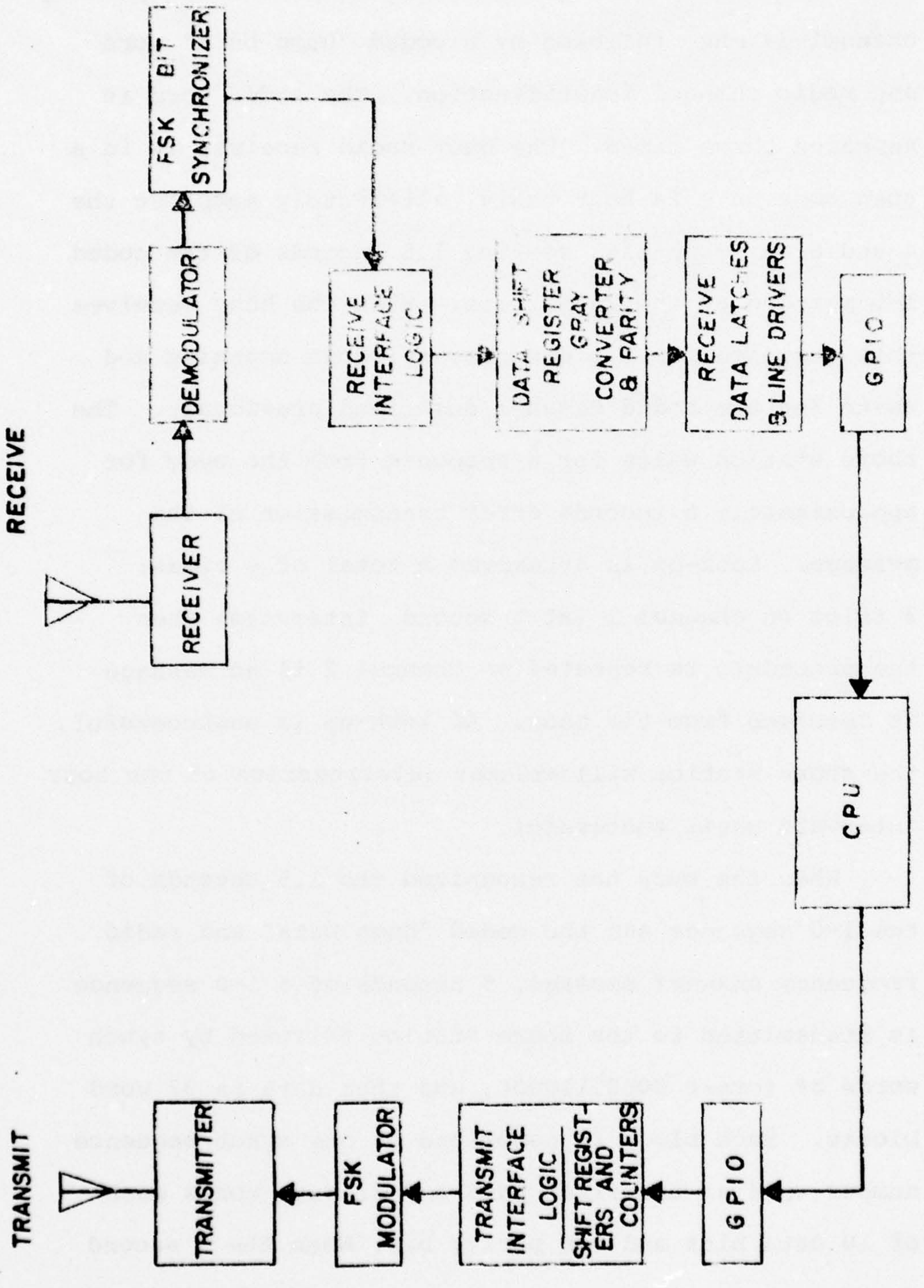
1.3 The Shore Station

The shore station (shown in Fig. 4) consists of the computer system and the receive and transmit sections. The computer initiates and controls all communication between the buoy and shore station.



BEAR BUOY SYSTEM

Fig. 3



SHORE STATION SYSTEM

Fig. 4

Lock-up between buoy and shore is established in the following manner. The shore station, at times designated by the computer program, transmits a 1-0 sequence at a rate of 75 Hz for 5 seconds on the primary channel (4 mHz) followed by a coded "Dump Data" word and radio channel identification. The coded word is repeated three times. The buoy radio receiver is in a scan mode on a 24-hour basis, alternately sampling the 4 and 8 mHz channels, seeking 1.5 seconds of the coded 1-0 pattern at the 75 Hz rate. When the buoy receives this sequence for 1.5 seconds, it stops scanning and waits for the coded message described previously. The shore station waits for a response from the buoy for approximately 5 seconds after transmission of the message. Lock-up is attempted a total of 6 times; 3 tries on channel 1 (at 5 second intervals) then the procedure is repeated on channel 2 if no message is received from the buoy. If lock-up is unsuccessful, the shore station will attempt interrogation at one hour intervals until successful.

When the buoy has recognized the 1.5 seconds of the 1-0 sequence and the coded "Dump Data" and radio frequency channel message, 5 seconds of a 1-0 sequence is transmitted to the shore station followed by synch words of format 00001110000, and then data in 32 word blocks. Each block is comprised of one synch/sequence number word as the first word and 31 data words each of 10 data bits and one parity bit. When the 5 second lock-up sequence is received on shore, the shore system switches from the 75 Hz bit synchronizer to a phase-locked loop which synchronizes a crystal controlled clock in the shore station with a similar clock on the buoy. From this point on data transmission is under the control of the crystal-controlled clocks. The clock accuracy over the short term is stable to 1 part in 10^7 and does not introduce any phase shift in the data.

When the data are received on shore, the computer checks for synchronism, parity errors, and range conformance. If errors are encountered, the shore station calls for retransmission of the blocks in which the errors occurred. The correct words are then "or'd" into the appropriate locations in the memory.

The central processing unit is a General Automation SPC 16/65 with 32K words of rapid access memory. It has a 40-channel high-speed A/D converter, filter, and multiplex front end, all under computer control. Peripherals include an oscilloscope for quick-look access, two Linc-type magnetic tape recorders for data, and a teletype unit for input and hard-copy output.

Except for the validation process as described, which ascertains that the data are within prescribed limits and in their proper sequence as determined by the synch words, the data are stored on tape in raw form.

1.4 The Mooring System

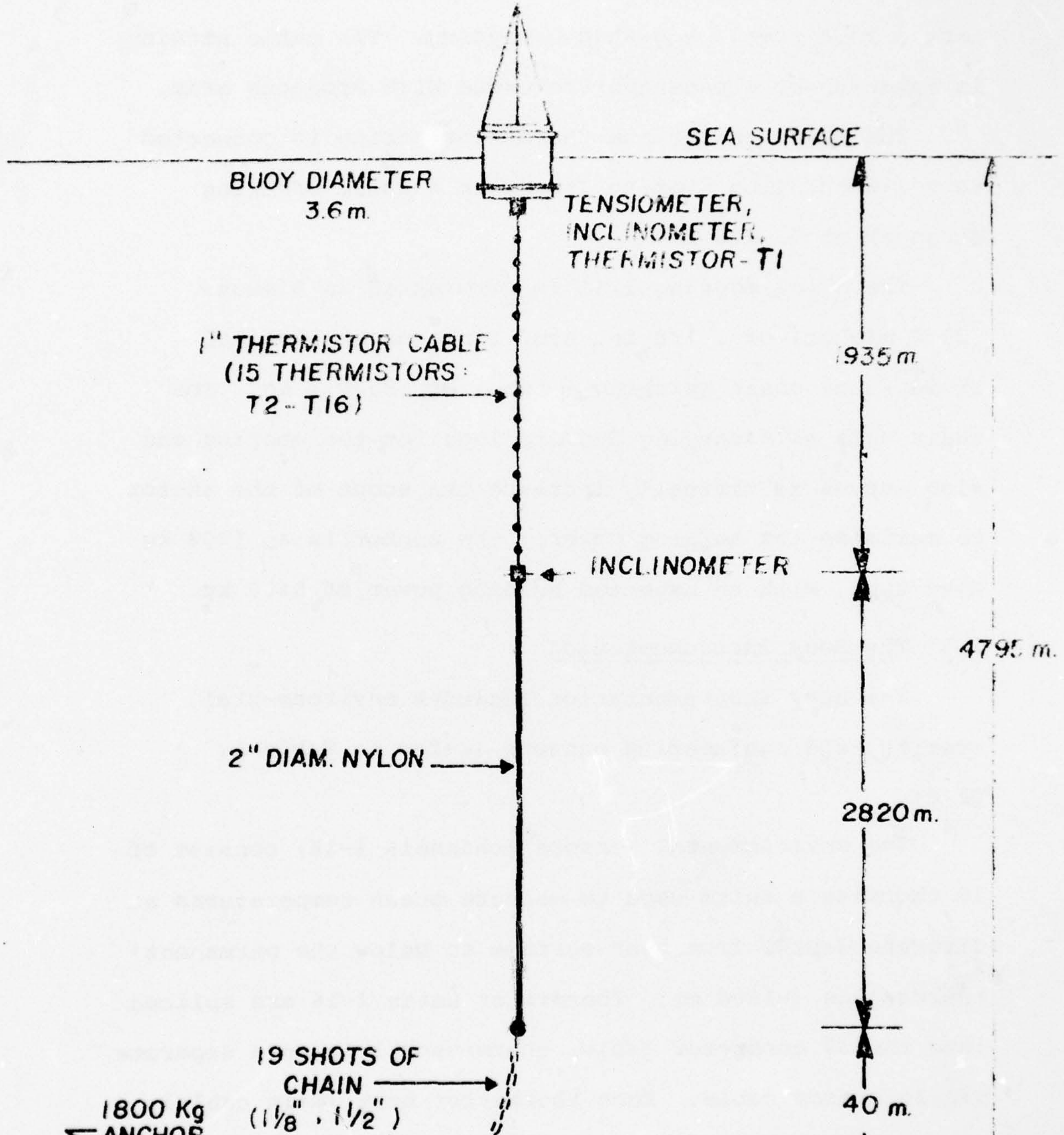
The mooring system as shown in Fig. 5 is comprised of the thermistor cable, nylon mooring line, and the ground tackle (chain sections and anchor). Table 2 summarizes the lengths of each section under no-load and load. The static load includes the stretch of each member computed for conditions of zero surface and subsurface forcing.

Table 2

BEAR Buoy Mooring Components

Section	Length (m) Unstretched	Length (m) Static Load	Percent Stretch	wt/unit length ($Kg\ m^{-1}$)
T. cable	1924.4	1933.8	0.49	1.69
Nylon	2713.6	2821.1	4.00	0.14
Chain - 1	137.2	-	-	15.54
Chain - 2	384.0	-	-	25.75

The thermistor cable is the upper portion of the mooring system and consists of an inner core of 37, number 18 conductors in a wet core configuration. It is protected by a double lay torque balanced steel armor with a rated breaking strength of 33,000 kg. The armored cable is mechanically connected to the buoy through a clevis and then led through a pipe to the top of the buoy where it is connected by waterproof connectors (Fig. 2). Plastic ribbon fairing is interwoven into the armor to a depth of 1000 meters to reduce the strumming of the cable. The individual thermistor



BEAR BUOY SYSTEM

Fig. 5

units are potted and spliced into the cable. Each wet splice, including the balance of the conductors, is protected in a steel, egg-shaped housing. The cable strain is taken-up by a patented Preformed Wire Products grip.

The lower end of the thermistor string is connected to a 2-inch nylon mooring line with a rated breaking strength of 41,000 kg.

The nylon mooring line is terminated in 5 shots (27.4 m/shot) of 1 1/8 in. stud link and 14 shots of 1½ in. buoy chain weighing a total of 12020.1 kg. The chain acts as a varying dynamic load for the mooring and also serves to virtually increase the scope of the anchor to maximize its holding power. The anchor is an 1800 kg Navy-type, with an expected holding power of 5400 kg.

1.5 The Buoy Instrumentation

The buoy instrumentation includes environmental, mooring, and engineering sensors (refer to Table 1, p. 8).

The environmental sensors (channels 1-16) consist of 16 thermistor units used to measure ocean temperatures at discrete depths from near surface to below the permanent thermocline (~1800 m). Thermistor units 2-16 are spliced into the 37 conductor cable; thermistor 1 is on a separate single sensor cable. Each thermistor unit (main cable) was constructed by wiring two thermistor probes in series and mounting the pair on a plastic board. The mounting board serves as a strain relief to prevent the probe leads from breaking. The unit was then potted and encased in a protective tape wrapping. Each thermistor unit was connected in series with one of a pair of the cable conductors; its pair acts as the return. After the unit was connected into the cable the entire wet splice, including the remaining conductors, was encased in a protective metal housing. Imbedding the unit provides a time constant of 12.83 min.

The mooring sensors (channels 22, 26-28) include the tensiometer, inclinometers, and pressure gauge. The strain gauge tensiometer is mounted in the clevis at the base of the buoy. The tensiometer provides a measure of the sum of the forces acting on the buoy due to the surface forces of wind, current, and waves, to the sum of the subsurface drag, and to the weight of the mooring. The strain gauge read-out is monitored at regular intervals by the shore station computer. This serves as an additional alarm device should the buoy break loose from its mooring. Two inclinometers are mounted on the thermistor cable: one near the surface and one at the lower end of the thermistor string. The inclinometers are filled with silicon oil of 60,000 centistoke viscosity in the upper unit and 30,000 centistoke in the lower, resulting in a time constant of approximately 60 seconds for both units. This damps out the major portion of the higher frequency cable vibration. A pressure gauge located at a depth of 650 meters flooded during the buoy deployment and is not operational. The information from the strain gauge tensiometer and the two inclinometers provide inputs to an analytical model which is used to estimate the thermistor depth.

The engineering sensors (channels 17-19, 21, 24-25) monitor the state of buoy system and serve as alarm devices in the event of system component malfunction and/or failure. The cal resistor and cable test pair units are two 50 parts-per-million per °C metalfilm resistors. These units provide a two point check of the analog circuitry. Their primary function is to detect circuitry drift and secondarily to provide circuitry calibration offsets in the event of drift. Channel 19 is a voltage divider network used to monitor the 28 v bus. Channels 21 and 24-25 are used to monitor the watertight integrity of the electronics capsule. The bilge flood alarm is a 3-position float switch (empty, ½ full, full). The capsule temperature is monitored by a thermistor within the capsule and the pressure by a differential pressure gauge (±2.5 psi).

2.0 The Sensor Subsystem

This section treats the specifics of the sensor subsystem. The subsystem, shown schematically in Fig. 3, includes the following components: 1) the sensors, 2) the bridge circuitry (for the resistance type sensors), 3) the signal conditioner amplifier and 4) the A-D converter. The signal conditioner amplifier and A-D converter are common to all sensors; channel outputs are multiplexed prior to those stages.

The first part of this section lists and discusses the engineering specifications by component and sensor type. The engineering sensors are not included since they do not pertain directly to the scientific applications. The second part developes the scientific and engineering criteria used to specify the operational ranges of the environmental sensors. Experimentally it is desireable to be able to resolve temperature differences to within 0.01°C. With this objective in mind existing temperature data for areas within a reasonable proximity of the study area were examined. This included summer and winter temperature profiles from the Fleet Numerical Weather Center, XBT data from the Jan. 1974 NAVELEX Phase Detection Study, and XBT data obtained from WHOI. The max/min resistance ranges used for the thermistor bridges also include an estimate of temperature change resulting from vertical displacements due to changes in mooring configuration. The estimates of depth change were obtained from model computations.

2.1 Component Specifications

1) A/D Converter

Manufacture	Analog Devices, Inc.	
Model	ADC - 120 L	
Resolution	12 bits	
Accuracy		
Relative	.01%	
Quantization	±½LSB	
Monotonic	0° to + 70°C	
Differential Linearity	+1, -½LSB	
Differential Linearity TC	±5 ppm/°C max	
Temperature Stability		
Gain TC (of Range)	±20 ppm/°C max	
Zero TC (Unipolar)	±50 V/°C max	
Offset TC (Bipolar,-FS)	±20 ppm/°C max	
Conversion Time	85μsec with logic supply @ +15V	
Analog Input Range	+5V	
Input Impedance	4.1k	
Convert Command	1.0 to 4.0μsec pulse 70% of logic supply voltage	
Output Signals	C/MOS compatible with +15V logic supply	
Power supply	Logic: +6V to +15V Analog: +12V to +15V	
Power Supply Sensitivity	±1 bit for 15V to 12V range	
Power Consumption	Conversion Rate	Current Drain
	Standby	.04mA
	100 Hz	.52mA
	1kHz	5mA
	5kHz	25mA
Temperature Range		
Operating	0°C to + 70°C standard	

2) Signal Conditioner Amplifier

Manufacture	Analog Devices, Inc.
Model	AD504m
Output Characteristics	
Voltage @ $R_L \geq 2k\Omega$ T_A= 0°C to +70°C	±10V min (±13V typ)
Load Capacitance	1000pF
Output Current	10mA min
Short Circuit Current	25mA
Input Offset Voltage	
Initial Offset, $R_S \leq 10k\Omega$	0.5mV max(0.2mV typ)
vs. Temp.,	
T_A=0°C to +70°C, V_{os} nulled	0.5μV/°C max(0.2μV/°C typ)
T_A=0°C to +70°C, V_{os} unnulled	1.0μV/°C max(0.5 V/°C typ)
vs. Supply	10μV/V max
@ T_A=0°C to +70°C	15μV/V max
vs Time	10μV/mo

Input Offset Current	
@T_A = +25°C	10nA max
Input Bias Current	
Initial	80nA max
@T_A= 0°C to +70°C	100nA max
vs.Temp.,	
T_A= 0°C to +70°C	200pA/°C
Input Impedance	
Differential	1.3MΩ
Input Noise	
Voltage, 0.1Hz to 10 Hz	0.6μV(p-p) max
f= 10Hz	13nV/√Hz max
f= 100Hz	10nV/√Hz max
f= 1kHz	9nV/√Hz max
Current, f= 10Hz	1.3pA/√Hz max
f= 100Hz	0.6pA/√Hz max
f= 1kHz	0.3pA/√Hz max
Input Voltage Range	
Differential or Common Mode, max safe	±15V
Power Supply	
Rated Performance	±15V
Operating	±(5 to 18)V
Current, Quiescent	±3.0mA max (±1.5mA typ)
Temperature Range	
Operating, Rated Performance	0°C to + 70°C

3) Line Inclination

Manufacture	Offshore Instruments Co. IAR, PGI Modified
Type	Pendulum Inclinometer

Sensor Description: Inclination is measured using a pendulum whose inclination to the instrument housing is sensed by a potentiometer. The pendulum/pot is free to rotate about a vertical axis and 30° from the vertical. Readings are continuous to 30° from the vertical. The sensor unit is mounted in an anodized aluminum pressure housing.

4) Mooring Tension

Manufacture	Brewer Eng. Labs Inc.
Type	Tension Clevis
Capacity	22,680 Kg
Input Resistance	239.3 ohms at 25°C ±1.67°
Output Resistance	239.2 ohms at 25°C ±1.67°
Bridge to Gound Resistance	5 'G' ohms
Zero Balance	±0.25 mv/v
Zero Return	±0.25 mv/v
Linearity	±2%
Hysteresis	±2%
Calibration	±1%
Temperature Compensation	21°C - 32°C

5) Temperature (Thermistor)

Manufacture	Fenwal Electronics, Inc.
Sensor Type	Oceanographic series Isocurve, GB34P92
R_o @ 25°C	4000 Ω ±2%
Identical R-T curves	±2% from 18 - 177°C
Dissipation constant	1.9 mw
Time constant	25 s

The general R-T curve for the thermistor type used is shown in Fig. 6.

Installation configuration

Two thermistor probes were wired in series and imbedded as a single unit in a potting compound then wrapped with a protective tape. This in turned is encased in a protective metal housing.

Imbedded characteristics:

Dissipation constant	7.6 mw (10 mw/°C typ)
Time constant	12.83 min.

