TECHNICAL REPORT

SUBMARINE OCEANOGRAPHIC DIGITAL DATA SYSTEM

Oceanographic Branch
Marine Surveys Division

JUNE 1961

U. S. NAVY HYDROGRAPHIC OFFICE
WASHINGTON 25, D. C.
Price 35 cents

ABSTRACT

This report describes a system for sensing, processing, and recording sound velocity, sea water temperature, wave heights, ambient light, date, time, transducer depth, and certain ship motions. The system is digital and is designed principally for use aboard submarines. The output is punched paper tape for computer entry and all variables are displayed and recorded in their absolute units. The system, in a slightly modified form, is now in use aboard the USS [redacted] block dia[redacted]

FOREWORD

The importance of the submarine as a working platform for the Oceanographer is rapidly gaining recognition. As the youthful science of oceanography pushes forward in its quest to probe the mysteries held by the oceans, the need for stability and maneuverability in the oceanic environment becomes evident. These requirements are fully attained with the modern submersible. Space economy, a most critical item for this type of data collection, is used sensibly in the prototype recording system described.

If one can envision the day when the entire underwater fleet is oceanographically operational, the gap between the known and unknown could be seen to close rapidly within the field of oceanography.

E. C. STEPHAN
Rear Admiral, U. S. Navy
Hydrographer

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I. INTRODUCTION

This report presents a description of and operating instructions for the Submarine Oceanographic Digital Data System which was developed by the U. S. Navy Hydrographic Office* and was installed on USS ARCHERFISH (AGSS-311) in December 1960 following several months testing of various components aboard USS REDFIN (SS-272).

The System in its complete form is described in Appendix C of Hydrographic Office Special Publication 41 (SP-41)**; however, the installation on ARCHERFISH does not include devices for measuring ambient light, conductivity, and roll angle. The following new concepts in the collection of oceanographic data are employed by this system: First, the operation of equipment is virtually automatic except for manual introduction of ship's position and switching on and off. Second, the electronic signals received from the transducers are processed in such a manner as to display and record all variables in their ultimate absolute units. Third, the output of the system can be read directly from the digital displays and is put on digital punched paper tape. This tape can be fed into the Hydrographic Office computer for further analysis. Fourth, data from transducers are recorded simultaneously, and each data sample includes all the supporting information such as time, date, and submarine position.

Data collection with the System is associated with general submarine maneuvers (Appendix A).

Mode 1

This mode is used to measure depth of transducers, sound velocity, and sea temperature.

Mode 2

This mode is used to measure ambient light as well as those parameters listed in Mode 1.

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* Submarine Systems Section, Oceanographic Branch.

** U. S. NAVY HYDROGRAPHIC OFFICE. SP-41, Special Publication, Oceanographic Instrumentation, Final Report of the Committee on Instrumentation. 2d ed. Washington, D. C. 1960.

Mode 3

This mode is used to determine wave heights by measuring the time required for sound pulses to reach the water surface and return to the submarine; however, roll angle or heave measurements can be made also.

Figure 1 is a block diagram of the operational system, showing the transducer and recording relationship. Also shown are Modes 1 and 3 with their options.

II. SYSTEM DESCRIPTION

A. General

The System consists of sensors for measuring the appropriate variables, digitizing components to convert sensor outputs to digital form where required, displays for all recorded information, a scanner to feed the information alternately from each sensor to the recorder or tape punch, a digital recorder for optional use in lieu of the tape punch, and a tape punch to make a permanent record of the recorded variables for direct input to the Hydrographic Office digital computer. A Flexowriter can be added, for verification of tape punch data in the field. The oceanographic console is shown in Plate 1 and Figure 2. Plate 2 shows the individual components of the system.

B. Transducers (shown on Plate 2)

The vibrotron, sound velocity, thermister, and fathometer transducers are all mounted in a single transducer housing as shown in Figure 3. This housing requires a single foundation and can be mounted anywhere on topside of the submarine in the free flow of water. On the ARCHERFISH, the transducer housing is mounted on the forward gun mount deck near the number 48 frame.

Pressure (depth) is sensed by a vibrating wire transducer (vibrotron) in the sensor housing. Its output is a frequency inversely proportional to depth. This instrument has undergone repeated tests aboard the REDFIN without a single failure.

Sound velocity is obtained from a Bureau of Standards velocimeter located in the sensor housing. This instrument was found to be quite reliable during shipboard operations. The output of this transducer is a frequency which is directly proportional to sound velocity in meters per second.

Temperature is measured with a temperature probe consisting of dual thermister elements. Output of the bridge is a voltage which is directly proportional to temperature. The thermisters were tested both in the laboratory and aboard the REDFIN and yield accuracies better than $\pm$ 0.1°C.

