FISHERIES RESEARCH BOARD OF CANADA

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ON-LINE DIGITIZING OF EXPENDABLE BATHYTHERMOGRAPH DATA WITH A SHIPBOARD COMPUTER

by

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1. Introduction

A small computer manufactured by Hewlett-Packard was used to digitize the analog signal of an expendable bathythermograph (XBT) system (Sippican model Mk-2A recorder and model LM-2A launcher). This digitizing system was successfully used at sea in September 1969. The purpose of this manuscript is to describe this digitizing system (hardware) and associated computer programs (software).

2. Description of the hardware

Hardware includes the XBT, a small computer and its peripherals, and a time base generator. A block diagram of the system is shown in Fig. 1.

2.1 The XBT

A complete description of the XBT is given by the manufacturer's manuals (Sippican, 1968). Two features essential for digitization are a retransmitting potentiometer and an internal switch.

2.1.1 The retransmitting potentiometer

The XBT recorder was modified by the manufacturer to include a retransmitting potentiometer. The retransmitting potentiometer provides a variable resistance dependent on the BT temperature input. By proper phasing with the recorder shaft and the application of precision voltages, the variable resistance can be converted to an analog voltage whose magnitude is a direct measurement of temperature. This is shown schematically in Fig. 2.

The retransmitting potentiometer operates as a slave to the recorder output shaft and is thus dependent on the accuracy of the recorder's mechanical loop. Since coupling to the recorder is mechanical, output isolation from the internal recorder electronics is insured. The design of the potentiometer taper compensates for the thermistor non-linearity; output is linearized and directly proportional to temperature. For the output to give a direct reading of the actual temperature, proper phasing adjustment between the recorder and potentiometer shafts is necessary. This phasing is achieved as follows:

(1) Adjust the phasing of the servo feedback potentiometer to the recorder shaft as called out in the recorder calibration procedure (Sippican Corp., 1968).

(2) Set the recorder to 16.7 C ± 0.1 C.

(3) With the dual-gang pot clamping ring loosened, rotate the rear potentiometer section with respect to the front section until the rear armature is at mid resistance.

(4) Recheck that the recorder is still set to 16.7 C and retighten the clamping ring.

(5) Set the recorder to -1.1 C ± 0.1 C and adjust V_1 for an output voltage of 3.00 volts (Refer to Fig. 2).

(6) Set the recorder to 34.4 C ± 0.1 C and adjust V_2 for an output voltage of 9.40 volts.

(7) Recheck steps 5 and 6.

(8) Set the recorder to 16.7 C ± 0.1 C and check for an output voltage of 6.20 volts.

Other information pertinent to the potentiometer is as follows:

Resistance value	- 10,000 ohms
Resolution	- Infinite
Linearity	- 0.1% full scale
Noise resistance	- 150 ohms maximum
Cost (manufacturer-installed)	- $300 C (approximate)

2.1.2 <u>The switch</u>

Because only temperature is present, for a depth-temperature relationship an external time base is necessary to provide depth readings. A switch is provided on the XBT recorder which is 'on' when the retransmitting potentiometer is actually retransmitting temperature information, i.e. when the XBT probe is in the water. This switch is used to initiate digitization.

2.2 <u>The computer</u>

The heart of the digitizing system is a Hewlett-Packard 2115A computer which has 16-bit words, an 8K memory and eight input-output channels. Seven of the input-output channels are used as follows: teletype (HP 2752A), photo-reader (HP 2737A), high-speed paper tape punch (HP 2753A), reed scanner (HP 2912A), digital voltmeter (HP 2401C) input and output, and time base generator (HP 12539A). A software "driver" was provided with each of these peripheral units. Each peripheral is assigned an octal unit reference number and an octal input-output (I/O) channel number.

Table 1 lists the peripheral units, the associated drivers, their unit reference numbers, and the I/O channel numbers as used in September 1969. The I/O channel number of a peripheral device can be changed simply by moving the interface board in the input-output frame. This may be done at any time and is called "reconfiguration"; it necessitates configuring some of the standard software. It may be desirable to reconfigure the system when new peripherals are added, or when the priorities are changed, since peripheral units with lower I/O channel numbers may interrupt those with higher I/O channel numbers.

The digitizing system may be programmed in Algol, Fortran, Basic or an assembly language. Source programs are punched on the teletype and compiled in two passes. Result of compilation is a relocatable binary tape. Software known as the BASIC CONTROL SYSTEM is used to run the program or to produce an absolute binary tape which is loaded alone to run the program.