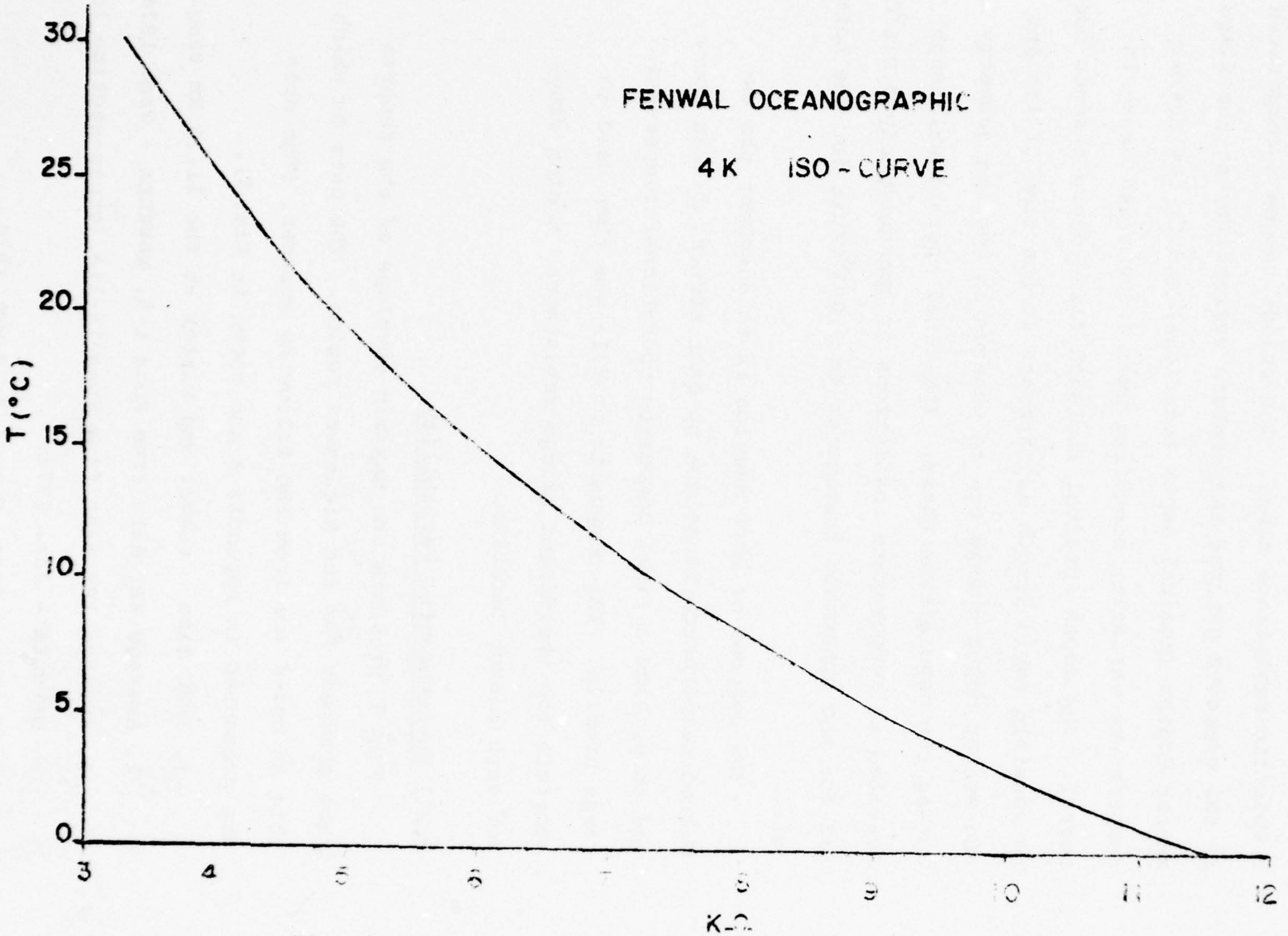


Fig. 6 Thermistor R-T Curve (General)

2.2 Thermistor Bridge Tuning - Operational Range

To provide the maximum temperature resolution yet remain within measureable limits each thermistor bridge was tuned to a specific resistance range. The bridge ranges incorporated 1) the expected natural temperature variability at the fixed sensor depths (nominal depth locations) and 2) the max/min temperature variation occurring over a specified depth interval. The depth interval included fixed depth changes due to possible cable length adjustments at the time of implant and sensor depth change due to changes in mooring geometry during the acquisition phase. The final operational range resulted in temperature resolutions of approximately 0.016^{o}C/bit for the uppermost thermistor to 0.003^{o}C/bit for the bottom unit.

The purpose of this section is to document the expected temperature range due to each effect, listed above, and to provide a final composite operational temperature range profile. The composite profile was then used to generate the thermistor bridge resistance tuning range for each sensor location.

2.2.1 Environmental Variability

Fig. 7 presents the max/min envelope of the temperature gradient for the Eleuthera region. The data on which this is based are from the following sources. (The data are presented in Appendix A and shown in Fig. 8).

1. FNWC data - summer and winter at the 111.8 Km range, only.
2. Average XBT data from Runs 1-5, NAVELEX - Jan. 1974.
3. Average XBT data from Runs 1A-11A (cross-section leg), NAVELEX - Jan. 1974.
4. WHOI XBT data, Runs 1-3, Sept. 1974.

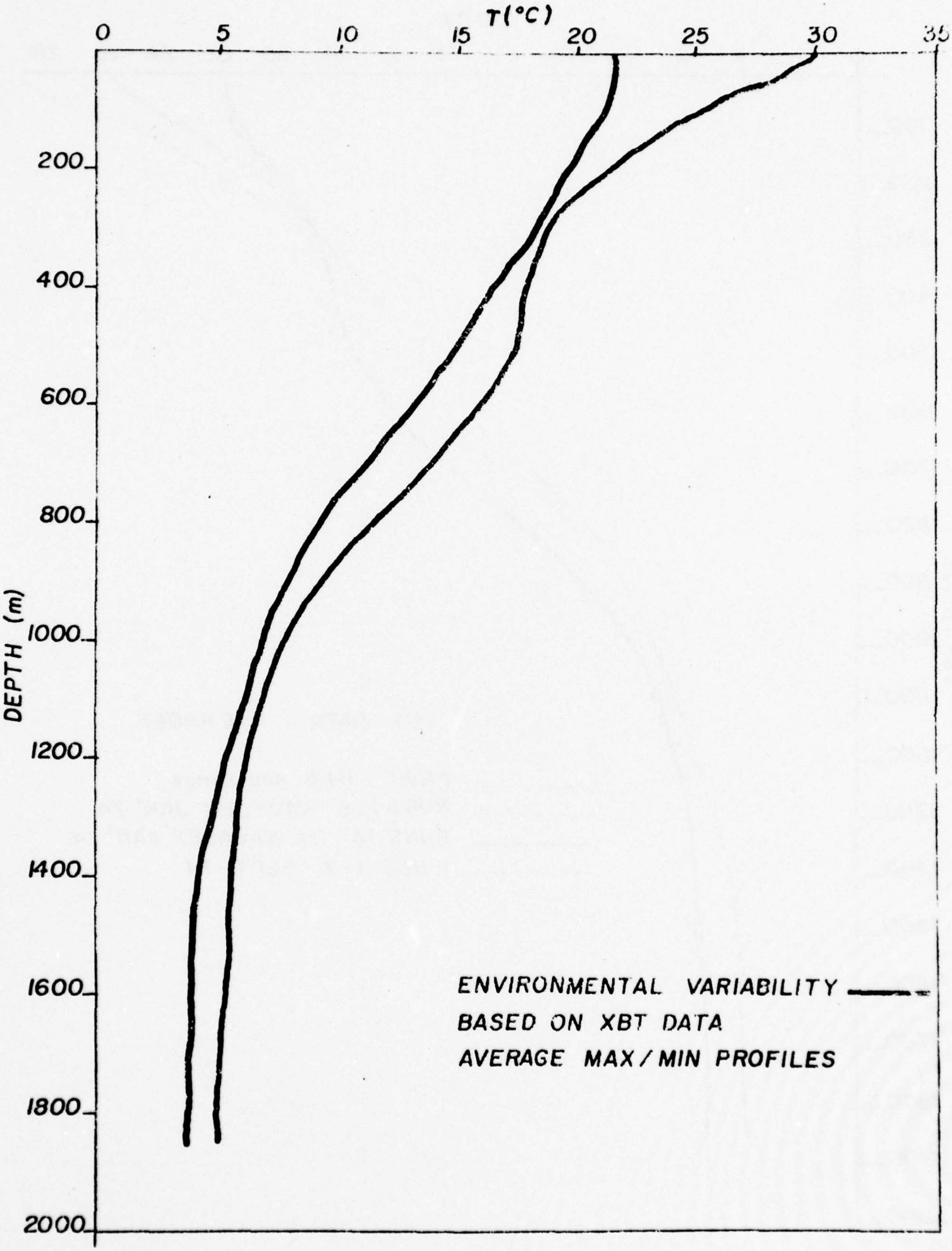
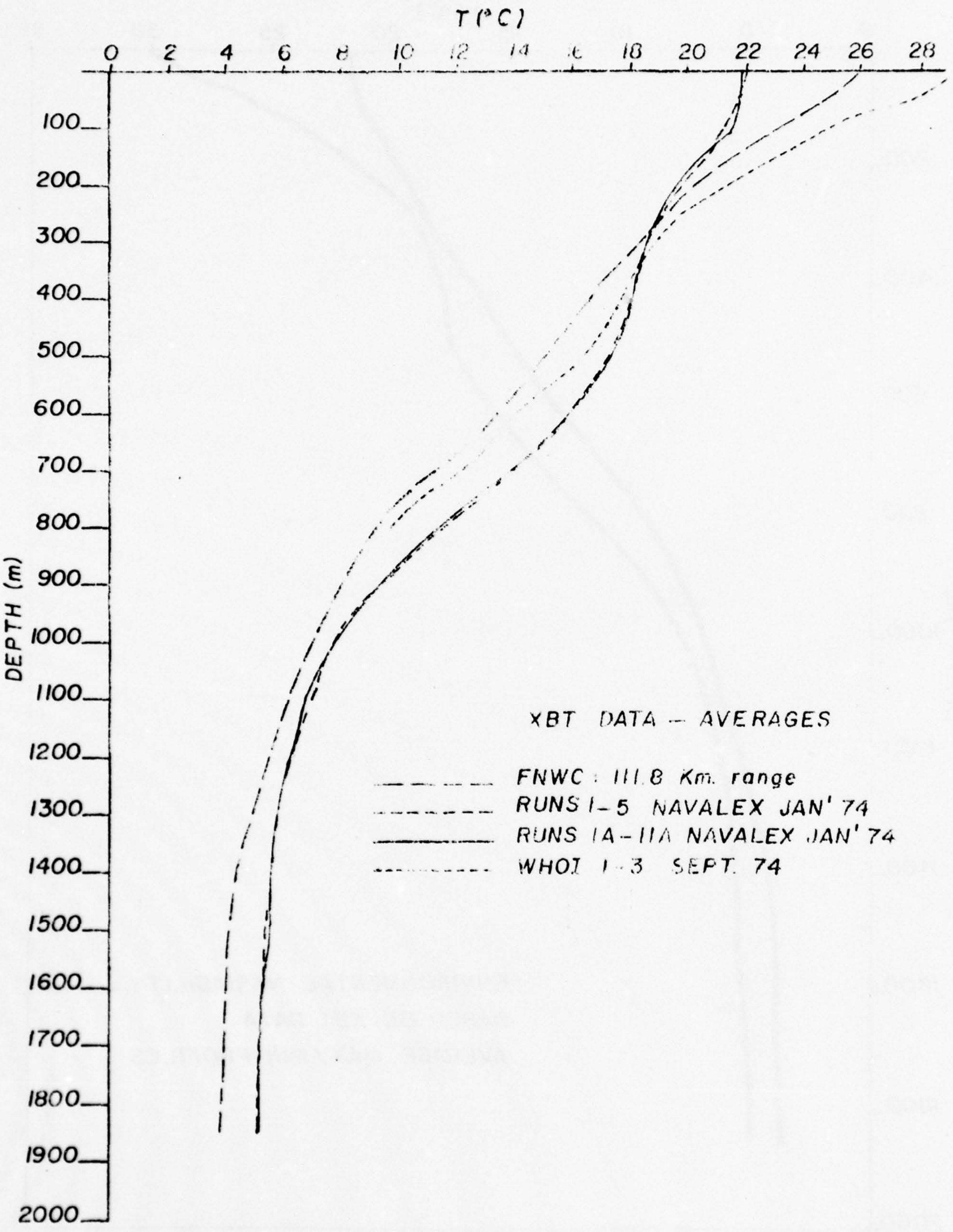

T(°C)
0
5
10
15
20
25
30
35
DEPTH (m)
200
400
600
800
1000
1200
1400
1600
1800
2000
ENVIRONMENTAL VARIABILITY
BASED ON XBT DATA
AVERAGE MAX/MIN PROFILES

Fig. 7


T(°C)
0
2
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24
26
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DEPTH (m)
100
200
300
400
500
600
700
800
900
1000
1100
1200
1300
1400
1500
1600
1700
1800
1900
2000
XBT DATA — AVERAGES
FNWC : 111.8 Km. range
RUNS 1-5 NAVALEX JAN' 74
RUNS 1A-11A NAVALEX JAN' 74
WHOI 1-3 SEPT. 74

Fig. 8

However, there is some uncertainty in these data. The NAVELEX data were taken in a region to the north of the proposed array. Secondly, surface - bucket temperatures were not collected prior to XBT drops. In order to reduce the above uncertainty the max/min. FNWC data for both summer and winter months for all available ranges in the vicinity of Eleuthera were included to extend the environmental estimate.

Table 3. Max/Min. FNWC Data

Depth (m)	min (°C)	max (°C)
0	20.5	28.9
122	20.5	23.7
243	18.2	19.7
300	-	18.7
365	16.5	-
400	15.6	17.4
600	10.8	16.1
800	7.6	12.2
1000	5.6	9.5
1500	3.9	4.4
2000	3.1	3.6

The above data, Table 3, present max/min. temperatures for the Eleuthera area. The data are from the FNWC sets for both winter and summer. The data were collected over the following ranges from Eleuthera: 0., 111.8, 245.3, 446.7, 661.2, and 815.4 Km.

In summary, Fig. 9 presents an assesment of the environmental variability to be expected. This includes seasonal and diurnal ranges.

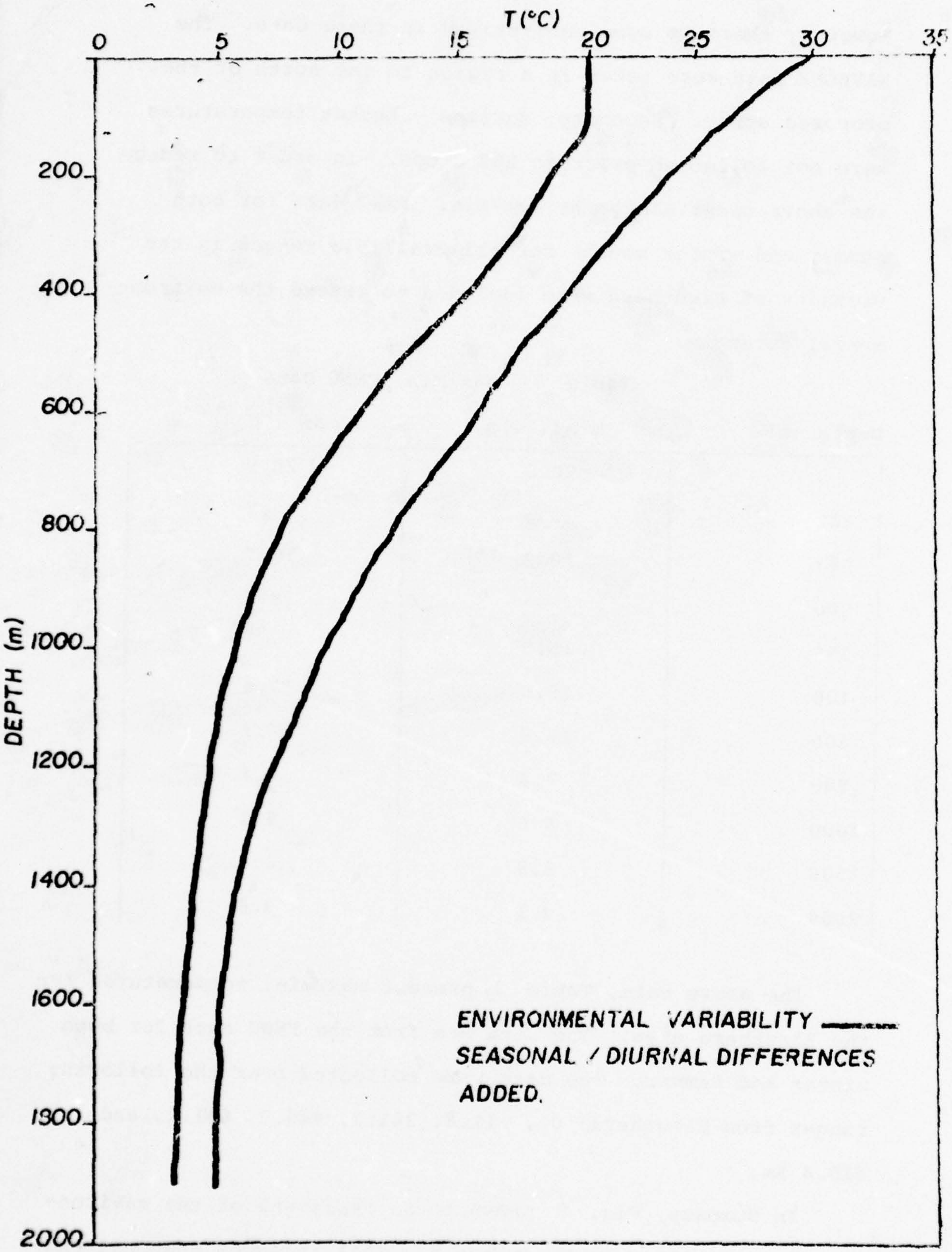
T(°C)
0
5
10
15
20
25
30
35
DEPTH (m)
200
400
600
800
1000
1200
1400
1600
1300
2000
ENVIRONMENTAL VARIABILITY
SEASONAL / DIURNAL DIFFERENCES ADDED.

Fig. 9

2.2.2 Inclusion of Sampling Bias and Instrument Error

As discussed in Section 2.2.1, Fig. 9 is an assessment of the environmental variability. The estimate is inadequate, however, in that it is based on (1) a limited sampling and (2) instrument error is not included.

The major sources of anticipated error in XBT measurements are: (1) sensor bias and (2) sensor response lag. Sensor bias results in a constant (positive or negative) temperature offset throughout the record. Response lag results in an apparent depth increase at inflection points and in zones of abrupt changes in gradient.

When comparing the NAVELEX and FNWC data it was noted that NAVELEX profiles, in general, were warmer by $\simeq 1.0^{o}C$ below the main thermocline. Below the seasonal thermocline ($z \simeq 300$ m) the degree of warming was variable with a maximum of the order of $3^{o}C$ at a depth of 550 m. Since bucket temperatures were not recorded, instrument bias and sensor response lag is suspected, but real environmental variability cannot be discounted. The direction of the offset and variability is, however, consistent with possible instrument error sources discussed previously.

Based on the above findings the environmental estimate was adjusted using a two-step process. First, the temperature range in the region of maximum uncertainty - surface to 1400 m - was expanded to allow for a maximum variability. The operation consisted of smoothing the minimum profile. This is shown in Fig. 10. Table 4 presents the max/min. temperatures and differences (ΔT) prior to smoothing. The smoothed values are shown in Table 5 (Initial columns). Second, to account for sensor bias and response lag, 20% of the ΔT value (Table 5)

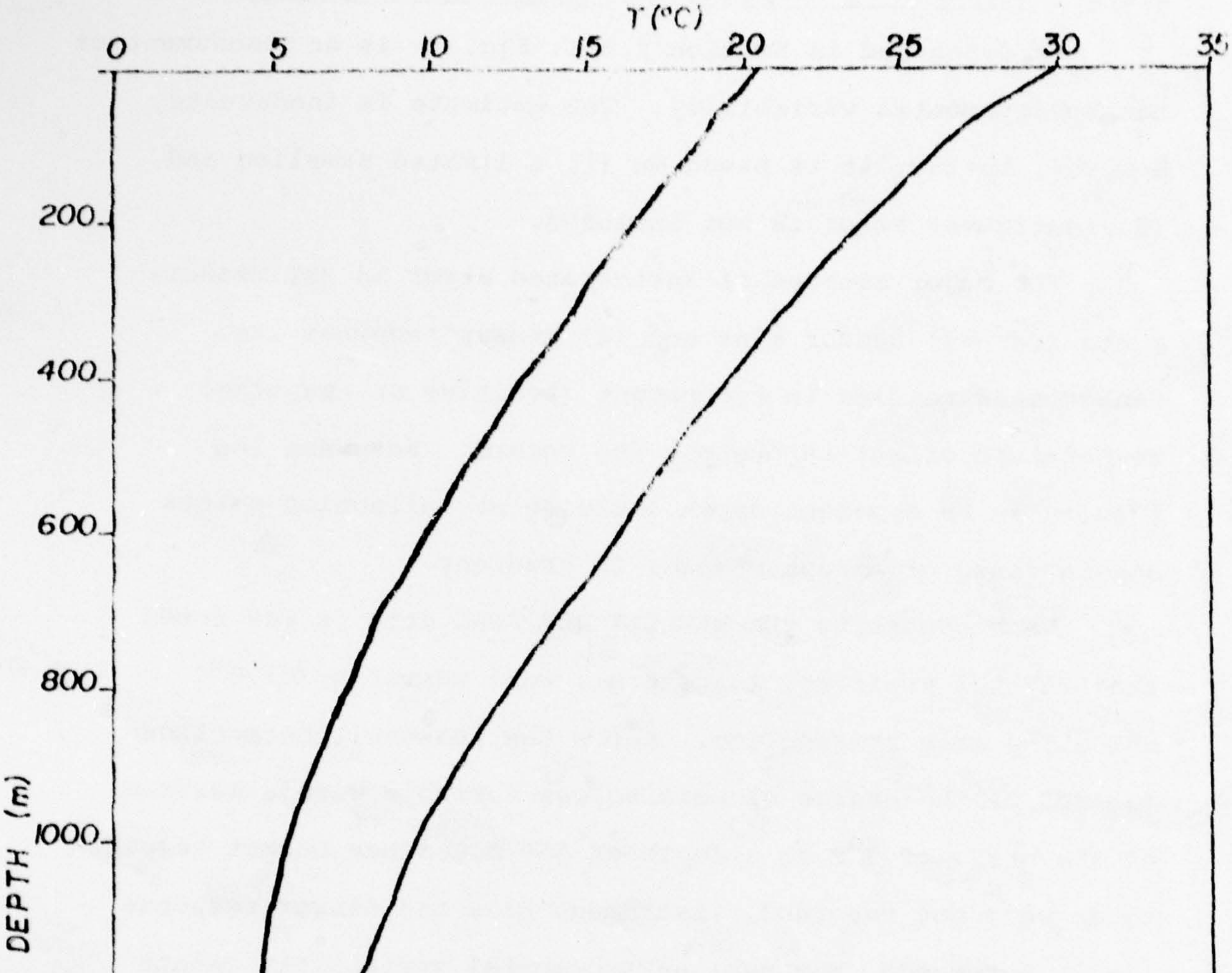
T(°C)
0
5
10
15
20
25
30
35
DEPTH (m)
200
400
600
800
1000
1200
1400
1600
1800
2000
ENVIRONMENTAL VARIABILITY
AFTER SMOOTHING

Fig. 10

TABLE 4

T Difference Between max/min. Profiles (Ref. Fig. 9)

Depth (m)	T_{max}	T_{min}	ΔT
0	30.0	20.5	9.5
100	26.5	20.5	6.0
200	24.0	19.0	5.0
300	21.5	17.5	4.0
400	19.5	15.5	4.0
500	17.5	13.0	4.5
600	16.0	11.0	5.0
700	14.2	9.2	5.0
800	12.5	7.5	5.0
900	10.8	6.5	4.3
1000	9.5	5.5	4.0
1100	8.5	4.9	3.6
1200	7.5	4.6	2.9
1300	6.5	4.4	2.1
1400	6.0	4.0	2.0
1500	5.5	3.8	1.7
1600	5.0	3.7	1.3
1700	5.0	3.5	1.5
1800	5.0	3.5	1.5
1900	5.0	3.3	1.7

TABLE 5

Max/min profile temp. with error percentage included

	Initial					Final	
Depth (m)	T_{max}	T_{min}	ΔT	-20%	+10%	T_{max}	T_{min}
0	30.0	20.5	9.5	1.9	1.0	31.0	18.6
100	26.5	18.5	8.0	1.6	.8	27.3	16.9
200	24.0	16.5	7.5	1.5	.8	24.8	15.0
300	21.5	14.7	6.8	1.4	.7	22.2	13.3
400	19.5	13.0	6.5	1.3	.6	20.1	11.7
500	17.5	11.5	6.0	1.2	.6	18.1	10.3
600	16.0	10.0	6.0	1.2	.6	16.6	8.8
700	14.2	8.5	5.7	1.1	.6	14.8	7.4
800	12.5	7.2	5.3	1.1	.5	13.0	6.1
900	10.8	6.3	4.5	.9	.4	11.2	5.4
1000	9.5	5.4	4.1	.8	.4	9.9	4.6
1100	8.5	4.8	3.7	.7	.4	8.9	4.1
1200	7.5	4.5	3.0	.8	.3	7.8	3.7
1300	6.5	4.3	2.2	1.0	.3	6.7	3.3
1400	6.0	4.0	2.0	1.0	.2	6.2	3.0
1500	5.5	3.8	1.7	1.0	.2	5.7	2.8
1600	5.0	3.7	1.3	1.0	.2	5.2	2.7
1700	5.0	3.5	1.5	1.0	.2	5.2	2.5
1800	5.0	3.5	1.5	1.0	.2	5.2	2.5
1900	5.0	3.3	1.7	1.0	.2	5.2	2.3

was subtracted from the minimum profile and 10% added to the maximum profile at depths less than 1200 m. Below this depth a constant value was added to and subtracted from the max. and min. profiles, respectively. The resulting max/min temperature values are listed in Table 5 (Final columns) and shown in Fig. 11.