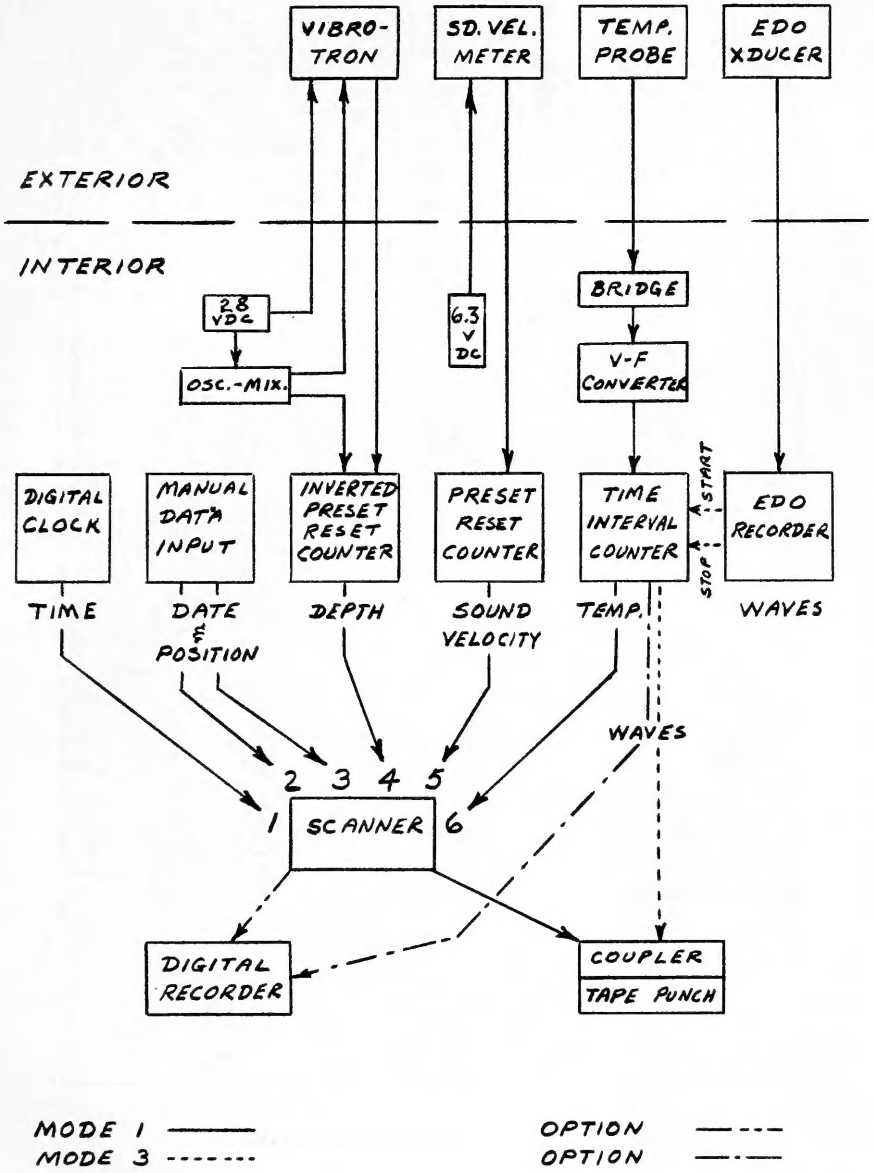


FIGURE 1. BLOCK DIAGRAM SUBMARINE OCEANOGRAPHIC DIGITAL DATA SYSTEM

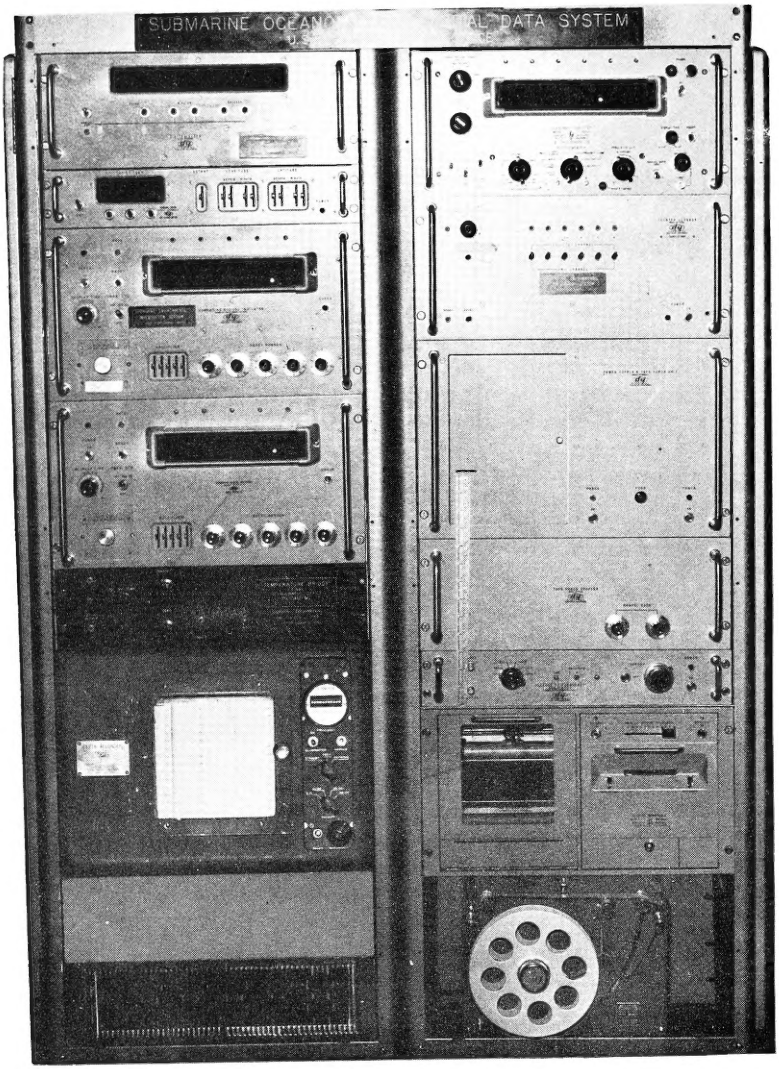


PLATE I. OCEANOGRAPHIC CONSOLE

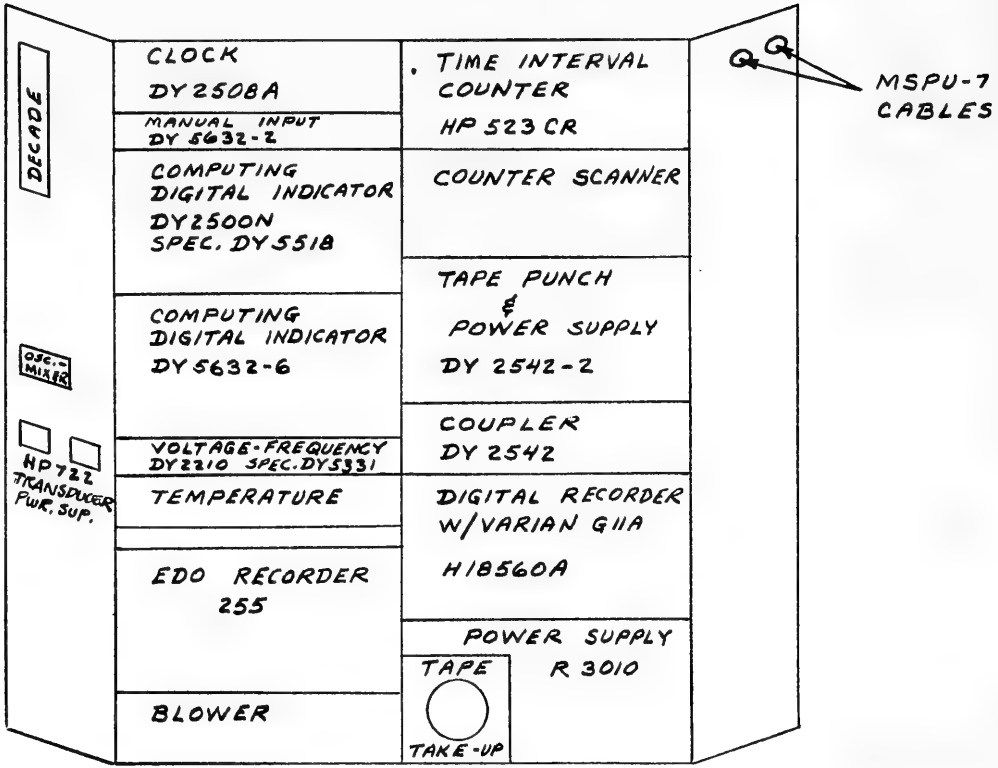


FIGURE 2. DIAGRAM OF OCEANOGRAPHIC CONSOLE

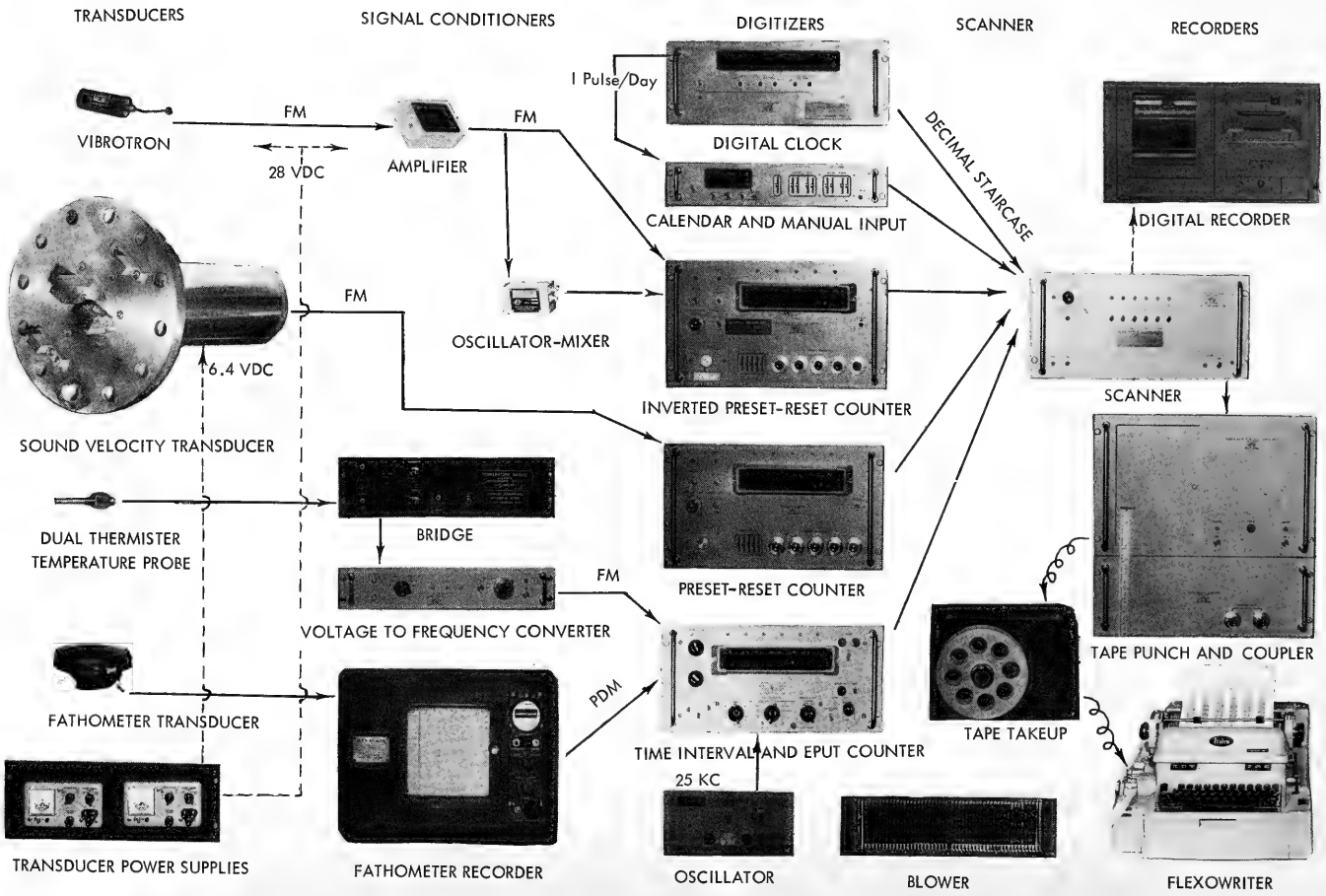


PLATE 2. COMPONENT PARTS OF SUBMARINE OCEANOGRAPHIC DIGITAL DATA SYSTEM

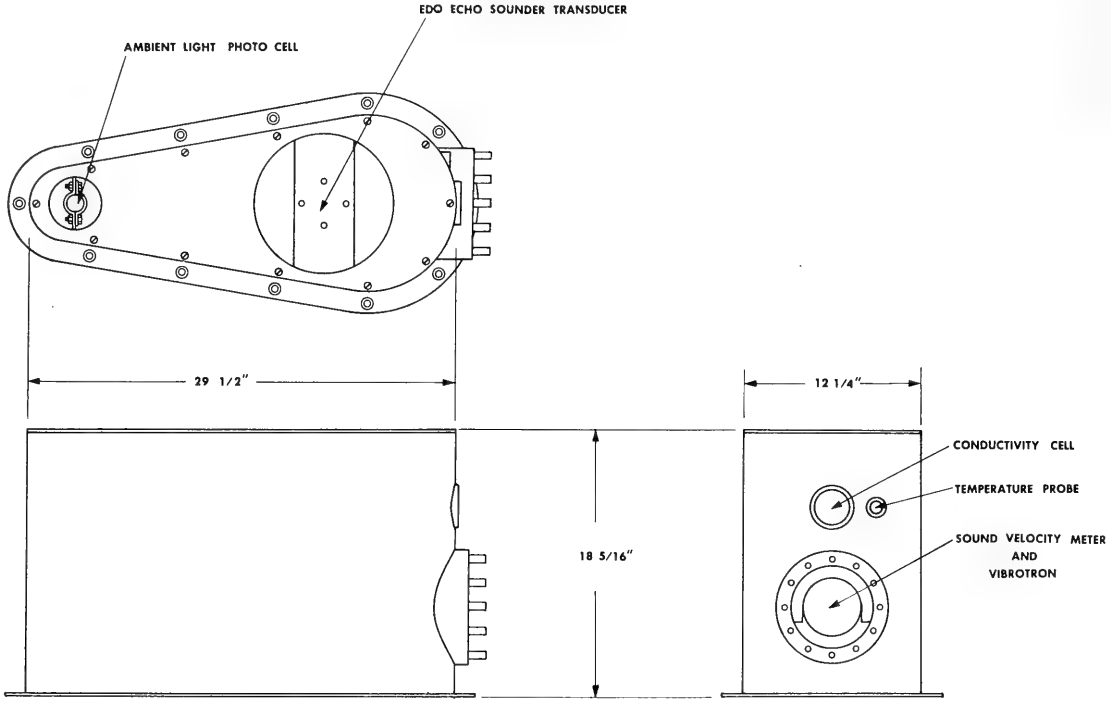


FIGURE 3. HOUSING FOR SENSING ELEMENTS FOR SUBMARINE OCEANOGRAPHIC DIGITAL DATA SYSTEM

Wave heights are recorded from an EDO 255B transducer mounted in the transducer housing. The distance to the surface is recorded approximately every 0.6 second. These data are adequate to allow spectral analysis of wave heights.

C. Signal Conditioners

In the case of depth and sound velocity transducers, outputs are frequency modulated. The thermister bridge output is converted to FM by the use of a linear voltage to frequency converter.

The depth transducer output is linearized by the use of an oscillator-mixer driven by the depth transducer, it's output is fed into the time base of the depth counter. This counter is modified to count backwards since the depth transducer output is inversely proportional to depth. Special counter reset dials allow the counter to be reset to any desired number, thus effecting an automatic zero suppress operation.