2.3 The time base generator

The time base generator, available as an interface kit from Hewlett-Packard, provides the computer with a train of program interrupts at real time intervals. It consists of a crystal oscillator and decade frequency dividers, contained on one I/O card. The interval between interrupts is computer selectable in decade steps from 100 micro seconds to 1000 seconds (approximately 16 minutes); time-of-day, if required, is obtained from this real time reference by software. Accuracy is better than 1/2 second per 24-hour day, under typical operating conditions.

The software used to control the time base generator consists of the Bailey clock routine (see Huyer and Collins, 1969, p. 9).

3. The digitizing program, XBT1

3.1 Description

The XBT digitizing program was written in Fortran and an absolute binary tape was produced. This tape is referred to as program XBT1. A logic (flow) diagram is given in Fig. 3. Important relationships are:

(1) the relationship between elapsed time, t, and depth, z,

$z = t/1.6 \times 10^3$

where z is in meters and t is seconds;

(2) $\Delta\theta$ = the change in temperature necessary for a temperature value to be stored;

$= 0.1$ C

(note that this means that the temperature between digitized values is equal to the first temperature value);

(3) N = the dimension of the temperature and depth arrays

= 500.

These relationships have been determined empirically in the northeast Pacific. Experience suggests that the lower limit for $\Delta\theta$ is 0.05 C.

3.2 Operating procedures

These instructions are for the absolute binary tape of XBT1. Procedures for preparing an absolute tape are described in Appendix A.

(1) With the computer off, make sure that the interface boards of the peripheral units are in the input-output channels shown in Table 1.

(2) Connect XBT D.C. voltage outputs to the scanner as shown in Fig. 2.

Switch - Channel No. 10

Temperature - Channel No. 11

(3) Connect scanner output J8 to digital voltmeter D.C. voltage input.

(4) Turn on digital voltmeter, scanner, XBT Recorder reload light will go "ON". (Check to see that chart is indexed properly.)

(5) Set scanner controls:

RESET/START	on EXT
MODE	on MON
SYSTEM CONTROL	on REMOTE

(6) Set voltmeter controls:

FUNCTION	to EXT SEL
SAMPLE PERIOD	to EXT SEL
SAMPLING RATE	to fully clockwise
RANGE	to any position except INT-IV, INT + IV, or ZERO
ATTENUATION	at about middle of range

(7) Turn on computer and photo-reader.

(8) Place absolute binary tape of XBT1 in the photo-reader with the narrow portion of the tape toward the photo-reader. Thread the leader portion of the tape through the brake, under the hold-down spring and under the rubber roller. Raise the tape guide until RUN is exposed.

(9) Set the computer switch register to 177ØØ.

(10) Press LOAD ADDRESS.

(11) Set LOADER switch to ENABLED.

(12) Press PRESET.

(13) Press RUN. The tape is read through the photo-reader. When it stops the T-register should contain 1Ø2Ø77. If not, see note below.

(14) Set LOADER switch to PROTECT.

(15) Remove tape from photo-reader and rewind it.

(16) Turn teletype to LINE, and turn high-speed punch on. Press the white button on the punch to produce some leader and thread the tape so it will be wound onto the spool. Check to make sure there is sufficient paper tape on the supply reel.

(17) Set switch register to 3634.

(18) Press LOAD ADDRESS.

(19) Press RUN.

(20) Enter heading data as requested. Separate the data by a space or comma. After each response check that there is no error. If an error was made, type the key labelled RUB OUT and then RETURN, LINE FEED, and repreat the entire line. If there is no error, type RETURN, LINE FEED.

(21)

Teletype prints:	Response
(a) ENTER TIME (Hrs:Min:Sec)	- Type in the Greenwich mean time in hours, minutes and seconds, separating them with a space. Press RUN on computer.
(b) ENTER MONTH, DAY	- The date G.M.T.
(c) ENTER IDENTIFICATION NUMBER	- An integral number.

(22) Insert probe in launcher. After closing breech, wait a minimum of five seconds for the recorder to assume launcher condition before launching probe. (Reload light will go "out" and launch light will go "on".)

(23) Pull the probe launch pin.

(24) When the probe reaches maximum depth of 450 m, data are punched from the high speed punch. The teletype prints:

TIME RAN OUT.

READY FOR NEXT CAST.