2.2.3 Fixed Depth Changes Due to Cable Length Adjustments

During implant, the possible depth change to the nominal sensor depths due to cable trim was a maximum depth decrease of 100 m and/or a depth increase of 60 m. The temperature range shown in Fig. 11 is applicable only to the fixed nominal depth and does not take into account vertical exursions of the thermistor chain.

To include the possible fixed depth changes (-100 m, +60 m) 100 m was added to the maximum curve (Fig. 11) and 60 m subtracted from the minimum curve. The new composite is shown in Fig. 12.

As an example, consider a thermistor located at a nominal depth of 1000 m. If there were no depth changes due to cable trim the temperature range would be 4.5 - 10.0°C (ref - Fig. 11). When including the trim range the thermistor can range in depth between 900 and 1060 m. The temperature limits within this depth range are as follows:

$$\begin{array}{ll} & T(^{\circ}C) \\ 900\text{ m:} & 5.5 - 11.2 \\ 1000\text{ m:} & 4.5 - 10.0 \\ 1060\text{ m:} & 4.2 - 9.2 \end{array}\left.\vphantom{\begin{array}{l}a\\a\\a\\a\end{array}}\right\} \quad T_{1000}\text{ range} = 4.2 - 11.2^{\circ}C$$

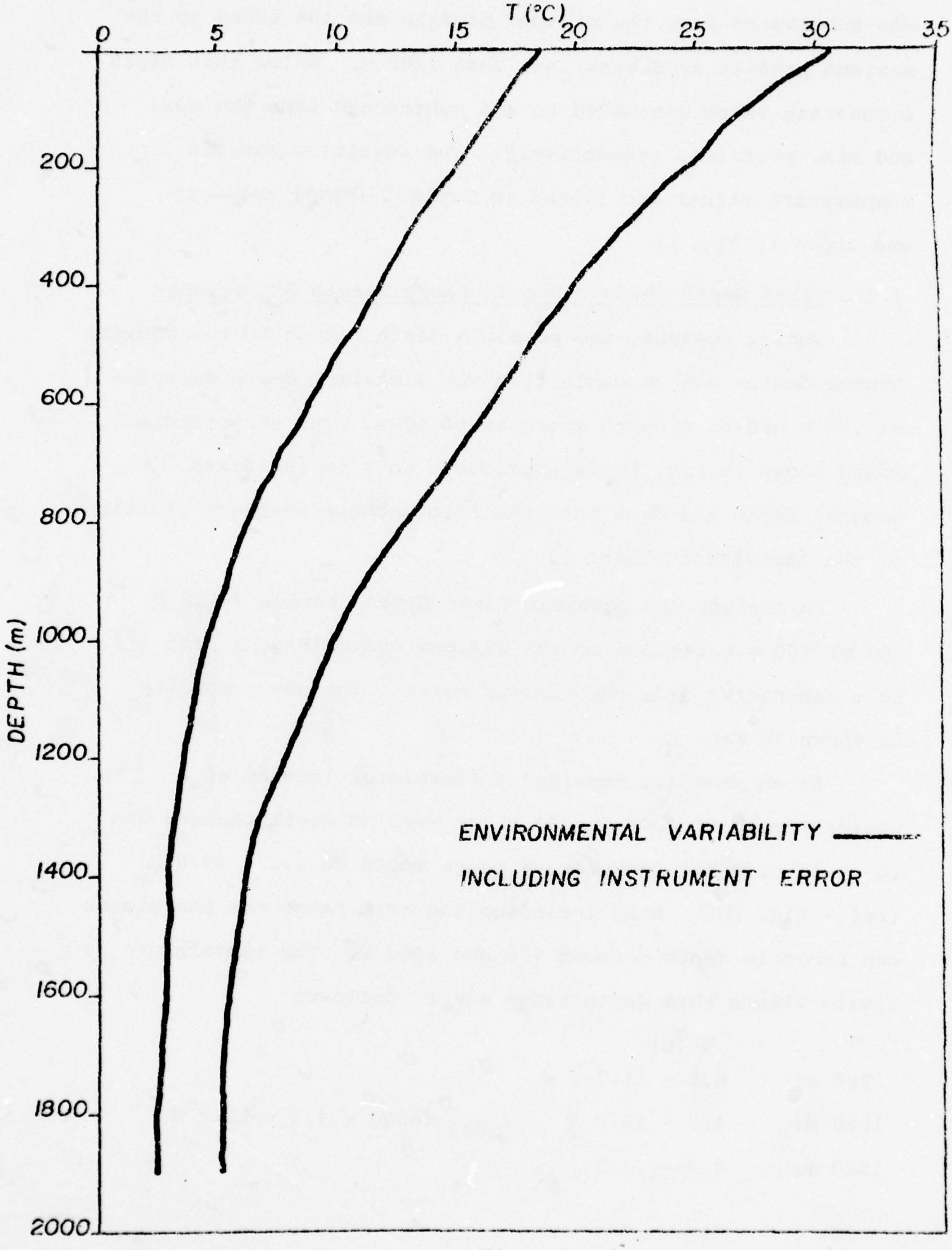
T (°C)
0
5
10
15
20
25
30
35
DEPTH (m)
200
400
600
800
1000
1200
1400
1600
1800
2000
ENVIRONMENTAL VARIABILITY
INCLUDING INSTRUMENT ERROR

Fig. 11

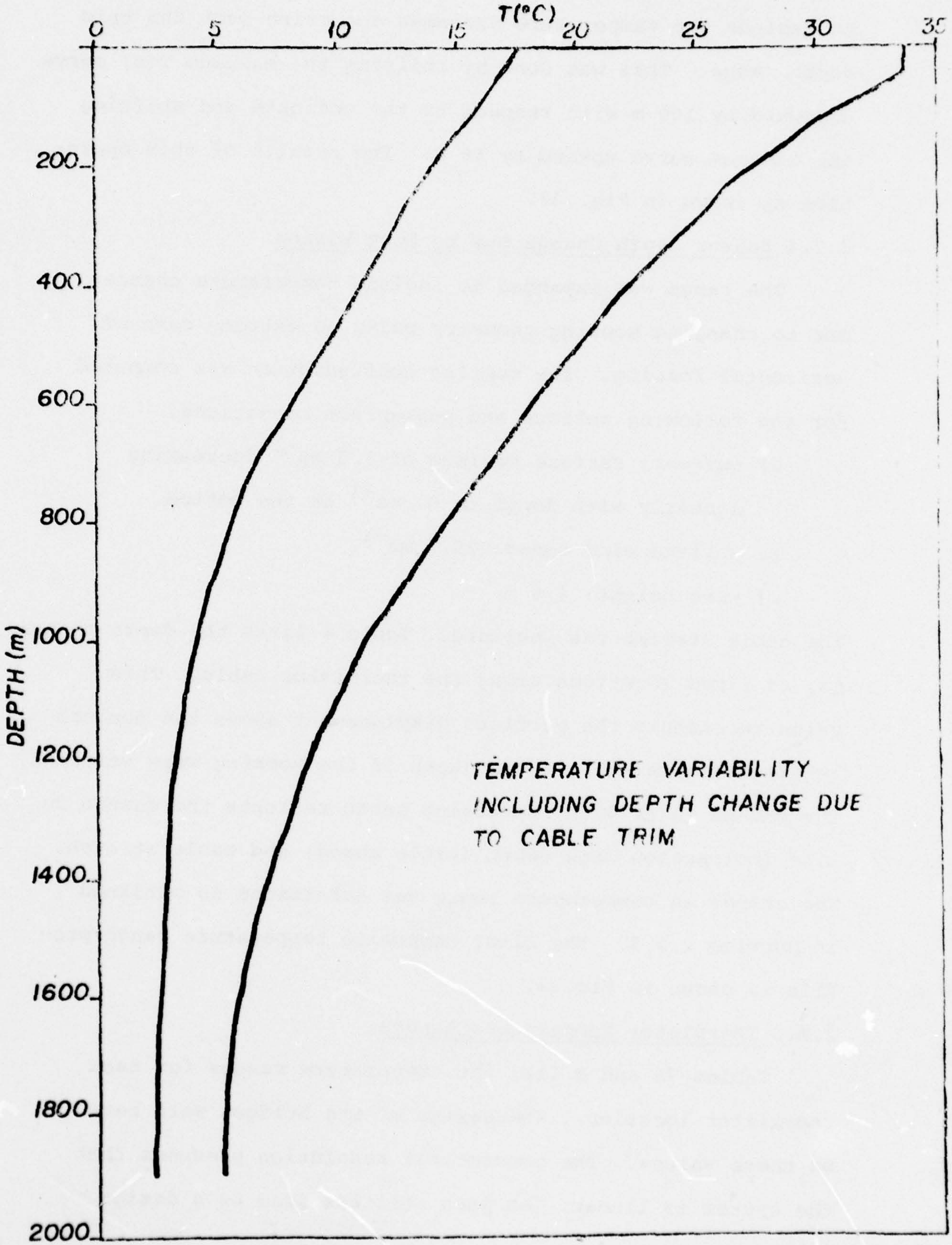
T(°C)
0
5
10
15
20
25
30
35
DEPTH (m)
200
400
600
800
1000
1200
1400
1600
1800
2000
TEMPERATURE VARIABILITY INCLUDING DEPTH CHANGE DUE TO CABLE TRIM

Fig. 12

Thus the maximum and minimum nominal limits must be expanded to include the temperature extremes occurring over the trim depth range. This was done by shifting the maximum T(z) curve downward by 100 m with respect to the ordinate and shifting the minimum curve upward by 60 m. The results of this operation as shown in Fig. 12.

2.2.4 Sensor Depth Change Due to Buoy Motion

The range was expanded to include temperature changes due to changing mooring geometry using an extreme case of horizontal forcing. The mooring configuration was computed for the following surface and subsurface conditions.

a) current: surface maximum of 1.0 ms^{-1} decreasing linearly with depth to 0. ms^{-1} at the bottom.

b) surface wind speed: 25.7 ms^{-1}.

c) wave height: 4.6 m

The cable stretch was included. Table 6 lists the depth change, ΔZ, at fixed locations along the thermistor cable. This value represents the vertical displacement above the nominal reference depth - i.e., the depth if the mooring were vertical. The change in ΔZ with increasing depth reflects the change in line inclination with depth (cable shape) and cable stretch. The change in temperature range was determined as outlined in Section 2.2.3. The final composite temperature range profile is shown in Fig. 13.

2.2.5 Thermistor Temperature Ranges

Tables 7A and B list the temperature ranges for each thermistor location. The design of the bridges were based on these values. The theoretical resolution presumes that the system is linear. As such this was used as a design

Table 6

Sensor Depth Change Due to Advective Forces:

Surface Current = 1.0 ms^{-1}, Surface Wind = 25.7 ms^{-1}

wave height = 4.6 m.

Nominal Sensor Depth Z (m)	Extreme Forcing		
	Sensor Depth Z (m)	Hor. Displ. (m)	Vert. Disp. ΔZ (m)
20.0	14.5	4051.4	5.5
150.0	140.1	4017.8	9.9
250.0	236.2	3990.3	13.8
350.0	331.8	3961.1	18.2
450.0	426.9	3930.1	23.1
550.0	521.4	3897.5	28.6
650.0	615.3	3862.9	34.7
750.0	708.4	3826.5	41.6
850.0	800.8	3788.2	49.2
950.0	892.3	3747.8	57.7
1050.0	982.9	3705.5	67.1
1150.0	1072.4	3661.0	77.6
1300.0	1204.8	3590.4	95.2
1475.0	1355.7	3501.9	119.3
1650.0	1502.7	3406.8	147.3
1825.0	1645.1	3305.2	179.9

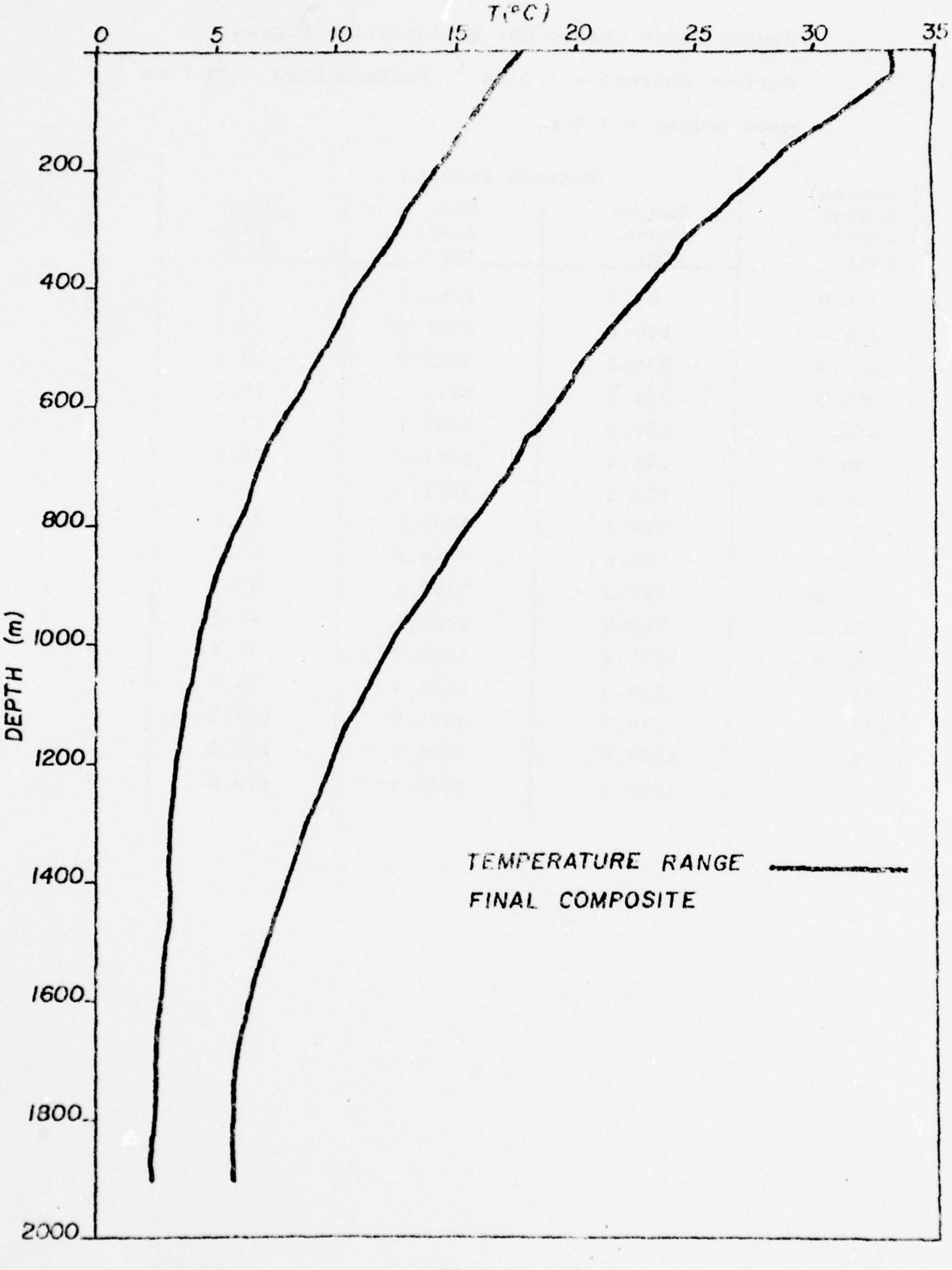
T(°C)
0
5
10
15
20
25
30
35
DEPTH (m)
200
400
600
800
1000
1200
1400
1600
1800
2000
TEMPERATURE RANGE
FINAL COMPOSITE

Fig. 13

criterion only and not used to generate the final transfer functions.

Table 7A

Thermistor Temperature Range - Thermistor Cable

Therm. Loc. No.	Depth (m)	Temp Range (^oC)	Δ (^oC)	Theoret. Resol. (^oC/bit)
2	150	14.6-29.3	14.7	.0144
3	250	13.2-26.5	13.3	.0130
4	350	11.7-24.0	12.3	.0120
5	450	10.2-21.8	11.6	.0113
6	550	8.6-19.9	11.3	.0110
7	650	7.2-18.3	11.1	.0108
8	750	6.1-16.5	10.4	.0102
9	850	5.3-14.7	9.4	.0092
10	950	4.5-13.0	8.5	.0083
11	1050	3.8-11.5	7.7	.0075
12	1150	3.4-10.4	7.0	.0068
13	1300	3.0-8.8	5.8	.0054
14	1475	2.7-7.0	4.3	.0042
15	1650	2.4-6.0	3.6	.0035
16	1825	2.2-5.6	3.4	.0033

Table 7B

Thermistor Temperature Range - Single Cable

Therm. Loc. No	Depth (m)	Temp Range (^oC)	Δ (^oC)	Theort. Resol. (^oC/bit)
1	20	17.3-33.3	16.0	.0156

3.0 Sensor Subsystem Component Calibrations and Data Conversion Transfer Functions

The sensor subsystem (refer to Fig. 3, p. 10) includes four component sections: 1) the sensors, 2) bridge circuitry (for resistance type sensors), 3) the signal conditioner amplifier, and 4) the A-D converter. The subsystem was calibrated in stages consisting of single components and/or component groups as outlined in the following table. The engineering sensors were "calibrated" via system tests.

Table 8

Calibration Stages - Environmental and Mooring Sensor

Sensor Type	Calibration stage	Subsystem Component
Thermistor	$^{o}C \rightarrow \Omega$	sensor
	$\Omega \longrightarrow Du$	bridge ⟶ A/D
Inclinometer	$^{o}Incl \rightarrow mv$	sensor ⟶ bridge
	$mv \longrightarrow Du$	amp. ⟶ A/D
Tensiometer	$Kg \longrightarrow Du$	sensor ⟶ A/D

The first part of the section describes the calibration methodology used and presents the results by sensor type. The detailed calibration data, however, are contained in Appendix B. The second part developes the intermediate and final subsystem transfer functions. The intermediate set is derived explicitly from the calibration data and relates the output to input parameters for each calibration stage. The intermediate functions for each sensor are used to construct the final subsystem function. It is the final set that is used in the post-data processing to convert the data from digital to engineering units.

3.1 Subsystem Calibrations

3.1.1 Thermistors - Engineering Units (EU) to Resistance

The design temperature range for each thermistor unit was specified to the manufacturer - Fenwal Electronics, Inc. Matched thermistor probe pairs were calibrated by the manufacturer using a circulating, constant temperature bath. The calibration data are given in Tables 35A-F (Appendix B). The calibration difference between matched thermistor pairs was computed and found to be $<$ 1.0% (Table 36, Appendix B). Table 9 lists the calibration range which was based on the specified design range (refer to Section 2.2.5). The probes were calibrated at multiple points because of the inherent nonlinearity in thermistor R-T characteristics.