D. Digitizers

Signals from the transducers are converted to absolute units and digitized by the use of two variable time base counters and a time interval counter.

Echo sounder outgoing pulses and return echo gate an electronic counter, resulting in digitized values of distance to the surface in feet and tenths, or metric units if desired.

Outputs from the clock, calendar, and manual inputs are in digital form and require no further digitizing.

E. Recorders

The scanner is a six-digit, six-channel stepping switch which allows the digitized outputs of each sensor to pass in sequence to the digital recorder or tape punch coupler.

The digital recorder is operated by the scanner and provides a printed record similar to a cash register receipt of all variables sampled by the scanner.

The paper tape punch is connected to the scanner by means of the coupler. The coupler's function is to convert the parallel data from the scanner to the serial form required by the tape punch. Both coupler and tape punch operate directly from the scanner and cannot be used simultaneously with the digital recorder. The punched tape format is compatible with the electronic computer and the Flexowriter.

F. Cables

Two specially constructed 100-foot sections of MSPU-7 sonar cable connect the deck-mounted transducer with the below deck recording area. The outboard sensing element ends are fitted with waterproofed female Joy connectors, built to withstand the pressures encountered during diving. The cables lead from the sensor housing, passing under the deck, and enter the hull through two "E"-type hull fittings in the recording compartment.

Figure 4 illustrates cable connections at the oceanographic console. Spare conductors are shown which can be used to expand the system for measuring other variables. Special cables (Fig. 5) were necessary to connect the sound velocity-depth housing to the MSPU-7 cable.

III. OPERATING INSTRUCTIONS

A. Standby

Prior to beginning the actual collection of data, power to all equipment should be on, the digital clock running, the EDO recorder on "STANDBY," all counters set on "INFINITY," and the tape punch switch in the "OFF" position (the above conditions will prevail at all times, except when data is being collected, or when trouble shooting is in progress).

B. Format of Data Message

The data message varies in format with the modes employed, and prior to periods of data collection or calibration appropriate format codes are manually introduced into the tape punch coupler. See Appendix B for format codes.

All data messages can be read directly from the digital recorder, or can be recorded on digital punch tape.