ENTER IDENTIFICATION NUMBER.

(25) In case of a shallow depth or if probe wire breaks, the teletype prints:

VOLTAGE TOO HIGH, or VOLTAGE TOO LOW.

READY FOR NEXT CAST.

ENTER IDENTIFICATION NUMBER

(26) Press the white button on tape punch to produce some leader.

(27) If a new probe is to be launched soon, go to step 21c.

(28) Turn off all equipment.

(29) Rewind the data tape as it is wound with the beginning on the inside of the spool. Keep both the data tape and the teletype printout.

(30) At the next station, if the computer has not been used for another program, turn on all equipment and begin at step 17.

Note: The program is loaded by the BASIC BINARY LOADER or ABSOLUTE BLOCK LOADER which is "permanently" stored in the computer's memory. If the tape is partially read and the computer halts with 1Ø2Ø11 in the T-register, a checksum error has occurred. Release the tape in the photo-reader, slide it back to the beginning of the record, i.e., to the preceding gap of four feed holes, put tape guide back up to RUN, and press RUN. If computer halts again at the same place, check the tape for tears or dirt. If the tape looks all right, clean the photo-reader, and check that the tape guide is not loose. If it is, tighten the screw; there is a hole in the front of the casing so the screw can be reached easily.

If the tape is not read at all, it is likely that the ABSOLUTE BLOCK LOADER has been destroyed. For checking or restoring it, see page 7. When it has been restored, begin again at step 8.

3.3 Results

Figure 4 illustrates a temperature section plotted from digitized XBT data. STD data were obtained at each end of the section and used to check digitized XBT results. At most depths, XBT temperatures differed from STD temperatures by less than 0.1 C; the depth of temperature features such as the mixed layer depth and the depth of the temperature maximum differed by less than 5 m.

When the XBT probe hit the bottom, the resulting temperature spike was not sufficient to cause the program to initialize and punch the stored data. However, the temperature spike was of sufficient amplitude to be stored and thus provided a feature in the digitized data field which could be used for editing purposes (see Table 3).

4. THE ABSOLUTE BLOCK LOADER

The ABSOLUTE BLOCK LOADER, also known as the BASIC BINARY LOADER, is a program stored in the sixty-four highest memory addresses (from 177ØØ to 17777). It is used to load all absolute binary programs. A switch on the front panel of the computer is used to protect this portion of memory during normal operation; before the ABSOLUTE BLOCK LOADER can be used, this switch must be set to ENABLED.

Occasionally, through errors in operation, some or all of the ABSOLUTE BLOCK LOADER can be lost from memory. When this occurs, it can be restored manually using the switch register and LOAD ADDRESS and LOAD MEMORY (see operating manual) or by using a "BOOTSTRAP LOADER" as follows:

(1) Set switch register to 2Ø.

(2) Press LOAD ADDRESS.

(3) Set switch register to each of the numbers listed; after each press LOAD MEMORY.

1Ø3712
1Ø2312
Ø24Ø21
1Ø2512
ØØ1727
1Ø3712
1Ø2312
Ø24Ø26
1Ø2412
18ØØØ1
ØØ6ØØ4
Ø24Ø2Ø

(4) Set switch register to 2Ø.

(5) Place BOOTSTRAP tape in the photo-reader so that a short (about half inch) section of the tape without feed holes precedes the first character.

(6) Set LOADER switch to ENABLE.

(7) Press PRESET.

(8) Press RUN.

(9) When the tape stops press HALT.

(10) Set switch register to 17763. Press LOAD ADDRESS. Set switch register to 1Ø3712. Press LOAD MEMORY.

(11) Set switch register to 1Ø2312. Press LOAD MEMORY.

(12) Set switch register to 17766. Press LOAD ADDRESS. Set switch register to 1Ø2512. Press LOAD MEMORY.

(13) Set LOADER switch to PROTECT.

The ABSOLUTE BLOCK LOADER is restored.

REFERENCES

Huyer, A., and C. A. Collins. 1969. On-line digitizing of salinity-temperature-pressure data with a shipboard computer. Fish. Res. Bd. Canada Tech. Rept. No. 152, 26 pp.

Sippican Corporation. 1968. Instructions for installation, operation and maintenance of Sippican expendable bathythermograph system. R-467B. Marion, Mass.