As discussed previously in Sections 1.5 and 2.1 each thermistor unit was constructed using two matched thermistor probes wired in series. Based on this the thermistor unit calibration values were formed by adding the resistance values for each of the matched pairs at each calibration point. The unit calibration values are given in Tables 10A and B. This does not present a problem since the thermistor pair R-T values are matched to $<$ 1.0%. In order to tune each bridge to the actual max/min

Unit Ser. No.	Cal. Range (°C)	No. Cal. Points	Design Op Range (°C)	Cable Resist. (Ω)
19	15.0-30.0	6	17.3-33.3	1.4
21	15.0-30.0	6	14.6-29.3	10.8
20	15.0-30.0	6	13.2-26.5	16.8
18	15.0-25.0	5	11.7-24.0	23.6
17	10.0-20.0	5	10.2-21.8	29.4
16	8.0-18.0	4	8.6-19.9	35.4
15	8.0-18.0	4	7.2-18.3	41.9
14	5.0-15.0	5	6.1-16.5	45.5
13	5.0-15.0	5	5.3-14.7	55.0
12	5.0-12.0	4	4.5-13.0	61.3
11	3.0-10.0	4	3.8-11.5	67.2
9	3.0-10.0	4	3.4-10.4	73.1
5	3.0- 8.0	3	3.0- 8.8	81.6
3	1.0- 8.0	4	2.7- 7.0	94.1
2	1.0- 5.0	3	2.4- 6.0	103.7
1	1.0- 5.0	3	2.2- 5.6	115.0

Table 9

Thermistor Calibration and
Design Ranges

Thermistor Serial No.

	1	2	3	4	5	6	7	8	9	10	11
	21731.	21886.	21870.	21715.							
	19903.2	20006.6	20009.2	19880.2	19851.8	19956.9	20027.	20073.	19939.7	19950.1	20034.
	17528.	17622.2	17602.6	17514.6	17487.4	17556.4	17644.7	17636.2	17595.4	17579.1	17633.8
			16069.2	15990.6	15975.1	16028.	16105.7	16097.1	16063.3	16047.3	16094.2
									14761.7	14730.8	14774.5

THERMISTOR CALIBRATION (Resistance vs °C)

by Manufacturer

TABLE 10A

Thermistor Serial No.

12	13	14	15	16	17	18	19	20	21	22
17620.4	17551.7	17611.1								
16079.1	16027.3	16073.4	16048.1	16080.5						
14763.7	14716.4	14761.4			14678.					
13559.4	13564.2	13563.1	13534.4	13528.2	13537.8					
	11941.4	11978.4	11961.	11958.	11973.5	11964.	11936.5	11962.4	11970.4	11992.1
			10572.8	10568.3	10576.5	10571.0	10545.6	10572.9	10576.	10597.8
					9747.8	9722.1	9705.1	9724.2	9725.2	9746.2
						9010.5	8998.5	9013.	9011.4	9032.3
						8008.8	8000.5	8013.7	8012.6	8028.6
							6610.8	6618.5	6619.2	6633.9

THERMISTOR CALIBRATION (Resistance vs °C)

by Manufacturer

TABLE 10B

	Thermistor Serial No.							
$^{\circ}$C	1	2	3	5	9	11	12	13
1	21846.	21989.7	21964.1					
3	20018.2	20110.3	20103.3	19933.4	20012.8	20101.2		
5	17643.	17725.9	17696.7	17569.	17668.5	17701.	17681.7	17606.7
8			16163.3	16056.7	16136.4	16161.4	16140.4	16082.3
10					14834.8	14841.7	14825.	14771.4
12							13620.7	13619.2
15								11996.4

THERMISTOR CALIBRATION (RESISTANCE vs $^{\circ}$C)

(Cable resistance added as per location)

TABLE 11A

Thermistor Serial No.

^{o}C	14	15	16	17	18	19	20	21
1								
3								
5	17656.6							
8	16118.9	16090.	16115.9					
10	14806.9			14707.4				
12	13608.6	13576.3	13563.6	13567.2				
15	12023.9	12002.9	11993.4	12002.8	11987.6	11937.9	11979.2	11981.2
18		10614.7	10603.7	10605.8	10594.6	10547.	10589.7	10586.8
20				9777.2	9745.7	9706.5	9741.	9736.
22					9034.1	8999.9	9029.8	9022.2
25					8032.4	8001.9	8030.5	8023.4
30						6612.2	6635.3	6630.

THERMISTOR CALIBRATION (Resistance vs ^{o}C)

(Cable resistance added as per location)

TABLE 11B

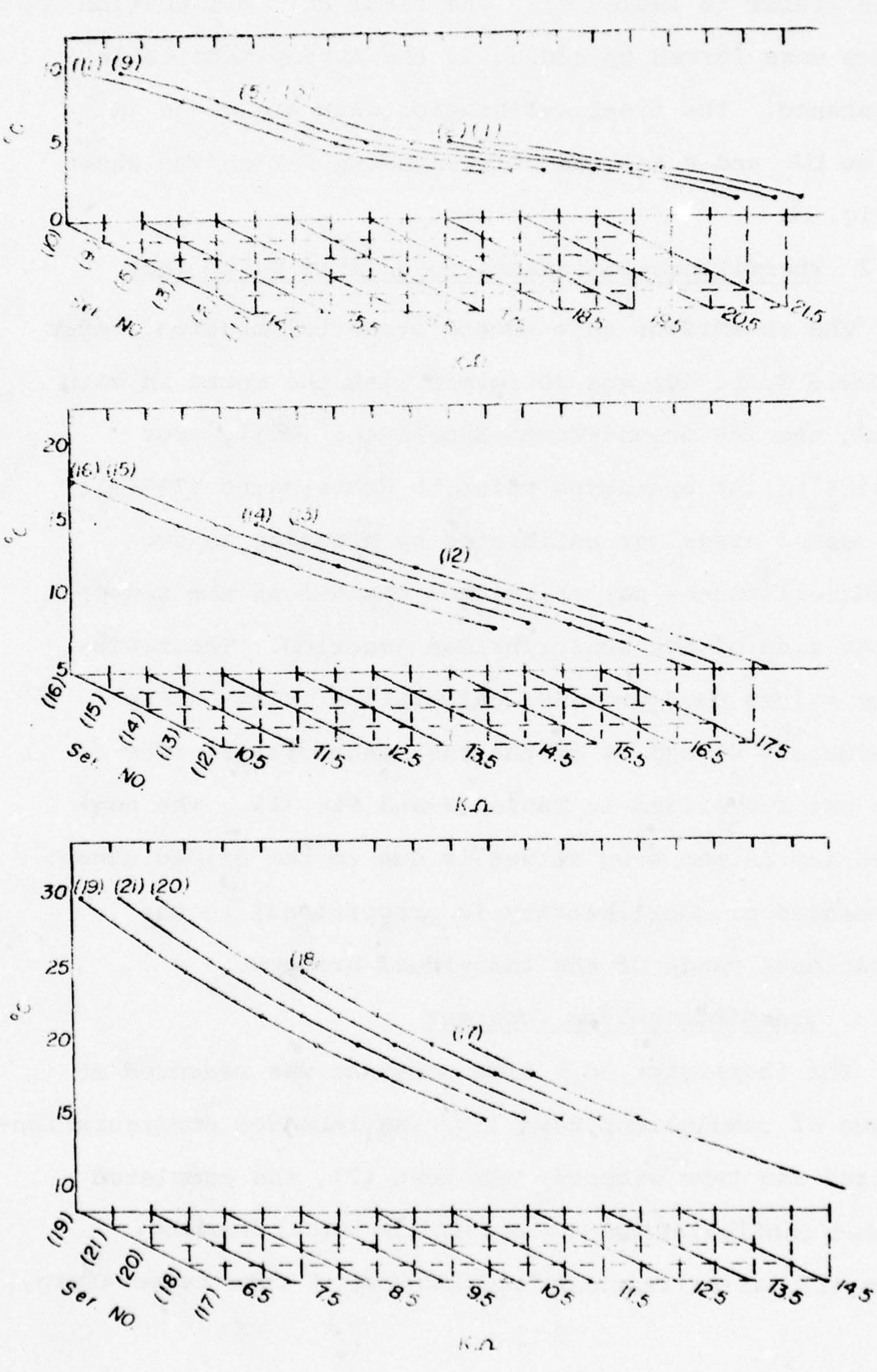
THERMISTOR CALIBRATION
°C
10
5
0
(11) (9)
(5) (3)
(7) (1)
Ser NO
14.5
15.5
18.5
19.5
20.5
21.5
KΩ
°C
20
15
10
5
(16) (15)
(14) (13)
(12)
(16)
(15)
(14)
(13)
(12)
Ser NO
10.5
11.5
12.5
13.5
14.5
15.5
16.5
17.5
KΩ
°C
30
25
20
15
10
(19) (21) (20)
(18)
(17)
(19)
(21)
(20)
(18)
(17)
Ser NO
6.5
7.5
8.5
9.5
10.5
11.5
12.5
13.5
14.5
KΩ

Fig. 14

resistance range it was also necessary to include the cable resistance for each of the thermistor unit locations (refer to Table 9). The final unit calibration values were formed by adding in the appropriate cable resistance. The final calibration data are given in Tables 11A and B and the corresponding R-T curves shown in Fig. 14.

3.1.2 Thermistors-Resistance to Digital Units (DU)

The thermistor unit second stage calibration (refer to Table 8, p. 40) was performed with the units in situ during the IAR Ground-Truth Experiment (GTE). For details of the operation refer to Echternacht (1976a). The second stage was calibrated by plugging in two fixed resistances per thermistor channel at the sensor output side of the sensor/bridge junction. The resistance values used provided calibration points at approximately 61 and 7% of the resistance range. The data are summarized in Table 12 and Fig. 15. The non-linearity in the R-Du curves is due to the bridge stage. The degree of non-linearity is proportional to the operational range of the individual bridges.

3.1.3 Thermistors-Time Constant

The thermistor unit time constant was measured at two stages of completion: test (1), the imbedded configuration-unit potted and tape wrapped- and test (2), the completed deployment configuration encased in the metal housing. For test (1), after reaching equilibrium at room temperature,

Therm.									
POS	No.	Ω max	Du	Ω 61	Du	Ω 7	Du	Ω min	Du
1	19	10871.6	1023	8792.4	703	6199.4	118	5842.4	0
2	-	-	-	-	-	-	-	-	-
3	20	12884.2	1023	10738.6	691	7942.0	105	7569.4	0
4	18	13724.2	1023	11556.8	686	8723.4	99	8345.8	0
5	17	14625.4	1023	12293.2	653	9517.8	113	9104.0	0
6	16	15660.8	1023	13360.2	698	10230.0	105	9823.2	0
7	15	16636.3	1023	14179.0	695	10914.4	108	10480.3	0
8	14	17449.5	1023	15036.4	698	11699.8	102	11275.9	0
9	13	18076.2	1023	15759.8	683	12550.6	98	12146.8	0
10	12	18724.7	1023	16523.0	676	13416.2	71	13036.5	0
11	11	19313.8	1023	17253.6	680	14290.2	-	13883.6	0
12	9	19662.5	1023	17709.4	680	14909.0	76	14545.9	0
13	-	-	-	-	-	-	-	-	-
14	3	20300.1	1023	18994.2	652	17030.6	63	16832.5	0
15	2	20579.7	1023	19417.2	639	17786.8	71	17583.5	0
16	1	20775.0	1023	19676.2	639	18021.2	55	17901.8	0

Table 12 - Thermistor Unit Calibration (DU vs Ω)

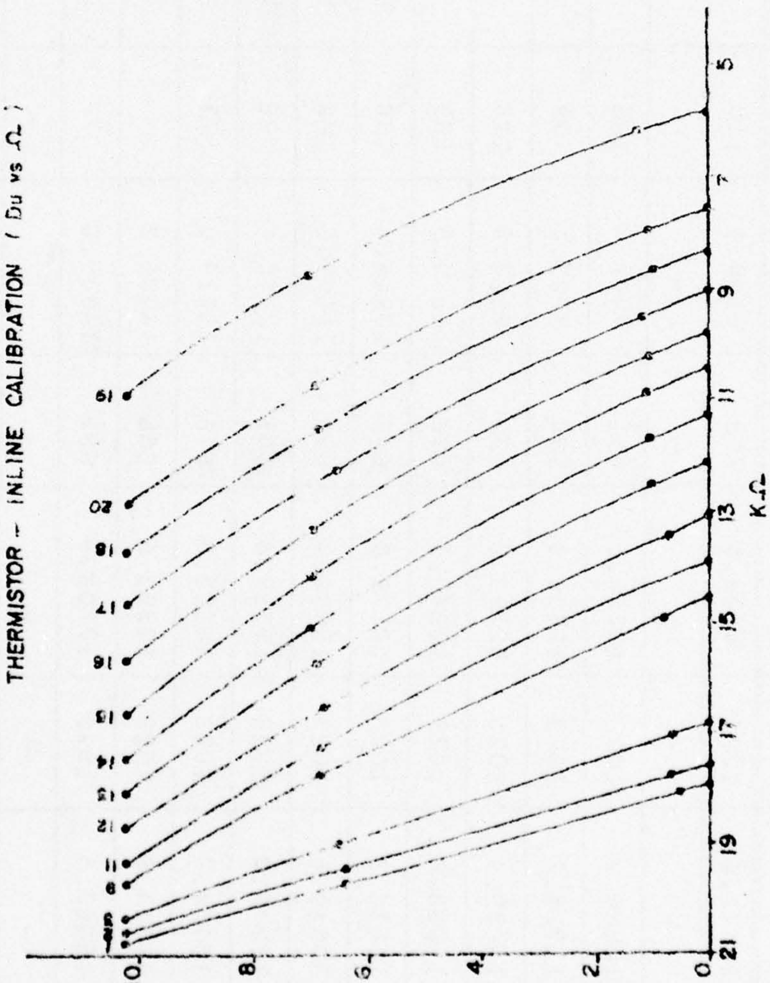
THERMISTOR - INLINE CALIBRATION (Du vs Ω)
Du (x10^2)
0
2
4
6
8
10
21
19
17
15
13
11
9
7
5
KΩ
19
20
18
17
16
15
14
13
12
11
9

Fig. 15

the unit was immersed in a circulating, constant temperature wet bath (Rosemount, Model 910AP). A quartz thermometer (Hewlett Packard, Model 2801A) and a precision digital multimeter (Hewlett Packard, Model 3490A) were used to monitor, respectively, the bath temperature and resistance of the unit. For test (2), after reaching equilibrium in a primary water bath, the unit was transferred to a second tank at a lower temperature. The bath and unit were monitored as in the previous test and the unit output recorded on strip chart.

The thermistor time constant is defined as follows: the time interval needed to reach 63% of the final equilibrium value following an instantaneous change in temperature. The measured time constants were found to be 4.97 min for the imbedded unit and 12.83 min for the unit as configured for deployment. The deployment constant is slightly longer than the slowest sampling rate (12 min sampling interval). The results of the tests are shown in Fig. 16. The test procedures are detailed in Echternacht (1975 , 1976b) and the data summarized in Appendix B of this report (Tables 37 and 38).

3.1.4 Signal Conditioner Amplifier and A/D Converter

Tests were conducted to check the linearity characteristics of the signal conditioner amplifier and the A/D converter (refer to Section 2.1 for the manufacturer specifications). The linearity characteristics are shown in Figs. 17 and 18. Based on these results the amplifier - A/D stage transfer function

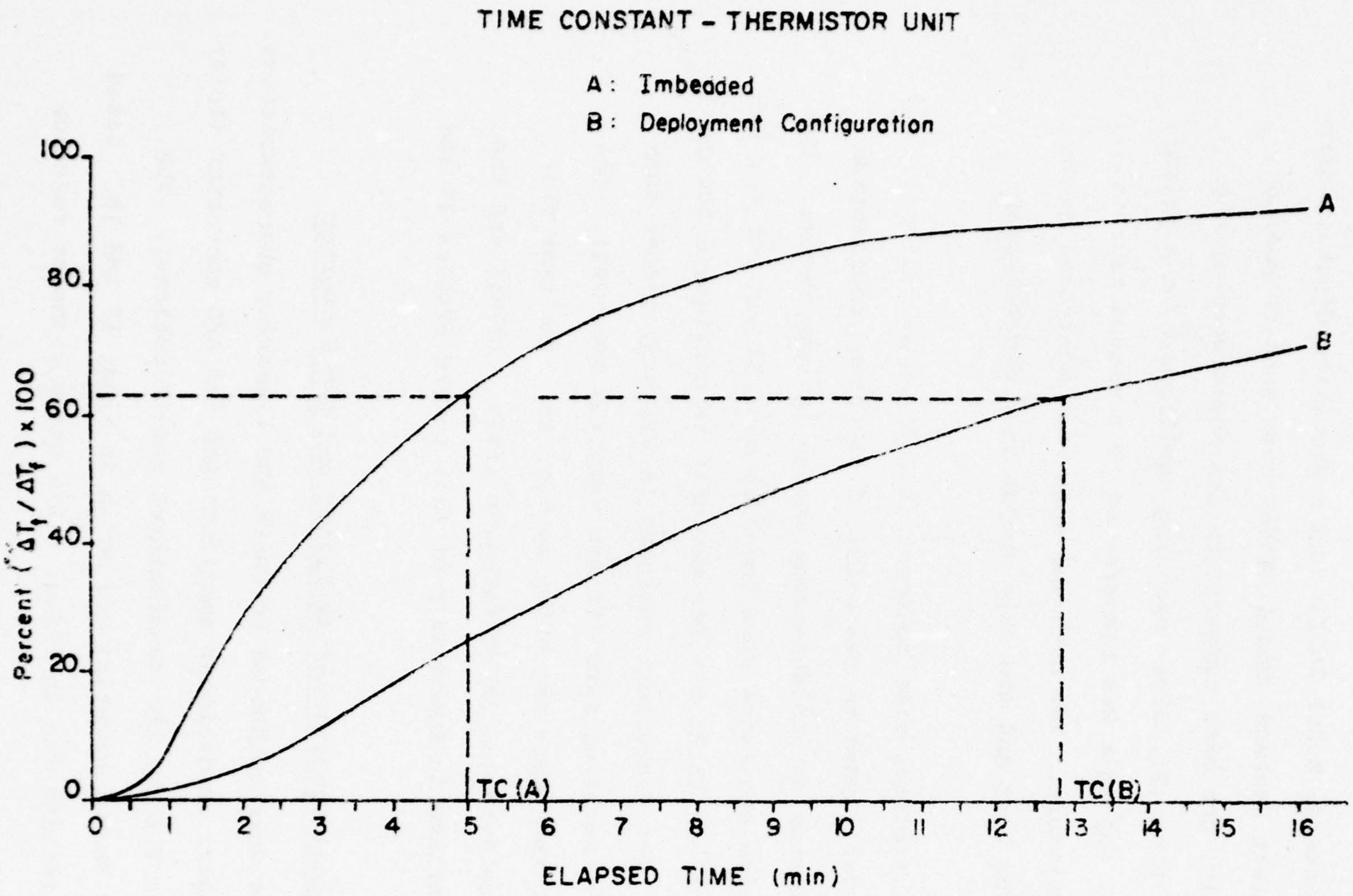
TIME CONSTANT - THERMISTOR UNIT
A : Imbedded
B : Deployment Configuration
100
80
60
40
20
0
Percent (ΔTt / ΔTf) x 100
A
B
TC(A)
TC(B)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
ELAPSED TIME (min)

Fig. 16

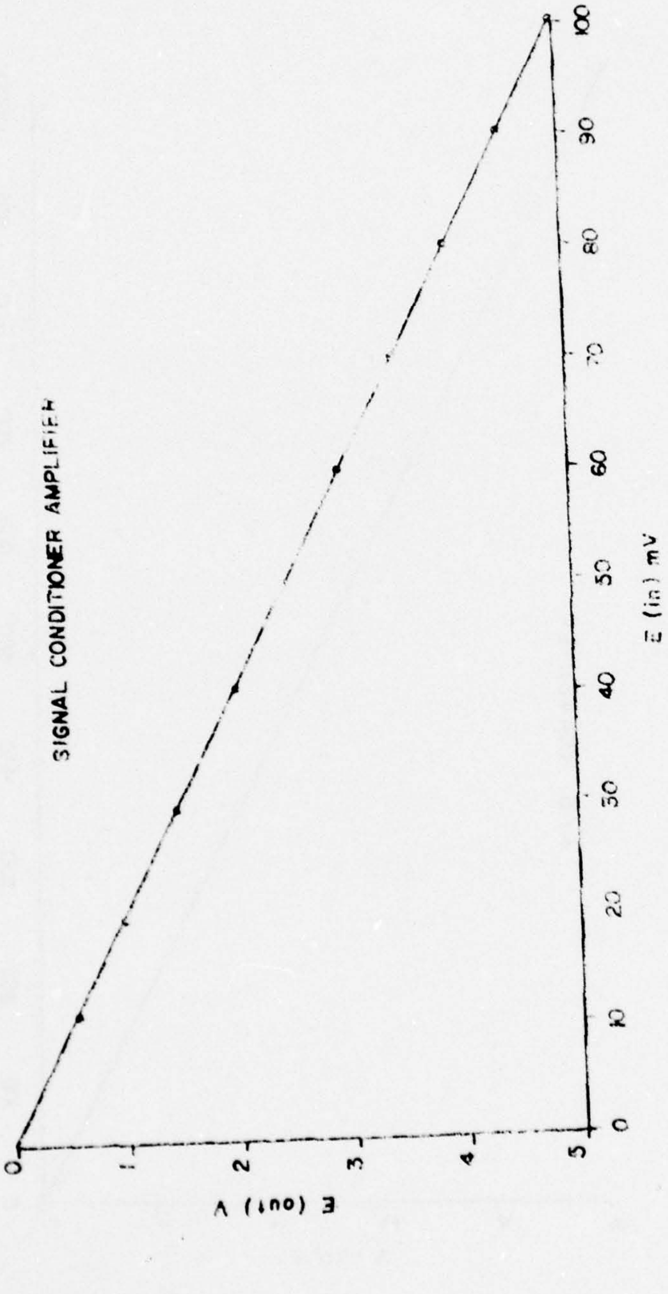
SIGNAL CONDITIONER AMPLIFIER
E (out) V
0
1
2
3
4
5
E (in) mV
0
10
20
30
40
50
60
70
80
90
100