1. Mode 1 data message

a. Digital Recorder

Recorder	6002335
	5015156
Paper	4000243
	3507655
Movement	2130038
	1111827

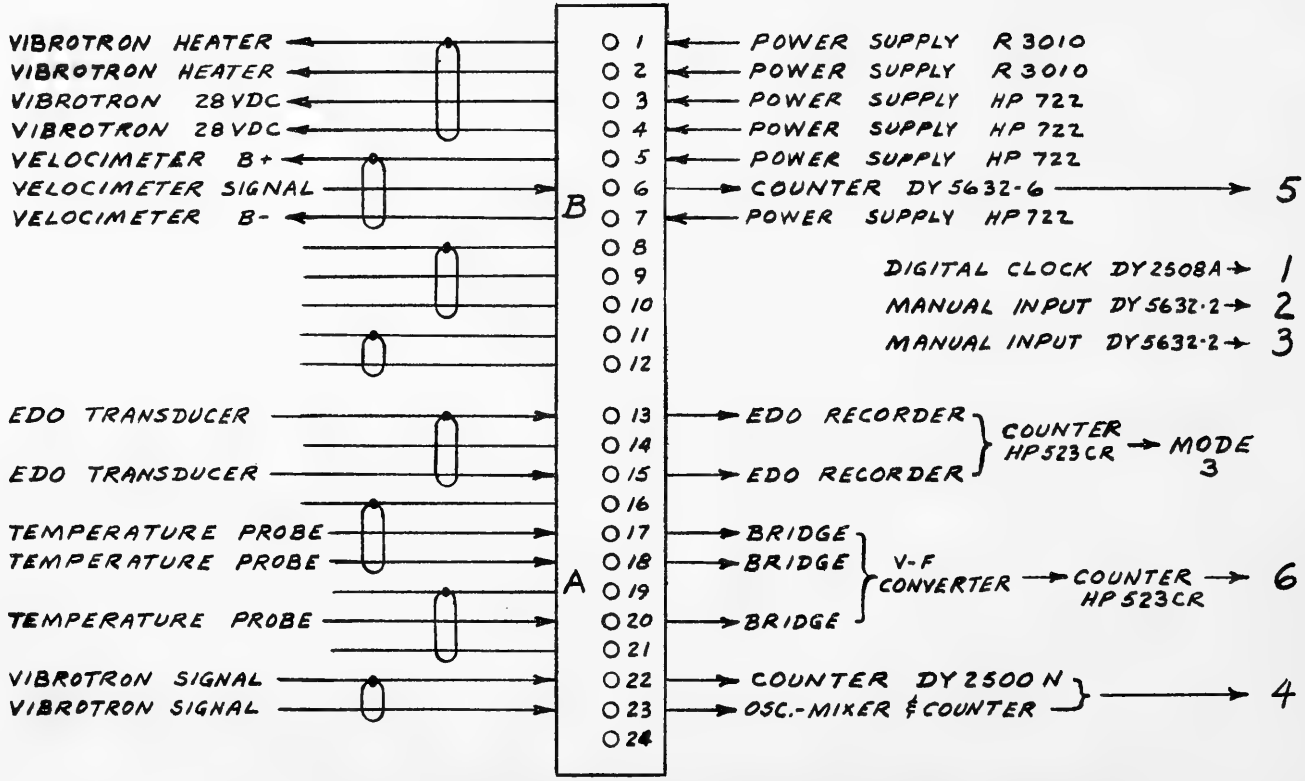


FIGURE 4. CABLE CONNECTIONS AT THE CONSOLE

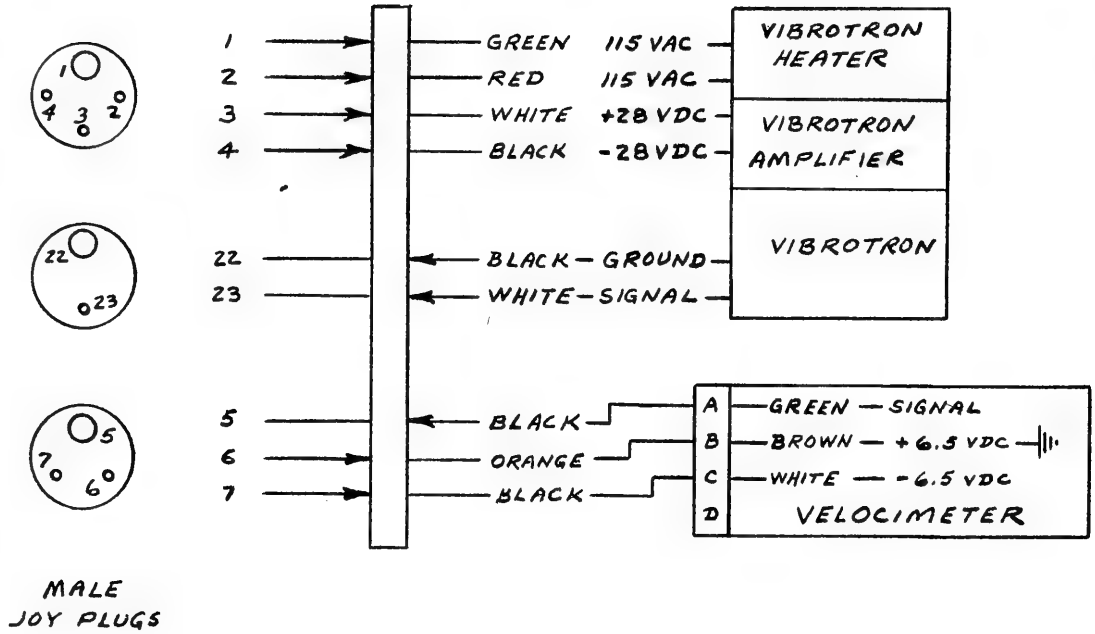


FIGURE 5. CABLE CONNECTIONS IN THE SOUND VELOCIMETER HOUSING

The digital recorder data message can be re-cycled as often as every 2 seconds.

The first digit at the left of each line indicates the channel, and each channel contains a part of the data message.

Channel 1: Indicates time of observation (GMT)
1111827 --- 11 hours, 18 minutes, 27 seconds

Channel 2: Digits 2, 3, and 4 indicate day of year
2130038 --- 130th is 9 May
The next digit is octant of the globe (See Table 1)
(0 for 0° to 90°W - North Latitude)
The last 2 digits are degrees latitude 38°

TABLE 1. OCTANT OF GLOBE CODE

0 - 0-90 W x North Latitude
1 - 90-180 W x North Latitude
2 - 180-90 E x North Latitude
3 - 0-90 E x North Latitude
5 - 0-90 W x South Latitude
6 - 90-180 W x South Latitude
7 - 180-90 E x South Latitude
8 - 90-0 E x South Latitude

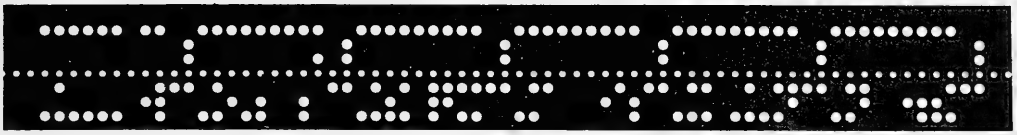
Channel 3: Digits 2 and 3 are minutes of latitude 50'
3507655 --- The next four digits are longitude in degrees and minutes; 76°55'