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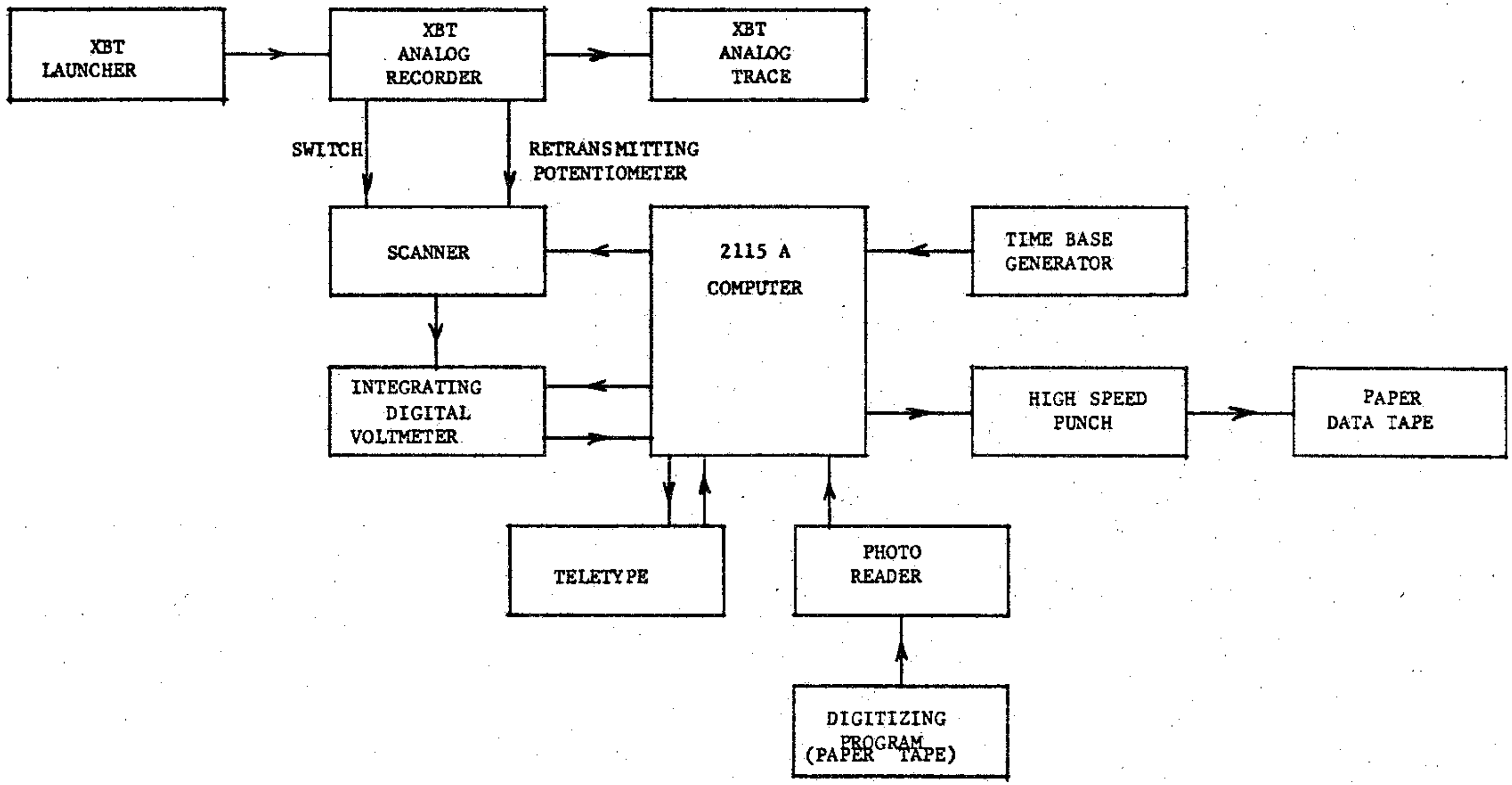

Fig. 1. Block diagram of the hardware (expendable bathythermograph and computer).