Fig. 17

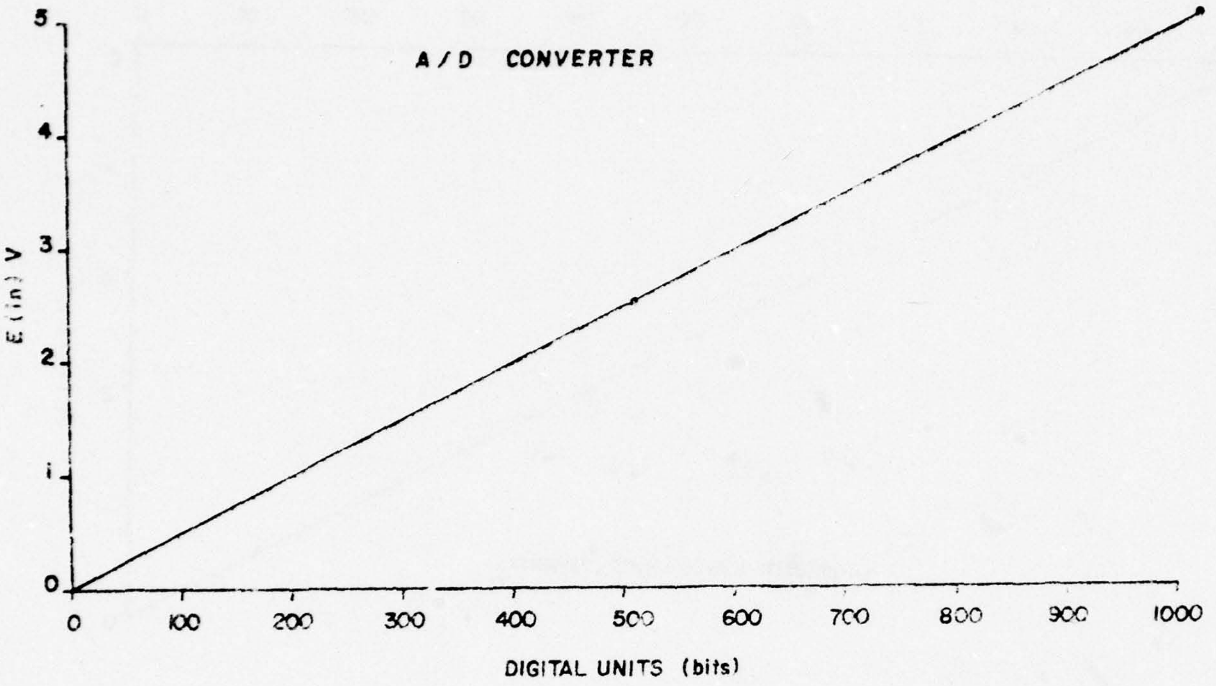
A / D CONVERTER
E (in) V
5
4
3
2
1
0
0
100
200
300
400
500
600
700
800
900
1000
DIGITAL UNITS (bits)

Fig. 18

is derived as follows. For the A/D converter the relation V vs Du is:

$$V = -1.043 \times 10^{-3} + 4.888 \times 10^{-3}\ (Du) \qquad (1)$$

and for the amplifier (mv vs V):

$$mV = 2.101 \times 10^{-2} + 20.054\ (V) \qquad (2)$$

Substituting Eq. (1) into (2) yields the stage transfer function, Eq. (3)

$$mV = 9.000 \times 10^{-5} + 9.802 \times 10^{-2}\ (Du) \qquad (3)$$

3.1.5 Inclinometers

Each inclinometer and associated bridge was calibrated as a unit. The sensors, mounted on an adjustable tilt arm, were calibrated in 3° intervals from 0° to 30° inclination. The mV output was measured using a precision digital multimeter (Hewlett Packard, Model 3490A). Each unit was run four times: two runs of increasing inclination (0-30°) and two runs of decreasing inclination (30-0°). The results are shown in Figs. 19 and 20 and the data given in Table 40 (Appendix B).

3.1.6 Tensiometer

During the implant checkout it was necessary to change the excitation voltage of the tensiometer. This resulted in an unknown change in the slope of the transfer function. In order to define the new function the tension was measured in situ at several points ranging from zero tension on the buoy to the tension due to the full weight of the mooring. The in situ calibration was carried out during the April 1976 GTE (Echternacht, 1976a). The mechanical set up was the following:

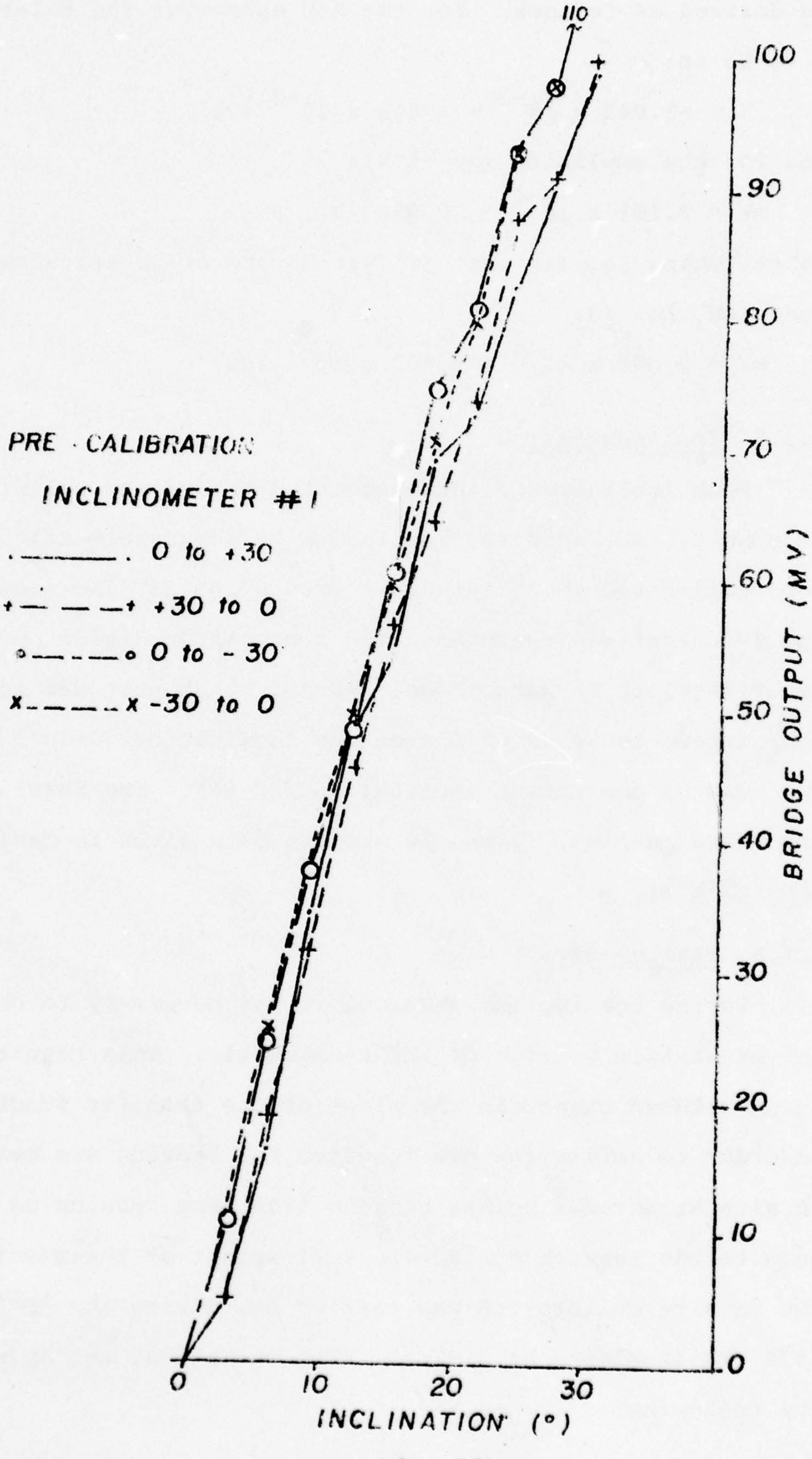
110
100
90
80
70
60
50
40
30
20
10
0
BRIDGE OUTPUT (MV)
PRE - CALIBRATION
INCLINOMETER #1
. ———— . 0 to +30
+— — —+ +30 to 0
○– – – –○ 0 to - 30
x– – – –x -30 to 0
0
10
20
30
INCLINATION (°)

Fig. 19

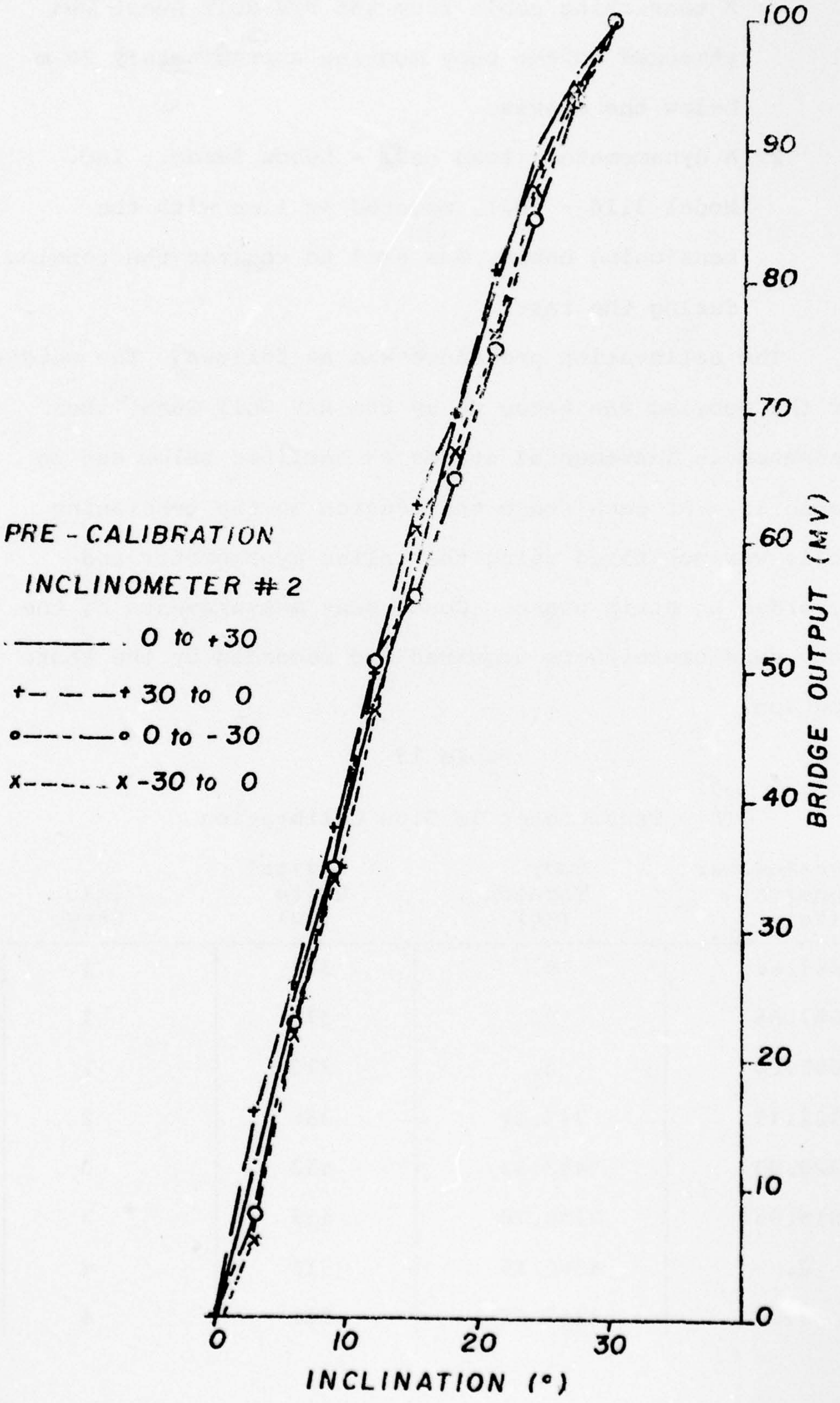
PRE - CALIBRATION
INCLINOMETER # 2
———— 0 to +30
+— — —+ 30 to 0
o---—o 0 to -30
x-----x -30 to 0
0
10
20
30
40
50
60
70
80
90
100
BRIDGE OUTPUT (MV)
0
10
20
30
INCLINATION (°)

Fig. 20

1) A tensioning cable from the R/V Gulf Quest was attached to the buoy mooring approximately 20 m below the clevis.
2) A dynamometer (load cell - Lebow Assoc., Inc. Model 3116 - 10K), mounted in line with the tensioning cable, was used to monitor the tension during the test.

The calibration procedure was as follows. The weight of the mooring was taken up by the R/V Gulf Quest then released in incremental stages as outlined below and in Table 13. At each stage the tension on the tensioning cable was monitored using the inline dynamometer and recorded on strip chart. Concurrent measurements of the buoy tensiometer were acquired and recorded by the shore station.

Table 13

GTE - Tensiometer In Situ Calibration

Dynamometer Tension (Kg)	Buoy Tension (Kg)	Digital Units (Du)	Cal. Stage
4267.66	0.	377	1
4267.66	0.	377	1
4205.00	0.	375	1
3922.49	345.17	386	2
1820.03	2447.63	453	3
1816.96	2450.70	455	3
0.	4360.10	515	4
0.	4267.66	511	4

1) Stage 1 - max. tension:

The maximum calibration tension was set based on model predictions of the surface tension under varying conditions of surface and subsurface forcing. During the experimental period sea and atmospheric conditions were calm such that the total force acting on the buoy was assumed to be due only to the weight of the mooring. The maximum tension was set to the predicted mooring weight.

2) Stages 2-4:

Following the Stage 1 test the tension was reduced in incremental steps as outlined in Table 13. The tension at each stage was held for a minimum of one interrogate cycle (~ order of 12 to 15 min).

3.2 Transfer Functions

The transfer functions used to convert the data from digital to engineering units were developed in a two step process. First, intermediate functions were derived explicitly from the calibration data for each calibration stage (refer to Table 8, p. 40). Secondly, the independent intermediate equations were combined by variable substitution to form the final transfer function.

The Lagrange interpolating polynomial was used to develop the intermediate transfer functions. The form used, as given by Carnahan et al (1969), is:

$$P_n(x) = \sum_{i=o}^{n} L_i(x) f(x_i) \tag{4}$$

where

$$L_i(x) = \prod_{\substack{j=0\\ j\neq i}}^{n} \frac{(x-x_j)}{(x_i-x_j)}, \quad i = 0(1)n \qquad (5)$$

In Eq. (4) $f(x_i)$ is the value of the stage calibration function, $f(x)$, for the distinct base points, x_i. $L_i(x)$ contains the polynomial coefficients and $P_n(x)$ is the intermediate transfer function. Eq. (4) establishes the value of $P_n(x)$ for all x but does not guarantee accurate approximation of $f(x)$ for arguments other than the n+1 base points. To minimize approximation error, (1) the desired degree of polynomial was chosen a priori for a given $f(x)$ but restricted to a maximum of second degree. This criterion required piecewise curve fitting for some $f(x)$. (2) $P_n(x)$ was tested for goodness of fit for all x over the specified range.

3.2.1 Thermistors

The intermediate transfer functions were derived for the calibration stages, (1) ^{o}C or EU$\rightarrow\Omega$ and (2) $\Omega\longrightarrow$ DU. The first stage (EU$\rightarrow\Omega$) polynomials were fit to the data given in Tables 11A and B and shown in Fig. 14 (p. 47). For thermistor serial numbers 2-14 it was necessary to piecewise fit two polynomials. To maintain continuity the joining end points were common to both functions. The coefficients of the polynomial were determined using Eq. (4). The general form of the resulting first stage function is given by:

Ser. No.	Channel	T-Range (^{o}C)	C	D	E
19	1	17.17-33.02	$1.817x10^{-7}$	$-6.188x10^{-3}$	62.970
21	2	14.60-29.30			
20	3	13.47-26.53	$1.845x10^{-7}$	$-6.241x10^{-3}$	63.290
18	4	12.34-24.01	$1.740x10^{-7}$	$-6.011x10^{-3}$	62.060
17	5	10.13-21.67	$8.073x10^{-8}$	$-4.005x10^{-3}$	51.439
16	6	8.64-19.83	$8.343x10^{-8}$	$-4.043x10^{-3}$	51.494
15	7	7.27-18.31	$7.938x10^{-8}$	$-3.946x10^{-3}$	50.944
14	8	6.10-10.00	$-1.497x10^{-7}$	$3.105x10^{-3}$	- 3.155
		10.00-16.55	$8.052x10^{-8}$	$-3.957x10^{-3}$	50.937
13	9	4.31- 8.00	$2.897x10^{-7}$	$-1.173x10^{-4}$	121.679
		8.00-14.71	$5.499x10^{-8}$	$-3.257x10^{-3}$	46.162
12	10	3.82- 8.00	$2.820x10^{-7}$	$-1.148x10^{-2}$	119.910
		8.00-13.03	$5.567x10^{-8}$	$-3.244x10^{-3}$	45.861
11	11	3.66- 5.00		$-8.333x10^{-4}$	19.750
		5.00-11.11	$-1.515x10^{-7}$	$3.180x10^{-3}$	- 3.836
9	12	3.30- 5.00		$-8.531x10^{-4}$	20.074
		5.00-10.37	$-1.488x10^{-7}$	$3.071x10^{-3}$	- 2.814
5	13	3.00- 8.80			
3	14	2.86- 5.00	$-5.712x10^{-8}$	$1.328x10^{-3}$	- $5.642x10^{-1}$
		5.00- 6.74		$-1.956x10^{-3}$	39.622
2	15	2.53- 5.00	$-5.286x10^{-8}$	$1.161x10^{-3}$	1.025
		5.00- 5.31		$-2.109x10^{-3}$	42.391
1	16	2.23- 4.82	$-6.000x10^{-8}$	$1.418x10^{-3}$	- 1.335

Thermistor - Transfer Function Coefficients

Resistance (Ω) to Engineering Unit (EU)

Table 14

$$EU(N) = C\cdot(\Omega)^2 + D\cdot(\Omega) + E \tag{6}$$

where N is the thermistor serial number. The coefficients are given in Table 14.

The second stage functions ($\Omega \rightarrow$ DU) were derived in the same manner using Eq. (4). The data used are shown in Fig. 15 (p. 50). The second stage function is given by Eq. (7) and the corresponding coefficients listed in Table 15.

$$\Omega(N) = C\cdot(DU)^2 + D\cdot(DU) + E \tag{7}$$

It should be noted that the functions were not derived for channels 2 and 13. These sensors failed during the buoy implant.

The final transfer functions were developed by substituting Eq. (7) into (6). The generalized form of the transfer function is given by:

$$EU(N) = A\cdot(DU)^4 + B\cdot(DU)^3 + C\cdot(DU)^2 + D\cdot(DU) + E \tag{8}$$

The coefficients for Eq. (8) are listed in Table 16. Note: the functions for channels 2 and 13 yield a constant, the minimum EU value.

3.2.2 Mooring Sensors

The intermediate inclinometer transfer equations were developed for two calibration stages as well (refer to Table 8, p. 40). The first stage polynomials ($^{\circ}$Incl. ⟶ mV) were piecewise fit to the calibration data (Figs. 19 and 20) and evaluated using Eq. (4) in the same manner as the thermistors.