Channel 4: Indicates depth of transducers in meters and tenths;
4000243 --- 00024.3 meters

Channel 5: Indicates sound velocity in meters per second
5015156 --- 01515.6 meters/second

Channel 6: Indicates sea temperature in degrees and hundredths centigrade
6002335 --- + 23.35°C
The sign of the observation is given by the first digit following the channel indicator.
0 = positive, 1 = negative

b. Digital Punch Tape



When the punch tape is printed on a Flexowriter, the data message will appear as follows:

SUBMARINE OCEANOGRAPHIC DIGITAL DATA

Channel 1 Time 1HrMi Se	Channel 2 Date & Position 2Day0La d	Channel 3 Position 3LaLoLo m d m	Channel 4 Transducer Depth 4 TDep Mx10	Channel 5 Sound Velocity 5 SdVel M/sx10	Channel 6 Temperature 6 Temp dCx100
151111827	152130038	153507655	154000243	155015156	156002335
151111829	152130038	153507655	154000243	155015156	156002335

The 15 which precedes the channel indicator is the format code.

2. Mode 3 Data Message (Wave heights)

In this mode, the channel scanner is not used as only one parameter is being measured. Wave heights go directly from the counters into the digital recorder or on punch tape. The message appears as a single line of data, repeated every 0.6 seconds.

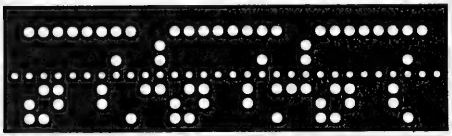
a. Digital Recorder

Record	000681
Paper	000685
Direction	000690

Each line indicates the distance from the transducer to the surface in feet and tenths: 69.0 feet, 68.5 feet, 68.1 feet.

b. Digital Punch Tape (See Section B-1-b)

(1) Sample of Flexowriter print out from punch tape



= 35600681 35600685 35600690

35 is the Format Code

C. Operate

1. Descent (Mode 1)

a. Before Dive

(1) Obtain Position
(2) Enter Position manually into System

b. During Dive

(1) Press "RESET" button on Scanner
(2) Turn on Punch
(3) Set Scanner display time to minimum

c. At maximum depth

(1) Turn off punch

2. Ascent (Mode 1). Same as Decent.

3. Wave Measurements (Mode 3)

a. Operate in Mode 1 until optimum heading and depth* are reached.

b. Make a note of sea and ship heading.

c. Switch off all channels on scanner except Channel 6. Switch scanner display control to manual and counter display control to minimum.

d. Change coupler manual data to new format indicator (35). See Appendix A.

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*Best depth to conduct wave observation must be determined. It will be a compromise between decreasing EDO performance at greater depths and increasing ship motions at shallow depths. During this operation submarine heading should be such as to reduce roll (either into seas or with seas following).

e. Switch "Function Selector" of HP 523 counter to "Time Interval."

f. Switch "Time Unit" switch to external. This will convert readings from time to distance. Check to see that the external oscillator (Krohn-Hite Model 420-A) is set to 2.5 kc, and its output is connected to the counter through "std freq ctd" input in front or back. If there is a time base toggle switch in the back of this counter it must be set to "EXT."

g. Switch EDO from "Standby" to "Fathoms." Adjust EDO gain and "Start" and "Stop" trigger levels of counter for reliable triggering.

h. The rep-rate of the EDO on the fathom scale is equivalent to about 523.2 meters. This number will indicate that the "Start Circuit" is adjusted properly. Adjust "Stop" trigger level until the counter reads approximately the same as the depth counter, when the latter is reset manually.

IV. CALIBRATION AND CHECKOUT PROCEDURES

A. Temperature

Temperature probe calibrations are accomplished by use of a decade box, the resistances varying with the individual probes. The following are the temperature calibration procedures:

1. Energize equipment.

2. Connect decade resistance to "Cal" jacks.

3. Connect Dymec Voltage to Frequency converter to output jacks.

4. Connect temperature probe to input jacks.

5. On 0 to 10 volt range, check B+ on counter, (should be 5.5 to 6.0 volts) switch on B+ position.

6. Switch to "Cal" position and set decade for 0°C setting. With zero control on bridge, set for 0000 on counter, converter on 0-to 1-volt range.

7. Set decade for 30°C setting with sensitivity control on bridge, set counter for 3000.

8. Set decade for 15°C setting, and check for 1500 on counter.

9. Switch to temperature position on bridge, and read temperature on counter.

The following calibration constants are for specific probes and are included as examples.

PROBE #4

5.5 K Cal. Res.
Green = Common
White = 2 K
Black = 30 K
0° = 9999 ohms (Approx)
.6° = 9843 "
6.6° = 8517 "
16.4° = 9660 "
22.0° = 6291 "
29.3° = 5556 "

PROBE #5

5.5 K Cal. Res.
Green = Common
White = 30 K
Black = 2 K
0° = 10054 ohms (Approx)
.5° = 9922 "
5° = 8886 "
16° = 7071 "
21.75° = 6383 "
24.20° = 6119 "
29.70° = 5587 "

PROBE #6

5.4 K Cal. Res.
Green = Common
White = 2 K
Black = 30 K
0° = 9945 ohms (Approx)
.65° = 9783 "
8.05° = 8200 "
15.60° = 7013 "
22.10° = 6227 "
29.50° = 5491 "

PROBE #7

5.5 K Cal. Res.
Green = Common
White = 30 K
Black = 2 K
0° = 9990 ohms (Approx)
.7° = 9823 "
15.1° = 7130 "
21.5° = 6337 "
29.5° = 5516 "

Wiring Diagram of Temperature Bridge and Probe is shown in Figure 6.