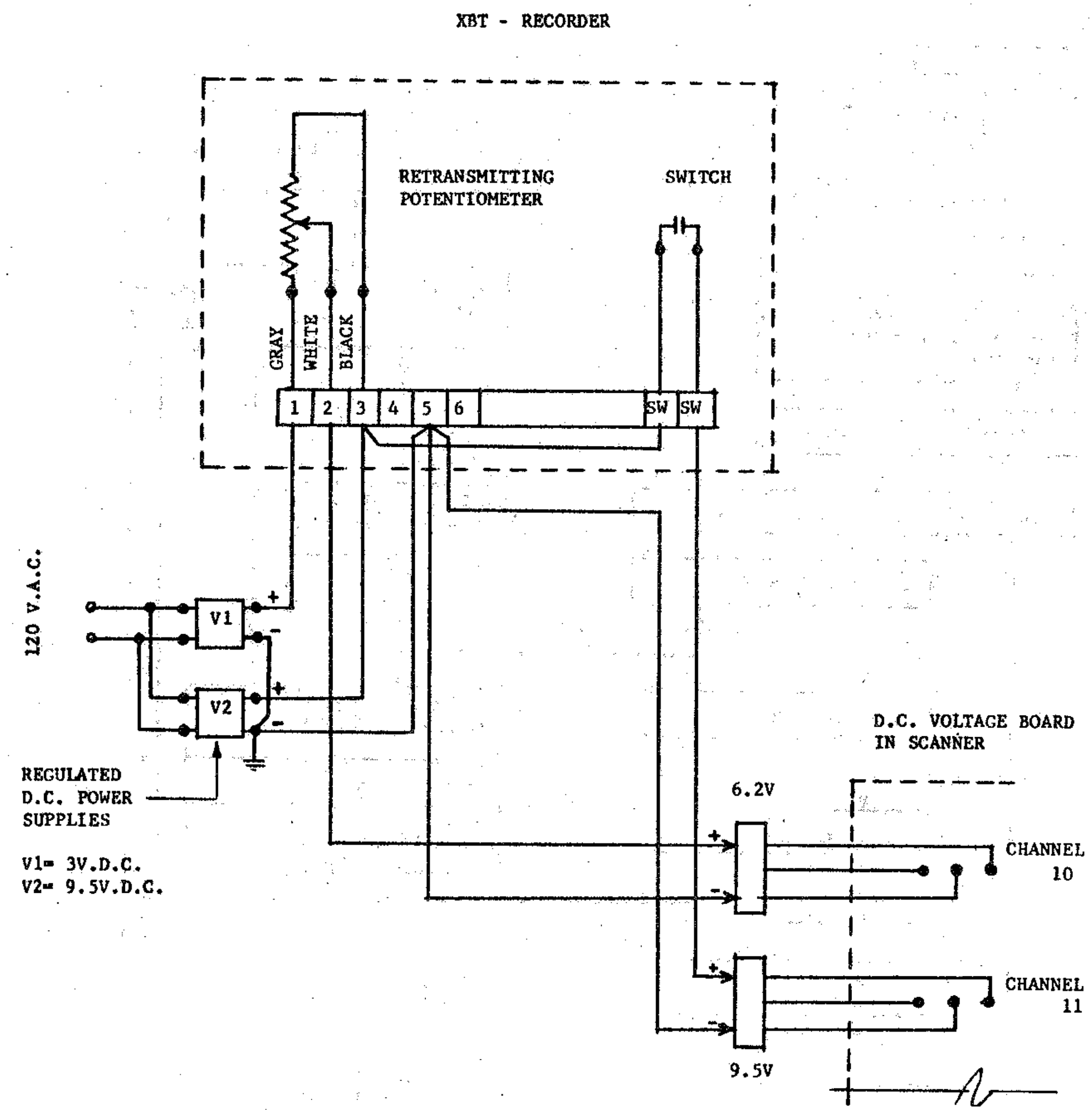

Fig. 2. Schematic wiring diagram illustrating connections between retransmitting potentiometer, switch, rectifiers, and scanner.