Channel	Ser. No.	C(x10^{-3})	D	E
1	19	2.249	2.615	5842.4
2	21			
3	20	1.834	3.319	7569.4
4	18	1.711	3.507	8345.8
5	17	1.385	3.980	9104.0
6	16	1.966	3.965	9823.2
7	15	2.121	3.848	10480.3
8	14	1.992	3.997	11275.9
9	13	1.489	4.273	12146.8
10	12	1.161	4.373	13036.5
11	11	1.027	4.258	13883.6
12	9	1.018	3.960	14545.9
13	5			
14	3		3.390	16832.5
15	2		2.929	17583.5
16	1		2.809	17901.8

Thermistor - Transfer Function

Coefficients

Digital Unit (DU) to Resistance (Ω)

Table 15

Ser. No.	Ch.	Du Range	A	B	C	D	E
19	1	1023-0	9.190×10^{-13}	2.137×10^{-9}	-7.902×10^{-6}	-1.063×10^{-2}	33.019
21	2	1023-0				-1.437×10^{-2}	29.300
20	3	1023-0	6.206×10^{-13}	2.245×10^{-9}	-4.285×10^{-6}	-1.144×10^{-2}	26.620
18	4	1023-0	5.095×10^{-13}	2.088×10^{-9}	-3.171×10^{-6}	-1.090×10^{-2}	24.013
17	5	1023-0	1.548×10^{-13}	8.896×10^{-10}	-2.232×10^{-6}	-1.009×10^{-2}	21.668
16	6	1023-0	3.224×10^{-13}	1.212×10^{-9}	-3.587×10^{-6}	-8.884×10^{-3}	19.829
15	7	1023-0	3.571×10^{-13}	1.295×10^{-9}	-3.665×10^{-6}	-8.778×10^{-3}	18.308
14	8	1023-664	-5.940×10^{-13}	-2.383×10^{-9}	-2.932×10^{-6}	-1.080×10^{-3}	12.823
		663-0	3.195×10^{-13}	1.282×10^{-9}	-2.978×10^{-6}	-8.562×10^{-3}	16.556
13	9	1023-733	6.423×10^{-13}	3.685×10^{-9}	-1.690×10^{-6}	-2.005×10^{-2}	21.941
		732-0	1.219×10^{-13}	6.995×10^{-10}	-1.857×10^{-6}	-8.212×10^{-3}	14.713
12	10	1023-611	3.801×10^{-13}	2.862×10^{-9}	6.000×10^{-7}	-1.805×10^{-2}	18.177
		610-0	7.504×10^{-14}	5.650×10^{-10}	-1.016×10^{-6}	-7.843×10^{-3}	13.032
11	11	1023-759			-8.558×10^{-7}	-3.548×10^{-3}	8.181
		758-0	-1.598×10^{-13}	-1.325×10^{-9}	-3.801×10^{-6}	-4.370×10^{-3}	11.112
9	12	1023-673			-8.684×10^{-7}	-3.378×10^{-3}	7.665
		672-0	-1.542×10^{-13}	-1.200×10^{-9}	-3.614×10^{-6}	-4.980×10^{-3}	10.372
5	13	1023-0				-5.670×10^{-3}	8.800
3	14	1023-256			-6.564×10^{-7}	-2.017×10^{-3}	5.606
		255-0				-6.631×10^{-3}	6.738
2	15	1023-49			-4.535×10^{-7}	-2.045×10^{-3}	5.096
		48-0				-6.177×10^{-3}	5.307
1	16	1023-0			-4.734×10^{-7}	-2.051×10^{-3}	4.822

Thermistor - Composite Transfer Function Coefficients

Digital Unit (DU) to Engineering Unit (EU)

Table 16

Table 17A
Inclinometer - Transfer Function Coefficients

(mV to °Tilt)

No.	mV Range	C	D	E
1	0.-17.667	$-1.808x10^{-2}$	$6.590x10^{-1}$	
	17.667-99.667	$1.270x10^{-3}$	$1.437x10^{-1}$	3.063
2	0.-78.667	$3.970x10^{-4}$	$2.357x10^{-1}$	
	78.667-100.	$1.090x10^{-2}$	-1.527.	73.602

Table 17B
Inclinometer - Composite Transfer Function Coefficients

(Du to °Tilt)

No.	Du Range (°Tilt Range)	C	D	E
1	0.-180 (0.-6°)	$-1.737x10^{-4}$	$6.460x10^{-2}$	$5.931x10^{-5}$
	181-1023 (6-30°)	$1.220x10^{-5}$	$1.408x10^{-2}$	3.063
2	0-802 (0-21°)	$3.814x10^{-6}$	$2.310x10^{-2}$	$2.121x10^{-5}$
	803-1023 (21-30°)	$1.047x10^{-4}$	$-1.497x10^{-1}$	73.602

Table 18
Tensiometer - Transfer Function Coefficients

Range (kg)	C	D	E
0.-20334.23		31.38	-11767.51

The corresponding first stage coefficients are listed in Table 17A. The second stage consisted of the signal conditioner amplifier and A/D converter. The intermediate transfer function for that stage was derived in Section 3.1.4 (Eqs. (1)-(3)). As was done for the thermistors the final inclinometer transfer functions were formed by substituting the second stage equation (Eq. (3)) into the first stage equation. The generalized function is given by:

$$^{o}\text{Tilt}(N) = C\cdot(DU)^{2} + D\cdot(DU) + E \qquad (9)$$

The coefficients are listed in Table 17B.

The tensiometer transfer function was derived directly from the GTE calibration data (Table 13, p. 58). The transfer function was formed by fitting a Least Squares line to the data. The coefficients are given in Table 18.

3.3 Sensor and Calibration Summary

The BEAR Buoy sensor configuration is summarized in Table 19 by sensor location. The scope is defined as follows: the thermistor cable length to the sensor location, referenced to the clevis - the point of attachment of the cable to the buoy. The scope does not include stretch due to loading. The nominal sensor depth is referenced to the mean waterline of the buoy and includes cable stretch. The nominal depth was computed for conditions of zero surface and subsurface external

Channel No.	Sensor	Scope (m)	Nominal Depth (m)	Status
22	Tensiometer	0.	1.7 *	
26	Inclinometer - 1	21.3	21.4	
1	Thermistor - 1	20.0	22.0	
2	" - 2	146.3	148.9	Non-Op
3	" - 3	246.3	249.4	
4	" - 4	346.3	349.9	
5	" - 5	446.3	450.4	
6	" - 6	546.3	550.9	
7	" - 7	646.3	651.3	
28	Depth Gauge	650.0	654.9	Non-Op
8	Thermistor - 8	746.3	751.9	
9	" - 9	846.3	852.4	
10	" -10	946.3	952.8	
11	" -11	1046.3	1053.3	
12	" -12	1146.3	1153.8	
13	" -13	1296.5	1304.8	Non-Op
14	" -14	1471.5	1480.4	
15	" -15	1646.3	1656.3	
16	" -16	1821.3	1832.3	
27	Inclinometer - 2	1907.1	1916.0	

* Note : Tensiometer depth measured from the mean waterline - nominal conditions

Table 19

Bear Buoy Sensor Locations

forcing due to wind, wave, and current. The three sensors listed as non-operational failed during the buoy deployment phase.

The final thermistor transfer equations were checked out by comparing, 1) the max/min values returned by the transfer functions vs the values using the design functions and 2) vs XBT data collected by the R/V Lamb. The first test also provided the actual measurement range at each thermistor location.

The design functions were based on the general thermistor R-T curve (shown in Fig. 6, p. 23) and did not include the calibration data (EU→Ω) for the particular thermistor units. The actual and design ranges are given in Table 20 and in Fig. 21. The actual range, in general, meets the original design criteria. The differences as shown in Fig. 21 are due to deviations of the specific thermistor unit R-T characteristics from the general curve, particularly at lower temperatures. The reduction in the max. limit, however, does not present a problem. The max. limit is still greater than the anticipated temperatures at these depths (refer to the development of the design range - Section 2.2).

Temperature profiles based on BEAR Buoy data were compared with XBT data collected during the buoy implant period (Fig. 22). The comparison was conducted for the purpose of quality control. The buoy thermistor data were not corrected for sensor depth changes due to changes in mooring configuration.

Therm. Bridge	Ser. No.	Nom. Depth (m)	Total Resistance (Ω) max.	Total Resistance (Ω) min.	Design Range T(^{o}C) min.	Design Range T(^{o}C) max.	Actual Range T(^{o}C) min.	Actual Range T(^{o}C) max.
1	19	22.0	10871.6	5842.4	17.3	33.3	17.17	33.02
2	21	148.9	12152.6	6796.8	14.6	29.3	14.60	29.30
3	20	249.4	12884.2	7569.4	13.2	26.5	13.52	26.62
4	18	349.9	13724.2	8345.8	11.7	24.0	12.34	24.01
5	17	450.4	14625.4	9104.0	10.2	21.8	10.13	21.67
6	16	550.9	15660.8	9823.2	8.6	19.9	8.64	19.83
7	15	651.3	16636.3	10480.3	7.2	18.3	7.27	18.31
8	14	751.9	17449.3	11275.9	6.1	16.5	6.10	16.55
9	13	852.4	18076.2	12146.8	5.3	14.7	4.31	14.71
10	12	952.8	18724.7	13036.5	4.5	13.0	3.82	13.03
11	11	1053.3	19313.8	13883.6	3.8	11.5	3.66	11.11
12	9	1153.8	19662.5	14545.9	3.4	10.4	3.30	10.37
13	5	1304.8	20020.6	15573.8	3.0	8.8	3.00	8.80
14	3	1480.4	20300.1	16832.5	2.7	7.0	2.86	6.74
15	2	1656.3	20579.7	17583.5	2.4	6.0	2.53	5.31
16	1	1832.3	20775.0	17901.8	2.2	5.6	2.23	4.82

Table 20

Thermistors - Design vs actual calibrated range

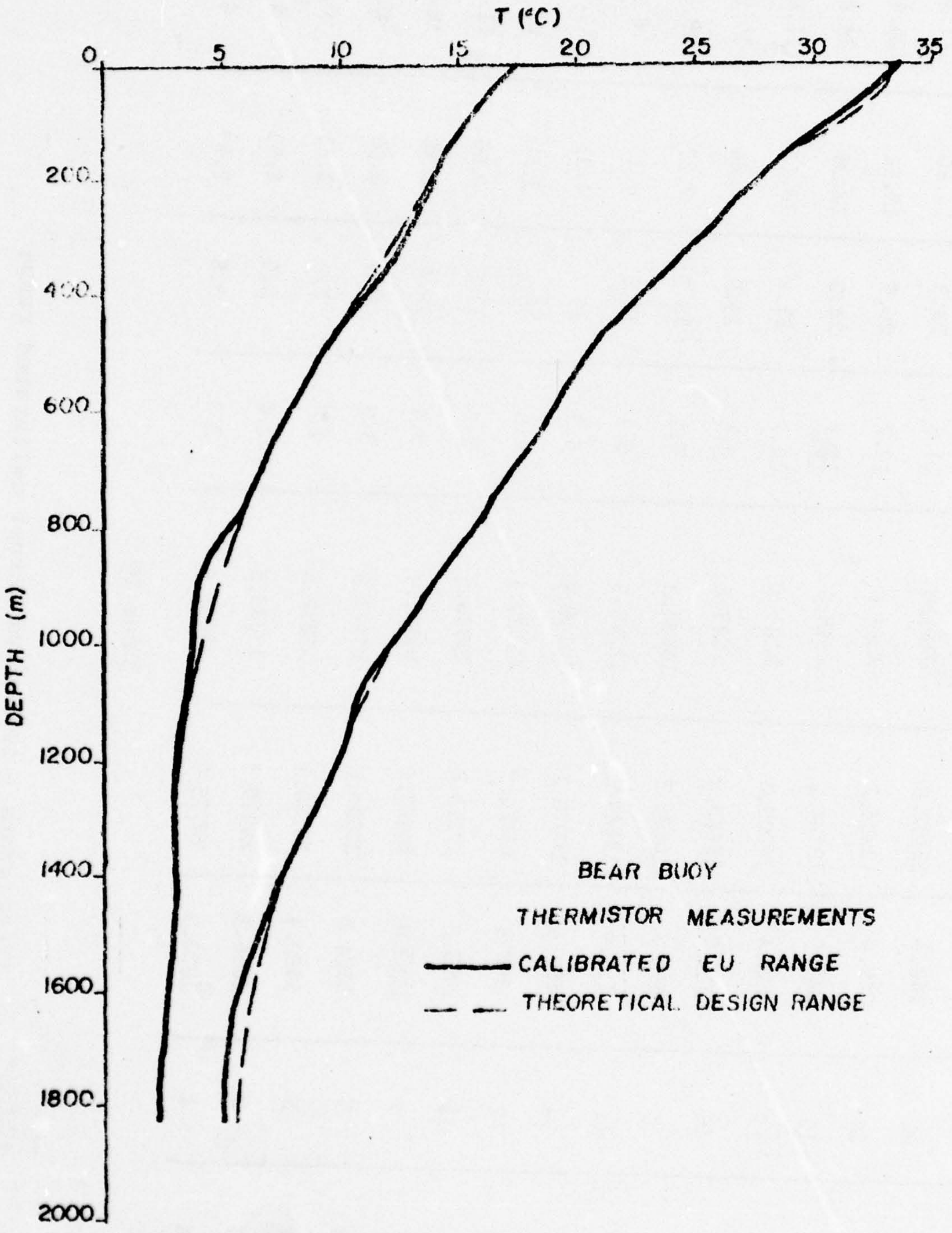
T (°C)
0
5
10
15
20
25
30
35
200
400
600
800
1000
1200
1400
1600
1800
2000
DEPTH (m)
BEAR BUOY
THERMISTOR MEASUREMENTS
CALIBRATED EU RANGE
THEORETICAL DESIGN RANGE

Fig. 21

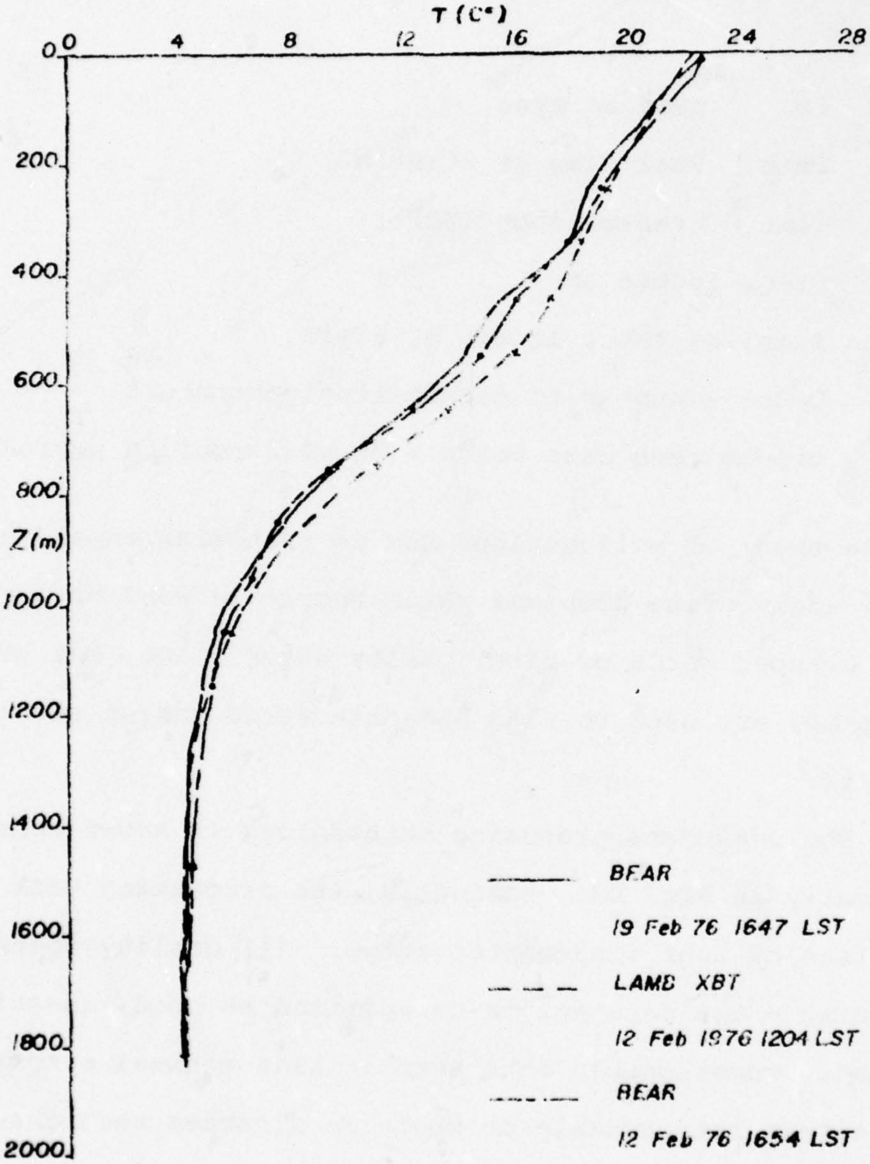
T (C°)
0
4
8
12
16
20
24
28
0
200
400
600
800
1000
1200
1400
1600
1800
2000
Z (m)
BEAR
19 Feb 76 1647 LST
LAMB XBT
12 Feb 1976 1204 LST
BEAR
12 Feb 76 1654 LST

Fig. 22

4.0 Summary of the Post-Data Processing Methodology

As described in Section 1.3 the acquired data are recorded on Linc tape in raw form at the shore station. The data logging format is the following.

Word		
1	ID	used as sync
2-4	Date	Real time at start of transmission (SOT)
5-7	Time	
8	Freq. locked on	
9	Sampling rate: 12 min or 6 min.	
10	Count - number of transmitted parameters	
11-n	transmitted data words - 32 wds/sampling period	

In the event of malfunctions due to transmission and/or other engineering problems which result in word errors (eg; dropped words or bits) parity error flags, set at log time, are used to flag bad data words and/or sections of data.

The post-data procesing methodology is shown schematically in Fig. 23. Basically, the processing task consists of four fundamental steps. (1) Quality control scanning - the data set is categorized as good, questionable, or bad. Questionable data sets include minimal errors which are either retrieveable or short in duration such that error sections can be filtered out prior to time series analysis. Bad sets are non-retrieveable. (2) Assignment of acquisition time. As shown in the above logging format the only recorded time is the real time at the start of transmission (SOT) -

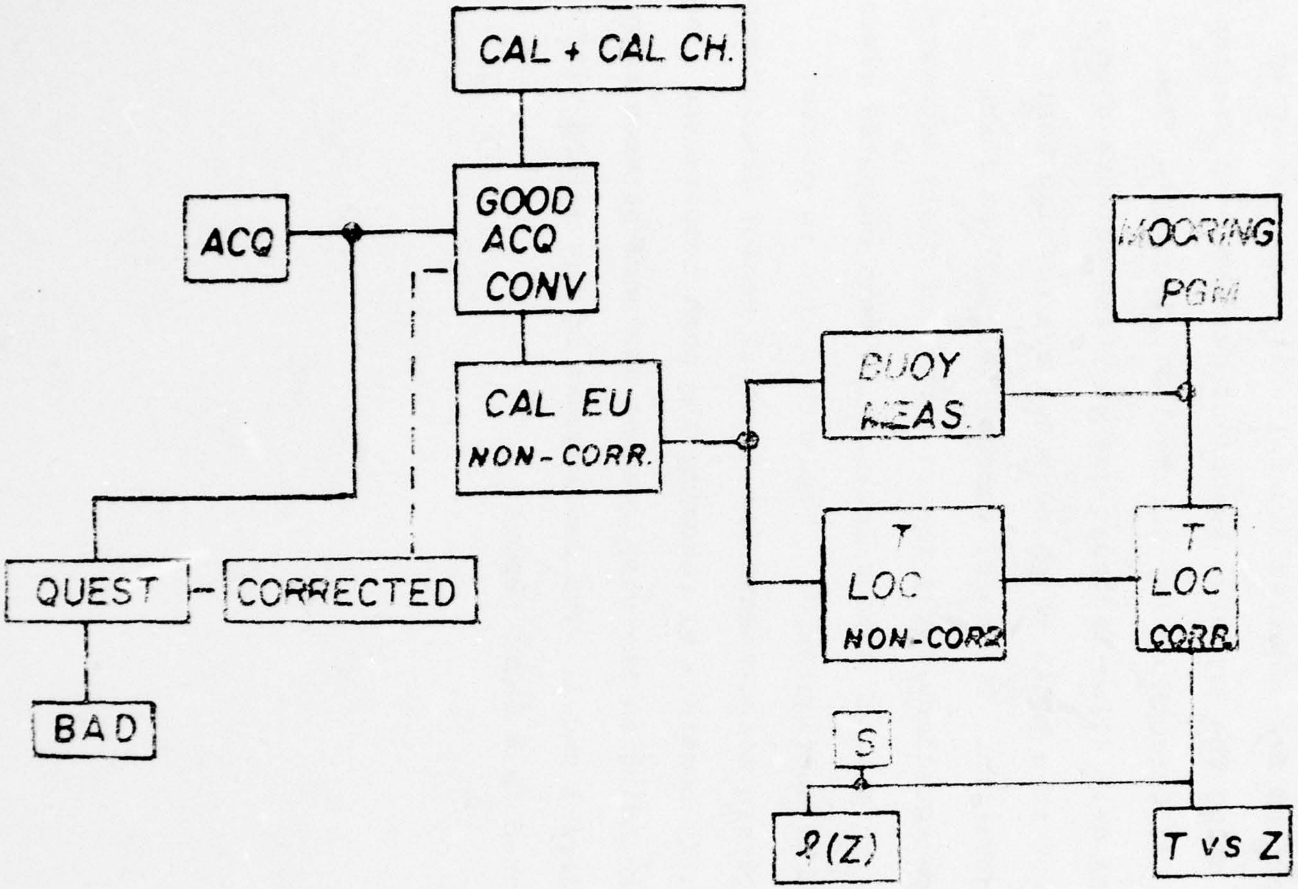

Fig. 23 Post-Data Processing Summary

assigned by the shore station. The actual time of acquisition for each sampling period is computed using the SOT, the sampling rate (word 9), and the number count (word 10). (3) The data (environmental and mooring sensors) are converted from raw acquired digital units to engineering units using the transfer functions developed in Section 3.2. (4) Correction for vertical displacement. The mooring data (line inclinations and tension) are used as input to a model which computes the mooring cable configuration. The model successively solves force balance equations for a finite series of cable segments. The depth at each sensor location is then computed given the cable configuration. The method used to correct temperature measurements for vertical sensor displacements basically consists of removing the mean temperature gradient corresponding to the displacement distance between sampling periods i-1 and i. The development of the method will be presented in a later report.

References

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Appendix A: Summary of Environmental Data

The following appendix presents the FNWC, NAVELEX, and WHOI XBT data. These data sets were used to derive the operational ranges for each thermistor bridge (refer to Section 2.2).