B. Sound Velocity

The sound velocity meter is initially calibrated in the laboratory. Field calibration checks are impossible; however, malfunctioning can be detected by checking the free-running effect with the sensor in air, which should be approximately 2800 cycles per second, as compared to 3000-3500 cycles per second with the sensor submerged.

C. Depth

Vibrotron depth gage calibrations are similar to those of the sound velocity meter, in that calibrations are made prior to field operations. Depth calibrations are made with a dead weight tester, while the ship is dockside with ship motion at a

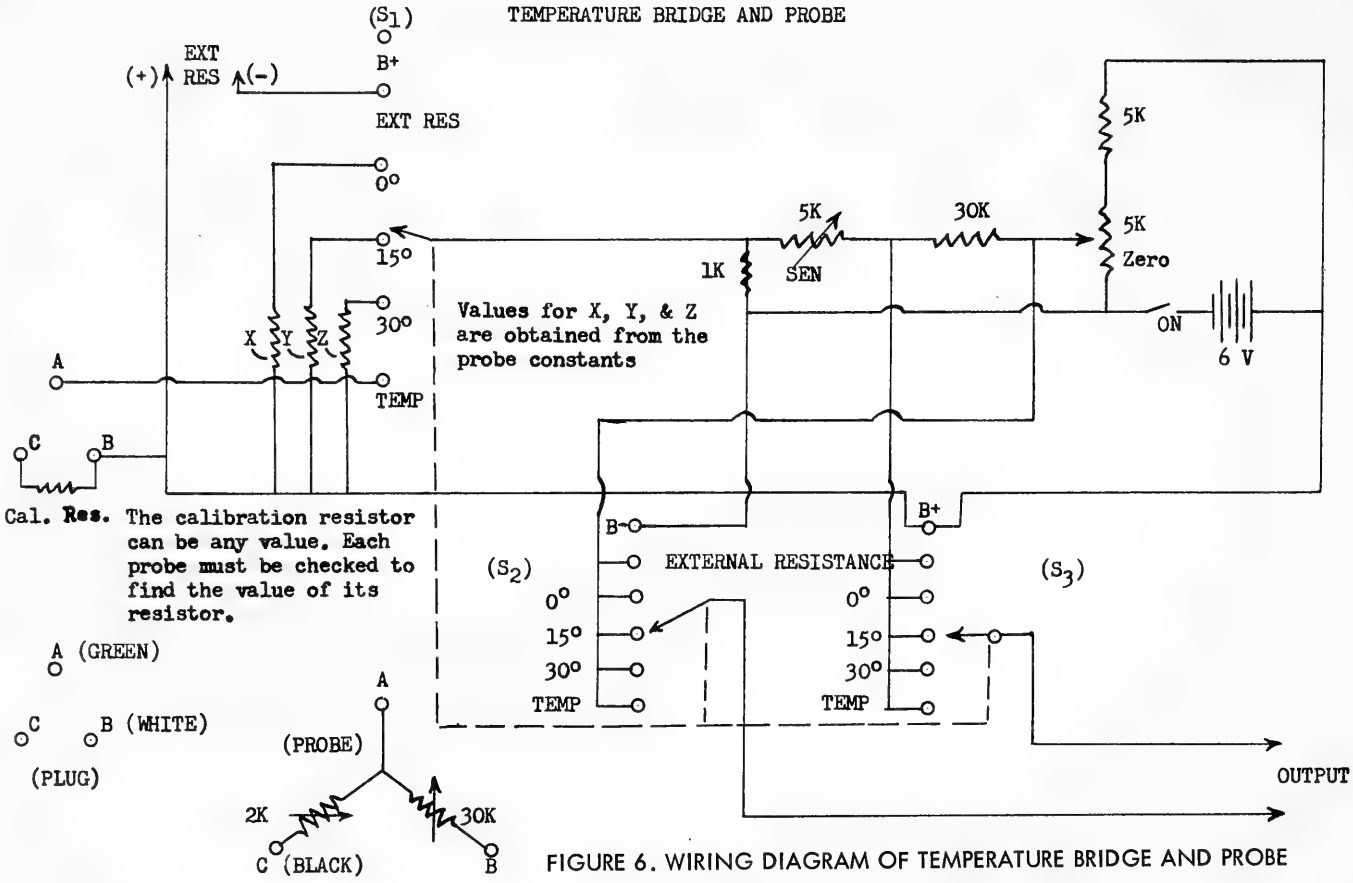

FIGURE 6. WIRING DIAGRAM OF TEMPERATURE BRIDGE AND PROBE

minimum. Depth checks can be obtained using ship's depth finding equipment. Another method of checking depth would be a comparison with the EDO reading.

The following procedure is used for determining counter constants for inverted preset reset counter using a specific Vibrotron.

1. Connect Vibrotron amplifier output to inverted preset reset counter input "A" and oscillator mixer input. Connect (oscillator mixer) output to counter input "B."

2. Allow counter and Vibrotron to warm up for 1 hour.

3. Set "Freq. Std." toggle switch to "External."

4. Set MULTIPLIER to 10000.

5. Apply atmospheric pressure to Vibrotron and make display read 00000 by adjusting RESET NUMBER.

6. Apply 100 psi to Vibrotron with dead weight gage. Make a note of display number after it repeats itself.

7. Divide 68.6 meters by displayed number.

8. Enter the quotient into MULTIPLIER.

9. Return dead weight gage to zero and make display read 00000 by adjusting RESET NUMBER.

10. Test 50 psi and 100 psi to see if the display reads 34.3 meters and 68.6 meters, respectively.

11. Counter is now set to read transducer depth in meters and tenths. DO NOT MAKE COUNTER READ KEEL DEPTH.

D. Wave Profile

The inverted EDO fathometer recorder, which is utilized for wave recording measurements, does not require calibration. To check satisfactory operation of transmitter and receiver, a suitable zero mark on the 0-70 Phase must be evident on the chart recorder. The time period between consecutive open air transmitted pulses can also be checked, this should be .112 second (87 meters) on "Feet" range or .679 second (523 meters) on "Fathoms" range.