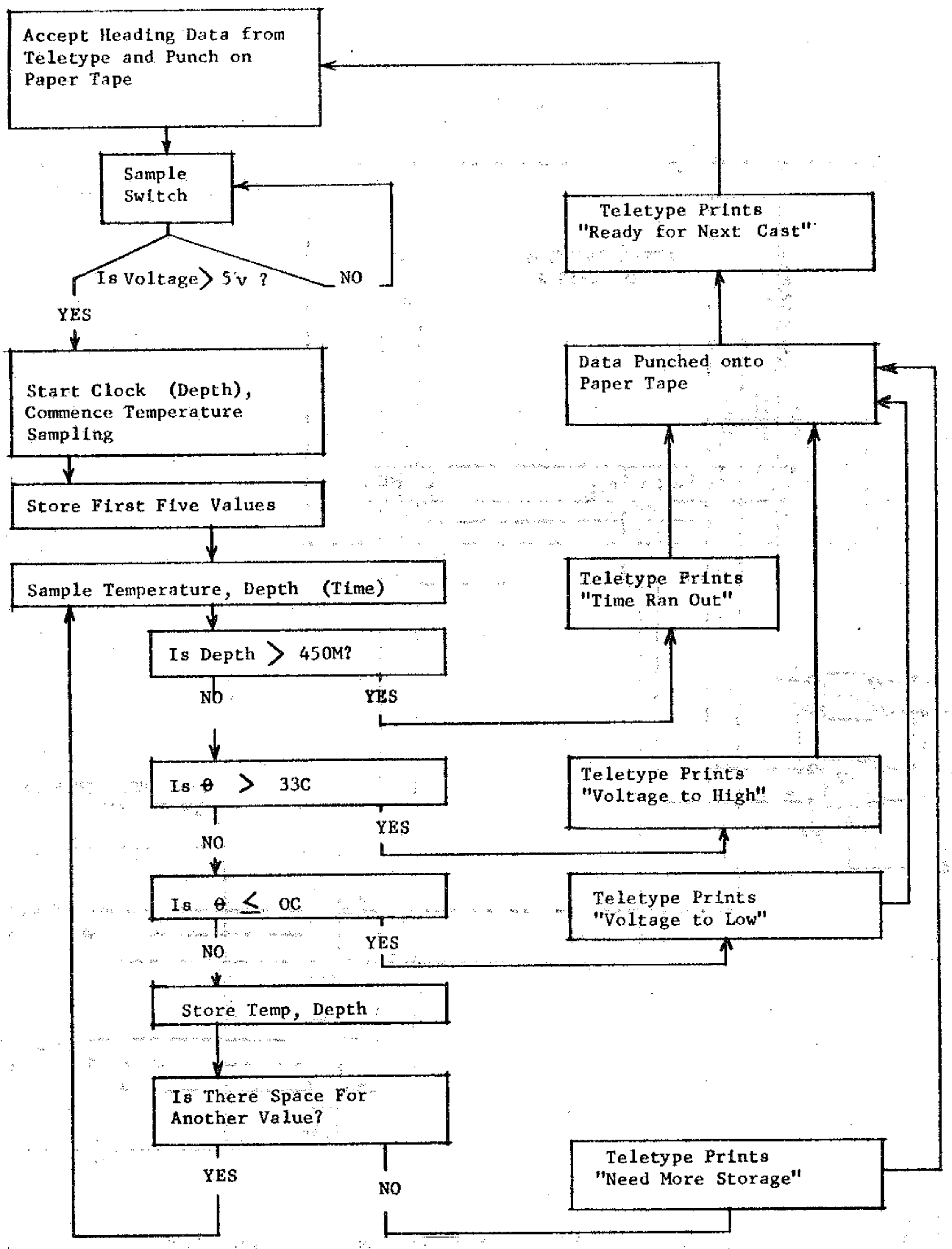

Fig. 3. Logic (flow) diagram for program XBT1.