RANGE = 0 Km			WINTER	RANGE = 111.7 Km	
Depth (Meters)	Temp (Deg C)	Salinity (Parts/1000)	Depth (Meters)	Temp (Deg C)	Salinity (Parts/1000)
0.00	23.90	36.29	0.00	22.90	36.54
30.00	23.90	36.29	30.00	22.90	36.54
50.00	23.90	36.29	50.00	22.90	36.54
61.00	23.90	36.29	61.00	22.90	36.54
70.00	23.90	36.29	70.00	22.90	36.54
75.00	23.90	36.29	75.00	22.90	36.54
80.00	23.90	36.29	80.00	22.90	36.54
85.00	23.90	36.29	85.00	22.90	36.54
90.00	23.90	36.29	90.00	22.90	36.54
95.00	23.90	36.29	95.00	22.90	36.54
100.00	23.90	36.29	100.00	22.90	36.54
105.00	23.90	36.29	105.00	22.90	36.54
110.00	23.90	36.29	110.00	22.90	36.54
115.00	23.90	36.29	115.00	22.90	36.54
120.00	23.70	36.29	120.00	22.90	36.54
125.00	23.40	36.28	125.00	22.90	36.54
130.00	23.10	36.28	130.00	22.80	36.54
135.00	22.80	36.27	135.00	22.50	36.54
140.00	22.50	36.27	140.00	22.40	36.53
145.00	22.20	36.27	145.00	22.20	36.52
150.00	21.90	36.26	150.00	22.00	36.52
200.00	20.20	36.61	200.00	20.30	36.74
243.00	19.40	36.52	243.00	19.30	36.66
365.00	16.50	36.25	365.00	17.30	36.42
400.00	15.63	36.16	400.00	16.50	36.34
600.00	10.80	35.28	600.00	13.62	35.75
800.00	7.67	35.06	800.00	9.03	35.24
1000.00	5.68	34.96	1000.00	6.89	35.03
1500.00	3.92	34.95	1500.00	4.06	35.00
2000.00	3.19	34.87	2000.00	3.50	34.95
2500.00	2.83	34.88	2500.00	3.17	34.95
3000.00	2.70	34.91	3000.00	2.86	34.95
3500.00	2.33	34.87	3500.00	2.56	34.93
4000.00	2.21	34.86	4000.00	2.41	34.91
5000.00	2.00	34.82	5000.00	2.13	34.85

TABLE 21A

FNWC XBT DATA

RANGE = 245.3 Km WINTER RANGE = 446.7 Km

Depth (Meters)	Temp (Deg C)	Salinity (Parts/1000)	Depth (Meters)	Temp. (Deg C)	Salinity (Parts/1000)
0.00	22.30	36.55	0.00	20.90	36.56
30.00	22.30	36.55	30.00	20.90	36.56
50.00	22.30	36.55	50.00	20.90	36.56
61.00	22.30	36.55	61.00	20.90	36.56
70.00	22.30	36.55	70.00	20.90	36.56
75.00	22.30	36.55	75.00	20.90	36.56
80.00	22.30	36.55	80.00	20.90	36.56
85.00	22.30	36.55	85.00	20.90	36.56
90.00	22.30	36.55	90.00	20.90	36.56
95.00	22.30	36.55	95.00	20.90	36.56
100.00	22.30	36.55	100.00	20.90	36.56
105.00	22.30	36.55	105.00	20.90	36.56
110.00	22.30	36.55	110.00	20.90	36.56
115.00	22.30	36.55	115.00	20.90	36.56
120.00	22.30	36.55	120.00	20.90	36.56
125.00	22.30	36.55	125.00	20.90	36.56
130.00	22.30	36.55	130.00	20.80	36.56
135.00	22.10	36.55	135.00	20.60	36.56
140.00	22.00	36.55	140.00	20.40	36.55
145.00	21.80	36.54	145.00	20.30	36.55
150.00	21.60	36.54	150.00	20.10	36.55
200.00	20.30	36.68	200.00	18.90	36.49
243.00	19.30	36.66	243.00	18.60	36.47
365.00	17.30	36.39	365.00	17.20	36.44
400.00	16.64	36.37	400.00	16.89	36.42
600.00	14.22	35.89	600.00	15.14	36.02
800.00	9.99	35.26	800.00	10.76	35.34
1000.00	8.02	35.04	1000.00	9.49	35.11
1500.00	4.11	35.00	1500.00	4.15	35.00
2000.00	3.51	34.95	2000.00	3.51	34.96
2500.00	3.21	34.95	2500.00	3.23	35.95
3000.00	2.92	34.95	3000.00	2.97	35.95
3500.00	2.56	34.93	3500.00	2.56	34.93
4000.00	2.41	34.91	4000.00	2.41	34.91
5000.00	2.21	34.87	5000.00	2.20	34.86

TABLE 21B

FNWC XBT DATA

RANGE = 661.2 Km			WINTER	RANGE = 815.4 Km	
Depth (Meters)	Temp (Deg C)	Salinity (Parts/1000)	Depth (Meters)	Temp (Deg C)	Salinity (Parts/1000)
0.00	20.60	36.60	0.00	20.50	36.61
30.00	20.60	36.60	30.00	20.50	36.61
50.00	20.60	36.60	50.00	20.50	36.61
61.00	20.60	36.60	61.00	20.50	36.61
70.00	20.60	36.60	70.00	20.50	36.61
75.00	20.60	36.60	75.00	20.50	36.61
80.00	20.60	36.60	80.00	20.50	36.61
85.00	20.60	36.60	85.00	20.50	36.61
90.00	20.60	36.60	90.00	20.50	36.61
95.00	20.60	36.60	95.00	20.50	36.61
100.00	20.60	36.60	100.00	20.50	36.61
105.00	20.60	36.60	105.00	20.50	36.61
110.00	20.60	36.60	110.00	20.50	36.61
115.00	20.60	36.60	115.00	20.50	36.61
120.00	20.60	36.60	120.00	20.50	36.61
125.00	20.60	36.60	125.00	20.50	36.61
130.00	20.60	36.60	130.00	20.50	36.61
135.00	20.60	36.60	135.00	20.50	36.61
140.00	20.40	36.60	140.00	20.50	36.61
145.00	20.20	36.60	145.00	20.40	36.61
150.00	20.00	36.60	150.00	20.10	36.61
200.00	18.90	36.49	200.00	18.90	36.49
243.00	18.20	36.47	243.00	18.40	36.47
365.00	17.20	36.41	365.00	17.50	36.41
400.00	17.18	36.40	400.00	17.32	36.39
600.00	15.83	36.12	600.00	16.10	36.17
800.00	12.08	35.53	800.00	12.13	35.59
1000.00	8.22	35.14	1000.00	8.13	35.14
1500.00	4.28	35.00	1500.00	4.37	35.00
2000.00	3.53	34.97	2000.00	3.54	34.97
2500.00	3.26	34.96	2500.00	3.25	34.96
3000.00	2.99	34.96	3000.00	2.95	34.97
3500.00	2.58	34.93	3500.00	2.59	34.93
4000.00	2.42	34.91	4000.00	2.41	34.91
5000.00	2.31	34.89	5000.00	2.31	34.89

TABLE 21C

FNWC XBT DATA

RANGE = 0 Km SUMMER RANGE = 111.7 Km

Depth (Meters)	Temp (Deg C)	Salinity (Parts/1000)	Depth (Meters)	Temp (Deg C)	Salinity (Parts/1000)
0.00	28.80	36.22	0.00	28.90	36.51
10.00	28.80	36.22	10.00	28.90	36.51
15.00	28.80	36.22	15.00	28.90	36.51
20.00	28.80	36.22	20.00	28.90	36.51
25.00	28.80	36.22	25.00	28.90	36.51
30.00	28.80	36.22	30.00	28.90	36.51
35.00	28.80	36.22	35.00	28.90	36.51
40.00	28.50	36.23	40.00	28.70	36.51
45.00	28.20	36.24	45.00	28.30	36.52
50.00	28.00	36.24	50.00	27.90	36.52
55.00	27.60	36.26	55.00	27.30	36.54
61.00	27.20	36.28	61.00	26.70	36.56
91.00	25.20	36.39	91.00	24.20	36.67
122.00	23.70	36.36	122.00	22.60	36.59
182.00	21.20	36.63	182.00	20.60	36.67
243.00	19.70	36.52	243.00	19.50	36.66
300.00	18.10	36.39	300.00	18.60	36.54
365.00	16.30	36.24	365.00	17.40	36.41
400.00	15.63	36.16	400.00	16.50	36.34
600.00	10.80	35.29	600.00	13.62	35.75
800.00	7.67	35.06	800.00	9.03	35.24
1000.00	5.68	34.96	1000.00	6.89	35.03
1500.00	3.92	34.95	1500.00	4.06	35.00
2000.00	3.19	34.87	2000.00	3.50	34.95
2500.00	2.83	34.88	2500.00	3.17	34.95
3000.00	2.70	34.91	3000.00	2.86	34.95
3500.00	2.33	34.87	3500.00	2.56	34.93
4000.00	2.21	34.86	4000.00	2.41	34.91
5000.00	2.00	34.82	5000.00	2.13	34.85

TABLE 21D

FNWC XBT DATA

RANGE = 245.3 Km SUMMER RANGE = 446.7 Km

Depth (Meters)	Temp (Deg C)	Salinity (Parts/1000)	Depth (Meters)	Temp (Deg C)	Salinity (Parts/1000)
0.00	28.70	36.50	0.00	28.10	36.34
10.00	28.70	36.50	10.00	28.10	36.37
15.00	28.70	36.50	15.00	28.10	36.39
20.00	28.70	36.50	20.00	28.10	36.41
25.00	28.70	36.50	25.00	28.10	36.43
30.00	28.70	36.50	30.00	28.10	36.44
35.00	28.40	36.51	35.00	27.70	36.45
40.00	28.00	36.51	40.00	27.00	36.46
45.00	27.40	36.52	45.00	26.00	36.47
50.00	26.80	36.52	50.00	25.00	36.48
55.00	26.20	36.54	55.00	24.00	36.49
61.00	25.50	36.56	61.00	23.20	36.51
91.00	23.00	36.66	91.00	21.40	36.61
122.00	21.70	36.62	122.00	20.60	36.61
182.00	20.10	36.65	182.00	19.70	36.52
243.00	19.40	36.62	243.00	18.70	36.48
300.00	18.70	36.53	300.00	17.90	36.44
365.00	17.50	36.43	365.00	17.20	36.43
400.00	16.64	36.37	400.00	16.89	36.42
600.00	14.22	35.89	600.00	15.14	36.02
800.00	9.99	35.26	800.00	10.76	35.34
1000.00	8.02	35.04	1000.00	9.49	35.11
1500.00	4.11	35.00	1500.00	4.15	35.00
2000.00	3.51	34.95	2000.00	3.51	34.96
2500.00	3.21	34.95	2500.00	3.23	34.95
3000.00	2.92	34.95	3000.00	2.97	34.95
3500.00	2.56	34.93	3500.00	2.56	34.93
4000.00	2.41	34.91	4000.00	2.41	34.91
5000.00	2.21	34.87	5000.00	2.20	34.86

TABLE 21E

FNWC XBT DATA

RANGE = 661.2 Km SUMMER RANGE = 815.4 Km

Depth (Meters)	Temp (Deg. C)	Salinity (Parts/1000)	Depth (Meters)	Temp (Deg. C)	Salinity (Parts/1000)
0.00	28.30	36.40	0.00	28.40	36.43
10.00	28.30	36.43	10.00	28.40	36.46
15.00	28.30	36.45	15.00	28.40	36.48
20.00	28.30	36.47	20.00	28.40	36.49
25.00	28.30	36.49	25.00	28.40	36.50
30.00	27.00	36.49	30.00	26.20	36.51
35.00	25.90	36.50	35.00	25.50	36.52
40.00	25.20	36.51	40.00	25.00	36.53
45.00	24.60	36.52	45.00	24.30	36.55
50.00	24.00	36.53	50.00	23.90	36.56
55.00	23.60	36.55	55.00	23.50	36.59
61.00	23.00	36.57	61.00	22.90	36.62
91.00	21.00	36.65	91.00	20.80	36.68
122.00	19.80	36.67	122.00	19.80	36.69
182.00	18.60	36.55	182.00	18.60	36.56
243.00	18.10	36.47	243.00	17.80	36.47
300.00	17.80	36.44	300.00	17.50	36.44
365.00	17.40	36.41	365.00	17.40	36.41
400.00	17.18	36.39	400.00	17.32	36.39
600.00	15.83	36.12	600.00	16.10	36.17
800.00	12.08	35.53	800.00	12.13	35.59
1000.00	8.22	35.14	1000.00	8.13	35.14
1500.00	4.28	35.00	1500.00	4.37	35.00
2000.00	3.53	34.97	2000.00	3.54	34.97
2500.00	3.26	34.96	2500.00	3.25	34.96
3000.00	2.99	34.96	3000.00	2.95	34.97
3500.00	2.58	34.93	3500.00	2.59	34.93
4000.00	2.42	34.91	4000.00	2.41	34.91
5000.00	2.31	34.89	5000.00	2.31	34.89

TABLE 21F

FNWC XBT DATA

RUN NO.	DATE	TIME (GMT)	LAT	LONG
1	19 Jan.	1330	30-04	77-16
2	24 "	2130	30-25	68-43
3	27 "	1200	30-26	68-31
4	26 "	0445	29-44	69-28
5	28 "	1315	30-19	71-21
1A	21 Jan	0510	30-10	73-10
2A	"	0800	30-15	72-55
3A	"	1205	30-15	72-35
4A	"	1535	30-15	72-00
5A	"	1830	30-20	71-45
6A	"	2145	30-20	71-15
7A	22 Jan.	0030	30-20	70-55
8A	"	0330	30-25	70-35
9A	"	0630	30-27	70-15
10A	"	0930	30-27	69-55
11A	"	1300	30-27	69-35

TABLE 22

NAVELEX, 1974
SUMMARY - XBT
TIME, POSITION

Depth (m)	#1	#2	#3	#4	#5	AVG
0	23.5	22.0	21.5	21.5	22.0	22.1
120	22.7	20.5	20.0	21.0	21.1	21.1
240	20.1	19.1	18.6	19.1	19.1	19.2
370	18.3	18.2	18.2	18.4	18.4	18.3
490	17.6	17.3	17.1	17.6	17.6	17.4
610	16.3	15.6	15.3	15.9	16.1	15.8
730	13.7	12.8	12.6	13.4	13.3	13.2
850	11.0	10.0	9.5	10.5	10.5	10.3
975	8.0	7.6	7.75	8.1	8.25	7.9
1100	7.25	6.5	6.5	6.5	7.0	6.8
1220	6.4	6.0	5.7	5.9	5.9	6.0
1340	5.8	5.8	5.5	5.5	5.5	5.6
1460	5.5	5.5	5.2	5.3	5.3	5.4
1585	5.3	5.3	5.0	5.0	5.25	5.2
1710	5.0	5.0	5.0	5.0	5.0	5.0
1830	5.0	5.0	5.0	5.0	5.0	5.0

TABLE 23

NAVELEX - SUMMARY

RUNS 1-5

No. 1

Z (m)	^{o}C	S^{o}/oo	Z	^{o}C	S^{o}/oo
0	23.5	36.76	1000	8.5	35.40
50	23.0	36.76	1100	7.2	35.12
100	23.0	36.72	1200	6.5	35.10
130	22.5	36.71	1300	6.0	35.08
150	22.0	36.70	1400	5.5	35.08
200	20.5	36.68	1500	5.5	35.08
250	20.0	36.68	1600	5.2	35.08
300	19.0	36.60	1700	5.0	35.06
350	18.5	36.60	1800	5.0	35.06
400	18.0	36.56			
450	18.0	36.56			
500	17.5	36.50			
550	17.5	36.44			
600	16.5	36.40			
650	15.5	36.26			
670	15.0	36.23			
700	14.5	36.10			
720	14.0	36.00			
750	13.0	36.00			
800	12.5	35.80			
850	11.0	35.62			
900	10.5	35.50			
920	10.0	35.46			
950	9.2	35.40			

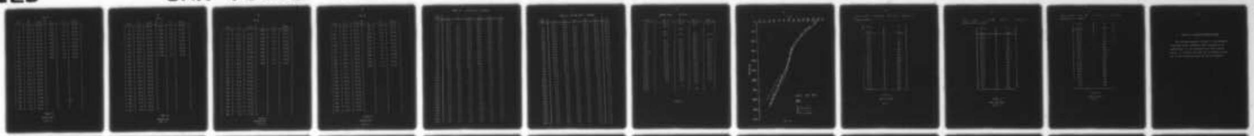
TABLE 24

NAVELEX XBT

RUN #1

AD-A051 517   INSTITUTE FOR ACOUSTICAL RESEARCH MIAMI FLA   F/G 8/10
BEAR BUOY: THE ENGINEERING DOCUMENTATION FOR SCIENTIFIC APPLICA--ETC(U)
NOV 76 K L ECHTERNACHT   N00014-74-C-0229
UNCLASSIFIED   IAR-76002   NL

2 OF 2
AD
A051517



END
DATE
FILMED
4-78
DDC

No. 2

Z (m)	^{o}C	S^{o}/oo	Z	^{o}C	S^{o}/oo
0	22.0	36.76	1000	7.2	35.40
20	21.0	36.76	1050	7.0	35.20
50	21.8	36.76	1100	6.5	35.12
100	20.5	36.72	1200	6.0	35.10
150	20.5	36.70	1300	6.0	35.08
170	20.0	36.69	1400	5.5	35.08
200	19.5	36.68	1500	5.5	35.08
250	19.0	36.68	1600	5.2	35.08
300	18.5	36.60	1700	5.0	35.06
350	18.2	36.60	1800	5.0	35.06
400	18.0	36.56			
450	17.8	36.56			
500	17.2	36.50			
550	16.5	36.44			
600	15.8	36.40			
630	15.0	36.33			
650	14.5	36.26			
700	13.5	36.10			
720	13.0	36.00			
750	12.2	36.00			
800	11.0	35.80			
850	10.0	35.62			
900	9.0	35.50			
950	8.0	35.40			

TABLE 25

NAVELEX XBT

RUN # 2

No. 3

Z (m)	^{o}C	S^{o}/oo	Z	^{o}C	S^{o}/oo
0	21.5	36.76	1000	7.5	35.40
50	21.0	36.76	1100	6.5	35.12
100	20.5	36.72	1200	5.8	35.10
120	20.0	36.72	1300	5.5	35.08
150	19.5	36.70	1400	5.5	35.08
200	19.2	36.68	1500	5.0	35.08
250	18.5	36.68	1600	5.0	35.08
300	18.2	36.60	1700	5.0	35.08
350	18.2	36.60	1800	5.0	35.06
400	18.0	36.56			
450	17.5	36.56			
500	17.0	36.50			
550	16.5	36.44			
600	15.5	36.40			
650	14.5	36.26			
670	14.0	36.20			
700	13.5	36.10			
750	12.0	36.00			
770	11.5	35.91			
800	10.8	35.80			
830	10.0	35.71			
850	9.5	35.62			
900	8.8	35.50			
950	8.0	35.40			

TABLE 26

NAVELEX XBT

RUN #3

No. 4

Z (m)	°C	S°/oo	Z	°C	S°/oo
0	-	-	1000	7.8	35.40
20	21.5	36.76	1050	7.0	35.20
50	21.0	36.76	1100	6.5	35.12
100	21.0	36.72	1200	6.0	35.10
120	21.0	36.72	1300	5.5	35.08
150	20.0	36.70	1400	5.5	35.08
200	19.2	36.68	1500	5.2	35.08
250	19.0	36.68	1600	5.0	35.08
280	18.5	36.65	1700	5.0	35.06
300	18.8	36.60	1800	5.0	35.06
350	18.5	36.60			
400	18.2	36.56			
450	18.0	36.56			
500	17.5	36.50			
550	16.8	36.44			
600	16.0	36.44			
650	15.2	36.26			
680	14.5	36.25			
700	14.0	36.10			
750	12.8	36.00			
800	11.5	35.80			
850	10.5	35.62			
900	9.5	35.50			
950	8.5	35.40			

TABLE 27
NAVELEX XBT
RUN NO 4

No. 5

Z(m)	^{o}C	S^{o}/oo	Z	^{o}C	S^{o}/oo
0	22.0	36.76	880	10.0	35.56
50	21.8	36.76	900	9.5	35.50
100	21.2	36.72	950	8.8	35.40
130	21.0	36.71	1000	7.8	35.40
150	21.0	36.70	1100	7.0	35.12
170	20.0	36.69	1200	6.0	35.10
200	19.5	36.68	1300	5.5	35.08
250	19.0	36.68	1400	5.5	35.08
300	18.8	36.60	1500	5.2	35.08
350	18.5	36.60	1600	5.2	35.08
400	18.2	36.56	1700	5.0	35.06
450	18.0	36.56	1800	5.0	35.06
500	17.5	36.50			
550	17.0	36.44			
600	16.2	36.40			
620	16.0	36.38			
650	15.0	36.26			
680	14.5	36.25			
700	14.2	36.10			
750	13.0	36.00			
770	12.5	35.93			
800	11.5	35.80			
830	11.0	35.70			
850	10.5	35.62			