V. TROUBLE SHOOTING PROCEDURES

In the event of console equipment malfunctioning, reference should be made to the maintenance sections of the factory instruction manuals furnished. Use can be made of the schematics to localize the trouble and assist in checking resistance, voltage, and tube readings. If after thorough investigation, the malfunctioning can not be properly corrected, it is best to enlist the aid of the ship's company E. T. If the trouble is traced to the sensor elements, the latter should be removed from the deck-mounted sensor housing and bench checked, using the appropriate manual.

DAYSTROM ELECTRIC INCORPORATED

Deep Sea Velocimeter Model V-11, Serial No. 14 Instruction Manual.

DYMEC INCORPORATED

Handbook for Hewlett-Packard 523 CR Electronic Counter-Specification DY-5632-3.

Handbook for Model 2500N Computing Digital Indicator-Specification DY-5632-6.

Handbook for Model DY-2508A Digital Clock.

Handbook for Model DY-2513A Counter Scanner, Serial 11 and Above.

Handbook for Model DY-2513A Counter Scanner-Specification DY-5519.

Handbook for Model 2513A Counter Scanner-Specification DY-5632-8.

Handbook for Model 2542 Tape Punch Coupler Option 12.

Handbook for Manual Data Panel Specification DY-5632-2.

Handbook for Voltage to Frequency Converter-Specification DY-5331.

EDO CORPORATION

Instruction Book for Models 255AM and 255BM Depth Recorders. Report No. 4742.

HEWLETT-PACKARD COMPANY

Operating and Servicing Manual for Model AC-4A and AC-4B Decade Counters.

Operating and Servicing Manual for Specifications K07-560A and K08-560A Dual Input Couplers.

Operating and Servicing Manual for Model 560A Digital Recorder Serial 896 and Above.

Operating and Servicing Manual for Model 560A Digital Recorder Serials Prefixed: 002.

Operating and Servicing Manual for Model 565A Digital Printer.

Operating and Servicing Manual for Model 721A Power Supply Serial 1 and Above.

KROHN-HITE CORPORATION

Low Frequency Oscillator Operating Instructions for Model 420A.

U. S. NAVY HYDROGRAPHIC OFFICE

Instructions in Use of EDO-Counter Keying Equipment.

Submarine oceanographic instrument installation aboard USS REDFIN (SS-272). Hydrographic Office Technical Report 91. 29 p. 1960. CONFIDENTIAL.

VARIAN ASSOCIATES

Model G-11A Strip-Chart Recorder Instruction Manual. Varian Publication No. 87-300-002.

1. Mode 1 Variables

Channel 1 Time
2 Day of Year, Octant, Latitude
3 Latitude, Longitude
4 Transducer Depth
5 Sound Velocity
6 Sea Water Temperature

2. Mode 2 Variables

Channel 1 Time
2 Ambient Light
3 Speed
4 Transducer Depth
5 Sound Velocity
6 Sea Water Temperature

3. Mode 3 Variables

Channel 6 Waves (distance to surface)
Two digits of roll or heave may eventually be included replacing zeros in Mode 3 example on page 14.

APPENDIX B - FORMAT CODES

Prior to periods of data collection, various format codes must be manually introduced into the tape punch coupler section for the modes employed. The format code consists of 2 digits: the first indicates the mode; the second indicates a specific ship or cruise, or it may be used to indicate that the system is being calibrated. Following is a list of format codes:

0X - Nondata Information

1-Format Code for Mode 1 - Routine

10 - Calibration - Zero
11 - Calibration - Low
12 - Calibration - High
13 - Data-Sensor Chamber sensors - REDFIN 1960
14 - Data-Sail sensors - REDFIN 1960
15 - Data - ARCHERFISH 1961
16 - Data - Unassigned
17 - Data - Unassigned
18 - Data - Unassigned
19 - Data - Unassigned

2-Format Code for Mode 2

20 - Calibration - Zero
21 - Calibration - Low
22 - Calibration - High
23 - Data - Unassigned
24 - Data - Unassigned
25 - Data - Unassigned
26 - Data - Unassigned
27 - Data - Unassigned
28 - Data - Unassigned
29 - Data - Unassigned

3-Format Code for Mode 3

30 - Calibration - Zero
31 - Calibration - Low
32 - Calibration - High
33 - Data - Unassigned
34 - Data - Unassigned

35 - Data - ARCHERFISH 1961 (Omitting Roll Angle)
36 - Data - Unassigned
37 - Data - Unassigned
38 - Data - Unassigned
39 - Data - Unassigned

U. S. Navy Hydrographic Office
SUBMARINE OCEANOGRAPHIC DIGITAL DATA SYSTEM, June 1961. 26 p., including 6 figs., 2 pl. 1 table. (H. O. TR-88).

This report describes a system for sensing, processing, and recording sound velocity, sea water temperature, wave heights, ambient light, date, time, transducer depth, and certain ship motions. The system is digital and automatic. It is designed principally for use aboard submarines.

Appendix A presents oceanographic variables measured during various Modes, or submarine maneuvers; Appendix B, format codes entered into the recording system to identify data on punched tape.

1. Submarine - oceanography
2. Oceanography - submarine
3. Instrumentation - oceanographic
4. Ships - USS ARCHERFISH
5. Ships - USS REDFIN

i. Title: Submarine Oceanographic Digital Data System.

ii. H. O. TR-88

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3. Instrumentation - oceanographic
4. Ships - USS ARCHERFISH
5. Ships - USS REDFIN

I. Title: Submarine Oceanographic Digital Data System.

II. H. O. TR-88

U. S. Navy Hydrographic Office
SUBMARINE OCEANOGRAPHIC DIGITAL DATA SYSTEM, June 1961. 26 p., including 6 figs., 2 pl. 1 table. (H. O. TR-88).

This report describes a system for sensing, processing, and recording sound velocity, sea water temperature, wave heights, ambient light, date, time, transducer depth, and certain ship motions. The system is digital and automatic. It is designed principally for use aboard submarines.

Appendix A presents oceanographic variables measured during various Modes, or submarine maneuvers; Appendix B, format codes entered into the recording system to identify data on punched tape.

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