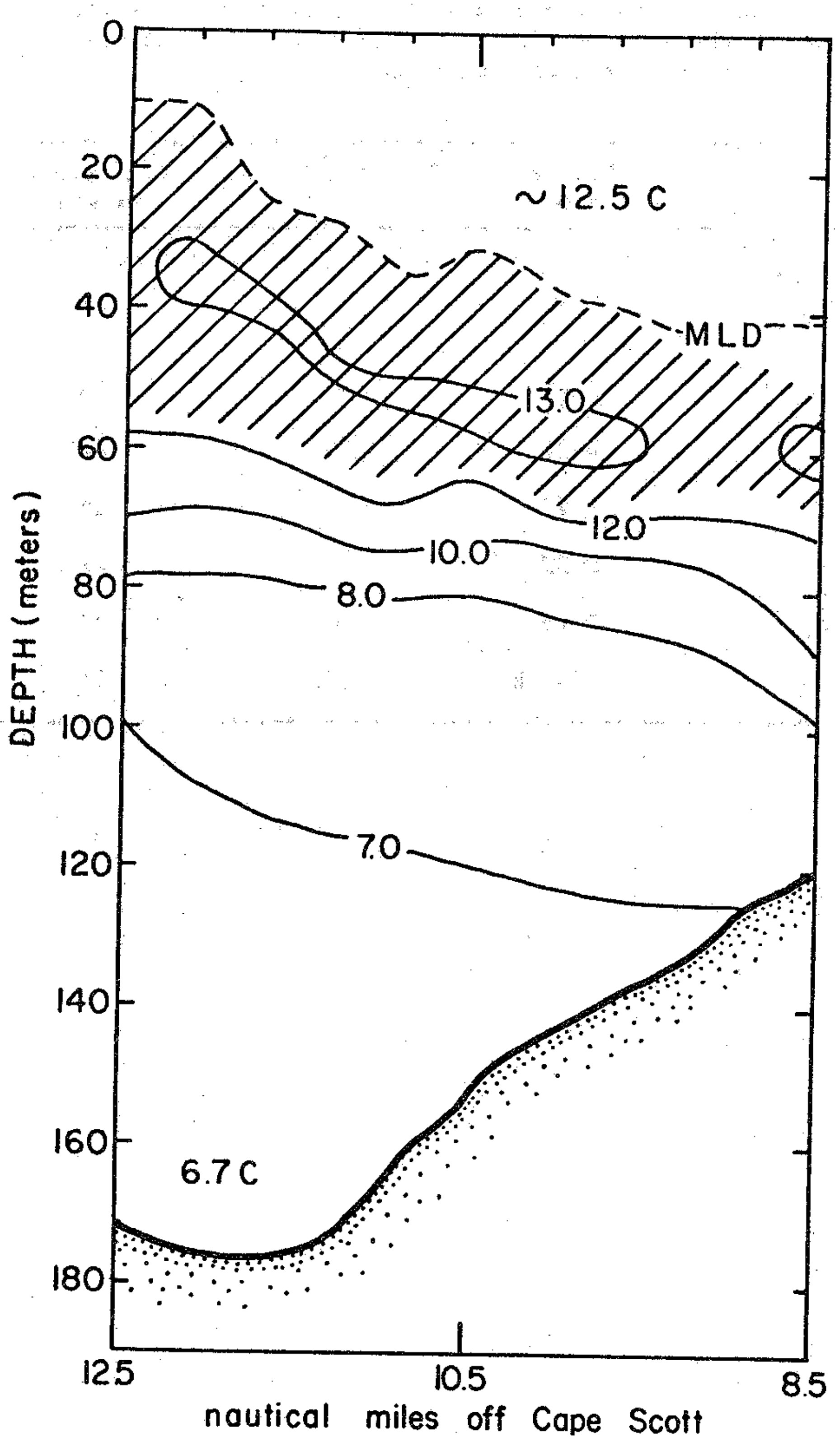

Fig. 4. Temperature section off Cape Scott, October 1969.

Table 1. Equipment table of the computing system, showing the peripheral equipment, the names of the software "drivers", unit reference numbers and input-output channel numbers.

Peripheral equipment	Driver name	Unit reference number	I/O channel number
Data source interface from digital voltmeter	D.40	7	13
Program interface for digital voltmeter	D.41	10	15
Photo-reader	D.Ø1	11	12
High speed punch	D.Ø2	12	16
Teletype	D.ØØ	13	11
Time base generator	D.43	14	10
Reed scanner	D.42 B	15	14

TABLE 2. FORTRAN LISTING OF PROGRAM XBT1.

```
     FTN,B
     PROGRAM XBT1
     DIMENSION VOLTS (5ØØ), ITIME (5ØØ)
C
C    DIGITIZE XBT CAST
C
C    SCANNER CHANNELS ARE ASSIGNED AS FOLLOWS
C            CHANNEL 1Ø  - TEMPERATURE
C            CHANNEL 11  - SWITCH
C
C
             IDSI=7B
             IDVM=1ØB
             ISCNR=15B
             CALL SETUP
C
C    ENTER CAST INDENTIFICATION
C
             WRITE (2,3Ø)
     3Ø   FORMAT ("ENTER MONTH, DAY")
          READ (1,*) MO, I DAY
      3   I=1
          WRITE (4,42)
     42   FORMAT (1ØØX)
          WRITE (2,32)
     32   FORMAT ("ENTER IDENTIFICATION NUMBER")
          CALL DATIM (IH,IM,IS)
          IGMT=1ØØ*IH+IM
          READ (1,*)  IDNO
          WRITE (4,4Ø ) MO, I DAY, IGMT, IDNO
     4Ø   FORMAT (4 (15,1X), 1ØX)
C
C    START CHECKING SWITCH
C
C    REMOVE HOLDOFF
     1 WRITE (IDSI)
C    SELECT VOLTMETER FUNCTION
     WRITE (IDVM) 244B
C    SELECT CHANNEL
     WRITE (ISCNR) 11, Ø
     1ØØ READ (IDSI,25) DUMMY, IFUN
     25 FORMAT (2X,E1Ø.Ø,14)
     IF (DUMMY-5.) 1,2
C
C    COMMENCE XBT DIGITIZATION
C
```