TABLE 28

NAVELEX XBT

RUN No 5

TABLE 29 IAR XBT DATA - NAVELEX

Depth (m)	1A	2A	3A	4A	5A	6A
0	22.0	-	21.8	21.8	22.0	21.9
50	21.5	-	21.7	21.7	21.8	21.9
100	21.1	21.3	21.5	21.5	21.7	21.5
150	20.1	20.3	19.8	19.9	20.0	20.0
200	19.4	19.5	19.5	19.4	19.3	19.3
250	18.7	19.1	19.0	18.9	18.8	18.9
300	18.3	18.6	18.6	18.5	18.5	18.6
350	18.1	18.3	18.3	18.2	18.3	18.3
400	17.8	18.0	18.0	17.9	18.0	18.0
450	17.6	17.7	17.8	17.6	17.6	17.7
500	17.4	17.2	17.4	17.2	17.2	17.3
550	16.8	16.6	16.8	16.1	16.4	16.6
600	15.8	15.8	16.0	16.0	15.4	15.7
650	14.8	14.8	14.9	15.0	14.5	14.5
700	13.7	13.7	14.1	13.6	13.4	13.5
750	12.5	12.5	13.1	12.1	12.0	12.4
800	10.9	11.4	12.0	10.8	10.5	11.3
850	10.0	10.0	10.9	9.8	9.9	10.2
900	9.2	9.1	9.7	9.1	8.7	9.2
950	8.2	8.2	8.7	8.1	7.9	8.4
1000	7.5	7.6	7.8	7.5	7.4	7.7
1050	7.0	7.0	7.2	7.0	7.0	7.2
1100	6.5	6.7	6.8	6.5	6.6	6.7
1150	6.2	6.3	6.4	7.0	6.3	6.5
1200	5.9	5.8	6.2	6.7	6.0	6.2
1250	5.7	5.8	5.8	6.6	5.8	6.0
1300	5.6	5.6	5.7	6.0	5.7	5.8
1350	5.5	5.6	5.6	5.9	5.5	5.6
1400	5.4	5.5	5.5	5.9	5.5	5.5
1450	5.3	5.5	5.4	5.6	5.3	5.4
1500	5.1	5.4	5.3	5.6	5.3	5.3
1550	5.0	5.3	5.2	5.7 *	5.2	5.3
1600	5.0	5.2	5.1	5.9 *	5.1	5.2
1650	5.0	5.1	5.1	5.9 *	5.1	5.0
1700	5.0	5.1	5.0	5.9 *	5.1	5.0
1750	4.9	5.0	5.0	5.7 *	5.1	5.0
1800	4.9	5.0	5.0	5.6 *	5.0	4.9
1850	4.9	5.0	5.0	5.6 *	5.0	4.9

TABLE 30 IAR XBT DATA - NAVELEX

Depth (m)	7A	8A	9A	10A	11A	$\overline{T}$
0	21.8	22.0	-	21.6	21.6	21.8
50	21.7	21.8	21.9	21.3	21.3	21.7
100	21.7	21.7	21.9	21.1	21.2	21.5
150	21.1	20.6	21.5	21.0	20.5	20.4
200	19.8	19.5	19.9	20.0	19.7	19.6
250	19.0	19.1	19.3	19.4	19.2	19.0
300	18.5	18.7	18.7	18.8	18.8	18.6
350	18.4	18.4	18.4	18.5	18.5	18.3
400	18.2	18.0	18.1	18.3	18.2	18.0
450	17.8	17.7	17.8	17.9	17.7	17.7
500	17.6	17.4	17.5	17.5	17.4	17.4
550	16.8	16.6	16.9	16.9	17.0	16.7
600	16.0	15.7	16.0	16.2	16.1	15.9
650	15.0	14.7	15.0	15.1	15.0	14.8
700	13.8	13.8	14.0	14.0	13.8	13.8
750	12.7	12.5	12.8	12.8	12.6	12.5
800	11.7	11.3	11.6	11.6	11.5	11.3
850	10.4	10.1	10.5	10.5	10.1	10.2
900	9.4	9.1	9.6	9.3	9.3	9.2
950	8.6	8.2	8.5	8.5	8.3	8.3
1000	7.8	7.5	7.8	7.6	7.6	7.6
1050	7.2	7.0	7.0	7.1	7.0	7.1
1100	6.8	6.6	6.7	6.7	6.6	6.6
1150	6.5	6.2	6.3	6.3	6.3	6.4
1200	6.2	6.0	6.0	6.2	6.2	6.1
1250	6.0	5.8	5.9	5.9	5.9	5.9
1300	5.8	5.6	5.7	5.9	5.8	5.7
1350	5.6	5.5	5.6	5.6	5.6	5.6
1400	5.5	5.4	5.5	5.5	5.5	5.5
1450	5.3	5.3	5.3	5.5	5.4	5.4
1500	5.8	5.2	5.2	5.4	5.3	5.4
1550	5.7	5.2	5.2	5.3	5.2	5.3
1600	5.3	5.2	5.2	5.2	5.1	5.2
1650	5.1	5.1	5.1	5.1	5.1	5.1
1700	5.0	5.1	5.0	5.1	5.1	5.0
1750	4.9	5.0	5.0	5.0	5.0	5.0
1800	4.9	5.0	5.0	5.0	5.0	5.0
						5.0

SUMMARY WHOI - XBT DATA

Depth (m)	No. 1	No. 2	No. 3	$\overline{T}_{wn}$
0	31.0	29.0	29.0	29.7
10	29.4			
38		28.8		
43	29.2			
48	28.4	27.5	28.0	28.0
67			26.5	
95	25.7	24.4	25.0	25.0
141.5	23.9	22.7	23.5	23.4
189	21.8	21.2	21.8	21.6
236	20.3	19.6	20.5	20.1
282.5	19.2	18.5	19.5	19.1
331.5	18.3	18.1	18.6	18.3
376	17.7	17.7	18.2	17.9
425	17.0	17.2	17.7	17.3
474	16.2	16.7	17.3	16.7
523	15.2	15.8	16.8	15.9
570	13.6	14.8	15.8	14.7
615	12.2	13.8	14.8	13.6
661	11.2	13.2	13.7	12.7
709	10.3	12.6	12.5	11.8
753	9.0	11.3	11.5	10.6
797	8.2	10.3	10.6	9.7
830			9.6	
843		9.6		
870			9.0	

TABLE 31

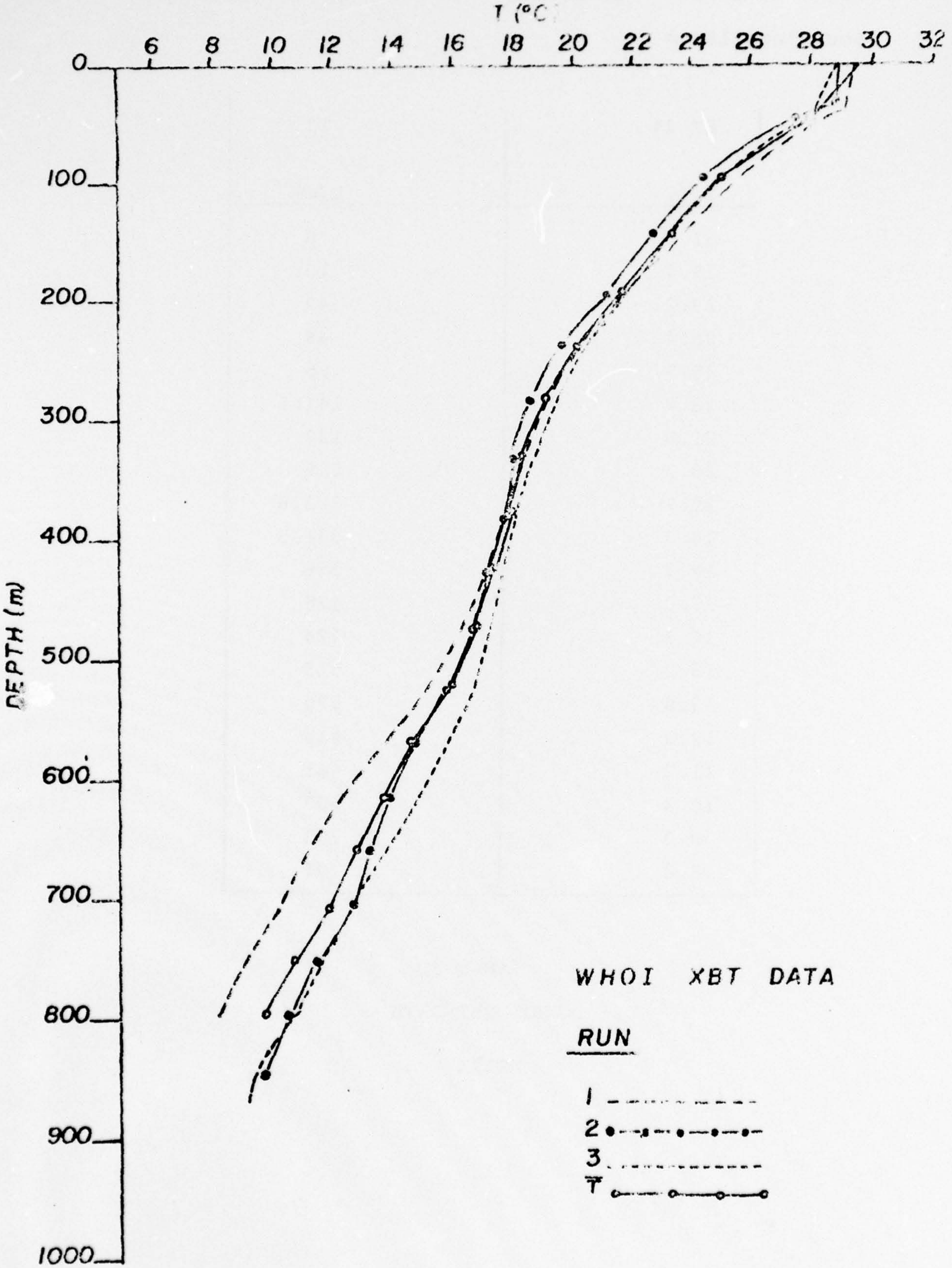

T (°C)
6
8
10
12
14
16
18
20
22
24
26
28
30
32
0
100
200
300
400
500
600
700
800
900
1000
DEPTH (m)
WHOI XBT DATA
RUN
1
2
3
T̄

Fig. 24

Sept. 3, 1974 19:35 GMT $25^{\circ}23.9'$ N $76^{\circ}18.6$ W

Sounding 1180 m

BT 24	T7
T °C	D(m)
31.0	0
29.4	10
29.2	43
28.4	48
25.7	95
23.9	141.5
21.8	189
20.3	236
19.2	282.5
18.3	331.5
17.7	376
17.0	425
16.2	474
15.2	523
13.6	570
12.2	615
11.2	661
10.3	709
9.0	753
8.2	797

TABLE 32

WHOI XBT DATA

BT 24

Sept. 4, 1974 03:15 GMT 25° 55 N 75° 09.3' W

Sounding 4500 m (chart)

BT 25 T °C	T7 D(m)
29.0	0
28.75	38
27.5	48
24.4	95
22.7	141.5
21.2	189
19.6	236
18.5	282.5
18.1	331.5
17.7	376
17.2	425
16.7	474
15.8	523
14.8	570
13.75	615
13.2	661
12.6	709
11.3	753
10.3	797
9.6	830

TABLE 33

WHOI XBT DATA
BT 25

Sept. 4, 1974 14:25 GMT 26. 25.2' N 73° 59.4' W
Sounding 4575 m (chart)

BT 26	T7
T °C	D(m)
29.0	0
28.0	48
26.5	67
25.0	95
23.5	141.5
21.8	189
20.5	236
19.5	282.5
18.6	331.5
18.2	376
17.7	425
17.3	474
16.8	523
15.8	570
14.8	615
13.7	661
12.5	709
11.5	753
10.6	797
9.6	843
9.0	870

TABLE 34

WHOI XBT DATA

BT 26

Appendix B: Sensor Calibration Data

The following appendix includes 1) the thermistor (individual probe) calibration data supplied by the manufacturer, 2) the thermistor unit time constant tests, 3) linearity test data for the amplifier stage, and 4) the calibration data for the inclinometers.

Thermistor S/N

°C	1A	1B	2A	2B	3A	3B	4A	4B
1	10,860.	10,871.	10,970.	10,916.	10,900.	10,970.	10,895.	10,820.
3	9,946.6	9,956.6	10,016.	9,990.6	9,976.2	10,033.	9,973.3	9,906.9
5	8,755.9	8,772.1	8,820.1	8,802.1	8,780.1	8,822.5	8,782.3	8,732.3
8					8,011.1	8,058.1	8,013.5	7,977.1

Table 35A

Thermistor Probe Calibration Data

	Thermistor S/N							
°C	5A	5B	6A	6B	7A	7B	8A	8B
3	9,901.6	9,950.2	9,967.7	9,989.2	10,011.	10,016.	10,034.	10,039.
5	8,720.8	8,766.6	8,760.5	8,795.9	8,818.1	8,826.1	8,806.0	8,830.2
8	7,960.2	8,014.9	7,999.6	8,028.4	8,048.0	8,057.7	8,039.1	8,058.0

Table 35B

Thermistor Probe Calibration Data

Thermistor S/N

°C	9A	9B	10A	10B	11A	11B	12A	12B
3	9,936.3	10,003.0	9,970.4	9,979.7	10,017.	10,017.		
5	8,762.4	8,833.0	8,781.5	8,797.6	8,822.4	8,811.4	8,820.1	8,800.3
8	8,001.3	8,062.0	8,014.3	8,033.0	8,054.0	8,040.2	8,050.0	8,029.1
10	7,351.0	7,410.7	7,360.7	7,370.1	7,397.0	7,377.5	7,390.5	7,373.2
12							6,788.7	6,770.7

Table 35C

Thermistor Probe Calibration Data

Thermistor S/N

°C	13A	13B	14A	14B	15A	15B	16A	16B
5	8,781.6	8,770.1	8,791.6	8,819.5				
8	8,019.3	8,008.0	8,021.4	8,052.0	8,020.0	8,028.1	8,032.1	8,048.4
10	7,364.2	7,352.2	7,369.2	7,392.2				
12	6,790.1	6,774.1	6,771.1	6,792.0	6,763.8	6,770.6	6,773.6	6,754.5
15	5,971.2	5,970.2	5,976.2	6,002.2	5,977.0	5,984.0	5,987.0	5,971.0
18					5,284.4	5,288.4	5,289.3	5,279.0

Table 35D

Thermistor Probe Calibration Data

Thermistor S/N

°C	17A	17B	18A	18B	19A	19B	20A	20B
10	7,352.0	7,326.0						
12	6,754.8	6,783.0						
15	5,974.0	5,999.5	5,982.5	5,981.5	5,962.2	5,974.3	5,978.3	5,984.1
18	5,288.3	5,288.2	5,285.5	5,285.5	5,270.3	5,275.3	5,284.6	5,288.3
20	4,854.4	4,893.4	4,861.1	4,861.0	4,853.0	4,852.1	4,862.8	4,861.4
22			4,505.4	4,505.1	4,500.4	4,498.1	4,507.6	4,505.4
25			4,006.1	4,002.7	4,000.8	3,999.7	4,007.1	4,006.6
30					3,307.8	3,303.0	3,309.3	3,309.2

Table 35E

Thermistor Probe Calibration Data

	Thermistor S/N			
°C	21A	21B	22A	22B
15	5,989.3	5,981.1	5,993.1	5,999.0
18	5,293.9	5,282.1	5,296.3	5,301.5
20	4,867.2	4,858.0	4,868.3	4,877.9
22	4,509.8	4,501.6	4,512.4	4,519.9
25	4,010.1	4,002.5	4,011.3	4,017.3
30	3,311.4	3,307.8	3,314.9	3,319.0

Table 35F

Thermistor Probe Calibration Data

Probe S/N	Calibration Points 1	2	3	4	5	6
1	.10	.10	.18			
2	.49	.25	.20			
3	.64	.57	.48	.59		
4	.69	.66	.57	.45		
5	.49	.52	.69			
6	.22	.40	.36			
7	.05	.10	.12			
8	.05	.27	.24			
9	.68	.80	.76	.81		
10	.09	.18	.23	.13		
11	0.0	.12	.17	.26		
12	.22	.26	.23	.26		
13	.13	.14	.16	.24	.02	
14	.32	.38	.31	.31	.44	
15	.10	.10	.12	.08		
16	.20	.28	.27	.19		
17	.35	.42	.43	.01	.80	
18	.02	0.0	.01	.01	.08	
19	.20	.09	.02	.05	.03	.14
20	.10	.07	.03	.05	.01	0.0
21	.14	.22	.19	.18	.19	.11
22	.10	.10	.20	.17	.15	.12

Table 36

Percentage Difference in Calibration Values Between Matched Thermistor Pairs

Table 37 Time Constant: Thermistor Unit - Deployment Configuration

Sec Elapsed	min	sec	Cu	TCR	Sec Elapsed	min	sec	Cu	TCR
0	0	00	0.0	0.0	840	14	00	54.7	.663
		30	0.1	.001			30	55.8	.677
60	1	00	0.9	.011	900	15	00	56.8	.689
		30	2.0	.024			30	57.8	.702
120	2	00	4.0	.049	960	16	00	58.8	.714
		30	6.4	.078			30	59.6	.724
180	3	00	9.0	.109	1020	17	00	60.3	.732
		30	12.0	.146			30	61.1	.742
240	4	00	14.8	.180	1080	18	00	62.0	.753
		30	17.7	.215			30	62.6	.761
300	5	00	20.5	.249	1140	19	00	63.3	.768
		30	23.3	.283			30	63.9	.776
360	6	00	25.9	.314	1200	20	00	64.5	.783
		30	28.5	.346			30	65.0	.789
420	7	00	30.9	.375	1260	21	00	65.5	.794
		30	33.2	.403			30	66.0	.802
480	8	00	35.4	.430	1320	22	00		
		30	37.6	.457			30		
540	9	00	39.5	.480					
		30	41.5	.504					
600	10	00	43.3	.525					
		30	45.0	.547					
660	11	00	46.7	.567					
		30	48.1	.584					
720	12	00	49.6	.603					
		30	51.0	.620					
780	13	00	52.3	.635					
		30	53.5	.650					

TABLE 38 TEST 1 Time Constant: Thermistor Unit Imbedded

Time	(sec)	R(Ω)	TCR	T_t	T-bath	Comments
1437	00	3850	0.	26.0	4.99	Air temp
	30				"	at time
1438	00				"	of start,
	30	4470	.18	22.2	"	$\bar{T}_a$= 26.30
1439	00				"	
	30				"	
1440	00	5495	.43	17.0	"	
	30	5770	.48	15.8	"	T_{63}= 12.76
1441	00	6050	.54	14.7	"	t_o = 1437:00.0
	30	6310	.58	13.7	"	t_{63}= 1441:58.2
1442	00	6570	.63	12.7	"	t_{63}=4m58.2S
	30	6809	.68	11.8	"	
1443	00	7030	.71	11.1	"	
	30	7225	.74	10.4	"	
1444	00	7400	.77	9.9	"	
	30	7550	.79	9.4	"	
1445	00	7690	.81	9.0	"	
	30	7815	.83	8.6	"	
1446	00	7920	.84	8.3	"	
	30	8010	.86	8.0	"	
1447	00	8096	.87	7.8	"	
	30	8160	.88	7.6	"	
1448	00	8225	.88	7.4	"	
	30	8275	.89	7.3	"	
1449	00	8320	.90	7.1	"	
	30	8360	.90	7.0	"	
1450	00	8395	.91	6.9	"	
	30	8425	.91	6.8	"	
1451	00	8451	.91	6.8	"	
	30	8473	.92	6.7	"	
1452	00	8492	.92	6.7	"	
	30	8508	.92	6.6	"	
1453	00	8523	.92	6.6	"	
	30	8535	.93	6.5	"	
1454	00	8545	.93	6.5	"	
	30	8554	.93	6.5	"	

TABLE 38 (cont)

Time	(sec)	R(Ω)	TCR	T_t	T-bath	Comments
1455	00	8562	.93	6.5	4.99	
	30	8569	.93	6.5	"	
1456	00	8575	.93	6.4	"	
	30	8580	.93	6.4	"	
1457	00	8584	.93	6.4	"	
	30	8588	.93	6.4	"	
1458	00	8591	.93	6.4	"	
	30	8594	.93	6.4	"	
1459	00	8596	.93	6.4	"	
	30	8598	.93	6.4	"	
1500	00	8600	.93	6.4	"	
	30	8602	.93	6.4	"	
1501	00	8603	.93	6.4	"	
	30					

E_{in} (mv)	E_{in} (x 50) (mv)	Meas E_{out} (v)	$\delta(E_{out} - E_{in} x\ 50)$
11.7	.585	.575	-.010
20.2	1.010	1.018	+.008
30.1	1.505	1.497	-.008
40.7	2.035	2.028	-.007
50.0	2.500	2.492	-.008
60.2	3.010	2.997	-.013
70.2	3.510	3.500	-.010
80.0	4.000	3.988	-.012
90.1	4.505	4.493	-.010
100.3	5.015	5.000	-.015

Deviation (heating/cooling) $\simeq$ 0.005V

Table 39

Signal Conditioner Amplifier -

Linearity Test

Table 40 Calibration Data

Inclinometer - 1

°Tilt	1 mv	2 mv	3 mv	4 mv
0	0	0	0	0
3	6	5	5	11
6	17	17	19	26
9	35	35	32	39
12	46	49	46	50
15	55	55	57	60
18	66	70	65	71
21	74	73	74	80
24	83	83	88	93
27	93	91	91	98
30	100	99	100	110

Inclinometer - 2

°Tilt	1 mv	2 mv	3 mv	4 mv
0	0	0	0	0
3	12	16	8	6
6	24	26	23	22
9	35	38	35	34
12	48	50	51	47
15	58	63	56	61
18	70	70	65	67
21	80	81	75	76
24	90	89	85	87
27	96	95	94	94
30	100	100	100	100

INCLINOMETER CALIBRATION

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(Bermuda Eleuthera Acoustics Range)

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The intent of this report is to serve as the working documentation of the BEAR Buoy System for scientific application. As such the report is oriented toward the engineering aspects of the project. The report includes the following: (1) a general description of the system by component subsystem; (2) a detailed engineering breakdown of the sensor subsystem and the development of the rationale used to determine the operational ranges of the → (over)

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sensors; (3) calibration procedures and the development of the data conversion transfer functions; and (4) a summary of the post-data processing methodology.

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