TABLE 2 CONT'D

```
C         STARTS CLOCK AND GENERATES TICKS AT 1ØMS INTERVALS
     2    CALL STCLK (1)
     51   WRITE (IDSI)
          WRITE (IDVM) 144B
          WRITE (ISCNR) 1Ø,Ø
          READ (IDSI,25) DUMMY, IFUN
          CALL  RDCLK(M)
          IF(712Ø-M) 56,56,5Ø
     5Ø   DUMMY = 5.* (1Ø.*DUMMY -32.)/9.
          IF (DUMMY-33.)52,52,57
     52   IF (DUMMY) 58,58,55
     55   IF (I-25)2Ø,2Ø,21
     2Ø   VOLTS (I) = DUMMY
          ITIME (I)= M
          IF (5ØØ - I) 59,59,6
      6   I=I+1
          GO TO 51
     21   IF (ABS (DUMMY-VOLTS (I-1))-Ø.1) 51,2Ø,2Ø
C
C         DIAGNOSTIC COMMENTS
C
     56   WRITE (2,6Ø)
     6Ø   FORMAT ("TIME RAN OUT")
          GO TO 53
     57   WRITE (2,61)
     61   FORMAT ("VOLTAGE TOO HIGH")
          GO TO 53
     58   WRTE (2,62)
     62   FORMAT ("VOLTAGE TOO LOW")
          GO TO 53
     59   WRITE (2,63)
     63   FORMAT ("NEED MORE STORAGE")
C
C         OUTPUT ON PAPER TAPE
C
     53   ILAST=I-1
          DO 54 K=1,ILAST
          C=ITIME(K)
          DEPTH=C/16.
          WRITE (4,41) DEPTH, VOLTS (K)
     41   FORMAT (2F8.2)
     54   CONTINUE
C
C    CONTINUE TO NEXT CAST
C
     WRITE (2,31)
     31   FORMAT ("READY FOR NEXT CAST")
          GO TO 3
          END
          END$
```

TABLE 3. THE REQUESTING AND ENTERING OF HEADING DATA VIA THE TELETYPE FOR PROGRAM XBT1.

```
ENTER TIME (HRS:  MIN:  SEC)
Ø8 3Ø ØØ
ENTER MONTH, DAY
1Ø 9
ENTER IDENTIFICATION NUMBER
78
TIME RAN OUT
READY FOR NEXT CAST
ENTER IDENTIFICATION NUMBER
78
TIME RAN OUT
READY FOR NEXT CAST
ENTER IDENTIFICATION NUMBER
1
VOLTAGE TOO HIGH
READY FOR NEXT CAST
ENTER IDENTIFICATION NUMBER
2
VOLTAGE TOO LOW
READY FOR NEXT CAST
ENTER IDENTIFICATION NUMBER
3
VOLTAGE TOO HIGH
READY FOR NEXT CAST
ENTER IDENTIFICATION NUMBER
```

TABLE 4. SAMPLE OUTPUT OF PROGRAM XBT1.

10	9	1038	1Ø
.19	12.22		
1.31	12.56		
2.44	12.56		
3.56	12.61		
4.75	12.61		
4.Ø25	12.50		
54.00	12.72		
55.19	12.89		
56.31	13.00		
64.31	12.89		
67.81	12.67		
71.25	12.39		
72.37	12.28		
73.5Ø	11.89		
74.69	11.78		
75.81	11.67		
76.94	11.56		
8Ø.44	11.39		
82.69	11.22		
83.87	10.94		
85.00	10.61		
86.12	10.39		
88.44	10.28		
89.56	10.17		
91.87	9.39		
93.06	8.94		
94.19	8.67		
95.31	8.56		
97.62	8.22		
98.75	8.00		
99.94	7.78		
104.50	7.67		
107.94	7.56		
12Ø.56	7.33		
121.69	7.56		
100.19	7.67		
215.69	7.78		
270.75	7.89		